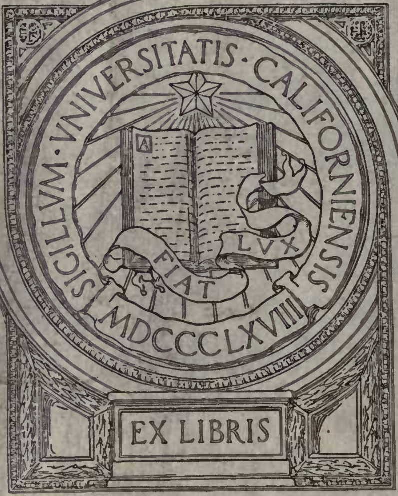
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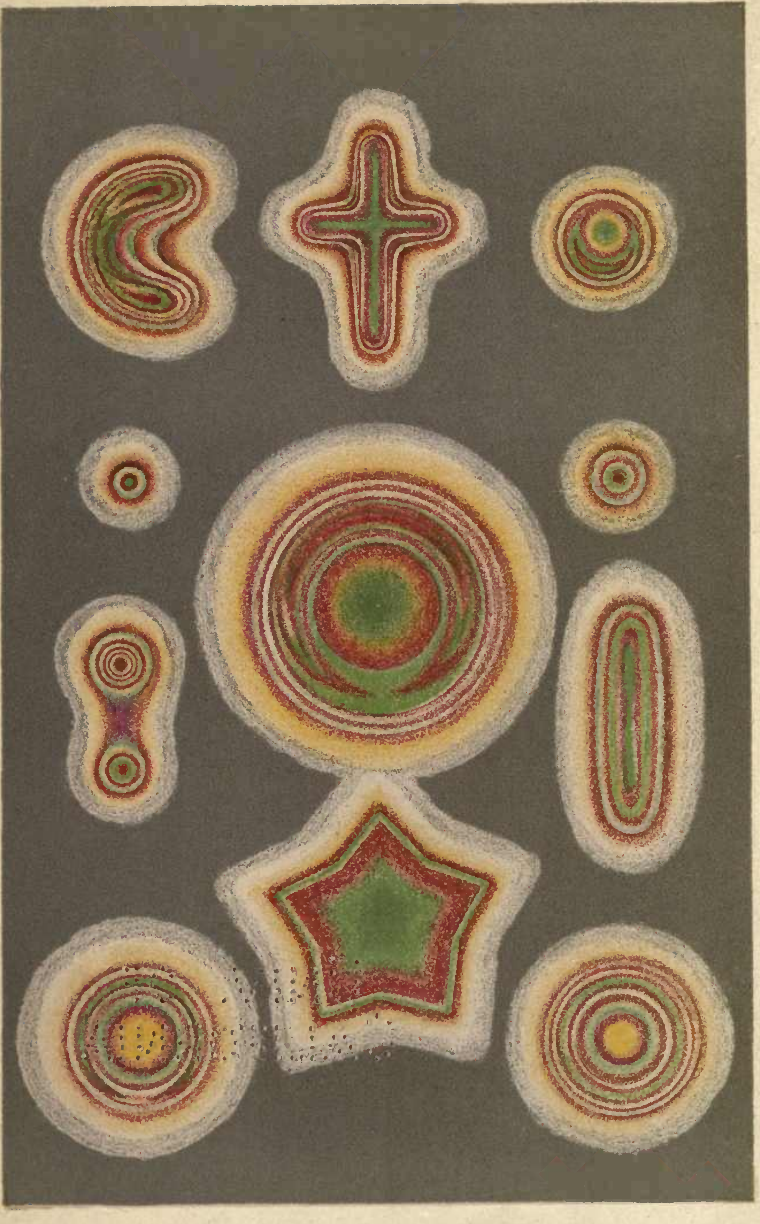

METALLO CHROMES (*see page* 358).

ELECTRO-DEPOSITION

A PRACTICAL TREATISE

ON THE

ELECTROLYSIS OF GOLD, SILVER, COPPER, NICKEL,
AND OTHER METALS, AND ALLOYS

WITH

*DESCRIPTIONS OF VOLTAIC BATTERIES, MAGNETO AND
DYNAMO-ELECTRIC MACHINES, THERMOPILES, AND
OF THE MATERIALS AND PROCESSES USED IN
EVERY DEPARTMENT OF THE ART*

AND SEVERAL CHAPTERS ON

ELECTRO-METALLURGY

By ALEXANDER WATT

AUTHOR OF "ELECTRO-METALLURGY" "THE ART OF SOAP-MAKING," "THE ART OF
LEATHER MANUFACTURE," ETC.

With numerous Illustrations

THIRD EDITION, REVISED, CORRECTED, AND ENLARGED

Capio Lumen

LONDON
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1889

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PREFACE.

In contemplating the present work, the Author's desire was to furnish those who are engaged in the Electro-Deposition of Metals, and in the equally important department of Applied Science Electro-Metallurgy, with a comprehensive treatise, embodying all the practical processes and improvements which the progress of Science has, up to the present time, placed at our command.

While the long-continued success of the Author's former work upon this subject, "Electro-Metallurgy Practically Treated"—now passing through its Eighth Edition—testifies to its having filled a useful place in technical literature, the art of which it treats has during recent years attained such a high degree of development, that it was felt that a more extended and complete work was needed to represent the present advanced state of this important industry.

In carrying out this project, the Author's aim has been to treat the more scientific portion of the work in such a manner that those who are not deeply learned in Science may readily comprehend the chemical and electrical principles of Electrolysis, the knowledge of which is essential to those who would practise the art of Electro-Deposition with economy and success. He has also endeavoured to render the work thoroughly practical in character in all its most important details; and having himself worked most of the operations of the art upon a very extensive scale, he is enabled in many instances to give the results of his own practical experience.

Electro-Metallurgy, which is now recognised as a distinct branch of electro-chemistry, has been treated separately, and those processes which have been practically adopted, such as the electrolytic refining of crude copper, are exhaustively given, while other processes, now only upon their trial, are described. In this section also will be found a description of the new process of electric smelting, as applied, more especially, to the production of aluminium and silicon bronzes.

In conclusion, the author tenders his best thanks to those who kindly furnished him with information, for the readiness and promptitude with which they complied with his requests.

London, *December*, 1885.

PREFACE TO THE THIRD EDITION.

In producing a new and revised Edition of this work, the Author has been enabled to make some further additions, in the form of an Appendix, which it is hoped will be found interesting and useful. He has also eliminated certain details from the body of the work which later experience has shown to be of a doubtful character, and substituted other matter which he trusts will be more useful to his readers.

London, *November*, 1888.

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CHAPTER I.

HISTORICAL REVIEW OF VOLTAIC ELECTRICITY.

Galvani's Discovery.—Volta's Discovery.—Simple Voltaic Circle.—The Voltaic Pile.—Cruickshank's Trough Battery.—Dr. Babbington's Battery.—Volta's Couronne des Tasses.—Dr. Wollaston's Battery.—Daniell's Battery.—Smee's Battery.—Grove's Battery.—Compound Grove Battery.—Callan's Iron Battery.—Bunsen's Battery.—Walker's Graphite Battery.—Leclanché's Battery.—Bichromate Battery.—Marié-Davy Battery.—Secondary Batteries, or Accumulators.

From the date of the discovery of Voltaic Electricity, or Voltaism, in the year 1799, experimental philosophers in all parts of the world unceasingly devoted their labours to the investigation of the phenomena which the electric current, generated by chemical action upon metals, is capable of producing, until, step by step, the great Art of Electro-Metallurgy was called into existence, and brought to its present high state of development.

Before entering into the numerous applications of current electricity in the deposition of metals upon each other, or upon other conducting surfaces, it will be interesting and instructive to consider how this remarkable force was discovered, and the various means which have been adopted to bring it under our control as an agent of practical utility. It has long been the custom to confound the terms voltaism and galvanism, voltaic battery and galvanic battery, in relation to the electric current produced or evolved by the action of chemical substances upon metals of opposite character, but we think it is quite time that the conventional error should be rectified, more especially for the advantage of those who may be entering into the study of electrical phenomena for the first time. Galvani's discovery—which was of a purely accidental nature—in no respect resembles that of his equally illustrious fellow-countryman, Volta; but since it undoubtedly led to the still more important discovery of what has been termed *chemical electricity*—that is, electricity obtained by the action of acids,

&c., upon metals—we will briefly describe its origin, and thus render more clear the applicability of the terms *voltaic electricity* or *voltaism*, to the current produced by metals excited into chemical action by acid or other solutions, in any way whatsoever.

Galvani's Discovery.—Galvani, while professor of anatomy at the University of Bologna, was suffering from indisposition, and his wife, according to the custom of the country, was preparing for him a soup made from frogs. The animals had been skinned, preparatory to cooking, in the professor's laboratory, where, probably, it was intended to cook them. An electrical machine stood close to the spot where the prepared reptiles lay, and the assistant, having set the machine in action, happened, accidentally, to touch with the point of a scalpel the crural nerve of one of the frogs which was close to the prime conductor of the machine, when the limbs were instantly thrown into strong convulsions. The phenomena was soon communicated to Galvani by his wife, and he shortly after repeated the experiment with various modifications, and found that the convulsions only took place when the spark was drawn from the prime conductor, the crural nerve being at the same time touched by a substance which was a conductor of electricity. This was Galvani's, if not his assistant's, discovery,* and formed the basis of much subsequent research, but it is only related to what the world erroneously terms *galvanism* (voltaic electricity) so far as it prompted Volta to investigate the subject, and led to his brilliant discovery of *chemical electricity*.

Volta's Discovery.—This grand discovery was of an entirely different character to Galvani's and of infinitely greater importance, since it formed the basis of all the host of electric generators properly known as voltaic batteries, but erroneously, as we have said, termed *galvanic batteries*, which have since been devised. Professor Volta, of Como, in one of his original experiments, discovered that when two perfectly smooth and polished discs of metal—one being zinc and the other copper—had their faces brought in close contact, that the zinc became slightly charged with *positive* and the copper with *negative* electricity. To illustrate the experiment, the metallic discs are usually about 6 inches in diameter, and each is furnished with

---

* There have been many different versions of the above incident, amongst which the following was given by Arago: "It may be proved," said the illustrious philosopher, "that the immortal discovery of the Voltaic pile arose in the most immediate and direct manner from a slight cold with which a Bolognese lady was attacked in 1790, for which her physician prescribed the use of *frog broth*." Since it is hardly conceivable that a physician's wife would have undertaken the task of preparing frog broth (an ordinary Italian delicacy) with her own hands, *in her husband's laboratory*, we are disposed to believe that the incident, as above related, is more likely to be the correct one.

a glass handle, as at Fig. 1. After being in contact for a moment the discs are drawn apart (without friction) and either of them is presented to the cap of a delicate gold-leaf electroscope, furnished with a condenser, as shown in Fig. 2, when the gold-leaves will separate, or diverge, as seen in the cut. Let A B represent a metallic disc insulated on a varnished glass rod and connected by a wire with the cap E of the electroscope, and let A′ B′ represent a similar disc in free communication with the earth by the wire, W. If the discs, Fig. 1, be drawn apart after a moment's contact and either of them be presented to the cap E, the gold-leaves will diverge to a certain extent. The process is to be repeated six or eight times, taking care to touch the cap of the electroscope each time with the same disc, and holding it by its glass handle. If now the disc A′ B′ be moved towards the disc A B, as they approach each other the gold-leaves will gradually collapse, and when nearly in contact the electricity will be so far withdrawn from E, and concentrated at A B, that the leaves will hang nearly parallel. Let A′ B′ be now suddenly withdrawn to a distance; the electricity accumulated on A B will, in virtue of its expansive power, return and diffuse itself over E, when the gold-leaves will again expand as before. This evidence of electric action, set up by contact of two dissimilar metals, is not confined to zinc and copper, but may be developed in any two metals of opposite electric condition. A list of metals showing their electric relations to each other will be given hereafter.

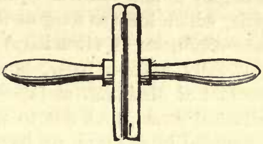

Fig. 1.

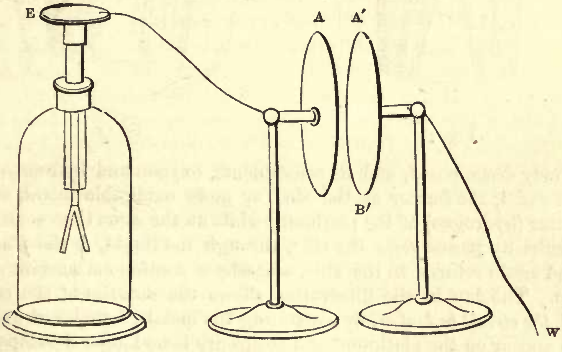

Fig 2.

Simple Voltaic Circle.—From the above important discovery

Volta propounded the law: That by simple contact of dissimilar bodies, the electricity belonging to one of them passes to the other, whereby a new electric equilibrium is established in the individual pair, which lasts so long as they are insulated (that is, separated by a non-conductor of electricity) from other bodies, but *no longer*. It is generally believed now, however, that the electricity developed by contact of dissimilar metals—zinc and copper, for instance—is due to *chemical action*, and not to mere contact alone, for if this action be promoted in *any way*, we have at once an evident increase of electrical energy. For example, if we immerse a strip of zinc and a strip of platinum in pure water, as in Fig. 3, a new kind of electric action, termed *electro-chemical action*, is set up, by which the water becomes slowly decomposed, and its constituents, oxygen and hydrogen gases, liberated, the former at the zinc, or more oxidisable metal, and the latter (hydrogen) at the platinum, while at the same time a current of electricity passes *from* the zinc, through the liquid, *to* the platinum, and again returns to the zinc, whereby a continuous current is kept up. The dart in the illustration shows the *direction* of the current. If *the circuit be broken*, by separating the metals, bubbles of gas cease to appear on the platinum, and electricity is no longer developed.

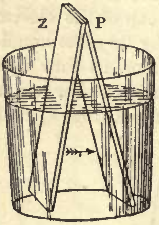

Fig. 3.

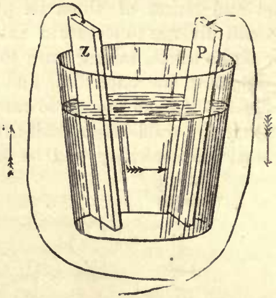

Fig. 4.

To illustrate the above facts more clearly, we will take two similar strips of metal—zinc and platinum—to each of which a piece of copper wire is soldered, and we *amalgamate* the zinc by dipping it into a dilute sulphuric or hydrochloric acid, and then rubbing mercury (quicksilver) all over it. If we now immerse the two strips in water slightly acidulated with sulphuric acid, we find that there is no effect produced upon either metal; if, however, we bring the ends of the two wires in close contact, as in Fig. 4, we at once observe that a copious stream of bubbles of gas (hydrogen) issues from the surface of the platinum, as though it were undergoing violent chemical action, while the zinc is apparently unaffected. We say *apparently*, but in fact the zinc is gradually, though silently, being dissolved in the acid solution, while the platinum is totally unacted upon. From this it is evident that some influence other than chemical action must cause the phenomena observed. To prove that such is really the case, let us dip the ends of the wires successively in a solution of sulphate of copper (bluestone). Here again we find no effect, because the circuit is broken; but if we *complete the circuit* by dipping *both* wires into the solution simultaneously (the copper solution being a conductor of electricity), in a few moments, on removing the wires, we shall find that one of them—the wire attached to the zinc—has become coated with a deposit of metallic copper. The effect is more striking if a brass or German silver wire be connected to the zinc. In this simple arrangement, therefore, we have a perfect *voltaic circle*, or battery, capable of doing a certain, though small, amount of electric work proportionate to the size of the plates.

Voltaic Pile.—Volta's next important application of his great discovery was in the construction of his famous apparatus or arrangement of metals, known as the *Voltaic Pile.* This consisted of a number of pairs of zinc and copper plates piled one above another, with a piece of pasteboard, moistened with dilute sulphuric acid, or a solution of common salt, between each pair of plates. The original form of the pile or battery is shown in Fig. 5. In this arrangement it is essential that the plates of each pair of metals be in absolute *electrical contact*, either by having the surfaces perfectly bright and clean, or by uniting them by means of solder, which is the more convenient method. The pile may consist of any number of pairs, but their arrangement must be strictly in the alternate order of zinc and copper, with the intervening layer of pasteboard or moist cloth between each pair. It is usual for the top plate to be zinc, and the bottom one copper, to each of which a copper conducting wire is soldered, for conveying the current to any substance to be operated upon.

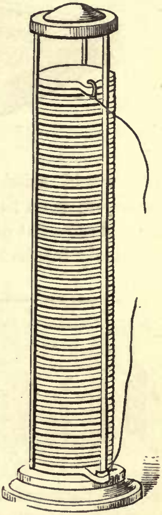

Fig. 5.

It will be seen that in neither of Volta's methods of producing a current of electricity was there any connection with the interesting fact which constituted the discovery attributed to Galvani. In Volta's discovery we have a definite electro-chemical arrangement capable of unlimited extension, and susceptible of an endless variety of modifications, all based upon the same grand principle, to which, as we shall show, we are indebted for every form of chemical battery which has since been devised.

Cruickshank's Trough Battery.—It will be obvious that in the construction of the voltaic pile, as above arranged, much inconvenience would arise, especially when a great number of plates are employed, from the weight of the upper portion of the pile pressing the moisture out of the lower portion, and thereby rendering it comparatively inactive. To overcome this, Cruickshank devised his well-known *trough battery*, Fig. 6, in which the plates were let into grooves formed in a shallow wooden trough, the separate rows of plates being connected (as shown by the curved wires) by a short conducting wire, while a length of copper wire was attached to each terminal plate of the series, forming the positive and negative wires respectively. The plates were excited by a dilute solution of sulphuric acid. This battery created considerable interest at the time, and afforded experimentalists the means of pursuing their investigations in current electricity with greater facility than was possible with the pile. It may fairly be considered the first really practical compound circle, or battery, that had been produced up to that period. Although this was a considerable improvement upon the pile, however, there was

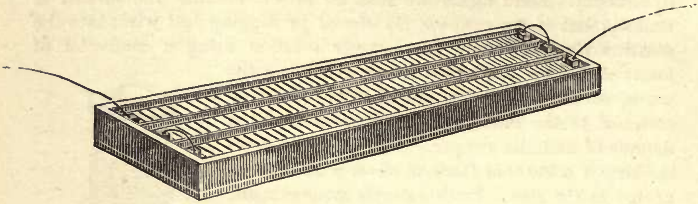

Fig. 6.

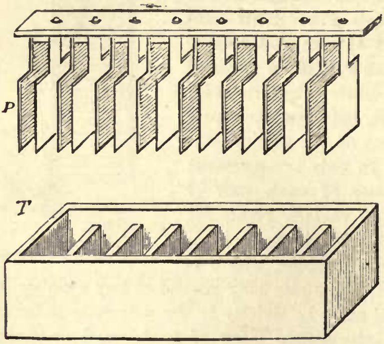

Fig. 7.

some inconvenience in removing the exhausted acid solution, and this suggested a further improvement, for which we are indebted to Dr. Babbington.

Dr. Babbington's Battery.—This battery (Fig. 7) consists of eight or more pairs of copper and zinc plates, usually about 4 inches square, each pair being united by soldering at one point only. The trough, which contains as many cells as there are pairs of plates, is generally made of earthenware, and the plates are attached to a bar of wood, by which arrangement the plates may be withdrawn from the exciting fluid (dilute sulphuric acid, for instance) when the battery is not required for use. It is necessary that the bar of wood should be perfectly dry, and coated with varnish in order to render it non-conductive of electricity.

Volta's Couronne des Tasses.—Still pursuing the subject, Volta afterwards invented an arrangement, to which he gave the name *couronne des tasses* (crown of cups) which was exceedingly simple and effective. This consisted of a row of glasses or cups, each containing dilute sulphuric acid. Zinc and copper plates, about 2 inches square, are connected by a copper conducting wire (which may be conveniently attached by soldering), and the plates are immersed in the cups in the following order (see Fig. 8): the zinc plate z of one pair is immersed in one of the cups, and the copper c in the next cup. Another zinc plate is then placed in this second cup, but not touching the copper plate, and its connected copper plate immersed in a third cup, in which again another zinc plate is immersed, and so on, through the whole series, the metals being arranged alternately, zinc and copper, zinc and copper, until the entire number of vessels are supplied with one pair of *opposite* metals. It will thus be seen that, regardless of the number of *pairs*, the last plate at one end will be *zinc*, and at the other, *copper*. The direction of the current is *from* the zinc *to* the copper. If the zinc plates be amalgamated, as before mentioned, by which the chemical action of the acid solution upon the zinc is prevented, except when the circuit is complete, either by contact of the terminal wires, or by being immersed in a solution which is a

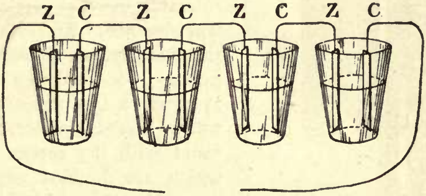

Fig. 8.

conductor of electricity, we shall observe that the moment we bring the wires in contact, a violent effervescence occurs at each of the copper plates, which instantly ceases when the wires are again separated. If glasses are employed in this arrangement, we can readily observe the interesting excitement which is brought about in each vessel the moment contact is made between the terminal wires, and this lesson will explain to us what must and does take place in all voltaic arrangements, no matter what may be the metals or *elements* employed in the construction of the battery.

Dr. Wollaston's Battery.—An important improvement in the preceding arrangements, but more directly in the battery designed by Dr. Babbington (Fig. 7), was the famous battery constructed by Dr. Wollaston in 1815, in which the copper plates were doubled, as in Fig. 9, by which each surface of the zinc plates became opposed to a surface of copper, whereby a considerable increase of electric energy was obtained. The original form of this battery, as shown in the engraving, consisted of a bar of wood A, to which the plates are screwed. B B are the zinc plates, connected as usual with the copper plates, C C, which are doubled over the zinc plates, and opposed to them in every direction; but the contact of their surfaces is prevented by pieces of wood or cork placed between them. When in use, the plates are lowered into a wooden trough containing a solution of sulphuric and nitric acids—one part of each acid to sixty parts of water. This important improvement in voltaic batteries led to the discovery, by its gifted inventor, that by increasing the *copper surface*, the *quantity* of electricity was greatly augmented—one of the most valuable facts that had yet been made known in connection with voltaism.

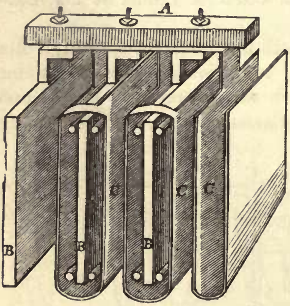

Fig. 9.

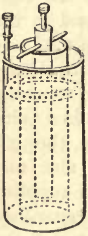

Fig. 10.

Daniell's Battery.—Another remarkable advance in the construction of voltaic circles was due to Professor Daniell, who, in 1836, contrived his celebrated *Constant Battery*, a description of which appears in the *Philosophical Transactions*, 1836, p. 117, and runs as follows: "A cell of this battery (Fig. 10) consists of a cylinder of copper $3\frac{1}{2}$ inches in diameter, which experience has proved to afford the most advantageous distance between the generating and conducting surfaces, but which may vary in height according to the power it is wished to obtain. A membranous tube, formed of the gullet of an ox, is hung in the centre by a collar and circular copper plate resting upon a rim placed near the top of the cylinder; and in this is suspended, by a wooden cross-bar, a cylindrical rod of amalgamated zinc, half an inch in diameter.* The cell is charged with a mixture of 8 parts of water and 1 part of oil of vitriol, which has been saturated with sulphate of copper; and portions of the solid salt [crystals] are placed upon the upper copper-plate, which is perforated like a colander, for the purpose of keeping the solution always in a state of saturation. The internal tube is filled with the same acid mixture, without the copper. A tube of porous earthenware may be substituted for the membrane, with great convenience, but probably with some little loss of power. A number of such cells admit of being connected together very readily into a compound circle, and will maintain a perfectly equal and steady current for many hours together, with a power far beyond that which can be produced by any other arrangement of a similar quantity of metals."

The introduction of this remarkable voltaic battery established an important era in electro-chemical history, not only on account of its practical merit as a generator of current electricity of great constancy, but from the possibility, if not probability, of its having indirectly led to the discovery of the electrotype process, upon which, as we have shown elsewhere, the whole art of electro-deposition is founded.

Smee's Battery.—Another valuable addition to the series of voltaic circles or batteries already known was invented by Mr. Alfred Smee, to whom, more than any other, the early electro-metallurgists were indebted for a clear exposition of the principles of the art, at a time when, being in its infancy, effects, rather than causes, occupied the

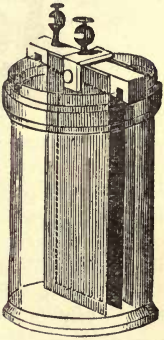
Fig. 11.

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* In this battery the local action of the sulphuric acid on the zinc is prevented by its amalgamation, which causes a film of hydrogen to adhere to it so long as the circuit is incomplete. When complete this hydrogen goes over to the copper, and by adhering to it interferes with the passage of the electricity; but the presence of the oxide of copper of the sulphate [of copper] tends by secondary action to get rid of this hydrogen, which is employed in reducing the oxide; and successive films of metallic copper are thus thrown down upon the copper, and a clean metallic surface always preserved; while the deposition of copper upon the zinc plate (which would cause numerous secondary circles) is prevented by the diaphragms [ox gullets].

attention of its practical followers. Smee's battery, Fig. 11, consists of a pair of amalgamated zinc plates, with a plate of thin sheet-silver coated with black deposit of platinum (by which a permanent rough surface is obtained, which favours the escape of the hydrogen). The plates are supported by a bar of wood, and are furnished with *binding-screws* for connecting the conducting wires. The parts of the battery may be thus described: 1, an earthenware or glass vessel containing dilute sulphuric acid (1 part acid to 7 parts of water); 2, the bar of wood to which the platinised silver plate is attached; 3, the two plates of amalgamated zinc, secured to the wooden bar by the binding-screw or clamp; 4, a second binding-screw connected by means of solder to the silver plates.

Grove's Battery.—In the year 1839, Professor Grove (the present eminent judge), invented the most powerful voltaic battery known, in which the elements are zinc and platinum, excited, respectively, by sulphuric acid and nitric acid. This famous battery, which is commonly known as the "Nitric Acid Battery," or "Grove's Battery," consists of a flat cell of glazed porcelain, inside which is another cell of similar shape but smaller and thinner, composed of *porous* (that is unglazed)

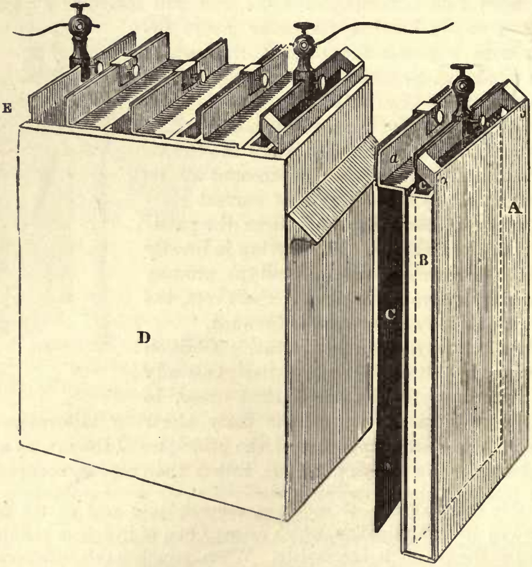

Fig. 12.

earthenware. A flat plate of zinc is bent in such a form that the porous cell may be placed within its folds, by which a surface of zinc is exposed to each side of the inner cell. A plate of thick platinum foil is inserted in the porous cell, and is of sufficient length to be attached to the projecting end of the zinc plate by means of a binding-screw or clamp. The inner porous cell is charged with strong nitric acid, and the outer vessel with a mixture composed of 1 part of oil of vitriol to 6 parts water. The zinc plate is well amalgamated.

Compound Grove Battery.—In the accompanying engraving, Fig. 12, is shown a single and also a compound arrangement of four cells of the battery. A *a* is the bent zinc plate, B the platinum plate in the porous cell. At C is another platinum plate to show how it is to be connected to a second zinc plate when more than one cell of the battery is to be employed. D is a glazed porcelain vessel containing a series of four pairs of metals connected by clamps and binding-screws; the two latter (furnished with copper conducting wires) are connected, one to the terminal zinc plate at E, and the other to the platinum element at the opposite end of the series. Although an exceedingly powerful battery and admirably suited for exhibiting the effects of voltaic or current electricity, Grove's battery is not well adapted to the purposes of electro-deposition, owing to its costliness both in construction and use; its importance in scientific research, however, cannot be overestimated.

Callan's Iron Battery.—Another remarkable battery was invented by Dr. Callan, and termed by him the Maynooth battery. This consisted of a cast-iron cell charged with a mixture composed of twelve parts of concentrated nitric acid and eleven and a half parts of strong oil of vitriol. A porous cell, containing a plate of zinc and a solution of nitric and sulphuric acids, was placed in the centre of the iron cell, and a binding screw was attached to the iron cell, as also one to the zinc plate, when the battery was complete. Dr. Callan constructed a series of such circles consisting of 557 pairs, containing 96 square feet of zinc and about 200 square feet of cast-iron. The discharge of this powerful battery through a very large turkey instantly killed it, and a luminous flame (or *arc*) was produced 5 *inches in length*. The iron battery, though very interesting and useful for experimental purposes, is not suited for electro-deposition.

Bunsen's Battery.—One of the most useful batteries for the practical purposes of the electro-metallurgist was invented by the gifted Chevalier Bunsen, the elements of which are zinc and carbon (graphite). As in the case of Grove's battery the exciting fluids are, for the zinc, dilute sulphuric acid (oil of vitriol), and for the carbon strong nitric acid. The modern form of the battery is shown in Fig. 13. The outer vessel is a cylindrical stoneware jar capable of holding about 4 gallons (though, of course, smaller cells may be used). A plate of stout sheet zinc is turned up in the form of a cylinder, A, and this is well amalgamated with mercury. A suitable binding screw is attached to this cylinder to receive the conducting wire. A porous cell, about 3½ inches in diameter, is placed within the zinc, and in this a block of *gas carbon* (obtained from the linings of old and much-used gas retorts) is furnished with a suitable clamp B for attaching a conducting wire, and the block is then gently deposited in the porous cell. This cell is then nearly filled with strong nitric acid, and the outer vessel is next filled to the same height as the nitric acid in the porous cell, with dilute sulphuric acid—about 1 part acid to 10 parts water, when the arrangement is complete. This battery is exceedingly powerful, and is much employed in many of the processes of electro-deposition.

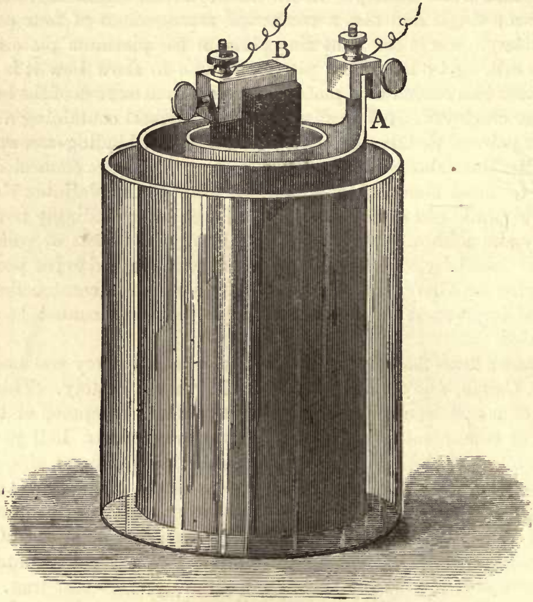

Fig. 13.—Bunsen's Battery.

In the original form of Bunsen battery a cylindrical block of carbon was employed, but, since it was difficult to obtain these cylinders from gas carbon, Bunsen adopted the following method of preparing them artificially: A quantity of well-baked coke and pit coal was ground to a fine powder and the mixture heated over a low charcoal fire, in sheet-iron moulds, or in the form of hollow cylinders, by introducing into the iron mould a cylindrical wooden box and filling with the mixture the space between the two walls of the mould. To render the porous mass compact it was plunged into a concentrated solution of sugar, and then dried until the sugar had acquired a solid consistence. It was then exposed, for several hours, to a very intense white heat in a covered vessel, and afterwards allowed to cool gradually. The original form of this battery and its dissected parts are shown in Fig. 14. The carbon cylinder carries a collar at its upper part, upon which may be deposited a stout coating of copper in the electrotyping bath, and to this a strip or band of sheet copper may be attached, by means of soldering, to form the conducting medium, a similar strip of copper being connected to the zinc cylinder of the battery. The copper deposited upon the carbon should be well varnished with black japan varnish, so as to protect it from the action of the nitric acid used as the exciting fluid in the porous cell. The outer vessel being nearly filled with dilute sulphuric acid, and the porous cell with nitric acid—both exactly at the same level—the battery is then ready for work, and is undoubtedly one of the most useful of all voltaic circles.

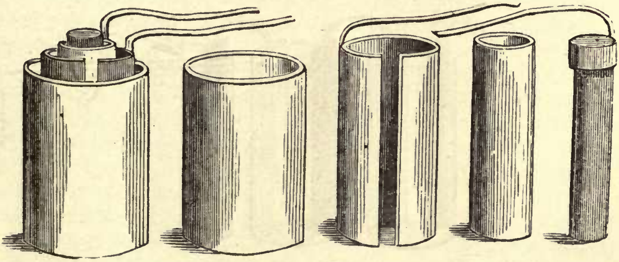

Fig. 14.

Walker's Graphite Battery.—The late Mr. C. V. Walker introduced a modification of Smee's battery (page 9), in which he substituted plates of platinised graphite (carbon) for platinised silver, by which an exceedingly effective battery is produced. These batteries have been very extensively used in working the telegraph system of the South-Eastern Railway, and may be advantageously employed in electrotyping. The carbon plates are either cut from the graphite obtained from exhausted gas retorts (the best material for the purpose), or they may be substituted by artificially prepared carbon which is now being sold for this and other similar purposes. Mr. Walker thus describes his graphite battery: Having obtained the plates, the first operation is to prepare a mixture of one part sulphuric acid, and four parts water, and to let the plates lie in this for at least a couple of days and nights. This operation will clean them from all foreign matter that is soluble in sulphuric acid. They are now to be rinsed in plain water, and set to dry. Each plate is then to have a hole drilled in it, in order to receive a rivet. The top of the plate is now to be protected with varnish on either side of the rivet hole, and on both sides of the plate. An unvarnished part of about an inch in width, and on both sides, is to be left in the middle, having the rivet-hole in the centre. Electrotype copper is now to be deposited upon the part that is left unvarnished (by any of the processes hereafter described). The object of coppering this part of the plate is to enable a strip of copper to be soldered to it, which could not be effected upon the graphite surface. A strip of copper, about 6 inches long, is then *tinned*, by moistening it with a solution of chloride of zinc (zinc dissolved in muriatic acid), and applying pewter solder by means of a soldering iron. The object in tinning the surface of the copper is to prevent the acid from acting upon it. The copper deposited upon the graphite is also tinned in the same manner. The next operation is to attach the slip of copper to the graphite plate. This is done by means of a copper rivet, previously tinned, and then by means of a soldering iron. A strong and perfect connection is thus obtained. The plate is next to be *platinised* by the process given in another chapter, after which the top of the plate and the copper strip are to be thoroughly coated with varnish. Fig. 15 represents three cells of the graphite battery, as employed for telegraph purposes. The cells are stone jars, holding a pint or a quart; the zinc plates, which are well amalgamated, are placed with their foot in a "slipper" made of gutta-percha, in which mercury is placed, the

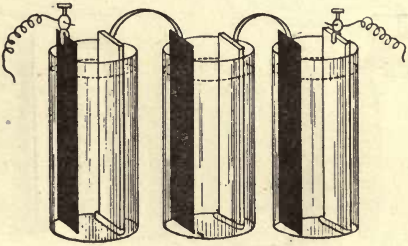

Fig. 15.

object of which is to keep the plates constantly amalgamated. The reader will observe how closely the arrangement of the plates resembles Volta's *couronne des tasses.* The exciting fluid, as in the Smee battery, is dilute sulphuric acid.

Besides the more important voltaic batteries referred to, numerous other arrangements have been devised, but since most of these are of little applicability in electro-deposition, a mere passing reference to some of the more striking modifications will be sufficient to show how varied are the means by which voltaic electricity may be generated. It had been proved, as we have shown, that water alone was capable of generating a current of *intensity* electricity, and this led to the construction of a battery which received the name of the *water battery.* Mr. Pepys had such a battery constructed of 2,000 pairs, which was capable of giving a shock resembling that from the Leyden jar employed in receiving electricity from an electrical machine. Mr. Crosse and Mr. Gassiot constructed a still more extensive water battery, consisting of 3,520 pairs, which were cylinders of zinc and copper, separated by string. The exciting liquid was distilled water. In this arrangement, sparks were found to pass *before* contact of the terminal wires, or *poles,* was made, which proves that the current more resembles that obtained by friction (as from an electrical machine) than from a voltaic circle. It is in fact an *intensity* current, with but little of the quality termed *quantity,* and therefore represents *current* electricity in its weakest form.

Leclanché's Battery.—A battery which has been extensively adopted for electric bells, and is now being much used as a substitute for the Daniell battery and for telegraphic purposes, is the *Leclanché battery.* It consists of an outer glass vessel in which the zinc element (a rod of zinc) is immersed in a solution of sal ammoniac (*chloride of ammonium*). A porous cell stands in the centre of the vessel, and in this is placed a plate of carbon, surrounded by a mixture of peroxide of manganese and carbon in coarse grains. This battery is very constant in its action. Its inventor, M. Leclanché, of Paris, lays great stress upon the importance of employing *very pure* peroxide of manganese.

The Bichromate Battery, for experimental purposes, is a very energetic and agreeable voltaic arrangement, and, unlike the batteries in which nitric acid is used, it gives off no pungent fumes. The battery, which is represented in Fig. 16, consists of a glass wide-mouthed bottle, filled nearly up to its neck with a solution of bichromate of potash, to which sulphuric acid is added. The solution is thus prepared: A saturated solution of the bichromate is first prepared, by dissolving about 3 ozs. of bichromate of potash in a pint of boiling water. When quite cold, add about 1½ ozs. of oil of vitriol, when the liquid will acquire a considerable degree of heat. The liquid must be again allowed to cool, when it is ready to be poured into the bottle. The *mechanical* arrangement of the battery consists of a wooden cap, turned so as to fit into the bottle, like a cork, but not too tightly. Two plates of carbon are connected by a couple of binding-screws to the cap, and between this pair of plates a square plate of zinc, connected by a rod to the centre binding-screw, is placed, the rod passing through a round hole in the centre of the cap, so that the zinc plate may be raised out of the liquid into the empty neck of the bottle when the battery is not required for use.

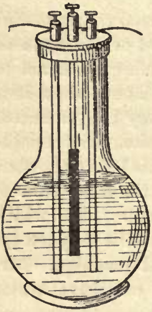
Fig. 16.

Marié-Davy Battery.—An ingenious modification of several of the voltaic circles before named is that known as the *Marié-Davy battery;* but its employment is chiefly in connection with telegraphy. The elements are zinc and carbon (graphite plates), and these excited by moistened bisulphide of mercury, the zinc plates being amalgamated, and the graphite plate platinised, as in Walker's battery. A section of this battery is shown in Fig. 17, in which *a* is the platinised graphite, *b b* the bisulphide of mercury, *c* a circular zinc plate, and *d* a porous cell.

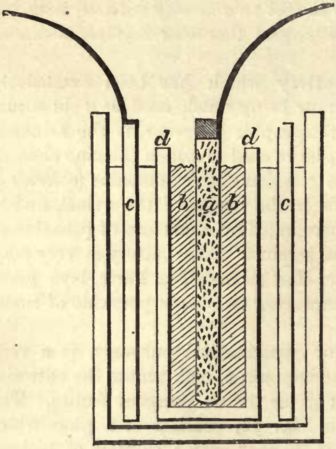

Fig. 17.

Secondary Batteries or Accumulators. — Volta observed that when a piece of moistened paper was placed upon a strip of glass, and caused to complete the circuit of a voltaic battery, that it was found to become *electro-polar*, that is to say, that half which was in contact with the positive extremity of the battery became positive, while the portion at the negative end became negative; and this electrical condition of the paper continued for some time after its separation from the poles of the battery, provided that the insulation were maintained. This is termed *polarisation*. The subject was afterwards further investigated, but no practical application of the fact seems to have taken place until Planté formed his now famous "secondary battery," in 1860, based upon the powerful affinity which exists between *peroxide of lead* and *hydrogen*, a fact first noticed by De la Rive. Planté's battery is constructed as follows :—

It consists of nine elements, presenting a total surface of ten square metres, each element being formed of two large lead plates rolled into a spiral, and separated by coarse cloth, and immersed in water acidulated with one-tenth of sulphuric acid. The kind of current used to excite this battery depends on the manner in which the secondary couples are arranged. If they are arranged so as to give three elements of triple surface, five small Bunsen cells, the zincs of which are immersed to a depth of seven centimetres, are sufficient to give, after a few minutes' action, a spark of extraordinary intensity when the current is closed. The apparatus, in fact, plays the part of a condenser, for by its means the work performed by the battery, after the lapse of a certain time, may be collected in an instant. This secondary battery has since been greatly improved by Faure, Sellon, and others, and during the past few years secondary batteries have been very extensively adopted in connection with electric lighting, and even for the purposes of electro-deposition. When it is desired to keep the baths at work during the night, as when depositing thick coatings of copper, without running the dynamo, accompanied by the necessary attendance, the secondary batteries are charged, and being put in connection with the work and anodes in the tanks, are left to quietly yield up their current and continue the deposition until the following morning. Secondary batteries are extensively manufactured by the Electric Storage Company, London, and will doubtless be adopted by many electro-depositors to perform useful night work.

In the preceding pages we have directed attention more especially to the principal modifications of voltaic couples or circles, to which Volta's splendid discovery gave rise; we may state, however, that many other more or less ingenious batteries have been devised, but since most of these are ill-suited to the purposes of electro-deposition, a detailed description of them may be conveniently omitted. Indeed, we may say, as regards those voltaic couples to which we have referred, that for all practical purposes of the electro-depositor of metals—or, if we may so designate him, *electrolysist*—the voltaic batteries of Daniell, Smee, Wollaston, Grove, and Bunsen will fulfil all his requirements.

CHAPTER II.

ELECTRO-MAGNETISM.—MAGNETO-ELECTRICITY.—DYNAMO-ELECTRICITY.

Oersted's Discovery.—Electro-magnetism.—The Galvanometer.—Electro-magnets.—Magneto-electricity.—Saxton's Magneto-electric Machine.—Woolrich's Magneto-electric Machine.—Wilde's Magneto-electric Machine.—Gramme's Magneto-electric Machine.—Dynamo-electricity.—Siemens' Dynamo-electric Machine.—Weston's Dynamo-electric Machine.—Gülcher Dynamo-electric Machine.—Crompton's Dynamo-electric Machine.—Schuckert's Dynamo-electric Machine.—Mather's Dynamo-electric Machine.

Oersted's Discovery.—In the year 1819, Professor Oersted, of Copenhagen, made the important discovery that magnetism could be produced by electricity, and it will be necessary to give a brief résumé of the principal facts connected with this great discovery before treating of other discoveries to which, in course of time, it gave rise. It had never been believed that an electrified wire—that is, the wire which conveys the current from a voltaic battery—and a magnetised needle (as the needle of an ordinary mariners' compass) had any mutual influence; it was considered merely the means of conveying, or conducting, the voltaic current, and nothing more. Oersted proved, however, that *while a voltaic current is passing through the conducting wire*, it has the power of attracting and repelling a magnetic needle placed beneath it.

Electro-Magnetism.—If the needle be allowed to assume its natural direction, and a straight portion of the electrified wire then held above and *parallel* to it, the pole of the needle which is next to the negative end of the battery (the wire connected to the zinc) moves towards *the west;* if it be *below* the conducting wire the same pole moves towards *the east*. This striking phenomenon may be illustrated by taking a piece of copper wire (ordinary bell-wire, for example) about eighteen inches long, and connecting one end of it, by means of solder, to a strip of amalgamated zinc, the other end being connected in the same way to a strip of platinum or silver. The wire must be bent in the form indicated in Fig. 18. If the plates be now placed in a small glass or jar, and a magnetic needle (a pocket compass will do) placed beneath the lower bend of the wire and exactly parallel to it, no change will be observable; if, however, we now pour water acidulated with sulphuric acid into the glass, the needle will be at once *deflected*, or turned from its course, and exhibit a tremulous motion, as though under some irritating influence. There is not stronger evidence of the development of an invisible force, by the chemical action which takes place in the cell, than is produced by the motion of the needle under the influence of the copper wire through which that force is passing.

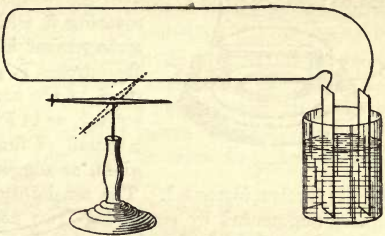

Fig. 18.

The Galvanometer.—The above important fact led to the construction of a most valuable instrument for detecting the presence of voltaic or current electricity and measuring its intensity, and is termed a *galvanometer*. These instruments are manufactured with great delicacy and are constantly employed by electricians and telegraphists. When the voltaic current passes above and below the needle at the same time and in opposite directions, the deflection of the needle is more powerful, for the current passing through the wire *above* the needle conspires, equally with the current passing along the wire *below*, to deflect the needle from its normal position and to bring it into a new position nearer at right angles to the plane of the wire. Taking advantage of these facts, Schweigger first conceived the idea of utilising them as a means of detecting the presence of current electricity. The simplest form of galvanometer is shown in Fig. 19. It consists of a magnetised needle so poised as to be affected by the current passing above and beneath it. N S indicate the north and south poles of the needle, and the darts explain the direction of the current, from its first entry at P to its exit at N. The two small copper or brass cups are for the reception of mercury for the purpose of connecting the wire with the voltaic battery or other source of the electric current.

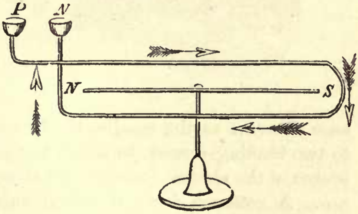

Fig. 19.

Another important fact in connection with Oersted's fundamental discovery, is that an electrified wire not only possesses the power of turning the magnetic needle from its natural position, but it can also affect contiguous wires; moreover, the effects above described can be *multiplied* by multiplying the convolutions of the wire, and if the wire be *insulated* so as to prevent the escape of the current laterally, by covering it with silk, the delicacy of the arrangement in detecting weak traces of the current is greatly increased. If, instead of the needle being supported upon a pivot, as in Fig. 19, it be suspended by a thread of fine silk or filament of spun glass, as suggested by Ritchie, its sensibility is further increased. The sensibility of the instrument is still further augmented by employing two needles, one above and one within the coil, and placed parallel, but with their poles reversed, whereby the magnetic influence of the earth is neutralised.

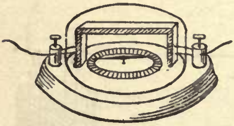

Fig. 20.

There are many forms of the galvanometer, but they all consist essentially of a compass needle, with one or more strands of covered, that is insulated, copper wire surrounding it, and arranged *in the same direction* as the needle, the two ends of the wire being connected to two binding-screws, to which the terminals of the battery, or other source of the electric current, are attached when the instrument is in use. A common form of galvanometer is shown in Fig. 20, and a still more convenient instrument in Fig. 21.

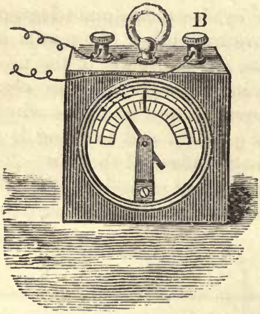

Fig. 21.

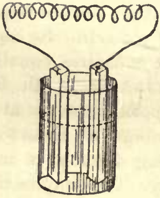

Fig. 22.

Having thus shown how the electric current, traversing copper wire, influences the position of a magnetic needle, let us now see what effect it will have upon iron. To illustrate this, we will take the same simple voltaic circle as before (Fig. 18), but in place of the naked straight wire employed in the former case, we will take a length of covered copper wire and form it into a helix, or coil, as in the accompanying cut, Fig. 22. Now, if we pass a small rod of iron through the coil, and then pour dilute sulphuric acid into the glass cell, we shall find, on bringing an ordinary steel needle, or iron filings near the projecting end of the iron rod, that they will be attracted by it, showing that the iron has become magnetic. On removing the rod, however, the iron will be found at once to lose its magnetic property, for the filings will instantly fall from it. If the rod be replaced in the helix it will again become magnetic. From this it is evident that an insulated wire through which an electric current passes acquires a temporary magnetic property; and the fact may be more fully demonstrated in the following way.

Electro-Magnets.—A bar of soft iron is bent in the form of a horse-shoe, as in Fig. 23. Covered copper wire is now twisted round the bar, as in the illustration, and the two ends of the wire are connected to a voltaic battery, as a Smee or Daniell battery, for example. If, now, a bar of iron be brought near the two *poles* of the *artificial magnet* thus formed it will be at once attracted to them; and if the current have sufficient power, this will be capable of sustaining an additional weight. Indeed, such *electro-magnets*, as they are termed, have been constructed which were capable of sustaining many hundreds of pounds weight. The magnetic state established in the way described is termed *induced magnetism*, to distinguish it from the *permanent* magnetic condition of *steel* bar or horse-shoe magnets with which all are familiar. We thus see how Oersted's fundamental discovery led up to the invention of the galvanometer and the construction of electro-magnets.

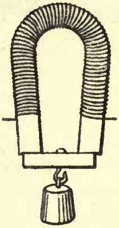
Fig. 23.

Magneto-Electricity.—In the year 1831, Michael Faraday—one of the most brilliant observers of the present century—had been engaged in investigating the phenomena above referred to, when it occurred to him, since magnetism could be produced by electricity, that magnetism in motion ought to produce an electric current, and in order to verify his conclusion, he adopted the following device: A long spiral coil of covered copper wire was connected by its ends to a galvanometer, which would, of course, indicate a current of electricity in the helix and wires connected with it; he found that in the act of introducing the pole of a powerful bar magnet within the coils of the spiral, a deflection of the galvanometer needle took place, in one direction, and in the act of withdrawing it, took place in the opposite direction; so that each time the conducting wire cut the magnetic curves, a current of electricity was for the moment produced in it. He subsequently had a copper disc (Fig. 24) mounted so that it could be made to revolve upon its own axis between the poles of a powerful horse-shoe magnet; a conducting wire w was placed in contact with the axis of the copper disc, and a second wire w' was put in contact with the circumference of the disc. The terminals of the wires are shown dipping into the mercury cups of a galvanometer *g*, and the darts indicate the direction of the current. N S represent the north and south poles of the magnet. When the copper disc is made to revolve from right to left, a current of electricity is produced in the direction of the darts, and the galvanometer needle is at once deflected; if, however, the disc is made to revolve in the opposite direction, or if the poles of the magnet are reversed, the electric current moves in an opposite direction.

Not only did Faraday obtain indications of an electric current by the galvanometer under the above conditions, but by another modification of the arrangement, in which the current was induced by *an electro-magnet*, he succeeded in obtaining an electric spark. Subsequently, Nobili and Antinori, and in this country Professor Forbes, obtained a spark from a permanent magnet. For this purpose a helix of insulated copper wire was formed round the middle of the soft iron *keeper* (or *armature*) of a powerful horse-shoe magnet; on *making* and *breaking* contact between the keeper and the magnet, magnetism was alternately created and destroyed within it, and at these periods of transition, electric currents were induced in the helix, and on so arranging the conducting wires as at these moments to make and break contact with mercury, a brilliant spark was observed at each motion of the keeper. It was afterwards found that by causing the poles of a powerful horse-shoe magnet to revolve rapidly before a soft iron armature covered with insulated wire, or by a still better arrangement to make the armature revolve before the poles of the

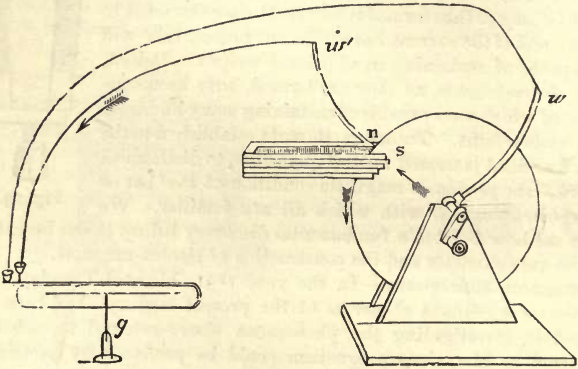

Fig. 24.

magnet, an electric current was obtained possessing sufficient power to render iron wire red hot. Thus the foundation was laid for the construction of still more powerful contrivances, which, in due course, were produced, the first of which was invented by Pixii, of Paris, and first made known at a meeting of the Academy of Sciences on September 3rd, 1832. In June of the following year, Mr. Saxton introduced an improvement on Pixii's machine, which, in 1835, he further improved by adding to the machine a *double armature.* With this machine he could not only produce brilliant sparks and give powerful shocks, but it was found very effective in chemical decomposition. The following description of this machine is thus given by Professor Daniell, and since it was the first really practical magneto-electric machine, its introduction here will be both interesting and instructive.

Saxton's Magneto-electric Machine.—A very powerful horseshoe magnet, formed of numerous steel plates [a compound magnet] closely applied together, or an electro-magnet of soft iron of the same form, is placed in a horizontal position. An armature or bar of the purest soft iron has each of its ends bent at a right angle, and is mounted in such a way that the surfaces of those ends are directly opposed and close to the poles of the magnet; in this position it may be made to rotate rapidly in a vertical direction by means of multiplying wheels and an endless band. Two series of copper wires, covered with silk, are wound round either end of this bar as compound helices. The extremities of these wires, having the same direction, are connected together and with a small circular disc, rotating with the armature in a cup of mercury, with which it is, therefore, in metallic communication in every position of the disc. The other extremities of the wires are united together, and, passing without metallic contact through the spindle upon which the apparatus turns, terminate in a small slip of copper with two opposite points placed at right angles to the axis. These, in the act of rotation, alternately dip into and rise above the mercury in another cup, which may be connected with the first at pleasure by means of a copper wire. By the laws of magnetic induction the armature becomes a temporary magnet whenever its bent ends are opposite the poles of the magnet, and ceases to be magnetic when they are at right angles to them. The momentary generation and destruction of the magnetic force, which will be oppositely directed in the bar as its opposite ends become opposed to the same poles in the act of rotation, must, by the laws of magneto-electric induction, induce corresponding opposite electric currents in the copper wire, if the circuit be complete, by the immersion of the points at the moment of their passage. The points are so arranged that, standing nearly at right angles to the revolving bar, they just rise from the mercury as its ends become opposed to the poles of the magnet, and, the circuit being thus suddenly broken at the moment of the electric wave, the current passes in the form of a brilliant spark. An illustration of Saxton's magneto-electric machine is shown in Fig. 25, of which the following description is given in Noad's "Text-Book of Electricity":—*

"A is a compound horse-shoe magnet, composed of six or more bars, and supported on the rests *b e*, which are screwed firmly on the board B D; into the rest *e* is screwed the brass pillar *c*, carrying the wheel *f*, having a groove in its circumference and a handle by which it can readily be revolved on its axis. A spindle passes from one end of the magnet to the other, between the poles, and projects beyond them about three inches, where it terminates in a screw at *k*, to which the armatures, to be described immediately, are attached; at the farther extremity is a small pulley, over which a gut band passes, by means of which, and the multiplying wheel *f*, the armatures can be revolved with great rapidity.

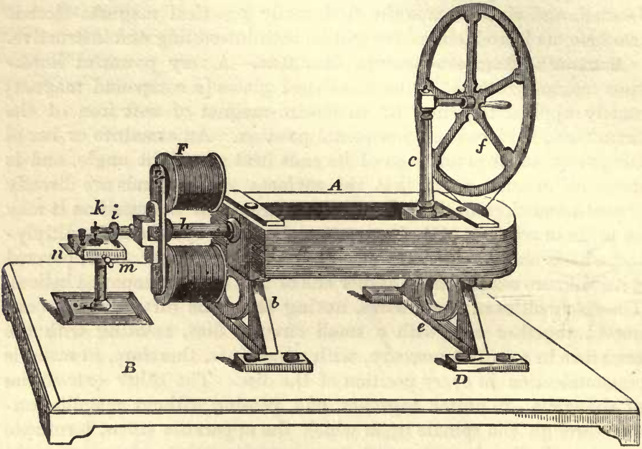

Fig. 25.—Saxton's Magneto-Electric Machine.

"The armatures, or *inductors*, as seen at F, are nothing more than electro-magnets. Two pieces of round iron are attached to a cross-piece, into the centre of which the spindle *h* screws. Round each of these bars is wound, in a continuous circuit, a quantity of insulated

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* "The Student's Text-book of Electricity." By Henry M. Noad, F.R.S., &c. Edited by W. H. Preece, M.I.C.E.

copper wire, one end being soldered to the disc *i*, the other connected to the copper wire passing through but insulated from it by an ivory ring. By means of the wheel and spindle each pole of the armature is brought in rapid succession opposite each pole of the magnet, and that, as near as possible, without touching. The two armatures differ from one another; the one termed the *quantity* armature is constructed of stout iron, and covered with thick insulated wire; the other, termed the *intensity* armature, is constructed of slighter iron, and covered with from 1,000 to 2,000 yards, according to the size of the instrument, of fine insulated wire. The illustration exhibits the machine with its *quantity* armature."

In the year 1847, the author's brother, Mr. Charles Watt, Chemist to the Australian Government, had such a machine constructed by the late Mr. Henley, in which the driving-wheel, with spindle attached, was fixed beneath the table, and the rotary motion given by means of a treadle, as in an ordinary lathe. Considering the early period at which it was made, the machine gave very satisfactory results in electro-chemical experiments upon a moderate scale, but for any really practical purpose it was quite unsuitable.

Woolrich's Magneto-electric Machine.—The first practical application of magneto-electricity to the electro-deposition of metals was made by Mr. J. S. Woolrich, who, on August 1st, 1842, obtained a patent for a magneto-electric machine which was adopted in several large electro-plating establishments—the first of these machines having been adopted, we believe, by Messrs. Prime and Son, of Birmingham, and which those gentlemen, a few years since, exhibited to the author as a disused relic, the functions of which had been transferred to a more effective contrivance. We lately recognised this machine, which had long done duty for this firm as a substitute for voltaic batteries, at an establishment in London.

Wilde's Magneto-electric Machine.—This important machine, for which Mr. Henry Wilde obtained a patent in the year 1865, has proved of immense service to those who required to deposit large quantities of silver and other metals from their solutions. The machines have also been largely used at the copper works of Messrs. Elkington and Co., at Pembrey, near Swansea, for refining copper from crude slabs of the unrefined metal. For a long time after its introduction the Wilde machine remained without a competitor, and was the means of greatly extending the usefulness of the art of electro-deposition, more especially in the towns of Sheffield and Birmingham, where they have been very extensively employed. We may state, however, that the original form of machine has since been considerably improved, and we are enabled, through the courtesy of the Electric Engineering Company, of Manchester, successors to Messrs. H. Wilde and Co., to furnish the following particulars of the new machines, which will doubtless prove interesting to those who deposit metals by electrolysis upon a large scale.

Fig. 26 represents a 32-magnet machine embodying Mr. Wilde's latest improvements. This machine is capable of depositing, in a series of 130 vats, each having 40 square feet of positive and the same negative surface, an aggregate weight of over 900 pounds of copper per day of 24 hours, with an expenditure of 13 horse-power. The same firm manufacture a 12-magnet machine of the same type as the foregoing, for the purposes of electro-plating, which has been adopted by many firms in Sheffield and Birmingham. This machine deposits about 30 ounces of silver per hour, with an expenditure of ½ to 2 horse-power.

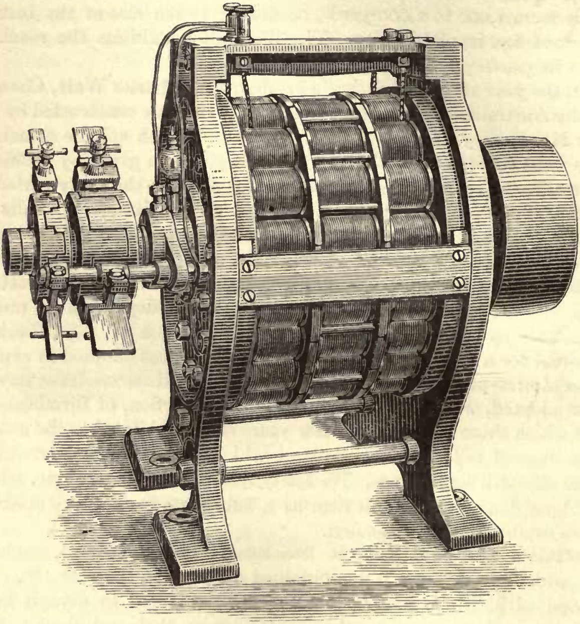

Fig. 26.—Wilde's Magneto-electric Machine.

The action of these machines is thus described by the Electric Engineering Company in a communication to the author: "These machines (unlike the earlier ones of Mr. Wilde's invention, which are excited by a separate machine), are self-exciting, but at the same time are double-circuit machines; that is, while the current from one or two of the coils in the revolving armature disc is used for exciting the series of electro-magnets, the current from the remainder of the coils is used for external work. This arrangement is free from the objectionable feature, common to single-circuit machines, of reversing the current whenever the speed is from any cause reduced below the usual amount, as the current from the polarised electrodes in the depositing vats is then at liberty to return, and reverse the magnetism of the machine while the speed is reduced, and is often a source of much inconvenience and loss to the electro-plater." We are in a position to corroborate this statement, having frequently known dynamo-machines, otherwise exceedingly effective and regular in their action, which have suddenly reversed while the bath was full of work, causing the whole of the deposited coating to disappear, and necessitating the recleaning of the articles. This untoward event has usually occurred in establishments which derived their steam-power from adjacent premises, the regularity of which could not be depended upon, owing to the variety of purposes to which the power was applied outside the plating works. It is within our own knowledge that many nickel-platers, who had adopted dynamo-electric machines in substitution for voltaic batteries, suffered much inconvenience from the irregularity of hired steam-power, and in not a few instances they have wisely purchased a gas-engine, with incalculable advantage to their daily work, and far greater economy.

We understand that the Wilde machines have been successfully adopted by electrotypers, in which field there will doubtless be great extension of usefulness when our large printing firms recognise the full importance of the American system of substituting electrotyping for stereotyping, over which it has advantages which cannot long remain open to doubt. These machines are also extensively used in producing copper rollers for calico printing.

Gramme's Magneto-electric Machine.—This machine, which has attained a high rank as an electric-light machine, has not been much adopted in this country for the purposes of electro-deposition. It is, however, extensively applied on the Continent for these purposes, and notably at the electro-plating works of MM. Cristofle, in Paris. We lately observed one of these machines at work at the well-known establishment of the Nickel-plating Company, Greek Street, Soho, London, where it is employed in nickel-plating, and in depositing copper upon steel shot for the Nordenfelt gun. The author's friend and former pupil, Mr. Charles Blaker, chemist to the above firm, expresses himself much pleased with his Gramme, which appears to do excellent work, and to give no trouble whatever.

The Gramme machine, Fig. 27, consists essentially of a ring of soft iron, covered with a large number of coils of insulated copper wire, the respective ends of which are connected with the separate sections of two commutators fixed upon the axis of the machine. This ring, with its coils and commutators fixed upon its axis, revolves between the poles of an electro-magnet. The capabilities of the machine are thus described :—

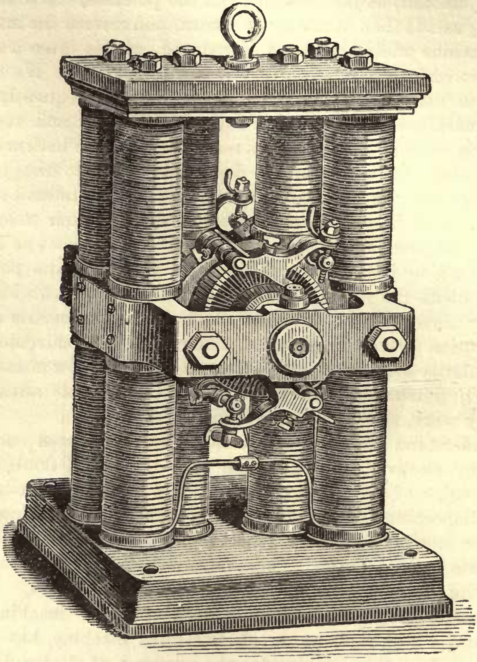

Fig. 27.—Gramme's Magneto-electric Machine.

"To deposit 600 grammes of silver requires one horse-power, and a speed of 300 turns per minute; the tension (electromotive force) of the current being equal to that of two of Bunsen's cells, and its quantity equal to thirty-two such cells of ordinary size. At a speed of 275 revolutions per minute it has deposited 525 grammes of silver per hour; at 300 turns, 605 grammes; and at 325 turns, 675 grammes.*

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* When worked at so high a speed, the machine is liable to become heated and its effectiveness thereby considerably impaired.

The weight of the copper wire on the fixed electro-magnets was 135, and on the movable ones 40 kilogrammes.* The present form of the machine, as used for electro-deposition, is composed as follows:—†

Total weight	117·5 kilogrammes.
Copper coils	47·0 „
Total height	·6 metre.
Total width	·55 „
Deposits silver per hour	600· grammes.
Required power to work it	50· kilogrammetres.

Dynamo-Electricity.—After the introduction of Wilde's Magneto-electric Machine in 1866, and its subsequent exhibition before the Royal Society, where its capabilities were fully demonstrated, the late Sir Charles Wheatstone and Dr. Werner Siemens, experimenting quite independently of each other, produced, almost simultaneously, two machines, which were identical in principle, and involved a new feature in magneto-electricity—the conversion of *dynamic* or *mechanical* force into *electric force* without the aid of permanent magnetism. The principle of this machine was explained by the late Sir C. W. Siemens, in a paper submitted to the Royal Society in February, 1867,‡ from which we extract the following: "Since the great discovery of magnetic electricity by Faraday, in 1830, electricians have had recourse to mechanical force for the production of their most powerful effects; but the power of the magneto-electric machine seems to depend in an equal measure upon the *force expended* on the one hand, and upon *permanent* magnetism on the other. An experiment, however, has been lately suggested to me by my brother, Dr. Werner Siemens, of Berlin, which proves that permanent magnetism is not requisite in order to convert *mechanical* into *electrical* force; and the result obtained by this experiment is remarkable, not only because it demonstrates this hitherto unrecognised fact, but also because it provides a simple means of producing very powerful electrical effects. The apparatus employed in this experiment is an electro-magnetic machine, consisting of one or more horse-shoes of soft iron, surrounded with insulated wire in the usual manner of a rotating keeper [armature] of soft iron, surrounded also with an insulated wire, and of a commutator connecting the respective coils in the manner of a magneto-electric machine. If a galvanic battery were connected with this arrangement, rotation of the keeper in a given direction would ensue. If the battery were

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* *Telegraphic Journal*, vol. i. p. 54.

† *Ibid.*, vol. iii. p. 198.

‡ *Proceedings of the Royal Society*, vol. xv. p. 397

excluded from the circuit, and rotation imparted to the keeper in the opposite direction to that resulting from the galvanic current, there would be no electrical effect produced, supposing the electro-magnet were absolutely free of magnetism; but by inserting a battery of a single cell in the circuit, a certain magnetic condition would be set up, causing similar electro-magnetic poles to be forcibly approached to each other, and dissimilar poles to be severed, alternatively, the rotation being contrary in direction to that which would be produced by the exciting current.

"Each forcible approach of similar poles must augment the magnetic tension and increase, consequently, the power of the circulating current; the resistance of the keeper to the rotation must also increase at every step until it reaches a maximum, imposed by the available force and the conductivity of the wires employed. The co-operation of the battery is only necessary for a moment of time after the rotation has commenced, in order to introduce the magnetic action, which will thereupon continue to accumulate without its aid. With the rotation the current ceases; and if, upon restarting the machine, the battery is connected with the circuit for a moment of time with its poles reversed, then the direction of the continuous current produced by the machine will also be the reverse of what it was before. Instead of employing a battery to commence the accumulative action of the machine, it suffices to touch the soft iron bars employed with a permanent magnet, or dip the former into a position parallel to the magnetic axis of the earth, in order to produce the same phenomenon as before. Practically it is not even necessary to give any external impulse upon restarting the machine, the residuary magnetism of the electro-magnetic arrangements employed being found sufficient for that purpose."* The principle of the dynamo-electric machine is thus further described by Dr. Siemens: "Induced currents are directed through the coils of the electro-magnets which produce them, increasing their magnetic intensity, which in its turn strengthens the induced currents, and so on, accumulating by mutual action until a limit is reached. . . . The name *dynamo*-electric machine is given to it because the electric current is not induced by a *permanent magnet*, but is accumulated by the mutual action of electro-magnets and a revolving wire cylinder or armature. It is found that as the dynamic force required to drive the machine increases, so also does the electric current; it is, therefore, called a *dynamo-electric machine.*"

Siemens' Dynamo-electric Machine.—This remarkably effective

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* In wrought iron there is always some residual magnetism; there is, therefore, no necessity to start the magnetism with a permanent magnet.—*Dr. Siemens.*

apparatus (Fig. 28), which, in its application to electric lighting has attained the highest rank, and from its great power, uniform action, and reliability has done much to establish the practicability and usefulness of electric lighting, is also manufactured by Messrs. Siemens Brothers, at their extensive works at Charlton Pier, Woolwich, specially for the purposes of electro-deposition and the refining of copper by electrolysis. One of these machines, suitable for electrotyping, works up to 4 baths arranged in series, and deposits in each cell up to 7 ozs. of copper per hour, the cathode surface of each cell being 21 square feet. The electromotive force is equal to 3 to 6 Daniell batteries, and the power absorbed 1½ horse-power. A machine suitable for silver-plating, coppering iron, &c., works through a

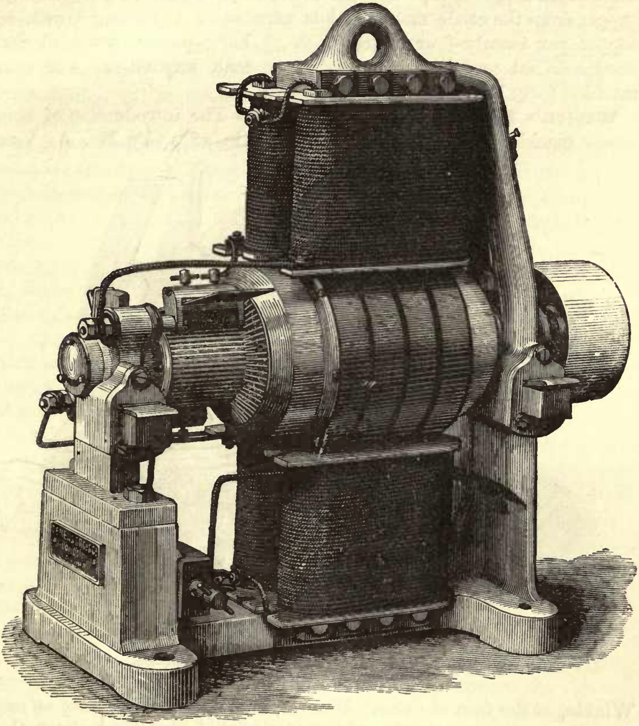
Fig. 28.—Siemens' Dynamo-electric Machine.

single bath or more, placed parallel, and deposits 11 ozs. of silver per hour, with an absorption of $\frac{1}{2}$ to 1 horse-power. A third type, suitable for nickeling, brassing, &c., deposits $1\frac{3}{4}$ ozs. of nickel per hour, producing "a good deposit of nickel in three minutes over a surface of 10 square feet. Difference of potential at the terminals, 6 to 12 Daniells; absorption of horse-power $\frac{1}{2}$ to 1." The larger type of these machines, "C 12," is constructed for the purposes of refining copper from the crude metal, and is capable of depositing 5 cwt. of copper per twenty-four hours, with $7\frac{1}{2}$ horse-power, provided the anodes do not contain more than 4 per cent. impurities. For this machine forty baths are required.

Weston's Dynamo-electric Machine.—The introduction of this clever machine from the United States, in 1874, by Mr. A. Van Winkle, of the firm of Condit, Hanson, and Van Winkle, gave an extraordinary impetus to the nickel-plating industry throughout the whole country. Being of small dimensions, of compact form, and yielding an abundant current, it became readily adopted by a large number of firms. It was at the author's suggestion and recommendation that the first of these machines was tried and adopted by the Plating Company, Limited, of Kirby Street, London, in that year, and though he had some difficulty in overcoming the prejudices of the foreman of that establishment, by insisting upon a fair trial being given

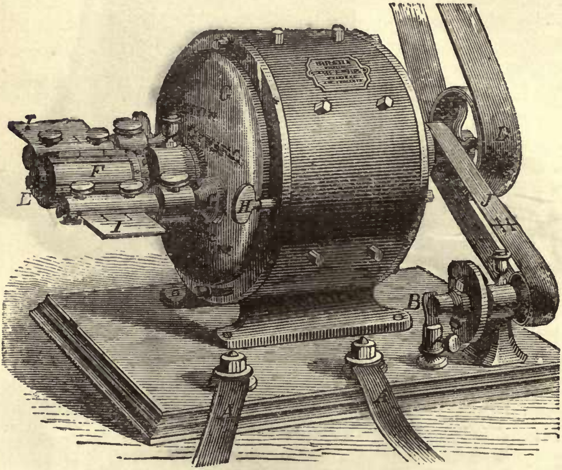

Fig. 29.—Weston's Dynamo-electric Machine.

and taking care that no obstacle should be thrown in the way, he succeeded in securing not only a fair trial of its capabilities, but its ready adoption by the company. The Weston machine was subsequently adopted by a great number of firms, amongst which were many that would probably never have embarked in nickel-plating but for the facility which this machine offered in generating the requisite electric current at the cost of less than one horse-power. There can be no doubt whatever that the remarkable development of nickel-plating in this country and in America, as also the substitution of electrotyping for the stereotype process in American printing establishments, are greatly, if not chiefly, due to the introduction of the Weston dynamo-electric machine.

Gulcher Dynamo-Electric Machine.—This machine, which is manufactured by the Gülcher Electric Light Company, at Battersea, is specially constructed to suit the requirements of electro-metallurgists and electro-platers, and has been successfully adopted, at Swansea, by Messrs. Vivian, and Messrs. Lambert and Co., for the electrolytic refining of copper. The machine has also been adopted by Mr. W. H. Hills, of Chester, for the same purpose, and by Mr. Bown, of Birmingham and others for nickel-plating. Several large firms are also using this machine for electro-pickling sheet-iron plates previous to tinning them. These machines work at low speed, and have ample bearing surfaces, so that while steadiness and regularity of current are insured, with absence of sparking, the wear and tear are greatly reduced. Having used one of the improved Gülcher machines during a period of many months, we may say that it enabled us to carry out a long series of practical trials with perfect ease and certainty, and in no instance did it fail to yield what was required—a perfectly steady and regular current. The following description explaining the construction of the Gülcher machine has been forwarded at our request by Mr. W. C. Mountain, the manager of the Gülcher Works:—

This dynamo may be described as of the Paccinoti type, *i.e.* the armature of the machine is in the form of a fly-wheel, and the copper conductors in which the current is induced are wound on the rim at right angles to the circumference. This armature, when finished, is mounted upon a steel spindle, and revolves between electro-magnets having alternate north and south polarity grouped round its circumference. The engraving, Fig. 30, represents a Gülcher dynamo with four poles, that is, two north and two south. It has been recently found, in making the ordinary sizes of this dynamo, that it is not advisable to increase the number of the poles beyond four or six, the most economical plan being to make the magnets heavy, that is, large in section, on account of the increased efficiency thus obtained.

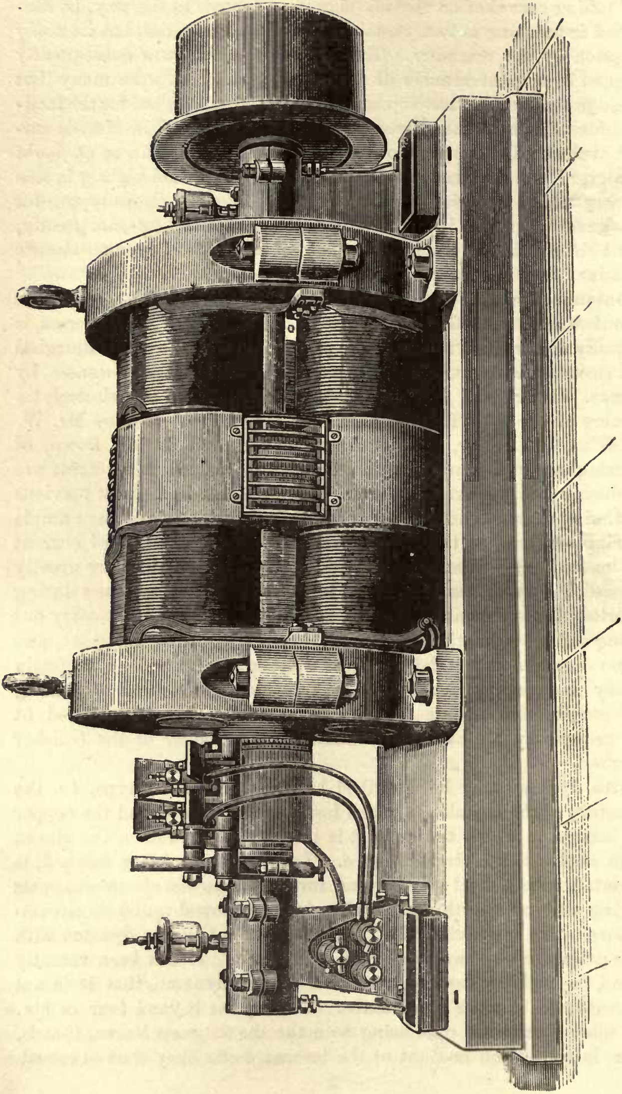

Fig. 30.—Gülcher's Dynamo-electric Machine.

Upon examination of the woodcut it will be noticed that as the armature revolves in the bearings it passes between the pole-shoes grouped round the circumference, the result being that lines of magnetic force, which may be said to sprout out from the magnets, are cut at right angles by the armature coils, which sets up an E.M.F. and current. The current from the armature then passes by connecting-wires to the commutator, which is placed between the outside bearing and the frame of the machine. The commutator is composed of a number of wedge-shaped copper bars, cramped together by a gun-metal sleeve, each section being carefully insulated with mica; the number of sections corresponds with those on the armature, and varies from sixty to one hundred and eighty, according to the size of the dynamo.

On the end bearing a revolving strap is fixed carrying two spindles, upon which the collecting brushes are placed. The strap is made so that it will revolve backwards or forwards, in order that the brushes may be placed in any desired position upon the commutator. The brush-holders are made of gun-metal, and are never less than two, and sometimes as many as six in number, according to the output of the dynamo. These are arranged with a throw-off catch and tension-adjusting screw, so that the brushes may be thrown back, and held off the commutator when desired; or the tension of the brush upon the surface of the commutator can be accurately adjusted. Flexible connecting-cables are attached to each brush-holder, and led to terminals on each side of the machine, from which points the current generated by the dynamo passes by main cables to the depositing or plating tanks, or to the arc and incandescent lamps, according to the purpose for which the dynamo is required. The magnets used in these machines are constructed of the softest wrought iron obtainable, which is carefully annealed before using; the inside ends of the magnets are connected by a cast-iron pole-shoe; the outside ends of the bars are turned down slightly, and are secured by nuts into the two cast-iron circular frames of the machine; this method of construction gives ample magnetic contact. The magnet coils are wound on loose bobbins made of charcoal iron, the object being to enable the coils to be taken off and readily replaced in case of accident.

The armature hub, which is in the form of a pulley, is made of the finest quality of phosphor bronze, and the rim wound up with charcoal-iron wire of rectangular section; when finished it has the form of a fly-wheel. This construction of the armature totally avoids all heating, and consequent loss of efficiency. Special attention is also paid to the construction of the bearings, a point of vital importance in any class of machinery constructed to run at high speeds for a lengthened period. The cast-iron brackets or pedestals are bolted to the bedplate of the machine, each bracket being fitted with a cast-iron cap, which affords means of adjustment. The bed for the phosphor bronze bearing is then carefully bored and faced to a standard size and length, and bushes of the same material, which are also of standard sizes, and in halves, are fitted. The side frames of the machine are made in halves, and secured by four turned bolts, so that by simply removing them, and taking off the bearing caps, the top of the machine can be lifted off, and the armature and spindle lifted out of the dynamo.

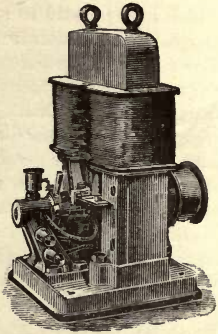

Fig. 31.

The Gülcher Company also manufacture a 2-pole vertical type dynamo, specially for electro-plating purposes. This machine, which is shown in Fig. 31, is made in four sizes, and from the moderate prices charged, from £25 to £40, are well suited for small plating works. The smallest of these machines is constructed to give a current of 100 ampères, and the larger machine 300 ampères, with an E M.F. of 5 volts. The speed required is about 1,500 revolutions. We recently saw some of these machines in course of construction, and were much pleased with the evident care that was bestowed upon them.

Crompton's Dynamo-Electric Machine.—This machine (Fig. 32), which is manufactured by Messrs. R. E. Crompton & Co., of Chelmsford and London, has been extensively adopted for electric lighting, both for public and private use, and has also been applied to the refining of copper by electrolysis, several of the machines having been supplied to Messrs. Vivian & Sons, and Messrs. Williams; Foster & Co., of Swansea. The special advantages claimed for the Crompton dynamo have been described to us as follows:—The machines have a very strong magnetic field; the armature, which in large machines has to stand so severe a strain, is a thoroughly good mechanical job, as the core is carried on radial bars made of the hardest and toughest aluminium bronze, fitted to the spindle by a dove-tailed joint, so that the whole of the twisting strains are transmitted direct from the spindle to the winding, and thus many of the old breakdowns arising from the slipping of the core, or the rising of the core, are entirely done away with. The efficiency of these machines is remarkably high, 94 per cent. appearing as useful electrical power at the terminals of the dynamo. The machines for electro-deposition are in three standard sizes, namely: 50 volts, 500 ampères; 50 volts, 750 ampères; and 50 volts, 1000 ampères: the horse-power required being respectively $35\frac{1}{2}$, 53, and 71. The same firm have recently constructed the largest dynamo in the world for the Cowles Electric Smelting Furnaces at Stoke-on-Trent, to which reference is made in another part of this work.

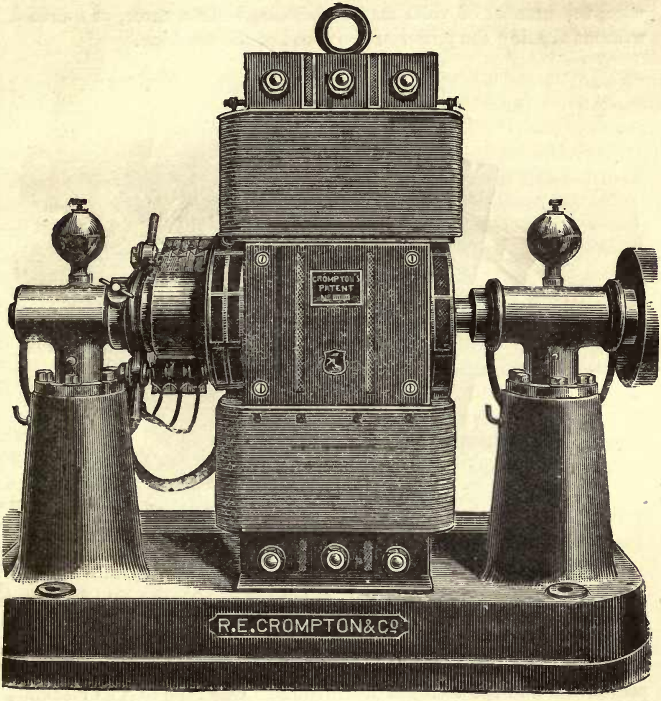

Fig. 32.—Crompton's Dynamo-electric Machine.

Schuckert's Dynamo-electric Machine.—This machine, which is extensively used in Germany, is said to be very successful, more especially in its larger types. We have, however, seen one of the smaller machines employed for electrotyping, at Messrs. Cassell and Co.'s, Ludgate Hill, London, which we were informed gave perfect satisfaction. Whilst almost noiseless in action, it presented the appearance of being an exceedingly well-constructed machine. We understand that the more closely the maker follows the original design of the inventor, the greater is the practical value of the machines. The larger type of this dynamo is shown in Fig. 33. By winding the bobbin and the coils of the electro-magnets with a finer wire, the number of volts may be increased—two, three, or fourfold, without altering the power or the speed of the machine.

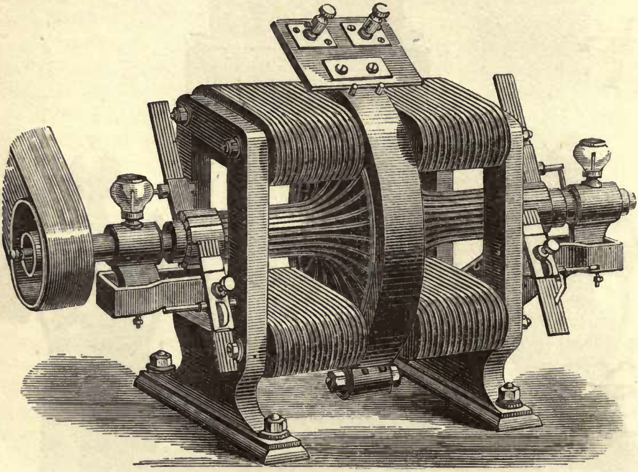

Fig. 33.—Schuckert's Dynamo-electric Machine.

Mather's Dynamo-electric Machine.—This is an American machine, designed by Mr. Mather, of New York, in which the Siemens armature plays an important part. It is said to be a very strongly constructed machine, and well combined as regards the magnetism and the access of the brushes. One type of this machine, which runs at a speed of 800 revolutions per minute, is said to deposit 10 kilogrammes of copper at an expenditure of 7 horse-power.

CHAPTER III.

THERMO-ELECTRICITY.

Seebeck's Discovery of Thermo-Electricity.—Thermo-electric Laws.—Thermo-electric Piles and Batteries.—C. Watt's Thermo-electric Battery.—Becquerel's Thermo-Pile.— Clamond's Thermo-electric Pile.—Wray's Thermo-Pile.—Nöe's Thermo-Battery.—The Future of Thermo-Electricity.

Seebeck's Discovery of Thermo-Electricity.—In the year 1821 Professor Seebeck, of Berlin, made the remarkable discovery that when a bar of antimony, *a*, Fig. 34, with a piece of brass wire coiled round it, *b*, and attached to the other end in the form of a loop, *c*, was *heated* by the flame of a spirit lamp at *b*, where the two metals were in contact, that this caused the deflection of a magnetic needle placed at *d*. The discovery established the fact that electricity could be generated by the action of heat upon two different metals. A more effective arrangement for producing a current in this way is obtained by means of antimony and bismuth united, as in Fig. 35, so as to form a hollow parallelogram, A representing the bar of antimony, and B, a bar of bismuth; on applying heat to one of the junctions, by a spirit lamp, a *quantitative* current of electricity is put in motion through the metals, which is immediately indicated by the deflection of a magnetic needle, and this effect is considerably increased if the opposite junction of the metallic bars be at the same time cooled, by the application of ice, or a freezing mixture (or blotting-paper saturated with ether). It is not necessary, however, that two metals should be employed to produce the above result, for although a platinum wire, connected to a galvanometer, and heated, produces no

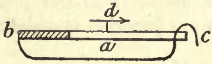

Fig. 34.

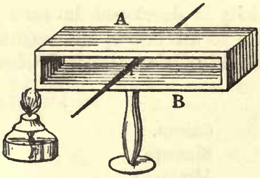

Fig. 35.

effect upon the needle, if it be knotted or twisted a deflection is noticed, showing, when heat is applied on the right of the knot, that the direction of the current is towards the left; this effect is ascribed to the unequal rate at which the heat travels on the two sides of the obstruction; and again, if the wire be divided, one end of it being cooled, and the other heated, the needle will deviate when the metals are brought into contact, indicating a current from the hot to the cool surface. If a bar of bismuth be soldered to one end of the galvanometer wire, and a bar of antimony to the other, no effect is produced on bringing the two bars into contact when they are both of the same temperature; but if one of them be either heated or cooled, and then made to touch the other, the flowing of an electric current is immediately indicated.—*Brande.*

Sir William Thomson proved, in 1856, that if portions of a metallic wire be stretched by weights, and connected with other portions of the same wire not so stretched, that, on applying heat to their junctions, a current is determined from the stretched to the unstretched wire through the heated point.

All metals, as also some other bodies, are capable of yielding thermo-electric currents, and it has been shown that this property has no connection with their voltaic relations to each other or with their conductibility, either as regards heat or electricity. In arranging a thermo-electric series, the greatest effects are obtained when the most positive is connected with the most negative metal. When any two metals in the subjoined series are *heated* at their point of junction, electricity is developed in such a manner that each metal becomes positive to all below, and negative to all above it in the list, the reverse order being observed when the point of junction is *cooled*:—

Thermo-electric Series.

Galena.
Bismuth.
Mercury }
Nickel }
Platinum.
Palladium.
Cobalt }
Manganese }
Tin.
Lead.
Brass.
Rhodium.
Gold.
Copper.
Silver.
Zinc.
Cadmium.
Charcoal.
Plumbago.
Iron.
Arsenic.
Antimony.

Dr. Matthiessen arranged the following order and electric energy of various bodies for temperatures usually ranging between about 40° and 100°. In the table the electromotive force of the thermo-current excited between silver and copper is taken as equal to 1, the current passing from the silver to the copper at the heated end. The numbers represent the force of the current between silver and each metal in succession, heated at the same point. Where the positive sign + is prefixed the current is from the silver to the other metal at the point of junction; and where the negative sign — is prefixed, the current is from the other metal at the heated point towards the silver. The asterisks signify that the metal specified is supposed to be *chemically pure.*

THERMO-ELECTRIC ORDER OF METALS.

	+		—
Bismuth, commercial pressed wire	35·81	Gas coke, hard	0·057
*Bismuth, pressed wire	32·91	*Zinc, pressed wire	0·208
*Bismuth, cast	24·96	*Copper, voltaic *	0·244
Crystallised Bismuth, axial	24·59	*Cadmium	0·332
Crystal of Bismuth, equatorial	17·17	Antimony, pressed wire	1·897
Cobalt	8·97	Strontium	2·028
Potassium	5·49	Lithium	3·768
Nickel	5·02	*Arsenic	3·828
Palladium	3·56	Calcium	5·260
Sodium	3·094	Iron, piano wire	5·218
*Mercury	2·524	Antimony, axial	6·965
Aluminium	1·283	Antimony, equatorial	9·435
Magnesium	1·175	*Red Phosphorus	9·600
*Lead, pressed wire	1·029	*Antimony, cast	9·871
*Tin, pressed wire	1·000	Alloy, 12 bismuth „ 1 tin, cast	13·670
Copper wire	1·000	Alloy, 2 antimony „ 1 zinc, cast	22·70
Platinum	0·723	*Tellurium	179·80
Iridium	0·163	*Selenium	290·0
*Antimony, pressed wire	0·036		
*Silver	0·000		

Thermo-electric Laws.—According to Becquerel, the following laws govern the development of electricity in thermo-electric pairs:—

1. In a thermo-electric couple, so long as the difference in temperature between the two junctions remains the same, the current is rigorously constant.

2. In a thermo-electric pile the intensity of the current, all else being equal, is proportional to the number of couples.

3. The intensity of thermo-electric currents increases with the difference of temperature between the junctions; and if one be at zero, this intensity is proportional, within the limit of 40° to 45°, to

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* Electrolytic Copper.

the temperature of the other junction. In this law the limit of 45° is applicable to a copper-antimony couple, but it varies with the metals. For iron and copper it extends as far as 300°, and as much above that for iron and palladium.

Thermo-electric Piles and Batteries.—Since Seebeck's discovery was made known, many attempts have been made to design thermo-electric apparatus capable of being utilised as an economical source of electric power. The arguments adopted, when the first efforts were made in this direction, some forty years ago, when electricity, for practical purposes, was chiefly derived from voltaic batteries, was this: "There will be no consumption of zinc, acids, and mercury; no attention necessary after the thermo-battery is once set in action; only moderate heat required to excite electric action in the metals; so we shall get our electricity for next thing to nothing." That was the impression in the minds of many at the time we refer to, and it will certainly not astonish us if at some future period thermo-electricity realises the hopes and aspirations then expressed. The splendid results obtained by means of magneto and dynamo-electric machines may have diverted the attention of electricians from a closer study of thermo-electricity than we believe the subject demands, but we are inclined to think that at no distant date the conversion of heat into electric energy will receive more attention than has hitherto been accorded to it.

The first practical application of Seebeck's discovery was made by Moses Poole, who, in 1843, obtained a patent for the use of a thermopile, which, however, did not meet with much success. Many subsequent efforts were made to bring thermo-electricity into practical use, amongst which may be mentioned a thermo-electric battery devised by the author's brother, Mr. Charles Watt, in 1851, and reconstructed by the author two years later. This battery was originally designed to consist of two thousand pairs of bismuth and antimony plates, but a difficulty arose in its construction owing to the very fragile nature of the metals, when combined in an extended series. Each pair of plates having to be united by pewter solder, it was found to be exceedingly difficult to complete even a single row of couples without an accidental fracture, or fusion of the bismuth while soldering the junctions, and after many futile attempts the construction of the battery had to be abandoned. In 1853, however, the author determined to make an attempt to reconstruct the battery, which he succeeded in doing, unaided, in about six or eight weeks. This thermo-battery was constructed as follows:—

C. Watt's Thermo-electric Battery.—The elements employed were bismuth and antimony, and the plates were of the form shown in Fig. 36, being about 3 inches in length, and about one-eighth of an inch in thickness, the different metals being cast in moulds of uniform size and form. Fig. 37 represents a single pair of elements united by solder at their lower extremity, *a* being the antimony and *b* the bismuth plate. Two conducting wires (P and N) indicate the poles or electrodes. To construct the battery in such a way that it would not be liable to injury, even from trifling accidental causes, was by no means an easy task; the solder employed, owing to the ready fusibility of bismuth as compared with antimony, was the most "easy running" solder that could be procured, and if great care were not exercised in heating and applying the soldering iron, the bismuth, uniting with the solder and forming *fusible metal*, would *run*, or melt, before the solder could be made to attach itself to the antimony. To prevent these mishaps, which had been greatly the cause of failure in constructing the battery originally, it was determined in the first instance to "tin," that is spread, the solder upon those edges of each of the antimony plates which were to be united to the bismuth, and, by so doing, a very delicate application of the soldering-iron, well supplied with the molten alloy, soon united the metals at their extremities with little or no accidental melting of the bismuth. In fact, the soldering-iron was simply drawn along the points of junction with a steady and uniform sweep, by which the respective couples were securely and perfectly united with little or no accident when the hand had become accustomed to the manipulation. It may be mentioned as a fact that many different workmen had endeavoured to solder the bismuth and antimony couples, but had been compelled to give up the task as hopeless owing to the frequent melting of the bismuth when the soldering-iron was applied, and the snapping of the fragile plates when but a few of them were united. In order to prevent the breaking of the plates by their own weight when a large number were united in a series, a bar of well-seasoned beech, smoothly planed on all sides, and nearly two inches in thickness, being perforated at the ends to receive screw bolts, was laid across a trestle; one or two pairs of the metals were then laid edgewise across the bar, with their projecting surfaces overlapping the two vertical surfaces of the wooden bar; a second wooden bar was then placed over the couples in the same way, a half-inch wooden wedge being placed between the two bars, at the opposite end, corresponding with the narrower parts of the plates, the two ends of the bars nearest the plates were then securely tied together, and those at the opposite end temporarily fastened in the same way. Being thus secured, the soldering-iron was applied first to the lower end of the first

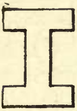

Fig. 36.

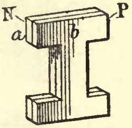

Fig. 37.

couple, then to the upper ends of the second and third plate, and next to the lower end of the second couple; these being secured, other couples were introduced by carefully untying the cord at the opposite end of the wooden bars, removing the wedge, and passing the pairs of metals between the wooden bars until the whole series were introduced. The cord was again applied and made rigidly secure, and the soldering-iron again applied until the entire series of couples had been soldered *on one side;* when this was effected the bars were turned over and the bottom surfaces of each couple carefully soldered; by shifting the position of the wooden bars the three angles of each pair, alternately top and bottom, were united by soldering until the whole row or series of plates had been connected. The ends of the wooden bars were next made secure by means of screwed bolts, when the arrangement of the first series was complete. The end plates of each series were, respectively, bismuth and antimony. Five such groups were constructed, and these were afterwards formed into a compound battery in the following way:—

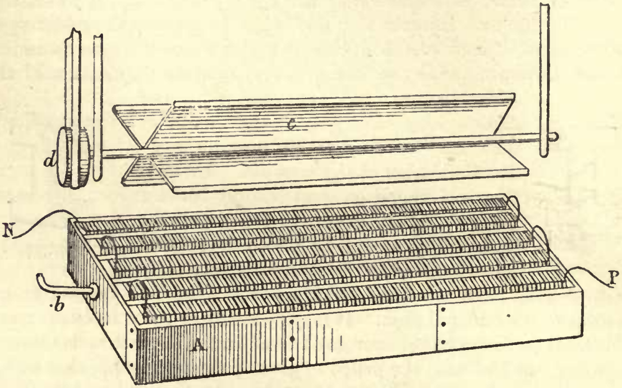

Fig. 38.—C. Watt's Thermo-electric Battery.

A wrought-iron chamber A, Fig. 38, fitted with a pipe *b*, was furnished with an inner flange at each end, upon which the bars carrying the soldered couples rested; each row of plates was connected at its positive end with the negative plate of the next row by a bent wire, as in the engraving, and the terminal wires N and P then connected by soldering. The chamber was supplied with oil to the depth of about three inches, heated, when the battery was required for use, by means of gas jets from a perforated pipe placed beneath the chamber. The upper surfaces of the plates were cooled by means of a four-winged fan (*c*) of simple construction, set in motion by a pulley (*d*) connected by a strap to a revolving shaft above. This fan, the frame-work of which was of wood, was covered with calico coated with a thin mixture of size and whiting. When the fan was in motion the cold produced was considerable, and, by carefully regulating the heat of the oil in the chamber beneath, an uniform action of heat and cold on the opposite surfaces of the couples could be readily maintained.

Becquerel's Thermo-Pile.—As far back as 1827 M. Becquerel, sen., had noticed that a copper wire, coupled with a wire of the same metal sulphuretted on its surface, formed, by raising the temperature of one of the junctions from 200° to 300°, a thermo-electric couple more energetic than could be obtained with other metals. In 1865 M. Ed. Becquerel conducted a series of experiments to determine the thermo-electric power of artificial sulphuret of copper, and found that this substance, heated to 200° or 300°, was strongly positive, and that a couple composed of this sulphuret and copper had an electromotive force nearly ten times greater than that of a bismuth-copper couple. Native sulphuret of copper, on the contrary, is highly negative. The melting point of the artificial sulphuret being about 1,035° this substance may be employed at very high temperatures. In constructing a thermo-pile with this sulphuret it is united to an alloy composed of copper 90, nickel 10 parts.

Clamond's Thermo-electric Pile.—This thermo-pile, which has been much adopted on the continent, and has also been used to some extent by electro-plating firms in Birmingham and Sheffield, though with variable success, owing, probably, to the conventional distaste which some English workmen have for recognising merit or advantage in anything novel. Since Clamond's pile, regardless of all prejudice, has been proved to be an exceedingly effective generator of thermo-electricity, the following description of the contrivance, by Mr. Latimer Clark, will be read with interest*:—

"The mixture employed by Clamond consists of an alloy of 2 parts antimony and 1 of zinc for the negative metal, and for the positive element he employs ordinary tinned sheet-iron, the current flowing through the hot junction from the iron to the alloy. The combination is one of great power. Each element consists of a flat bar of the alloy from 2 inches to 2¾ inches in length, and from ⅜ to 1 inch in thickness. Their form is shown in Fig. 39, by which it will be seen that, looking at the plan, they are spindle-shaped or broader in the middle than at the ends. The sheet-tin is stamped out in the form shown in Fig. 40; the narrow portion is then bent in the forms

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* *Journal of the Society of Telegraph Engineers*, vol. v. p. 321.

shown, in which state they are ready for being fixed in the mould. The melted alloy is poured in, and, before it has cooled, the mould is opened and the bars removed with the lugs securely cast into them. The mould is heated nearly to the melting point of the alloy, and 10 or 12 bars are cast at one time. A little zinc is added from time to time to make up for the loss due to volatilisation. The alloy melts at about 500° Fahr.; it expands considerably on cooling. The more frequently the alloy is recast the more perfect becomes the mixture, so that old piles can be reconverted with advantage and with little loss beyond that of the labour. The alloy is extremely weak and brittle and easily broken by a blow—in fact, is scarcely stronger than loaf sugar.

"The tin lugs are bent into form, and the bars are arranged in a radial manner round a temporary brass cylinder, as shown in Fig. 39, a thin slip of mica being inserted between the tin lug and the alloy, to prevent contact, except at the junction. The number of radia bars varies with the size of the pile, but for the usual sizes eight or ten are employed. As fast as the bars are laid in position, they are secured by a paste or cement formed of powdered asbestos and soluble glass, or solution of silicate of potassa; flat rings are also formed of the same composition, which possesses considerable tenacity when dry; and as soon as one circle of bars is completed, a ring of the dry asbestos cement is placed upon it, and another circle of elements is built upon this, and so on until the whole battery is formed. Cast-iron frames are then placed at top and bottom of the pile, and drawn together by screws and rods, so as to consolidate the whole, and in this condition the pile is allowed to dry and harden. Looked at from the inside, the faces of the elements form a perfect cylinder, within which the gas is burned. The inner face of each element is protected from excessive heat by a tin strip or cap of tin bent round it, before it is imbedded in the cement, the projecting strips of tin from the opposite ends of each pair of elements are brought together and soldered with a blowpipe and soft solder. The respective rings are similarly connected, and the

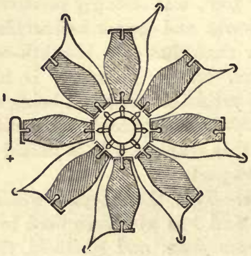

Fig. 39.

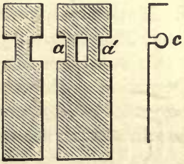

Fig. 40.

whole pile is complete, except as regards the heating arrangements. The positive pole of these piles is always placed at the top. Cumming was the first to use this stellar arrangement of couples. The pile is usually heated by gas mingled with air, on the Bunsen principle; gas is introduced at the bottom of a tube of earthenware, which is closed at the top, and is pierced with a number of small holes throughout its length, corresponding, approximately, in number and position with the number of elements employed. Before entering this tube, the gas is allowed to mix with a regulated proportion of air, by an orifice in the supply tube, the size of which can be adjusted; the mixed gases escape through the hole in the earthenware tube, and there burn in small blue jets, the annular space between the gas tube and the elements forming a chimney to which air is admitted at bottom, the products of combustion escaping at the top. In order to prevent injury from over-heating, and to diminish the consumption of gas,

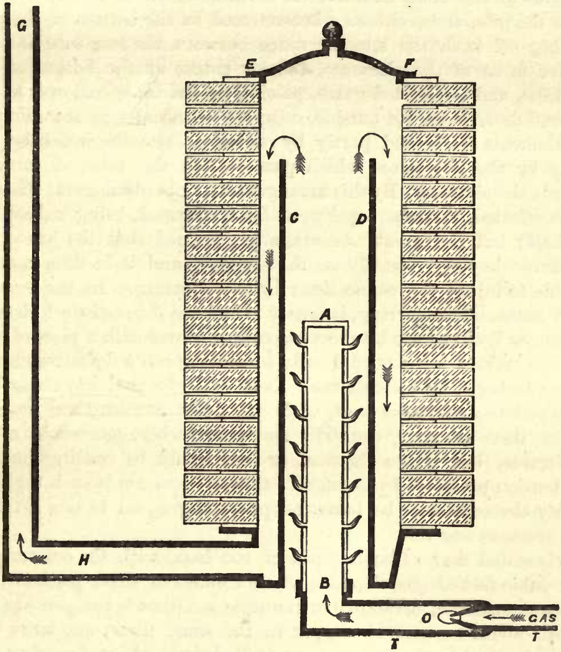

Fig. 41.—Section of Clamond's Thermo-pile.

M. Clamond has introduced a new form of combustion chamber, by which he obtains very great advantages. This form is shown in Fig. 41. The mixture of air and gas is burnt in a perforated earthenware tube, as before described, but instead of extending the whole height of the battery, it only extends to about one-half of its height. The earthenware tube is surrounded by an iron tube of larger diameter, which extends nearly to the top of the battery, and is open at the top. Outside this iron tube, and at some distance from it, are arranged the elements in the usual manner. A movable cover fits closely over the top of the pile, and a chimney is connected to the bottom of the pile. Leading off from the annular space between the iron tube and the interior faces of the elements, the air enters at the bottom of the iron tube, and the heated gases, passing up the tube, curl over at the top, and descend on its outside, escaping eventually by the chimney. The elements are heated partly by radiation from the iron tube, and partly by the hot gases which pass outside the tube, downwards towards the chimney. By this arrangement, not only is great economy of gas effected, the consumption, as I am informed, being reduced by one-half; but the great advantage is obtained that the jets of gas can never impinge directly on the elements, and it is thus scarcely possible to injure the connections by over-heating. In the event of a bad connection occurring, it is easy to find out the imperfect element, and throw it out of use by short-circuiting it over with a piece of wire, and the makers have no difficulty in cutting out a defective element and replacing it by a sound one. Coke and charcoal have also been employed as a source of heat, with very great economy and success; in fact, there are many countries and places where gas would not be procurable, but where charcoal or coke could be readily obtained. The tension produced by Clamond's thermo-elements is such that each twenty elements may be taken as practically equal to one Daniell's cell, or about one volt."

It is stated that a Clamond pile of 100 bars, with the consumption of 5 cubic feet of gas, deposits about 1 ounce of silver per hour, and the same machine, arranged in multiple arc (that is for *quantity*) will deposit about 1 ounce of copper in the same time; 400 large bars, consuming 2 lbs. of coke per hour, will deposit about four times the above quantities in the same period of time.

Wray's Thermo-Pile.—In this improvement, the bars are cast, as usual, under pressure, and a small tongue of tinned iron is cast down the centre of the bar, extending nearly its whole length, by which the strength is greatly increased, and it is also stated that it not only decreases the resistance, but also increases the electromotive force. The battery is built up by a number of discs made up of burnt clay, pipe clay, or biscuit ware, and between each disc a small triangle of the same material is interposed, with metal rods to hold the whole together, consequently these discs and triangles, when in place, sustain the whole pressure, and the thermo-bars rest upon them, and can be removed and rearranged when necessary; by this arrangement they are not so liable to be injured by the heat of the gas. To prevent the gas flames from impinging directly upon the bars, or against the iron cylinder within the thermo-battery, an inner cylinder of earthenware is employed, which forms the centre of the battery, and the bars of metal are built up around the cylinder, and in close contact with it, each bar being bedded up against it with asbestos cement. The gas flame, therefore, cannot come in direct contact with the bars, consequently they are less liable to injury from heat, while the heat is also more uniformly distributed. The supply of air is regulated by small covers of fire-clay, consisting of perforated radial discs, placed on the top of the pile.

Noe's Thermo-electric Battery.—This machine, invented by M. Nöe, of Vienna, consists of a series of small cylinders, about $1\frac{1}{4}$ inch in length, and $\frac{5}{8}$ths of an inch in diameter, composed of an alloy of thirty-six and a half parts of zinc and sixty-two and a half parts of antimony for the positive element, and stout German silver wire as the negative element. The junctions of the elements are heated by small gas jets, and the alternate junctions are cooled by the heat being conducted away by large blackened sheets of thin copper. It is stated that from nine to ten of these couples have an electromotive force equal to one Daniell cell, and twenty pairs, with great external resistance, are equal to one Bunsen. With small external resistance, twenty quadrupled Nöe elements are somewhat stronger than one Bunsen. In another arrangement of this thermo-battery, the negative wire, fixed to the positive metal, is bent back from the point of contact, in an acute angle. A small metallic rod is fused to the two elements at the same point. Twenty elements are arranged in a circle, the metallic rods being in the centre. The space in the centre is covered with a plate of mica, and the metallic rods are then heated by means of a circular gas-flame. The electromotive force of twenty such elements is equal to 19·4, one Bunsen being equal to twenty. The resistance of each element equals ·056. These machines have been used both in Vienna and Berlin for electroplating and electrotyping.

The Future of Thermo-Electricity.—When we reflect that in the present advanced state of electrical science many difficulties which were formerly considered almost insurmountable have been overcome, and the imperfect efforts of our predecessors have been improved upon and brought into practical use, it may not be too much to say that we believe that thermo-electricity has a great future before it.

C. L. Cory

Indeed, the success of M. Clamond's exertions, as also those of his competitors—which will doubtless be supplemented by still greater results hereafter—are but evidences that thermo-electricity *can* be utilised for practical purposes, as a substitute not only for the voltaic current, but also, in a minor degree *at present*, for magneto and dynamo-electricity. When it is borne in mind that in the thermo-pile the current is obtained solely at the cost of so much heat, and that there is no exhaustion of the elements or wear and tear of its constituent parts, we may readily conceive that great exertions will yet be made to construct thermo-piles or batteries, capable of yielding currents of far greater power than has yet been obtained from this source. The thermo-pile is the only example of the direct conversion of heat into electric energy, and, so far as is known, this is obtained without any other waste beyond that of the fuel consumed in generating the heat necessary to excite and keep in action the elements of which the pile is composed.

CHAPTER IV.

HISTORICAL REVIEW OF ELECTRO-DEPOSITION.

Announcement of Jacobi's Discovery.—Jordan's Process Published.—Jordan's Process.—Spencer's Paper on the Electrotype Process.—Effect of Spencer's Paper.—Vindication of Jordan's Claim.—Mr. Dircks on Jordan's Discovery.—Sir Henry Bessemer's Experiments.—Dr. Golding Bird's Experiments.—Origin of the Porous Cell.

LONG before the art of Electro-deposition was founded upon a practical basis, it was well known, experimentally, that several metals could be deposited from their solutions upon other metals, by simply immersing them in such solutions; but this knowledge was of little importance beyond the interesting nature of the results obtained. The schoolboy had been accustomed to amuse himself by producing the ever-popular "lead tree," by suspending a piece of zinc attached to a copper-wire in a solution of sugar of lead, or the "silver tree," with a solution of nitrate of silver and mercury; or he would coat the blade of his penknife with copper, by dipping it for a moment in a weak solution of sulphate of copper (bluestone). But these, and the like interesting facts, were of no practical value in the arts. It was also known that articles of steel could be gilt by simple immersion in a dilute solution of chloride of gold (that is gold dissolved in aqua regia), or still better, in an ethereal solution of the chloride, and this simple process was sometimes adopted in the ornamentation of engraved articles, in imitation of the process of *damascening*. The eyes of needles were also gilt by a similar process, and "golden-eyed needles" became popular amongst the fair sex. With this exception, however, the deposition of metals, even by simple immersion in metallic solutions, was regarded as interesting and wonderful, but nothing more.

As far back as about the year 1820, the author's father covered the "barrels" of quill pens with silver, by first steeping them in a solution of nitrate of silver, and afterwards reducing the metal to the metallic state in bottles charged with hydrogen gas, the object being to protect the quills from the softening influence of the ink.

In the year 1836, Professor Daniell made known his *constant battery*, and in the same year, Mr. De la Rue constructed a modification of this battery, in working which he observed that "the copper-plate is also covered with a coating of metallic copper which is continually being deposited; and so perfect is the sheet of copper thus formed, that, being stripped off, it has the counterpart of every scratch of the plate on which it is deposited.* Although this interesting observation did not lead to any direct application at the time, it is but reasonable to presume that in the minds of some persons the important fact which it disclosed would have suggested the possibility of its being susceptible of some practical application. It was not until the following year (1837), however, that the electro-deposition of metals, experimentally, seriously occupied the attention of persons devoted to research, the first of whom was Dr. Golding Bird, who decomposed solutions of the chlorides of ammonium, potassium, and sodium, and succeeded in depositing these metals upon a negative electrode of mercury,† whereby he obtained their amalgams. From the time when his interesting results became known, many persons repeated his experiments, while others turned their attention to electrolysis as a new subject of investigation, and pursued it with different objects, as will be shown hereafter.

Mr. G. R. Elkington, in 1836, obtained a patent for "Gilding copper, brass, and other metals" by immersing the articles in a boiling alkaline solution containing dissolved gold. This was followed, in 1837, by several other patents granted to Mr. H. Elkington for coating metals with gold and platinum, and for gilding and silvering articles. In 1838, Mr. G. R. Elkington, with Mr. O. W. Barratt, patented a process for coating articles of copper and brass with zinc, by means of an electric current generated by a piece of zinc attached to the articles by a wire, and immersing them in a boiling neutral solution of chloride of zinc. This was the first process in which a separate metal was employed in electro-deposition.

Announcement of Jacobi's Discovery.—About the period at which the above processes were being developed, it appears that several other persons were engaged in experiments of an entirely different character and of far greater importance, as will be seen by the results which followed their labours. In St. Petersburg, Professor Jacobi had been experimenting in the deposition of copper upon engraved copper-plates, a notice of which appeared in the *Athenæum*, May 4th, 1839. The paragraph ran as follows:—"*Galvanic Engraving in Relief.*—While M. Daguerre and Mr. Fox Talbot have been dipping their pencils in the solar spectrum,‡ and astonishing us with their

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* *Philosophical Magazine*, 1836.

† "Philosophical Transactions of the Royal Society," 1837.

‡ It was about this period that the famous *Daguerreotype process* of portrait-taking was being developed in England.

inventions [photographic], it appears that Professor Jacobi, at St. Petersburg, has also made a discovery which promises to be of little less importance to the arts. He has found a method—if we understand our informant rightly—of converting any line, however fine, engraved on copper, into a relief by galvanic process. The Emperor of Russia has placed at the professor's disposal funds to enable him to complete his discovery."

Jordan's Process published.—Having seen a copy of the above paragraph in the *Mechanic's Magazine*, May 11th, 1839, Mr. J. C. Jordan, of London, eleven days afterwards sent a communication to the editor of that journal, in which he put in his claim—if not to priority, as far as Jacobi was concerned, at least to prove that he had been experimenting in electro-deposition some twelve months before the announcement of Jacobi's discovery was published in this country. Indeed, Jordan's communication did more, for it contained a *definite process*, and since this was undoubtedly the first publication of the kind which had appeared in England, the merit of originality—so far as *publication* goes—is clearly due to Jordan. As an important item in the history of electro-deposition, we give the subjoined extract from his letter from the *Mechanic's Magazine*, June 8th, 1839. The letter was headed "Engraving by Galvanism."

Jordan's Process.—"It is well known to experimentalists on the chemical action of voltaic electricity that solutions of several metallic salts are decomposed by its agency and the metal procured in a free state. Such results are very conspicuous with copper salts, which metal may be obtained from its sulphate (blue vitriol) by simply immersing the poles of a galvanic battery in its solution, the positive wire becoming gradually coated with copper. This phenomenon of metallic reduction is an essential feature in the action of *sustaining* batteries, the effect in this case taking place on more extensive surfaces. But the form of voltaic apparatus which exhibits this result in the most interesting manner, and relates more immediately to the subject of the present communication, may be thus described:—It consists of a glass tube closed at one extremity with a plug of plaster of Paris, and nearly filled with a solution of *sulphate of copper*. This tube and its contents are immersed in a solution of *common salt*. A plate of copper is placed in the first solution, and is connected by means of a wire and solder with a zinc plate, which dips into the latter. A slow electric action is thus established through the pores of the plaster which it is not necessary to mention here, the result of which is the precipitation of minutely-crystallised copper on the plate of that metal in a state of greater or less malleability, according to the slowness or rapidity with which it is deposited. In some experiments of this nature, on removing the copper thus formed, I remarked that the surface in contact with the plate equalled the latter in smoothness and polish, and mentioned this fact to some individuals of my acquaintance. It occurred to me therefore, that if the surface of the plate was *engraved*, an *impression* might be obtained. This was found to be the case, for, on detaching the precipitated metal, the more delicate and superficial markings, from the fine particles of powder used in polishing, to the deeper touches of a needle or graver, exhibited their corresponding impressions in *relief* with great fidelity. It is, therefore, evident that this principle will admit of improvement and that casts and moulds may be obtained from any form of copper.

"This rendered it probable that impressions might be obtained from those other metals having an electro-negative relation to the zinc plate of the battery. With this view a common printing type was substituted for the copperplate and treated in the same manner. This also was successful; the reduced copper coated that portion of the type immersed in the solution. This, when removed, was found to be a perfect matrix, and might be employed for the purpose of casting when time is not an object.

"It appears, therefore, that this discovery may possibly be turned to some practical account. It may be taken advantage of in procuring casts from various metals as above alluded to; for instance, a copper die may be formed from a cast of a coin or medal, in silver, typemetal, lead, &c., which may be employed for striking impressions in soft metals. Casts may probably be *obtained* from a *plaster* surface surrounding a plate of copper; tubes or any small vessel may also be made by precipitating the metal around a wire or any kind of surface to form the interior, which may be removed mechanically by the aid of an acid solvent, or by heat." [May 22nd, 1839.]

It is a remarkable fact that Jordan's letter, regardless of the valuable information it contained, commanded no attention at the time. Indeed, the subject of which it treated (as also did Jacobi's announced discovery), apparently passed away from public view, until a paper by Mr. Thomas Spencer, of Liverpool, was read before the Liverpool Philosophical Society on the 12th of September in the same year. Omitting the prefatory observations with which the paper commenced, its reproduction will form a necessary link in the chain of evidence respecting the origin of the electrotype process, and assist the reader in forming his own judgment as to whom the merit of the discovery is really due.

Spencer's Paper on the Electrotype Process.—"In September, 1837, I was induced to try some experiments in electro-chemistry with a single pair of plates, consisting of a small piece of zinc and an equal sized piece of copper, connected together with a piece of wire of the latter metal. It was intended that the action should be slow; the fluids in which the metallic electrodes were immersed were in consequence separated by a thick disc of plaster of Paris. In one of the cells was sulphate of copper solution, in the other a weak solution of common salt. I need scarcely add that the copper electrode was placed in the cupreous solution, not because it is *directly* connected with what I have to lay before the society, but because, by a portion of its results, I was induced to come to the conclusion I have done in the following paper. I was desirous that no action should take place on the wire by which the electrodes were held together. To attain this object I varnished it with sealing-wax varnish ; but, in so doing, I dropped a portion of it on the copper that was attached. I thought nothing of this circumstance at the moment, but put the experiment in action.

"The operation was conducted in a glass vessel ; I had, consequently, an opportunity of occasionally examining its progress. When, after the lapse of a few days, metallic crystals had covered the copper electrode, *with the exception of that portion* which had been spotted with the drops of varnish, I at once saw that I had it in my power to guide the metallic deposition in any shape or form I chose by a corresponding application of varnish or other non-metallic substance.

"I had been long aware of what every one who uses a sustaining galvanic battery with sulphate of copper in solution must know, that the copper plates acquire a coating of copper from the action of the battery ; but I had never thought of applying it to a useful purpose before. My first essay was with a piece of thin copper-plate, having about four inches of superfices, with an equal-sized piece of zinc, connected together with a piece of copper wire. I gave the copper a coating of soft cement consisting of bees-wax, resin, and a red earth—Indian or Calcutta red. The cement was compounded after the manner recommended by Dr. Faraday in his work on chemical manipulation, but with a larger proportion of wax. The plate received its coating while hot. On cooling, I scratched the initials of my own name rudely on the plate, taking special care that the cement was quite removed from the scratches, that the copper might be thoroughly exposed. This was put into action in a cylindrical glass vessel about half filled with a saturated solution of sulphate of copper. I then took a common gas glass, similar to that used to envelop an argand burner, and filled one end of it with plaster of Paris to the depth of three-quarters of an inch. In this I put some water, adding a few crystals of sulphate of soda to excite action, the plaster of Paris serving as a partition to separate the fluids, but sufficiently porous to allow the electro-chemical fluid to penetrate its substance.

"I now bent the wires in such a form that the zinc end of the arrangement should be in the saline solution, while the copper end should be in the cupreous one. The gas glass, with the wire, was then placed in the vessel containing the sulphate of copper.

"It was then suffered to remain, and in a few hours I perceived that action had commenced, and that the portion of the copper rendered bare by the scratches was coated with a pure bright deposited metal, whilst all the surrounding portions were not at all acted upon. I now saw my former observations realised; but whether the deposition so formed would retain its hold on the plate, and whether it would be of sufficient solidity or strength to bear working if applied to a useful purpose, became questions which I now endeavoured to solve by experiment. It also became a question whether, should I be successful in these two points, I should be able to produce lines sufficiently in relief to print from. The latter appeared to depend entirely on the nature of the cement or etching ground I might use.

"This last I endeavoured to solve at once. And, I may state, this appeared to be the principal difficulty, as my own impression then was that little less than $\frac{1}{8}$th of an inch of relief would be requisite.

"I then took a piece of copper, and gave it a coating of a modification of the cement I have already mentioned, to about $\frac{1}{8}$th of an inch in thickness; and, with a steel point, endeavoured to draw lines in the form of net-work, that should entirely penetrate the cement, and leave the surface of the copper exposed. But in this I experienced much difficulty, from the thickness I deemed it necessary to use; more especially when I came to draw the cross lines of the net-work. When the cement was soft, the lines were pushed as it were into each other; and when it was made of a harder texture, the intervening squares of net-work chipped off the surface of the metallic plate. However, those that remained perfect I put in action as before.

"In the progress of this experiment, I discovered that the solidity of the metallic deposition depended entirely on the weakness or intensity of the electro-chemical action, which I found I had in my power to regulate at pleasure, by the thickness of the intervening wall of plaster of Paris, and by the coarseness and fineness of the material. I made three similar experiments, altering the texture and thickness of the plaster each time, by which I ascertained that if the plaster partitions were *thin* and *coarse*, the metallic depositions proceeded with great *rapidity*, but the crystals were friable and easily separated; on the other hand, if I made the partition thicker, and of a little finer material, the action was much slower, and the metallic deposition was as solid and ductile as copper formed by the usual methods, indeed, when the action was exceedingly slow, I have had a metallic deposition apparently much harder than common sheet copper but more brittle.

"There was one most important (and, to me, discouraging) circumstance attending these experiments, which was that when I heated the plates to get off the covering of cement, the meshes of copper net-work invariably *came off with it*. I at one time imagined this difficulty insuperable, as it appeared to me that I had cleared the cement entirely from the surface of the copper I meant to have exposed, but that there was a difference in the molecular arrangement of copper prepared by heat and that prepared by voltaic action which prevented their chemical combination. However, I then determined, should this prove so, to turn it to account in another manner, which I shall relate in a second portion of this paper. I then occupied myself for a considerable period in making experiments on this latter section of the subject.

"In one of them I found on examination a portion of the copper deposition, which I had been forming on the surface of a coin, adhered so strongly that I was quite unable to get it off; indeed, a chemical combination had apparently taken place. This was only in one or two spots on the prominent parts of the coin. I immediately recollected that on the day I put the experiment in action I had been using nitric acid for another purpose on the table I was operating on, and that in all probability the coin might have been laid down where a few drops of the acid had accidentally fallen. I then took a piece of copper, coated it with cement, made a few scratches on its surface until the copper appeared, and immersed it for a short time in dilute nitric acid, until I perceived, by an elimination of nitrous gas, that the exposed portions were acted upon sufficiently to be slightly corroded. I then washed the copper with water, and put it in action, as before described. In forty-eight hours I examined it, and found the lines were entirely filled with copper; I applied heat, and then spirit of turpentine, to get off the cement; and, to my satisfaction, I found that the voltaic copper had completely combined itself with the sheet on which it was deposited.

"I then gave a plate a coating of cement to a considerable thickness, and sent it to an engraver; but when it was returned, I found the lines were cleared out, so as to be wedge-shaped, or somewhat in form of a V, leaving a hair line of copper exposed at the bottom and broad space near the surface; and where the turn of the letters took place, the top edges of the lines were galled and rendered ragged by the action of the graver. This, of course, was an important objection, which I have since been able to remedy in some respects by alteration in the shape of the graver, which should be made of a shape more resembling a narrow parallelogram than those in common use; some of the engravers have many of their tools so made. I did not put this plate in action, as I saw that the lines, when in relief, would have been broad at the top and narrow at the bottom. I took another plate, gave it a coating of the wax, and had it written on with a mere point. I deposited copper on the lines and afterwards had it printed from.

"I now considered part of the difficulties removed; the principal one that yet remained was to find a cement or etching-ground, the texture of which should be capable of being cut to the required depth, and without raising what is technically termed a burr, and at the same time of sufficient toughness to adhere to the plates where reduced to a small isolated point, which would necessarily occur in the operation which wood-engravers term cross-hatching.

"I tried a number of experiments with different combinations of wax, resin, varnishes and earths, and also metallic oxides, all with more or less success. The one combination that exceeded all others in its texture, having nearly every requisite (indeed, I was enabled to polish the surface nearly as smooth as a plate of glass), was principally composed of virgin wax, resin, and carbonate of lead—the white-lead of the shops. With this compound I had two plates, 5 inches by 7, coated over, and portions of maps cut on the cement, which I had intended should have been printed off and laid before the British Association at its meeting."

Effect of Spencer's Paper.—When Spencer's paper was published it at once commanded profound attention, and many persons practised the new art either for amusement or scientific research, while others turned their attention to it with a view to making it a source of commercial profit. It was not, however, until Mr. Robert Murray, in January, 1840, informed the members of the Royal Institution, London, that he had discovered a method of rendering non-conducting surfaces—such as wax, &c.—conductive of electricity by employing plumbago, or black lead, that the art became really popular in the fullest sense. This conducting medium was the one thing wanted to render the process facile and complete; and soon after Mr. Murray's invaluable discovery had been made known, thousands of persons in every grade of life at once turned their attention to the electrotype process until it soon became the most popular scientific amusement that had ever engaged the mind, we may say, of a nation. The simplicity of the process, the trifling cost of the apparatus and materials, and the beautiful results which it was capable of yielding, without any preliminary knowledge of science, all combined to render the new art at once popular in every home. Every one practised it, including the youth of both sexes.

It is not to be wondered at that an art so fascinating should have produced more than an ephemeral effect upon the minds of some of those who pursued it. Indeed, it is within our own knowledge that many a youth whose first introduction to chemical manipulation was the electro-deposition of copper upon a sealing-wax impression of a signet-ring or other small object, acquired therefrom a taste for a more extended study of scientific matters, which eventually led up to his devoting himself to chemical pursuits for the remainder of his days. At the period we refer to there were but few institutions in this country for the encouragement of scientific study. One of the most accessible and useful of these, however, was that founded by Dr. Birkbeck, the well-known Literary and Scientific Institution at that time in Southampton Buildings, London.

Vindication of Jordan's Claim.—Although Jordan's letter was published, as we have shown, three months prior to the reading of Spencer's paper in Liverpool, that important communication was overlooked, not only by the editor of the journal in which it appeared, but also by the scientific men of the period. Even the late Alfred Smee, to whose memory we are indebted for the most delightful work on electro-metallurgy that has appeared in any language, failed to recognise the priority of Jordan's claim. Impelled by a strong sense of justice, however, the late Mr. Henry Dircks wrote a series of articles in the *Mechanic's Magazine* in 1844, in which he proved that whatever merit might have been due to Spencer and Jacobi, Jordan was unquestionably the first to *publish* a process of electrotyping. Indeed, he went further, for he proved that the electro-deposition of copper had been accomplished *practically* long before the publication of *any* process. Before entering into the merits of Jordan's priority, Mr. Dircks makes this interesting statement:—

Mr. Dircks on Jordan's Discovery.—"The earliest application of galvanic action to a useful and ornamental purpose that I am acquainted with was practised by Mr. Henry Bessemer, of Baxter House, Camden Town, who, above ten years ago [about 1832] employed galvanic apparatus to deposit a coating of copper on lead castings. The specimens I have seen are antique heads in relief, the whole occupying a space of 3 inches by 4 inches. They have lain as ornaments on his mantel-piece for many years, and have been seen by a great number of persons."

Appreciating—from its historic and scientific interest—the importance of the above statement, it occurred to the author that if the means adopted at so early a period in electro-metallurgical history could become known, this would form an important link in the chain of research respecting the deposition of metals by electrolysis. He, therefore, wrote to Sir Henry Bessemer, requesting him to furnish such particulars of the method adopted by him in depositing copper upon the objects referred to as lay in his power after so long a period of time. With kind courtesy, and a generous desire to comply with the author's wishes, Sir Henry took the trouble to furnish the information conveyed in the following interesting communication, which cannot fail to be read with much gratification by all who have studied the art of electro-deposition, either from its scientific or practical aspect. When we call to remembrance the numerous inventions with which the active mind of Sir Henry Bessemer has been associated during the greater portion of the present century, culminating in his remarkably successful improvements in the manufacture of steel, it is pleasing to read that at the youthful age of eighteen—when voltaic electricity was but little understood, and Daniell's, Grove's, and Smee's batteries unknown—he was engaged in experiments with metals, which were evidently conducted with an amount of patience and careful observation which would have been highly creditable in a person of more advanced years.

Sir Henry Bessemer's Experiments.—Replying to the author's inquiry as to the method he adopted in coating with copper the objects referred to above, Sir Henry, in January of the present year, wrote as follows: the minuteness of the details given, after so great a lapse of time, will doubtless strike the reader with some astonishment:—

"I have much pleasure in replying to your note of inquiry in reference to the deposition of copper from its solutions on white metal castings.

"My first experiments began when I was about eighteen years of age, say in 1831-2. At that period, after much practice, I was most successful in producing castings of natural objects in an alloy of tin, bismuth, and antimony. In this alloy I cast such things as beetles, frogs, prawns, &c.; also leaves of plants, flowers, moss-rose buds; and also medallions, and larger works in basso-relievo. By my system of casting in nearly red-hot metal, the metal was retained for ten or fifteen minutes in a state of perfect fluidity in the mould, and hence, by its pressure, forced itself into every minute portion of the natural object, whatever it might be; thus every minute thorn on the stem of the rose was produced like so many fine projecting needles. I exhibited several of these castings, coated with copper, at 'Topliss's Museum of Arts and Manufactures,' at that time occupying the site of the present National Gallery, and which museum was afterwards removed to a large building in Leicester Square, now the Alhambra Theatre, where I also exhibited them.

"Beautiful as were the forms so produced, they had a common lead-like appearance, which took much from their value and artistic beauty, and as a remedy for this defect, it occurred to me that it was possible to give them a thin coat of copper, deposited from its solution in dilute nitric acid. This I made by putting a few pence [copper coins were in currency in those days] into a basin with water and nitric acid. My early attempts were not very successful, for the deposited metal could be rubbed off, and was in other ways defective. I next tried sulphate of copper, both cold and boiling solutions. I found the sulphate much better adapted for the purpose than the nitrate solution. At first I relied on the property which iron has of throwing down copper from its solutions, and by combining iron, in comparatively large quantities, with antimony, and using this alloy with tin, bismuth, and lead, I succeeded in getting a very thin, but even, coating of copper; but it was not sufficiently solid, and easily rubbed off.

"In pursuing my experiments, I found that the result was much improved by using a metallic vessel for the bath instead of an earthenware one, such as a shallow iron, tin, or copper dish, as a slight galvanic action was set up, but the best results were obtained by using a zinc tray, on the bottom of which the object was laid, face upwards, and the solution then poured in. By this means a very firm and solid coating was obtained, which could be burnished with a steel burnisher without giving way. By adding to the copper solution a few crystals of distilled verdigris, I obtained some beautiful green bronze deposits, a colour far more suitable for *medallions* and *busts* than the bright copper coating obtained by the sulphate when used alone.

"I cast and coated with green copper a small bust of Shakespeare, which, with many other specimens, I sold to Mr. Campbell, the sculptor, who at that time was modelling a life-sized bust of Canning: he had arranged that I should cast it from the "lost-wax," and deposit green copper thereon. Unfortunately Campbell died before his model was completed. But for this incident I might possibly have carried the depositing process much further, but at that time my success in casting, in a very hard alloy, dies used for embossing cardboard and leather, offered a more direct and immediate commercial result, and thus the artistic branch was lost sight of. I remember showing some of these castings to my friend the late Dr. Andrew Ure, about the year 1835-6, with which he was much pleased. In referring to them several years later, in the second edition of his supplement to his 'Dictionary of Arts and Manufactures,' published in 1846, he mentions these castings as *lead castings*, at page 70, under the head of 'Electro-Metallurgy,' which commences in these words:—

"'*Electro-Metallurgy.*—By this elegant art, perfectly exact copies of any object can be made in copper, silver, gold, and some other metals, through the agency of electricity. The earliest application of this kind seems to have been practised about *ten years ago*, by Mr. Bessemer, of Camden Town, London, who deposited a coating of copper upon lead castings so as to produce antique heads, in relief, about three or four inches in size. He contented himself with forming a few such ornaments for his mantel-piece, and though he made no secret of his purpose, he published nothing upon the subject. A letter of the 22nd of May, 1839, written by Mr. C. Jordan, which appeared in the *Mechanic's Magazine* for June 8th following, contains the first printed notice of the manipulation requisite for obtaining electro-metallic casts, and to this gentleman, therefore, the world is indebted for the first discovery of this new and important application of science to the uses of life.'

"The first inception of the idea of coating works of art in metal with a deposited coating of another metal, if not resting solely with me, at least I certainly was within measurable distance of this great discovery some three or four years before it was brought forward by any other person, but I failed to see its true significance, and consequently lost a grand opportunity.

"You are quite at liberty to make any use you like of this information."

We will now return to Mr. Dircks' vindication of Jordan's claim.

Referring to Jordan's letter to the *Mechanic's Magazine*, Mr. Dircks says, "In particular I would direct attention to the fact of the main incidents named by Mr. Jordan, published June 8th, 1839, agreeing with those published by Mr. Spencer, September 12th, 1839, and, curious enough, being called forth by the same vague announcement of Professor Jacobi's experiments which was then making our round of periodicals. Both parties described Dr. Golding Bird's small galvanic apparatus; one used a printer's type, the other a copper coin, and both recommend the application of heat to remove the precipitated copper.

"I was aware of Mr. Jordan's letter at the time of its publication, and have frequently been surprised since that his name has not transpired in any discussion I have heard upon the subject. Nothing can be clearer than his reasoning, the details of his experiments, and his several concluding observations."

Dr. Golding Bird's Experiments.—There can be no doubt whatever that after Dr. Golding Bird published the results of his interesting experiments in 1837, and the means by which he obtained his important results, many scientific men devoted themselves to investigating the new application of electricity, amongst whom was Mr. Henry Dircks. "It was particularly in September and October, 1837," wrote Mr. Dircks, "that several parties attached to scientific pursuits in Liverpool, were engaged in repeating the experiments of Dr. Golding Bird, and of which he gave an account before the chemical section of the British Association at Liverpool, over which Dr. Faraday presided.

The apparatus used on that occasion by myself and others was precisely that recommended by Dr. Bird, consisting of simply any glass vessel capable of holding a solution of common salt, into which is inserted a gas lamp chimney, having its lower end plugged up by pouring into it plaster of Paris; a solution of sulphate of copper is then poured into it, and the whole immersed into the contents of the glass, and tightened with pieces of cork. The result expected from this arrangement was the deposit of metallic veins of the copper within the plaster diaphragm, independent of any connection with the poles of the battery. Dr. Faraday, and every other electrician, expressed surprise and doubt at the results in this respect said to have been obtained by Dr. Bird; and Dr. Faraday particularly urged the necessity and importance of caution in receiving as established a result so greatly at variance with all former experience, and proceeded to explain a variety of causes tending to lead to fallacious results in the curious and interesting experiments."

Up to this time, the possibility of obtaining electrical effects by means of a single metal, in the manner pursued by Dr. Bird, would have been considered theoretically impossible. It must not be wondered at, therefore, that even the greatest of our philosophers—Michael Faraday—should have been sceptical in the matter. It is clear now, however, that Dr. Golding Bird's results were based upon principles not then understood, and that to this gifted physician we are indebted for what is termed the "single-cell" voltaic arrangement—the first, and for some time after the only, apparatus employed in producing electrotypes.

Origin of the Porous Cell.—It appears that while Mr. Dircks was experimenting (in 1837) in obtaining crystals of copper by Dr. Bird's method, he was frequently in communication with Mr. John Dancer, a philosophical instrument maker in Liverpool, and in October of the following year (1838) that gentleman showed him a "ribbon of copper, thin, but very firm, granular on one side, while it was bright and smooth, all but some raised lines, on the other." This result, Mr. Dancer informed him, was obtained by galvanic action, observing that some specimens were as tenacious as rolled copper, while others were crystalline and brittle. Mr. Dancer attributed the superiority of the former to the following cause: "Having gone to the potteries to look out suitable jars for sustaining batteries, and having fixed on a lot which he was told would not answer as *they were not glazed*, and would not hold liquor," it occurred to him that such *unglazed* jars might be turned to account, and used instead of bladder, brown paper plaster of Paris, and other porous substances he had previously employed. Having obtained a sample for experiment, he subsequently found that he could obtain a more firm and compact deposit of copper than in any previous experiment. To the accidental circumstance above referred to, we are undoubtedly indebted for that most important accessory to the single-cell apparatus and the two-fluid battery—*the porous cell.*

In a letter to Mr. Dircks, relative to Spencer's claim to the discovery of a means of obtaining "metallic casts" by electro-deposition, Mr. Dancer says, "I met Mr. Spencer one morning in Berry Street, Liverpool, and happened to have one of these precipitated copper plates with me, which I showed to him. When I told him how it had been formed he would scarcely believe it, until I pointed out the impressions in relief of all the minute scratches that were on the plate against which it had been deposited. The surprise that Mr. Spencer expressed very naturally led me to suppose that it was the first compact piece of precipitated copper he had seen." At this early period (1838) Mr. Dancer had not only deposited tough *reguline* copper, but he went a step farther. He attached to a copper plate, by means of varnish, "a letter cut out from a printed bill. The copper precipitated on all parts of the plate, except where the letter was fixed; when I peeled the precipitated copper off, the letter came out, not having connection with the outside edge. I also obtained an impression by stamping my name on a copper cylinder, the impression being the reverse way. . . . . All this happened many months before I was aware that Mr. Spencer had been engaged in anything of the kind, except that he had Dr. Bird's experiments in action. Some time after this Mr. Spencer applied to me for one of my porous jars, and one day at his house he told me for what purpose he wanted it."

It is perfectly evident that Mr. Dancer's results were obtained long before the publication of Spencer's paper, and that both were indebted to Dr. Golding Bird's simple but ingenious contrivance for prosecuting their first experiments; and it is also clear that Dancer's brilliant idea of substituting porous earthenware for the crude plaster diaphragms greatly facilitated experimental researches in this direction; while at the same time it placed within our reach one of the most valuable accessories of the two-fluid voltaic battery—the porous cell.

Being desirous of placing Jordan's claim to priority—as the first to make publicly known the process of electrotyping, or *electrography*, as he termed it—Mr. Dircks followed up the subject in the *Mechanic's Magazine*, in a series of papers, in which he not only traced Mr. Spencer's experiments to their true origin, namely, Dr. Bird's experiments published two years before, and the hints which he had derived from Dancer, but he moreover showed that Spencer must have been aware of Jordan's published process, for he says, in summing up the evidence he had produced against Spencer's position in the matter thus: "Lastly, therefore, that through the *Mechanic's Magazine* (which Mr. Spencer was regularly taking in) the experimental results obtained by Mr. Dancer, and the reports in April and May, 1839, in public papers, of Jacobi's experiments, all being broad hints, and abundant assistance to aid Mr. Spencer, that he is rather to be praised for his expression of what was already known, on a smaller and less perfect scale, than to be adjudged a discoverer, much less the father of electro-metallurgy, having a preference to every other claimant." Following the paper from which the foregoing extract is taken, is a footnote by the Editor of the *Mechanic's Magazine*, which is important as showing how strange it was that Jordan's communication not only escaped the attention of scientists, but even that of the conductor of the journal in which it appeared: "Mr. Dircks has proved beyond all doubt that we have made a great mistake in advocating so strenuously the claims of Mr. Spencer to the invention of electrography. No one, however, can suppose that we would intentionally exalt any one at the expense of our own journal, which we are now pleased to find was the honoured medium of the first distinct revelation of this important art to the public, by an old and esteemed correspondent of ours, Mr. Jordan. Whatever Mr. Bessemer, Mr. Dancer, Mr. Spencer, or others, may have previously said or done, it was in private—made no secret of, perhaps, but still not communicated to the public at large—not recorded in any printed work for general benefit. For anything previously done by any of them, they might have still remained in the profoundest obscurity. No public descrip- of an earlier date than Mr. Jordan's can, we believe, be produced; and when we look upon that description, it is really surprising to see with what fulness and precision the writer predicated of an art nearly all that has been since accomplished. In supporting, as we did, the claims of Mr. Spencer to be considered as the first discoverer, we had lost all recollection of Mr. Jordan's communication. We have no personal acquaintance with either of the gentlemen, and could have no motive for favouring one more than the other. We took up the cause of Mr. Spencer with spontaneous warmth because we thought him to be a person most unfairly and ungenerously used, as in truth he was so far as the intention went, by those who, having at the time none of those reasons we now have for questioning Mr. Spencer's pretensions, yet obstinately refused to acknowledge them. If it should seem to the reader more than usually surprising that Mr. Jordan's paper escaped the recollection of the editor, through whose hands it passed to the public, his surprise will be lessened, perhaps, when he observes how it appears to have escaped notice, or been passed over in silence, by every one else down to the present moment—even those, not a few, who have expressly occupied themselves in electrography. . . . To us, the most surprising thing of any connected with the case is, that neither Mr. Jordan himself, nor any of his friends, should before now have thought it worth while to vindicate his claims to the promulgation of an art which justly entitles him to take a high place among the benefactors of his age and country.—*Ed. M. M.*"

While Mr. Dircks' "Contributions to the History of Electro-Metallurgy" were being published in the columns of the *Mechanic's Magazine*, the arguments and facts which he adduced created a deep impression in the minds of scientific men of the day, who had unfortunately accepted Spencer as the originator of electrotypy. Of all men, scientists are the most anxious to accord the merit of *discovery* to those who are really entitled to it. Devoting themselves to the investigation of natural laws, and their application to the useful purposes of man, they are naturally jealous of any attempt on the part of one to appropriate the honour—usually the only reward—due to another. It is not surprising, therefore, that when it became fully proved that to Jordan and not Spencer was due the credit of having been the first to publish a process for the practical deposition of copper by electrolysis, that such men should frankly acknowledge their mistake. Amongst those who came forward to do justice to Jordan's claim were the late Professor Faraday, Dr. Andrew Ure, and Professor Brande, then chemist to the Royal Mint. The latter eminent chemist and author of the best chemical manual in our language, sent the following letter to Mr. Dircks, which clearly acknowledges the error into which, in common with others, he had fallen in attributing to Spencer the merit of the electrotype process:—

"I am much obliged by your copy of the *Mechanic's Magazine* and the information it contains respecting Mr. Spencer's pretensions. I certainly always gave him credit for much more merit than he appears to have deserved."

When Spencer found that his position was so severely shaken by Mr. Dircks' powerful defence of Jordan's claim to priority, he wrote several letters in reply, which appeared in the columns of the above journal, with a view to refute his opponent's arguments, and shake his testimony; but in this he was unsuccessful, for the facts which Mr. Dircks had made known were absolutely beyond refutation. It is not often that men of science enter into a controversy of this nature, but silence under such circumstances would have been an act of injustice to Jordan, by leaving the question still in doubt.

Amongst those who ascribed to Spencer the discovery of the electrotype process was Mr. George Shaw, of Birmingham, in the first edition of his "Manual of Electro-Metallurgy." In the second edition of his work, however, he made the *amende* to Jordan, by frankly acknowledging his mistake. The following letter from the late Dr. Andrew Ure to Mr. Dircks shows how fully he recognised that gentleman's advocacy of Jordan's claim: "I read with great interest your narrative of the discovery or invention of the electrotype art, and am much pleased to see justice done to modest retiring merit in the persons of Mr. Jordan and Mr. Dancer. The jay will feel a little awkward this cold weather, stripped of his peacock plumage."

The following letter from Faraday tends to show that the great philosopher, in common with most other persons, had, prior to Mr. Dircks' explanation of the facts, believed in Spencer being the originator of electrotyping: "I am very much obliged by your kindness in sending me your account of the facts, &c., &c. It is very valuable as respects the fixing of dates, and has rather surprised me." *

It is a pity, but none the less true, that while Jordan's communication received no attention whatever, although published in a well-read journal, Spencer's paper—which had merely been read before a local society in Liverpool, and afterwards printed for *private circulation only*—commanded the profoundest attention. In short, to use a common phrase, it "took the world by storm." The name of "Spencer, the discoverer of Electrotyping," was on every lip, and men of science of all nations regarded him as one who had made a great addition to the long roll of important discoveries which science had placed at the disposal of art. Henry Dircks' championship of Jordan's just claim, however, eventually broke up Spencer's position, and to *the first publisher of the electrotype process*, Mr. C. J. Jordan, was at last accorded the *merit*—for he received no other recognition—of having published a process, if we may not say discovery, which was destined to prove of inestimable advantage to his fellows, not only in itself, but as being the means by which the minds of men were directed to the deposition of other metals by electrical agency. It would not be out of place to suggest that in commemoration of Jordan's *gift* to mankind of so useful and valuable a process, an appropriate testimonial should be set on foot—if not by the public, at least by those who have directly gained so much by his initiation of the art of electro-deposition.

The success which attended the electrotype process induced many persons to turn their attention to the deposition of gold and silver, by means of the direct current; but up to the year 1840 no really successful solution of either metal was available. In that year Mr. John Wright, a surgeon in Birmingham, and Mr. Alexander Parkes, in the employment of Messrs. Elkington, were engaged in making experiments in electro-deposition, when the former gentleman hap-

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* The three foregoing letters, which we transcribed from the originals, are now, we believe, published for the first time.

pened to meet with a passage in Scheele's "Chemical Essays," in which he found that cyanides of gold, silver, and copper, were soluble in an excess of cyanide of potassium. It at once occurred to him that solutions of gold and silver thus obtained might be employed in electro-deposition, and he then formed a solution by dissolving chloride of silver in a solution of ferro-cyanide of potassium, from which he obtained, by electrolysis, a stout and firm deposit of silver, a result which had never before been obtained. A few weeks after, Mr. Wright prepared a solution with cyanide of potassium, instead of the ferro-cyanide, and although various cyanide solutions of silver and copper had already been employed in the simple immersion process of depositing these metals, there is no doubt that it is to Mr. Wright that we are really indebted for the practical application of cyanide of potassium as a solvent for metallic oxides and other salts used in electro-deposition. About this time (1840) Messrs. Elkington were preparing to take out another patent, when Mr. Wright, having submitted his results to them, agreed to include his process in their patent, in consideration of which it was agreed that he should receive a royalty of one shilling per ounce for all silver deposited under the patent: on his decease, which took place soon afterwards, an annuity was granted to his widow. This patent, with Wright's important addition, namely the employment of alkaline cyanides, formed the basis of the now great art of electro-gilding and plating; but it was some time before the proper working strength of baths and the proportion of cyanide could be arrived at, the deposits being frequently non-adherent, which caused them to strip or peel off the coated articles in the process of burnishing. This was afterwards remedied to some extent by dipping the articles (German silver chiefly) in a very dilute solution of mercury. About this time, the author, in conjunction with his brother, Mr. John Watt, introduced electro-gilt and silvered steel pens, which were sold in considerable quantities.

In the same year, Mr. Murray discovered a means of rendering non-conducting surfaces, as wax, &c., conductive, by coating them with powdered plumbago, and this important suggestion proved of inestimable advantage to those who desired to follow the art of electrotyping commercially. Indeed, without the aid of this useful substance, it is doubtful whether the important art would have greatly exceeded the bounds of experiment. At this period, also, another important improvement in the electrotype process was introduced by Mr. Mason, which consisted in employing a separate battery as a substitute for the "single-cell" process up to that time adopted in electrotyping. By the new arrangement, a copper plate was connected to the positive pole of a Daniell Battery, while the mould to be coated with copper was attached to the negative pole. When these were immersed in the electrotyping bath (a solution of sulphate of copper), under the action of the current the copper-plate became dissolved as fast as pure copper was deposited upon the mould, whereby the strength of the solution was kept in an uniform condition. It is this method which is now almost universally adopted (when dynamo machines are not employed) in practising the art of electrotyping upon a large scale.

In 1841, Mr. Alfred Smee published his admirable work on Electrometallurgy, which at that period proved of the greatest service to all persons interested in the new art. In the year following, Mr. J. S. Woolrich introduced his magneto-electric machine, which for many years after occupied a useful position as a substitute for voltaic batteries, in several large plating works. In this year also, Dr. H. R. Leeson took out a patent for improvements in electro-depositing processes, in which he introduced the important elastic moulding material, "guiding wires," keeping articles in motion while in the bath, &c.

In 1843, Moses Poole obtained a patent for the use of a thermo-electric pile as a substitute for the voltaic battery; but the invention was not, however, successful. Many patents were taken out in the following years for various processes connected with electro-deposition; but the next most important improvement was due to Mr. W. Milward, of Birmingham, who accidentally noticed that after wax-moulds, which had been covered with a film of phosphorus—by applying a solution of that substance in bisulphide of carbon to their surfaces—had been immersed in the cyanide of silver plating bath, the silver deposit upon other articles, such as spoons and forks, for example, which were afterwards coated in the same bath, presented an unusually bright appearance in parts, instead of the dull pearly lustre which generally characterises the silver deposit. This incident induced Mr. Milward to try the effect of adding bisulphide of carbon to the plating bath, which produced the desired result. For some time he kept the secret to himself; but finding that it eventually became known, he afterwards patented the process in conjunction with a Mr. Lyons, who had somehow possessed himself of the secret. From that time the addition of bisulphide of carbon to silver baths for the purposes of "bright" plating has been in constant use.

Further reference to subsequent inventions connected with the art will be found in other chapters.

In the foregoing sketch of the origin and history of electro-deposition we have endeavoured to give such information as we hoped would be interesting to many who are engaged in the art, and also instructive to those who may be about to enter into a study of the subject, believing that the work would be incomplete without some special reference to the interesting origin of so great and useful an art.

CHAPTER V.

THEORY OF ELECTROLYSIS.

Chemical Powers of the Voltaic Pile.—Faraday's Nomenclature of Electro-chemical Action.—Direction of the Current.—Decomposition of Water.—Action of the Electric Current upon Compound Substances.—Electrolysis of Sulphate of Copper.—Electrolysis of Sulphate of Potash, &c.—Electrical Transfer of Elements.—Practical Illustrations of the Electrolytic Theory.

Chemical Powers of the Voltaic Pile.—We are indebted to Nicholson and Carlisle for the discovery of the *chemical powers* of the voltaic pile, which were first observed in the decomposition of water, and subsequently of certain saline solutions, in the year 1800. The subject was afterwards more closely investigated by Hisinger and Berzelins, in 1803, and in 1807 Sir Humphrey Davy, who had been experimenting in the same direction, delivered his famous lecture "On some Chemical Agencies of Electricity," before the Royal Society, in which the electro-chemical powers of the pile were more minutely demonstrated, and which formed the basis of some splendid discoveries made by that gifted philosopher, including the great discovery of the decomposition of the fixed alkalies. Many later experimentalists devoted their attention to this field of research, but more especially Faraday, to whose indefatigable labours and profound reasoning we are indebted for a clear exposition of the laws which govern electro-chemical decomposition, or *Electrolysis*, as also for a host of discoveries which have proved of inestimable service to the devotees of electrical science. His "Experimental Researches in Electricity" contain the results of his labours in this department of science, and "they have not only explained," says Brande, "and enlightened much that was before unintelligible and obscure in regard to statical electricity, but have also stamped a new character upon electrical as connected with chemical science; in point of originality in devising experiments, skill in carrying them into effect, and perspicuity in tracing out and unravelling the complicated relations and bearings of the new truths which are elicited, Faraday stands, if not unrivalled, at least unsurpassed."

Faraday's Nomenclature of Electro-chemical Action.—The free ends of the conducting wires of a voltaic battery, generally termed the *positive* and *negative poles*, are those sufaces by which the electric current enters and leaves the battery, simply acting as a pathway for the current. This being so, Faraday adopted the term *electrode*, as a substitute for *pole*, the word being derived from ηλεκτρον and οδος, *a way*, thereby signifying *that substance or surface, whether of air, water, or metal, which bounds the extent of the decomposing matter, in the direction of the current.* The conductors immersed in the liquids to be decomposed by the current are therefore termed, respectively, the positive and negative *electrodes.* The conductor by which the current *enters* the liquid he terms the *anode* (from ανα, *upwards*, and οδος, *a way*), and that by which it *leaves* the liquid the *cathode* (from κατα, *downwards*, οδος, *a way*), assuming the current of electricity to follow the passage of the sun—that is to pass from east to west—in its rising and setting. Faraday also applied the terms *anelectrode* and *cathelectrode* for the respective poles of the battery. All substances which are susceptible of *direct* decomposition by the current are called *electrolytes;* the process of electro-chemical decomposition is termed *electrolysis*, and for *electro-chemically decomposed*, he substituted *electrolysed.* The elements of the electrolysed liquid which are liberated by the action of the current are termed *ions*, those set free at the *anode*, or positive electrode, being termed *anions*, and those at the *cathode*, or negative electrode, *cations.* Thus, when acidulated water is *electrolysed*, two ions are evolved, namely *oxygen* and *hydrogen*, the former at the positive, and the latter at the negative electrode.

Direction of the Current.—In the simple voltaic circle, as shown in Fig. 42, Z represents a plate of zinc, and S a plate of silver,

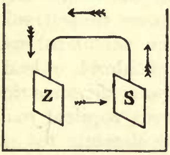

Fig. 42.

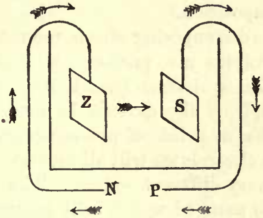

Fig. 43.

immersed in a vessel containing dilute sulphuric acid. The darts indicate the current passing from the zinc through the liquid to the silver, and returning through the conducting wire to the zinc; Z therefore represents the *positive* metal in relation to S through the liquid, and S the negative metal in relation to Z through the liquid. If separate wires are employed, as in Fig. 43, the current would pass as before from the *positive* metal Z to the negative metal S, traversing the conducting wire, in the direction of the darts, so that P would become the *positive electrode*, or *anode*, and N the *negative electrode*, or *cathode*. The metal which becomes dissolved in a voltaic couple is always the *positive* or active metal (as zinc, for example) upon which oxygen, chlorine, and other anions (*electro-negative* bodies) are evolved; the *inactive* or *passive* metal (as silver, platinum, &c.) is the *negative*, and upon it hydrogen and the metals or other *cations* (electro-positive bodies) are evolved in all cases of electrolytic action. If the above voltaic pair were immersed in a solution which would act upon the silver, and not upon the zinc, the electrical order would be reversed, the silver would become the positive metal and the zinc negative. One of the indispensable conditions of electrolysis is *fluidity*, and when a liquid is decomposed by electricity, or *electrolysed*, its constituents are disengaged solely at the poles or electrodes—that is where the current enters and leaves the liquid, the remainder being in a comparatively undisturbed state. We say *comparatively*, for we have always observed that the liquid, from the moment the current enters it, and during the entire progress of the electrolytic action, is kept in continual, though almost imperceptible, motion.

It had generally been supposed, according to the old electro-chemical theory, that the electro-positive bodies (*cations*) and electro-negative bodies (*anions*) were under the influence of direct attractive forces residing in the opposite poles of the voltaic battery; but Faraday proved, by conclusive experiments, that the decomposing force is *not at the poles*, or *electrodes*,* but *within the substance* acted upon by the current, and the terms he has introduced express the phenomena which are observable in *all* cases of electro-chemical decomposition.

The decomposing effects produced by the voltaic current in different electrolytes are precisely in accordance with the *atomic weights* or *chemical equivalents* (which see) of the substances electrolysed. For example, if the current be made to act upon acidulated water, a solution of iodide of potassium and a solution of chloride of lead, these three electrolytes will all undergo decomposition at the same time, but to a very different extent. The electric current required to decompose 9 parts of water, will separate into their elements 166 parts of iodide of potassium, and 139 parts of chloride of lead. In other words, the same amount of electricity that would reduce 56 parts of iron from its solution to the metallic state, would reduce 207 parts of lead, or 108 parts of silver.

Decomposition of Water.—In order to understand the principles

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* By common consent these terms are used indiscriminately.

of electrolysis, it will be necessary to have recourse to a few experimental illustrations, which we will endeavour to render as simple and as brief as possible. Fig. 44 represents a glass globe *a* with three openings, two of which are at the sides and are fitted with corks, perforated to admit glass tubes of such length as to meet near the centre of the globe. Each of these tubes is traversed by a platinum wire bent in the form of a hook at one end, and connected at the other end to a strip of platinum foil, these latter being adjusted so as to stand erect within the tenth of an inch of each other. A glass tube *b* is inverted into the neck of the globe, in which a notch is filed to allow a portion of the fluid to ooze out. The globe is now to be filled with water acidulated with sulphuric acid, and the two hooked ends of the platinum wire connected to the conducting wires of a voltaic battery. The moment the circuit is thus completed, bubbles of gas arise in the tube, displacing the liquid, which trickles out of the neck of the globe. While the decomposition is going on, it will be noticed that twice the quantity of gas escapes from the platinum plate in communication with the *cathode* or negative pole, as compared with that liberated at the *anode* or positive electrode. The inverted tube now contains a mixture of oxygen and hydrogen gases, in the proportion of *two* volumes of the latter to *one* volume of the former; and if it be again inverted (its mouth being closed by the thumb while doing so), and the mouth of the tube brought near a lighted match, upon removing the thumb an explosion will take place, when the gases re-combine, forming water.

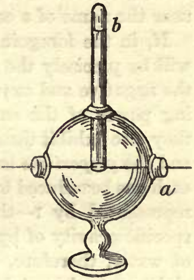

Fig. 44.

By another experiment the gases may be collected in separate tubes which, for the purpose of estimating their relative proportions, *in volume*, should be graduated into cubic inches. Such an arrangement is shown in Fig. 45, in which a globe with two necks, each having a tube so connected as to receive the gas liberated at each electrode. As the decomposition progresses, it will be observed that rather more than double the quantity of gas occupies the tube inverted over the negative pole to that contained in the tube enclosing the positive pole. If a lighted match be applied to the tube containing

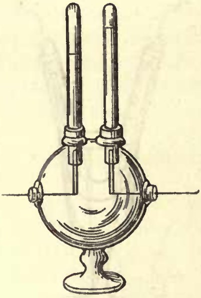

Fig. 45.

the hydrogen, this gas will quietly burn with a pale blue flame; and if an ignited match be blown out, and the glowing end plunged into the tube containing the oxygen, it will instantly be rekindled into a flame; but if the mouths of the two tubes be brought simultaneously near the flame of a candle a violent explosion will take place as before.

If, in the foregoing experiments, the poles be reversed, the results will be precisely the same, that is to say, hydrogen will be evolved at the negative and oxygen at the positive pole. Besides the decomposing power of the current which these simple experiments illustrate, they also exhibit the *composition of water* both as regards its constituents and the *proportions* in which they are combined. Thus, if the *volume* of each gas be reduced to its actual *weight*—the volume of hydrogen being represented by 1—the *half*-volume of oxygen will be $=8$, since the specific gravity of hydrogen and oxygen is as 1 to 16; the nine parts of water, therefore, consist of one part, *by weight*, of hydrogen, and eight parts, *by weight*, of oxygen; or by volume, 1 part hydrogen and 16 parts oxygen.

Action of the Electric Current upon Compound Substances.—When solutions of neutral salts, as sulphate of soda, for example, are subjected to the action of the electric current, or *electrolysed*, they yield *acids* and *alkalies*, the former *always* at the positive electrode, and the latter at the negative. When solutions of metallic salts are electrolysed, oxygen and the acids are developed at the positive, and hydrogen and the metals at the negative pole. To illustrate the decomposition of a neutral salt, we may take a solution of sulphate of soda (Glauber's salt). A glass tube is bent in the form of a syphon, as indicated in Fig. 46, and placed in a wine-glass as a support. The syphon-tube is now to be filled with a weak solution of sulphate of soda tinted blue with tincture of litmus; a platinum wire or strip of platinum foil, soldered to a wire of the same metal, is now to be introduced into each leg of the syphon, but must not be allowed to come in contact at the bend of the tube. One of the platinum wires is now to be connected to the negative, and the other to the positive terminals of a voltaic battery, when, in a short time, the blue colour of the liquid, in which the negative electrode is placed, will be changed to *green*, while the fluid in which the positive electrode is inserted will have acquired a *red* colour. The former indicates the presence of an *alkali*, and the latter of an *acid;** in other words, the

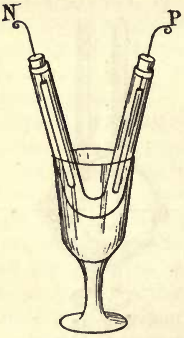

Fig. 46.

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* Vegetable blues are always turned red by acids.

soda is set free at the one pole, and the sulphuric acid at the other. If the poles be now reversed, the respective colours will also, after a time, become reversed.

A modification of the above experiment consists of the following arrangement :— Two tubes (Fig. 47), each furnished with a strip of platinum connected to a wire of the same metal, are to be filled with the blue solution of sulphate of soda, and inverted in two separate glasses also nearly filled with the same liquor. The two glasses are to be connected together by means of a syphon-shaped tube filled with the same solution. If the platinum wires N and P be now connected to a voltaic battery, in a short time it will be observed that, notwithstanding their being in separate vessels, the blue liquor will, as in the foregoing experiment, become red and green respectively. Moreover, if the voltaic action be kept up for a sufficient length of time, the *alkali* of the salt will have passed from P to N and the acid from N to P. It thus appears that the acid and alkali of the sulphate of soda have traversed the connecting syphon in opposite directions, and it is inferred that, under the influence of electrical attraction, the usual chemical affinities become suspended, otherwise the acid and alkali would unite (which is not the case) in their transit through the tube. Further examples of the transfer of elements are given at page 76.

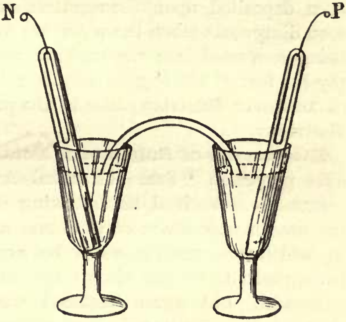

Fig. 47.

Electrolysis of Sulphate of Copper.—A very simple but instructive experiment in electrolysis is the following :— Make a moderately strong solution of sulphate of copper and nearly fill a glass tumbler with the liquid, as in Fig. 48. Now connect two strips of platinum foil to the terminals of a battery, and immerse them in the copper solution. In a few moments a bright deposit of pure metallic copper will appear upon the *negative* electrode N, while the positive will exhibit no change. If the poles be now reversed, by disconnecting the conducting wires from the binding-screws of the battery and reversing their position, the copper will speedily disappear from the

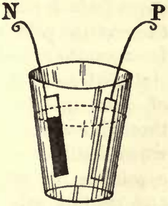

Fig. 48.

negative (*now* the positive) electrode, having become dissolved in the solution, and a deposit of the metal will appear upon the other pole. In this result we observe that the metallic deposit always takes place upon the negative terminal of the voltaic battery (that which is connected to the zinc or *positive element*), while the copper, which had been deposited upon the negative electrode in the first experiment, soon disappears when the poles are reversed, the copper-coated strip being converted into the anode or positive electrode. Hence we see (by the fact of the copper becoming dissolved in the solution) the use of anodes or *dissolving plates* in the practical deposition of metals by electricity.

Electrolysis of Sulphate of Potash, &c.—Davy, in his remarkable paper on "Some Chemical Agencies of Electricity," before referred to, described the following interesting experiment, which at the time created the most profound astonishment, since the only way in which the results could be explained was by assuming that throughout the whole circuit the natural affinities of substances are suspended, but again restored when they are dismissed at the electrodes by which they were attracted:—

Fig. 49.

"An arrangement was made consisting of three vessels, as shown in Fig. 49. A solution of *sulphate of potash* was placed in contact with the negatively electrified point, pure water was placed in contact with the positively electrified point, and a weak solution of *ammonia* was made the middle link of the conducting chain, so that no sulphuric acid could pass to the positive point in the distilled water without passing through the solution of ammonia; the three glasses were connected together by pieces of amianthus (fibrous and silky asbestos). A power of 150 pairs was used. In less than five minutes it was found, by litmus paper [which is turned *red* by acids], that acid was collecting round the positive point; in half an hour the result was sufficiently distinct for accurate examination. The water was sour to the taste, and precipitated a solution of nitrate of baryta; muriatic acid from muriate of soda, and nitric acid from nitrate of potash were transmitted through concentrated alkaline menstrua under similar circumstances; when distilled water was placed in the negative part of the circuit, a solution of sulphuric, muriatic, or nitric acid in the middle, and any neutral salt with the base of *lime*, *soda*, *potash*, *ammonia*, or *magnesia* in the positive part, the alkaline matter was transmitted through the acid matter to the negative surface with similar circumstances to those occurring during the passage of the acid through alkaline menstrua."

Electrical Transfer of Elements.—Sir H. Davy, in some of his experiments on the transference of elements from pole to pole of an electric circuit, employed vessels consisting of the substance to be decomposed. In one experiment, for example, two cups of *sulphate of lime* (gypsum) were filled with water and connected by means of moist cotton, one pole of the pile (Volta's pile being the source of electricity) was placed in each cup, and soon after it was found that the negative cup contained a solution of *lime*, and the positive cup a solution of *sulphuric acid*.

A very striking illustration of the transfer of elements under the decomposing influence of the electric current is shown in the decomposition of *chloride of silver* (a compound of chlorine and silver) when two silver wires are employed as the electrodes. If a small quantity of the chloride be fused upon a piece of glass, and the two poles placed in contact with it, metallic silver is abundantly deposited at the *negative* electrode, while an equal quantity is dissolved from the *positive* wire. In this case the chlorine is not set free, but is engaged in dissolving the silver of the positive wire exactly in the proportion in which it is being *deposited* at the negative wire. If this latter electrode be carefully drawn from the fused globules as the silver is reduced there, and without interruption in its continuity, a wire or thread of reduced silver several inches in length may be produced. It will be necessary, however, while the silver is being dissolved from the positive wire, to keep it continually in contact with the fused mass and at a short distance from the negative wire.

Practical Illustrations of the Electrolytic Theory.—Suppose we take a solution of sulphate of copper, composed of 4 ounces of the sulphate dissolved in a quart of water, to which is added about 2 ounces of oil of vitriol. We next attach a piece of sheet copper, about 3 inches square, to the positive pole of a Smee or Daniell battery, and a plate of clean sheet-brass or German-silver of about the same dimensions to the negative pole, and immerse both plates in the copper solution: in a few moments we shall observe that the brass has become coated with copper. If the operation be allowed to proceed undisturbed for a few hours, at the end of that time we shall find that a copper deposit of considerable thickness has taken place upon the brass plate, while the copper plate (the *anode*) has become greatly reduced in substance. If the two plates are weighed *before* and after the prolonged immersion, it will be found, on re-weighing them, that one plate (the copper) has lost what the other (the brass) has gained, while the copper solution will have preserved its equilibrium. In this experiment several important facts are elicited:—

1. That the metal is deposited upon the *negative electrode.* 2. That the *positive electrode* becomes dissolved. 3. That the copper is deposited direct *from the solution* on to the brass plate. 4. That the metallic strength of the solution is kept up by the gradual dissolving of the copper anode, which may be thus explained: the *water* of the solution, being decomposed by the current, its oxygen is liberated at the positive (in this case copper) pole, when it combines with the metal, forming *oxide of copper;* at the same time the sulphuric acid of the sulphate of copper is set free, and this, seizing the oxide of copper, forms sulphate of copper, which at once becomes dissolved in the solution. The hydrogen, liberated at the negative pole, does not escape in the form of gas, but, as it becomes released from the water, it takes the place of the copper removed from the solution during the process of *electro-deposition.*

A very useful little apparatus for experimenting upon the electro-decomposition of liquids is represented in Fig. 50. It consists of a plate-glass cell, made by cementing five pieces of glass together with transparent cement and supporting them upon a wooden stand, as in the engraving, upon which they are fastened with cement. The cell is about five or six inches long and two inches in width. The cell is divided into two compartments by inserting a temporary diaphragm (*a*, Fig. 51), which is a small cane or wooden frame with muslin stretched over it. When this is put into its place, as at *a*, a separate electrode may be introduced into each of the compartments thus formed, and these may consist of two strips of thin platinum foil, or thin plates of carbon, about four inches long and half an inch in width. To illustrate the evolution of chlorine at the anode or positive pole, nearly fill the glass cell with a weak solution of salt-and-water, slightly acidulated with hydrochloric acid, and colour the solution blue with a few drops of a sulphuric solution of indigo. The electrodes are then introduced, when, in a few minutes, the solution in the *anode* compartment will be found to lose its colour and eventually become quite colourless, owing to the action of the chlorine disengaged at the anode, which has the power of *bleaching* the indigo.

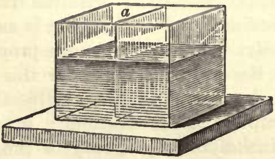

Fig. 50.

Fig. 51.

Another interesting experiment is to fill the glass cell with a weak solution of *starch*, to which a little iodide of potassium must be added. When the current is passed through the solution the *iodine* will show itself at the anode by a beautiful blue colour, it being the peculiar property of this substance to strike a blue colour with starch, forming an *iodide* of starch.

Lastly, if the cell be filled with a solution of common salt, to which a few drops of yellow prussiate of potash are added, and an *iron* electrode introduced into each compartment, the division in which the anode or positive electrode is placed will assume a beautiful deep blue colour, while the solution in the other or *negative* compartment will remain colourless. The blue colour in the anode division is due to the oxidation of the iron and its solution by the prussiate of potash forming *prussian blue.*

CHAPTER VI.

ELECTRICAL THEORIES IN THEIR RELATION TO THE DEPOSITION OF METALS.

Conductors and Insulators.—Relative Conducting Powers of Metals.—Definition of Electrical Terms.—Simple and compound Voltaic Circles.—Resistance: Ohm's Law.—Application of Ohm's Law to Compound Voltaic Circles.—Electrical Units.—Electromotive Force of Batteries.—Electrolytic Classification of Elements.

WHILE it would be beyond the province of the present work to enter deeply into theoretical considerations, it is necessary, in the present advanced state of electrical science, that both the student and practical operator should be acquainted with the principles and laws which govern the development of electricity—that *force* or *power* with which he has to deal in all electrolytic operations. No matter how it may be obtained, whether it be generated by chemical or mechanical means, or by heat (as in thermo-piles), the "current" or *force* is, to the electro-metallurgist, what steam is to the engineer—a means of doing a certain amount of work. When we take into consideration the many ways at present known of generating or bringing into action this subtle force, and the marvellous effects which it is capable of producing, it becomes at once apparent that if we desire to render this power subservient to practical purposes in the arts, we should know something of the principles which are involved in its production and influence its action, that we may be the better able to regulate or control the current to suit the various purposes to which we desire to apply it. For a full knowledge of the laws of electrical science, the reader is referred to standard works on electricity, those mentioned in the footnote * being specially recommended.

Conductors and Insulators.—It is understood that all bodies are capable of conducting or transmitting electricity, though in very different degrees, and that all substances insulate or resist the passage of the current also in different degrees. Faraday was of opinion that

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* "The Student's Text-Book of Electricity," by H. M. Noad, Ph.D., F.R.S., &c; revised edition by W. H. Preece, M.I.C.E.; and Fleeming Jenkin's "Treatise on Electricity and Magnetism."

conduction and insulation are only extreme degrees of one common condition; that they are the same in principle and in action, except that in conduction an effect common to both is raised to the highest degree, whereas in insulation it occurs in the best cases only in an almost insensible quantity. In the following list the bodies are arranged in the order of their conducting power, silver being recognised as the best conductor, and ebonite the most perfect insulator.

All the metals.
Well-burnt charcoal.
Plumbago.
Concentrated acids.
Powdered charcoal.
Dilute acids.
Saline solutions.
Metallic ores.
Animal fluids.
Sea water.
Spring water.
Rain water.
Ice above 13° Fahr.
Snow.
Living vegetables.
Living animals.
Flame smoke.
Steam.
Salts soluble in water.
Rarefied air.
Vapour of alcohol.
Vapour of ether.
Moist earth and stones.
Powdered glass.
Flowers of sulphur.
Dry metallic oxides.
Oils, the heaviest the best.
Ashes of vegetables.
Many transparent crystals.
Dry ice below 13° Fahr.
Phosphorus.
Lime.
Dry chalk.
Native carbonate of baryta.
Lycopodium.
Caoutchouc.
Camphor.
Siliceous and argillaceous stones.
Dry marble.
Porcelain.
Dry vegetables.
Baked wood.
Leather.
Parchment.
Dry paper.
Hair.
Wool.
Dried silk
Bleached silk.
Raw silk.
Transparent gums.
Diamond.
Mica.
All vitrifications.
Glass.
Jet.
Wax.
Sulphur.
Resins.
Amber.
Gutta-percha.
Shellac.
Ebonite.

The conductor commonly employed for conveying the current from voltaic batteries, and magneto and dynamo-electric machines to the depositing baths, as also for suspending the anodes and objects to be coated with metal, is copper, which, besides being the second best conductor, has the advantage of being comparatively cheap and readily procurable, while its extreme pliability renders it easy to adapt to the various purposes of electro-deposition. The copper wire employed for transmitting the current from voltaic batteries of moderate dimensions may be from $\frac{1}{16}$ to $\frac{1}{8}$ inch in thickness, while the wire, or "cable" as it is sometimes called, used to connect powerful magneto and dynamo-electric machines with the depositing tanks is generally from half to one inch in diameter; these leading wires are sometimes *insulated* by being covered with gutta-percha or other insulating material.

Relative Conducting Power of Metals.—The following table gives the relative conducting powers of pure metals and other conductors, according to Dr. Matthiessen:—

Silver	100·0
Copper	99·9
Gold	77·9
Zinc	29·0
Cadmium	23·7
Palladium	18·4
Platinum	18·0
Cobalt	17·2
Nickel	13·1
Tin	12·4
Thallium	9·2
Lead	8·3
Arsenic	4·8
Antimony	4·6
Mercury	1·6
Bismuth	1·2
Graphite	·069
Gas Coke	·038
Bunsen's Coke	·025

It will thus be seen how nearly silver and copper approximate each other in conducting power, and how greatly the conductivity of metals diminishes after gold is reached. The conduction-resistance of liquids, as compared to metals, is enormous; for example, if that of copper at 32° Fahr. equals 1, those of the following liquids are—

Nitric acid at 55° Fahr.	976,000
Sulphuric acid diluted to $\frac{1}{11}$ at 68° Fahr.	1,032,020
Saturated solution of chloride of sodium at 56° Fahr.	2,903,538
„ „ sulphate of zinc	15,861,267
„ „ sulphate of copper at 48° Fahr.	16,885,520
Distilled water at 59° Fahr.	6,754,208,000

Definition of Electrical Terms.—The late Professor T. Clark-Maxwell and Mr. Fleeming Jenkin, in their report "On Standard Electrical Resistances," as members of a committee appointed by the British Association,* adopted the following definitions of the terms *electromotive force*, *resistance*, *current*, and *quantity*, which are now generally accepted.

Electromotive Force.—By this term, which is frequently written

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* Report, 1863.

E.M.F., is to be understood that quality of a voltaic battery or other source of electricity, in virtue of which it tends to do work by the transfer of electricity from one point to another, and this force is measured by measuring the work done during the transfer of a given quantity of electricity between these two points. Dr. Joule proved that whether the work done be mechanical, chemical, or thermal, it is proportional to the *square* of the current, to the *time* during which it acts, and to the resistance of the circuit. The electromotive force is, in fact, the strength or power of the current to overcome resistance. The unit of electromotive force adopted in this country is termed a *volt*.

Electrical Resistance.—By this term is understood that quality of a conductor in which it prevents the performance of more than a certain amount of work in a given time by a given electromotive force. The resistance of a conductor is, therefore, inversely proportional to the work done in it when a given electromotive force is maintained between the two ends. The unit of resistance is termed an *ohm*.

Electrical Current.—By this term is meant the cause of the peculiar properties possessed by a conductor used to join the opposite poles of a voltaic battery; namely, those of exerting a force on a magnet in its neighbourhood; of decomposing certain compound bodies called *electrolytes*, when any part of the conductor is formed of such compound bodies; or of producing currents in neighbouring conductors as they approach or recede from them.

Quantity.—The force with which one electrified body acts upon another at a constant distance, varies under different circumstances. When the force between the two bodies, at this constant distance and separated by air, is observed to increase, it is said to be due to an increase in the *quantity* of electricity, and the quantity at any spot is defined as proportional to the force with which it acts through air on some other constant quantity at a distance. If two bodies charged with a given quantity of electricity are incorporated, the single body thus composed will be charged with the sum of the two quantities.

Intensity.—Mr. Latimer Clark pointed out* that the expression *intensity*, as ordinarily used, involves two perfectly distinct qualities, viz.: *tension*, or *electromotive force*, or *electric potential*, and *quantity*. All the most striking properties of electricity, such as the decomposition of water and salts, the combustion of metals, the deflection of the galvanometer, the attraction of the electro-magnet, and the physiological effects of the current are really dependent, as regards their magnitude and energy, solely on the *quantity* of electricity passing. Their greater energy, when the tension is increased, is an indirect effect due not to that tension, but to the increased quantity which

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* "Proceedings of the Royal Institution," March 15th, 1861.

passes in a given time by reason of the increased tension. The unit of current strength is termed an *ampère.*

Simple and Compound Voltaic Circles.—In a simple voltaic circle or battery, in which the plates are large, the *quantity* of electricity generated or set in motion is very considerable, while its intensity or power of overcoming resistance is low. The energy depends on the size of the plates, the intensity of the chemical action on the oxidisable metal, the rapidity of its oxidation and the speedy removal of the oxide. It is not, however, necessary that the plates composing a simple voltaic circle should consist of *two* opposed surfaces only; the same electrical effect is obtained if the plates are cut up into a number of pieces and placed in different vessels, each containing the same exciting fluid, provided the same extent of surface be preserved and the pieces be kept at the same distance apart. Thus, let a plate of platinum and another of amalgamated zinc, each four inches square, be immersed at a distance of one inch apart in dilute sulphuric acid, and connected by a stout copper wire; after the lapse of a certain time a certain quantity of zinc will be dissolved, and a corresponding quantity of hydrogen gas will be evolved on the surface of the platinum; now let each plate be cut into four strips, each 1 inch broad and 4 inches long, and let a pair of each metals be immersed, at a distance of one inch apart, in four separate vessels containing dilute sulphuric acid; let all the platinum plates be connected together by a stout copper wire, and all the zinc plates by a similar wire, and let the two wires be united; the same amount of zinc will be dissolved in the same time, and the same amount of hydrogen liberated, and the same quantity of electricity thrown into circulation, as with a single pair; the four pairs and the single pair are equally *simple* voltaic circles.—*Noad.*

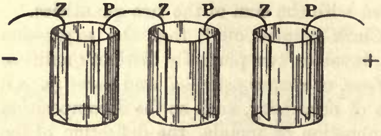

Fig. 52.

If, however, instead of uniting all the plates together in two separate groups, as above, we *alternate* the series by connecting the zinc of one cell with the platinum of the next cell, and so on throughout the whole series, as in Fig. 52, by which arrangement a zinc plate will be at one end of the series, and a platinum plate at the other, the amount of zinc dissolved and hydrogen set free will be precisely the same as before, but the *electromotive force is increased fourfold;* the *resistances* are at the same time still further increased, for while in the former arrangement a stratum of liquid 4 inches wide and 1 inch thick had to be traversed by the current, in the second arrangement it has to pass through 4 separate inches of liquid, each 1 inch in width. By this latter method of connecting the plates, however, there is a starting-point of power in each cell, whereby each contributes its energy in urging forward the current, and though the *quantity* of electricity is not greater than when the plates were arranged as a single pair, its intensity (electromotive force) or power of overcoming resistance is greatly increased, and, within certain limits, this power is increased in proportion to the number of couples arranged in alternate series. This arrangement constitutes a *compound voltaic circle*, or *compound battery*.

Resistance: Ohm's Law.—Even under the most favourable conditions, it is well known that from a voltaic battery we never get a full equivalent of electrical power in return for the chemical action which takes place within the battery cell, and this loss of power is due to *internal resistance* within the battery itself, and this, as we have shown, is overcome when several cells are connected in alternate series, that is the zinc of one cell with the copper of the next, and so on throughout the series. *External resistance* is that which opposes the current in the conducting wires, the electrolyte, or other body employed to complete the circuit. A current which is not much affected by external resistance is said to possess considerable electromotive force, or in other words is of "high intensity."

We are indebted to Professor Ohm, of Nuremberg, for an exposition of the causes which influence the quantity of electricity obtained in a voltaic circuit, who investigated the subject mathematically, and his formulæ have been verified experimentally by Daniell, Wheatstone, and others, and are regarded as the basis on which all other investigations that have since been made relative to the force of the current are founded. Ohm's law may be thus briefly defined: the strength or force of the current is equal to the electromotive force divided by the resistance in the circuit; thus, if we take C to denote the actual strength of the current, that is its power to produce heat, magnetism, chemical action, &c., E the electromotive force, and R the resistance of the wires and electrolytes, then

$$C = \frac{E}{R}$$

Ohm's law may also be explained as follows:—

1. The volume or strength of the current in any circuit is found by dividing the value of the E.M.F. (as measured by the difference of potential existing in the circuit) by the value of its total resistance.

2. The resistance in any circuit is found by dividing the value of the E.M.F by the value of the current.

3. The E.M.F. in any circuit is found by multiplying the value of the resistance contained in it by the value of the current traversing it.

4. The *quantity* of electricity produced in any circuit is found by multiplying the value of the current by the time during which the current flows.

The term *quantity* in its proper significance refers solely to *static* and not to *dynamic* electricity, although the duration of the dynamic effect depends upon the quantity originally present.

When the conductor or storage battery is discharged, by joining its poles to a conductor, the conductor is traversed by the current. If the conductor has a great resistance, it will require considerable *time* for the whole to pass, and thus the current will be a comparatively weak one. If, on the other hand, the resistance of the conductor is small, the whole quantity will pass in a much shorter time, and the current will be a much stronger one.

If we increase the number of elements of a voltaic battery, arranging them in alternate series, we increase the tension, urging the electricity forward, but at the same time we increase the amount of resistance offered by the liquid portion of the circuit; so that, provided in both cases the circuit be completed by a competent conductor, such as a stout copper wire, we obtain the same results in both cases, the electromotive forces and the resistances being increased by an equal amount. The resistance includes the resistance of the conducting wires, the electrolyte, and the resistance of the liquid and elements of the battery itself. The resistance of the battery is found to decrease in exact proportion as the surface is increased, and the resistance of the wire is directly as its length, and inversely proportional to its section.

Application of Ohm's Law to Compound Voltaic Circles.—Since each pair of elements of a voltaic battery contributes its own E.M.F. to the current, it follows that the whole E.M.F. will be proportional to the number of pairs, provided they are all equal. The following general law has been established by Wheatstone:—

1. The electromotive force of a voltaic current varies with the number of the elements and with the nature of the metals and liquids which constitute each element, but is in no degree dependent on the dimensions of any of their parts.

2. The resistance of each element is directly proportional to the distances of the plates from each other in the liquid, and to the specific resistance of the liquid, and is also inversely proportional to the surface of the plates in contact with the liquid.

3. The resistance of the connecting wire of the circuit is directly proportional to its length and to its specific resistance, and inversely proportional to its section.

The resistances of different metals are inversely as their conducting powers, and their conductivity is greatly influenced by temperature, as will be seen in the following table by Dr. Matthiessen :—

Metal—Pure.	Conductivity.		Conductivity at 212°.		
	Silver at 32° = 100.		Silver at 212° = 100.	Each metal compared with itself at 32° = 100.	
	At 32°	At 212°			Loss p. c.
Silver (hard drawn)	100·00	71·56	100·00	71·56	28·44
Copper (hard drawn)	99·95	70·27	98·20	70·31	29·69
Gold (hard drawn)	77·96	55·90	78·11	71·70	28·30
Zinc	29·02	20·67	28·89	71·23	28·77
Cadmium	23·72	16·77	23·44	70·70	29·30
Cobalt	17·22	—	—	—	—
Iron (hard drawn)	16·81	—	—	—	—
Nickel	13·11	—	—	—	—
Tin	12·36	8·67	12·12	70·11	29·89
Thallium	9·16	—	—	68·58	31·42
Lead	8·32	5·86	8·18	70·39	29·61
Arsenicum	4·76	3·33	4·65	69·88	30·12
Antimony	4·62	3·26	4·55	70·54	29·46
Bismuth	1·245	0·878	1·227	70·51	29·69

Electrical Units.—There has been much diversity amongst English and Continental electricians as to the best system of electrical measurement to be founded on the various theories of Ohm, Weber, Thomson, Ampère, and others ; but we may take it as a general rule that in this country the *Volt* is accepted as the unit of electromotive force, the *Ohm*, the unit of resistance, and the *Ampère*, the unit of quantity, or current strength, which determines the amount of electric work done in a given time. In estimating the electric power of a dynamo-electric machine or battery, its electromotive force is taken in volts, its resistance in ohms, and its quantity or strength is determined in ampères. For these purposes certain measuring instruments are employed, termed *voltmeters* and *ammeters* respectively, of which there are many different forms in use. One of the most delicate and reliable instruments for measuring the current is Siemens' *dynamometer ;* but for workshop uses those instruments which are enclosed in a lacquered brass, or a wooden case, are to be preferred.

The volt is also called the unit of potential, and does not differ greatly from the potential which normally exists between the poles of a single sulphate of copper cell (being about 95 per cent. of it), and for approximate calculations may be considered equivalent to it. In other words, a Daniell cell is a little more than a volt, the determinations of it value by different experimentalists being as below :—

Werner Siemens	1·106 volt.
Latimer Clark	1·079 „
Sir W. Thomson	1·012 „
F. Kolrausch	1·138 „

Electromotive Force of Batteries.—The following table, after Ferrini, gives the E.M.F. of various batteries, in volts, and will be very useful for reference :—

TABLE OF ELECTROMOTIVE FORCE OF BATTERIES.

Name of Element.	Constitution.	Electromotive Force in Volts.	Authority.
Wollaston . .	Amalgamated zinc and copper in dilute sulphuric acid (1 : 12)	0·886	Clark and Sabine.
		0·861	Sprague.
		0·719	De la Rive.
Smee	Amalgamated zinc in sulphuric acid, platinised silver, or platinum in sulphuric acid (1 : 12)	1·098	Clark and Sabine.
		1·107	Sprague.
		0·541	De la Rive.
		1·192	Naclari.
Daniell . . .	Amalgamated zinc in sulphuric acid (1 : 4); copper in saturated solution of copper sulphate	1·079	Clark and Sabine.
		1·079	Sprague.
		1·079	De la Rive.
		1·079	Naclari.
	Zinc in dilute sulphuric acid (1 : 12); copper in saturated solution	0·978	Clark and Sabine.
		0·98	Du Moncel.
Leclanché . .	Zinc in sal-ammoniac; carbon with manganese peroxide in sal-ammoniac	1·481	Clark and Sabine.
		1·561	Sprague.
		1·942	De la Rive.
		1·259	Beetz.
	Zinc in solution of common salt; carbon with manganese peroxide in common salt solution	1·493	Sprague.
		1·360	Naclari.
		1·34	Du Moncel.
Marié-Davey .	Zinc in dilute sulphuric acid (1 : 12); carbon in mercurous sulphate	1·524	Clark and Sabine.
		1·542	Sprague.
		1·482	Naclari.
		1·440	Du Moncel.
Grove	Zinc in dilute sulphuric acid (1 : 12); platinum in fuming nitric acid	1·956	Clark and Sabine.
	Zinc in dilute sulphuric acid (1 : 12); platinum in nitric acid of 1·38 sp. gr.	1·524	Clark and Sabine,
		1·542	Sprague.

TABLE OF ELECTROMOTIVE FORCE (*continued*).

Name of Element.	Constitution.	Electro-motive Force in Volts.	Authority.
Bunsen . . .	Zinc in dilute sulphuric acid (1 : 12); carbon in fuming nitric acid	1·964 1·95	Clark and Sabine. Du Moncel.
	Zinc in dilute sulphuric acid (1 : 12); carbon in nitric acid of 1·38 sp. gr.	1·888 1·941 1·880	Clark and Sabine. Beetz. Naclari.
	Zinc in dilute sulphuric acid (1 : 12); carbon in bichromate of potassium	2·028 1·905 2·120	Clark and Sabine. Sprague. Naclari.
Grenet . . .	Zinc and carbon in bichromate of potassium	1·825	Naclari.

Electrolytic Classification of Elements.—The following table indicates the electric relations of simple or elementary bodies to each other, but is subject to modifications, and indeed reversal of order, according to the nature of the exciting fluid in which the pairs of elements may be immersed. The list will, however, prove useful as a general guide. In the first column of *negative* bodies, each element is to be considered negative to all *below*, and positive to all above it, and the same applies to the second column of *positive* bodies. The elements are therefore negative or positive only in relation to each other; as an example, if a compound of *oxygen* and *chlorine* be electrolysed, the former would go to the *positive* and the chlorine to the *negative* electrode; if the compound were composed of *chlorine* and *phosphorus*, the chlorine would then go to the positive, and the phosphorus to the negative pole:—

Electro-negative Elements.

Oxygen.
Sulphur.
Selenium.
Nitrogen.
Fluorine.
Chlorine.
Bromine.
Iodine.
Phosphorus.
Arsenic.
Chromium.
Vanadium.

Electro-positive Elements.

Potassium.
Sodium.
Lithium.
Barium.
Strontium.
Calcium.
Magnesium.
Aluminium.
Uranium.
Manganese.
Zinc.
Iron.

Electro-negative Elements.

Tungsten.
Boron.
Carbon.
Antimony.
Tellurium.
Titanium.
Silicon.
Hydrogen.

Electro-positive Elements.

Nickel.
Cobalt.
Cadmium.
Lead.
Tin.
Bismuth.
Copper.
Silver.
Mercury.
Palladium.
Platinum.
Gold.

In the foregoing pages we have briefly dwelt upon such theoretical considerations as are more directly connected with the principles of electrolysis explained in the previous chapter; for a more intimate acquaintance with the principles of voltaic and dynamic electricity, we must again refer the reader to Noad's "Text-Book of Electricity," Fleeming Jenkins' "Electricity and Magnetism," and the numerous other treatises upon electrical science of recent date.

CHAPTER VII.

ELECTRO-DEPOSITION OF COPPER.

Electrotyping by Single-cell Process.—Copying Coins and Medals.—Moulding Materials.—Gutta-percha.—Plastic Gutta-percha.—Gutta-percha and Marine Glue.—Beeswax.—Sealing-wax.—Stearine.—Stearic Acid.—Fusible Metal.—Elastic Moulding Material.—Plaster of Paris.

It may fairly be said that the discovery of the electrotype process formed the basis of the whole electrolytic industry; and, in its applications to various purposes of the arts and to literature, it has proved of inestimable value. While, in its infancy, the electrotype process was a source of scientific recreation to thousands of persons of all classes, many were those who saw in the new process a wide field of research, from which much was expected and more has been realised. While Faraday, Becquerel and others were investigating the process in its more scientific relations, practical men were trying to apply it to various art purposes, until, in course of time, electrotyping was added to our list of chemical arts.

The simplest form of arrangement for electrotyping small objects is known as the "single-cell" process, which it will be well to consider before describing the more elaborate apparatus employed for larger work.

Electrotyping by the Single-cell Process.—In its most simple form, a small jar, Fig. 53, may be used as the outer vessel, and in this is placed a small porous cell, made of unglazed earthenware or biscuit porcelain, somewhat taller than the containing vessel. A strip of stout sheet-zinc, with a piece of copper wire attached, either by means of solder or by a proper binding screw, is placed in the porous cell. A *saturated* solution of sulphate of copper (bluestone), made by dissolving crystals of that substance in hot water, and pouring the liquid, when cold, into the outer cell. The porous cell is then filled to the same height as the copper solution with a solution of sal-ammoniac or common salt. To keep up the strength of the solution when in use a few crystals of sulphate of copper are placed in a muslin bag, which is hooked on to the

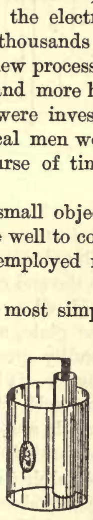

Fig. 53.

edge of the vessel by means of a short copper hook, and the bag allowed to dip a little way into the liquid. The prepared mould is connected to the end of the wire (which is bent in this ∩ form) and gently lowered into the solution, when the whole arrangement is complete. In place of the porous cell the zinc may be wrapped in several folds of brown paper, enclosing a little common salt, but the porous cells are so readily obtained that it is never worth while to seek a substitute for them. This simple arrangement will easily be understood by referring to the cut.

A more convenient single-cell apparatus is shown in Fig. 54, in which the containing vessel, or *cell*, is a glass or stoneware jar capable of holding about three pints. In this is placed a porous cell (p). A bar or plate of zinc (z), with binding screw attached, is deposited in the porous cell; a short piece of copper wire (w), for suspending the *mould* (m) or object to be copied, has its shorter end inserted in the hole of the binding-screw. The outer vessel is about three parts filled with a *saturated* solution of sulphate of copper (c), and the porous cell is filled to the same height with a half-saturated solution of sal-ammoniac or common salt. If the zinc is *amalgamated*, however, dilute sulphuric acid is used instead of the latter solution in the porous cell, and a small quantity of oil of vitriol (from half an ounce to one ounce of acid to the quart of copper solution) added.

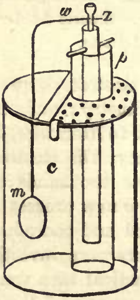

Fig. 54.

Amalgamating the Zinc.—Pour a little dilute sulphuric acid, or undiluted muriatic acid, into a dish, and, having tied a piece of flannel to the end of a stick, lay the zinc in the dish and proceed to brush the acid all over the plate; now pour a little mercury (quicksilver) on the plate, and rub it over the zinc with the little mop, when it will readily spread all over the surface, giving the zinc a bright silvery lustre. It is important that the zinc should be *thoroughly* cleaned by the acid, otherwise the mercury will fail to amalgamate with the metal, and dark patches of unamalgamated zinc will appear. The perforated shelf, or tray, in the engraving is a receptacle for crystals of sulphate of copper, which, being placed upon it, gradually become dissolved while the deposit of copper is going on, and thus re-supply the solution as it becomes exhausted, whereby the operation progresses uniformly.

To prepare the copper solution for small experimental purposes, dissolve about 10 ounces of sulphate of copper in 1 quart of hot water and stir until the crystals are all dissolved; then set the vessel aside until cold, when the *clear* liquor is to be carefully poured into the depositing cell. When unamalgamated zinc is used in the single-cell arrangement the sulphate of copper should be simply a saturated solution of the salt without that addition of acid, though a *few drops only* may be added with advantage.

It is of great importance that the sulphate of copper should be *pure*. The crystals should be of a rich dark blue colour and absolutely free from greenish crystals (*sulphate of iron*), which not unfrequently get mixed with the copper salt by the carelessness of the shopkeepers' assistants.

Copying Coins and Medals.—Before explaining the various methods of obtaining moulds from different objects, for the purpose of producing fac-similes in copper, let us see how we may employ the above apparatus in a more direct way. Suppose we desire to obtain a copy, in reverse, of some medal or old coin, or even a bronze penny-piece, having decided which side of the coin it is intended to electrotype—say the *obverse* or "head" side—we must first render the surface clean and bright. This may be very readily done by means of rottenstone and a little olive oil, applied with a piece of chamois leather and briskly rubbed over the face of the coin. In two or three minutes the surface will be sufficiently bright, when the oil must be wiped off thoroughly either with cotton wool or blotting paper. A short piece of copper wire is next to be soldered to the back of the coin, and the polished side is then to be brushed over with a soft plate-brush and plumbago, or blacklead, which will prevent the deposited copper from adhering to the medal. In order to prevent the copper from being deposited upon the back and rim these parts must be coated with some *non-conducting* material. For this purpose paraffin wax, applied by gently heating the medal and touching it with the wax, or red sealing-wax, dissolved in spirit of wine or wood spirit (pyroxylic spirit), brushed over the surfaces to be protected, will answer well; but if the latter is employed it must become thoroughly dry before being placed in the copper solution.

Being thus prepared, the end of the conducting wire is to be inserted in the binding screw attached to the zinc and securely fixed by turning the screw until it grips the wire firmly. The coin must be lowered into the solution steadily, with its face towards the porous cell, and if any air-bubbles appear upon its face they must be removed by means of a camel-hair brush, or, still better, by blowing upon them through a glass tube. It is a good plan to breathe upon the face of the coin before placing it in the solution, which, by covering it with a layer of moisture, effectually prevents the formation of air-bubbles.

In about twenty-four hours from the first immersion of the medal the deposit of copper will generally be sufficiently stout to bear removing from the original, when the extraneous copper, which has spread round the edge of the deposit, or electrotype, may be carefully broken away by means of small pliers; if the medal be gently heated over a small lamp, the electrotype will readily become detached, and will present, in *reverse*, a perfect copy of the original, in which even the very finest lines will be accurately reproduced. In its present condition the electrotype is hard and brittle, and will, therefore, require careful handling. To give it the toughness and flexibility of rolled copper it is only necessary to heat the electrotype to dull redness, which may be conveniently done by placing it on a piece of sheet-iron, and laying this on the clear part of a fire until red hot, when it must be withdrawn and the "type" set aside to cool. If placed in a very weak solution of sulphuric acid for a few moments, then rinsed and dried, and afterwards brushed over with a little rouge or whiting, its surface may be readily brightened.

If we desire to obtain a copy *in relief* from our electrotype (also in copper) we must now treat it as *the mould*, following the same routine as before in all respects, by which we shall obtain a perfect fac-simile of the original coin, which may be mounted and bronzed by any of the processes hereafter given.

Having thus seen what results may be obtained with the most simple application of the single-cell process, we will next turn our attention to the different methods of obtaining moulds from various objects, but, before doing so, it will be necessary to consider the nature of the several substances which are employed in *moulding* and the methods of preparing them for use.

Moulding Materials.—The chief substances used in the electrotyping art for making moulds are gutta-percha, wax, and fusible metal; other materials, however, are employed in certain cases in which the substances named would be inapplicable. The various materials will be considered under their separate heads, as follows:—

Gutta-percha.—This most useful moulding material is the concrete juice of *Isonandra Gutta*, a tree growing only in the Malayan Archipelago, and of other species of the same genus. The stem of the gutta-percha tree, which sometimes acquires the diameter of 5 or 6 feet, after being notched yields a milky juice which, when exposed to the air for some time, solidifies, and this constitutes the gutta-percha of commerce. As imported, it is in irregular blocks of some pounds in weight, and commonly containing a large proportion of impurities in the shape of bark, wood, stones, and earthy matter. To purify the crude article it is first cut in thin slices, which are afterwards torn into shreds by machinery. These are next softened by hot water and afterwards kneaded in a *masticator*, by which the impurities become gradually washed away by the water. After several hours the gutta-percha is found to be kneaded into a perfectly homogeneous mass, which is rolled or drawn into sheets, bands, &c.

Gutta-percha becomes soft and plastic at the temperature of boiling water (212° Fahr.), when two pieces may be welded together. It is a non-conductor of electricity, and is indeed one of the best *insulating* materials known; it is impervious to moisture, and is scarcely at all affected by either acids or alkalies. Owing to its plasticity when soft, it is one of the most useful materials for making moulds, yielding impressions which are exquisitely sharp in the very finest lines. When used for making moulds from small objects, as coins, medallions, or sealing-wax impressions of seals, a piece of gutta-percha of the required size is placed in hot water (the temperature of which should be about 160° Fahr.), and, when sufficiently soft, it should be rolled while still wet in the palms of the hands until it assumes the form of a ball; it should then again be soaked in the hot water for a short time, and be again rolled as before, care being taken to observe that the surface of the ball exhibits no seams or fissures. When larger objects have to be copied stout sheet gutta-percha is used, and a piece of the required size cut from the sheet, which is softened as before, then applied to the object, and the necessary pressure given to secure a faithful impression.

Plastic Gutta-percha.—When gutta-percha is steeped for a few hours in benzol or naphtha it becomes considerably swollen; if afterwards soaked in hot water it is exceedingly plastic, and requires but moderate pressure to obtain most perfect copies from even such fragile objects as plaster of Paris models.

Gutta-percha and Marine Glue.—The following has also been recommended: gutta-percha 2 parts, Jeffrey's marine glue 1 part. Each of the materials is first to be cut up into thin strips; they are then to be mixed, placed in a pipkin and heated gently, with continual stirring, until the substances have become well incorporated: the mixture is now ready for use, and should be rolled into the form of balls before being applied for taking impressions. A very useful mixture is made by melting thin strips of gutta-percha as before, and adding one-third part of lard, keeping the mixture well stirred. It is applied by pouring it over flat surfaces, as steel plates, &c.

Beeswax.—This is a very useful material for moulding, and may be applied either in the form of virgin or white wax, or the ordinary commercial article—yellow beeswax. Since this substance, however, is very commonly adulterated, it may be useful to know something of its natural characteristics. At the temperature of 32° Fahr. beeswax becomes brittle, at from 80° to 90° it becomes soft and plastic, and it melts at about 155° Fahr. Mr. B. S. Proctor says: "It becomes plastic or kneadable at about 85° Fahr., and its behaviour while worked between the finger and thumb is characteristic. A piece the size of a pea being worked in the hand till tough with the warmth, then placed upon the thumb and forcibly stroked down with the forefinger, curls up, following the finger, and is marked by it with longitudinal streaks." Its ordinary adulterants are resin, farina, mutton suet, and stearine, though more ponderous substances, such as plaster of Paris, have sometimes been detected. White wax is very commonly adulterated with spermaceti, sometimes to the extent of two-thirds of the latter to one of wax. These sophistications, although not necessarily fatal to the preparation of good moulds, are certainly objectionable, inasmuch as it not unfrequently happens that a wax mould splits or cracks, not alone from cooling too quickly, but owing to the presence of foreign substances which impair its toughness.

Sealing-wax.—This substance may be employed for taking impressions of seals or crests, and was, indeed, one of the first materials used in the earliest days of electrotyping. The material, however, should be of good quality, and only sufficient heat applied to melt, without inflaming it.

Stearine. Stearic Acid.—The former substance is the solid constituent of tallow, and the latter (stearic acid) is the same substance separated from fats by chemical processes. Either may be used for making moulds instead of wax; but the late C. V. Walker recommended the following mixture in preference to either:—

	ozs.
Spermaceti	8
Wax	1¾
Mutton Suet	1¾

Another formula consists of:—

	ozs.
White Wax	8
Stearine	3
Flake White or Litharge	½

The whole ingredients are put into a pipkin and gently heated over a low fire, with continual stirring, for about half an hour, after which the mixture is allowed to rest until the excess of litharge (oxide of lead) has deposited. The clear residue is then to be poured into a shallow dish, and when cold is put aside until required for use.

Fusible Metal.—This alloy, which melts at the temperature of boiling water, and in some preparations very much below that point, is very useful for making moulds from metallic and some other objects; and since it can be used over and over again, and is capable of yielding exceedingly sharp impressions, it may be considered one of the most serviceable materials employed for such purposes. The following represent the principal formulæ for fusible metal, the last of which melts at the low temperature of 151° Fahr. or 61° below the boiling point of water :—

	ozs.		ozs.		ozs.
I. Bismuth	8	II. Bismuth	8	III. Bismuth	8
Lead	4	Lead	5	Lead	4
Tin	4	Tin	4	Tin	2
		Antimony	1	Cadmium	2
	16		18		16

The metals are to be put into a crucible or clean iron ladle, and melted over a low fire; when thoroughly fused, the alloy is poured out upon a cold surface in small buttons or drops, and these, when cold, are to be again melted and poured out as before, the operations to be repeated several times in order to ensure a perfect admixture of the metals. Another and better plan is to *granulate* the metal, or reduce it to small grains in the following way :—Fill a tall jar or other vessel with cold water, and on the surface of the water place a little chopped straw (about 3 inches in length). When the metal is melted, get an assistant to stir the water briskly in one direction, then pour in the metal, holding the ladle at some distance from the surface of the water; by this means the metal will be diffused and separated into a considerable number of small grains. The water is then to be poured off, and the grains collected, dried, and re-melted, after which another melting and granulation may be effected, and the alloy finally melted and cast into a mould, or simply poured out upon a flat iron or other surface, when it will be ready for future use. By the repeated melting, the alloy loses a little by the oxidation of the metals; but since the heat required to fuse it is less than that of boiling water, the loss is but trifling, as compared with the importance of obtaining a *perfect* alloy of the various metals. It should be the practice to remove the crucible or ladle from the fire the moment the alloy begins to melt, and to depend upon the heat of the vessel to complete the fusion.

Elastic Moulding Material.—For making moulds from objects which are much *under cut*, in which case neither of the foregoing substances would be available, an elastic material is employed which has the same composition as that from which printers' rollers are made, that is to say, a mixture of glue and treacle, the formula for which is:—

	ozs.
Glue of the best quality . . .	12
Treacle	3
	15

The glue is first to be covered with *cold* water and allowed to stand for at least twelve hours, by which time it should be perfetly soft throughout. The excess of water is then to be poured off, and the vessel placed in a saucepan or other convenient utensil, containing a little water, and heat applied until the glue is completely melted, which may be aided by frequent stirring. When quite melted, pour in the treacle, and again stir until perfect incorporation of the ingredients is effected, when the composition may be set aside to cool until required for use. To check evaporation and consequent drying of the surface, the vessel, when the material is quite cold, may be inverted over a piece of clean paper, by which, also, it will be protected from dust. The compound thus formed is exceedingly elastic, and may readily be separated from models even when severely undercut. Owing to the *solubility* of this composition, however, some care is necessary in using it, otherwise it will become partially dissolved in the copper solution or both. This is more likely to occur, however, when the solutions are of less strength than *saturated*, by which term we understand that the water present holds as much sulphate of copper in solution as it is capable of doing. Various remedies for overcoming this disadvantage will be given when treating of the methods of obtaining moulds from the material.

Plaster of Paris.—This substance is also used for mould-making, either from metallic or natural objects; but the plaster should be of the finest quality, such as is used by Italian image makers for the *surface* of their work, and not the coarse material usually sold in the shops. The plaster should be *fresh* when purchased and preserved in a closely-covered jar until required for use.

Having thus far considered the materials used in making moulds for electrotype purposes, we will next explain the methods of applying them, confining our observations to the more simple examples in the initial stages of the process.

CHAPTER VIII.

ELECTRO-DEPOSITION OF COPPER (*continued*).

Moulding in Gutta-percha.—Plumbagoing the Mould.—Treatment of the Electrotype.—Bronzing the Electrotype.—Moulds of Sealing-wax.—Copying Plaster of Paris Medallions.—Preparing the Mould.—Plumbagoing.—Clearing the Mould.—Wax Moulds from Plaster Medallions.—Moulds from Fusible Metal.

Moulding in Gutta-percha.—In the former case, we explained how a copy of a coin could be obtained, in reverse, by making the original act as the mould. We will now turn our attention to obtaining fac-simile duplicates in relief, from impressions or moulds of similar objects, from such of the materials described in the last chapter as will best answer the purpose; and since the application of these materials in the simple way we shall indicate will lead to an understanding of the general principles of mould-making, it is recommended that the student should endeavour to acquire adroitness in taking impressions which will be perfectly sharp and clear, before he attempts to obtain metallic deposits of copper upon them.

To obtain a copy of a medal, coin, or other similar object, the most convenient material to employ is gutta-percha. Take a small piece of this substance and place it in hot but not boiling water for a few minutes, or until it is perfectly soft; while still wet, roll it between the palms of the hands until it assumes the form of a ball; it should then be replaced in the water for a short time, and again rolled as before. The coin to be copied is now to be laid, face upward, upon a piece of plate-glass, slate, or polished wood. Now take the ball of gutta-percha and place it in the centre of the coin, and press it firmly all over it, *from the centre to its circumference*, so as to exclude the air, and in doing this it may be necessary to occasionally moisten the tips of the fingers with the tongue to prevent the gutta-percha from sticking to them. A flat piece of wood may now be laid over the gutta-percha, and if this be pressed forcibly by the hands this will ensure a perfect impression. After about a quarter of an hour or so, the gutta-percha mould may be readily removed from the coin, provided that the material has set hard.

Plumbagoing the Mould.—Having thus obtained a mould from a material which is a *non-conductor* of electricity, we next proceed to give it a conducting surface, without which it would be incapable of receiving the metallic deposit of copper which constitutes an electrotype. For this purpose, *plumbago*, or *graphite*,* is usually employed. To plumbago the surface of the gutta-percha mould proceed as follows:—Hold the mould between the fingers of the left hand, face upwards; now dip a soft camel-hair brush in finely-powdered plumbago (which should be of good quality) and briskly brush it all over the surface, every now and then taking up a fresh supply of plumbago with the brush. Care must be taken to well brush the powder into every crevice of the impression, and it is better to work the brush *in circles*, rather than to and fro, by which a more perfect coating is obtained. When properly done, the face of the mould has a bright metallic lustre, resembling a well-polished (that is blackleaded) stove.

In order to prevent the deposit of copper from taking place on the upper edge (beyond the actual impression), the plumbago which has been accidentally brushed over this surface should be removed, which may be conveniently done by rubbing it off with a piece of damp rag placed over the forefinger. The mould is now to be attached to the conducting wire by gently heating its longer end in the flame of a candle or ignited match, and then placing it on the edge of the mould, as far as the circumference of the impression; by giving it gentle pressure it will become sufficiently imbedded; the wire must not, however, be below the flat surface of the mould. If held steadily in the hand for a few moments, or until the wire and gutta-percha have cooled, the joint will *set*, and the mould may then be carefully laid aside until the point of junction has set firm. A little plumbago must now be brushed over the joint, so as to ensure a perfect *electrical connection* between the wire and the plumbagoed mould.

The mould being attached to the conducting wire, must now be connected to the zinc by its binding-screws as before (Fig. 54), and both should be immersed at the same time in their respective solutions, but this must be done with care, otherwise the mould may become separated from the wire. It may be well, in this place, to call attention to certain precautions which, if carefully followed, will prevent failure, and consequent disappointment, in electrotyping.

Precautions.—1. The solution of copper to be used in the single-cell apparatus must be kept as nearly as possible in a *saturated* condition, which is effected by keeping the shelf or tray constantly supplied with crystals of sulphate of copper. 2. The superficial surface of zinc immersed in the porous cell should not be much greater than that of the mould to be copied. 3. The solution should be stirred with a

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* Commonly called *blacklead*, but in reality *carbon* in a crude state.

glass rod or strip of wood before immersing the mould, especially if it has been previously used for electrotyping; if this is not done, the deposit may become irregular in thickness. 4. The plumbagoed mould should not be disturbed until its entire surface is covered with copper. A few moments after immersion, a bright pinkish red deposit of copper will be observed at the end of the wire, which in a short time will radiate in the direction of the plumbagoed surface, and this will gradually extend wherever this conducting medium has been spread with the brush, provided the operation has been conducted with proper care, and an uniform coating obtained.

Treatment of the Electrotype.—A sufficiently stout deposit of copper, upon a gutta-percha mould of a small coin, may generally be obtained in about two days, or even in less time, under the most favourable conditions; but it is not advisable to attempt to separate the electrotype from the mould while the deposit is very thin, otherwise the former may become broken in the operation. Assuming the deposit to be thick enough, the first thing to do is to cut the end of the wire connected to the mould with a pair of cutting pliers or a file, after which the superfluous copper may be removed from the outer edge by breaking it away with the pliers, taking care not to injure the "type" itself. The mould may then be placed in hot water for a moment, when the electrotype will readily separate from the gutta-percha. In order to give additional solidity to the electrotype, it should be *backed up* with pewter solder, which may easily be done as follows:—Put a small piece of zinc into about a teaspoonful of hydrochloric acid (muriatic acid); when the effervescence which takes place has ceased, brush a little of the liquid, which is a solution of chloride of zinc, over the back of the electrotype, and then apply solder by means of a moderately-hot soldering iron, until the entire surface is *tinned,* as it is called, when a further supply of solder should be run on to the back to give the required solidity. When this is done, the rough edge of the electrotype should be rendered smooth with a keen file.

Bronzing the Electrotype.—To impart an agreeable bronze appearance to the type, it should first be cleaned by brushing it with a solution of carbonate of potash (about half a teaspoonful in an ounce of water), and applying at the same time a little whiting. An ordinary tooth-brush may be used for this purpose, and after brisk rubbing the type must be well rinsed in clean water. The bronze tint may be given by brushing over it a weak solution of chloride of platinum (1 grain to an ounce of water); when the desired tint is obtained, the type is to be rinsed with hot water and allowed to dry. The tone may be varied from a delicate olive-brown to deep black, according to the proportion of platinum salt employed. A few drops of sulphide of ammonium in water, or, still better, a few grains of sulphide of barium dissolved in water, will give very pleasing bronze tints to the copper surface, the depth of which may be regulated at will by a longer or shorter exposure to the action of the bronzing material. If a solution of sulphide of barium be used, about 5 grains to the ounce of water will produce a pleasing tone in a few seconds. It is better to immerse the electrotype in the liquid (previously filtered) and to remove it the instant the desired tone is reached, and to place it at once in clean water.

Another method of bronzing electrotypes is by the application of plumbago, by which very pleasing effects may be obtained with a little care in the manipulation. The surface of the electrotype is to be first cleaned with rotten stone and oil; the oil is then to be partially removed by a tuft of cotton wool, and the surface is next to be brushed lightly over with plumbago (a soft brush being used) until a perfectly uniform coating is given. It is next to be heated to a point that would singe the hair of the blacklead brush, and then set aside to cool, after which it must be brushed with considerable friction. The tint will depend upon the quantity of oil allowed to remain, this enabling the surface to retain more of the blacklead, consequently to appear of a darker colour. The effect is very fine, and gives high relief to the prominent parts, from their getting so much more polish than the hollows, thus obviating the disagreeable effect which all unbronzed bassi-relievi produce by reason of their metallic glare.—*Hockin.*

The beautiful red bronze tone which is seen on exhibition and other medals is produced by brushing over the medal a paste composed of peroxide of iron (jewellers' rouge) and plumbago, after which the article is moderatly heated, and when cold is well brushed until it acquires the necessary brightness and uniformity of surface. Equal parts of fine plumbago and jewellers' rouge are mixed up into an uniform paste with water, and the cleaned medal is then uniformly brushed over with the mixture, care being taken not to allow the fingers to come in contact with the face of the object. The medal is then placed on a stout plate of iron or copper, and this is heated until it acquires a dark colour; it is then removed from the fire and allowed to become cold. It is next brushed for a long time, and in all directions, with a moderatly stiff brush, which is frequently passed over a block of yellow beeswax, and afterwards upon the paste of plumbago and rouge. The bronzing may also be produced by dipping the cleaned medal in a mixture composed of equal parts of perchloride and pernitrate of iron; the medal is then to be heated until these salts are thoroughly dry. It is afterwards brushed as before with the waxed brush until a perfectly uniform and bright surface is obtained.

Bronzing may also be effected by dipping the medal in a solution of sulphide of ammonium, and when this has dried, the plumbago and rouge paste is to be applied as before, and the waxed brush again employed. If the object be heated after applying the sulphide of ammonium, a black bronze, called "smoky bronze," is produced, and if the high lights be lightly rubbed with a piece of chamois leather dipped in spirit of wine, a very pleasing effect of contrast is obtained.

Moulds of Sealing Wax.—This material is, as we have said, very useful for obtaining impressions of seals, signet rings, and other small objects. A simple way of taking an impression in sealing-wax is as follows: Hold a card over a small benzoline lamp, but not touching the flame; now take a stick of the best red sealing-wax and allow it to touch the heated part of the paper, working it round and round until a sufficient quantity of the wax becomes melted upon the card. Now place the card upon the table, and having gently breathed upon the seal or signet ring, impress it in the usual way. Having secured an impression, cut away the superfluous portions of the card with a pair of scissors, and moisten the wax impression with a few drops of spirits of wine. When this has apparently dried, proceed to brush plumbago over the surface, using a camel-hair brush, and when perfectly coated, gently heat the end of the conducting-wire and apply it to the edge of the sealing-wax, allowing the point of the wire to approach the edge of the impression. Now brush a little plumbago on the point, and connect the short end of the wire to the binding-screw.

After having obtained several electrotypes successfully, and thereby become *au fait* to the manipulation of the single-cell apparatus, the student will naturally desire to extend operations to objects of a more important nature, such as medallions, busts, statuettes, and natural objects, as leaves, fishes, &c. But before attempting the more elaborate subjects it will be well to select, for our next operation, one of a simpler character, such as a plaster of Paris medallion, an admirable model to reproduce in metallic copper.

Copying Plaster of Paris Medallions.—These pleasing works of art, which may be obtained at small cost from the Italian image makers, are specially suited for the elementary study of the electrotype process, while a cabinet collection of such objects reproduced in copper forms an exceedingly interesting record of the manipulator's skill and perseverance. There are several materials from which moulds from plaster medallions may be obtained; but we will first describe the method of preparing a mould with gutta-percha. To render the plaster more capable of bearing the treatment it will have to be subjected to, the face of the medallion should first be brushed over with boiled linseed oil, and this allowed to sink well into the plaster. After about two days the oil will have sufficiently dried and hardened upon the surface to render the plaster less liable to injury. The medallion thus prepared is next to be provided with a rim or collar of pasteboard or thin sheet tin, which must be tightly secured round its circumference either by means of thin copper wire, jeweller's "binding-wire," or strong twine. The rim should project about half an inch above the highest point on the face of the medallion, and must be on a level with its base; it is then to be laid upon a perfectly smooth surface until the moulding material is ready. We recommend the student to practise upon small medallions at first; say about two inches or two inches and a half in diameter.

Preparing the Mould.—A lump of gutta-percha is now to be taken of sufficient size to cover the medallion, fill the vacant space up to the top of the rim, and project above it. The gutta-percha is to be softened in hot water and rolled up into the form of a ball, as before directed, care being taken to obliterate all *seams* or cracks by repeatedly soaking in the hot water and rolling in the hands. It must on no account be applied until it is perfectly smooth, and as soft as hot water will make it. To give additional smoothness to the surface of the ball, it may be lightly rolled round and round, with one hand only, for an instant upon a polished table just before being used. Now take the ball in one hand and place it in the centre of the medallion; then press it firmly from the centre towards the circumference, taking care not to shift it in the least degree. The gutta-percha must be pressed well into the cavity, and when this is done, a piece of flat wood may be placed on the mass and this pressed with both hands with as much force as possible for a few moments, when it may be left until the gutta-percha has set hard. If convenient, a weight may be placed upon the board after having pressed it with the hands. In about half an hour the board may be removed, and the mould allowed to rest until quite cold, when the rim may be removed and the mould separated by gently pulling it away from the medallion. As a precaution against breaking the plaster medallion, it may be well to suggest that its back should be examined, and if it be otherwise than perfectly flat, it may be advisable to gently rub it upon a sheet of glass-paper, which will readily remove all irregularities from the surface. It is also important that the surface upon which the medallion is laid, when applying the gutta-percha, should be quite level; and it will be still better if several folds of blotting-paper are placed between the table and the medallion before the necessary pressure is given. These points being attended to, there is little fear of the medallion becoming broken.

Plumbagoing.—The gutta-percha mould is now to be well plumbagoed, for which purpose a soft brush, such as jewellers use for brushing plate and jewellery that has been rouged, may be used, and this being frequently dipped into the plumbago is to be lightly but briskly applied, special care being taken to well plumbago the *hollows.* When it is borne in mind that the most delicate line, even if imperceptible to the eye, will be reproduced in the metallic copy, the importance of not injuring the face of the mould will become at once apparent. It is also absolutely necessary that the gutta-percha should be of the best quality, and since the same material may be used over and over again, its first cost is of little consideration.

Clearing the Mould.—The mould being well coated with plumbago, all excess of this material which has become spread over the outer edges, beyond the impression itself, must be wiped away, and the more completely this is done the less trouble will there be afterwards in clearing away from the electrotype the crystalline deposit which, under any circumstances, forms around the circumference of the electrotype. Indeed, when the student has once or twice experienced the inconvenience of having to remove the superfluous copper from his electrotypes, he will not fail to exert his wits to diminish the labour which this involves as far as practicable, by every possible care before the mould goes into the copper bath. We therefore urge for his guidance, that the removal of the excess of plumbago should be deemed one of the important details of his manipulation, and that it should never be neglected. After wiping away the excess of blacklead, it will be found a good plan to place a piece of dry rag on the forefinger and to rub it on a common tallow candle, so as to make the part slightly greasy ; if now the edge of the mould (carefully avoiding the impression) be rubbed with the rag-covered finger, this will effectually prevent the deposit from taking place upon such part ; before doing this, however, the conducting wire should be gently heated and imbedded in the edge of the mould as before, taking care that the point of the wire touches the extreme edge of the impression, and a *perfect connection* between the wire and the latter must be secured by applying a little plumbago with a camel-hair brush or the tip of the finger. It is sometimes the practice to apply varnish of some kind to the edges of moulds, and also to the conducting wire as far as the joining, but until the student has thoroughly mastered the process of copying simple objects in the way we have indicated, we do not recommend him to employ varnishes ; indeed not until dealing with objects of a larger and more elaborate kind.

The mould being now ready, is to be connected to the binding-screw by its wire, and since the material of which it is composed is much lighter than the copper solution, the wire must be sufficiently rigid, when bent at right angles, as in Fig. 54 to keep the mould well down in the bath. Being placed in the solution, it must be allowed to remain undisturbed until the entire surface of the impression is covered. In from two to three days the deposit should be of sufficient thickness to allow of its separation from the mould.

For copying small medallions of the size referred to, the single-cell apparatus shown in Fig. 54 may be used, but for larger sizes or for depositing upon several moulds at the same time, the arrangement shown in Fig. 55 will be most suitable. This apparatus consists of a wood box well varnished in the interior, and divided into two cells or compartments by a partition of thin porous wood. The larger cell is nearly filled with a saturated solution of sulphate of copper, and the smaller cell with a half-saturated solution of sal-ammoniac. A perforated shelf is suspended in the larger compartment to contain a supply of crystals of the sulphate. A plate of *pure* zinc, connected by a copper conducting wire, is suspended in the smaller cell, and the mould connected to the opposite end of the wire by suitable binding-screws. In this arrangement neither acid nor mercury are used, and although the action is not so rapid as in the former arrangements, it is very reliable for obtaining good results.

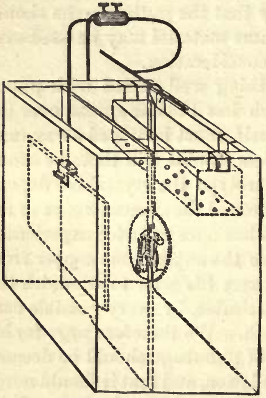

Fig. 55.

Wax Moulds from Plaster Medallions.—Beeswax is a very useful material for preparing moulds from plaster medallions, the following simple method being adopted:—The medallion, instead of being oiled as in the previous case, is simply soaked in hot water for a short time or until it has become completely saturated. First put a sufficient quantity of wax into a pipkin and melt it by a slow fire; when melted, place it on the hob until wanted. Place the medallion face upwards in a plate or large saucer, into which pour boiling water until it reaches nearly half-way up its edge. In a minute or two the face of the plaster will assume a moist appearance, when the excess of water is to be poured out of the plate. A rim of card is now to be fastened round the edge of the medallion, which may be secured either by means of sealing-wax or a piece of twine. As before, the rim should extend about half an inch above the most prominent point of the image. The medallion being returned to the plate, the wax is now to be steadily poured on to the face of the object, the lip of the pipkin being placed near the pasteboard rim and nearly touching it, to prevent the formation of air-bubbles. When the cavity is filled up to the top of the rim, if any air-bubbles appear they must be at once removed with a camel-hair brush kept for this purpose, or the feather end of a quill, or even a strip of paper may be used. The wax must now be allowed to cool as slowly as possible, and in order to favour this gradual cooling, a clean, dry jar may be inverted over the mould and there left until the wax is quite cold. This precaution will tend to prevent the wax from cracking, an event which sometimes, but not very frequently, occurs.

When quite cold, the wax mould will generally separate from the plaster by the application of moderate force to pull them asunder. If such is not the case, however, return the medallion to the plate and pour in a little boiling water. After a *few seconds*' immersion the mould will easily come away. If, however, owing to some irregularity in the face of the medallion, the mould still refuses to separate, plunge the whole into *cold* water, and, if necessary, use the edge of a knife as a lever between the two surfaces and force them asunder. If it be found that small portions of plaster adhere to the mould these may be carefully picked out with a fine-pointed piece of wood, and the mould afterwards very lightly brushed over with a soft plate brush. Should it be found that some particles still obstinately adhere to the wax, apply a little oil of vitriol with a thin strip of wood to the parts and set the mould aside for about twelve hours, by which time the acid, by attracting moisture from the air, will loosen the plaster, which may then be brushed away with a soft brush and water. The mould must then be put away to dry, or may be laid, face downward, upon a pad of blotting-paper or calico.

The mould is now to be plumbagoed with a very soft brush, but, owing to the yielding nature of the wax, the greatest care must be taken not to apply the brush too severely, only sufficient friction being used to coat the surface uniformly. It is a good plan to sprinkle a little plumbago over the face of the mould, and then to work the brush about in circles, by which means a well plumbagoed surface may readily be obtained. This operation being complete, the superfluous plumbago is to be brushed off, and, by blowing upon the face of the mould, any plumbago remaining in the crevices may be removed. The conducting wire is to be attached, as in the case of gutta-percha, by gently *warming* the end of the wire; but, if the mould be a tolerably large one (say, 3 inches in diameter) it will be well to bend the end of the wire so as to leave a length of about an inch or more to be embedded in the edge of the mould, by which means it will be more effectually supported than if the point of the wire only were attached. The joint must now be well plumbagoed, and the excess of this material which has been brushed over the edges may easily be removed by scraping it away with a pen-knife.

The same precautions must be observed with regard to wax-moulds as with those made from gutta-percha when immersing them in the bath, otherwise they will, from their exceeding lightness, be disposed to rise out of the solution. In the case of large moulds made from such light materials they require to be *weighted* in order to keep them beneath the surface of the copper solution, as we shall explain when treating of them.

The stearine composition may be employed instead of wax in the preceding operation, but we recommend the student to adopt the latter material for copying small medallions, since, with a little care, it will answer every purpose, and needs no preparation beyond melting it.

Moulds from Fusible Metal.—There are many ways of making moulds from fusible metal, but, for our present purpose, we will select the most simple. To obtain an impression of a coin or medal, melt a sufficient quantity of the alloy in a small ladle or iron spoon, then, holding the coin face downward between the forefinger and thumb of the right hand, pour the alloy into the rim of an *inverted* cup or basin, and, bringing the coin within a distance of about 2 inches from the molten alloy, allow it to fall *flat* upon the metal and there leave it until cold. If, when the metal is poured out, there is an appearance of dulness on the surface (arising from oxidation of the metals) a piece of card or strip of stiff paper should be drawn over it, which will at once leave the surface bright. As the metal soon cools, however, this may be more conveniently done by an assistant just before the coin is allowed to fall. If no other help is at hand a piece of card should be placed close to the cup, so that the moment the metal is poured out it may be applied as suggested, and the coin promptly dropped upon the cleaned surface of the alloy. A very little practice will render the student expert in obtaining moulds in this way, and, considering how very readily the material is re-melted, a few failures need not trouble him.

The fusible alloy may also be employed in the form of a paste, but, in this case, it is advisable to have the assistance of another pair of hands, since, in this condition, it soon becomes solid and therefore unusable. The coin should first have a temporary handle attached to it, which may readily be done by rolling a small lump of gutta-percha into the form of a ball; one part of this should now be held in the flame of a candle until the part fuses, when it is to be pressed upon the back of the coin and allowed to remain until cold. This gutta-percha knob will serve as a handle by which the coin may be held when the impression is about to be taken. The requisite quantity of the fusible alloy is now to be poured upon a piece of board and worked up into a stiff paste by means of a flat piece of wood—an operation that only occupies a few moments. *The instant* the alloy has assumed the pasty condition the coin, being held by its gutta-percha handle, is to be promptly and firmly pressed upon the mass until it is sufficiently imbedded in it. In the course of a minute or so the coin may be withdrawn, when the mould should present a perfect and delicate impression of the original—of course in reverse. Should any faults be visible, owing to want of dexterity on the part of the operator, the metal must be re-melted and the operation conducted again. A very little practice will enable the student to produce moulds in this alloy with perfect ease. The coin, in each of the above cases, should be perfectly cold before applying it to the alloy. Large medals are moulded by simply dropping them—a little sideways—into the metal when on the point of solidification.

Connecting the Mould to the Wire.—When a perfect mould is obtained the conducting wire is to be attached, which is done by first scraping the longer end of the wire so as to render it perfectly clean; it is then to be held in the flame of a candle, but at a little distance from the clean end. The mould being now held in the left hand, is to be brought near, but not touching, the flame, and, when the wire is sufficiently hot, it is to be pressed against the *back* of the mould, when it will at once become imbedded in it, and in a few moments will be firmly set. A small portion of powdered resin applied to the spot will assist the union of the two metals. The back and upper edge of the mould must now be coated with sealing-wax varnish or some other quick-drying varnish, or, if carefully applied, paraffin wax (which melts at a very low heat) may be applied by first *gently* heating the mould and touching it with a small stick of the paraffin wax. It is well, also, to varnish that portion of the conducting wire *above* the joint which has to be immersed in the copper bath, in order to prevent it from receiving the copper deposit.

CHAPTER IX.

ELECTRO-DEPOSITION OF COPPER (*continued*).

Electrotyping by Separate Battery.—Arrangement of the Battery.—Copying Plaster Busts.—Guiding Wires.—Moulding in Plaster of Paris.—Copying Animal Substances.—Electro-coppering Flowers, Insects, &c.—Copying Vegetable Substances.—Depositing Copper upon Glass, Porcelain, &c.—Coppering Cloth.

Electrotyping by Separate Battery.—In employing the single-cell apparatus, we have seen that it is necessary to keep up the strength of the solution by a constant supply of crystals of sulphate of copper, otherwise the solution would soon become exhausted of its *metal*, and therefore useless. If we employ a *separate battery*, however, this method of sustaining the normal condition of the bath is unnecessary, as we will now endeavour to show; but in doing so we must direct the reader's attention for the moment to the principles of electrolysis, explained in a former chapter. The practical application of those principles may be readily expressed in a few words: If, instead of making the mould, or object to be copied, the *negative element*, as in the single-cell apparatus, we take a separate battery composed of two elements—say, zinc and copper, as in Daniell's battery, we must then employ a *separate* copper solution or electrolytic bath, in which case the object to be deposited upon must be connected to the zinc element, as before, but the wire attached to the negative element of the battery (the free end of which is the *positive electrode*) must have attached to it a plate of sheet copper, which with the mould must be immersed in the solution of sulphate of copper. By this arrangement, while the copper is being deposited upon the mould, the sheet copper becomes dissolved by the sulphuric acid set free, forming sulphate of copper, which continued action re-supplies the bath with metal in the proportion (all things being equal) in which it is exhausted by deposition of copper upon the mould.

Arrangement of the Battery.—At Fig. 56 is shown a Daniell's battery, A, connected, by its negative conducting wire (proceeding from the zinc), to the mould, B, with its face turned towards the copper plate or anode, C. The depositing vessel, D, which may be of glass or stoneware, for small operations, is charged with an acid solution of sulphate of copper, which is composed as follows:—

Sulphate of Copper	1 lb.
Sulphuric Acid	1 ,,
Water (about)	1 gallon.

The sulphate of copper, as before, is dissolved in a sufficient quantity of hot water, after which cold water is added to make up one gallon; the sulphuric acid is then added and the solution is set aside until quite cold, when it is to be poured into the depositing bath, which should be quite clean. When first placing the mould to be copied in the bath, a small surface only of the copper plate should be immersed in the solution, and this may be gradually increased (by lowering the copper plate) as the deposit extends over the surface of the mould.

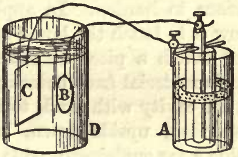

Fig. 56.

In Fig. 54 is shown an arrangement in which several moulds are suspended by a brass rod laid across the bath B, the rod being connected to the zinc element of the battery, A, by the wire, *x*. Strips of sheet copper are suspended by a brass rod, *c*, which is connected by a binding-screw to the positive conducting wire, *z*, of the battery, which in the woodcut represents a Daniell cell. In this arrangement, the sheet copper, by becoming dissolved in the solution during the electrolytic action, keeps up the normal strength of the bath, which in the single-cell arrangement is attained by the supply of crystals of sulphate of copper. It may be well to mention that it is always preferable, besides being more economical of time, to deposit upon

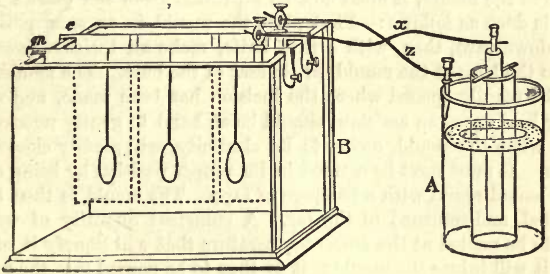

Fig. 57.

several moulds at a time in the bath, and this can be effected even with apparatus of small dimensions. The more extensive arrangements for depositing upon large objects by means of powerful battery currents will be considered in another chapter.

Copying Plaster Busts.—For this purpose, the elastic moulding material is used. Suppose we desire to obtain an electrotype from a small plaster bust, the object must first be well brushed over with boiled linseed oil, and then set aside for two or three days to allow the surface to harden. In applying the oil, care should be taken not to allow it to touch the lower surface surrounding the orifice at its base, over which a piece of stout paper must be pasted to prevent the elastic material from entering the cavity, but before doing this partly fill the cavity with sand, to increase its weight. The bust is next to be suspended, upside down, by means of twine or thin copper wire, inside a jar sufficiently wide and deep to leave at least half an inch all round and at the bottom. When thus placed in its proper position, the elastic composition (page 97), having been previously melted, is poured in, and if any air-bubbles appear, these must be removed with the feather of a quill, when the vessel is allowed to rest until the composition is quite cold.

The vessel is now to be inverted, when the solidified mass and the imbedded bust will gradually slip out. To facilitate this by preventing the composition from sticking to the jar, it is a good plan to slightly oil the interior of the vessel in the first instance. Having removed the mould, it must now be separated from the plaster bust. This is done as follows:—First place the mould in an erect position, base downward, then, with a thin knife, make an incision from the top to the base of the mould, *at the back* of the bust. The mould may now be readily opened where the incision has been made, and while being held open, an assistant should be at hand to gently remove the bust, when the mould, owing to its elasticity, will readily close itself again. It must next be secured in its proper position by being carefully bound round with a bandage of tape. The mould is then to be inverted, and returned to the jar. A sufficient quantity of wax is now to be melted at the *lowest* temperature that will liquefy it, otherwise it will injure the mould; it is then to be poured into the mould and allowed to rest until thoroughly cold. When cold, the elastic mould is to be again removed from the jar, and separated by untying the bandages from the wax-casting. This latter must now be well plumbagoed, a conducting wire attached, and the joint coated with plumbago as before directed. Since it will be difficult, however, to obtain an uniform deposit over such a comparatively large surface, it will be necessary to apply *guiding* wires, as they are called, and to which we must now direct special attention.

Guiding Wires.—The application of additional wires, to facilitate the deposition of copper in the cavities, or undercut surfaces, of moulds was first introduced by Dr. Leeson. A sufficient number of lengths of fine brass wire are twisted firmly round the main conducting wire, at a short distance from its junction with the mould, and these, one by one, are bent in such a way that their extreme points may rest, *lightly*, upon the hollow surfaces of the mould, whereby the current is diverted, to a certain extent, from the main wire to the cavities or hollows, which are less favourably situated for receiving the metallic deposit than the plane surfaces. The application of guiding wires is more especially necessary when the object to be copied is of considerable dimensions; the principle of their arrangement is shown in Fig. 58.

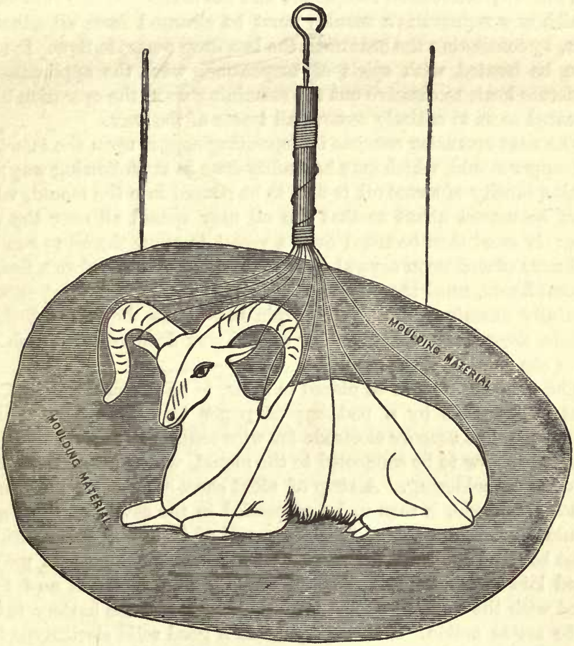

Fig. 58.

The mould, prepared as described, is to be put in connection with the battery, by suspending it from the negative conducting-rod, and then gently lowered into the coppering bath. In the present case only a moderately stout deposit, or "shell," of copper will be necessary, since, as we shall explain, this deposit will, in the next operation, act the part of a *mould*, in producing a fac-simile of the original. When a perfect coating is obtained, of sufficient thickness to bear handling, it is to be removed from the bath, rinsed, and allowed to drain. It must then be heated sufficiently to melt the wax, which is allowed to run into any convenient receptacle, and the interior of the electrotype (which now represents a mould) must be cleansed from all adhering wax, by continuing the heat until the last drop ceases to flow. It must then be treated with spirit of turpentine, with the application of moderate heat, to dissolve out the remaining wax, the operation being repeated so as to entirely remove all traces of the wax.

The next operation consists in depositing copper upon the *interior* of the copper mould, which may be readily done in the following way:—A small quantity of sweet oil is first to be poured into the mould, which must be moved about so that the oil may spread all over the surface; it must then be tilted over a vessel to allow the oil to run out, and next placed upon several folds of blotting-paper before a fire, for several hours, until the oil ceases to flow. The mould must now be carefully examined, and if any "pin-holes," as they are called, are visible, these must be stopped by melted wax dropped upon each spot upon the outside of the mould.

The mould is now to be placed in a jar, in an inverted position, and held in its place by a padding of paper or rag, wedged around its base. The *negative* electrode (or wire connected to the zinc of the battery) is now to be connected to the mould, which may conveniently be done by soldering. A strip of stout sheet copper, attached to the *positive* electrode, is then to be suspended in the cavity of the copper mould, but not allowed to touch any part of it, and in this position it must be fixed securely, which may be conveniently done by a piece of wood laid across the orifice of the mould. The mould is now to be filled with the copper solution last mentioned, and the battery is then to be set in action. In order to obtain a good solid electrotype from the copper mould, it will be necessary to renew the copper plate, or anode, from time to time when it becomes worn away, unless it be of sufficient thickness to render such renewal unnecessary. The strength of the battery must also be well kept up by renewing the acid solution in the porous cell. When a deposit of sufficient thickness is obtained, the conducting wires may be disconnected, the copper solution poured out, and the interior rinsed with water.

The next operation is to remove the shell of copper constituting the mould, which is done by *breaking it away*—beginning at the base—

with a pair of pliers. When the first layer of metal has been lifted from the underlying deposit, the remainder may generally be *peeled off* with but little trouble, when the electrotype proper will be exhibited, and if successfully accomplished it will amply reward the operator for the trouble and care devoted to its production. The student should not, however, undertake the manipulation of the elastic moulding composition until he has acquired a skilful aptness in the simpler processes of electrotyping. It may be well to mention that the elastic composition may be re-used several times, provided it has been kept in a covered vessel, to exclude it from the action of either a moist or a very dry atmosphere.

Moulding in Plaster of Paris.—This material, especially for copying natural objects, such as leaves, ferns, fishes, &c., is exceedingly useful, and we will, as in former instances, first give the more simple method of applying it, so that the student may have no difficulty in its manipulation. To obtain a plaster mould from a coin or medal, for example, first oil the face of the object slightly by applying a single drop of oil, with a tuft of cotton wool, and with a fresh piece of wool gently rub the coin all over, so as to leave but a trace of oil on the surface, the most trifling quantity being sufficient to prevent the adhesion of the plaster to the original. A rim of card is now to be fixed round the medal, to form a receptacle for the plaster. A little cold water is then to be poured in a cup, or other convenient vessel, and a small portion of *fine plaster* dropped into the water. The excess of water is now to be poured off and the plaster briskly stirred with a spoon. Now fill the spoon with the plaster (which should be about the consistency of cream) and pour it carefully over the face of the medal. If any air-bubbles appear, disperse them with a feather or camel-hair brush, which should be immediately after plunged into cold water, so that the plaster may easily be removed, and the brush thus left ready for future use. In about half-an-hour or so, the coin and mould may be detached, and the latter should then be placed in a moderately warm oven until dry. When perfectly dry, the face of the mould is to be well painted over with boiled linseed oil, repeating the operation several times; or the mould may be saturated with wax, by pouring a little of this substance, in a melted state, over the face of the mould, and then placing it in the oven until the wax becomes absorbed by the plaster. When cold, the mould must be plumbagoed in the ordinary way, and a copper conducting wire attached by twisting the wire round its circumference, and forming a connection with the plumbagoed surface by means of a drop of melted wax, afterwards brushed over with plumbago. That portion of the wire which surrounds the mould should be coated with varnish to prevent the copper from being deposited upon it. The superfluous plumbago should, as in the former cases, be removed, by scraping it away with a knife, leaving the connection, of course, untouched. The mould is now ready for the depositing bath, into which it must be gently lowered, so as to avoid breaking the connection between the conducting wire and the plumbagoed surface, a precaution which must in all similar cases be strictly observed.

Copying Animal Substances.—Suppose we desire to obtain an electrotype of a small fish (the scaly roach being very suitable), for example. The object is first brushed over lightly with a little linseed oil; we next mix a sufficient quantity of plaster of Paris into a thinnish paste, and pour this in a shallow rim of metal or stout cardboard placed upon a piece of glass or sheet of paper, previously rubbed over with a little oil or grease; before the plaster has time to *set*, the fish is to be held by its head and tail, and laid on its side upon the paste, using sufficient pressure to imbed one half of the fish. To assist this, the soft plaster may be worked up or guided to its proper places by means of a knife-blade, care being taken to avoid spreading the plaster beyond that part which is to form the *first half* of the mould. The plaster is now allowed to set hard, which occupies about half an hour. We next proceed to mould the second half of the fish. A small brush, say a painter's sash tool, is dipped in warm water, and then well rubbed over a lump of soap; this is to be brushed all over the plaster, but avoiding the fish, and the soap and water applied several times to ensure a perfect coating. A rim of greater depth, say ¾ of an inch deeper, must be fixed round the mould, in place of the former rim, and a second quantity of plaster made into a thinnish paste, as before, which must then be carefully poured over the fish and upper surface of the mould, taking care not to let it flow over the rim. This second batch of plaster should be sufficient to form a thick half mould, as in the former case, otherwise it may break when being separated from the first half mould.

When the plaster has set quite hard, the two moulds may be separated by gently forcing them asunder, the soap and water having the effect of preventing the two plaster surfaces from adhering, while the oil applied to the fish also prevents the moulding material from sticking to it. When the two halves of the mould are separated, the fish is to be carefully removed, and the plaster moulds placed in a warm, but not very hot, oven, and allowed to become *perfectly* dry. They are then to be placed faced downwards in a plate or other shallow vessel, containing melted bees-wax, and allowed to remain until saturated with the material, especially on the faces of the moulds; these are now allowed to become quite cold, when they are ready to receive a coating of plumbago, which must be well brushed into every part of the impression, until the entire surfaces present the bright metallic lustre of a well-polished fire-stove. The conducting wire must now be attached, which may be effected in this way: Bend a piece of stout copper wire in the form shown in Fig. 59, and pass the mould under the hook at *a*, and beneath the coil of the wire at *b*; the shorter end of wire at *a* should just touch the edge of the impression, near the mouth or tail of the fish. The wire thus adjusted must be secured firmly in its place, by being bound to the mould with thin copper wire. Before placing the conducting wire in its position, as above described, it will be advisable to wipe away all superfluous plumbago from the face of the mould, carefully avoiding injury to the impression, and when the conducting wire is adjusted, it is a good plan to coat the wire at all parts but the extreme point at *a* with varnish, or melted paraffin wax, to prevent the copper from becoming deposited upon it. The end of the wire at *a* must be put in *metallic contact*, so to speak, with the plumbagoed impression, by brushing a little of that substance over the point of junction. Thus prepared, the long end of the conducting wire is to be connected to the negative pole of the battery, and the mould gently immersed in the bath, the copper anode previously being suspended from the positive electrode.

The second half mould may now be treated in same way as the above, and when two perfect electrotypes, or *shells*, are obtained, the superfluous copper should be removed by aid of a pair of pliers and a file; when this is done the inner edges of each electrotype may be *tinned*, by first brushing a little chloride of zinc round the edge, and then passing a soldering iron, charged with pewter solder, over the surface. When the two halves of the fish are thus prepared, they may be brought together and held in position by means of thin iron "binding wire." The flame of a spirit-lamp or a blow-pipe flame may now be applied, which, by melting the solder, will soon complete the union, when a perfect representation of a fish will be obtained. This may afterwards be bronzed, gilt, or silvered by the processes described hereafter, and, if desired, mounted upon a suitable stand.

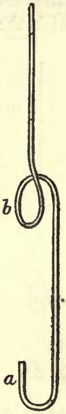

Fig. 59.

The elastic moulding material may also be used for copying animal substances; in this case, one half of the fish must be imbedded in moulding sand; a cylinder of thin sheet tin, bound together with fine copper wire, or by soldering, is then placed round the sand, so as to enclose it, and the sand is made as level as possible, by gently pressing it with any convenient instrument. The melted elastic material is now to be poured into the cylinder, which should be about two inches higher than the highest part of the object, until it nearly reaches the top; it is then allowed to rest for at least twelve hours, when the metal rim is to be removed and the mould withdrawn; the object is next to be liberated from the mould, and the other half moulded in the same way. The wax and stearine composition is to be poured into each half mould, and from the models thus obtained plaster moulds may be procured in the same way as from the natural object, but in this case the wax models must be well brushed over with plumbago before being embedded in the plaster. Since electrotypes of fishes look exceedingly well as wall ornaments, it will be only necessary, for this purpose, to obtain an electrotype of one half of the fish, which may, after trimming and bronzing, be cemented to an oval board, stained black and polished, and, if desired, mounted in a suitable frame.

Electro-Coppering Flowers, Insects, &c.—Fragile objects, to which the ordinary methods of plumbagoing could not be applied, may be prepared to receive a deposit of copper in the sulphate bath by either of the following methods:—

Fig. 60.

1. The object, say a rose-bud or a beetle, for instance, is first attached to a copper wire; it is next dipped in a weak solution of nitrate of silver (about forty grains of the nitrate dissolved in one ounce of distilled water), and after being allowed to drain, but before it is dry, it is to be exposed to the vapour of phosphorus under a bell-glass. To produce the vapour a small piece of phosphorus is dissolved in a little alcohol; this is poured into a watch-glass (chemical "watch-glasses" are readily procurable), which is then placed in a plate containing hot sand. The object being fixed by its wire in such a position that it cannot shift, the bell-glass (an ordinary fern-glass will answer admirably) is to be placed over the whole, and allowed to remain undisturbed for about half an hour. The sand should not be hot enough to endanger the bell-glass. By this process, the silver of the nitrate is reduced to its metallic state, causing the object to become a conductor of electricity; it is then ready for the coppering bath, in which it must be immersed with great care. Since very light objects will not sink in the solution bath, it is a good plan to form a loop in the conducting wire, as shown in Fig. 60, to which a piece of strong silk thread or twine, having a small leaden weight connected to the opposite end, may be fastened, as in the sketch. By this simple contrivance light objects and *floating moulds*, as those made of gutta-percha, wax, &c., may be easily sunk into the bath, and retained therein until sufficiently coated.

2. The most effective application of phosphorus for the above purpose consists in dipping the object in a solution of phosphorus in

bisulphide of carbon. This highly volatile and inflammable substance dissolves phosphorus very freely; the solution, known as "Greek fire," is a most dangerous compound to handle, and if any of it drop upon the skin it may produce sores of a serious nature; moreover, if it be incautiously allowed to drop upon the clothing, or upon the floor, it may afterwards ignite and do much mischief. In employing the solution of phosphorus, therefore, the greatest possible care must be observed. The object, being attached to a wire, is dipped into the solution, and after being allowed to rest for a few seconds, is next immersed in a weak solution of nitrate of silver, and afterwards allowed to dry in the light. If the object, after being dipped in the phosphorus solution, be allowed to remain in the air for more than a few seconds before being placed in the nitrate solution, it is very liable to become ignited. The solution of phosphorus is prepared by dissolving a small portion of the substance in bisulphide of carbon, about one-twentieth part of the former being sufficient for the purpose.

3. A safer method of producing a conducting surface on these objects is to employ an alcoholic solution of nitrate of silver, made by adding an excess of powdered nitrate of silver to alcohol, and heating the mixture over a hot-water bath. The object is to be dipped in the warm solution for an instant, and then exposed to the air for a short time until the spirit has evaporated. If now submitted to the fumes of phosphorus, as before described, the film of nitrate of silver soon becomes reduced to the metallic state, when the object is ready for the coppering bath.

To render non-metallic substances conductive, Mr. Alexander Parkes introduced the subjoined ingenious processes.

1. A mixture is made from the following ingredients:—

Wax or tallow	1 ounce
India-rubber	1 drachm
Asphalte	1 ounce
Spirit of turpentine	1½ fl. ounce

The india-rubber and asphalte are to be dissolved in the turpentine, the wax is then to be melted, and the former added to it and incorporated by stirring. To this is added one ounce of a solution of phosphorus in bisulphide of carbon, in the proportion of one part of the former to fifteen parts of the latter. The articles, being attached to a wire, are dipped in this mixture; they are next dipped in a weak solution of nitrate of silver, and when the black appearance of the silver is fully developed, the article is washed in water; it is afterwards dipped in a weak solution of chloride of gold, and again washed. Being now coated with a film of gold, it is ready for immersion in the copper bath.

2. In this process, the solution of phosphorus is introduced into the materials used for making the mould, thus:—

Wax and deer's fat, of each	½ pound

Melt together and then add:—

Phosphorus	10 grains
Dissolved in bisulphide of carbon . . .	150 „

The wax mixture must be allowed to become nearly cool, when the phosphorus solution is to be added very carefully, through a tube dipping under the surface of the mixture; the whole are then to be well incorporated by stirring. Moulds prepared from this composition are rendered conductive by being first dipped in a solution of nitrate of silver, then rinsed, and afterwards dipped in a weak solution of chloride of gold, and again washed, when they are ready for the coppering solution.

Copying Vegetable Substances.—The leaves of plants, seaweeds, ferns, &c., may be reproduced in electrotype, and form very pleasing objects of ornament when successfully produced. If we wish to copy a vine-leaf, for example, the leaf should be laid face downwards upon a level surface, and its back then covered with several layers of thin plaster of Paris until a tolerably stout coating is given; the leaf is then to be inverted and embedded in a paste of plaster, care being taken not to allow the material to spread over the face of the leaf. When the plaster has become hard, finely powdered plumbago is to be dusted over the entire surface from a muslin bag. A rim of pasteboard, slightly greased on one side, is now to be fixed round the outer edge of the plaster, and secured by a piece of twine. To render this more easy, the plaster may be pared away with a knife, so as to leave a broad flat edge for the card rim to rest against. Melted wax is now to be poured into the pasteboard cylinder thus formed, in sufficient quantity to make a tolerably stout mould. When thoroughly cold, the rim is to be removed and the mould liberated carefully. It is then to be plumbagoed, connected to the negative electrode of the battery, and immersed in the copper bath. The elastic material may also be employed in making moulds from vegetable objects.

Depositing Copper upon Glass, Porcelain, &c.—The article should first be brushed over with a tough varnish, such as copal, or with a solution of gutta-percha in benzol; when dry it is to be well plumbagoed. In some cases it may be necessary to render the surface of the glass rough, which is effected by submitting it to the fumes of hydrofluoric acid; this is only necessary, however, when the vessel is of such a form that the deposited copper might slip away from the glass. Porcelain capsules, or evaporating dishes, may receive a coating of copper at the outside, by varnishing this surface, extending the coating to the upper rim of the vessel, then applying the plumbago and depositing a coating of copper of sufficient thickness. Another and more effectual way of obtaining an adhesive deposit upon glass or porcelain is to send the article to a glass or porcelain gilder, and have gold burnt into its surface, and then depositing upon the gold coating in the usual manner. MM. Noualhier and Prevost patented a process for producing a conducting surface upon glass or vitreous substances, which consists in first coating the object with varnish or gold size, and then covering it with leaf copper. By another method they triturated bronze powder with mercury and common salt, and then dissolved out the salt with hot water, leaving the bronze powder to settle. When dry, this powder is to be applied to the varnished object in the same way as plumbago. For this purpose, however, Bessemer bronzes, which are exquisitely impalpable, and produce a very good conducting surface, may be employed with or without being mixed with plumbago.

Coppering Cloth.—In 1843, Mr. J. Schottlaender obtained a patent for depositing either plain or figured copper upon felted fabrics. The cloth is passed under either a plain or engraved copper roller, immersed horizontally in a sulphate of copper bath, containing but little free acid. The deposit takes place upon the roller as it slowly revolves; the meshes of the cloth are thus filled with metal, and the design of the roller copied upon it. The coppered cloth is slowly rolled off and passes through a second vessel filled with clean water. The roller is previously prepared for a non-adhesive deposit.

CHAPTER X.

ELECTRO-DEPOSITION OF COPPER (*continued*).

Electrotyping Printers' Set-up Type.—Plumbagoing the Forme.—Preparation of the Mould.—Filling the Case.—Taking the Impression.—The Cloth.—Removing the Forme.—Building.—Plumbagoing the Mould.—Knight's Plumbagoing Process.—Wiring.—Hoe's Electric Connection Gripper.—Metallising the Moulds.—Adams' Process of Metallising Moulds.—Quicking.—The Depositing Bath.—Batteries.—Treatment of the Electrotype.—Finishing.—Electrotyping Wood Engravings, &c.—Tin Powder for Electrotyping.

Of all the purposes to which the art of electrotyping is applied, none is of greater importance than its application to letterpress printing and the copying of wood engravings to be printed from instead of from the wooden blocks themselves. Although this latter branch of the art is very extensively adopted in this country, in the reproduction of large and small engraved blocks for illustrated works and periodicals, newspaper titles, &c., the application of electrotyping as a substitute for stereotyping in letterpress printing has not, as yet, attained the dignity of an art in England. In America, however, the art of reproducing set-up type in electrotype copper has not only acquired a high state of development as a thoroughly practical branch of electro-deposition, but it has almost entirely superseded the process of stereotyping. There are several reasons why this art has been more fully developed in the States than here. In the first place our transatlantic kindred are more prompt in recognising and adopting real improvements; they are less mindful of cost for machinery when the object to be attained is an important one; they are not so much under the influence of so-called "practical men" as to ignore scientific help; finally, they do not wait until all their competitors have adopted a process before they run the risk of trying it for themselves.

During the past few years we have been much impressed by the extreme beauty of the American printing, and the exquisite brilliancy of their engravings. Being printed from copper surfaces, the ink delivers more freely than from stereotype metal, while, we believe, a smaller amount of ink is required. Again, the Americans extensively employ wood pulp in the manufacture of their paper, and this material being less absorbant than cotton-pulp, causes the ink to remain *on the* *surface* rather than to sink into the substance of the paper—a fact which was established by the author's father, the late Mr. Charles Watt (the inventor of the wood-paper process), when it was first exhibited in London in the year 1853,* in the presence of the present Earl of Derby and many scientific men and representatives of the press.

With a full belief that the American system of electrotyping, as applied to letterpress printing, will eventually be adopted in this country—at first by the more enterprising members of the printing community—we propose to explain as concisely as the subject will admit the method which has been practically adopted in the United States, and we have to thank the distinguished firm of R. Hoe and Co., of New York, the well-known manufacturers of printing and electrotyping machinery, for much of the information we desire to convey, as also for their courtesy in furnishing us, at our request, with electrotypes of their machinery for the purposes of illustration. We are also indebted to Mr. Wahl † for additional information on this subject.

"As applied to letterpress printing, electrotyping is strictly an American art." This is the claim put forward by the firm referred to, and we freely acknowledge the fact. We gave our cousins the art of electrotyping, and in exchange they show us how we may apply it to one of the most useful of all purposes—the production of good printing from a more durable metal than either ordinary type or stereotype metal.

Electrotyping Printers' Set-up Type.—In pursuing the art of electrotyping, as applied to letterpress printing, the *compositor*, *electrotyper*, and *mounter* must work with one common object, each having a knowledge of what the other requires to perform his part of the work properly. In carrying out the operation on an extensive scale, the depositing room should be on the ground floor, owing to the weight of the vats, and the flooring should be cemented and well drained. The apartment should be well lighted, and provided with an ample supply of water. The depositing vats may be of wood, lined with pitch; and where a magneto or dynamo-electric machine is employed, this should be fixed at such a distance from the vats as not to be in the way, but at the same time to be as near to them as possible without inconvenience.

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* Manufacturers in this country refused to adopt this process. It was, however, "taken up" in America in the same year, where it has been worked ever since. It is now used in this country to some extent, as also in many other parts of the world.

† "Galvanoplastic Manipulations." By W. H. Wahl.

Preparing the Formes.—When the formes, or pages of set-up type, have to be electrotyped, it is necessary that great care should be exercised in selecting the types, rules, &c., in *justifying* the same, and in locking-up the forme. When the art of electrotyping comes to be a recognised substitute for stereotyping, it is probable that some modifications in the structure of printers' type may be made to suit more fully the requirements of the electrotyper than the ordinary type. The following suggestions are given relative to the *composition* of the type for reproduction in electrotype, and these should be well understood by those who may hereafter be called upon to produce electrotypes from printers' formes.

Composition.—Every *quadrat*, *space*, *lead-slug*, *reglet*, or piece of *furniture* should be *high*. Some leads have one or both edges bevelled; but even though the bevel is small it is sufficient to cause considerable trouble, and such leads should not be used in moulding, as the wax is sure to be forced into the space of the bevel, to be broken off, and to require extra labour in distributing the type, besides making it necessary to scrape the wax from the leads before they can be used again. So far as possible, use thick rules and those having a bevel on each side of the face. Thin rules make so small an opening in the wax that there is great difficulty in blackleading the mould, and in the bath the copper may *bridge* across a small opening, leaving the face and sides of the rule uncovered, or at most with but a thin, imperfect deposit that is useless. For this reason, type having considerable bevel, is best for electrotyping. English type has more bevel than American. Bevelled rules also make impressions in which the hairs of the blackleading brush can penetrate more deeply. Type-high bearers, or *guards*, about ¼ of an inch thick, should be put around each page, and scattered through blank spaces, to prevent the wax from spreading while the forme is pressed in it, and also to facilitate the operation of "backing." If there are several pages in a forme, separate them by two guards; one guard does not give sufficient room to saw between the pages and leave enough of the bearer to protect the edges of the plate in "shaving." When the matter occupies but a portion of a page, or the lines are shorter than the full width of the page, as in poetry, an *em* dash or a letter should be placed bottom up in each corner of the page, as a guide to the finisher in trimming the the plate. When the folio is at one corner, that will answer for one of the guides. All large blanks, chapter heads, and lines unprotected by other matter, should have type-high bearers so placed as to guard the exposed parts from injury.

Locking-up.—The formes must be locked much tighter than for printing, for, in order that the mould shall be perfect, the wax must enter and fill solidly all the interstices of the forme. This requires great pressure, and the movement of the wax caused by the entering of the type in taking the impression, or mould, is very likely to displace any portions of the forme that may be loose. A proof should always be taken after the forme is locked up for the foundry, and both should be examined to make sure that no part has shifted in driving the *quoins*. Sometimes the matter is set with high spaces but low leads, or *vice versâ*, or low spaces but no leads; frequently copper-faced and white-faced type are used in the same forme. None of these combinations should be allowed, but the whole forme should be either high spaces and high leads or low spaces and low leads. In offices having no high quads, &c., low material must be used; but greater care is necessary in preparing the forme, more labour required of the electrotyper, and the plate is much less satisfactory than when high material is used. Woodcuts which are locked up with the type must be perfectly cleaned with naphtha or benzine, and dried thoroughly before the forme is blackleaded, and great care must be taken not to clog the fine lines of the engraving.

Moulds should not be taken from electrotype cuts, since much better ones can be obtained direct from the woodcut.

Correcting the Matter.—When necessary to make alterations in electrotype plates, the matter for corrections should be set up and electrotyped, but the compositor should separate each correction by a space about a pica, in order that there may be room to saw between them. If the alteration is but a single letter or short word, it is usual to solder the type to the plate. By setting up corrections in their regular order, the labour and cost of plate alterations may frequently be much reduced.

The above technical hints will aid the electrotyper into whose hands a printers' forme may be placed for reproduction in electrotype copper.

Plumbagoing the Forme.—The forme of type must first be cleansed from printing-ink, if very dirty, either with potash ley or benzine; or, if not very dirty, with water distributed from a rubber pipe with rose sprinkler, after which it must be dried. The forme is next to be well brushed over with plumbago, to prevent the wax from sticking. This is applied with a soft hand-brush, the plumbago being made to penetrate every crevice. In doing this, great care must be taken not to fill up the fine lines of the forme with the plumbago.

Preparation of the Mould.—For this purpose a *moulding case* (Fig. 61) is employed, which is a flat brass pan about three-sixteenths of an inch in depth, with two flanges, which fit into the clamps of the *moulding press*. This is fitted with an "electric connection gripper." The *moulding composition* consists of the best pure yellow beeswax, to which is added from five to twenty per cent. of virgin turpentine, to prevent it from cracking. If the temperature of the apartment is from 90° to 95° Fahr., the wax may not require any addition. The composition should be melted by steam heat.*

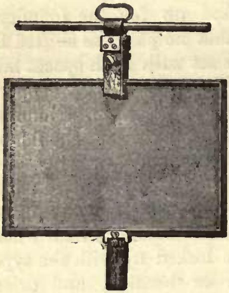

Fig. 61.—Moulding Case.

Filling the Case.—The moulding case having been slightly warmed, on the *steam-heating* table, *a*, Fig. 62, is placed on the *case-filling table*, *b*, truly levelled, and the melted wax, contained in the small jacketed pan, is poured into it with a clean iron or copper ladle, great care being taken to run the wax entirely over the case while it is hot, so that it may not, by cooling too quickly in any part, cause irregularities. The air-bubbles which rise to the surface must be touched with the heated *building-iron*, Fig. 64, when they will disappear. If, on cooling, the wax shrinks away from the edges of the case, it can be re-melted there by running the point of the heated building-iron over it, so as to close up any fissure. When cool, the wax should present a smooth, even surface; if this be not the case it is useless, and must be put back into the pot and re-melted. The whole surface is now to be carefully and thoroughly rubbed over with plumbago, and polished with soft hand-brush; when this is effected, the wax is ready to receive the impression.

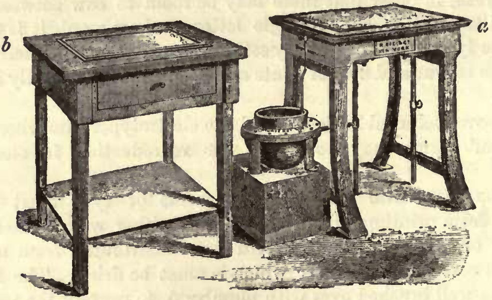

Fig. 62.—Case-filling and Steam-heating Tables.

Taking the Impression, or Moulding.—For this purpose considerable and steady pressure is necessary, and this is given either by

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* Gutta-percha is seldom used in America for making moulds.

means of a hydraulic press, or by the "toggle" press, one form of which, as manufactured by Hoe & Co., is shown in Fig. 63. This form of press consists of a massive frame, having a planed bed, over which is a fixed head. There is a projecting table, on which the forme and case may be arranged before sliding them to receive the pressure, which is put upon them by raising the bed by means of the hand wheel and screw, and the two toggles. In this way enormous pressure is obtained with but little manual exertion.

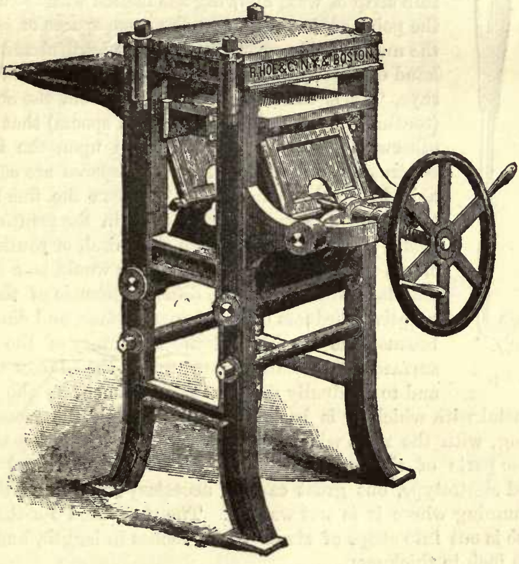

Fig. 63.—Toggle Press for Electrotype Mould.

The Cloth.—Where low spaces are used, it is customary to make a preliminary impression with a thin sheet of gum cloth interposed; this is then removed and the pressure put on again. Where the cloth is not used, it is necessary to shave off, with a wide, thin knife, the projecting wax ridges.

Removing the Forme.—In case the forme should stick to the wax, it may be relieved by touching the chase gently in two or three places with a long screw driver, taking care not to break the face of the wax. The case is now to be placed upon a table, ready for the process of *building*.

Building.—The mould is now taken in hand by a workman who, with the wide, thin bladed knife, shaves off the projecting wax ridges forced up about the edges and low parts of the mould by the press, and which, if not removed, would impede the separation of the "shell" from the face of the mould, when removed from the depositing tank. The operation of "building" is thus performed: the workman takes an implement such as is shown in Fig. 64 (called a "building-iron"), several of which are laid on a rack in a small oven heated by gas, and applies to it from time to time a thin strip of wax, allowing the melted wax to run from the point of the tool on to the open spaces or *blanks* of the mould. The operation requires a skilful and steady hand of a practised workman. Upon this point Wahl says, "It is essential, in order to avoid the chiseling (routing or deepening of the open spaces) that would otherwise be necessary to perform upon the finished electrotype, for, unless these open spaces are considerably lower than the spaces between the fine lines of the subject, they are apt to *smut* in the printing process. To cut these out with the chisel, or routing machine, from the finished electrotype would be a difficult and dangerous operation, difficult because of the comparative hardness of the copper surface, and dangerous because the breaking of the continuity of the copper surface will be liable to curl up on the edge of the cut, and to gradually destroy its attachment to the stereotype metal with which it is backed up." To avoid the necessity of chiseling, with the risks which it entails, a ridge of wax is built up on those parts of the mould which require to be depressed in the finished electrotype, but great care is necessary to prevent the wax from running where it is not wanted. The wax used for the above purpose is cut into strips of six or eight inches in length, and about half an inch in thickness.

Fig. 64.

Plumbagoing the Mould.—The wax mould being prepared as above, is next coated with plumbago, the material used in America being obtained from Ceylon graphite. The plumbagoing is generally performed by a machine, the most approved form of which is represented in Fig. 65, its cover being removed to show its construction. The machine has a travelling carriage, holding one or more forms, which passes to and fro under a laterally-vibrating brush. An apron is placed below to receive the loose plumbago, which is used over and over again. As soon as the mould is sufficiently plumbagoed, it is removed from the press, and the surplus material is either dislodged by a hand-brush or with broad-nosed bellows. It is essential that all excess of plumbago be removed, otherwise a coarse and faulty electrotype will be obtained.

Owing to the unavoidable *dust* created by the dry plumbagoing machine, by the impalpable graphite powder, some electrotypists prefer to adopt the *wet* process invented by Mr. Silas P. Knight, of the electrotyping department of Messrs. Harper Brothers, New York. This process is said to work more speedily and delicately than the former, the moulds being thinly and uniformly coated, neither omitting the dot of an *i*, nor allowing the *bridging* over of fine lines.

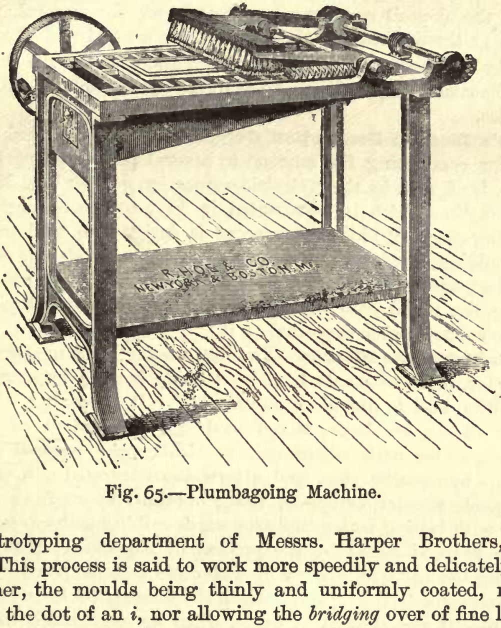

Fig. 65.—Plumbagoing Machine.

Knight's Plumbagoing Process.—By this method, the moulds are placed upon a shelf, in a suitable receptacle, and a rotary pump forces an emulsion of plumbago and water over their faces, through a travelling fine-rose nozzle. This process is said to be "rapid, efficient, neat, and economical."

Wiring.—When the plumbagoing is complete, the workman takes one or more lengths of stout copper wire, the ends of which are first cleaned, and then gently heated; the wires are then embedded in the wax composition on the *side* of the mould, and the joints are then plumbagoed with the finger so as to ensure a perfect *electrical connection* between the wire and the plumbagoed surface. In order to prevent the copper deposit from taking place upon such surfaces beyond the face of the mould as may have become coated with the graphite, the workman takes his hot building-iron, and passes it over these outlying parts of the mould so as to destroy the conductibility of the superfluous plumbago ; this is termed *stopping*.

When moulds of large size have to be treated, it is necessary to place a series of copper wires on the edges of the mould, by which means the deposit commences uniformly at the several points of junction ; these wires are then brought in contact with the slinging wires by which the mould is suspended, and thus receive the current from the conducting rod connected to the dynamo-electric machine or batteries.

Hoe's Electric Connection Gripper.—A very practical arrangement for conducting the current to several points, or parts of the mould, is effected by the "electric connection gripper" of Messrs. R. Hoe and Co., which is represented in Fig. 61, as connected to the moulding case. "This arrangement is designed to hold and sustain the moulding case, and at the same time to make an electric connection with the prepared conducting face of the mould itself, consequently leaving the metal case itself entirely out of the current (circuit), so that no copper can be deposited on it."

Metallising the Moulds.—Plumbago being but a moderately good conductor, many attempts have been made both to improve its conductibility, and to provide a substitute for it altogether. With the former object, we have mixed moderate proportions of Bessemer bronze powder with advantage, as also copper reduced from the sulphate by metallic zinc, and afterwards triturated with honey, an impalpable powder, or *bronze*, being obtained by washing away the honey with boiling water, and afterwards collecting the *finest* particles of the reduced metal by the process of *elutriation ;* that is, after allowing the agitated mixture of water and metallic powder to repose for a few seconds, the liquid, holding the finest particles in suspension, is poured off and allowed to settle, when an exceedingly fine deposit of metallic copper is obtained. The process of coppering the mould, devised by Mr. Silas Knight, is generally adopted in America. By this method, a thin film of copper is deposited on the mould in a few seconds, the operation being conducted as follows : "After stopping out those portions of the mould that are not to receive the deposit, it is laid in a shallow trough, and a stream of water turned upon it from a rose jet, to remove any particles of blacklead that may remain in the lines or letters. The workman then ladles out of a conveniently placed vessel some sulphate of copper solution, pours it upon the face of the mould, then dusts upon it from a pepper box some impalpably fine iron filings, and brushes the mixture over the whole surface, which thus becomes coated with a thin, bright, adherent coat of copper. Should any portion of the surface, after such treatment, remain uncoppered, the operation is repeated. The excess of copper is washed off, and the mould is then ready for the bath." The washing of the mould is effected by means of a stream of water applied from a rubber hose and pipe, and the mould must be placed in the bath directly after the washing is complete.

Adams' Process of Metallising Moulds.—This process, which was patented in America in 1870, is said to give a perfect conducting surface to wax moulds with greater certainty and rapidity than any other, and will accomplish in a few minutes that which plumbago alone would require from two to four hours. The process is conducted as follows: While the mould is still warm in the moulding case, apply freely powdered tin (tin bronze powder, or white bronze powder) with a soft brush until the surface presents a bright, metallic appearance; then brush off the superfluous powder. The forme of type or wood-cut is then plumbagoed, and an impression or mould taken in the wax as before described, the mould being built up and connected as before. The tin powder is now to be brushed over it either by hand or machine, and the superfluous tin blown away by the bellows, after which the building-iron is applied for stopping all parts upon which copper is not to be deposited. The mould is then to be immersed in alcohol, then washed with water "to remove the air from the surface," when it is ready to be immersed in a solution prepared as follows: Fill a depositing tank nearly full of water, keeping account of the number of gallons poured in; hang a bag of crystals of sulphate of copper until the water is saturated; for every gallon of water used add from half a pint to three gills of sulphuric acid, and mix the whole thoroughly. In this solution hang a sheet of copper, connected to the positive pole of the battery, and when the solution becomes cool and settled, immerse the mould and connect it with the negative electrode, when the surface of the mould will be quickly covered with thin copper. Then remove for completion to another and larger depositing vat, containing a solution made in the proportion of one pound of sulphate of copper and one gill of sulphuric acid to each gallon of water. If crystals of sulphate of copper form on the copper plate in the first depositing vat, disconnect it and dissolve them off, substituting for it a clean plate.

Since, in the above process, the tin powder becomes dissolved and enters into the solution, when this liquid becomes saturated with tin, after being long in use, it must be cast aside and replaced by fresh solution. The tin powder may be employed, as a substitute for plumbago, without changing from one bath to another, thus: After the mould has received the desired impression, it is taken to the plumbago table, and held face downward with one end resting on the table, while the other is supported by the hand. It is then struck on the back several times to loosen the blacklead that is pressed on the wax while moulding, and all the fine dust that may cling to the mould must be blown away. After building up and making all connections, it is to be placed in the hand-case or plumbagoing machine, and the tin powder applied in the same way as plumbago. Both the machine and hand-case should be kept free from plumbago, the tin powder only being used to metallise the surface of the mould. If the machine be used, place the mould, or moulds, on the carriage, cover well over with tin powder, close the door, and run once forward and backward under the vibrating brush; then turn the moulds round, put on more tin powder, and run through again. It takes three minutes for the whole operation. The tin powder is to be beaten out on the table used for this powder as before, and then thoroughly well blown out. Instead of using the building-iron for stopping off, any suitable varnish, or an alcoholic solution of sealing-wax, may be used.

Quicking.—To prevent the copper deposit from being broken over lines of set-up type, the lines may be wetted with a dilute solution of nitrate of mercury, or with the cyanide quicking solution used in preparing work for plating. A further deposit is then given in the sulphate of copper bath.

The Depositing Bath.—The solution employed is a saturated solution of sulphate of copper, acidulated with sulphuric acid, and large copper anodes are suspended in the bath, between which the cases containing the prepared moulds are suspended, *back to back*, so that the faces of the moulds may be directly opposite the anodes. The time occupied in obtaining the electro deposit of copper depends upon the power of the current employed and the thickness of metal desired. For ordinary book or job work, the shell of copper should be about the thickness of good book paper, and this should be obtained in from three to five hours. Electros for newspaper, titles, and such blocks as are subjected to much use, should receive a stouter deposit.

Batteries.—Several modifications of the Smee battery have been extensively adopted in the United States, including copper plates, electro-silvered, and platinised; but the most generally accepted improvement consists in employing *platinised platinum* plates for the negative element instead of platinised silver of the Smee battery. The battery plates, instead of nearly touching the bottom of the cell, as in the ordinary Smee battery, whereby, after being in use some time, they become immersed in a saturated solution of sulphate of zinc, causing great diminution of the current, only extend to about one-third of the depth of the battery cell. By this arrangement, which was devised by Mr. Adams, of America, in 1841, an equal action of the battery is kept up for a much longer period than would be possible with a Smee battery of ordinary construction. Wahl says that a Smee battery of twenty-six pairs, each 12 by 12 inches, will deposit from six to six-and-half square feet of copper upon prepared moulds in four hours. Batteries, however, are not now much used in the States, having been greatly superseded by the dynamo-electric machine, whereby the electrotyping and electro-depositing arts in general have become enormously increased.

Treatment of the Electrotype.—When the mould has received the requisite deposit, it is to be removed from the bath, and is next to be separated from the wax composition. This is done by placing the mould in an inclined position, and passing a stream of hot water over the copper surface, which, by softening the wax, enables the copper shell to be stripped off, by raising it from one corner while the hot water is passing over the mould. The shell should be removed with care and must not be allowed to *bend* in the least degree. The thin film of wax which adheres to the face of the electro is removed by placing it upon a wire rack, resting on a vessel containing a solution of caustic potash, which is poured over the electro by means of a ladle, the liquor returning to the vessel beneath. The potash has the effect of dissolving the wax in a short time, after which the electro is well rinsed in cold water.

Tinning and Backing the Electrotype.—The first of these operations, *tinning*, is necessary in order to ensure a perfect union between the "backing-up metal" (stereotype metal) and the electrotype. The back of the electro is first brushed over with a solution of *chloride of zinc*, made by dissolving zinc in muriatic acid, and diluting it with about one-third of water, to which, sometimes, a little sal ammoniac is added. The electrotype is now laid, face downwards, upon an iron soldering plate, floated on a bath of melted stereotype metal, and when sufficiently hot, melted solder, composed of equal parts lead and tin, is poured over the back, by which it acquires a clean bright coating of solder. Another method is the following: The shell being placed face downward, in the *backing-pan*, is brushed over with the "tinning liquid" as before, and *alloyed tin foil* is spread over it, and the pan again floated on the hot backing-up metal until the foil melts and covers the whole back of the electrotype. When the foil is melted, the backing-pan is swung on to a levelling stand, and the melted backing metal is carefully poured on the back of the shell from

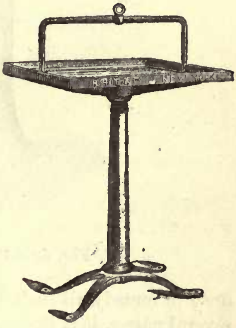
Fig. 66.

an iron ladle, commencing at one of the corners and gradually running over the surface until it is covered with a backing of sufficient thickness. A convenient form of backing-pan and stand is shown in Fig. 66. The thickness of the backing is about one-eighth of an inch, or sufficient to enable the electro, when trimmed and mounted, to withstand the pressure of the printing press. The backing-up alloy is variously composed, but the following is a good practical formula :—

Tin	4 parts
Antimony	5 "
Lead	91 "
	100

Finishing.—As they pass from the hands of the "backer," the plates present a rough and uneven surface on the back, and the blanks are higher than they should be for mounting. It is the finisher's duty to remedy all such defects. If the backed electrotype consists of several pages, it is first taken to the saw table, Fig. 67, where it is roughly sawn apart by a circular saw, the eyes of the workman being protected from the particles of flying metal by a *square plate of glass*, as shown in the figure. Each plate is then trimmed all round to remove rough edges, and if there are any projections which would prevent it from lying flat, these are carefully cut down with a small chisel. The plate is next *shaved* to remove the roughness from the back and make

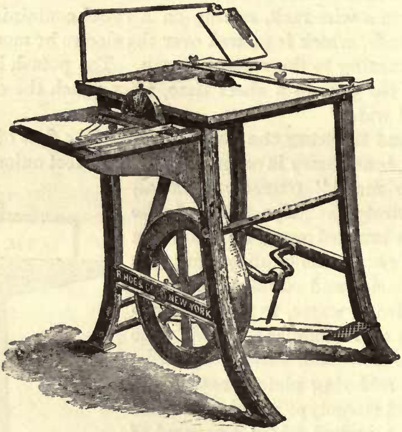

Fig. 67.—Saw Table, with Squaring Table.

it of uniform thickness in all parts. This is effected in small establishments by the hand shaving machine, Fig. 68, but since this operais the most laborious part of the finishing process, it is far preferable to employ a power machine for this purpose. The plate being now brought to nearly its proper thickness, and almost true, is next tested with a straight-edge, and all unevennesses beaten down with a light hammer and planer, preparatory to the final shaving; the plate is then passed through the hand shaving machine, accurately adjusted, and two or three light cuts are taken off. The face is then tested by rubbing with a flat piece of willow charcoal, which, by not blackening the low parts, or hollows, enables the workman to see if any such exist, in which case he puts a corresponding mark to indicate these places on the back with a suitable tool. The plate is then laid, face downward, and the marked places are struck with a ball-faced hammer which forces up the printing surface beneath to its proper level. The plate is next subjected to the hand shaving machine (Fig. 68), by which the back becomes shaved down to its proper thickness and rendered perfectly level and smooth. The edges are next planed square and to the proper size, after which they are transferred to the carpenter, who mounts them, *type-high*, on blocks of wood, which may be either of cherry, mahogany, or other suitable wood, which is cut perfectly true and square in every direction. The plates, when mounted, are ready for the printer.

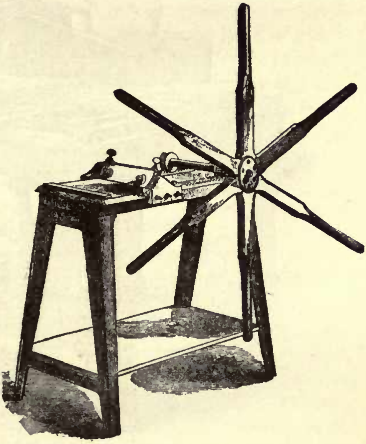

Fig. 68.—Hand Shaving Machine.

Bookwork is usually not mounted on wood, the plates being left unmounted, and finished with bevelled edges, by which they are secured on suitable plate blocks of wood or iron, supplied with gripping pieces which hold them firmly at the proper height, and enable them to be properly locked up.

Fig. 69 represents Messrs. R. Hoe & Co.'s power planing and sawing machine, which is intended for roughing off plates before sending them to the shaving machine, and is said to be very simple, quick, and efficient in operation. A circular saw runs in an elevating table at one corner, for squaring up, and an outside cutter, with sliding table, is attached for squaring up metal bodies, &c.

Electrotyping from Plaster Moulds.—Plaster of Paris may be employed for making electrotype moulds instead of wax, in which case the plaster mould is first soaked in wax; it is then coated with a mixture composed as follows: nitrate of silver 1 gramme, dissolved in water, 2 grammes; to this is added 2½ grammes of ammonia, and then 3 grammes of absolute alcohol. The mould is then to be exposed to sulphuretted hydrogen gas—made by pouring dilute sulphuric acid on powdered sulphide of iron.

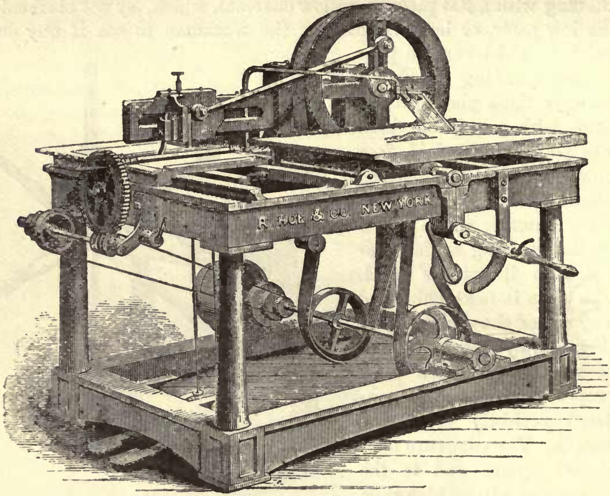

Fig. 69.—Power Planing and Sawing Machine.

Electrotyping Wood Engravings, &c.—One of the most useful and extensive applications of electrotyping is in the copying of wood engravings in electrolytic copper, to form metallic printing surfaces in lieu of printing from the less durable material, wood. The value and importance of electrotype blocks to the proprietors of illustrated publications—many of which have an enormous sale—will be at once recognised when we state that the electrotype heading of *The Times* newspaper is reputed to have produced no less than twenty millions of copies or impressions before it required renewal. It would be difficult to estimate how many wood blocks would have been required to furnish so large a number of impressions, equally perfect. Indeed, if we take the trouble to examine some of the illustrations of our periodical literature which have been produced direct from wood blocks, we cannot fail to notice the gradual depreciation of the original engraved blocks.

In copying an engraved wood block, it is first well brushed over with plumbago, or simply moistened with water; it is then placed upon a level bench, and a metal frame somewhat higher than the block is fastened round it. A lump of softened gutta-percha is then placed in the centre of the engraving, and forcibly spread outward (towards the frame), by which air becomes excluded. A plate of cold iron is now placed over the gutta-percha, with gentle pressure, which is afterwards gradually increased, by means of a press, as the gutta-percha becomes harder. When the mould has cooled, it is carefully separated from the block, and well plumbagoed, after which the connecting wire and "guiding wires" are attached; it is then ready for the depositing bath, where it is allowed to remain until a shell of sufficient thickness is obtained, which will depend upon the size of the mould and the strength of the current employed. Under favourable conditions, a shell of copper, say, of about one square foot of surface, will be obtained in about eight or ten hours, or even less; it is commonly the practice to put a series of moulds in the bath towards the evening, and to leave them in the bath all night; on the following morning the deposit is found to be ready to separate from the mould. In electrotype works where magneto or dynamo machines are employed (as in some of our larger printing establishments), a good shell is obtained in from three to five hours,* according to the dimensions of the mould. After removing the mould from the bath, it is rinsed in water, and the shell carefully detached, and the electrotype is next backed-up with solder or a mixture of type metal and tin, the back of the electrotype being first brushed over with a solution of chloride of zinc. The edges of the electrotype are next trimmed with a circular saw, and are afterwards submitted to the planing machine, by which the backing metal is planed perfectly level and flat; the edges are then bevelled by a bevelling machine, when the plate is ready for mounting on a block of cedar or mahogany, which is effected by

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* An American electrotypist, on a visit to London, told the author, about five years ago, that, having adopted the Weston dynamo machine in place of voltaic batteries, he could deposit a shell of copper upon fifteen moulds, each having about two square feet of surface, in about two and a half hours; that is to say, by the time the fifteenth or last mould was put into the bath the one which had first been immersed was sufficiently coated for backing up.

means of small iron pins driven into the bevel edges of the backing metal. When complete, the block, with its mounted electrotype, should be exactly *type high*. Respecting electrotypes from wood engravings, or "electros," as they are commonly called in the printing trade, we may mention that many of our larger illustrations are produced from electrotypes. Engraved steel plates are copied in the same way as above, and their reproduction in copper by the electrotype process is extensively practised.

Tin Powder for Electrotyping.—Grain tin may be reduced to an impalpable powder by either of the following methods:—1. Melt the grain tin in an iron crucible or ladle, and pour it into an earthenware mortar, heated a little above its melting point, and triturate briskly as the metal cools. Put the product in a muslin sieve and sift out the finer particles, and repeat the trituration with the coarser particles retained in the sieve. To obtain a still finer product place the fine powder in a vessel of clean water and stir briskly; after a few seconds' repose, pour off the liquor in which the finer particles are suspended, and allow them to subside, when the water is to be again poured off and a fresh quantity of the powder treated as before. The impalpable powder is finally to be drained and dried, and should be kept in a wide-mouthed stoppered bottle for use. 2. Melt grain tin in a graphite crucible, and when in the act of cooling, stir with a clean rod of iron until the metal is reduced to a powder. The powder should then either be passed through a fine sieve or *elutriated* as above described, which is by far the best method of obtaining an absolutely impalpable product. In using this powder for electrotyping purposes in the manner previously described, it must not be forgotten that the tin becomes dissolved in the copper bath; it should therefore only be employed in a bath kept specially for the purpose, and not be suffered to enter the ordinary electrotyping vat.

CHAPTER XI.

ELECTRO-DEPOSITION OF COPPER (*continued*).

Deposition of Copper by Dynamo-electricity.—Copying Statues, &c.—Lenoir's Process.—Deposition of Copper on Iron.—Coppering Printing Rollers.—Schlumberger's Process.—Producing Printing Rollers by Electricity.—Coppering Cast Iron.—Coppering Steel Wire for Telegraphic Purposes.—Coppering Solutions.—Dr. Elsner's Solution.—Walenn's Process.—Gulensohn's Process.—Weil's Coppering Process.—Electro-etching.—Glyphography.—Making Copper Moulds by Electrolysis.—Making Electrotype Plates from Drawings.—Coppering Steel Shot.—Coppering Notes.

Deposition of Copper by Dynamo-electricity.—Within the past few years, owing to the great advance made in the production of powerful and reliable magneto and dynamo-electric machines, the reduction of copper by electrolysis in the various branches of electrodeposition has assumed proportions of great magnitude; and while nickel-deposition—which fifteen years ago was a comparatively undeveloped art—has quietly settled down into its legitimate position as an important addition to the great electrolytic industry, the electrodeposition of copper, and its extraction from crude metal, have progressed with marvellous rapidity, both at home and abroad, but more especially so within the past five or six years, and we may safely predict from our knowledge of the vast number of magneto and dynamo machines which are now being constructed, under special contracts, that in a very short time the electrolytic reduction of copper will reach a scale of magnitude which will place it amongst the foremost of our scientific industries in many parts of the world. Before describing the processes of coppering large metallic objects, we must turn our attention to the production of electrotypes of larger dimensions than those previously considered. At a very early period of the electrotype art, Russia, under the guidance of the famous Professor Jacobi, produced colossal statues in electrolytic copper, which at the time created profound astonishment and admiration. About the same period our own countrymen directed their attention to this application of electrotypy, and at subsequent periods electrotypes of considerable dimensions were produced not only in this country but on the Continent. Some exceedingly fine specimens have been produced by Messrs. Elkington & Co., one of the most notable of which is that of the Earl of Eglinton, 13½ feet high and weighing two tons, while some other equally good specimens of life-size busts and bas-reliefs are to be seen in Wellington College, the House of Lords, &c. The well-known Paris firm, Messrs. Christofle & Co., have also produced colossal electrotype statues, one of which is 29 feet 6 inches in height, and weighs nearly three tons and a half; the completion of the deposit occupied about ten weeks.

Copying Statues, &c.—When very large objects have to be reproduced in electrotype, the method adopted is usually as follows: The original, formed of plaster of Paris, produced by the modeller or sculptor, is first brushed all over with boiled linseed oil, until the surface is completely saturated with the drying oil. After standing for two or three days, according to the temperature and condition of the atmosphere, the object, which is thus rendered impervious to moisture, and readily receives a coating of plumbago, is thoroughly well brushed over with blacklead until the entire surface is perfectly coated with the conducting material. The model is next connected to conducting wires, assisted by guiding wires, and placed in a sulphate of copper bath, where it receives a deposit of about one-sixteenth of an inch in thickness, or a shell sufficiently stout to enable it to retain its form after the inner plaster figure has been removed, which is effected in this way: the electrotype, with its enclosed model, being taken out of the bath, is first thoroughly well rinsed, the copper shell is then cut through with a sharp tool at suitable places, according to the form of the original figure, by which these various parts, with their guiding wires attached, become separated; the plaster figure is then carefully broken away, and all parts of it removed. After rinsing in hot water, the outer surface of the copper "formes" are well varnished over to prevent them from receiving the copper deposit in the next operation. The formes are next exposed to the fumes of sulphide of hydrogen, or dipped in a weak solution of sulphide of potassium (liver of sulphur), to prevent the adhesion of the copper deposit. These "formes," or parts of the electrotype shell, constitute the moulds upon which the final deposit, or electrotype proper, is to be formed, and these are returned to the depositing tank and filled with the solution of sulphate of copper, anodes of pure electrolytic copper being suspended in each portion. Deposition is then allowed to take place until the interior parts or moulds receive a coating of from one-eighth to one-third of an inch in thickness. The various pieces are then removed from the bath, and after well rinsing in water, the outer shell, or mould, is carefully stripped off, and the respective parts of the electrotype figure are afterwards fixed together when the operation is complete.

Lenoir's Process.—A very ingenious method of electrotyping large figures was devised by M. Lenoir, which consists in first taking impressions in gutta-percha of the object in several pieces, which may afterwards be put together to form a perfect figure; the inner surfaces of these impressions, or parts of the mould, are then well coated with plumbago. A "dummy" of the form of the interior of the mould, but of smaller dimensions, is now formed of platinum wire, to act as an anode, and the several parts of the plumbagoed gutta-percha mould are put together to form a complete mould all round it. The mould, with its platinum wire core (the anode)—which is insulated from metallic contact with the mould by a covering of india-rubber thread—is then placed vertically in the bath, weights being attached to allow the mould to sink into the solution. The platinum anode and the plumbagoed mould are then put in circuit and deposition allowed to progress. To keep up the strength of the copper solution within the mould, in the absence of a soluble anode, a continual flow of fresh copper solution is allowed to enter the mould, from a hole at the top of the head, which makes its escape through holes in the feet of the mould. When a sufficiently stout deposit is obtained, the flexible wire anode is withdrawn through the aperture in the head, after which the various portions of the gutta-percha mould are removed, and the seams at the junctions of the electrotype are cleared away by appropriate tools.

Deposition of Copper on Iron.—Since iron receives the copper deposit from acid solutions without the aid of a separate current, and the deposit under these conditions is non-adherent, it is the practice to give a preliminary coating of copper to iron objects in an *alkaline* bath, ordinary cyanide solutions being most generally adopted for this purpose. Many other solutions have, however, been recommended, some of which may deserve consideration. In any case, the iron article is first steeped in a hot potash bath, when the presence of greasy matter is suspected, and after rinsing, is immersed in a pickle of dilute sulphuric acid, $\frac{1}{2}$ lb. of acid to each gallon of water. After well rinsing, the article is scoured with coarse sand and water, applied with a hard brush, and after again rinsing, is immersed in the alkaline bath until perfectly coated with a film of copper. It is then again rinsed, and at once placed in a sulphate of copper bath, where it is allowed to remain until a sufficiently stout coating of copper is obtained. In some cases, where the object is of considerable proportions, it is kept in motion while in the solution, by various mechanical contrivances, as in Wilde's process, to be referred to shortly.

Coppering Printing Rollers.—Many attempts have been made, during the past thirty years or so, to substitute for the costly solid copper rollers used in calico-printing, iron rollers coated with a layer of copper by electrolysis. The early efforts were conducted with the ordinary voltaic batteries, but the cost of the electricity thus obtained was far too great to admit of the process being practically successful, while at the same time the operation was exceedingly slow. A method which was partially successful consisted in depositing, in the form of a flat plate, an electrotype bearing the design, which was afterwards coiled up in a tubular form, and connected to an iron cylinder or roller by means of solder, the seam being afterwards touched up by the engraver. A far better system, however, is now adopted, which is in every way perfectly successful; and printing rollers are produced in large quantities by electro-deposition at about one-half the cost of the solid copper article. Before describing the methods by which cast-iron rollers are faced with copper at the present time, it may be instructive to consider briefly some of the means that have been adopted to deposit a sufficient thickness of copper upon a cast-iron core to withstand the cutting action of the engraver's tools.

Schlumberger's Process.—This consists in depositing copper upon previously well-cleaned cast-iron cylinders by means of the "single-cell" process. The solution bath consists of a mixture of two solutions composed of (1) Sulphate of copper, 1 part; sulphate of soda, 2 parts; carbonate of soda, 4 parts; water, 16 parts. (2) Cyanide of potassium, 3; water, 12 parts. The interior of the bath is surrounded by porous cells containing amalgamated zinc bars with copper wires attached, and dilute sulphuric acid. The solution is worked at a temperature of from 59° to 65° Fahr., and the iron cylinder, being put in contact with the zinc elements, remains in the bath for twenty-four hours, at the expiration of which time it is removed, well washed, rubbed with pumice-powder, again washed in a solution of sulphate of copper having a specific gravity of 1·161, containing $\frac{1}{300}$th part of its volume of sulphuric acid; scraps of copper are kept in the bath, to supply the loss of copper, and prevent the liquid becoming too acid. The cylinder is then returned to the bath, or placed in a mixture composed of the following two solutions: (1) Acetate of copper, 2; sulphate of soda, 2; carbonate of soda, 4; water, 16 parts. (2) Cyanide of potassium, 3; liquid ammonia, 3; water, 10 parts. The cylinders are to be turned round once a day, in order to render the deposit uniform, and the action is continued during three or four weeks, or until the deposit is $\frac{1}{25}$th of an inch thick.

Another method consists in first coppering the well-cleaned cast-iron cylinder in an ordinary alkaline coppering bath, and then transferring it to an acid bath of sulphate of copper, the cylinder in each case being surrounded by a hollow cylinder of copper for the anode; the process is allowed to proceed slowly, in order to obtain a good reguline coating, and when this is obtained of sufficient thickness to bear engraving upon, the surface is rendered smooth by turning at the lathe.

Producing Printing Rollers by Magneto-electricity.—*Wilde's Process.*—It is obvious that the electrical power obtained from magneto and dynamo-electric machines is more capable of depositing economically the requisite thickness of copper upon cast-iron cylinders to form printing rollers than could be expected from voltaic electricity, which necessarily involves the solution of an equivalent of zinc and the consumption of sulphuric acid to deposit a given weight of copper. It is well known that deposition takes place more freely upon the lower surfaces of the cathode, and consequently, when the deposited metal is of any considerable thickness, the irregular surface thus produced is often a source of great trouble to the electro-depositor; in the case of printing rollers, however, in which a perfectly uniform thickness of the deposit is absolutely indispensable, some means must be adopted to render the deposit as uniform as possible from end to end of the cylinder. To accomplish this, Mr. Henry Wilde, of Manchester, effected an arrangement for which he obtained a patent in 1875, which consists in "giving to the electrolyte or depositing liquid in which the roller to be coated is immersed, or the positive and negative electrodes themselves, a rapid motion of rotation, in order that fresh particles of the electrolyte may be brought successively in contact with the metallic surfaces. By this," says the patentee, "powerful currents of electricity may be brought to bear upon small surfaces of metal without detriment to the quality of the copper deposited, while the rate of the deposit is greatly accelerated.

"Motion may be communicated to the electrolyte, either by the rotation of the electrodes themselves, or when the latter are stationary, by paddles revolving in an annular space between them. The iron roller to be coated with copper is mounted on an axis, the lower end of which is insulated, to prevent its receiving the deposit of copper at the same time as the roller. The roller, after having received a film deposit of copper from an alkaline solution in a manner well understood, is immersed in a vertical position in a sulphate solution of copper, and a motion of rotation is given to the roller or rollers by means of suitable gearing. The positive electrodes are copper rollers or cylinders, of about the same length and diameter as the roller to be coated, and are placed parallel with it in the sulphate solution. The electrical contacts are made near the upper and lower extremities of the electrodes respectively, for the purpose of securing uniformity in the thickness of the deposit. The sulphate solution may be maintained at an uniform density, from the top to the bottom of the bath, by rotating a small screw propeller, enclosed in a tube communicating with the liquid, and driven by the same gearing that imparts motion to the roller."

The electric current employed for depositing copper by the above method may be obtained from Wilde's magneto-electric machine, which has been very extensively adopted for this purpose, or from any dynamo electric machine capable of yielding an adequate current. Mr. Wilde says, in the specification above quoted, "Although I have only mentioned cast-iron as the metal upon which the copper is deposited, the process is applicable to rollers made of zinc or other metals, and their alloys. The method of accelerating the rate of deposit, by giving to the electrolyte, or to the electrodes, a motion of rotation, may be applied to the electrolytic method of refining copper described in Mr. J. B. Elkington's patent." Mr. Wilde's system of coppering cast-iron rollers was established in 1878, but he subsequently disposed of his patent rights to the Broughton Copper Company, who carry on the process successfully, and have extended it to the coating of hydraulic rams, &c.

Coppering Cast Iron.—The great progress which has been made in the production of artistic castings in iron during the past thirty years or so, not only in this country, but on the Continent, has always created a desire that some economical and reliable method of coating such work with copper could be devised, not alone to preserve the iron from atmospheric influence, but also to enhance the beauty of the work by facing it with a superior metal. To deposit a protective coating of copper upon large pieces of cast iron, however, has generally been a matter of considerable difficulty, owing to the almost inevitable presence of sand-holes and other flaws which, even when not of large size, are often of sufficient depth to retain particles of silicious or other matter which cannot readily be dislodged by the ordinary methods of pickling and scouring; and since these defective spots do not receive the deposit of copper, the underlying metal must always be liable to corrosion at such parts, when subjected to the effects of moisture. These observations are chiefly directed to the coppering of cast-iron work destined to be exposed to the vicissitudes of the weather, as street lamp-posts, for example; and though we have not yet devoted much attention to this branch of industry in this country, it has received a good deal of attention in France, but more especially in Paris. To overcome the difficulties above mentioned, copper is not deposited direct upon the iron, as will be seen below, but upon a coating of varnish, rendered conductive by the application of plumbago. The system adopted by M. Oudrey, at his works at Auteuil, may be thus briefly described:—The cast-iron object is first coated all over with a varnish composed of resinous matters dissolved in benzol, to which is added a sufficient quantity of red or white lead, the varnish being then allowed to dry. The surface thus prepared is next brushed over with plumbago, and the article then coated with copper in the ordinary sulphate bath by the "single-cell" method, for which very large porous cells are employed. In about four or five days a sufficiently thick coating of copper is obtained, when, after rinsing and drying, a bronzed appearance is given to the work by the application of a solution of ammonio-acetate of copper. With respect to this process M. Fontaine observes: "It is evident that a coating of copper so deposited can be possessed of no other solidity than its own, and the latter is entirely dependent on the thickness and tenacity of the deposit. M. Oudry was accordingly led to effect depositions having one-half a millimetre on ordinary objects and one millimetre or more on fine works. If to that thickness is added those of a layer of plumbago and three layers of insulating coating material, it will be readily conceived that such a system of coppering is only suitable in the case of very large objects. In the case of small objects—such as a bust, for example—the nicety of the details would be irretrievably spoiled by these five layers, and it would amount to sacrificing to too great an extent the artistic worth of the object for the purpose of attaining its preservation. It is, nevertheless, certain that this process has really become a branch of industry, and that it is the first one which has been applied on a large scale. All the lamp-posts of the city of Paris, the beautiful fountains of the Place de la Concorde and of the Place Louvois, and a considerable number of statues and bas-reliefs, have been coppered at Auteuil, in the inventor's factory." It appears that M. Oudry's son subsequently modified the above process by substituting for the coatings of paint and plumbago an immersion of the cast-iron objects in a thick paint composed of hot oil and copper-dust suspended in the liquid. The objects, when removed from this bath, are first dried in an oven and then rubbed with a wire-brush and copper dust. They are afterwards immersed in a sulphate of copper bath.

It is obvious that in either of the above processes a quantity of copper far in excess of what would be required as a protective coating for iron—provided it could be deposited *direct* upon the metal—must from necessity be deposited upon the plumbagoed, or copper-dusted surface; and it is also clear that since the copper represents merely a thin shell upon the surface, that a very moderate amount of rough usage, such as the Parisian *gamin* or London street Arab could inflict on very easy terms, by the simple process of climbing the lamp-posts with metal-tipped boots, would quickly break this "shell" and expose the underlying layer of plumbagoed varnish. When all these objections are taken into consideration—the partial obliteration of the finer details of the object, the labour, cost of material, the length of time required to complete a single article before it is ready to be placed in position, and add to this the constant liability to damage from accident or mischief, this method of coppering iron does not appear to have much to recommend it.

Cold Coppering Solution.—One of the chief reasons why alkaline coppering solutions seldom work vigorously when used at the ordinary temperature, is that they are too frequently prepared with cheap commercial cyanide, containing but a small percentage of real cyanide, and consequently overloaded with carbonate of potash, a salt which has no solvent action on the anode, and is of little or no service in the coppering bath. While experimenting in this direction some time since, we found that a good coppering solution, to be worked in the cold, could be prepared from the following formula; but it is essential that the cyanide be of good quality. For each gallon of solution required, 3 ounces of chloride of copper are to be dissolved in about a pint and a-half of cold water; 12 ounces of soda crystals are next dissolved in about a quart of water. The latter solution is then to be gradually added to the chloride of copper solution, with gentle stirring after each addition, until the whole of the alkaline liquid has been added, when the resulting carbonate of copper is allowed to settle. After an hour or so the supernatant liquor is poured off and fresh water added to wash the precipitate, which is again allowed to subside as before, the washings being repeated several times, and the precipitate then dissolved in a solution of cyanide of potassium composed of six ounces of the cyanide dissolved in about a quart of water, the whole being well stirred until the copper salt has become dissolved. The solution thus formed is now to be set aside for several hours and the clear liquor then carefully decanted from any sediment that may be present; water is then added to make up one gallon of bath. This solution will coat cast or wrought iron very readily with a current from two to three Daniells, in series, and may be used to give a preliminary coating to iron work which is to be afterwards thickly coppered in an ordinary sulphate bath. The anode used in this, and all other alkaline coppering baths, should be of pure electrolytic copper.

Coppering Steel Wire for Telegraphic Purposes.—It had always been held that if iron wire could be successfully and economically coated with copper, it would be of incalculable service in telegraphy; and, indeed, many attempts to accomplish this were made at a period when magneto and dynamo-electric machines were unknown. It soon became apparent, however, that, independent of other difficulties, the object could never be practically attained by means of the voltaic battery. Now that we are enabled to obtain electricity simply at the cost of motive power, that which was impossible thirty years ago has been to some extent accomplished, and the coppering of steel wire for telegraph purposes forms an extensive branch of manufacture in connection with one of the telegraph systems of America. The manufacture of "compound wire," as it is called, has been carried out on a very large scale at Ansonia, Connecticut, by the Postal Telegraph

Company, who, Professor Silliman, of Yale College, U.S.A., states, have acquired "the largest electro-plating establishment in the world; yet its capacity is soon to be trebled. The works are employed in coppering steel wire used in the company's system of telegraphy, and now deposit two tons of pure copper per day. The steel core of the wire gives the required tensile strength, while the copper coating gives extraordinary conducting power, reducing the electrical resistance enormously. The compound wire consists of a steel wire core weighing 200 lbs. to the mile, and having a tensile strength of 1650 lbs., upon which copper is deposited, by dynamo-electricity, of any required thickness. Twenty-five large dynamo machines are employed, which deposit collectively 10,000 lbs. of copper per day, representing 20 miles of 'compound wire,' carrying 500 lbs. of copper to the mile. When the works are completed, three 300 horse-power engines will drive dynamo machines for supplying the current to deposit copper upon 30 miles of wire per day. In the process of deposition the wire is drawn slowly over spiral coils, through the depositing vats, until the desired thickness is obtained." The advantages of coppered steel wire over ordinary galvanised iron wire for telegraph purposes cannot well be over-estimated, and if the process prove as successful as it is stated to be, it will undoubtedly be a great electrolytic achievement.

Coppering Solutions.—In preparing alkaline coppering solutions, for depositing a preliminary coating of copper upon iron, and for other purposes of electro-coppering, either of the formulæ for brassing solutions may be used, by omitting the zinc salt and doubling the quantity of copper salt; or either of the following formulæ may be adopted. As a rule, copper solutions should be worked hot, say at a temperature of about 130° Fahr., with an energetic current, especially for cast-iron work, since even with the best solution deposition is but slow when these solutions are worked cold. It is important to bear in mind in making up copper solutions—and the same observation applies with at least equal force to brassing solutions—that commercial cyanide of potassium is largely adulterated with an excess of carbonate of potash, and unless a cyanide of known good quality be employed, the solution will be not only a poor conductor of the current, but the anodes will fail to become freely dissolved, whereby the solution will soon become exhausted of a greater portion of its metal in the process of deposition. The cyanide to be used for making up such solutions should contain at least 75 per cent. of *real* cyanide.

Solution 1.—Dissolve 8 ounces of sulphate of copper in about 1 quart of hot water; when cold, add liquid ammonia of the specific gravity of ·880 gradually, stirring with a glass rod or strip of wood after each addition, until the precipitate which at first forms becomes re-dissolved; dilute the solution by adding 1 quart of cold water. Now prepare a solution of cyanide of potassium by dissolving about 1¼ lb. of the salt in 2 quarts of water, and add this gradually to the copper solution, with stirring, until the blue colour of the ammonio-sulphate entirely disappears; finally add the remainder of the cyanide solution, and allow the mixture to rest for a few hours, when the clear liquor may be decanted into the depositing vessel or tank, and is then ready for use. This solution may be used cold, with a strong current, but it is preferable to work it at about 110° to 130° Fahr.

Solution 2.—The acetate or chloride of copper may be used instead of the sulphate in making up a coppering bath, the latter salt being preferable.

Solution 3.—A solution prepared as follows has been recommended: Dissolve cyanide of copper in a solution of cyanide of potassium, consisting of 2 pounds of cyanide to 1 gallon of water, then adding about 4 ounces more of the salt as free cyanide; the solution is then ready, and should be worked at a temperature of about 150° Fahr. Cyanide of copper is not freely soluble in a solution of cyanide of potassium, and the liquid does not readily dissolve the anodes, nor is it a good conductor. It has also a tendency to evolve hydrogen at the cathode; this, however, may be lessened or wholly prevented by avoiding the use of free cyanide, employing a weaker current, and adding liquid ammonia and oxide of copper. From our own experience, the addition of liquid ammonia to copper solutions, if not applied in the first instance, becomes a necessity afterwards.

Solution 4.—Roseleur gives the following formula for a coppering solution: 20 parts of crystallised acetate of copper are reduced to a powder, and formed into a paste with water; to this is added 20 parts of soda crystals, dissolved in 200 parts of water, the mixture being well stirred. To the green precipitate thus formed, 20 parts of bisulphite of sodium, dissolved in 200 parts of water, are added, by which the precipitate assumes a dirty yellow colour. 20 parts of *pure* cyanide of potassium, dissolved in 600 parts of water, are finally added, and the whole well stirred together. If the solution does not become colourless, an addition of cyanide must be given. It is said that this solution may be worked either hot or cold, with a moderately strong current.

Dr. Elsner's Solution.—In the preparation of this solution, 1 part of powdered bitartrate of potassium is boiled in 10 parts of water, and as much recently prepared and wet hydrated carbonate of copper, which has been washed with *cold* water, stirred with it as the above solution will dissolve. The dark blue liquid thus formed is next filtered, and afterwards rendered still more alkaline by adding a small quantity of carbonate of potash. This solution is stated to be applicable to coating iron, tin, and zinc articles.*

Walenn's Coppering Solution.—This solution, to be employed for coppering iron, consists in dissolving cyanide of copper in a solution composed of equal parts of cyanide of potassium and tartrate of ammonia. Oxide of copper and ammoniuret of copper are added in sufficient quantity to prevent the evolution of hydrogen at the surface of the work during deposition. The solution is worked at about 180° Fahr. The current from one Smee cell may be used with this solution. It has been found that 1½ ounce of copper per square foot will protect iron from rust.

Another process of Mr. Walenn's is as follows:—

The first part of this invention "relates to electro-depositing copper upon iron, or upon similar metals, so that the coating may be soft and adherent. This consists in using the solution at a boiling heat, or near thereto, namely, from 150° Fahr. to the boiling point of the solution. The second part is to prevent the evaporation of a solution which is heated during deposition. A cover, with a long condensing worm tube, is used in the depositing bath; the other end of the tube opens into a box containing materials to condense or appropriate the gases that escape. The liquids flow back down the tube into the tank. The third part of the invention consists in working electro-depositing solutions in a closed vessel under known pressure, being applied by heating the solution or otherwise. The closed vessel may be used for solutions in which there is free ammonia, or where other conditions arise in which it is necessary to enclose the solution, although neither appreciable increase of pressure arises nor is heat applied. If there be much gas coming off, the condensing tube, opening into a box of the second part of the improvements, may be employed." The fourth part of the invention consists in adding to the charged, and fully made, copper, brassing, or bronzing solution, cupric ammonide in the cold, until the solution is slightly green.

Gulensohn's Process.—A bath is made by first obtaining a solution of chloride of copper, the metal from which is precipitated in the form of phosphate, by means of pyrophosphate of soda. The precipitate is then thoroughly washed until all traces of the chloride of soda formed have been removed; the phosphate of copper is next dissolved in a solution of caustic soda, and, if necessary, a small quantity of liquid ammonia is added to assist the solution of the phosphate, and to render the deposit brighter and more solid. The strength of the solution must be regulated according to the strength of the current

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* *The Chemist*, vol. vii. p. 124.

employed in the deposition. The bath may be used for depositing upon iron or other metals.

Weil's Coppering Processes.—(1.) For coating large objects, as cast-iron fountains, lamp-posts, &c. M. Weil's patent gives the following process: Dissolve in 1,000 parts of water, 150 of sodio-potassic tartrate (Rochelle salt), 80 of caustic soda, containing from 50 to 60 per cent. of free soda, and 35 of sulphate of copper. Iron and steel, and the metals whose oxides are insoluble in alkalies, are not corroded in this solution. The iron or steel articles are cleaned with dilute sulphuric acid, of specific gravity 1·014, by immersing them in that liquid from five to twenty minutes, then washing with water, and finally with water made alkaline by soda. They are next cleaned with the scratch-brush, again washed, and then immersed in the cupreous bath, in contact with a piece of zinc or lead, or suspended by means of zinc wires; the latter is the most economical way. The articles must not be in contact with each other. They thus receive a strongly-adherent coating of copper, which increases in thickness (within certain limits) with the duration of immersion. Pure tin does not become coppered by contact with zinc in this solution; it oxidises, and its oxide decomposes the solution, and precipitates red sub-oxide of copper, and by prolonged action, all the copper is thus removed from the liquid. The iron articles require to be immersed from three to seventy-two hours according to the colour, quality, and thickness of the required deposit. The copper solution is then run out of the vat, and the coated articles washed in water, then cleaned with a scratch-brush, washed, dried in hot sawdust, and lastly in a stove. To keep the bath of uniform strength, the liquid is renewed from below, and flows away in a small stream at the top. After much use, the exhausted liquid is renewed by precipitating the zinc by means of sulphide of sodium (not in excess), and re-charging the solution with cupric sulphate. Weil also supplies to the bath hydrated oxide of copper.

(2.) A coppering bath is prepared as follows: 35 parts of crystallised sulphate, or an equivalent of any other salt of copper, are precipitated as hydrated oxide by means of caustic soda or potash. The oxide of copper is to be added to a solution of 150 parts of Rochelle salt, and dissolved in 1,000 parts of water. To this, 60 parts of caustic soda, of about 70 per cent., is to be added, when a clear solution of copper will be obtained. Other alkaline tartrates may be substituted for the Rochelle salt above mentioned, or even tartaric acid may be employed; but in the case of tartaric acid, or acid tartrates, a small additional quantity of caustic alkali must be added, sufficient to saturate the tartaric acid or acid tartrate. Oxide of copper may also be employed, precipitated by means of a hypochlorite, but in al cases the proportions between the copper and tartaric acid should be maintained as above, and it is advantageous not to increase to any notable extent the proportion of the caustic soda.

The object to be coppered is to be cleaned with a scratch-brush and then placed in the bath, when it will become rapidly coated with an adherent film of metallic copper. As the bath gradually loses its copper, oxide of copper as above prepared should be added to maintain it in a condition of activity, but the quantity of copper introduced should never exceed that above prescribed, as compared with the quantity of tartaric acid the bath may contain. If the copper notably exceeds this proportion, certain metallic iridescences are produced on the surface of the object. These effects may be employed for ornamental and artistic purposes. According to the time of the immersion, the strength of the current, and the proportion of copper to the tartaric acid, these iridescences may be produced of different shades and tints, which may be varied or intermingled by shielding certain parts of the object by a coating of paraffin or varnish, the iridescent effect being produced on the parts left exposed. All colours, from that of brass to bronze, scarlet, blue, and green, may be thus produced at will.

Electro-Etching.—When we bear in mind the fact that, with few exceptions, the anodes employed in electrolytic processes become dissolved in the bath during electro-deposition, it is evident that if certain portions of an anode were protected, by means of a suitable varnish, from the solvent action of the solution, that such parts, after the plate had been subjected to electro-chemical action in the bath, would, on removal of the varnish, appear in relief, owing to the exposed surfaces having been reduced in substance by being partially dissolved in the solution. Suppose a smooth and bright plate of copper, for instance, were to have a design sketched upon it with a suitable varnish, and the plate then connected to the positive electrode of a voltaic battery and immersed in a solution of sulphate of copper, a cathode of the same metal being suspended from the negative electrode ; if, after a few hours' immersion, the plate be taken from the bath, and the varnish removed, the design will appear in bright relief, while the unvarnished parts will have been eaten away, or dissolved, leaving hollows of a comparatively dull appearance ; the design now forms a printing surface, from which copies may be impressed upon paper in the usual way.

The process of voltaic etching is performed in various ways, but the following will explain the general principle upon which the art is conducted. A copper wire is first soldered to the plate, and the back is then coated with a tough varnish ; when this is dry, the face of the plate is coated with engraver's "etching-ground," a composition of beeswax 5 parts, linseed oil 1 part, melted together ; it is sometimes the practice to *smoke* the surface, before applying the etching needle, in order to render its tracings more visible. The design is then drawn upon the face of the plate, cutting through to the clean surface of the copper. When the etching is complete, the plate is made the anode in a sulphate of copper bath, while a plate of copper is immersed as the cathode. The electric current, passing out of the engraved lines, causes the copper to be dissolved from them, whereby they become *etched*, much in the same way, and with the same effect, as when acid is used in the ordinary etching process. The required gradations of light and shade are produced by suspending cathodes of different forms and sizes opposite the plate to be etched, in various positions, and at different distances from it, thus causing the plate to be acted upon in unequal depths in different parts, the deepest action being always at those portions of the electrodes which are nearest to each other.

Instead of using wax, or other etching-ground, as an insulating material, the plate may be coated with a film of some metal which will not be dissolved in the bath. For example, the plate may be first strongly gilt by electro-deposition, and the design then produced by means of a graver, the tool cutting just sufficiently deep to expose the copper; if now the plate be used as an anode, the copper will become dissolved, as before, leaving the gilt surface unacted upon, since the sulphuric acid set free during the voltaic action has no effect upon gold.

Again, the design may be made with lithographic ink or varnish, and the exposed parts of the plate then strongly gilt; if, thereafter, the varnish, or other insulating material be cleaned off the plate, the voltaic etching will follow the ungilt portions, causing them to become hollowed out as before.

The baths used for etching by electrolysis should be composed of the same metal as that to be etched; thus, a sulphate of copper bath is employed for etching copper plates, sulphate of zinc for zinc plates, and gold or silver solutions when their metals are to be treated in the same way. Copper and zinc plates, however, may be etched by means of the voltaic battery, in dilute solutions of nitric, sulphuric, hydrochloric, or acetic acid, a process which is said to be coming very much into practice.

Glyphography.—This process was invented by Mr. E. Palmer, and consists in first staining copper plate *black* on one side, over which a very thin layer of a *white* opaque composition, resembling white wax, is spread. The plate is then drawn upon with various etching needles in the usual way, which remove portions of the white composition, by which the blackened surface becomes exposed, forming a strong contrast to the surrounding white ground. When the drawing is complete, it is carefully inspected, and then passes into a third person's hands, "by whom it is brought in contact with a substance having a chemical affinity for the remaining portions of the composition, by whom they are heightened, *ad libitum*. Thus, by careful manipulation, the *lights* of the drawing become thickened all over the plate equally. . . . The depths of these non-printing parts of the block must be in some degree proportionate to their width; consequently the larger breadths of *lights* require to be thickened on the plate to a much greater extent. It is indispensably necessary that the printing surfaces of the block prepared for the press should project in such relief from the block itself as shall prevent the inking roller touching the interstices; this is accomplished in wood engraving by cutting out these intervening parts, which form the lights of the print, to a sufficient depth; but in glyphography the depth of these parts is formed by the remaining portions of the white composition on the plate, analogous to the thickness or height of which must be the depth on the block, seeing that the latter is in fact a *cast* or *reverse* of the former." The plate, thus prepared, is well plumbagoed all over, and is then placed in a sulphate of copper bath, and a deposit of sufficient thickness obtained, which, on being separated, will be found to be a perfect cast of the drawing which formed the *cliché*. The metallic plate thus obtained is afterwards backed up with solder and mounted in the same way as a stereotype plate, and is then ready for the printing press.

Making Copper Moulds by Electrolysis.—A drawing is made upon a varnished copper plate, as before described; the plate is then dipped into a weak "quicking" solution, and then laid upon a flat and level surface. The mercury attacks the surfaces exposed by the graver or etching needle, and takes the *meniscus*, or curved form, that is, the relief is greater as the etching lines are larger; the drawing, therefore, is reproduced in relief by the mercury. The plate is next covered with a thin paste of plaster of Paris, and when this has set, the two moulds are to be separated. A counter mould may now be taken from this, or it may be prepared in the usual way, and, after being well plumbagoed, receive a deposit of copper. By the following plan a mould is produced, which is at once ready for the bath. A copper plate is varnished and etched as before. A neutral solution of chloride of zinc is then poured upon the plate, and after this a quantity of fusible metal, which melts at from 175° to 212° Fahr. The flowing of the fusible metal over the surface of the plate is aided by the application of a spirit-lamp held beneath the plate, or by spreading the metal over the surface with a hot iron rod. The mould thus obtained may then be reproduced by the ordinary electrotype process.

Making Electrotype Plates from Drawings.—This invention relates to an improved process of forming matrices of designs for the production of electrotype plates directly by the hand of the artist or designer, in which the design is produced by means of a pointed tool upon a thin sheet of soft metal supported upon a peculiar backing of semi-plastic inelastic material of sufficient body or consistence to support the metal without pressure, but sufficiently yielding to give to the slightest touch of the artist, and allow the material to be depressed under the tool for the formation of the lines of design. In carrying out this invention a mixture is made of plaster of Paris 1 lb., chromate of potassa $\frac{1}{4}$ oz., and common salt, 1 oz., which forms a compound that will give the most delicate touch of the artist, and will allow the finest lines to be produced upon the metal by the tool. These ingredients may be mixed in various proportions, which will depend somewhat upon the boldness or delicacy of the design to be produced. The mixture may be brought to a semi-plastic state by the addition of about 1 pint of water, or sufficient to bring it to the proper consistence, and the plasticity of the compound may be modified to suit various requirements by using more or less water. The semi-plastic composition is moulded or otherwise formed into a flat tablet of suitable size, and a sheet of soft metal is carefully secured on the upper face of same, projecting edges being left, which are afterwards turned down over the sides of the tablet. The metal is then ready for the artist, who, with a pointed tool or tools, produces the required design by indenting the lines thereon. Wherever touched by the tool the metal will be depressed into the backing, which has just sufficient body to support the untouched parts, but yields to the slightest pressure of the tool. When the design is finished, the metal is carefully removed from the backing, having the design in relief on one side and in intaglio on the other, and is ready for the production of the electrotype plate in the ordinary way, which may be taken from either side, as circumstances require.

Coppering Steel Shot.—The electro-deposition of copper is being extensively applied by the Nickel Plating Company, Greek Street, Soho, London, to the coating of large and small steel shot with copper for the Nordenfelt gun.

Coppering Notes.—1. In preparing cast-iron work for electro-coppering, after the pieces have been pickled and scoured, they should be carefully examined for sand-holes, and if any such cavities appear upon the work, they must be well cleared from black or dirty matter, which may have escaped the brushing, by means of a steel point. It must always be borne in mind that copper, and indeed all other metals, refuse to deposit upon dirt. After having cleared out the objectionable matter from the sand-holes, and again well brushed the article with sand and water, it is a good plan to give the piece a slight coating of copper in the alkaline bath, and then to examine it again, when if any cavities show signs of being foul, they must be cleared with the steel point as before. The article should then have a final brushing with moist sand, and after well rinsing be placed in the alkaline coppering bath and allowed to remain, with an occasional shifting of position, until sufficiently coated. If the piece of work is required to have a stout coating of copper, it should receive only a moderate deposit in the cyanide bath, and after being well rinsed suspended in the sulphate of copper, or *acid* bath, as it is sometimes termed, and allowed to remain therein until the desired coating is obtained. To secure an uniform deposit, however, the object should be occasionally shifted while in the bath, except when mechanical motion is applied, as in coppering iron rollers and other similar work.

2. Respecting the working of copper solutions, Gore makes the following observations: "If the current is too great in relation to the amount of receiving surface, the metal is set free as a brown or nearly black metallic powder, and hydrogen gas may even be deposited with it and evolved. In the sulphate solution, if the liquid is too dense, streaks are apt to be formed upon the receiving surface, and the article (especially if a tall one) will receive a thick deposit at its lower part, and a thin one at the upper portion, or even have the deposit on the upper end redissolved. If there is too little water, crystals of sulphate of copper form upon the anode, and sometimes even upon the cathode, at its lower part, and also at the bottom of the vessel. If there is too much acid the anode is corroded whilst the current is not passing. The presence of a trace of bisulphide of carbon in the sulphate solution will make the deposit brittle, and this continues for some time, although the solution is continually depositing copper; in the presence of this substance the anode becomes black, but if there is also a great excess of acid, it becomes extremely bright. Solutions of cupric sulphate, containing sulphate of potassium, and the bisulphide of carbon applied to them, are sometimes employed for depositing copper in a bright condition. The copper obtained from the usual double cyanide of copper and potassium solution, by a weak current, is of a dull aspect, but with a strong current it is bright." For depositing copper from alkaline solutions, we prefer the Bunsen battery to all others.

3. The anodes used in electrotyping, as also those employed for depositing copper generally, should consist of pure electrolytic copper, in preference to the ordinary sheet metal, which invariably contains small traces of arsenic and other metals, which are known to diminish its conductivity considerably. Clippings and other fragments of copper from electrotypes may be used up as anodes, either by suspending them in a platinum-wire cradle or in a canvas bag, the fragments being put in connection with the positive electrode of the battery by

means of a stout rod or strip of copper. These make-shift anodes, however, should be used for thickening the deposit (if an electrotype) after the mould is completely coated with copper, and not in the earlier stage of the process.

4. When it is desired to obtain an electrotype of considerable thickness, this may be hastened in the following way: After the complete shell is obtained, clean copper filings are to be sifted over the surface, and deposition allowed to proceed as usual, when the newly deposited metal will unite with the copper filings and the original shell, and thus increase the thickness of the electrotype. By repeated additions of copper filings, followed by further deposition of copper, the back of the electrotype may be strengthened to any desired extent.

5. For coating with copper non-conducting substances, such as china or porcelain, the following process has been adopted in France: Sulphur is dissolved in oil of spike lavender to a sirupy consistence, to which is added either chloride of gold or chloride of platinum, dissolved in ether, the two liquids being mixed under gentle heat. The compound is next evaporated until it is of the consistency of ordinary paint, in which condition it is applied with a brush to such parts of a china or porcelain article as it is desired to coat with copper; the article is afterwards baked in the usual way, after which it is immersed and coated with copper in the ordinary sulphate bath.

CHAPTER XII.

DEPOSITION OF GOLD BY SIMPLE IMMERSION.

Preparation of Chloride of Gold.—Water Gilding.—Gilding by Immersion in a Solution of Chloride of Gold.—Gilding by Immersion in an Ethereal Solution of Gold.—Solution for Gilding Brass and Copper.—Solution for Gilding Silver.—Solution for Gilding Bronze.—French Gilding for Cheap Jewellery.— Colouring Gilt Work.—Gilding Silver by Dipping, or Simple Immersion.—Preparation of the Work for Gilding.—Gilding by Contact with Zinc, Steele's Process.—Gilding with the Rag.

Preparation of Chloride of Gold.—Since for all gilding purposes by the *wet way*, as we may term it in contradistinction to the process of mercury gilding, this metal requires to be brought to the state of *solution*, it will be well to explain the method of preparing the salt of gold commonly known as the *chloride of gold*, but which is, strictly speaking, a *terchloride* of the metal, since it contains three equivalents of chlorine. The most convenient way of dissolving the precious metal is to carefully place the required quantity in a glass flask, such as is shown in Fig. 70, and to pour upon it a mixture consisting of about 2 parts of hydrochloric acid and 1 part nitric acid *by measure*. This mixture of acids was called *aqua regia* by the ancients because it had the power of dissolving the king of metals—gold. To dissolve 1 ounce of gold (troy weight) about 4 ounces of *aqua regia* will be required, but this will depend upon the strength of the commercial acids. Soon after the mixed acids have been poured on the gold, gas is evolved, and the chemical action may be accelerated by placing the flask upon a sand-bath moderately heated. It is always advisable, when dissolving this or other metal, in order to avoid excess of acid, to apply less of the solvent than the maximum quantity in the first instance, and, when the chemical action has ceased, to pour off the dissolved metal and then add a further portion of the solvent to the remainder of the undissolved metal, and so on

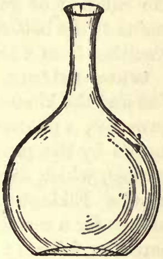

Fig. 70.

until the entire quantity is dissolved without any appreciable excess of acid, after which the various solutions are to be mixed together.

The solution of chloride of gold is to be carefully poured into a porcelain evaporating dish* (Fig. 71), and this, placed on a sand-bath or otherwise, gently heated until nearly all the acid is expelled, when the solution will assume a reddish hue. At this period the author prefers to move the evaporating dish round and round gently so as to spread the solution over a large surface of the interior of the vessel; in this way the evaporation of the acid is hastened considerably. When the solution assumes a blood-red colour the dish should be gently, but repeatedly, moved about as before until the semi-fluid mass—which gradually becomes deeper in colour and more dense in substance—*ceases to flow*. Towards the end of the operation the last remaining fluid portion flows torpidly, like molten metal, until it finally ceases altogether, at which moment the dish should be removed from the sand-bath and allowed to cool. It is necessary to mention that if too much heat be applied when the solution has acquired the blood-red colour the gold will quickly become reduced to the metallic state. If such an accident should occur the reduced metal, after dissolving out the chloride with distilled water, must be treated with a little *aqua regia*, which will again dissolve it.


Fig. 71.

The red mass resulting from the above operation (if properly conducted) is next to be dissolved in distilled water, in which it is readily soluble, and should form a perfectly clear and bright solution of a brownish-yellow colour. If, on the other hand, the evaporation has not been carried to an extent sufficient to expel all the acid the solution will be of a pure yellow colour. It invariably happens, after the chloride of gold is dissolved in water, that a white deposit remains at the bottom of the evaporating dish—this is *chloride of silver*, resulting from a trace of that metal having been present in the gold.

Water-Gilding.—Previous to the discovery of the electrotype process and the kindred arts of electro-gilding and silvering to which it gave rise, a process was patented by Mr. G. R. Elkington for gilding metals by the process of simple immersion or "dipping," and this process, which acquired the name of *water-gilding*, was carried on by Messrs. Elkington at Birmingham for a considerable time with success for a certain class of cheap jewellery. The solution was prepared as follows: A strong solution of chloride of gold was first obtained, to which *acid* carbonate of potash was added in the proportion of 1 part of the *metal* to 31 parts of the acid carbonate; to this mixture was added 30 parts more of the latter salt previously dis-

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* Evaporating dishes made from Berlin porcelain are the best for this purpose, since they are not liable to crack when heated.

solved in 200 parts of water. The mixture was then boiled for two hours, during which period the solution, at first yellow, assumed a green colour, when it was complete. To apply the above solution the metal articles, of brass or copper, are first well cleaned and then immersed in the solution, which must be hot, for about half a minute. Articles of silver or German-silver to be gilt in this solution must be placed in contact with either a copper or zinc wire.

Gilding by Immersion in a Solution of the Chloride of Gold.—Articles of steel, silver, copper, and some other of the baser metals, may be gilt by simply immersing them in a weak solution of the chloride of gold; this is, however, more interesting as a fact than of any practical value.

Gilding by Immersion in an Ethereal Solution of Gold.—Chloride of gold is soluble in alcohol and in ether. The latter solution may be obtained by agitating a solution of gold with ether, after which the mixture separates into two portions; the upper stratum, which is of a yellow colour, is an ethereal solution of chloride of gold, while the lower stratum is merely water and a little hydrochloric acid. Steel articles dipped in the ethereal solution become instantly covered with gold, and, at one time, this method of gilding steel was much employed for delicate surgical instruments, as also for the ornamentation of other articles of steel. After being applied, the ether speedily evaporates, leaving a film of gold upon the object. If the ethereal solution be applied with a camel-hair brush or quill pen, initials or other designs in gold may be traced upon plain steel surfaces. Or, if certain portions of a steel object be protected by wax or varnish, leaving the bare metal in the form of a design, the ethereal solution may then be applied to the exposed surfaces, which will appear in gold when the wax or varnish is dissolved or otherwise cleared away. Various ways of applying this solution for the ornamentation of steel will naturally occur to those who may be desirous of utilising it.

Solution for Gilding Brass and Copper.—The following formula has been adopted for "water-gilding" as it is termed:—

Fine gold	6¼ dwts.

Convert the gold into chloride, as before, and dissolve it in 1 quart of distilled water, then add

Bicarbonate of potassa	1 lb.

and boil the mixture for two hours. Immerse the articles to be gilt in the warm solution for a few seconds up to one minute according to the activity of the bath.

Solution for Gilding Silver.—Dissolve equal parts, by weight, of bichloride of mercury (corrosive sublimate) and chloride of ammonium (sal-ammoniac), in nitric acid; now add some grain gold to the mixture and evaporate the liquid to half its bulk; apply it, whilst hot, to the surface of the silver article.

Solution for Gilding Bronze, &c.—A preparatory film of gold may be given to large bronze articles that are to be fully gilt by either of the processes hereafter described, or small articles of "cheap" work may be gilt by immersing them in the following solution, which must be used at nearly boiling heat:—

Caustic potash	180 parts
Carbonate of potash . . .	20 „
Cyanide of potassium . . .	9 „
Water	1,000 „

Rather more than 1½ part of chloride of gold is to be dissolved in the water, when the other substances are to be added and the whole boiled together. The solution requires to be strengthened from time to time by the addition of chloride of gold, and also, after being worked four or five times, by additions of the other salts in the proportions given. This bath is recommended chiefly for gilding, economically, small articles of cheap jewellery, and for giving a preliminary coating of gold to large articles, such as bronzes, which are to receive a stronger coating in the pyrophosphate bath described further on, or in cyanide solutions by aid of the battery. In this bath articles readily receive a light coating of gold, and it will continue to work for a very long period by simply adding, from time to time as required, the proper proportions of gold and the other substances comprised in the formula. By keeping the bath in proper order a very large number of small articles may be gilt in it at the expense of a very small proportion of gold.

Another method of gilding by simple immersion, applicable to brass and copper articles, is to first dip them in a solution of protonitrate of mercury (made by dissolving quicksilver in nitric acid and diluting with water), and then dipping them into the gilding liquid—this plan being sometimes adopted for large articles. It is said that copper may be gilded so perfectly by this method as to resist for some time the corrosive action of strong acids. During the action which takes place, the film of mercury, which is electropositive to the gold, dissolves in the auriferous solution, and a film of gold is deposited in its place.

French Gilding for Cheap Jewellery.—The bath for gilding by dipping, recommended by Roseleur, is composed of—

Pyrophosphate of soda or potassa . .	800 grammes.
Hydrocyanic acid of ⅛ (prussic acid) .	8 „
Chloride of gold (crystallised) . . .	20 „
Distilled water	10 litres.

The pyrophosphate of soda is generally employed, and this may be prepared by melting, at a white heat, ordinary crystallised phosphate of soda in a crucible. The quantity of gold given in the above formula represents the grammes of the pure metal dissolved by aqua regia. In making up the bath, 9 litres of water are put into a porcelain or enamelled-iron vessel, and the pyrophosphate added, with stirring, a little at a time, moderate heat being applied until all the salt is dissolved. The solution is then to be filtered and allowed to cool. The chloride of gold must not be evaporated to dryness, as previously described, but allowed to crystallise; the crystals are to be dissolved in a little distilled water, and the solution filtered to keep back any chloride of silver that may be present in the dissolving flask, derived from the gold. The filter is next to be washed with the remainder of the distilled (or rain) water. The chloride solution is now to be added to the cold solution of pyrophosphate of soda, and well mixed by stirring with a glass rod. The hydrocyanic acid is then to be added, with stirring, and the whole heated to near the boiling point, when the solution is ready for use. If the pyrophosphate solution is tepid, or indeed in any case, Roseleur thinks it best to add the prussic acid before the solution of chloride of gold is poured in. The employment of prussic acid in the above solution is not absolutely necessary, indeed many persons dispense with it, but the solution is apt to deposit the gold too rapidly upon articles immersed in it, a defect which might be overcome by employing a weaker solution. If the solutions are cold when mixed, the liquor is of a yellowish colour, but it should become colourless when heated. It sometimes happens that the solution assumes a wine-red colour, which indicates that too little prussic acid has been used; in this case the acid must be added, drop by drop, until the solution becomes colourless. An excess of prussic acid must be avoided, since it has the effect of retarding the gold deposit upon articles immersed in the solution. The proper condition of the bath may be regulated by adding chloride of gold when prussic acid isi n excess, or this acid when chloride of gold predominates. In this way the bath may be rendered capable of gilding without difficulty, and of the proper colour.

Respecting the working of this solution, Roseleur says, "The bath will produce very fine gilding upon well-cleaned articles, which must also have been passed through a very diluted solution of nitrate of mercury, without which the deposit of gold is red and irregular, and will not cover the soldered portions. The articles to be gilded must be constantly agitated in the bath, and supported by a hook, or placed in a stoneware ladle perforated with holes, or in baskets of brass gauze, according to their shape or size."

In gilding by dipping, it is usual to have three separate baths placed in succession, and close to each other, all being heated upon the same furnace by gas or otherwise. The first bath consists of an old and nearly exhausted solution in which the articles are first dipped to free them from any trace of acid which may remain upon them after being dipped in aqua fortis. The second bath, somewhat richer in gold than the former, is used for the next dipping, and the articles then receive their final treatment in the third bath. By thus working the baths *in rounds*, "the fresh bath of to-day becomes the second of to-morrow, and the second takes the place of the first, and so on. This method of operating allows of much more gilding with a given quantity of gold than with one bath alone," and consequently is advantageous both on the score of economy and convenience. The gilding is effected in a few seconds, when the articles are rinsed in clear water and dried by means of hot sawdust, preferably from white woods; they are afterwards burnished if necessary. Roseleur does not approve of boxwood sawdust for this purpose, since it is liable to clog the wet pieces of work, besides being less absorbent than the sawdust of poplar, linden, or fir. The sawdust should neither be too fine nor too coarse, and kept in a box with two partitions, with a lining of zinc at the bottom. The box is supported upon a frame of sheet-iron or brickwork, which admits, at its lower part, of a stove filled with bakers' charcoal, which imparts a gentle and uniform heat, and keeps the sawdust constantly dry. After drying very small articles in sawdust, they are shaken in sieves of various degrees of fineness, or the sawdust may be removed by winnowing.

The above process of gilding by dipping, or "pot gilding," as it was formerly called, is applied to articles of cheap jewellery, as bracelets, brooches, lockets, &c., made from copper or its alloys, and has been extensively adopted in France for gilding the pretty but spurious articles known as French jewellery.

Colouring Gilt Work.—In working gold solutions employed in the dipping process, it may sometimes occur that the colour of the deposit is faulty and patchy instead of being of the desired rich gold colour. To overcome this, certain "colouring salts" are employed, the composition of which is as follows:—

Nitrate of potash . .	Of each equal parts.
Sulphate of zinc . .	
Sulphate of iron . .	
Alum	

These substances are placed in an earthenware pipkin, and melted at about the temperature of boiling water. When fused, the mixture is ready for use. The articles are to be brushed over with the composition, and are then placed in a charcoal furnace in which the fuel burns between the sides and a vertical and cylindrical grate, as shown in Figs. 72—3).

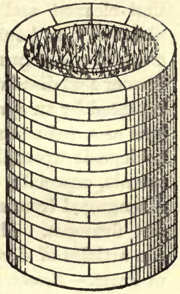

Fig. 72.

The work is placed in the hollow central portion where the heat radiates. A vertical section of the furnace is shown in Fig. 73. When put into the furnace, the salts upon the articles first begin to dry, after which they fuse, and acquire a dull, yellowish-red colour. On applying the moistened tip of the finger to one of the pieces, if a slight hissing sound is heard, this indicates that the heat has been sufficient, when the articles are at once removed and thrown briskly into a very weak sulphuric acid pickle, which in a short time dissolves the salts, leaving the work clear and bright, and of a fine gold colour. It must be borne in mind that this "colouring" process has a rather severe action upon gilt work, and should the gilding be a mere film, or the articles only gilt in parts, the fused salts will inevitably act upon the copper of which the articles are made, and strip the greater portion of the gold from the surface; as it would be a great risk to submit a large number of indifferently gilt articles to the colouring process unless it was known that sufficient gold had been deposited upon them, although of inferior colour, it would be better to operate upon one or two samples first, when, if the result prove satisfactory, the bulk of them may then be treated as above. Some operators, when the "dipping" has not been satisfactory as to *colour*, give the articles a *momentary* gilding with the battery in the usual way.

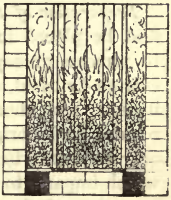

Fig. 73.

When it is desired to gild articles strongly by the dipping process, they are gilt several different times, being passed through a solution of nitrate of mercury previous to each immersion; the film of mercury thus deposited on the work becomes dissolved in the pyrophosphate bath, being replaced by the subsequent layer of gold. In this way articles may be made to receive a substantial coating of gold. In France, large articles, such as clocks, ornamental bronzes, &c., are gilt in this manner, by which they acquire the beautiful colour for which French clocks and goods of a similar character are so justly famed. Roseleur states that he has succeeded in gilding copper by this method sufficiently strong to resist the action of nitric acid for several hours. When articles are strongly gilt by the dipping process, they may be scratch-brushed, or subjected to the process called *or-mouluing* described in another place.

Gilding Silver by Dipping, or Simple Immersion.—The articles are first cleaned and scratch-brushed, after which they are boiled for about half an hour in the pyrophosphate gilding bath, to which a few extra drops of prussic acid or sulphurous acid have been added. The former acid dissolves a small portion of silver from the articles, which is replaced by an *equivalent* proportion of gold, while the sulphurous acid acts as a reducing agent in the gold solution, and causes the metal to deposit upon the silver from the affinity existing between the two metals, especially when one of them is in the nascent state, that is, just disengaged from a combination. This gilding is very fine, but without firmness. The deposit is rendered more rapid and thicker when the articles of silver are continually stirred with a rod of copper, zinc, or brass.—*Roseleur*. The deposition by contact of other metals, is, however, due to voltaic action set up by the pyrophosphate solution, and is altogether different to the action which takes place during the simple dipping process, in which a portion of the metal of which the article is composed is dissolved by the solution, and replaced by an *equivalent* proportion of gold.

Preparation of the Work for Gilding—As a rule, the articles should first be placed in a hot solution of caustic potash for a short time, to remove greasy matter, then well rinsed, and afterwards either scratch-brushed, or dipped in aqua fortis or "dipping acid" for an instant, and then thoroughly well rinsed. If the articles merely require to be brightened by scratch-brushing, after being gilt, it is only necessary to put them through the same process before gilding, which imparts to the work a surface which is highly favourable to the reception of the deposit, and which readily acquires the necessary brightness at the scratch-brush lathe as a finish. Articles which are to be left with a dead or frosted surface, must be dipped in dipping acid and rinsed before being placed in the gilding bath. It is commonly the practice to "quick" the articles, after dipping in acid, by immersing them in a solution of nitrate of mercury until they become white; after this dip, they are rinsed, and at once put into the bath.

Gilding by Contact with Zinc—Steele's Process.—In this process, a solution is made by adding chloride of gold to a solution of cyanide of potassium: in this the articles to be gilt are placed, in contact with a piece of zinc, which sets up electro-chemical action, by which the gold becomes deposited upon the articles; but since the metal also becomes reduced upon the zinc, the process would not be one to recommend on the score of economy. In some cases, however, in which it is necessary to deposit a film of gold upon some portion of an article which has *stripped* in the burnishing, a cyanide solution of gold may be dropped on the spot, and this touched by a zinc wire, when it will receive a slight coating of gold, and thus save the necessity of regilding the whole article. This system of "doctoring" is sometimes necessary, but should be avoided if possible, as it is undoubtedly a fraud upon the customer, since the doctored spot must, sooner or later, yield up its film of gold and lay bare the metal beneath.

Gilding with the Rag.—This old-fashioned process, which was at one time much used for gilding the insides of snuff-boxes, bowls of mustard and salt spoons, &c., is conducted as below. Instead of forming the chloride of gold in the ordinary way, the following ingredients are taken :—

Nitric acid	5 parts.
Sal-ammoniac (chloride of ammonium)	2 „
Saltpetre (nitrate of potassa)	1 „

A quantity of finely rolled gold is placed in a glass flask, and the other substances are then introduced ; the flask is next heated over a sand-bath. During the action which takes place, the nitric acid decomposes the chloride of ammonium, liberating hydrochloric acid, which combines with the nitric acid, forming aqua regia, which dissolves the gold, forming chloride ; the nitrate of potash remains mixed with the chloride of gold. The flask is then set aside to cool : when cold, the contents of the flask are poured into a flat-bottomed dish, and pieces of linen rag, cut into convenient squares, are laid one above another in the solution, being pressed with a glass rod, so that they may become thoroughly impregnated with the liquid. The squares of rag are next taken up, one by one, and carefully drained, after which they are hung up in a dark closet to dry. When nearly dry, each piece of rag, supported upon glass rods, is placed over a charcoal fire until it becomes ignited and burnt to tinder, which is promoted by the nitrate of potash ; the burning rag is laid upon a marble slab until the combustion is complete, when the ashes are to be rubbed with a muller, which reduces them to a fine powder. The powder is now collected and placed between pieces of parchment, round which a wet cloth is to be folded ; it is thus left for about a week, being stirred each day, however, to ensure an equal damping of the powder by the moisture which permeates the parchment.

To apply the powder, a certain quantity is placed on a slab and made into a paste with water ; the workman then takes up a small portion with his thumb, which he rubs upon the cleaned surface of the part to be gilt ; the crevices, fillets, or grooves are rubbed with pieces of cork cut to the shape required for the purpose, and the corners, or sharp angles, are rubbed with a stick of soft wood ; such as willow or poplar. When the articles have been gilt in this way, they are finished by burnishing in the usual manner. When a red-coloured gold is required, a small portion of copper is added to the other ingredients when preparing the salt of gold as above described.

CHAPTER XIII.

ELECTRO-DEPOSITION OF GOLD.

Gilding by Direct Current, or Electro-Gilding.—Preparation of Gilding Solutions.—Gilding Solutions: Becquerel's.—Fizeau's.—Wood's.—M. de Briant's.—French Gilding Solutions.—Gilding Solutions made by the Battery Process.—De Ruolz's.—Cold Electro-Gilding Solutions.—Observations on Gilding in Cold Baths.—Ferrocyanide Gilding Solution.—Watt's Gilding Solution.—Record's Gilding Bath.

Gilding by Direct Current, or Electro-gilding.—In gilding by dipping, or simple immersion, it is obvious that, as a rule, only a limited amount of gold can be deposited upon the work, and that the application of this method of gilding, therefore, must be confined to cheap classes of work, or to articles which will not be subjected to much friction in use. In gilding by the separate current, on the other hand, we are enabled to deposit the precious metal not only of any required thickness, but also upon many articles which it would be practically impossible to gild properly by simple immersion in a solution of gold.

Electro-gilding is performed either with hot or cold solutions; but for most practical purposes hot solutions are employed. When gold is deposited from *cold* solutions, the colour of the deposited metal is usually of a yellow colour, and not of the rich orange-yellow tint which is the natural characteristic of fine gold, the deposit, moreover, is more crystalline, and consequently more porous in cold than hot solutions, and is therefore not so good a protective coating to the underlying metal. The gold deposited from hot solutions is not only of a superior colour and of closer texture, but it is also obtained with much greater rapidity; indeed, from the moment the articles are immersed in the gilding bath, all things being equal, the colour, thickness, and rapidity of the deposit are greatly under the control of the operator. In a few seconds of time an article may be gilded of the finest gold colour, with scarcely an appreciable quantity of the precious metal, while in the course of a very few minutes a coating of sufficient thickness may be obtained to resist a considerable amount of wear.

The superior conductivity of hot gilding solutions enables the operator to gild many metallic surfaces, as tin, lead, Britannia metal, and steel, for example, which he could not accomplish satisfactorily with cold solutions; moreover, hot gilding solutions readily dissolve any trace of greasy matter, or film of oxide which may be present on the surface of the work, through careless treatment, and thus clean the surface of the work for the reception of the gold deposit.

Since *cold* gilding solutions are occasionally used in electro-deposition, these will be treated separately, as also the special purposes to which they are applied.

Preparation of Gilding Solutions.—In making up gilding baths from either of the following formulæ, except in such cases as will be specified, the gold is first to be converted into chloride, as before directed; but the actual weight of the pure metal required for each specified quantity of solution will be given in each case.

Of all the solutions of gold ordinarily employed in the operations of electro-gilding by the direct current, the *double cyanide of gold and potassium*, when prepared from pure materials, is undoubtedly the best, and has been far more extensively employed than any other. It is very important, however, in making up gold solutions, to employ the purest cyanide that can be obtained. A very good article, commonly known as "gold cyanide," if obtained from an establishment of known respectability, is well suited to the purpose of preparing these solutions. The following formulæ are those which have been most extensively adopted in practice; but it may be well to state that some persons employ a larger proportion of gold per gallan of solution than that given, a modification which may be followed according to the taste of the operator; but we may say that excellent results have been obtained by ourselves when employing solutions containing much less metal than some extensive firms have been known to adopt.

Gilding Solutions.—I. To make one quart of solution, convert 1½ dwt. of fine gold into chloride as before, then dissolve the mass in about half a pint of distilled water, and allow the solution to rest so that any trace of *chloride of silver* present may deposit. Pour the clear liquor, which is of a yellow colour, into a glass vessel of convenient size, and then dissolve about half an ounce of cyanide in four ounces of cold water, and add this solution, gradually, to the chloride of gold, stirring with a glass rod. On the first addition of the cyanide, the yellow colour of the chloride solution will disappear, and on fresh additions of the cyanide being made, a brownish precipitate will be formed, when the cyanide solution must be added, gradually, until no further precipitation takes place. Since the precipitate is freely soluble in cyanide of potassium, great care must be exercised not to add more of this solution than is necessary to throw down the metal in the form of *cyanide of gold*. To determine the right point at which to stop, the precipitate should now and then be allowed to fall, so that the clear supernatant liquor may be tested with a drop of the cyanide solution, delivered from one end of the glass rod; or a portion of the clear liquor may be poured into a test tube, or other glass vessel, and then tested with the cyanide. If cyanide has been accidentally added in excess, a little more chloride of gold must be added to neutralise it. The precipitate must be allowed to settle, when the supernatant liquor is to be poured off, and the precipitate washed several times with distilled water. Lastly, a little distilled water is to be added to the precipitate, and a sufficient quantity of cyanide solution poured in to dissolve it, after which a little excess of cyanide solution must be added, and the solution then made up to one quart with distilled water. Before adding the final quantity of water, however, it is a good plan, when convenient to do so, to pour the concentrated solution into an evaporating dish, and to evaporate it to dryness, which may be most conveniently done by means of a sand-bath, after which the resulting mass is to be dissolved in one quart of hot distilled water, and, should the solution work slowly in gilding, a little more cyanide must be added. The solution should be filtered before using, and must be worked hot, that is at about 130° Fahr.

II. Take the same quantity of gold, and form into chloride as before, and dissolve in half a pint of distilled water; precipitate the gold with ammonia, being careful not to add this in excess. The precipitate is to be washed as before, but must not be allowed to become *dry*, since it will explode with the slightest friction when it is in that state. A strong solution of cyanide is next added until the precipitate is dissolved. The concentrated solution is now to be filtered, and finally, distilled water added to make one quart. Of course it will be understood that the quantity of solution given in this and other formulæ merely represents the basis upon which larger quantities may be prepared. This solution must *not* be evaporated to dryness.

III. *Becquerel's Solution.*—This is composed of—

Chloride of gold	1 part
Ferrocyanide of potassium . .	10 parts
Water	100 „

The above salts are first to be dissolved in the water; the liquid is then to be filtered; 100 parts of a saturated solution of ferrocyanide of potassium are now to be added, and the mixture diluted with once or twice its volume of water. "In general, the tone of the gilding varies according as this solution is more or less diluted; the colour is most beautiful when the liquid is most dilute, and most free from iron [from the ferrocyanide]. To make the surface appear bright, it is sufficient to wash the article in water acidulated with sulphuric acid, rubbing it gently with a piece of cloth."

IV. *Fizeau's Solutions.* — (1.) 1 part of dry chloride of gold is dissolved in 160 parts of distilled water; to this is added, gradually, solution of a carbonated alkali in distilled water, until the liquid becomes cloudy. This solution may be used immediately. (2.) 1 gramme of chloride of gold and 4 grammes of hyposulphite of soda are dissolved in 1 litre of distilled water.

V. *Wood's Solution.* — 4 ounces (troy) of cyanide of potassium and 1 ounce of cyanide of gold are dissolved in 1 gallon of distilled water, and the solution is used at a temperature of about 90° Fahr., with a current of at least two cells.

VI. *M. de Briant's Solution.*—The preparation of this solution is thus described: "Dissolve 34 grammes of gold in aqua regia, and evaporate the solution until it becomes neutral chloride of gold; then dissolve the chloride in 4 kilogrammes of warm water, and add to it 200 grammes of magnesia; the gold is precipitated. Filter, and wash with pure water; digest the precipitate in 40 parts of water mixed with 3 parts of nitric acid, to remove magnesia, then wash the remaining [resulting] oxide of gold, with water, until the wash-water exhibits no acid reaction with test-paper [litmus-paper]. Next dissolve 400 grammes of ferrocyanide of potassium [yellow prussiate of potash] and 100 grammes of caustic potash in 4 litres of water, add the oxide of gold, and boil the solution about twenty minutes. When the gold is dissolved, there remains a small amount of iron precipitated which may be removed by filtration, and the liquid, of a fine gold colour, is ready for use; it may be employed either hot or cold."

VII. *French Gilding Solutions.*—The following solutions are recommended by Roseleur as those which he constantly adopted in practice —a sufficient recommendation of their usefulness. In the first of these both phosphate and bisulphite of soda are employed, with a small percentage of cyanide. The first formula is composed of—

Phosphate of soda (crystallised) .	60 parts
Bisulphite of soda	10 „
Cyanide of potassium (pure) . .	1 part
Gold (converted into chloride) .	1 „
Distilled or rain water . . .	1,000 parts.

The second formula consists of—

Phosphate of soda	50 parts
Bisulphite of soda . : . .	12½ „
Cyanide of potassium (pure) . .	½ part
Gold	1 „
Distilled water	1,000 parts.

In making up either of the above baths, the phosphate of soda is first dissolved in 800 parts of hot water; when thoroughly dissolved, the solution should be filtered, if not quite clear, and allowed to cool.

The gold having been converted into solid chloride, is next to be dissolved in 100 parts of water, and the bisulphite of soda and cyanide in the remaining 100 parts. The solution of gold is now to be poured slowly, with stirring, into the phosphate of soda solution, which acquires a greenish-yellow tint. The solution of bisulphite of soda and cyanide is next to be added, promptly, when the solution becomes colourless and is ready for use. If the solution of phosphate of soda is not allowed to become cold before the chloride of gold is added, a portion of this metal is apt to become reduced to the metallic state. Roseleur considers it of great importance to add the various solutions in the direct order specified.

The first-named bath is recommended for the rapid gilding of articles made from silver, bronze, copper, and German silver, or other alloys of copper. The second bath is modified so as to be suitable for gilding steel, as also cast and wrought iron *directly*; that is, without being previously coated with copper. The solutions are worked at a temperature of from 122° to 176° Fahr. In working the first bath, Roseleur says, "Small articles, such as brooches, bracelets, and jewellery-ware in general, are kept in the right hand with the conducting wire, and plunged, and constantly agitated in the bath. The left hand holds the anode of platinum wire, which is immersed more or less in the liquor according to the surface of the articles to be gilt. Large pieces are suspended by one or more brass rods, and, as with the platinum anode, are moved about. The shade of the gold deposit is modified by dipping the platinum anode more or less in the liquor, the paler tints being obtained when a small surface is exposed, and the darker shades with a larger surface. Gilders of small articles generally nearly exhaust their baths, and as soon as they cease to give satisfactory results, make a new one, and keep the old bath for coloured golds, or for beginning the gilding of articles, which are then scratch-brushed and finished in a fresh bath. Those who gild large pieces maintain the strength of their baths by successive additions of chloride of gold, or, what is better, of equal parts of ammoniuret of gold and cyanide of potassium." Articles of copper or its alloys, after being properly cleaned, are sometimes passed through a very weak solution of nitrate of mercury before being immersed in the gilding bath.

The above system of working *without* a gold anode is certainly economical for cheap jewellery, or such fancy articles as merely require the *colour* of gold upon their surface; but it will be readily understood that solutions worked with a platinum anode would be useless for depositing a durable coating of gold upon any metallic surface, unless the addition of chloride of gold were constantly made.

VIII. *Gilding Solutions Made by the Battery Process.*—The system of forming gold solutions by electrolysis has much to recommend it; the process is simple in itself; it requires but little manipulation, and in inexperienced hands is less liable to involve waste of gold than the ordinary chemical methods of preparing gilding solutions. A gold bath made by the battery process, moreover, if the cyanide be of good quality, is the purest form of solution obtainable. To prepare the solution, dissolve about 1 pound of good cyanide in 1 gallon of hot distilled water. When all is dissolved, nearly fill a perfectly clean and *new* porous cell with the cyanide solution, and stand it upright in the vessel containing the bulk of the solution, taking care that the liquid stands at the same height in each vessel. Next attach a clean block of carbon or strip of clean sheet copper to the negative pole of a voltaic battery, and immerse this in the porous cell. A gold anode attached to the positive pole is next to be placed in the bath, and the voltaic action kept up until about 1 ounce of gold has been dissolved into the solution, which is easily determined by weighing the gold both before and after immersion. The solution should be maintained at a temperature of 130° to 150° Fahr. while it is under the action of the current.

Another method of preparing gold solutions by the battery process, is to attach a large plate of gold to the positive, and a similar plate of gold or block of carbon to the negative electrode, both being immersed in the hot cyanide solution as above, and a current from 2 Daniell cells passed through the liquid. The negative electrode should be replaced by a clean cathode of sheet German silver for a few moments occasionally, to ascertain whether the solution is rich enough in metal to yield a deposit, and when the solution is in a condition to gild German silver promptly, with an anode surface of about the same extent, the bath may be considered ready for use. The proportion of gold, per gallon of solution, may be greatly varied, from ½ an ounce, or even less, to 2 ounces of gold per gallon of solution being employed, but larger quantities of cyanide must be used in proportion. While the gold is dissolving into the solution, the liquid should be occasionally stirred. The bath should be worked at from 130° to 150° Fahr., the lower temperature being preferable. In making solutions by the battery process, the position of the anode should be shifted from time to time, otherwise it is liable to be cut through at the part nearest the surface of the solution (the *waterline*) where the electro-chemical action is strongest. A good way to prevent this is to punch a hole at each corner of the gold anode, and also a hole midway between each of the corner holes, through which the supporting hook may be successively passed; this arrangement will admit of eight shiftings of the anode. Another plan is to connect a stout platinum wire or a bundle of fine wires to the anode by means of gold solder, and to immerse *the whole* of the anode in the cyanide solution; this is a very good plan for dissolving the gold uniformly, since the platinum is not acted upon by the cyanide. Sometimes gold wires are used to suspend the anode, in which case the wire should be protected from the action of the cyanide by slipping a glass tube or piece of vulcanised india-rubber tubing over it.

IX. *De Ruolz's Solution.*—10 parts of cyanide are dissolved in 100 parts of distilled water, and the solution then filtered; 1 part of cyanide of gold, carefully prepared and well washed, and dried out of the influence of light, is now added to the filtered solution of cyanide. It is recommended that the solution be kept in a closed vessel at a temperature of 60° to 77° Fahr. for two or three days, with frequent stirring, and away from the presence of light.

X. *Cold Electro-gilding Solutions.*—The cold gilding bath is sometimes used for very large objects, as clocks, chandeliers, &c., to avoid the necessity of heating great volumes of liquid. As in the case of hot solutions, the proportions of gold and cyanide may be modified considerably. Any double cyanide of gold solution may be used cold, provided it be rich both in metal and its solvent cyanide of potassium, and a sufficient surface of anode immersed in the bath during electro-deposition. For most practical purposes of cold gilding, the following formulæ are recommended by Roseleur:—

Fine gold	10 parts
Cyanide of potassium of 70 per cent. . .	30 „
Liquid ammonia	50 „
Distilled water	1,000 „

The gold is converted into chloride and crystallised, and is then dissolved in a small quantity of water; the liquid ammonia is now to be added, and the mixture stirred. The precipitate, of a yellowish brown colour, is *aurate of ammonia*, *ammoniuret of gold*, or *fulminating gold*, and is a highly explosive substance, which must not on any account be allowed to become dry, since in that state it would detonate with the slighest friction, or an accidental blow from the glass stirrer. Allow the precipitate to subside, then pour off the supernatant liquor and wash the precipitate several times; since the washing waters will retain a little gold, these should be set aside in order that the metal may be recovered at a future time. The same rule should apply to all washing waters, either from gold or silver precipitates. The aurate of gold is next to be poured on a filter of *bibulous paper*, that is filtering paper specially sold for such purposes. The cyanide should, in the interim, have been dissolved in the remainder of the water. The cyanide solution is now to be added to the precipitate, which it readily dissolves, and this may be conveniently done, if a large filter is used, by pouring it on to the wet precipitate while in the filter, a portion at a time, until the aurate of ammonia has disappeared, and the whole of the cyanide solution has passed through the filter. This will be a safer plan than removing the precipitate from the filter; or the filter may be suspended in the cyanide solution until the aurate is all dissolved. The solution is finally to be boiled for about an hour, to drive off excess of ammonia.

After this solution has been worked for some time it is apt to become weaker in metal, in which case it must be strengthened by additions of aurate of ammonia. For this purpose, a concentrated solution of the gold salt in cyanide of potassium is kept always at hand, and small quantities added to the bath from time to time when necessary. It is preferable to employ good ordinary cyanide in making up the bath, and *pure* cyanide for the concentrated solution.

2. This solution is composed of—

Fine gold	parts
Pure cyanide of potassium . .	20 „
Or commercial cyanide . . .	30 to 40 parts
Distilled water	1,000 parts.

The gold is to be formed into chloride and crystallised, as before, and dissolved in about 200 parts of the water; the cyanide is next to be dissolved in the remainder of the water, and, if necessary, filtered. The solutions are now to be mixed and boiled for a short time. When the solution becomes weakened by use, its strength is to be augmented by adding a strong solution of cyanide of gold, prepared by adding a solution made from 1 part of solid chloride dissolved in a little water, and from 1 to 1½ parts of pure cyanide of potassium, also dissolved in distilled water, the two solutions being then mixed together.

3. This solution consists of—

Ferrocyanide of potassium (yellow prussiate of potash)	20 parts
Pure carbonate of potash	30 „
Sal-ammoniac	3 „
Gold	15 „
Water	1,000 „

All the salts, excepting the chloride of gold, are to be added to the water, and the mixture boiled, and afterwards filtered. The chloride of gold is next to be dissolved in a little distilled water and added to the filtered liquor. Some persons prefer employing the aurate of ammonia in place of the chloride of gold, and sometimes small quantities of prussic acid are added to the bath, to improve the brightness of the deposit; but this acid makes the bath act more slowly.

The deposit of gold from cold solutions varies greatly as to colour. When the bath is in its best working condition, and a brisk current of electricity employed, the gold should be of a pure yellow colour; sometimes, however, it is several shades lighter, being of a pale yellow; it sometimes happens that the gold will be deposited of an earthy grey colour, in which case the articles require to be cautiously scratch-brushed, and afterwards coloured by the or-moulu process to be described hereafter. The proportion of cyanide in these baths should be about twice that of the chloride of gold; but since the cyanide is of variable quality, it may often be necessary to employ an excess, which is determined by the colour of the deposit; if the gold is in excess the deposit may be of a blackish or dark red colour; or if, on the contrary, cyanide preponderates, the operation is slow and the gold of a dull grey colour, and not unfrequently, when the bath is in this condition, the gold becomes re-dissolved from the work in solution, either entirely or in patches.

When the bath is not in good working order, the gold anode must be withdrawn from the solution, otherwise it will become dissolved by the cyanide. It is a "remarkable phenomenon," says Roseleur, "that solutions of cyanides, even without the action of the electric current, rapidly dissolve in the cold, or at a moderate temperature, all the metals, except platinum, and that at the boiling point they have scarcely any action upon the metals."

Observations on Gilding in Cold Baths.—When a pure yellow colour is desired, a newly-prepared double cyanide of gold solution, in which a moderate excess only of cyanide is present, and containing from 1 to 2 ounces of gold per gallon, will yield excellent results with the current from a single Wollaston or Daniell battery; but sufficient anode must be exposed *in the solution* to admit of the deposit taking place *almost* immediately after the article is immersed in the bath. The anode may then be partially raised out of the solution, and the deposition allowed to take place without further interference than an occasional shifting of the object to coat the spot where the slinging wire touches. After the article has been in the bath a minute or so, the operator may assure himself that deposition is progressing satisfactorily by dipping a piece of clean silvered copper wire in the bath and allowing it to touch the object being gilt, when, if the end of the wire becomes coated with gold, he may rest assured that deposition is proceeding favourably. Care must be taken, however, that the deposit is not taking place too rapidily, for it is absolutely necessary that the action should be gradual, otherwise the gold may strip off under the operation of the scratch-brush. If any portions of the work appear patchy or spotted, the pieces must be removed from the bath, rinsed, and well scratch-brushed. As in hot gilding, the plater will find the scratch-brush his best friend when the work presents an irregular appearance.

It is not advisable to employ a current of high intensity in cold gilding; the Wollaston or Daniell batteries, therefore, are most suitable, and when a series of cells are required to gild large surfaces or a considerable number of objects, the poles of the batteries should be connected for *quantity*, that is all the positive electrodes should be connected to the anodes, and all the negative electrodes put in communication with the conducting-rod supporting the work in the bath. After deposition has taken place to some extent, an extra cell may be connected, followed by another, if necessary, and so on; but while only a thin coating of gold is upon the work, the strength of the current should be kept low; deposition takes place more slowly upon gold than upon copper or its alloys, therefore an increase of battery power becomes a necessity after a certain thickness of gold has been deposited. If the current be too weak, on the other hand, the deposit is apt to occur only at the prominent points of the article, and upon those portions which are nearest the anode. It sometimes happens, with newly made baths, that when the articles are shifted to expose fresh surfaces to the anode, the gold already deposited upon the work becomes dissolved off; when such is the case, it generally indicates that there is too great an excess of cyanide in the solution, although the same result may occur if there be too little gold or the current too feeble.

When the gold deposited in a cold bath is of an inferior colour, the article may be dipped in a weak solution of nitrate of mercury until it is entirely white; it is then to be heated to expel the mercury, and afterwards scratch-brushed. Or the article may be brushed over with the "green colour," described in another chapter, and treated in the same way as bad-coloured gilding from hot solutions.

XI. *Ferrocyanide Gilding Solution.*—To avoid the use of large quantities of cyanide of potassium in gilding solutions, the following process has been proposed: In a vessel, capable of holding 4 litres, are dissolved in distilled water 300 grammes of ferrocyanide of potassium, and 50 grammes of sal-ammoniac; 100 grammes of gold, dissolved in aqua regia and evaporated to expel the acid as usual, are dissolved in 1 litre of distilled water. Of this solution, 200 cubic centimetres are added, little by little, to the ferrocyanide solution, when oxide of iron (from the ferrocyanide) is precipitated. The liquid is allowed to cool, and is then filtered and made up to 5 litres, when the bath is ready for use. Since it is not a good conductor, however, and deposits oxide of iron upon the anode, a small quantity of cyanide is added, but not sufficient to evolve hydrocyanic acid on boiling. The bath should be worked at from 100° to 150° Fahr. When the bath ceases to yield a good deposit, 200 c.c. of the gold solution must be added gradually, as before; if it is desired to increase this proportion of gold, one-tenth of the quantity of the other salts must also be added to the bath.

XII. *Watt's Gilding Solution.*—A gilding solution which the author has used very extensively, and which he first adopted about the year 1838, is formed as follows: 1½ pennyweight of fine gold is converted into chloride, as before described, and afterwards dissolved in about ½ pint of distilled water. Sulphide of ammonium is now added gradually with stirring, until all the gold is thrown down in the form of a brown precipitate. After repose the supernatant liquor is poured off, and the precipitate washed several times with distilled water; it is then dissolved in a strong solution of cyanide of potassium, a moderate excess being added as free cyanide, and the solution thus formed is diluted with distilled water to make up one quart. Before using this solution for gilding it should be maintained at the boiling point for about half an hour, and the loss by evaporation made up by addition of distilled water. This bath yields a fine gold colour, and if strengthened from time to time by a moderate addition of cyanide, will continue to work well for a very considerable period; it should be worked at about 130° Fahr. The above solution gives very good results with a Daniell battery, and the articles to be gilt do not require *quicking*, as the deposit is very adherent.

XIII. *Record's Gilding Bath.*—This solution, for which a patent was obtained in 1884, is formed by combining nickel and gold solutions, by which, the patentee avers, a considerable saving of gold is effected. To make this solution, he dissolves 5 ounces of nickel salts in about 2 gallons of water, to which 12 ounces of cyanide of potassium is added, "so that the nickel salts may be taken up quite clear." The solution is then boiled until the ammonia contained in the nickel salts is entirely evaporated. This solution is then added to the ordinary gold solution containing 1 ounce of gold. The proportions given are preferred, but may be varied at will.

CHAPTER XIV.

ELECTRO-DEPOSITION OF GOLD (*continued*).

General Manipulations of Electro-gilding.—Preparation of the Work.—Dead Gilding.—Causes which affect the Colour of the Deposit.—Gilding Gold Articles.—Gilding Insides of Vessels.—Gilding Silver Filigree Work.—Gilding Army Accoutrement Work.—Gilding German Silver.—Gilding Steel.—Gilding Watch Movements.

General Manipulations of Electro-Gilding.—In small gilding operations, the apparatus and arrangements are of an exceedingly simple character, and need not involve more than a trifling outlay. A 12-inch Daniell cell, or a small battery (say a half-gallon cell), constructed as follows, will answer well for gilding such small work as Albert chains, watch cases, pins, rings, and other work of small dimensions. This battery consists of a stone jar, within which is placed a cylinder of thin sheet-copper, having a binding screw attached. Within this cylinder is placed a porous cell, furnished with a plate or bar of amalgamated zinc, to the upper end of which a binding screw is connected. A dilute solution of sulphuric acid is poured into the porous cell, and a nearly saturated solution of sulphate of copper, moderately acidified with sulphuric acid, is poured into the outer cell. This simple battery costs very little, is very constant in action, and may readily be constructed by the amateur or small operator. The gilding bath may consist of one quart of solution, prepared from any of the formulæ given; a square piece of rolled gold, about 2 by 2 inches, weighing about five pennyweights, or even less, will serve for the anode; and an enamelled iron saucepan may be used to contain the solution. Since gilding baths require to be used hot (about 130° Fahr.), except for special purposes, the solution may be heated by means of a small 4-burner oil lamp, such as is shown in Fig. 74, the gilding vessel being supported upon an iron tripod or ordinary meat stand.

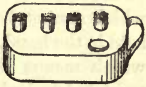

Fig. 74.

With this simple arrangement, it is quite possible to gild such articles as we have named, besides smaller articles, such as brooches, lockets, and scarf-pins; and provided the gold anode be replaced, as it becomes "worn away" in use, and the solution kept up to its normal height by additions of distilled water to make up for loss by evaporation, the same bath will be capable of gilding a good amount of small work. The bath will, however, require small additions of cyanide every now and then, that is when it shows signs of working slowly, or yields a deposit of an indifferent colour; the battery, also, will need proper attention by renewal of the dilute acid occasionally. In working on the small scale referred to, in the absence of a proper scratch-brush lathe, the hand "scratch-brush," Fig. 76, may be resorted to: this consists simply of a single scratch-brush, cut open at one end, and spread out before using, by well brushing it against some hard metal substance; to mollify the extreme harshness of the newly cut brass wire, of which the brush is composed, it may advantageously be rubbed to and fro upon a hard flagstone, after which it should be rinsed before using. To apply the hand scratch-brush, prepare a little warm soap and water, into which the brush must be dipped frequently while being used. In brushing Albert chains or similar work, the swivel may be hooked on to a brass pin, driven into the corner of a bench or table, while the other end of the chain is held in the hand; while thus stretched out, the moistened brush is dipped in the suds, and *lightly* passed to and fro from end to end, and the position of the article must be reversed to do the opposite side; to brush those parts of the links which cannot be reached while the chain is outstretched, the chain is held in the hand, and one part at a time passed over the first finger, by which means the unbrightened parts of the links may be readily scratch-brushed. It is important, in scratch-brushing, to keep the brush *constantly* and freely wetted as above.

Gilding on a somewhat larger scale—say with one or two gallons of gold solution—may be pursued without any very great outlay, and yet enable the gilder to do a considerable amount of work of various kinds and dimensions in the course of an ordinary working day. The arrangement we would suggest may be thus briefly explained: for the battery, a one-gallon Bunsen, or Smee, or an 18-inch Daniell cell; for the anode, two or more ounces of fine gold rolled to about 6 by 3 inches, to which a stout piece of platinum wire, about 4 inches in length, should be attached by means of gold solder. A small binding screw may be employed to connect the platinum wire with the positive electrode of the battery. The object of using platinum wire is to enable *the whole* of the anode to be immersed in the solution when a large surface is necessary, and which could not be properly done if copper wire were used, since this metal (unlike platinum, which is not affected by the solution) would become dissolved by the bath, and affect the colour of the deposit. A simple method of heating the gilding solution and keeping it hot while in use will be seen in the accompanying engraving, Fig. 75. The gilding bath rests upon a short-legged iron tripod, beneath which is a perforated gas burner, supplied with gas by means of flexible india-rubber tubing connected to an ordinary gas-burner. Perforated burners are readily procurable, and are of trifling cost. For brightening small articles the hand scratch-brush referred to (Fig. 76) may be used, but, for the convenience of handling, it should be tied to a stick, to prevent it from bending in the hand. The brush is to be dipped in soap-suds or stale beer frequently while being applied to the work.

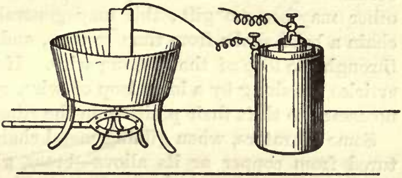

Fig. 75.

In gilding upon the above moderate scale, however, the lathe scratch-brush, described further on, will be as necessary as in still larger operations: an ordinary foot lathe, such as is used in silver plating (which see), is the machine generally used for this purpose, and is of very simple construction. Such lathes, or their chief parts, may often be procured second hand for a very moderate sum. As in scratch-brushing electro-silvered or plated work, stale beer is employed to keep the brushes constantly wet while the lathe is being used, and the work is pressed very lightly against the revolving brushes. It is important, however, when the scratch-brushes are new, that they should have some hard metallic surface pressed against them while in brisk motion for a few minutes, to spread them well out or make them *brushy*, and to reduce the extreme harshness of the newly-cut brass wire; if this precaution be not followed, the gold, if the coating be thin, may become partially removed from the gilt article, rendering its surface irregular and of an indifferent colour, necessitating regilding and scratch-brushing.

Fig. 76.

Preparation of the Work.—In electro-gilding watch chains of various kinds, brooches, lockets, scarf-pins, and other small articles of jewellery, it is generally sufficient to well scratch-brush and rinse them, after which they are at once put into the bath. A preparatory dip in a hot potash bath, however, may be resorted to. After scratch-brushing, a short length of copper "slinging" wire is attached to the article, and the free end is connected to the negative electrode of the battery by simply coiling it around the stouter wire several times; the ends of both wires, however, should previously be cleaned by means of a piece of emery cloth. When the articles are first dipped into the solution, they should be gently moved about, so that the deposit may be regular. Chains should be shifted from their position occasionally, so that those portions which are in contact with each other may become gilt; this may generally be done by giving the chain a brisk shake from time to time, and also by slipping the chain through the loop of the slinging wire. If brooches and other similar articles are slung by a loose loop of wire, gentle shaking is all that is necessary to shift their position on the slinging wire.

Some operators, when gilding metal chains or other work manufactured from copper or its alloys—brass, gilding metal, and German silver—prefer to *quick* them after steeping in the potash bath and scratch-brushing. In this case it will be necessary to have a quicking bath or "mercury dip" always at hand. The mercury dip consists of a very dilute solution of nitrate or cyanide of mercury, and after the articles have been *whitened* in this bath, they must be well rinsed in clean water before being immersed in the gilding bath. The object of mercury dipping is to ensure a perfect adhesion of the gold deposit. The author has never, either in electro-gilding or silvering, found it necessary to apply the quicking process, but the solutions both of gold and silver were not prepared in the same way as those ordinarily adopted by the trade. The solutions which the author worked for a great number years without the aid of the mercurial coating are mentioned in the chapters describing the preparation of gilding and silvering baths.

Dead Gilding.—There are several methods of preparing the work so that the deposit instead of being more or less bright when removed from the gilding-bath,may present a *dead* or *frosted* appearance, which is not only exceedingly beautiful in the rich dulness of its lustre, but is absolutely necessary for certain classes of work, portions of which are relieved by burnishing. To obtain a deposit of a somewhat dead lustre, copper and brass articles are dipped for a moment in a mixture of equal parts of oil of vitrol and nitric acid, to which is added a small quantity of common salt. The articles are slung on a stout wire, coiled into a loop, and dipped in the nitro-sulphuric acid "dip" for an instant, and immediately rinsed in clean water, kept in a vessel close to the dipping acid; if not sufficiently acted upon during the first dip, they must be again steeped for a moment, then rinsed in several successive waters, and at once put into the gilding bath. There should be as little delay a possible in transferring the articles to the gold bath, after dipping and rinsing, since copper and its alloys, after being cleaned by the acid and rinsed, are very susceptible of oxidation, even a very few moments being sufficient to tarnish them. If the mercury dip is employed, the work must be dipped in the quicking bath immediately after they have been rinsed from the acid dip.

The surface of articles may be rendered still more *dead*, or frosted, by slightly brushing them over with finely powdered pumice, or, still better, ordinary bath brick reduced to a powder. By this means the extreme point of dulness, or deadness, may be reached with very little trouble. Work which requires to be burnished after gilding should first be steeped in the potash bath, and after rinsing be well scratch-brushed, or scoured with silver sand, soap, and water, when, after again rinsing in hot water, it is ready for the bath. In scouring the work with sand and soap, it is necessary to use warm water freely; the soap may be conveniently applied by fixing a large piece of this material—say ½ lb. of yellow soap—to the scouring-board by means of four upright wooden pegs or skewers, forming a square about 2½ inches each way, within which the soap may be secured firmly, and will retain its position until nearly used up. By this simple plan the soap, being a fixture, may be rubbed with the scouring-brush, as occasion may require, without occupying a second hand for the purpose.

Causes which Affect the Colour of the Deposit.—In the operation of gilding, the colour of the deposit may be influenced almost momentarily in several ways. Assuming that the current of electricity is neither too strong nor too weak, and the bath in perfect order, if too small a surface of anode is immersed in the bath, the gold deposit will be of a pale yellow colour. Or, on the other hand, if too large a surface of anode is exposed *in solution*, the deposit may be of a dark brown or "foxy" colour, whereas the mean between these two extremes will cause the deposit to assume the rich orange-yellow colour of fine or pure gold. Again, the colour of the deposit is greatly affected by the motion of articles while in the bath; for example, if the gilding be of a dark colour, by briskly moving the articles about in the bath, they will quickly assume the proper colour. The temperature of the solution also affects the colour of the deposit, the tone being deeper as the solution becomes hotter, and *vice versâ*. The colour of the gilding is likewise much affected by the nature of the current employed. A weak current from a Wollaston or Daniell battery may cause the deposit to be of a paler colour than is desired, whereas a Smee, Grove, or Bunsen (but more especially the latter) will produce a deposit of a far richer tone. The presence of other metals in the solution, but copper and silver more particularly, will alter the colour of the deposit, and therefore it is of the greatest importance to keep these metals out of the ordinary gilding solution by careful means. When gilding in various colours is needed, recourse must be had to the solutions described elsewhere, but on no account should the gilding bath used for ordinary work be allowed to become impregnated with even small quantities of any other metal. When we state that trifling causes will sometimes interfere with the natural beauty of the pure gold deposit, the importance of preserving the baths from the introduction of foreign matters will be at once apparent. Another thing that affects the colour of the gilding is the accumulation of *organic matter*, that is, vegetable or animal matter, which is introduced into the bath by the articles immersed in it; thus, greasy matter from polished work, and beer from the scratch-brush, will sometimes lodge in the interstices of hollow work, and escape into the bath even after the articles have been rinsed; each in their turn convey organic matter to the gold solution, by which it acquires a darkened colour; indeed, we have known solutions acquire quite a brown colour from these causes. In our experience, however, the presence of a *small* amount of such foreign matter, in moderation, has often proved of advantage, especially in the gilding of insides of vessels, when a rich and deep-toned gilding is required: a solution in this condition we should prefer, for insides of cream ewers, sugar-bowls, and goblets, to a newly-prepared gold solution; indeed, when a bath works a little *foxy*, it is, to our mind, in the best condition for these purposes, since the former is apt to yield a deposit which is too yellow for such surfaces. There is an extreme, however, which must be avoided, that is when the bath yields a *brown-yellow* deposit, which is very unsightly, though not uncommonly to be seen in our shop windows.

When the gilding upon chains or articles of that class is of a deep brownish-yellow colour when removed from the bath, it will, when scratch-brushed, exhibit a fine gold appearance, specially suited to this class of work, and more like jewellers' "wet colour work" than electro-gilding, which will render it more acceptable to those who are judges of gold colour. Indeed, when the electro-gilding process was first introduced, it was a general complaint amongst shopkeepers that electro-gilding was too yellow, and that electro-gilt work could easily be distinguished from *coloured* gold in consequence, which was admitted to be a serious defect, since a person wearing a gilt article would naturally wish it to be assumed by others to be of gold. In gilding such articles, therefore, the aim of the gilder should be to imitate as closely as possible the colour of gold jewellery, whether it be *dry* or *wet* coloured work. In the latter there is a peculiar depth and softness of tone which is exceedingly pleasing; in dry coloured work a rich dead surface is produced which it is not so difficult to imitate in electro-gilding. The processes of "colouring" articles of gold will be given in another chapter, since a knowledge of these processes is not only useful but often necessary to an electro-gilder, in whose hands such work may sometimes be placed for restoration or recolouring.

Gilding Gold Articles.—Although "painting the lily" would not be a very profitable or successful operation, articles made from inferior gold alloys are frequently sent to the electro-gilder to be "coloured," that is, to receive a slight film of pure gold, to make them look like gold of a superior quality, like *coloured gold*, in fact. Although such an imposition is a positive fraud upon the purchaser, the electro-gilder has little choice in the matter; if his natural scruples would tempt him to refuse such unfair work, as it may be called, he knows full well that others will readily do the work and "ask no questions;" he must therefore undertake it or lose a customer—perhaps an important one. Albert chains, rings, pins, brooches, and a host of other articles manufactured from gold alloys of very low standard, are frequently "coloured" by electro-deposition, simply because the process of colouring by means of the "colouring salts" would *rot* them, if not dissolve them entirely.

Gilding Insides of Vessels.—Silver or electro-plated cream ewers, sugar-basins, mugs, &c., are electro-gilt inside in the following way: The inside of the vessel is first well scratch-brushed, for which purpose a special scratch-brush, called an *end-brush*, is used. Or this surface may be scoured with soap and water with a piece of stout flannel; the vessel, after well rinsing, is then placed upon a level table or bench; a gold anode, turned up in the form of a hollow cylinder, is now to be connected to the positive electrode of a battery, and lowered into the vessel, and supported in this position, care being taken that it does not touch the vessel at any point. The negative electrode is to be placed in contact with the vessel (Fig. 77), and hot gold solution then carefully poured in, up to its extreme inner edge, below the mount, if it have one. A few moments after pouring in the gold solution, the anode should be *gently* moved to and fro, without coming in contact with the vessel itself, so as to render the deposit more uniform; it may then be allowed to remain without interruption for a minute or so, when the gentle movement of the anode may be renewed for a few moments, these alternations of motion and repose being kept up for about five or six minutes—or perhaps a little longer—by which time a sufficiently stout coating is generally obtained. Moving the anode occasionally has the effect of rendering the deposit more regular, while it also exposes fresh surfaces of the solution to the metal surfaces under treatment; great care, how-

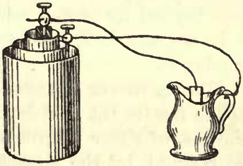

Fig. 77.

ever, is necessary to avoid driving the solution over the ornamental mount on the rim of the vessel. The *lips* of cream ewers, which the gold solution cannot reach when the vessel is filled with solution, are gilt by conducting the solution to such parts in this way: A small gold anode, with a short piece of copper wire attached, is enclosed in a piece of rag or chamois leather; the end of this wire is then connected to the positive electrode (the article itself being in direct contact with the negative), and the pad, or "doctor," as it is sometimes called, is dipped in the gold solution and applied to the part to be gilt; in this way, by repeatedly dipping the pad in the solution and conducting it over the surface, this part in a short time becomes sufficiently gilt; since the lip of a cream ewer, however, is the most important part of the gilt surface, the application of the pad should be continued until a proper coating is obtained, and care must be taken that the point of junction between the two deposits of gold is not visible when the gilding is complete. We should prefer to gild the lip of such vessels first, and after well scratch-brushing, or scouring the interior, and especially the line where the two gildings will meet, then to gild the interior of the body of the vessel, and finally to scratch-brush the whole surface. In gilding the insides of vessels, it is important that the outsides and mounts, or mouldings, should be perfectly dry, otherwise the gold solution may, by *capillary attraction*, pass beyond its proper boundary and gold become deposited where it is not required, thus entailing the trouble and annoyance of removing it.

Gilding Silver Filigree Work.—A *dead* surface of silver is very apt to receive the gold deposit ununiformly, and this is specially so in the case of silver filigree work, the interstices of which cannot fully be reached by the scratch-brush; the surfaces brightened by the scratch-brush readily receive the deposit, while those portions of the article which escape the action of the wire brush will sometimes fail to "take" the gold. When this is found to be the case, a large surface of anode should be immersed in the bath, and the article briskly moved about until the whole surface is coated, when the anode may be partially withdrawn, and a sufficient surface only exposed in the bath to complete the article as usual. In gilding work of this description it is necessary that a fair amount of *free* cyanide should be in the bath, but the excess must not be too great, or the deposit will be *foxy*—a colour which must be strenuously avoided, since the brown tint will be visible more or less upon those interstices (especially the soldered parts) which the scratch-brush cannot reach. As a rule, filigree work should not be risked in an old gold solution in which organic matter or other impurities may be present. It is a good plan, after giving the article a quick coating in the way indicated, to rinse and "scratch" it again, and then to re-immerse it in the bath. A solution for gilding filigree work should also be tolerably rich in gold—about 5 pennyweights to the quart of solution being a good proportion, though some gilders use a still larger proportion of metal. In gilding filigree work a rather intense current is necessary; a Bunsen battery, therefore, should be employed, or two Daniell cells arranged for intensity.

Gilding Army Accoutrement Work.—In the early days of electro-gilding, great difficulty was experienced by electro-gilders in imparting to sword-mounts, the threaded ornamentation of scabbards, and other army accoutrements the rich dead lustre, as the French term it, which the mercury gilders produced with so much perfection, and for a long period electro-gilders, in their anxiety to obtain contracts for gilding this class of work, made many unsuccessful attempts and suffered much disappointment from the repeated rejection of their work by the government authorities. At the period referred to, there was a great desire, if possible, to render the pernicious art of mercury gilding unnecessary, since it was too well known that those engaged in the art suffered severely from the effects of mercurial poisoning, by which their existence was rendered a misery to them, and their lives abbreviated to a remarkable degree. It may be stated, however, that the operations of gilding with an amalgam of gold and mercury were frequently conducted with little or no regard to the dangerous nature of the fluid metal which the workpeople were constantly handling, and the volatilised fumes of which they were as constantly inhaling. It was a happy epoch in the gilding art when deposition of gold by electricity rendered so baneful a process, incautiously practised, comparatively unnecessary. We say comparatively, because amalgam or mercury gilding is still adopted, though with a little better regard to the health of the workmen, for certain classes of work, for which, even up to the present period, electro-gilding is not recognised as a perfect substitute.

To gild army accoutrement work, so as to resemble, as closely as possible, mercury gilding, the *colour* and general appearance of the *matted* or *dead* parts must be imitated very closely indeed. There are no articles of gilt work that look more beautiful by contrast than those in which dead surfaces are relieved by the raised parts and surrounding edges being brightened by burnishing, and this effect is charmingly illustrated in the mountings of the regulation sword of the British officer. Indeed this class of work, when properly finished, may be considered the perfection of beauty in gilding.

To give the necessary *matted* surface to the chased portions of sword mounts, and work of a similar description, these parts should be brushed over with finely-powdered pumice, or bath-brick reduced to a powder and sifted, which latter substance answers the purpose very well. The application of either of these materials should be confined, as far as is practicable, to the chased parts of the article, so as to avoid rendering the surfaces to be afterwards burnished rough by the action of the pumice powder. The plain surfaces of the article may then be scoured with silver-sand, soap and water, or scratch-brushed; but great care must be taken not to allow the scratch-brush to touch the surfaces that are to be left dead. Sometimes it is the practice to add a little aurate of ammonia to the gilding solution to produce a dead lustre in gilt work. When it is preferred to adopt the *quicking* process, in gilding this class of work, the articles, after being quicked in the usual way, are placed in the bath until they have nearly received a sufficient deposit, when they are removed, rinsed, and the chased parts quickly brushed with pumice, as before, after which they are returned to the bath for a short time, or until the proper colour and matted appearance are imparted to the work.

Gilding German Silver.—This alloy of copper, as also brass, will receive a deposit of gold in strong and warm cyanide solutions of gold without the aid of the battery; this being the case, in order to prevent the deposit from taking place too rapidly, when electro-gilding articles made from these alloys, the temperature of the solution should be kept rather low—that is not beyond 120° Fahr.—and only sufficient surface of anode immersed in the solution to enable the article to become gilt with moderate speed when *first* placed in the bath. It is also advisable that the gold solution should be weaker, both in gold and cyanide, than solutions which are used for gilding silver or copper work. If, however, *quicking* be adopted, these precautions are not so necessary, since the film of mercury checks the rapidity of the gilding. Either method may be adopted according to the fancy of the gilder; but for our own part, we would not suffer a particle of mercury to enter the gilding-room (except upon the amalgamated plates of a battery) under any circumstances.

Gilding Steel.—The rapidity with which this metal receives a deposit of gold, even with a very weak battery current, in ordinary cyanide solutions, renders it imperative that a separate solution should be prepared and kept specially for steel articles. We have obtained excellent results by employing a bath composed of

Ordinary double cyanide of gold solution . .	1 part.
Water	4 to 6 parts.

To this weakened solution a small quantity of cyanide of potassium may be added, and the current employed should be of low tension—a Wollaston or Daniell battery being preferable. The temperature of the bath should be warm, but not hot. The surface of anode in solution must be just so much as will enable the gold to deposit soon after the article is placed in the bath, but not immediately after its immersion. In other words, if the gold is allowed to *jump* on, it will most assuredly as quickly jump off when the scratch-brush is applied.

In preparing steel articles for gilding, the author has found that by scratch-brushing the work with vinegar, or very dilute hydrochloric acid, instead of sour beer, a very fine coating of copper (derived from the brass wire of the brushes) has been imparted to the articles, to which the gold deposit, from a weak bath, adhered with great firmness.

A very successful method of gilding steel is to first copper or brass the articles in the alkaline solutions of these metals, as recommended for silvering steel and iron. The brass or copper solutions should be used warm, and be in good working order, so as to yield bright deposits of good colour. Before electro-brassing the articles, however, they must be thoroughly cleansed by scouring with silver-sand, soap and water, or scratch-brushed. Bright steel articles which are not required to have a durable coating of gold, but merely a slight film or "colouring" of the precious metal, generally need no preparation whatever, but may receive a momentary dip in the gilding bath, then rinsed in hot water, and at once placed in hot boxwood sawdust. In doing this cheap class of work, however, it is better to use a copper or platinum anode in place of the gold anode, and to make small additions of chloride of gold when the solution shows signs of becoming exhausted. It must be remembered, however, that the very dilute gold solution we have recommended for gilding steel contains in reality but very little gold, therefore, as it becomes further exhausted by working without a gold anode, additions of the chloride, in very small quantities, will require to be made so soon as the bath exhibits inactivity.

For gilding polished steel, a nearly neutral solution of chloride of gold is mixed with sulphuric ether, and well shaken; the ether will take up the gold, and the ethereal solution float above the denser acid. If the ethereal solution be applied by means of a camel-hair brush to brightly-polished steel or iron, the ether evaporates, and gold, which adheres more or less firmly, becomes reduced to the metallic state on the steel, and may be either polished or burnished.

In gilding upon an extensive scale, where large objects, such as time-pieces, chalices, patens, and other work of large dimensions, have to be gilt, the depositing tanks are generally enamelled iron jacketed pans, heated by steam. These vessels are placed in rows near the wall of the gilding-room, in a good light, and suitable iron piping conveys the steam to the various tanks, each of which is provided with a suitable stopcock to admit or shut off the steam as required; an exit pipe at the bottom of each "jacket" allows the water from the condensed steam to escape into a drain beneath. Each of these tanks is provided with the usual conducting rods, and the current, which is sometimes derived from a magneto or dynamo machine in large establishments, is conveyed by suitable leading wires or rods, attached to the wall at a short distance from the series of depositing vessels. In gilding large quantities of small articles, as steel pens, for example, a considerable number of gilding tanks, of an oblong form, are placed in a row, at a moderate distance apart, and the pens or other small objects are introduced into these as the gilders receive the work prepared for them.

Gilding Watch Movements—Continental Method.—The remarkable beauty of the Swiss watch movements has always been the subject of much admiration, and for a long period this pleasing industry was solely confined to Switzerland; France, however, eventually got possession of the method, and the art has been extensively practised in that country, but more especially at Besançon and Morez, in Jura, and in Paris. M. Pinaire, a gilder at Besançon, generously communicated the process to the late M. Roseleur, to whom we are indebted for the process.

Pinaire's Method of Gilding Watch Movements.—In gilding watch parts, and other small articles for watchmakers, gold is seldom applied directly upon the copper. In the majority of cases there is a preliminary operation, called graining, by which a vary agreeable grained and slightly dead appearance is given to the articles. If we examine carefully the inside of a watch we may see the peculiar pointed dead lustre of the parts.

This peculiar bright dead lustre, if it may be so expressed, is totally different from that ordinarily obtained. For instance, it does not resemble the dead lustre obtained by slow and quick electrodeposition of gold, silver, or copper, which is coarser and duller than that of watch parts. Neither does it resemble the dead lustre obtained with the compound acids, which is the result of a multitude of small holes formed by the juxtaposition, upon a previously even surface, of a quantity of more or less large grains, *always in relief*.

The graining may be produced by different methods, and upon gold, platinum, and silver; and since the latter metal is that preferred we shall describe the process applied to it.

This kind of gilding requires the following successive operations:—

1. *Preparation of the Watch Parts.* — Coming from the hands of the watchmaker, they preserve the marks of the file, which are obliterated by rubbing upon a wet stone, and lastly upon an oilstone.

2. The oil or grease which soils them is removed by boiling the

watch parts for a few minutes in an alkaline solution made of 100 parts of water and 10 of caustic soda or potassa, and rinsing them in clean water, which should wet them thoroughly if all the oil has been removed. The articles are threaded upon a brass wire.

3. A few gilders then cleanse them rapidly by the compound acids for a bright lustre; others simply dry them carefully in sawdust from white wood.

4. *Holding the Parts.*—The parts thus prepared are fastened by means of brass pins with flat heads upon the even side of a block of cork.

5. The parts thus held upon the cork are thoroughly rubbed over with a brush quite free from greasy matters, and charged with a paste of the finest pumice-stone powder and water. The brush is made to move in circles in order not to abrade one side more than the other. The whole is thoroughly rinsed in clean water, and no particle of pumice dust should remain upon the pieces of the cork.

6. Afterwards we plunge the cork and all into a mercurial solution, which very slightly whitens the copper, and is composed of—

Water	10 litres.
Nitrate of binoxide of mercury . .	2 grammes.
Sulphuric acid	4 „

The pieces are simply passed through the solution, and then rinsed. This operation, which too many gilders neglect, gives strength to the graining, which without it possesses no adherence, especially when the watch parts are made of white German silver, dignified by the name of nickel by watchmakers, or when the baths contain tin in their composition.

7. *Graining.*—In this state the parts are ready for the graining—that is to say, a silvering done in a particular manner.

Nothing is more variable than the composition of the graining powders; and it may be said that each gilder has his own formula, according to the fineness of the grain desired.

The following formulæ are used in the works of M. Pinaire:—

Silver in impalpable powder.	30 grammes.
Bitartrate of potassa (cream of tartar) finely pulverised and passed through a silk sieve	300 „
Chloride of sodium (common salt) pulverised and sifted as above	1 kilogramme.

It is stated that the majority of operators, instead of preparing their graining-silver, prefer buying the Nuremburg powder, which is produced by grinding a mixture of honey and silver-foil with a muller upon a ground-glass plate, until the proper fineness is obtained. The silver is separated by dissolving the honey in boiling water, and washing the deposited metal in a filter until there is no remaining trace of honey. The silver is then carefully dried at a gentle heat. This silver, like bronze powder, is sold in small packages:—

Silver powder	30 grammes.
Cream of tartar	120 to 150 „
Common salt (white and clean)	100 „

Or—

Silver powder	30 „
Cream of tartar	100 „
Common salt	1 kilogramme.

All these substances should be as pure as possible, and perfectly dry. Cream of tartar is generally dry, but common salt often needs, before or after it has been pulverised, a thorough drying in a porcelain or silver dish, in which it is kept stirred with a glass rod or a silver spoon.

The mixture of the three substances must be thorough, and effected at a moderate and protracted heat.

The graining is the coarser as there is more common salt in the mixture; and conversely, it is the finer and more condensed as the proportion of cream of tartar is greater; but it is then more difficult to scratch-brush.

8. *The Graining Proper.*—This operation is effected as follows: A thin paste of one of the above mixtures with water is spread by means of a spatula upon the watch parts held upon the cork. The cork itself is fixed upon an earthenware dish, in which a movement of rotation is imparted by the left hand. An oval brush with close bristles is held in the right hand, and rubs the watch parts in every direction, but always with a rotary motion. A new quantity of the paste is added two or three times, and rubbed in the manner indicated. The more we turn the brush and the cork, the rounder becomes the grain, which is a good quality; and the more paste we add, the larger the grain.

The watchmakers generally require a fine grain, circular at its base, pointed at its apex, and close—that is to say, a multitude of juxtaposed small cones. A larger grain may, however, have a better appearance, but this depends on the nature and the size of the articles grained.

9. When the desired grain is obtained, the watch parts are washed and then scratch-brushed. The wire brushes employed also come from Nuremburg, and are made of brass wires as fine as hair. As these wires are very stiff and springy, they will, when cut, bend and

turn in every direction, and no work can be done with them. It is, therefore, absolutely necessary to anneal them more or less upon an even fire. An intelligent worker has always three scratch-brushes annealed to different degrees: one which is *half soft*, or half annealed, for the first operation of uncovering the grain; one *harder*, or little annealed, for bringing up lustre; and one *very soft*, or fully annealed, used before gilding, for removing the erasures which may have been made by the preceding tool, and for scratch-brushing after the gilding. Of course the scratch-brushing operation, like the graining proper, must be done by striking circles, and giving a rotary motion between the fingers to the tool. The cork is now and then made to revolve. After a good scratch-brushing, the grain, seen through a magnifier, should be regular, homogeneous, and with a lustre all over. Decoctions of liquorice, saponaire (soapwort), or Panama wood are employed in this operation.

CHAPTER XV.

VARIOUS GILDING OPERATIONS.

Electro-gilding Zinc Articles.—Gilding Metals with Gold Leaf.—Cold Gilding.—Gilding Silk, Cotton, &c.—Pyro-gilding.—Colour of Electro-deposited Gold.—Gilding in various Colours.—Colouring Processes.—Re-colouring Gold Articles—Wet-Colour Process.—French Wet-Colouring.—London Process of Wet-Colouring.

Electro-gilding Zinc Articles.—About thirty years ago a very important industry was introduced into France, which at once commanded universal admiration, and a rapid sale for the beautiful products which were abundantly sent into the market. We allude to the so-called *electro-bronzes*. These exquisite works of art, many of which would would bear comparison with the finest of real bronzes, were in fact zinc castings or copies from original works of high merit, coated with brass, or, as it was then called, *electro-bronze*, and artificially coloured, so as to imitate as closely as possible the characteristic tone of real bronze. At the time we speak of, articles of every conceivable form, from the stag beetle, mounted upon a leaf, electrotyped from nature, and reproduced in the form of a zinc casting, each object being electro-bronzed, to a highly-finished statuette or massive candelabrum, appeared in our shop windows and show-rooms, and presented a really beautiful and marvellously varied and cheap addition to our rather meagre display of art metal work. It was soon discovered by those who had the taste for possessing bronzes, but not the means to satisfy it, that the imitation bronzes lacked nothing of the beauty of the originals, while they presented the advantage of being remarkably cheap, and thus within the reach of many. The process by which the electro-bronzing upon zinc castings is conducted is considered in another place, and we will now explain how articles of this description, that is zinc castings, may be electro-gilt, and either a bright or dead surface imparted to the work according to the artistic requirements of the article to be treated.

Preparation of Zinc Castings for Gilding.—In order to obtain the best possible results, the zinc casting—presuming it to be a work of art which deserves the utmost care to turn it out creditably—should first be examined for air or sand-holes, and these, if present, must be stopped or plugged with *easy-running* pewter solder, and the spot afterwards touched up so as to resemble the surrounding surface, whether it be smooth or chased. When the whole article has been carefully examined and treated in this way, it is to be immersed for a few minutes only in a moderately strong potash bath, after which it must be well rinsed. It is next to be placed in a weak sulphuric acid pickle, consisting of—

Sulphuric acid	10 parts
Water	100 „

but should not remain in the acid liquor more than a minute or two, after which it is to be thoroughly well rinsed in clean water. The article, having a copper wire attached, is now to be placed in either a cold or warm brassing solution or alkaline coppering bath for a short time, or until it is covered with a thin deposit of either metal. If on removing it from the brassing bath it is found that the soldered spots have not received the deposit, and present a blackish appearance, the article must be well scratch-brushed all over, and again placed in the bath, which, by the way, will deposit more readily upon the solder if the bath be warm, a brisk current employed, and gentle motion given to the article when first placed in the bath. The object, when placed in the bath a second time, should be allowed to remain therein for about half an hour or somewhat longer, by which time, if the solution be in good order, and the current sufficiently active, it will yield a deposit sufficiently thick either for bronzing or gilding. It is a common practice to deposit a slight coating of brass or copper upon zinc-work in a warm solution in the first instance, and then to complete the operation in a cold bath.

When the object is to be left bright, that is merely scratch-brushed, after being coated with copper or brass as above, it is simply gilt in an ordinary cyanide gilding bath, and is then treated in the same way as ordinary brass or copper work. If, however, the article is to be left dead, the following method may be adopted: After being well rinsed, the object is to be immersed in a silvering bath in which it is allowed to remain until it assumes the characteristic white and dead lustre of electro-deposited silver. When the desired effect is produced, the article must be well rinsed in warm (not hot) water and *immediately* placed in a gilding bath which is in a good condition for yielding a deposit of the best possible colour.

Another method, which has been much practised on the Continent, is thus described by Roseleur: "Add to the necessary quantity of water one-tenth of its volume of sulphuric acid, and dissolve in this acid liquor as much sulphate of copper as it will take up at the ordinary temperature. This solution will mark from 20° to 24° Baumé (about 1·1600); now add water to reduce its specific gravity to 16° or 18° B. (about 1·1260). This galvano-plastic* bath is generally contained in large vessels of stoneware, slate, wood, or gutta-percha, and porous cells are immersed in it, which are filled with a weak solution of sulphuric acid and amalgamating salts. Plates or cylinders of zinc are put into these cells, and are connected with one or more brass rods, which rest upon the sides of the vat, and support the articles which are to receive the dead lustre."

The articles of zinc, previously coated with copper or brass in an alkaline solution, are suspended in the above bath until they have acquired the necessary dead lustre, after which they are treated as follows: After being thoroughly well rinsed, they are immersed for a moment in a bath composed of—

Nitrate of mercury . . .	1 part
Sulphuric acid	2 parts
Water	1,000 „

After again rinsing, the articles are steeped in the following solution:—

Cyanide of potassium . . .	40 parts
Nitrate of silver	10 „
Water	1,000 „

The articles are well rinsed after removal from this bath, and are then ready for gilding, the solution recommended for which is composed of—

Phosphate of soda	60 parts
Bisulphite of soda	10 „
Cyanide of potassium . . .	1 to 2 parts
Neutral chloride of gold . . .	2 parts
Water	1,000 „

This bath is used at nearly the boiling point, with an intense voltaic current. The anode consists of platinum wire, which at first is dipped deeply into the solution, and afterwards gradually raised out of the bath, as the article becomes coated with gold, until, towards the end of the operation, but a small surface of the wire remains in the bath. It is said that the colour of the gilding by this method is remarkable for its "freshness of tone." Some operators first gild the article by the *dipping* process before described, and then deposit the requisite quantity of gold to produce a dead surface by the electro process in a bath specially suited to the purpose. Other gilders first half-gild the

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* This term, though never a correct one, is still generally used on the continent to designate the art of electrotyping, or the deposition of copper from its sulphate.

article with the battery, then dip it in the mercury bath, and after well rinsing, finish the operation by a second deposit of gold. In either case, the article is finally well rinsed in warm water, and afterwards dried in hot sawdust or a warm stove. Great care is taken to avoid handling the article so as not to stain it with the fingers, or to scratch it in any way, since the delicate frosted surface is very readily injured. It is also very important that the rinsing, after each operation, should be perfectly carried out, and that the final drying is complete; for if any of the gold solution remain upon any part of the work, voltaic action will be set up between the zinc and copper at the spot, and the article disfigured by the formation of verdigris. The foregoing process is specially applied to articles of zinc, such as clock-cases, &c., which are generally kept under glass, but may be applied to smaller ornamental articles which are not liable to friction in use.

In our own practice we have found when gilding zinc, that the best results were obtained when *all* the various stages of the process, from the first pickling to the drying, were conducted with *rapidity*, the greatest possible attention being devoted to the various rinsing operations. If all baths are in proper order, the various *dips* and electro-deposits should each only occupy from a few seconds to a few minutes, while the drying should be effected with the greatest possible despatch, so that the object, being but thinly coated with metals which are electro-negative to itself, may not be subjected to electro-chemical action in parts owing to the presence of moisture or traces of the gilding solution.

Gilding Metals with Gold Leaf.—Articles of steel are heated until they acquire a bluish colour, and iron or copper are heated to the same degree. The first coating of gold leaf is now applied, which must be gently pressed down with a burnisher, and again exposed to gentle heat; the second leaf is then applied in the same way, followed by a third, and so on; or two leaves may be applied instead of one, but the last leaf should be burnished down while the article is cold.

Cold Gilding.—A very simple way of applying this process is to dissolve half a pennyweight of standard gold in aqua regia; now steep several small pieces of rag in the solution until it is all absorbed; dry the pieces of rag, and then burn them to tinder. To apply the ashes thus left, rub them to a powder, mix with a little water and common salt, then dip a cork into the paste thus formed, and rub it over the article to be gilt.

Gilding Silk, Cotton, &c.—There are several methods by which textile fabrics may be either gilt or silvered. One method is to stretch the fabric tightly upon a frame, after which it is immersed in a solution of acetate of silver, to which ammonia is added until the precipitate at first formed becomes dissolved, and a clear solution obtained.

After immersion in this solution for an hour or two, the thread or fabric is first dried, and then submitted to a current of hydrogen gas, by which the silver becomes reduced and the surface metallised. In this condition it is a conductor of electricity, and may be either gilt or silvered in any ordinary cyanide solution. By another method, the piece of white silk is dipped in an aqueous solution of chloride of gold; it is then exposed to the fumes of sulphurous acid gas, produced by burning sulphur in a closed box, when in a very short time the entire piece will be coated with the reduced metal.

Pyro-gilding.—This process, which is recommended for coating iron and steel, is conducted upon the same principle as pyro-plating, except that the precious metal is deposited in several layers, instead of, as in the former case, depositing the required coating in one operation. The steel article being prepared as recommended for pyro-plating, first receives a coating of gold in the gilding-bath; it is next heated until the film of gold disappears; it is then again gilt, and heated as before, these operations being repeated until the last layer remains fully on the surface.

Colour of Electro-deposited Gold.—It might readily be imagined that gold, when deposited from its solution upon another metal, would necessarily assume its natural colour, that is, a rich orange yellow. That such is not the case is well known to all who have practised the art of gilding, and the fact may easily be demonstrated by first gilding a piece of German silver in a *cold* cyanide solution of gold, and then raising the temperature of the solution to about 130° Fahr. If now a similar piece of metal be gilt in the warm solution, and the two gilt surfaces compared, it will be found that while the deposit from the cold solution is of a pale yellow colour, that obtained by the warm solution is of a deeper and richer hue. The colour of the deposit may also be influenced by the nature of the current, the same solution being used. For example, the gold deposited by the current from a Bunsen battery is generally of a finer and deeper colour than that obtained by the Wollaston battery. In the former case, the superior intensity of the current seems to favour the colour of the deposit. This difference, however, is not so strongly marked in the case of some other gold solutions, as that prepared by precipitating gold with sulphide of ammonium, and redissolving the precipitate with cyanide, for example, which yields an exceedingly good coloured deposit with copper and zinc elements (Wollaston or Daniell). Since the colour of the gold deposit is often of much importance to the electro-gilder, we purpose giving below the various means adopted for varying the colour of the deposit to suit the requirements of what we may term *fancy gilding*.

Gilding in Various Colours.—A very deep coloured deposit of gold may be obtained in an old gold solution, in which organic matter has accumulated from imperfect rinsing of the work after scratch-brushing, and in which there is a good proportion of free cyanide, by employing a strong current and exposing a large surface of anode. In this case the deposit is of a *foxy* colour, as it is termed, and when scratch-brushed exhibits a depth of tone which, while being unsuited for most purposes, may be useful as a variety in some kinds of fancy gilding where a strong contrast of colours is a requisite. The colour of the deposit is also much influenced, as before observed, by the extent of *anode surface* exposed in the bath during the operation of gilding; if a larger surface be exposed than is proportionate to the *cathode surface* (or work being gilt) the colour is dark, whereas when the anode surface exposed is *below* the proper proportion, the deposit will be of a pale colour. *Motion* also affects the colour of the gold deposit—sometimes in a very remarkable degree —the colour being *lighter* when the article is moved about in the solution, and *darker* when allowed to rest. These differences are more marked, however, with old and dark coloured solutions than with recently prepared solutions, or such as have been kept scrupulously free from the introduction of organic impurities.

For ornamental gilding, as in cases where chased or engraved silver or plated work is required to present different shades of colour on its various surfaces, solutions of gold may be prepared from which gold of various tints may be obtained by electro-deposition. These solutions are formed by adding to ordinary cyanide gilding baths varying proportions of silver or copper solution, or both, as also solutions of other metals; but in order to insure uniformity of results, the solutions should be worked with anodes formed from an alloy of the same character; or at least, if an alloy of silver and gold, for example, is to be deposited, an anode of gold and one of silver should be employed in order to keep up the condition of the compound solution.

Green Gold.—This is obtained by adding to a solution of double cyanide of gold and potassium a small proportion of cyanide of silver solution, until the desired tint is obtained. The solution should be worked cold, or nearly so.

Red Gold.—To a solution of cyanide of gold add a small quantity of cyanide of copper solution, and employ a moderately strong current. It is best, in making these additions, to *begin low*, by adding a very small proportion of the copper solution at first, and to increase the quantity gradually until the required tone is obtained, since an excess of the copper solution would produce a deposit of too *coppery* a hue. The tint generally required would be that of the old-fashioned gold and copper alloy with which the seals and watch cases of the last, and earlier part of the present, century were made.

Pink Gold.—This may be obtained by first gilding the article in the usual way, then depositing a slight coating in the preceding bath, and afterwards depositing a mere pellicle of silver in the silvering bath. The operation requires great care to obtain the desired pink tint. The article is afterwards burnished; but since the silver readily becomes oxidised (unless protected by a colourless varnish) the effect will not be of a permanent character.

Pale Straw-coloured Gold.—Add to an ordinary cyanide solution a small quantity of silver solution, and work the compound solution *cold*, with a small surface of anode and a weak current.

Colouring Processes.—When the gilding is of an inferior colour it is sometimes necessary to have at command some method by which the colour may be improved. There are several processes by which this may be effected, but in all cases there must be a sufficient coating of gold upon the article to withstand the action of the materials employed. This condition being fulfilled, the artificial colouring processes may be applied with advantage, and gold surfaces of great beauty obtained. Of the processes given below, the first formula will be found exceedingly useful, since it may be applied to work which, though fairly well gilt, need not be so stoutly coated as is necessary when employing the second formula. It is specially useful for bringing up a good colour upon brooches, albert chains, and small articles generally. It is technically known by the name "green colour," and is composed as follows:—

	ozs.	dwts.	grs.
I. Sulphate of copper	0	2	0
French verdigris	0	4	12
Sal ammoniac	0	4	0
Nitre	0	4	0
Acetic acid (about)	1	0	0

The sulphate of copper, sal ammoniac, and nitre are first to be pulverised in a mortar, when the verdigris is to be added and well mixed with the other ingredients. The acetic acid is then to be poured in, a little at a time, and the whole well worked up together, when a thin mass of a bluish green colour will result. The article to be coloured is to be dipped in the mixture and then placed on a clean piece of sheet copper, which is next to be heated over a clear fire, until the compound assumes a dull black colour; it is now allowed to cool, and is then plunged into a tolerably strong sulphuric acid pickle, which soon dissolves the colouring salts, leaving the article of a fine gold colour. It is generally advisable to well scratch-brush the article before colouring, when it will come out of the pickle perfectly bright. When removed from the pickle, the article must be well rinsed in hot water, to which a small quantity of carbonate of potash should be added; it should next be brushed with warm soap and water, a soft brush being employed, and again rinsed in hot water, after which it may be placed in warm box sawdust, being finally brushed with a long-haired brush.

II. When the work is strongly gilt, but of an indifferent colour, the following mixture may be used:—

Powdered alum	3 ounces
„ nitre	6 „
„ sulphate of zinc	3 „
„ common salt	3 „

These ingredients are to be worked up into a thickish paste, and the articles brushed over with it; they are then to be placed on a piece of sheet iron, and heated over a clear charcoal or coke fire until they become nearly black; when cool they are to be plunged into dilute muriatic or sulphuric acid pickle.

Recolouring Gold Articles.—It not unfrequently happens that an electro-gilder is required by his customers to renovate articles of gold jewellery, so as to restore them to the original condition in which they left the manufacturers. Although it has been the common practice, with some electro-gilders, to depend upon their baths to give the desired effect to what is called "coloured" jewellery, in some cases it would be better to apply the methods adopted by goldsmiths and jewellers for this purpose, by which the *exact* effect required can be more certainly obtained. There are two methods of colouring gold articles; namely, "dry colouring," which is applied to articles made from 18-carat gold and upwards, and "wet-colouring," which is adopted for alloys of gold below that standard, but seldom lower than 12-carat.

The mixture for *dry-colouring* is composed of

Nitre	8 ounces
Alum	4 „
Common salt	4 „
	16 „

Or the following:—

Sal ammoniac	4 ounces
Saltpetre	4 „
Borax	4 „
	12 „

The ingredients must first be reduced to a powder, and then put into an earthen pipkin, which is to be placed over a slow fire to allow the salts to fuse *gradually*; to assist this, the mixture should be stirred with an iron rod. When the fused salts begin to *rise* in the vessel, the pieces of work, suspended by a fine silver or platinum wire, should be at once immersed, and kept moved about until the liquid begins to sink in the colouring-pot, when the work must be removed, and plunged into clean muriatic acid pickle, which will dissolve the adhering salts. The colouring mixture will again rise in the pot, after the withdrawal of the work, when it may be reimmersed (when dry) for a short time, and then pickled as before; it is then to be rinsed in a weak solution of carbonate of soda or potash, and afterwards well washed in hot soda and water, next in clean boiling water, and finally put into warm box sawdust to dry. Previous to colouring the work, it should be highly polished or burnished, although the latter operation may be performed *after* the work has been coloured; the former method is, however, the best, and produces the most pleasing effect.

Wet-colouring Process.—This is applied to gold articles made from alloys *below* 18-carat, and though there are many formulæ adopted for colouring gold of various qualities below this standard, we must limit our reference to one or two only, and for ample information upon this subject direct the reader's attention to Mr. Gee's admirable *Goldsmith's Handbook.** The ordinary "wet colour," as the jewellers term it, consists chiefly in adding a little water to the ingredients formerly given, the proportions of the salts being generally about the same; that is, nitre 8 ounces, alum and common salt of each 4 ounces. These ingredients being reduced to a fine powder and mixed together, are worked up into a thick paste with a little hot water in a good-sized pipkin or crucible, which is placed over a slow fire and heated gradually, the mixture being stirred with a wooden spoon until it boils up. The work is now to be introduced as before and allowed to remain for several minutes, when it must be withdrawn and plunged into boiling water, which will dissolve the colouring salts and show how far the colouring has progressed. When the mixture exhibits a tendency to boil dry, an occasional spoonful of hot water must be added to thin it, but never while the work is in the pot. When the work is first put into the colour it becomes nearly black, but assumes a lighter tone after each immersion until the characteristic colour of fine gold is obtained. When the operation is complete, the work will bear a uniform appearance, though somewhat dead, and may be brightened by burnishing or scratch-brushing. After each dipping the work must be well rinsed in clean boiling water. It must be finally plunged into hot water, and, after well shaking, be put into warm boxwood sawdust.

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* "The Goldsmith's Handbook," by George E. Gee, 2nd edition, 1881. Crosby Lockwood and Co.

French Wet Colouring.—The formula for this is:—

Saltpetre	8 ounces
Common salt	4 „
Alum	4 „

The ingredients must be finely pulverised, as before, and intimately mixed; they are then to be put into a good-sized pipkin or crucible, and sufficient hot water added to form the whole into a thick paste. The mixture should be slowly heated, and stirred with a wooden spoon, when it will soon boil up. The work is then to be immersed for several minutes, then withdrawn and plunged into boiling water, which, dissolving the salts, will allow the work to be examined, when, if not of a sufficiently good colour, it must be reimmersed for a short time. As the mixture thickens by evaporation small quantities of boiling water must be added occasionally, but only after the work has been withdrawn. On the first immersion the work assumes a blackish colour, but at each successive immersion it becomes lighter, as the baser metals become removed from the surface of the work, until it finally assumes the characteristic colour of fine gold. This process should be applied to gold of less than 16 carats.

London Process of Wet Colouring.—For gold of not less than 15 carats the following mixture is used:—

Nitre	15 ounces
Common salt	7 „
Alum	7 „
Muriatic acid	1 „
	30

The salts are to be powdered, as before; into a crucible about 8 inches high and 7 inches in diameter, put about two spoonfuls of water, then add the salts, place the crucible on the fire, and heat gradually until fusion takes place, keeping the mixture well stirred with a wooden spoon. The article, which should first be boiled in nitric acid pickle, is then to be suspended by a platinum wire, and immersed in the fused mixture for about five minutes, then withdrawn and steeped in boiling water. The muriatic acid is now to be added to the mixture, and when it again boils up the article is to be immersed for about five minutes, then again rinsed in boiling water. A spoonful of water is now to be added to the mixture, and the work again put in for about three minutes, and again rinsed; now add two spoonfuls of water to the mixture, boil up, and immerse the work for two minutes, and rinse again. Finally, add about three spoonfuls of water, and, after boiling up, put in the work for one minute, then rinse in abundance of clean boiling water, when the work will present a beautiful colour. The work should then be rinsed in a very dilute hot solution of potash, and again in clean boiling water, after which it should be placed in clean, warm boxwood sawdust.

CHAPTER XVI.

MERCURY GILDING.

Preparation of the Amalgam.—The Mercurial Solution.—Applying the Amalgam—Evaporation of the Mercury.—Colouring.—Bright and Dead Gilding in Parts—Gilding Bronzes with Amalgam.—Ormoulu Colour. -Red-Gold Colour.—Ormoulu. — Red Ormoulu.—Yellow Ormoulu.—Dead Ormoulu.—Gilders' Wax.—Notes on Gilding.

ALTHOUGH the process of gilding metals with an amalgam of gold and mercury, or quicksilver, is not, strictly speaking, an electro-chemical art, it is important that this system of gilding should be known to the electro-gilder for several reasons: it is the chief process by which metals were coated with gold before the art of electro-gilding was introduced; it is still employed for certain purposes, and many articles of silver which have been mercury gilt occasionally come into the electro-depositor's hands for regilding, and which are sometimes specially required to be subjected to the same process, when the voltaic method is objected to.

Mercury-gilding, formerly called wash-gilding, water-gilding, or amalgam-gilding, essentially consists in brushing over the surface of silver, copper, bronze, or brass, an amalgam of gold and quicksilver, and afterwards volatilising the mercury by heat. By repeated applications of the amalgam and evaporation of the mercury, a coating of gold of any desired thickness may be obtained, and when properly carried out the gilding by this method is of a far more durable character than that obtained by any other means. As we have before observed, the process, unless conducted with great care, is a very unhealthy one, owing to the deleterious nature of the fumes of mercury to which the workmen are exposed, if these are not properly carried off by the flue of a suitable furnace.

Preparation of the Amalgam.—Mercury, as is well known, has the peculiar property of alloying or amalgamating itself with gold, silver, and some other metals and alloys, with or without the aid of heat. To prepare the amalgam of gold for the purpose of mercury gilding, a weighed quantity of fine or standard gold is first put into a crucible and heated to dull redness. The requisite proportion of mercury—8 parts to 1 part of gold—is now added, and the mixture is stirred with a slightly crooked iron rod, the heat being kept up until the gold is entirely dissolved by the mercury. The amalgam is now to be poured into a small dish about three parts filled with water, in which it is worked about with the fingers under the water, to squeeze out as much of the excess of mercury as possible. To facilitate this, the dish is slightly inclined to allow the superfluous mercury to flow from the mass, which soon acquires a pasty condition capable of receiving the impression of the fingers. The amalgam is afterwards to be squeezed in a chamois leather bag, by which a further quantity of mercury is liberated; the amalgam which remains after this final treatment consists of about 33 parts of mercury and 57 of gold in 100 parts. The mercury which is pressed through the bag retains a good deal of gold, and is employed in preparing fresh batches of amalgam. It is very important that the mercury employed for this purpose be pure. The gold employed may be either fine or standard, but water-gilders generally use the metal alloyed either with silver or copper; if to be subjected to the after process of *colouring*, standard alloys should be employed, since the beauty of the colouring process depends upon the removal, chemically, of the inferior metals, silver, copper, or both, from the alloy of gold, leaving the pure metal only upon the surface. The amalgam is crystalline, and produces a peculiar crackling sound when pressed between the fingers close to the ear.

It is usual to keep a moderate supply of gold amalgam in hand when mercury-gilding forms part of the gilder's ordinary business, and the compound is divided into a series of small balls, which are kept under water; it is not advisable, however, to allow the amalgam to remain for a long period before being employed, since a peculiar phenomenon known as *liquation* takes place, by which the amalgam loses its uniformity of composition, the gold being more dense in some parts than in others.

The Mercurial Solution.—To apply the amalgam, a solution of nitrate of mercury is employed, which is prepared by dissolving, in a glass flask, 100 parts of mercury in 110 parts of nitric acid of the specific gravity 1·33, gentle heat being applied to assist the chemical action. The red fumes which are given off during the decomposition must be allowed to escape into the chimney, since they are highly deleterious when inhaled. When the mercury is all dissolved, the solution is to be diluted with about 25 times its weight of distilled water, and bottled for use.

Applying the Amalgam.—The pasty amalgam is spread with the blade of a knife, upon a hard and flat stone called *the gilding stone*, and the article, after being well cleaned and scratch-brushed, is treated in the following way: the gilder takes a small scratch-brush, formed of stout brass wire, which he first dips in the solution of nitrate of mercury, and then next draws it over the amalgam, by which it takes up a small quantity of the composition; he then passes the brush carefully over the surface to be gilt, repeatedly dipping the brush in the mercurial solution and drawing it over the amalgam until the entire surface is uniformly and sufficiently coated. The article is afterwards well rinsed and dried, when it is ready for the next operation.

Evaporation of the Mercury.—For this purpose a charcoal fire, resting upon a cast-iron plate, has been generally adopted, a simple hood of sheet iron being the only means of partially protecting the workmen from the injurious effects of the mercurial vapours. M. D'Arcet, of Paris, invented a furnace, or forge, with an arrangement by which the workman could watch the progress of his work through glass, and thus escape the injurious effects of the mercury vapours. The difficulty of seeing the process clearly, however, during the more important stages of the operation (owing doubtless to the condensation of the mercurial vapour upon the glass), caused the arrangement to be disapproved by those for whose well-being it was specially designed, and the simple hood, regardless of its fatal inadequacy, is still preferred by many mercury gilders. When the amalgamated article is rinsed and dried, the gilder exposes it to the glowing charcoal, turning it about, and heating it by degrees to the proper point; he then withdraws it from the fire by means of long pincers or tongs, and takes it in his left hand, which is protected with a leather or padded glove, and turns it over the fire in every direction, and while the mercury is volatilising, he strikes the work with a long-haired brush, to equalise the amalgam coating, and to force it upon such parts as may appear to require it.

When the mercury has become entirely volatilised, the gilding has a dull greenish-yellow colour, and the workman examines it to ascertain if the coating is uniform; if any bare places are apparent, these are touched up with amalgam, and the article again submitted to the fire, care being taken to expel the mercury gradually.

Colouring.—The article is next well scratch-brushed, when it assumes a pale greenish colour; it is afterwards subjected to another heating to expel any remaining mercury, when, if sufficient amalgam has been applied, it acquires the characteristic orange-yellow colour of fine gold. It is next submitted to the process of *colouring*. If required to be bright, the piece of work is burnished in the ordinary way, or, according to the nature of the article, is subjected to the ormoulu process described further on. When the surface is required to be dead, or frosted, the article is treated somewhat in the same way as "dry coloured" gold jewellery work, that is, it is brushed over with a hot paste composed of common salt, nitre, and alum, fused in the water of crystallisation of the latter, after which it is heated upon a brisk charcoal fire, without draft, and moved about until the salts become first dried and then fused; the article is then plunged into a vessel containing a large quantity of cold water, in which the colouring salts are dissolved, and the dead or matted appearance of the work becomes at once visible. When applying the amalgam for dead gilding, great care must be exercised to insure a sufficiently stout coating of gold upon the work, otherwise the colouring salts will surely attack the underlying metal. When about to colour the work as above, the operator binds the article by means of iron wire to a short rod of the same metal; he then either dips the article in the colouring paste or applies it with a brush, and after gently drying it, holds the piece over the fire until the perfect fusion of the composition has taken place, when it is at once dipped in water. The coloured marks left by the wire are removed by a weak solution of nitric acid.

Bright and Dead Gilding in Parts.—When it is desired to have some parts of an article burnished and other parts left dead, the former are protected by a mixture of Spanish white (pure white chalk), bruised sugar candy, and either gum or glue, dissolved in water. The mixture of alum, nitre, and common salt is then applied to the parts to be left dead, the article afterwards dried, and heated over the charcoal fire as before until the dried salts have been fused, when it is at once plunged into cold water, and subsequently in dilute nitric acid, being finally well rinsed and dried. The protected parts are then subjected to the operation of burnishing, when the article is complete.

Another method adopted in France, in which electro-gilding takes a part, is described as follows: Those parts which are intended for a dead lustre are first gilt with the amalgam; the article is then heated, scratch-brushed, and re-heated to the orange-yellow colour. Then, with the battery, a sufficiently strong gold deposit is given to the whole, without regard to the parts already mercury-gilt. All the surfaces are next carefully scratch-brushed, and the electro-gilt portions are brushed over, first with a thin mixture of water, glue, and Spanish white, and afterwards with a thick paste of yellow clay. After drying, the mercury-gilt portions are covered with the paste for dead-gilding (alum, nitre, &c.), and the article heated until the salts fuse, when it is plunged into water and treated as above.

Roseleur, however, considers this method open to several objections, among which is, red spots are apt to be produced upon such places as may have been too much heated, or where the gold has not been sufficiently thick. He recommends the following by preference: "Gild with amalgam, and bring up the dead lustre upon those portions which are to receive it, and preserve [protect] them entirely with a stopping-off varnish. After thorough drying, cleanse the object by dipping it into acids in the usual manner, and gild in the electro-bath. The varnish withstands all these acids and solutions. When the desired shade is obtained, dissolve the varnish with gazoline or benzine, which, unless there has been friction applied, do not injure in any way either the shade or velvety appearance of the dead lustre. Wash in a hot solution of cyanide of potassium, then in boiling water, and allow to dry naturally. . . . Gilding with dead lustre, whatever process be employed, suits only those objects which will never be subjected to friction; even the contact of the fingers injures it."

Gilding Bronzes with Amalgam.—The article is first annealed very carefully, as follows: The gilder sets the piece upon burning charcoal, or peat, which yields a more lively and equal flame, covering it up so that it may be oxidised as little as possible, and taking care that the thinner parts do not receive an undue amount of heat. This operation is performed in a dark room, so that the workman may see when the desired cherry-red heat is reached. He then lifts the piece from the fire, and sets it aside to cool in the air gradually. When cold, the article is steeped in a weak sulphuric acid pickle, which removes or loosens the coating of oxide. To aid this he rubs it with a stiff and hard brush. When the article has been thus rendered bright, though it may appear uniform, it is dipped in nitric acid and rinsed, and again rubbed with a long-haired brush. After washing in clean water, it is dried in hot sawdust or bran. This treatment somewhat reduces the brightness of the surface, which is favourable to the adhesion of the gold. The amalgam is next applied with the scratch-brush, as before, and the object then heated to expel the mercury. If required to be dead, it is treated with the colouring-salts, as before described.

Ormoulu Colour.—To obtain this fine colour upon bronze or other work, the gilt object is first lightly scratch-brushed, and then made to *come back again*, as it is termed, by heating it more strongly than if it were to be left dead, and then allowed to cool a little. The ormoulu colouring is a mixture of hematite (peroxide of iron), alum, and sea-salt, made into a thin paste with vinegar, and applied with a brush until the whole of the gilded surface is covered, except such parts as are required to be burnished. The object is then heated until it begins to blacken, the proper heat being known by water sprinkled over it producing a hissing noise. It is next removed from the fire, plunged into cold water, and washed, and afterwards rubbed with a brush dipped in vinegar if the object be smooth, but if it be chased, dilute nitric acid is employed for this purpose. The article is finally washed in clean water, and dried at a gentle heat.

Red Gold Colour.—To produce this colour, the composition known as *gilders' wax* is used. The article, after being coated with amalgam, is heated, and while still hot is suspended by an iron wire, and coated with gilders' wax, a composition of beeswax, red ochre, verdigris, and alum. It is then strongly heated over the flame of a wood fire; sometimes small quantities of the gilders' wax are thrown into the fire to promote the burning of the fuel. The object is turned about in every direction, so as to render the action of the heat uniform. As soon as all the wax has become burnt off, the flame is put out, and the article plunged into cold water, well washed, and brushed over with a scratch-brush and pure vinegar. Should the colour not be uniform or sufficiently good, the article must be coated with verdigris dissolved in vinegar, dried over a gentle fire, then plunged into cold water and brushed over with vinegar; and if the colour is of too deep a tone, dilute nitric acid may be substituted for the vinegar. After well washing, the article is burnished, then again washed, and finally wiped with soft linen rag, and lastly dried at a gentle heat.

Ormoulu.—The beautiful surface noticeable on French clocks and other ornamental work is produced by the process called *ormoulu*. The article is first gilt, and afterwards scratch-brushed. It is then coated with the thin paste of saltpetre, alum, and oxide of iron before mentioned, the ingredients being reduced to a fine powder, and worked up into a paste with a solution of saffron, annatto, or other colouring matter, according to the tint required, whether red or yellow. When the gilding is strong, the article is heated until the coating of the above mixture curls over by being touched with a wet finger. But when the gilding is only a slight film of gold, the mixture is merely allowed to remain upon the article for a few minutes. In both cases, the article is quickly washed with warm water containing in suspension a certain quantity of the materials referred to. The article must not be dried without washing. Such parts as may have acquired too deep a colour are afterwards struck with a brush made with long bristles. By a series of vertical strokes with the brush the uniformity of surface is produced. If the first operation has not been successful, the colouring is removed by dipping the article in dilute sulphuric acid, and after well rinsing, the operation is repeated until the desired effect is obtained.

Red Ormoulu is produced by employing a mixture composed of alum and nitre, of each 30 parts; sulphate of zinc, 8 parts; common salt, 3 parts; red ochre, 28 parts; and sulphate of iron, 1 part. To this may be added a small quantity of annatto, madder, or other colouring matter, ground in water.

Yellow Ormoulu is produced by the following: red ochre, 17; potash alum, 50; sulphate of zinc, 10; common salt, 3; and saltpetre 20 parts, made up into a paste as before.

Dead Ormoulu, for clocks, is composed of saltpetre, 37; alum, 42; common salt, 12; powdered glass and sulphate of lime, 4; and water, 5 parts. The whole of these substances are to be well ground and mixed with water.

Gilders' Wax, for producing a rich colour upon gilt work, is made from oil and yellow wax, of each 25 parts; acetate of copper, 13 parts; and red ochre, 37 parts. The oil and wax are to be united by melting, and the substances, after being well pulverised, added gradually.

Notes on Gilding.—When gilding single small articles, it is a good plan to hold the anode by its conducting wire in the left hand, so as to be able to control the amount of surface to be immersed in the bath, which must be considerably less (with hot solutions especially) than that of the article to be gilt. The object being slung by thin copper wire, the free end of the wire is to be twisted round the negative electrode (the wire issuing from the zinc of the battery), and the article then dipped into the bath. The article should *gradually* become coated, that is, in a few seconds, but not *immediately* after it is immersed. *Gentle motion* will secure an uniform deposit. After the article has become gilt all over, the anode may be lowered a little deeper into the bath, and the gentle motion of the article kept up for a short time, say from three to five minutes, or until it appears to be fairly coated. The length of time the article is to remain in the bath must be regulated by the price to be paid for the gilding. If a really good gilding is required, it may be necessary, after about five minutes' immersion, to rescratch-brush the article, dip it in the mercurial solution for a moment, or until it is white, and then, after well rinsing, give it a second coating. Ordinary gilding, however, is generally accomplished in a single immersion.

1. *Gilding Jewellery Articles.*—Chains, brooches, rings, pins, and other small articles of silver or metal jewellery should first be slung upon thin copper wire, then dipped for a few moments only in a warm potash bath. The articles are then to be rinsed in warm water and scratch-brushed, after which they are again rinsed, and at once immersed in the gold bath. When sufficiently gilt, the work should be rinsed in a vessel kept specially for the first rinsing, which should be saved, and afterwards in clean water. It is then to be properly scratch-brushed, and plunged into hot water; next shaken about to remove as much water as possible, and finally put into warm boxwood sawdust. After moving it about in the boxdust for a few moments, the article requires to be shaken or knocked against the palm of the hand, to dislodge the sawdust. It is now ready to be wrapped up for the customer, pink tissue paper being preferable for gilt work, and blue or white tissue paper for silver or plated work.

2. *Treatment of Gilding Solutions.*—When the gilding bath has been

heated for a few hours, it will have lost a considerable proportion of its water, which must be made up by adding an equivalent of hot water. If this is not done, the bath, being stronger than it was originally, will probably yield a non-adhering deposit, and the gold may strip off the work under the scratch-brush. The solution should be kept up to its standard height in the gilding vessel by frequent additions of hot water during the whole time it is subjected to evaporation by the gas-burner, or other heating medium. The solution-line of the bath should be marked upon the inside of the vessel when the liquid is first poured in.

4. *Gilding different Metals.*—Silver and metal articles should not be slung upon the same wire and immersed in the bath at the same time, since brass, gilding metal, and copper receive the deposit more readily than silver. The latter metal should first receive a coating, after which, if time is an object, the metal articles may be placed in the bath with the partly-gilt silver articles.

5. *Employment of Impure Gold.*—When it is desired to make up a gold solution from impure material, as from "old gold," for instance, the alloy should first be treated as follows: To 1 ounce of the alloyed gold, if of good quality—say 18-carat gold, for example—add 2 ounces of silver, which should not be below *standard*; melt them in a crucible with a little borax, as a flux. When the alloy is thoroughly melted it is to be poured into a deep vessel containing cold water, which must be briskly stirred *in one direction*, while the molten alloy is being poured in. This operation, termed *granulation*, causes the metal to assume the form of small lumps, or *grains*, as they are called. The water is now to be poured off and the grains of alloy collected and placed in a flask, such as is shown in Fig. 70. To remove the silver and copper from the granulated metal, a mixture of two parts water and one part strong nitric acid is poured into the flask, which is then placed on a sand-bath, moderately heated, until the red fumes which at first appear have ceased to be visible in the bulb of the vessel. The clear liquid is now to be carefully poured off into a suitable vessel—a glass "beaker," such as is shown in Fig. 78, being a convenient vessel for the purpose. A small quantity of the dilute acid should then be poured into the flask, and heat again applied, in order to remove any remaining copper or silver. If, on the addition of the fresh acid, red fumes do not appear in the flask the operation is complete, and the grains of metal will have assumed a dark brown colour. The acid must now be poured off, and the grains well washed, while in the flask, with distilled water. The residuum is pure gold and

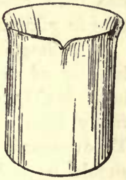

Fig. 78.

may be at once dissolved in aqua regia, and treated in the same way as recommended for ordinary grain gold. The silver may readily be recovered from the decanted liquor, which, owing to the presence of copper removed from the original alloy, will be of a green colour, by immersing in it a strip of stout sheet copper, which in the course of a few hours will reduce the silver to the metallic state, in the form of a grey, spongy mass. When all the silver is thus thrown down, the green liquor is to be poured off and the silver deposit well washed with hot water. Being now pure silver, it may be used for making up solution, or fused with dried carbonate of potash into a button.

6. *Gilding Filigree Work.*—Silver filigree work which has been annealed and pickled assumes a dead-white surface, which does not readily "take" the gilding unless the bath is rich in gold and free cyanide, and the current strong. If such parts of the article as can be reached by the scratch-brush are brightened by this means, the interstices which have escaped the action of the brush will sometimes be troublesome to gild, while the brightened parts will readily receive the deposit. In this case, if the bath is wanting in free cyanide, an addition of this substance must be made, and the article must be kept rather briskly moved about in the solution, and a good surface of anode immersed until the dead-white portions of the article are gilt. The anode may then be raised a little, and the piece of work allowed to rest in the bath, without movement, until the desired colour and thickness of coating are obtained. Some persons prefer dipping this kind of work in the mercury solution before gilding, by which a more uniform deposit is obtained. This plan is useful when the gold bath has been recently prepared. It must not be forgotten, however, that in gilding filigree work the battery current must be brisk.

7. *Gilding Insides of Vessels.*—It sometimes happens, when gilding the interior of silver or electro-plated tankards, mugs, &c., which have been highly embossed or chased, that the gold, while depositing freely upon the prominent parts, refuses to deposit in the hollows. To overcome this, and to render the deposit uniform, the solution should be well charged with free cyanide; the current must be of high tension (a Bunsen, for example), and the anode should be kept in motion during the first few moments. In this way very little trouble will be experienced from the causes referred to. It is important, however, that insides of such embossed work should be very thoroughly scratch-brushed in the first instance; indeed, as a mechanical assistant, the scratch-brush lathe is the gilder's best friend.

8. *Old Solutions.*—When a gold solution has been much used it acquires a dark colour, from being contaminated by impurities as beer from the scratch-brush lathe, &c., and in this condition is likely to yield a deposit of a dull red-brown colour, which,

while being favourable to certain classes of work which can be readily *got at* by the scratch-brush, is very objectionable to articles of jewellery which are required to present a clear orange-yellow colour in all parts, including the interstices and soldered joints which cannot be reached by the lathe-brush. When the solution is in this condition we have found it advantageous to evaporate it to dryness, then to re-dissolve it in hot distilled water, filter the solution when cold, and add a small proportion of free cyanide, finally making up the bath to about three-fourths of its original volume. The solution thus treated yields a very rich colour in gilding. It is necessary to mention, however, that gold solutions which have been prepared by precipitating the gold from its chloride with *ammonia* should not be evaporated to dryness, since the explosive *fulminate of gold* may be present to some extent, which would render the operation hazardous.

9. *Management of Gold Baths.*—The colour of the gilding may be varied from a pale straw or lemon colour to a dark orange-red at the will of the operator; thus, when the solution is cold, a pale lemon-coloured deposit will be obtained. If the bath be warm, a very small surface of anode exposed in the solution, and the article kept in brisk motion, the deposit will also be of a pale colour. If, on the other hand, there be a large excess of cyanide in the bath, a considerable surface of anode immersed and a strong current, the gilding will be of a dark red colour, approaching a brown tone, and the article, when scratch-brushed, will assume a rich orange-yellow colour, specially suited to certain classes of work, as the insides of cream-ewers, goblets, &c., and chains of various kinds. In order to obtain uniform results in any desired shade, when gilding a large number of articles of the same class, care must be exercised to keep the temperature of the bath uniform; the anode surface immersed in the solution the same for each batch of work, consisting of an equal number of pieces of the same dimensions; the battery current as uniform as possible, and, lastly, fresh additions of warm distilled water must be added frequently to the bath to make up for loss by evaporation. If these points be observed there will be no trouble in obtaining uniform results. It is scarcely necessary to state that a large bulk of gilding solution will keep in an uniform condition for a longer period than a smaller quantity, since the effect of evaporation is less marked than in the latter case.

10. *Worn Anodes.*—It is not advisable to employ anodes which have become ragged at the edges for gilding the insides of vessels, since particles of the metal are liable to be dislodged during the gilding process, and, falling to the bottom of the vessel, protect those parts upon which they drop from receiving the deposit; indeed, the smaller fragments will sometimes become *electro-soldered* to the bottom of the vessel, causing some trouble to remove them. When the edges of an

anode are very ragged it is well to trim them with shears or a pair of sharp scissors before using the anode for gilding insides. The anode should always be formed into a cylinder, and not used as a flat plate for these purposes, otherwise the deposition will be irregular, and the hollow surfaces of chased or embossed work may not receive the deposit at all.

11. *Defects in Gilding.*—When the gold becomes partially dissolved off portions of an article while in the gilding-bath, it generally indicates that there is too great an excess of cyanide in the solution. The same defect, however, may be caused by the current being too weak, the liquid poor in gold, too small a surface of anode in the solution, or by keeping the articles too briskly in motion in a bath containing a large excess of cyanide. Before attempting an alteration of the solution, the battery should be looked to, and, if necessary, its exciting liquids renewed. The solution should then be well stirred and tried again; if the same defect is observed an addition of chloride of gold should be made to the bath to overcome the excess of cyanide. If the deposit is of a very dark red colour, and of a dull appearance, this may be caused by employing too strong a current, by excess of cyanide, or too great a quantity of gold in the bath. If from the latter causes, the solution must be diluted; if from the former, the articles should be suspended by a very thin slinging wire, or the positive element of the battery partially raised out of the battery-cell.

12. *Gilding Pewter Solder.*—Common jewellery is frequently repaired with pewter solder, which does not so readily take the gilding as the other parts. A good plan to overcome this is first to well scratch-brush the articles, after which the solder may be treated as follows: Make a weak acid solution of sulphate of copper, dip a camel-hair brush into the solution and apply it to the soldered joint, and at the same time touch the spot with a steel point; in a few seconds the solder will become coated with a bright deposit of copper. Now rinse the article, and proceed to the gilding as usual, when it will be found that the soldered part upon which the film of copper has been deposited will readily receive a coating of gold, more readily, in fact, than the body of the article itself. The article, when gilt, is then scratch-brushed and treated as usual. The copper solution for the above purpose may be prepared by dissolving about ½ oz. of sulphate of copper in ½ pint of water, and adding to the solution about ½ oz. of oil of vitriol.

13. *Gilding Cheap Jewellery.*—This class of work, whether of French or Birmingham manufacture, seldom requires more than a mere *dip* to meet the requirements of the customer; indeed, the prices obtainable for gilding articles of this character will not admit of *gilding* in the proper sense of the term. In France it is usual to employ a platinum

anode, and to renew the gilding solution as it becomes exhausted of its metal by fresh additions of gold salt. The author has found it a very economical plan to use a *copper* anode for gilding work of this description, and by making small additions of chloride of gold when the bath exhibited signs of weakness, he has been able to gild a very large number of articles, of a very fine colour, with an infinitesimal amount of the precious metal. The only preparation such work received was a good scratch-brushing before gilding, and a very slight scratch-brushing after. In his experience, although the prices were very low, the result was exceedingly profitable. Against the employment of a copper anode, it has been argued that the solution must of necessity become highly impregnated with copper. To which we may reply that we did not find such to be the case in practice.

14. *Gilding German Silver.*—Since this alloy of copper, &c., will generally receive a coating of gold in ordinary cyanide solution, without the aid of the battery, the solution should be somewhat weaker, and the battery current also, otherwise the gold will not firmly adhere. The temperature of the solution should also be lower than is required for gilding articles of silver or electro-plate. When German silver articles are first placed in the gilding-bath a small surface of anode only should be immersed, and the deposit allowed to take place *gradually.* If these precautions be not observed the operator may suffer the annoyance of finding the work strip when the scratch-brush is applied, or at all events under the operation of burnishing.

15. *Stripping Gold from Silver.*—This may be done by making the article the anode in a strong solution of cyanide of potassium, or in an old gold solution containing a moderate amount of free cyanide. A quicker process, however, consists in immersing the articles in strong nitric acid, to which a little dry common salt is added. Care must be taken not to allow the article to remain in the stripping solution one moment after the gold has been removed, and the articles should be moved about in the liquid, especially towards the close of the operation, to facilitate the solution of the gold from the surface. The gold may afterwards be recovered from the exhausted acid bath by immersing in it several stout pieces of sheet zinc or iron, which will precipitate the gold in the metallic state, and this may be collected, dried, and fused with a little dried carbonate of potash. Or the exhausted stripping solution may be evaporated to dryness, and the residuum fused with dried carbonate of potash or soda, a little nitre being added towards the end of the operation, to refine it more completely.

16. *Spurious Gold—"Mystery Gold."*—Many attempts have been made from time to time to form an alloy which, having somewhat the colour

of gold, would also withstand the action of the usual test for gold—nitric acid. The introduction of the electro-gilding art greatly favoured such unscrupulous persons as desired to prey upon the public by selling as gold electro-gilt articles, which had not a fraction of the precious metal in their composition. An alloy of this kind entered the market many years ago, in the form of watch-chains and other articles of jewellery, the composition of which was, copper 16 parts, platinum 7 parts, and zinc 1 part. This alloy, when carefully prepared, bears a close resemblance to 16-carat gold, and when electro-gilt would readily pass for the genuine article. The manufacture of this variety of spurious gold seems to have received a check for a certain period; but somewhat recently, in a modified formula, it has reappeared, not only in the form of articles of jewellery, but actually as current coin, and from its highly deceptive character, being able to resist the usual test, it has acquired the name of "Mystery Gold." It appears that, when converted into jewellery, the chief aim of the "manufacturers" is to defraud pawnbrokers, to whom the articles are offered in pledge; and, since they readily withstand the nitric acid test, the "transactions" are often successful. According to Mr. W. F. Love, in a communication to the *Chemical News*, a bracelet made from an alloy of this character had been sold to a gentleman in Liverpool, and when the gilding was removed the alloy presented the colour of 9-carat gold. The *qualitative* analysis proved it to be composed of platinum, copper, and a little silver. A *quantitative* analysis yielded the following result:—

Silver	2·48
Platinum	32·02
Copper (by difference)	65·50

It was found that strong boiling nitric acid had apparently no effect upon it, even when kept in the acid for some time.

17. *Gilding Watch Dials.*—To prepare a silver watch dial (for example) for gilding, it should be laid, face upward, upon a flat piece of cork, and the face then gently rubbed all over with powdered pumice, sifted through a piece of fine muslin, and slightly moistened with water, using the end of the third finger of the right hand for the purpose. The finger being dipped in the pumice paste, should be worked with a rotary motion over the surface of the dial, so as to produce a perfectly uniform and soft dulness. When this is done, a piece of copper slinging wire is passed through the centre hole of the dial, and formed into a loop; the dial is then to be rinsed, and placed in the bath, care being taken not to touch the face of the article either before or after gilding, except in the way indicated. The dial must afterwards be repainted.

18. Gilding solutions which have been worked with but a small excess of cyanide are apt to deposit more gold than is dissolved from the anode, by which the action of the bath becomes lessened, while the colour of the gilding is indifferent. It must always be borne in mind that in all cyanide solutions, but more especially such as are worked hot, the cyanide of potassium gradually becomes converted into carbonate of potassium by the action of the atmosphere, and therefore loses its solvent power.

19. For producing a dead or matted surface upon brass articles of jewellery, as brooches, lockets, &c., they are first dipped for an instant in a mixture composed of equal parts of sulphuric and nitric acids, to which a small quantity of common salt is added, and immediately plunged into cold water. After being rinsed in one or two other waters, they are promptly immersed in the gilding-bath, in which, after a moment's immersion, they acquire the desired colour of gold. After rinsing in hot water, they are finally dried in hot boxwood sawdust. In treating this class of work, care should be taken to avoid handling the pieces; after they have been removed from the sawdust they should be at once wrapped up ready for delivery.

20. When it is desired to give a stout coating of gold to an article, it should be occasionally removed from the gilding-bath, then scratch-brushed, rinsed, and returned to the bath. If the article were allowed to remain in the bath undisturbed until a thick coating was deposited, the surface would probably be rough and crystalline, and moreover liable to strip when being scratch-brushed. It is sometimes the practice to dip the article for an instant in the quicking solution after each gilding, by which the respective layers of gold are less apt to separate in scratch-brushing or burnishing.

21. The wires used for slinging articles in the gilding-bath should never be reversed, but one end only employed for suspending the articles, the other being used for connection with the negative electrode of the battery. By adopting this system, the gold deposited upon the ends of the slinging wires is less liable to become wasted than when both ends of the wires are used indiscriminately. After the slinging wires have been used a few times, and before the gold upon them begins to chip or peel off, they should be carefully laid aside, with all the gilt ends in one direction, so that the gold may be removed, by stripping, at any convenient time. After stripping off the gold, the wires should be annealed, then pulled out straight, and placed in bundles. Before being again used, each end of the bundle of wires should be dipped for a few moments in an old dipping-bath, and then rinsed, when they will be ready for future use. It is better to treat slinging-wires thus carefully than to suffer them—which is commonly the case—to be scattered about.

22. *Gilding Lead, Britannia Metal, &c.*—When articles composed of lead, tin, Britannia metal, iron, or steel are required to be gilt, it is best to give them a preliminary coating of copper in an alkaline bath, or to electro-brass them, after which they may be gilt with perfect ease, and with but little liability to strip when scratch-brushed. The softer metals, however, will require to be burnished with great care, owing to their yielding nature under the pressure of the burnishing tools. The same observation also applies, inversely, to silvered or gilt steel work, in which case the superior metals, being softer than steel, become expanded under the influence of the burnishing tools, and are consequently liable to become separated, in *blisters*, from the underlying harder metal.

23. *Excess of Cyanide Injurious.*—When a newly prepared gilding solution is first used (hot), the deposit is usually of a rich, fine gold colour, if a sufficient quantity of free cyanide has been employed in its preparation, a proper surface of anode immersed in the solution, and the current brisk. If, on the other hand, the colour is pale—that is yellow, without the characteristic orange tint—this indicates that one or other of the above conditions is wanting. Before venturing to increase the amount of free cyanide, the condition of the battery should be examined, the temperature of the solution raised a little, and a larger anode surface immersed, when, if the solution still yields a light-coloured deposit, an addition of strong cyanide solution must be given gradually until the gilding assumes the proper orange-yellow colour. The addition of cyanide must always be made with caution, for if too great an excess be applied, the solution is apt to yield brown deposits, quite unsuitable for many articles of jewellery ware. This quality of gilding, however, is frequently taken advantage of for articles which are required to have a deep gold colour after scratch-brushing, as the insides of tankards, &c., and also Albert chains and work of a similar description. If a gold solution is in really good working condition, and the current sufficiently brisk, a copper or brass article should gild readily, in hot solutions, with an anode surface considerably less than that of the cathode, or article being gilt, especially if no motion be given to either electrode. A silver article, however, would require, in the same bath, a much larger surface of anode, but more especially if the surface were frosted, as in filigree work. In gilding articles of this description it is better to expose a large anode surface and keep the article in gentle motion when first put into the bath, after which a portion of the anode may be withdrawn, and the object allowed to rest undisturbed until the coating is sufficiently thick.

24. In working small baths, additions of hot distilled water must be given frequently to make up for the loss by evaporation; but where

large quantities of solution are employed, this addition need not be made more than once a day, or at the close of the operation. With this exception, a good gilding solution will continue to give uniformly good results for many days—especially if large in bulk—without alteration. When it begins to work tardily, however, which may readily be seen by the extra anode surface required to gild the articles promptly, moderate additions of cyanide must be given until the bath acquires its normal activity.

25. After working gilding-baths for a lengthened period, they generally assume a brown colour, and the gilding is, under such circumstances, of an indifferent colour. The chief causes of this discoloration have been already explained, and can be to a great extent avoided, by thoroughly rinsing the articles before putting them in the bath. When a solution is in this condition the best remedy is to evaporate it as before, and then redissolve the dried mass in distilled water, using about one-third less water than the original bulk. A little fresh cyanide must also be added, and the solution filtered, after which it will generally yield a deposit of excellent colour. Old solutions which give deposits of a greenish-black colour may be improved by evaporation, but the heating of the dried product should be carried somewhat farther than in the former cases. It is better, however, to abandon such a solution altogether and to make a fresh one. The gold from the waste solution may afterwards be recovered by the processes given in another chapter. When gilding solutions, after being worked some time, yield a pale straw-coloured gilding, this is attributed by some to the gradual accumulation of silver from the gold anodes (which always contain a trace of silver); we are, however, disinclined to accept this view, owing to the exceedingly small quantity of silver present in fine gold; moreover, since silver deposits first, if present in a gold solution, we doubt its liability to accumulate in the bath. We would rather attribute the paleness of deposit referred to, to one or both of the following causes:—1. To the presence of a large excess of carbonate of potash in the bath from using an inferior cyanide; 2. To the presence of tin derived from pewter soldered articles, imperfectly prepared for gilding.

26. The Bunsen battery is most generally used for gilding, and indeed the current from this source produces a gold deposit of very fine colour. It must be used with caution, however, when gilding articles at a low price, since it deposits the metal very freely from hot solutions, and would soon yield a coating of gold of greater thickness than would pay for ordinary cheap work. In gilding with this battery, the regulation of the anode surface in solution should be strictly observed, only a sufficient surface being exposed to enable the article to become gilt *almost* immediately after immersion; the anode

may be gradually lowered a little as the deposition progresses. Articles that only require to receive a mere colour of gold upon them (as in cheap jewellery) should be first scratch-brushed, then well rinsed in hot water; dipped for a moment in the gold bath, then rinsed, and lightly scratch-brushed again, and after again rinsing receive a momentary dip in the gilding bath; they are to be finally rinsed in boiling water, then shaken well, and placed in hot boxwood sawdust, from which they are afterwards removed and well shaken to cleanse them from this material.

CHAPTER XVII.

ELECTRO-DEPOSITION OF SILVER.

Preparation of Nitrate of Silver.—Observations on Commercial Cyanide.—Preparation of Silver Solutions.—Bright Plating.—Deposition by Simple Immersion.—Whitening Articles by Simple Immersion.—Whitening Brass Clock Dials, &c.

The process of "electro-plating" may be considered the most important branch of the great art of electro-deposition. Not only is it invaluable in giving to articles manufactured from German silver, Britannia metal, and other metallic surfaces, a beautifully white coating of the precious metal even superior in brilliancy to that of standard silver, but old plated and electro-silvered articles, from which the silver has worn off, may be resilvered by this process and made to look nearly equal to new, which there was no practical means of doing before the introduction of electro-plating. This term, by-the-bye, though generally used, is erroneous, since the process of *plating* consists in attaching two plates, or ingots of metal, and rolling them into sheets, from which, as in the old manufacture of Sheffield plate, various articles of utility are, or rather were, made.

Preparation of Nitrate of Silver.—Since the silvering or "plating" solutions—with one exception—are prepared from the *nitrate of silver*, it will be necessary to consider its preparation previous to explaining the various ways in which silver baths are made up from this salt of silver. To prepare nitrate of silver, the required quantity of *grain silver* is carefully put into a glass flask * or evaporating dish, the former by preference, since during the chemical action which ensues while the solution of the metal is taking place, a portion of the metal may be lost by the *spitting* of the solution when the chemical action is at its height. In dissolving silver, take, say—

Grain silver	2 ounces.
Pure nitric acid	3¼ „
Distilled or rain water	1½ „

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* When dissolving large quantities of silver, a stoneware vessel may be employed.

Put the silver carefully into the flask, then add the water, and lastly the acid. In a few moments vigorous ebullition takes place, with the disengagement of red fumes of nitrous gas, which should be allowed to escape through the chimney. When the action begins to quiet down a little, the flask must be placed on a warm sand-bath. For small operations, or where a proper sand-bath is not provided, an ordinary frying-pan nearly half-filled with silver-sand will answer the purpose well. The flask should remain upon the sand-bath until the red fumes cease to appear in the bulb, at which period the chemical action is at an end. It may be well to mention that, in dissolving silver, it is advisable in the first instance to use rather less of the acid than is necessary to dissolve the whole of the silver, and to treat the undissolved portion separately, by which means excess of acid is avoided. The nitrate of silver solution must now be decanted into an evaporating dish and placed in the sand-bath, where it is allowed to remain until a film or *pellicle* forms on the surface of the liquor, when the vessel must be set aside to cool. A few hours after, crystals of nitrate of silver will have deposited, from which the remaining liquor is to be poured off, and this again evaporated as before. Instead of crystallising the nitrate, it may simply be evaporated to nearly dryness, by which the free acid will become expelled.

Should the nitric acid used in dissolving silver contain even a slight portion of *hydrochloric acid*, an insoluble white precipitate will be found at the bottom of the flask, which is *chloride of silver*. This, however, will not be injurious to the plating solution. Sometimes, also, a slight deposit of a brownish-black colour is found at the bottom of the vessel in which silver is dissolved; this is *gold*, left in the grain silver through imperfect *parting* in the refining process. We have occasionally discovered more than a mere trace of gold at the bottom of the dissolving flask; indeed in several instances an appreciable quantity.

When dissolving the crystals of nitrate of silver, for the preparation of either of the following plating solutions, distilled or rain water only should be used, since river water always contains traces of substances which form a white precipitate in the presence of nitrate of silver.

In describing the silver solutions, the proportion of silver in the *metallic state* will be given, and it will be understood that in each case the weighed metal must be first converted into *nitrate*. We may also state that the proportion of silver to each gallon of solution may be varied according to the practice of the plater, some persons preferring solutions in which there is a moderate percentage of the metal, while others employ much greater quantities. The proportion of silver per gallon of solution ranges from ½ an ounce to 5 or 6 ounces, and even more; but for most practical purposes from 1½ to 2 ounces will be quite sufficient; indeed, some of our best results have been obtained with 1 ounce of silver per gallon.

In most of the formulæ given, 1 gallon of solution will be taken as the basis for making up any required quantity of silvering bath; and it will be readily understood that when larger proportions of silver to the gallon are preferred, a proportionate increase of cyanide must be used, not only to dissolve the precipitated metal, but also to play the part of *free cyanide* in the solution. It must be remarked here, that unless the silvering-bath contains an excess of cyanide of potassium, the anode, or *dissolving plate*, whose function it is to resupply the solution with silver in the proportion in which it is deposited upon the articles, will not keep up the *metallic strength* of the bath, and consequently it will deposit the metal slowly. A large excess of cyanide, on the other hand, is not only unnecessary, but is liable to cause the deposited silver to *blister* and *strip*, or peel off the work under the pressure of the burnishing tools; and when very greatly in excess, the coating will be so non-adherent that it may even yield to the scratch-brush, and separate from the underlying metal.

Observations on Commercial Cyanide of Potassium.—Since the cyanide of potassium is one of the most important and useful substances that come under the command of the electro-depositor, while the success of his operations greatly depends upon its *active* quality, it is advisable to state that ordinary commercial cyanide varies considerably in this property; so much so, indeed, as to render it absolutely necessary that the user should be put on his guard, lest in purchasing a cheap and worthless article, he should commit an error which may cost him much trouble and annoyance, as also pecuniary loss. Before making up *any solution* in large quantity, in which cyanide of potassium is the solvent, we advise him first to obtain samples of the commercial article, and to test them by either of the processes given in another chapter. We may state that some of the cheap cyanides contain a large excess of carbonate of potash. This substance, while being a necessary ingredient in the manufacture, is also frequently used greatly in excess to produce a cheap article, and may be called its natural adulterant. This salt (carbonate of potash), however, unless specifically recommended in the preparation of certain depositing solutions, is not only useless, but when greatly in excess reduces the conductivity of both silvering and gilding baths.

Preparation of Silver Solutions.—*Solution I.* The solutions of silver most generally used for electro-plating are those commonly called "cyanide solutions," the foremost of which is the *double cyanide of silver and potassium*, which is prepared as follows: 1 ounce of silver is converted into *nitrate*, as previously described, and the crystals dissolved, with stirring, in about 2 quarts of distilled or rain water, which may, in the case of small quantities, be effected in a glass vessel or glazed earthenware pan. For large quantities a stoneware vessel should be used. When the crystals are all dissolved, a strong solution of cyanide (about ½ a pound, dissolved in 1 quart of water) is added, a little at a time, when a precipitate of *cyanide of silver* will be formed, which will increase in bulk upon each addition of the cyanide. Each time, after adding the cyanide solution, the mixture must be well stirred with a glass rod or strip of wood free from resin. When it is found that the addition of cyanide produces but little effect, it must be added *very cautiously*, since an excess will redissolve the precipitate, and cause waste in the after process of washing this deposit. To avoid adding too much cyanide, the precipitate should be allowed to fall down an inch or so, when a glass rod may be dipped in the cyanide solution, and the clear liquor touched with this, when if a milkiness is produced, a little more cyanide must be added, and the stirring resumed. After a short repose, the same test may be applied, and so on, until a drop of cyanide solution produces no effect. Great care must be taken not to add more cyanide than is absolutely necessary to throw down the silver. As an additional precaution, when nearly the whole of the silver is precipitated, the vessel may be allowed to rest for an hour or so, and the clear liquor then poured off and treated separately, by which means the bulk of the precipitate will be saved from the risk of coming in contact with an excess of cyanide. If, through accident or faulty manipulation, too much cyanide has been added, more nitrate of silver solution must be poured in, which, combining with the surplus cyanide, will again produce the characteristic milkiness; and if the additions of nitrate are made with care, the clear liquor will be perfectly free from silver, and after allowing the cyanide of silver to deposit, may be poured off and thrown away.

Washing the Precipitate.—In all such cases the precipitate should be allowed fully to settle; the *supernatant liquor*, or "mother liquor," is next to be poured off slowly, so as not to disturb the solid matter (cyanide of silver); a large quantity of fresh water—which for this purpose may be common drinking water—is now to be poured on to the precipitate with brisk stirring, and the vessel again left to rest, after which the clear liquor is to be poured off as before, these *washings* being repeated three or four times.

Dissolving the Precipitate.—To convert the cyanide of silver into the *double cyanide of silver and potassium*, the strong solution of cyanide must be added in moderate portions at a time, constantly stirring as before, until the precipitate appears nearly all dissolved, at which period the additions of cyanide must be made with more caution. In this case, as in the former, it is a good plan, when nearly the whole of the precipitate is dissolved, to allow the vessel to stand for a short time, then to pour off the clear liquor—which is now a solution of the double cyanide of silver and potassium—and to treat the remainder of the precipitate with cyanide solution; by this means too great an excess of the solvent is avoided. When all the precipitated silver is redissolved, add about one-fourth more cyanide solution than that originally used, and pass the solution through a filter into the plating vat or depositing vessel, which may be conveniently done by means of a piece of unbleached calico (previously washed in lukewarm water to remove the "dressing") stretched over three strips of wood bound together in the form of a triangle either with copper wire or string, as in Fig. 79. When all the solution has passed through the filter, this may be washed by pouring a little water over it while resting over the bath. The solution is finally to be made up to the full quantity by adding the necessary proportion of water, when its preparation is complete; it will be better, however, to allow it to rest for twenty-four hours before using it for electro-plating.

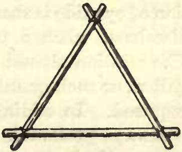
Fig. 79.

Free Cyanide.—This term is applied, as we have before hinted, to a moderate excess of cyanide of potassium which it is always necessary to have in the bath, to dissolve the insoluble cyanide of silver which forms on the anode, but since the ordinary commercial article is of very variable quality, the addition of this substance must to a great extent depend upon the judgment of the plater, subject to the precautions we have previously given; from one-fourth to one-half the quantity of cyanide used in dissolving the precipitate of cyanide of silver may be added to the solution as free cyanide, and water then added to make up 1 gallon. If the cyanide, in the first instance, be dissolved in a definite *measured* quantity of water, say at the rate of half a pound to a quart of water (40 ounces), the proportion of cyanide used in each of the former cases can be readily ascertained by simply measuring the balance of the solution and deducting its proportion of cyanide from the original weight taken. A fair quality of ordinary commercial cyanide should not contain less than 50 per cent. of pure cyanide, but we have frequently met with an article which contains a very much lower percentage, which should never be used for making up plating solutions, but may be employed in the less important process of *dipping* in the preparation of work for nickel-plating. Of course it will be understood that when cyanide containing a high percentage of the pure substance is obtained, a proportionately smaller quantity must be used.

Solution II.—One ounce or more of silver is converted into nitrate as before, and the crystals dissolved in from three to four pints of distilled water. A solution of carbonate of potash (salt of tartar), consisting of about six or eight ounces of the salt to a pint of water, is to be gradually added to the solution of nitrate of silver, with constant stirring, until no further precipitation takes place. After settling, the clear liquor is poured off, and the precipitate (*carbonate of silver*) washed with water several times, as before directed. A strong solution of cyanide is then to be added until all the precipitate is thoroughly dissolved, when a moderate excess is to be added as free cyanide. The solution should now be filtered and water added to make up one gallon, or such quantity in the same proportion of materials as may be required. In adding excess of cyanide to this and other solutions, it is always preferable to add it moderately at first, otherwise the work is very liable to strip. After working the bath for some time, an addition of cyanide may be made, but so long as the anode keeps perfectly clean while the work is being plated, the less free cyanide there is in the bath the better. A solution which has been worked for a considerable time acquires a good deal of organic matter, becoming dark in colour in consequence, and is then capable of bearing, without injury to the work, a larger proportion of free cyanide than newly prepared solutions.

Solution III.—Mr. Alexander Parkes, in 1871, patented a solution for depositing solid articles. One ounce of silver is first converted into nitrate, from which the silver is thrown down in the form of *oxide* of silver, by means of a solution of caustic potash gradually added, until no further precipitation takes place. After washing the oxide, it is dissolved in 2 gallons of water containing 16 ounces of cyanide of potassium.

Solution IV.—The best solution for depositing silver upon German silver without recourse to the process of "quicking," is one which the author employed upon an extensive scale for many years with great success; it is composed as follows, and although it is rather more expensive in its preparation than many other solutions, it is, so far as he is aware, the best solution in which German silver work may be plated without being previously coated with mercury, as in the "quicking" process hereafter referred to. To prepare the solution, 1 ounce of silver is converted into nitrate and dissolved in two or three pints of distilled water as before. About three ounces of *iodide of potassium* are next to be dissolved in about half a pint of distilled water. The iodide solution is to be gradually added to the nitrate solution, the operation being performed in a dark corner of the room, or preferably by feeble gaslight, when a bright lemon yellow precipitate will be formed. The liquid must be briskly stirred upon each addition of the iodide, and care must be taken not to add the latter salt on any account in excess, otherwise it will redissolve the precipitate. When the precipitation is nearly complete, it is better to allow the vessel to rest, and to put a little of the clear liquor in a test tube, Fig. 80, and to add a drop or two of the iodide solution, when if a cloudiness is produced, a moderate quantity of the iodide is to be added to the bulk and well stirred in. The clear liquor should be repeatedly tested in this way, until a single drop of the iodide solution produces no further effect upon it. In case of an accidental addition of too much iodide, nitrate of silver solution must be added to neutralise it. When the precipitation is complete, the vessel must be set aside—in a dark place, since the iodide of silver is affected by light—for an hour or so, after which the clear liquor must be poured off, and the precipitate repeatedly washed with cold water. Lastly, the iodide of silver is to be dissolved in a solution of cyanide of potassium, and a moderate excess added as before recommended. In working this solution, whenever the anode becomes coated with a greenish film, an addition of cyanide must be made to the bath.


Fig. 80.

Since the system of working the above solution differs in several respects from that adopted with other solutions, it may be well to describe our own practice in the treatment of German silver work. The articles are first placed in a warm solution of caustic potash, to remove greasy matter, after which they are well rinsed. Each article is then well scoured all over with powdered pumice and water, or finely powdered bath brick—an excellent substitute for the former—and water. As each article is brushed, it is to be well rinsed in clean water, and is then ready for the plating bath, in which it should be suspended without delay.

Solution V.—Mr. Tuck obtained a patent, in 1842, for "improvements in depositing silver upon German silver," in which he recommends, for plating inferior qualities of German silver, a liquid composed of *sulphate of silver* dissolved in a solution of carbonate of ammonia. Sulphate of silver is formed by adding a solution of sulphate of soda (Glauber's salt) to a solution of nitrate of silver, or by boiling silver with its weight of sulphuric acid. For plating the better qualities of German silver, cyanide of silver is dissolved in a solution of carbonate of ammonia. The proportions used are:—

Sulphate of silver	156 parts.
Carbonate of ammonia (dissolved in distilled water)	70 ,,

Or,

Cyanide of silver	134 ,,
Carbonate of ammonia	70 ,,

The silver salt in each case is boiled with the solution of the carbonate of ammonia until it is dissolved. For coating common German silver, he adds half an ounce of sulphate of silver to a solution containing 107 grains of bicarbonate of ammonia.

Solution VI.—For producing very white deposits of silver, the following may be used :—One ounce of silver is dissolved and treated as before, and the crystals of nitrate redissolved in about half a gallon of distilled water. A moderately strong solution of common salt is then prepared, and this is gradually added to the former, when a copious white precipitate of *chloride of silver* is formed, which must be well washed with cold water. After pouring off the last wash water, a strong solution of cyanide is to be added to the precipitate until it is all dissolved, when a moderate excess is to be added, and the solution carefully filtered through filtering paper, the first runnings to be passed at least twice through the same filter. Lastly, add water to make up 1 gallon. The solution may be used immediately, but will work better after a few hours' rest. This solution is very useful for obtaining delicately white deposits, but is not suitable for ordinary plating purposes, since the deposited silver is liable to strip under the action of the burnisher. If used somewhat weaker than in the above proportions, with a moderate current and small anode surface, the deposit will adhere to most metals with tolerable firmness ; it is, however, most suitable for coating articles which are either to be merely scratch-brushed or left a dead white. Chased figures and cast metal work receive a brilliant white coating in this solution, but to retain their beauty they must be kept beneath a glass case, since the fine silver surface soon discolours in the atmosphere.

Solution VII.—This plating solution, which is one of the best for most purposes, is prepared by dissolving silver in a solution of cyanide, by aid of the electric current. Suppose we wish the solution to contain 1 ounce of silver per gallon. The required quantity of water is first put into the bath, and for each gallon of liquid about 3 ounces of good cyanide is added, and allowed to dissolve. A porous cell is now to be nearly filled with this solution, and stood upright in the vessel containing the bulk of cyanide solution, the liquid being at the same height in both vessels. A strip of sheet copper is next to be connected to the negative

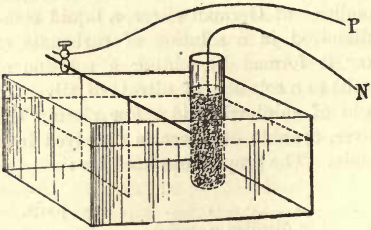

Fig. 81.

electrode of a strong voltaic battery, and placed in the porous cell. A large sheet of silver is next to be connected to the positive electrode, and immersed in the larger vessel. The arrangement is shown in Fig. 81. The weight of the sheet silver being ascertained beforehand, the battery is allowed to remain in action for several hours, when the silver plate may be weighed to determine how much of it has been dissolved in the solution, and the action is to be kept up until the proper proportion has been dissolved by the cyanide in the outer vessel. When this point has been reached the porous cell is to be removed, and its contents may be thrown away.

Another electrolytic method of preparing a silver bath is the following:—To make a bath containing, say, one ounce of silver per gallon, the cyanide should be of known strength. Assuming the commercial article to contain 50 per cent. of real cyanide, about 3 ounces are to be dissolved in each gallon of water; a large silver anode connected to the positive pole of a battery is to be suspended in the solution, and a smaller plate of silver as a cathode. A strong current should be used, and the anode weighed from time to time until the desired proportion of silver has become dissolved into the solution. The condition of the bath may then be tested by suspending a clean plate of brass from the negative rod, at the same time immersing about an equal surface of anode, using a moderate current, when if the solution be in good working order, the cathode will at once receive a bright deposit of silver. During the action some caustic potassa is formed in the liquid, which may be converted into cyanide, by adding a moderate quantity of hydrocyanic acid, which must be done, however, with exceeding care, owing to the deadly nature of the acid, the vapour of which must not on any account be inhaled. Respecting the use of this acid, however, we must strongly recommend that its employment should never, under any circumstances whatever, be placed in the hands of persons unacquainted with its highly poisonous character.

Besides the foregoing, many other processes for preparing silver solutions have been proposed; but since they are comparatively of little or no practical value, they deserve but a passing reference. By one of these processes chloride of silver is dissolved in hyposulphite of soda. The salt of silver thus formed (*hyposulphite of silver*) is readily acted upon by light, and the silver, being thus converted into an insoluble *sulphide*, gradually becomes deposited at the bottom of the bath. Solutions have also been prepared by employing ferrocyanide of potassium (yellow prussiate of potash) as the solvent of cyanide of silver. Again, the silver has been precipitated from its nitrate solution by lime-water, forming oxide of silver; as also by ammonia, soda, magnesia, &c.; the various precipitates being subsequently dissolved in a solution of cyanide of potassium. The ordinary double cyanide of silver and potassium solution, however, will be found most useful for the general purposes of electro-plating.

Bright Plating.—The silver deposited from ordinary cyanide solutions is of a pearly white or dull white, according to the condition and nature of the silver solution, and the strength of the current; and it is necessary to brighten the work by scratch-brushing before it is subjected to the operations of burnishing or polishing. It is possible, however, by adding to the plating-bath a small quantity of *bisulphide of carbon*, to obtain deposits of silver which are *bright* instead of dull, for the discovery of which important improvement we are indebted to Mr. W. Milward, of Birmingham, who made the discovery in the following way:—He had observed that when wax moulds for electrotyping, which had been coated with a film of phosphorus by applying a solution of that substance in bisulphide of carbon, were put into the cyanide plating solution to receive a deposit of silver, that other articles—as spoons and forks, for example—silvered in the same solution, assumed a brightness more or less uniform, sometimes extending all over the articles, and at others occurring in streaks and patches. This led him to try the effect of adding bisulphide of carbon alone to the plating solution, which produced very satisfactory results. The improvement was worked as a secret for some time, but eventually leaked out, in consequence of which Mr. Milward and a person named Lyons (who had become acquainted with the secret) took out a patent in March, 1847, for bright silver deposition by adding "compounds of sulphur and carbon," bisulphide of carbon being preferred. From that time the bisulphide of carbon has been constantly employed for producing bright deposits of silver.

To make up the solution for "bright plating," the following methods are adopted: 1. "6 ounces of bisulphide of carbon are put into a stoppered bottle, and 1 gallon of the usual plating solution added to it; the mixture is first to be well shaken, and then set aside for 24 hours. 2 ounces of the resulting solution are then added to every 20 gallons of ordinary plating solution in the vat, and the whole stirred together; this proportion must be added every day, on account of the loss by evaporation, but where the mixture has been made several days, less than this may be used at a time. This proportion gives a bright deposit, but by adding a larger amount a dead surface may be obtained, very different to the ordinary dead surface."

Another method of preparing a solution for bright plating is the following:—Put 1 quart of ordinary silver plating solution into a large stoppered bottle; now add 1 pint of strong solution of cyanide and shake well; 4 ounces of bisulphide of carbon are then to be added, as also 2 or 3 ounces of liquid ammonia, and the bottle again well shaken, which operation must be repeated every two or three hours.

The solution is then set aside to rest for about 24 hours, when it will be ready for use. About 2 ounces of the clear liquid may be added to every 20 gallons of ordinary plating solution, and well mixed by stirring. A small quantity of the brightening solution, or "bright," as it is termed in the plating-room, may be added to the solution every day, and the liquid then gently stirred. In course of time the bisulphide solution acquires a black colour, to modify which a quantity of strong cyanide solution, equal to the brightening liquor which has been removed from the bottle, should be added each time. In adding the bisulphide solution to the plating bath an excess must be avoided, otherwise the latter will be spoilt. Small doses repeated at intervals is the safer procedure, and less risky than the application of larger quantities, which may ruin the bath.

A very simple way to prepare the brightening solution is to put from 2 to 3 ounces of bisulphide of carbon in an ordinary "Winchester" bottle, which holds rather more than half a gallon. Now add to this about 3 pints of old silver solution, and shake the bottle well for a minute or so; lastly, nearly fill the bottle with a strong solution of cyanide, shake well as before, and set aside for at least 24 hours. Add about 2 ounces (not more) of the "bright" liquor, without shaking the bottle, to each 20 gallons of solution in the plating vat. Even at the risk of a little loss from evaporation, it is best to add the brightening liquor to the bath the last thing in the evening, when the solution should be well stirred so as to thoroughly diffuse the added liquor. The night's repose will leave the bath in good working order for the following morning.

Other substances besides the bisulphide of carbon have been used, or rather recommended, for producing a bright deposit of silver, but up to the present no really successful substitute has been practically adopted. Amongst other compounds which have been suggested, are a solution of iodine and gutta-percha in chloroform, which is said to have a more permanent effect than the bisulphide; carbonate, and acid carbonate of potassium, 1½ ounce of each, added once every nine or ten days to a plating solution containing 12 ounces of cyanide and 3½ ounces of silver per gallon. According to Planté, bright silver deposits may be obtained by adding a little sulphide of silver to the plating solution.

Although the solution for "bright plating" is useful for some purposes, it is not adopted as a substitute for the ordinary cyanide of silver bath for the general purposes of electro-plating. For articles which have deep hollows and interstices which cannot be burnished without considerable difficulty, and for the insides of tea and coffee-pots, and articles of a similar description, which are required to be bright, but which cannot be rendered so by mechanical methods, a slight coating of bright silver is an advantage. A bath of brightening solution is usually kept for this purpose, in which the articles, after being plated in the ordinary way, are immersed for a short time, by which they receive a superficial coating of the bright deposit. In the "bright solution" the articles first become bright at their lower surface, the effect gradually spreading upward, until in a short time they become bright all over, when they are removed from the bath and immediately immersed in boiling water, otherwise the silver would quickly assume a dark colour.

Deposition by Simple Immersion.—Articles of brass and copper readily become coated with a film of silver, without the aid of the battery current, in tolerably strong solutions of the double cyanide of silver and potassium ; the deposit, however, is not of such a degree of whiteness as to be of any practical use. Other solutions of silver are therefore employed when it is desired to give a slight coating of this metal to small brass or copper work which will present the necessary brilliant white colour. Silver may also be deposited upon these surfaces by means of a paste of chloride of silver, to which common salt or cream of tartar is added. The following processes are those most generally adopted :—

Whitening Articles by Simple Immersion.—For small brass and copper articles, as buttons, hooks and eyes, coffin-nails, &c., silvering by simple immersion is employed ; and in order to produce the best possible effect, the solution bath should not only be prepared with care, but kept as free as possible from contamination by other substances. To prepare a bath for this purpose, a given quantity of fine grain silver is dissolved in nitric acid. The solution of nitrate of silver thus formed is added to a large quantity of water, a strong solution of common salt is then poured in, which precipitates chloride of silver in the form of a dense white precipitate. When the whole of the silver is thrown down (which may be ascertained by adding a drop or two of hydrochloric acid or solution of salt to the clear liquor) the precipitate is allowed to subside, after which the supernatant liquor is to be poured off, and the precipitate washed several times. The last rinsing water should be tested with litmus paper, when, if there be the least trace of acid, further washing must be given. The precipitate, which is very readily acted upon by sunlight, should be prepared in a dull light, or by gaslight, and, if not required for immediate use, it should be bottled and kept in a dark cupboard. The chloride of silver is to be mixed with at least an equal weight of bitartrate of potassa (cream of tartar), and only sufficient water added to form a pasty mass of the consistency of cream. In this mixture the articles, having been previously cleaned or *dipped*, are immersed, and stirred about until they are sufficiently white, when they are to be rinsed in hot water, and shaken up with boxwood sawdust. These preparations are also used for silvering clock-faces, thermometer and barometer scales, and other brass and copper articles, by being rubbed over the surface to be whitened with a cork.

Another chloride of silver paste, for whitening articles of brass or copper, may be made by taking chloride of silver and prepared chalk, of each one part, common salt 1¼ part, and pearlash 3 parts, made into a paste, as before. A third mixture is prepared by taking chloride of silver 1 part, cream of tartar at least 80 parts, to which is sometimes added about 80 parts of common salt. The whole are dissolved in boiling water. This solution acquires a greenish tint, from the presence of copper, which takes the place of the silver in the liquid. In using this solution the articles are introduced by means of a perforated basket, which is briskly stirred about in the hot liquid until uniformly white. Some operators modify the above solution by adding common salt, Glauber's salt, corrosive sublimate, caustic lime, &c., but it is doubtful whether any advantage is derived therefrom.

A process, which is to be applied cold, was proposed by Roseleur, and seems to have worked exceedingly well in his experienced hands. A solution of the double sulphite of silver is formed in the following way: Four parts of soda crystals are dissolved in five parts of distilled water, sulphurous acid gas (prepared by heating in a glass retort strong oil of vitriol with some small pieces of copper wire) is then passed through the liquid, by allowing it to bubble through mercury at the bottom of the vessel, to prevent the exit tube from becoming clogged with crystals; the gas is allowed to pass until the fluid re-dissolves the crystals of bicarbonate, and slightly reddens blue litmus paper. It is then allowed to repose for twenty-four hours, so that some of the bisulphite of sodium formed may crystallise. The liquid portion is then to be poured off, and stirred briskly to expel the carbonic acid. If alkaline to test paper, more sulphuric acid gas must be added; or if acid, a little more carbonate of soda. After well stirring, the solution should only turn blue litmus paper violet, or at most slightly red. A solution of nitrate of silver is now to be added to the above liquid, with stirring, until the precipitate at first produced begins to dissolve slowly, when the bath is ready for use. The solution thus prepared is said to be always ready for work, and "produces, quite instantaneously, a magnificent silvering upon copper, bronze, or brass articles which have been thoroughly cleansed, and passed through a weak solution of nitrate of binoxide of mercury, although this is not absolutely necessary." To keep up the strength of the bath fresh additions of nitrate of silver must be made from time to time, and after awhile some bisulphite of soda must also be added. In working this bath the solution is placed in a copper vessel, which also receives a deposit of silver. Roseleur states that he used this bath for five years, during which period he daily silvered "as many articles as a man could conveniently carry." He also states that, without the aid of a separate current, the deposit from this solution may become nearly as thick as desired, and in direct ratio to the time of immersion.

Whitening Brass Clock-Dials, &c., with the Paste.—For this purpose chloride of silver and cream of tartar, with or without the addition of common salt, is made into a paste, as before described, and this should be well triturated in a mortar until it is impalpable to the touch. The paste is then spread, a little at a time, upon the brass surface—which may be a clock-face or thermometer-scale, for instance —and rubbed upon the metal surface with a piece of soft cork, or "velvet" cork as it is called. By thus working the silver paste over the metal it soon becomes silvered, and a coating of sufficient thickness for its purpose obtained in a very short time, according to the size of the object. When the silvering is complete the article is to be rinsed and dried in the hot sawdust. Although a very slight film of silver only is obtained in this way, its somewhat dull tone is specially applicable to barometer and galvanometer scales, clock-dials, and objects of a similar nature, and, as far as its non-liability to tarnish is concerned, it may be considered superior to all other methods of silvering.

CHAPTER XVIII.

ELECTRO-DEPOSITION OF SILVER (*continued*).

Preparation of New Work for the Bath.—Quicking Solutions, or Mercury Dips.—Potash Bath.—Acid Dips.—Dipping.—Spoon and Fork Work.—Wiring the Work.—Arrangement of the Plating Bath.—Plating Battery.—Motion given to Articles while in the Bath.—Cruet Stands, &c.—Tea and Coffee Services.—Scratch-brushing.

Preparation of New Work for the Bath.—In order to insure a perfect adhesion of the silver deposit to the surface of the article coated, or *plated*, as it is erroneously termed, with this or any other metal, the most important consideration is *absolute cleanliness*. By this term we do not mean that the article should be merely *clean* in the ordinary sense, but that it must be what is termed *chemically clean*, that is, perfectly and absolutely free from any substance which would prevent the silver from attaching itself firmly to the metal to be coated. As evidence of the extreme delicacy which it is necessary to observe in this respect, we may mention that if, after an article (say a German silver spoon, for example) has been well scoured with powdered pumice and water, it be exposed to the atmosphere even for a few seconds, it becomes coated with a slight film of oxide—owing to the rapidity with which copper (a constituent part of German silver) attracts oxygen from the air; this effect is still more marked in the case of articles made from copper and brass. Now, this slight and almost imperceptible film is quite sufficient to prevent perfect contact between the deposited metal and that of which the article is composed. This fact, in the early days of electro-plating, created a great deal of trouble, for it was found that the work, after being silvered, was very liable to strip under the pressure of the burnisher. To overcome the difficulty, and to secure a perfect adhesion of the two metals, a third metal—mercury or quicksilver—which has the power of alloying itself with silver, gold, German silver, copper, and brass, was employed, and though the author for many years obtained most successful and perfectly adherent deposits of silver without its aid, the process of *quicking* was, and still is, practised by the whole of the electro-plating trade. The silver solution which the author employed, however, and which is described in the foregoing chapter, was differently prepared to those ordinarily adopted by the trade. Since the process of "quicking" is generally adopted, it will be necessary to describe it in detail.

Quicking Solutions, or Mercury Dips.—This term is applied, as before hinted, to coating articles made of brass, copper, or German silver—the metals most usually subjected to the process of *electroplating*—with a thin film of quicksilver, which may be effected by either of the following solutions:—*Nitrate of Mercury Dip.*—Put an ounce of mercury into a glass flask, and pour in an ounce of pure nitric acid diluted with three times its bulk of distilled water; if, when the chemical action ceases, a small amount of undissolved mercury remains, add a little more acid, applying gentle heat, until the whole is dissolved. The solution is then to be poured into about 1 gallon of water, and well mixed by stirring. It is then ready for use, and is termed the *quicking solution*, or *mercury dip*. Articles of brass, copper, or German silver dipped into this solution at once become coated with a thin bright film of mercury.

Cyanide of Mercury Dip.—Dissolve one ounce of mercury as before, and dilute the solution with about 1 quart of distilled water. Now take a solution of cyanide of potassium, and add this gradually, stirring after each addition, until the whole of the mercury is precipitated, which may be determined by dipping a glass rod in the cyanide solution, and applying it to the clear liquor after the precipitate has subsided a little, when, if no further effect is produced, the precipitation is complete. The liquor is next to be separated by filtration. When all the liquor has passed through the filter, a little water is to be poured on to the mass, and when this has thoroughly drained off, the precipitate is to be placed in a glass or stoneware vessel, and strong solution of cyanide added, with constant stirring, until it is all dissolved, when a small excess of the cyanide solution is to be added, as also sufficient water to make up one gallon of solution.

Another mercury dip is made by dissolving *red precipitate* (red oxide of mercury) in a solution of cyanide, afterwards diluted with water.

Pernitrate of Mercury Solution.—This solution is composed of—

Pernitrate of mercury	1 part.
Sulphuric acid	2 parts.
Water	1000 „

A very good mercury dip may be made by simply dissolving two ounces of mercury in two ounces of nitric acid, without the aid of heat; the solution thus formed is to be diluted with about three gallons of water.

The quicking bath should contain just so much mercury in solution as will render a clean copper surface *white* almost immediately after immersion; if the solution be too strong, or too acid (when the nitrate of mercury solution is used), or if the solution has become nearly exhausted by use, when copper is dipped it may turn *black* or dark coloured instead of white, in which case the quicking bath must be rectified, otherwise it will be impossible to obtain an adherent coating of silver upon the article treated in it. As a rule, the articles merely require to become perfectly and uniformly white from the coating of mercury, but the practice is to give a stronger film to work which is required to receive a stout deposit of silver, or gold, as the case may be. When the mercury dip becomes nearly exhausted and the mercurial coating, in consequence, becomes dark coloured, the liquor should be thrown away and replaced by a new solution, which is considered better than strengthening the old liquor; indeed, the small amount of mercury which remains in the bath after having been freely used is of so little consideration, that the liquor may be cast aside without sacrifice the moment it gives evidence of weakness by the dark appearance of the work instead of the characteristic brightness of metallic mercury.

It is a good plan to keep a quantity of concentrated mercurial solution always in stock, so that when a bath becomes exhausted it may be renewed in a few minutes by simply throwing away the old liquor and adding the due proportions of strong solution and water to make up a fresh "dip."

Potash Bath.—To remove greasy matter communicated to the work by the polishing process, all articles to be plated must first be steeped for a short time in a hot solution of caustic potash, for which purpose about half a pound of American potash is dissolved in each gallon of water required to make up a bath, and as this solution becomes exhausted by use it must receive an addition of the caustic alkali. The workman may readily determine when the solution has lost its active property by simply dipping the tip of his finger in the solution and applying it to the tip of the tongue, when, if it fails to tingle or "bite" the tongue, the solution has lost its caustic property, and may either be thrown away or strengthened by the addition of more caustic potash. When the bath has been once or twice revived in this way it is better to discard it altogether, when inactive, than to revive it. Indeed, when we consider that the object of the caustic alkali is to convert the greasy matters on the work into soap, by which they become soluble and easily removed by brushing, it will be apparent that the bath can only be effective so long as the *causticity* of the alkali remains. Many persons, from ignorance of this matter, have frequently used their potash baths long after they have lost their activity, and as a natural consequence the work has come out of such baths nearly in the same state as they entered it, greasy and dirty.

Those who cannot conveniently obtain caustic potash (American potash, for example) may readily prepare it as follows: Obtain a few lumps of fresh lime and slake them by pouring water over them, and then covering them with a cloth; soon after, the lime will fall into a powder, which must be made into *milk of lime*, as it is called, by mixing it with water to the consistence of milk or cream. A solution of pearlash is then made in boiling water, to which is added the cream of lime, and the mixture is to be boiled for at least an hour, in an iron vessel. About half or three-quarters of a pound of pearlash to each gallon should be employed, and about one-fourth less lime than potash. If the solution is thoroughly *causticised*, no effervescence will occur in the liquor if a drop or two of hydrochloric acid are added; if, on the contrary, effervescence takes place on the addition of the acid, the boiling must be continued.

Acid Dips.—In the preparation of certain kinds of work, acid solutions or mixtures are employed which may be advantageously mentioned in this place. It is well to state, however, that after dipping the work in acid solutions it should be *thoroughly* rinsed in clean water, since the addition of even small quantities of acid to the alkaline plating or gilding baths would seriously injure these solutions. Indeed, careless and imperfect rinsing must always be avoided in all depositing operations, otherwise the baths will soon become deteriorated; the rinsing waters should be frequently changed, and the workman taught that in this item of his labour his motto should be "water no object."

Fig. 82.

Nitric Acid Dip.—This is frequently used for dipping copper, brass, and German silver work, and is the ordinary aquafortis of commerce, or *fuming* nitric acid (*nitrous* acid). Stoneware jugs of the form shown in Fig. 82 are used for conveying strong acids. A dipping acid, composed as follows, is also much used for producing a bright and clean surface upon certain classes of work:—

Nitric acid, commercial (by measure) . . .	1 part.
Sulphuric acid	2 parts.
Water	2 ,,

To this mixture some persons add a little hydrochloric acid, and others a small quantity of nitrate of potassa (nitre).

Dip for Bright Lustre.—To give a bright appearance to copper, &c., the following mixture may be employed:—Old aquafortis, or nitric acid dip which has been much used, 1 part; water, 2 parts; muriatic acid, 6 parts. The articles are immersed in this solution for a few minutes, when they are to be briskly shaken in clean cold water, and if not sufficiently bright must be dipped again. If they become covered with a dirty deposit, the articles should be scoured with pumice and water, then immersed in the dip for a short time and again rinsed. Another method is to first dip the articles in a weak *pickle*, formed by diluting old and nearly exhausted nitric acid dip with water for a few minutes, after which they are to be dipped in the same old acid dip in its undiluted condition, and finally in strong aquafortis for a moment; they are next to be well rinsed in several waters.

Dip for Dead Lustre.—To produce a *dead* or *matted* surface upon copper, brass, or German silver work, the following mixture is used:—

Brown, or fuming aquafortis (by measure) . . .	2 parts.
Oil of vitriol	1 part.

To the above mixture a small quantity of common salt is added. The articles are allowed to remain for some time in the dip, after which they are withdrawn and promptly dipped in the preceding liquid and immediately well rinsed.

Respecting old aquafortis dips, Gore says these may be "revived to a certain extent by addition of oil of vitriol and common salt; the sulphuric acid decomposes the nitrate of copper in it, and also the common salt, and sets free nitric and hydrochloric acids, and crystals of sulphate of copper form at the bottom of the liquid. All the nitric acid may be utilised in this manner." This is perfectly true, but as a rule acid "dips" which have become exhausted seldom produce the required brilliancy or tone of colour (when that is an object), even if strengthened by fresh additions of the concentrated acids with which they were first prepared. Zinc, tin, and lead, as also organic matter, generally find their way into these dips, and more or less interfere with the direct action of the nitric acid.

Dipping.—The article to be dipped should be suspended by a wire of the same metal, or by a wire covered with gutta-percha or india-rubber tubing, and after a moment's immersion in the acid solution, promptly plunged into clean cold water; if the desired effect—a bright or a dead lustre—is not fully produced by the first dip, the article must be again dipped for a moment and again rinsed. In order to remove the acid effectually, several washing vessels should be at hand, into each of which the article is plunged consecutively, but the last rinsing water, more especially, should be renewed frequently. When a number of


Fig. 83.

small articles require to be dipped, they may be suspended from a wire, looped up as in Fig. 83, or they may be placed in a perforated stoneware basket (Fig. 84), provided with a handle of the same material. These perforated baskets are specially manufactured at the potteries for acid dipping and other purposes, and if carefully treated will last for an indefinite period. The basket containing the articles to be dipped is plunged into the dipping acid, and moved briskly about, so as to expose every surface of the metal to the action of the acid; as the vessel is raised the liquid escapes through the perforations, and after a brisk shaking the basket and its contents are plunged into the first washing water, in which it is again vigourously shaken, to wash away the acid as far as possible; it is then treated in the same way in at least two more rinsing waters. The dipped articles are then to be thrown into a weak solution of crude bitartrate of potash, called *argol*, to prevent them from becoming oxidised or tarnished. From this liquid they are removed as required, and again rinsed before being quicked and plated. For dipping purposes, stoneware and gutta-percha bowls (Fig. 85) are also used, and sometimes platinum wire trays, supported by a hook, as in Fig. 87, are employed for very small articles. Hooks of the same kind, but in various forms, are likewise used for supporting various pieces of work during the dipping operations. One of these is shown in Fig. 86.

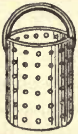

Fig. 84.

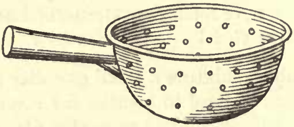

Fig. 85.

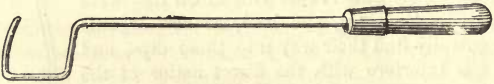

Fig. 86.

Spoon and Fork Work.—In large establishments this class of work may be said to hold the leading position, since, as articles of domestic utility, the spoon and fork are things of almost universal requirement. As in all other kinds of electro-plated ware—and we may add everything else under the sun—the silvering, or plating, is accomplished according to the requirement of the customer and the price to be paid for the work when done. In other words, the actual deposit of silver which each article receives depends upon whether it is intended *to wear well*, or merely required *to sell*. In the former case, it is usual for the customer to weigh the spoons and forks before he sends them to the plater, and again on their return, and he pays so much per ounce for the silver deposited, allowing a moderate discount from the original weight to cover any loss which may be sustained in preparing the work for the plating bath. When the goods, however, are merely required to look "marketable," the amount of silver deposited upon such a class of work often ranges from little or nothing to less, if possible.

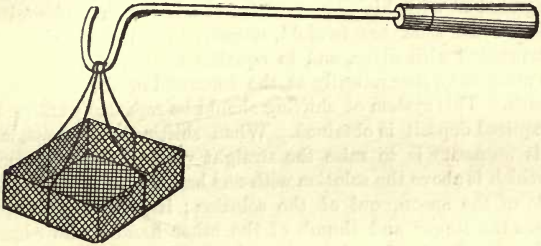

Fig. 87.

Wiring the Work.—Spoons and forks are first *wired*, as it is termed. For this purpose copper wire is cut into lengths of about 12 inches. A length of the wire is coiled once round the shank or narrow part of the article, and secured by twisting it several times; the loop thus formed should be quite loose, so that the position of the spoon or fork may be easily reversed or shifted while in the plating vat, to equalise the deposit, and to allow the parts where the wire has been in contact to become coated with silver. The copper wire used for "slinging" is usually about No. 20 B.W.G. (Birmingham Wire Gauge), which is the gauge most generally adopted in this country. The spoons, &c., are next placed in the hot potash bath, where they are allowed to remain for a short time, when they are removed, a few at a time, and rinsed in cold water. They are next to be brushed or scoured all over with fine pumice-powder moistened with water, and then thrown into clean water, where they remain until a sufficient number have been scoured, when these are taken out by their wires and immersed in the quicking solution, which, for spoon work, may conveniently be in a shallow oval pan of the form shown in Fig. 88. After remaining in the quicking bath a short time, they are examined, and if sufficiently *quicked*, and uniformly bright, like quicksilver, they are rinsed in water and at once suspended in the

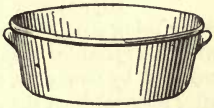

Fig. 88.

plating tank, as close together as possible without touching. When the bath is filled with work, the spoons or forks should be turned upside down by slipping the shank through the loop; and the workman who does this must be very careful to handle them as little as possible, and only to grip them with the fingers by the *edges*, which an experienced plater will do with great smartness, and with very trifling contact with his fingers. The objects of thus changing the position of the work are twofold, namely, to allow the *wire mark* to become coated with silver, and to equalise the deposit, which always takes place more energetically at the *lower* end of the article while in the bath. This system of shifting should be repeatedly effected until the required deposit is obtained. When shifting the spoons, &c., all that is necessary is to raise the straight portion of the suspending wire which is above the solution with one hand, which brings, say, the handle of the spoon, out of the solution; if this be now gripped between the finger and thumb of the other hand at its edges, and raised until the bowl end touches the loop, by simply turning the spoon round its bowl will be uppermost, in which position the article is carefully but quickly lowered into the bath again.

Another method of suspending spoons and forks in the plating bath is the following: Copper wire, about the thickness of ordinary bell wire, is cut up into suitable lengths, and which will depend upon the distance between the negative conducting-rod and the surface of the silver solution. These wires are next to be bent into the form of a hook at one end, and at the other end is formed a loop, as in Fig. 89, leaving an opening through which the shank of a spoon or fork may pass into the ring or loop and be supported by it. To prevent the silver from being deposited upon the vertical portion of the wire, where it would be useless and unnecessary, this portion of the wire should be protected by means of glass, gutta-percha, or vulcanised india-rubber tubing, which is slipped over the wire before the upper hook is formed. After being some time in use, the lower ring becomes thickly coated with a crystalline deposit of pure silver, when these wires must be replaced by new ones, and the insulating tubes may be again applied after removal from the old wires.

Fig. 89.

Ordinary slinging wires, as those previously described, should never be used more than once, and for this reason: when a certain amount of silver or other metal is deposited upon wire—except under certain conditions—it is invariably more or less brittle, and in attempting to twist it round an article it is very liable to break, often causing the article to fall from the hand—perhaps into the bath—and rendering the silver-covered fragments of wire liable to be wasted by being swept away with the dirt of the floor. It is more economical to employ fresh wires for each batch of work, and to *strip* the silver or other metal from the wires by either of the processes hereafter given, by which not only may all the metal be recovered, but by *annealing*, cleaning, and straightening the wires, they may be used again and again. Moreover, a wire that has been twisted once becomes hardened at that part, and cannot with safety be twisted again without being *annealed*.

Arrangement of the Plating Bath.—The size and form of depositing tanks for silver plating vary in different establishments, as also does the material of which they are constructed. For small quantities of silver solution, say from ten up to thirty gallons, oval stoneware pans may be used, and with ordinary care will last a great number of years. Wooden tubs, if absolutely clean, may also be employed for small operations, but since that material absorbs the silver solution, such vessels should be well soaked with hot water before pouring in the solution. Tanks made from slate, with india-rubber joints, have also been much used in silver-plating. Very good plating tanks may be made in the same way as directed for nickel-plating baths, that is, an outer vessel of wood, secured by screwed bolts, lined with sheet lead, and re-lined with matched boarding. Wrought-iron tanks, lined with wood, are, however, greatly preferred, and when properly constructed and lined, form the most durable of all vessels for solutions of this description. Depositing tanks for large operations are usually about six feet in length, three feet in width, and about two feet six inches in depth, and hold from two to three hundred gallons of solution; tanks of greater length are, however, sometimes employed. An ordinary wrought-iron plating tank is shown in Fig. 90, in which also the arrangement of the silver anodes and sundry articles in solution is seen. The upper rim of the tank is furnished with a flange of wood, firmly fixed in its position, upon which rest two rectangles of brass tubing or stout copper rod. The outer rectangle frequently consists of brass tubing about an inch in diameter, at one corner of which a binding screw is attached, by means of solder, for connecting it with the positive pole of the battery

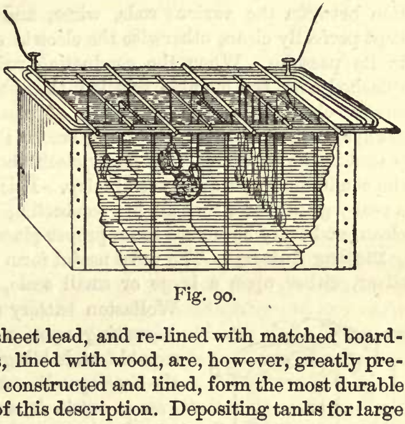

Fig. 90.

or other generator of electricity. The inner rectangle should be of stout copper rod, or wire—usually about one-half the thickness of the former, and is also provided with a binding screw at one corner, to connect it with the negative pole of the battery. A series of brass rods, from half to one inch in diameter, and each about the length of the tank's width, are laid across the outer rectangle, and from these are suspended the silver anodes; similar but shorter rods of brass are placed between each pair of anodes, and rest upon the inner rectangle; from these rods the articles to be plated are suspended, as shown in the engraving. Before the respective conducting rods are placed in position, they must be thoroughly well cleaned with emery cloth, as also must be the rectangular conductors and wire holes of binding screws which are to receive the positive and negative conducting wires, the ends of which must likewise be cleaned with emery cloth each time before making connection with the battery. It may be well here to remark that *all* the points of connection between the various rods, wires, and binding screws must be kept perfectly clean, otherwise the electric current will be obstructed in its passage. When the conducting rods become foul by being splashed with the cyanide solution, they should be well cleaned with emery cloth, and the operation of cleaning these rods should always be performed each morning before the first batch of work is placed in the solution; the emery cloth should only be applied when the conducting rods are perfectly dry. It is always a characteristic of a really good plater that all his conducting rods are kept bright and clean, and every appliance in its proper place.

Plating Battery.—The most useful form of battery for depositing silver, either upon a large or small scale, is a modification of the Wollaston battery shown in Fig. 91. For depositing upon a large scale, a stone jar capable of holding about ten gallons forms the battery cell. A bar of wood, D, having a groove cut in it, so as to allow a stout plate of zinc to pass freely through it, rests across the battery jar, A. Two sheets of copper, B *b*, connected by strips of the same metal soldered to the upper corners, are placed over the wooden bar, and a binding screw connected to one of the copper plates, either by means of solder or by a side screw. The copper plates should nearly reach to the bottom of the jar. A suitable binding screw is attached to the zinc plate, *c*, which must be well amalgamated. The exciting fluid consists of dilute sulphuric acid, in the proportion of one part of the latter to fifteen parts of cold water. To

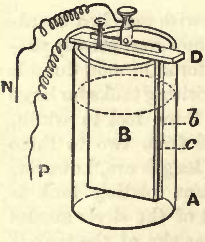

Fig. 91.

prevent the zinc from coming in contact with the copper plates, a small block of wood, having a tolerably deep groove of the same width as the thickness of the sheet of copper, may be fixed on to each edge of the pair of plates about midway between the top and the bottom. In order to regulate the amount of current in working these batteries, it is commonly the practice to drill a hole in the centre of the upper part of the zinc plate, to which a strong cord is attached, and allowed to pass over a pulley, the other end of the cord being connected to a counterweight. A windlass arrangement, as in Fig. 92, is also used for this purpose, by which the zinc plate can be raised and lowered by simply turning a handle connected to a revolving spindle, supported by uprights of wood, round which the cord becomes wound or unwound according to the motion given to the handle.

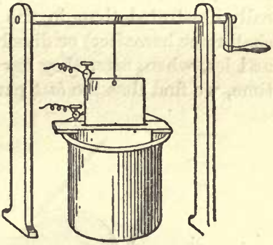
Fig. 92.

When the bath is about to be filled with work, the zinc plate should only be lowered a short distance into the acid solution, and the surface is to be increased as the filling of the bath progresses; if this precaution is not observed, the deposition will take place too rapidly upon the work, and the deposited metal will assume a grey colour instead of the characteristic white, besides which the silver will be liable to strip or separate from the underlying metal in the subsequent processes of scratch-brushing and burnishing, or even under the less severe process of polishing. A very safe way to check the too rapid deposit, is to suspend an anode from the negative conducting rod as a *cathode* when the first batch of articles is being placed in the bath. When very powerful batteries or dynamo-machines are used, the resistance coil (*vide* Nickel-plating) must be employed.

Motion given to Articles while in the Bath.—In order to insure uniformity of deposit while employing strong electric power from magneto or dynamo machines, it has been found that by keeping the articles slowly in motion while deposition is taking place, this desirable end can be effectually attained. There are several ingenious devices adopted for this purpose, to several of which we may now direct attention. It is a fact that deposition takes place first at the *extreme end* of the article in solution—that is the point *farthest from* the source of electricity;* and this being so, we may be sure that the deposition

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* Except in *electrotyping,* in which case the surface which receives the deposit (plumbago) is but an indifferent conductor of electricity.

progresses in the same ratio during the whole time the articles are receiving the deposited metal provided the solution and the work remain undisturbed. Indeed, in the case of table forks, if we suffer them to remain, with their prongs *downward*, undisturbed for a considerable time, we shall find, on removing them from the bath, that the prongs, from the extreme tips upward, will be coated with a crystalline or granular deposit, while the extreme upper portion of the article will be but poorly coated. In no case is the fact of the deposit taking place from the lowest part of an article upward more practically illustrated than in the process of "stripping" (to which we shall refer hereafter) or dissolving the silver from the surface of plated articles, when, after they have been in the stripping solution for some time, we find that the *last* particles of silver which will yield to the chemical action of the liquid are the points of the prongs of a fork, the lowest part of the bowl of a spoon, as also (if the articles have been duly shifted during the plating) the extreme ends of the handles of either article.

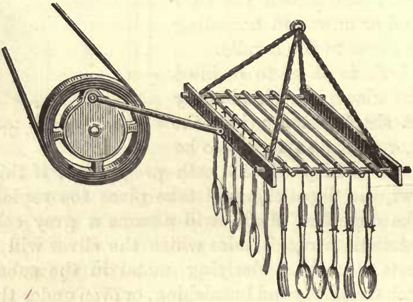


Fig. 93.

To keep the articles in gentle motion while in the bath, one method is to connect the suspending rods to a frame of iron, having four wheels about three inches in diameter connected to it, which slowly travel to and fro to the extent of three or four inches upon inclined rails attached to the upper edges of the tank, the motion, which is both horizontal and vertical, being given by means of an eccentric wheel driven by steam power. By another arrangement, the articles are suspended from a frame (as in Fig. 93), and the motion given by the eccentric wheel as shown in the engraving. The simplicity of the former arrangement, however, will be at once apparent.

Cruet Stands, &c.—Before being submitted to the cleansing operations, *quicking*, &c., before described, the "wires" of cruet and liqueur stands must be separated from the bottoms, to which they are generally connected by small nuts, and these latter should be slung upon a wire and laid aside until the other parts of the article are ready for plating. A wire is then to be connected to each part of the cruet frame, and these are then to be immersed in the hot potash liquor, being left therein sufficiently long to dissolve or loosen any greasy matter which may attach to them. After being rinsed, they are to be well brushed with powdered pumice and water. The brushes used for this and similar purposes are made from hog hair, and are supplied with one or more rows, to suit the various purposes for which they are required; for example, a one-rowed brush is very useful for cleaning the joints connecting the rings with the framework of cruet stands, as also for all crevices which cannot be reached by a wider tool; a two-rowed brush is useful for crevices of greater extent and for hollows; and three, four, five, and six-rowed brushes for flat surfaces, embossed work, and so on. One of these useful tools is shown in Fig. 94.

Fig 94.

After scouring and rinsing, the parts of the cruet stand or liqueur stand are to be immersed in the quicking solution until uniformly white in every part, after which they must be well rinsed and immediately put into the plating bath; after a short immersion, the pieces should be gently shaken, so as to shift the slinging wire from its point of contact, and thus enable that spot to become coated with silver; it is always advisable to repeatedly change the position of the wire so as to avoid the formation of what is termed a *wire mark*, and which is of course due to the deposit not taking place at the spot where the wire touches the article, thereby leaving a depression when the article is fully plated. The flat base of the cruet stand should be suspended by two wires, each being passed through one of the holes at the corner, and it should be slung sideways and not lengthwise; its position in the bath should be reversed occasionally, so as to render the deposit as uniform as possible; the same observation applies to the "wire" part of the cruet stand. When *mounts* are sent with the cruet stand, not separate, but cemented to the cruets, which is often the case, it will be well, if it can be conveniently done, to remove the pin which connects the top or cover with the rim of the mustard mount, so as to plate these parts separately, otherwise the cover will require shifting repeatedly in order to allow those parts of the joint which are protected from receiving the deposit when the cover is *open*, to become duly coated.

Tea and Coffee Services.—Like the foregoing articles, these are of very variable design, and are either plain, chased and embossed, or simply engraved. Unless sent direct from the manufacturer in the proper condition for plating—that is, with their handles and covers unfixed—it will be better to remove the pins connecting these parts with the bodies of tea and coffee pots before doing anything else to them, unless, as is sometimes the case, they are so well riveted as to render their severance a matter of difficulty. The disadvantages attending the plating of these vessels with their handles and lids on are that the solution is apt to get inside the sockets of the handles, and to ooze out at the joints when the article is finished, while the joint which unites the lid with the body can only be properly plated when the lid is shut, at which time the interior of the lid can receive no deposit. When sent to the plater by the manufacturer, the various parts are usually either separate, or merely held together by long pins, which may readily be withdrawn by a pair of pliers, and the parts again put together in the same way when the articles are plated and finished—that is burnished or polished, as the case may be.

In plating work of this description, the articles are potashed, scoured and quicked as before, and when ready for the plating bath, the tea and coffee pots are generally *wired* by passing the slinging wire through the rivet-holes of the joints; but in order to equalise the deposit as far as possible, it is a good plan, after the article has received a certain amount of deposit, to make a loop at one end of a copper wire, and to pass it under one of the feet of the teapot, then to raise the vessel somewhat, and connect the other end of the wire with the conducting rod; care must be taken, however, not to let the wire touch the body of the vessel, or if it does so, to shift it frequently.

Since deposition always takes place more fully at the *points* and projections of an article, it will be readily understood that the interiors of vessels—being also *out of electrical sight*, so to speak, of the anodes—will receive little if any deposit of silver. This being the case, if we wish to do the work thoroughly well in every part, it will be necessary to deposit a coating of silver upon the inside either before or after the exterior has been plated. To do this, the vessel being well cleaned inside, is placed upright on a level bench, and a wire connected to the negative pole of the battery is slipped through the joint as before. A small silver anode, being either a strip of the metal or a narrow cylinder, is to be attached to the positive pole, and the anode lowered into the hollow of the vessel, care being taken that it does not touch in any part. The vessel is then to be filled to the top with silver solution dipped out of the bath with a jug, and the whole allowed to rest for half an hour or so, at the end of which time the interior will generally have received a sufficient coating of silver.

Scratch-brushing.—One of the most important mechanical operations connected with silver-plating is that of scratch-brushing. For this purpose skeins of thin brass wire, bound round with stout brass or copper wire (Fig. 97), are used. When the plated articles are removed from the bath, they present a pearly white appearance not unlike very fine porcelain ware, but still more closely resembling standard silver that has been heated and pickled in dilute sulphuric acid, as in the process of *whitening* watch dials. The dead white lustre of electro-deposited silver is due to the metal being deposited in a crystalline form, and the dulness is of so fugitive a nature that even scratching the surface with the finger nail will render the part more or less bright by burnishing the soft and delicate crystalline texture of the deposit. The object of scratch-brushing is to obliterate the white "burr," as it is called, before the work is placed in the hands of the burnisher or polisher, otherwise it would be apt to show in such parts of the finished article as could not be reached by the tools employed in those operations. As in the case of gilding, the revolving scratch-brushes are kept constantly wetted by a thin stream of stale beer, or half beer and water, supplied, by means of a tap, from a small vessel (which may conveniently be a wooden bucket) placed on the top of the scratch-brush box. A tin can, or other light vessel, stands upon the floor, beneath the box, to catch the beer runnings, which escape through a pipe let into a hole in the bottom of the box. A still more handy plan is to have a small hook fixed below the right-hand corner of the scratch-brush box, for supporting a tin can or other vessel; and by giving the box a slight inclination forwards, and towards the right-hand corner, the liquor will flow out through a hole at the corner, in

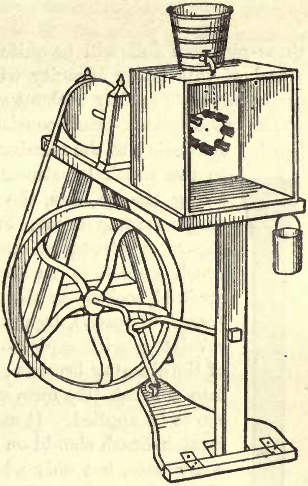
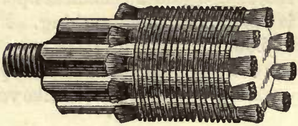


Fig. 95.

which a short piece of lead pipe should be inserted. By this arrangement (Fig. 95), the workman can empty the can into the vessel above, whenever the beer liquor ceases to drip upon the scratch-brushes, without allowing the driving wheel to stop. Much time may be saved in this way, especially when the liquid happens to run short, at which time the can requires to be emptied frequently. To prevent the beer runnings from overflowing, and thus making a mess on the floor, while wasting the liquor, no more liquor should be put into the cistern above than the vessel below will contain. A quart or three-pint can full will be quite sufficient for ordinary work, and a vessel of this latter capacity will be quite as large as the workman can manipulate readily without stopping the lathe.



g. 96.

The lathe scratch-brush consists of a series of six or eight scratch-brushes (according to the number of grooves in the "chuck") bound to the chuck by strong cord, as in Fig. 96. Previous to fixing the brushes, the skein of fine brass wire forming a single scratch-brush, Fig. 97, is to be cut with a pair of shears or strong scissors. Before applying the compound brush—which is connected to the lathe-head by means of its screwed socket—to the plated work, the brushes should be *opened*, or spread, by pressing rather hard upon them, while revolving, with a piece of stout metal, or the handle of one of the cleaning brushes; this will spread the bundles of wire into a brush-like form suitable for the purpose to which they are to be applied. It may be well to state that the revolving scratch-brush should on no account be applied to the work in a dry state, but only when the beer liquor is running sufficiently free to keep the brushes *wet*.

In working the scratch-brush, it must be allowed to revolve to the right of the operator, otherwise the "chuck" will be liable to come unscrewed; moreover, this is the most convenient motion for enabling the workman to guide the articles without risk of their being jerked out of his hand—an accident that might readily occur if he inadvertently turned the wheel the wrong way. In scratch-brushing spoons and forks, a very moderate pressure is all that is necessary to render the surface bright; a little more pressure, however, is required for the edges of salvers, dishes, handles and feet of cruet stands, and other work in which hollows of some depth form a necessary feature of the ornamental mounts.

Fig. 97.

Plating by Dynamo-Electricity.—In the larger electro-plating establishments, magneto or dynamo-electric machines are employed, and the current from these powerful machines is conveyed by stout leading wires to the various baths, the force of the current entering the baths being regulated by resistance coils. In works of moderate dimensions, a good machine, either of the magneto or dynamo-electric type, will supply sufficient electricity to work a large bath of each of the following solutions: nickel, silver, brass and copper, as also a good-sized gold bath. In working with these machines, it is of the greatest importance that they should be driven at an uniform speed; and though some machines require to be driven at a higher rate of speed than others, the maximum allowed by the respective makers should never be exceeded, or the machine may become considerably heated and seriously injured. When starting the machine, the number of its revolutions should be ascertained by means of the *speed indicator* referred to elsewhere, and as far as practicable the normal speed should be maintained without sensible variation while the current is passing into the vats. Although this uniformity of speed is more certainly obtained, we believe, with gas engines than with steam power, if proper care and attention are given, and frequent examination of the speed of the dynamo-armature made by the plater, tolerable regularity may be attained from the latter source of power. It must always be remembered by the plater, that when the engine which drives the dynamo is also employed for driving polishing lathes, emery wheels, &c., when very heavy pieces are being treated in the polishing shop the speed of the dynamo may be greatly influenced; indeed we have frequently known the belt to be suddenly thrown off the pulley of a dynamo from this cause, and the machine. of course, brought to a full stop.

CHAPTER XIX.

ELECTRO-DEPOSITION OF SILVER (*continued*).

Plating Britannia Metal, &c.—Plating Zinc, Iron, &c.—Replating Old Work.—Preparation of Old Plated Ware.—Stripping Silver from Old Plated Articles.—Stripping Gold from Old Plated Articles.—Hand Polishing.—Resilvering Electro-plate.—Characteristics of Electro-plate.—Depositing Silver by Weight.—Roseleur's Argyrometric Scale.—Solid Silver Deposits.—On the Thickness of Electro-deposited Silver.—Pyro-plating.—Whitening Electro-plated Articles.—Whitening Silver Work.

Plating Britannia Metal, &c.—It was formerly the practice to give a coating of copper or brass to articles made from Britannia metal, tin, lead, or pewter, since it was found difficult otherwise to plate such metals and alloys successfully, that is without being liable to strip. It is usual now, however, to immerse the articles first in the hot potash solution, and to place them, with or without previous rinsing, in the depositing-bath. Since the potash bath dissolves a small quantity of metal from the surface of articles made from these metals, a favourable surface is left for the reception of the silver deposit, to which the metal adheres tolerably well—indeed sufficiently so to bear the pressure of the burnishing tools. Since Britannia metal, pewter, &c., are not such good conductors of electricity as German silver, copper, or brass, an energetic current must be applied when the articles are first immersed in the bath, and when the whole surface of each article is perfectly coated with silver, the amount of current may be somewhat diminished for a time, and again augmented as the deposit becomes stouter; care being taken not to employ too strong a current, however, in any stage of the plating process. It may be mentioned that articles made from Britannia metal—which are generally sold at a very low price—are seldom honoured with more than a mere film of silver, in fact just so much as will render them marketable, and no more; still, however, a very extensive trade is done in work of this description, much of which presents an exceedingly creditable appearance.

Plating Zinc, Iron, &c.—To coat these metals with silver, it is best to first give them a slight coating of brass or copper, in an alkaline solution, which does not occupy much time, neither is it a costly proceeding. Both these metals adhere pretty firmly to zinc, iron, and steel, while silver attaches itself freely to brass and copper. If hot solutions of copper or brass are used, the trifling deposit required to enable the subsequent coating of silver to adhere to the zinc, &c., can be obtained in a very few minutes. Each operation, however, should follow in quick and unbroken succession, for if the brass or copper-coated article be allowed to remain, even for a few seconds, in the air before being placed in the silver bath, it will rapidly oxidise, and render the deposited silver liable to strip when the article is scratch-brushed. Moreover, if the brassed or coppered articles are allowed to remain for a short time in the air while in a moist condition, voltaic action will be set up between the zinc and the metallic covering, by which the latter will become loosened, and will readily peel off under the action of the scratch-brush. Each article, after being brassed or coppered, should, after rinsing, be placed at once in the silvering-bath.

Replating Old Work.—Under this head must be considered not only the old Sheffield and Birmingham ware, the manufacture of which became superseded by the electro-plating process, but also the more modern article known as "electro-plate" (the basis of which is German silver), which has, by domestic use, become unsightly in consequence of the silver having worn off the edges and other prominent parts most subject to friction in the process of cleaning. In the business of replating, there must ever be a constant if not a growing trade, if we consider the enormous quantity of plated goods which annually flow into the market, and which must—even the best of it—require resilvering at some time or other, while the inferior classes of goods may require the services of the electro-plater at a much earlier period than the purchaser of the articles expected.

Preparation of Old "Plated" Ware for Resilvering.—These articles, whether of Sheffield or Birmingham manufacture, have a basis of copper. The better class of plated ware, which was originally sold at about half the price of standard silver, and some of which may be occasionally met with, though doubtless becoming rarer every year, is of most excellent quality, both as to design and workmanship, and when properly prepared for replating, and well silvered and finished after, is well worthy of being replaced upon the table by the side of the more modern articles of electro-plate. Such articles, however, should never be replated with an insignificant coating of silver, since the copper surface beneath would soon reappear and expose the indifferent quality of the plater's work. It may be well to state, however, that by far the greater proportion of old "plated" articles are not of the same quality as the old Sheffield plate and the equally admirable work formerly manufactured by the distinguished firm of Boulton and

Watt, of Birmingham, some specimens of which may also be occasionally met with; but a very inferior class of goods, which may generally be recognised by their having lost nearly the whole of their silver covering—which was never very much—whereas in the better class of old plated ware the silver has worn off chiefly at the extreme edges, while the remainder of the article retains a sound coating of silver.

In preparing old plated cruet frames, &c., for replating, the wires, which are generally attached by soft solder to the stands, must be separated by first scraping the solder clean, and then applying a hot soldering-iron (using a little powdered resin), which must be done very carefully, otherwise the solder which connects the feet of the stand may become melted, causing them to drop off; it is safer, when applying the hot iron, to have an assistant at hand, who with a brush or hare's foot should wipe away the solder from the joint when it is melted. All the joints being treated in this way, in the first instance, the ground is cleared, when by a fresh application of the soldering-iron the legs of the wire may be loosened, one at a time, until the whole series have become partially displaced, after which, by again applying the hot iron, the legs, one after another, may be forced out. If the two parts of the frame are not taken asunder in this cautious way, the workman may involve himself in much trouble from the melting of the lead mounts (called "silver" mounts), the dropping off of legs, feet, &c., all of which may be avoided in the way we have suggested. It must be understood that our suggestions are specially made for the guidance of those who, though good platers, may not be experts in the application of the soldering-iron. It is usually the practice to remove what silver there may be upon old plated articles by the process termed "stripping." This consists in immersing the article in a hot acid liquid which, while dissolving the silver from the surface, acts but little upon the underlying metal, whether it be of copper, brass, or German silver. The process of *stripping* being an important auxiliary in connection with the replating of old work, as also in cases in which an unsuccessful deposit has been obtained upon new work, we may advantageously describe the process at once; but previous to doing so, we may state that the silver removed by stripping from the better class of old plated articles is sometimes an important gain to the electro-plater, if he be fortunate enough to receive a liberal amount of such work, while, on the other hand, the inferior qualities of plated ware will yield him no such satisfaction.

Stripping Silver from Old Plated Articles.—A *stripping-bath* is first made by pouring a sufficient quantity of strong oil of vitriol into a suitable stoneware vessel, which must be made hot, either by means of a sand bath, or in any other convenient way. To this must be added a small quantity of either nitrate of potash, or nitrate of soda, and the mixture stirred with a stout glass rod until the latter is dissolved. The article to be stripped is first slung upon a stout copper wire; it is then to be lowered in the liquid, being held by the wire, until wholly immersed. Leave the article thus for a few moments, then raise it out of the solution, and observe if the silver has been partially removed; then redip the article and leave it in the bath for a short time longer, then examine it again; if the action appears rather slow, add a little more nitre, and again immerse the article. When the silver appears to be dissolving off pretty freely, the operation must be watched with care, by dipping the article up and down in the solution, and looking at it occasionally, and the operation must be kept up until all the silver has disappeared, leaving a bare copper surface. When a large number of articles have to be stripped, a good many of these may be placed in a hot acid bath at the same time, but since they will doubtless vary greatly in the proportion of silver upon them, they should be constantly examined, and those which are first stripped, or *desilvered*, must be at once removed and plunged into cold water. When all the articles are thoroughly freed from silver, and well rinsed, they are to be prepared for plating by first *buffing* them, as described in the chapter on polishing, after which they are cleaned and quicked in the same way as new work.

A Cold Stripping Solution, which is not so quick in its action as the former, is made by putting in a stoneware vessel a quantity of strong sulphuric acid, to which is added concentrated nitric acid in the proportion of 1 part of the latter acid to 10 parts of the former (by measure). In this mixture the articles are suspended until they give signs of being nearly deprived of their silver, when they are somewhat more closely attended to until the removal of the silver is complete, when they are at once placed in cold water. The articles must be perfectly dry when placed in this stripping liquid, since the presence of even a small quantity of water will cause the acid to attack the copper, brass, or German silver, of which the articles may be made. The vessel should also be kept constantly covered, since sulphuric acid attracts moisture from the air. The silver may be recovered from old stripping solutions by either of the methods described elsewhere.

Buffing Old Work after Stripping.—The stripped articles, after being thoroughly well rinsed and dried, are sent to the polishing shop, where they are buffed and finished, and the cavities, caused by the action of vinegar or other condiments upon the base of cruet stands, as far as possible removed. Sometimes these depressions are so deep that they cannot be wholly removed without rendering the surface so thin that, in burnishing this portion of the article, it is liable to warp or become stretched, rendering the flat surface unsightly for ever after. The back of the stand, which is usually coated with tin, should be roughly "bobbed" with sand until all the tin is removed. The next items, which usually give some trouble, are the so-called "silver mounts," which are commonly of two kinds. The edge, or border of the stand, being originally a shell of silver foil, struck in design, and filled or backed up with lead or solder, is generally more or less free from silver, except in the hollows; and since the soft metal does not receive the silver deposit so favourably as the metal of which the rest of the article is composed, these edges must receive special treatment, otherwise the silver deposited upon them will be brushed off in the after-process of scratch-brushing. There are several ways of treating "lea edges," as they are properly called. Some persons remove them altogether, and replace them by brass mounts, which are specially sold fo this purpose. If this plan be not adopted, we must endeavour to induce the silver to adhere to the lead mounts by some means or other. The edge of the article, after being cleaned, may be suspended, one angle at a time, in a brassing bath, or alkaline coppering solution, until a film of either metal is deposited upon the leaden mount, when, after being rinsed, a second angle may be treated in the same way, and so on, until the entire edge is brassed or coppered. The small amount of brass or copper, as the case may be, which may have deposited upon the plain portions of the work, may be removed by means of a soft piece of wood, powdered pumice, and water. Edges treated in this way generally receive a good adherent coating of silver. Sometimes, but not always, the ordinary "quicking" will assist the adhesion of the silver to the lead mounts. Another method of depositing a firm coating of copper upon lead edges is to put a weak acid solution of sulphate of copper in a shallow vessel, and having a small piece of iron rod in one hand, to lower one portion of the edge of the cruet bottom into the solution; then touching the article under the liquid, in a short time a bright coating of copper will be deposited upon the leaden surfaces, by means of the voltaic action thus set up, when this portion may be rinsed, and the remainder treated in the same way. Or take a small piece of copper, and connect it by a wire to the positive electrode of a battery, envelop this copper in a piece of chamois leather or rag, then put the article in connection with the negative electrode. By dipping the pad, or "doctor," in either an acid or an alkaline solution of copper, or in a warm brassing solution, and applying it to the part required to be coated, a deposit will at once take place, which may be strengthened by repeatedly dipping the pad in the solution and applying again. In this way, by moving the pad containing the small anode of copper or brass along the edge, the required deposit may be effected in a very short time with a battery of good power—a Bunsen cell, for example.

Old "plated" tea and coffee pots are invariably coated inside with tin; and if this part of the article is required to be silvered—which is sometimes, though not always, the case—the tin should first be removed by dissolving it in some menstruum which will not dissolve the copper beneath. For this purpose either hydrochloric acid or a solution of caustic potash may be used. If the former, the inside of the vessel should first be filled with a boiling hot solution of potash, and after a time the liquid is to be poured out and thoroughly rinsed. It must then be filled with strong muriatic acid, and allowed to rest until the upper surface, upon being rubbed with a strip of wood, exposes the copper, when the acid is to be poured out, and the vessel again rinsed. The inside must now be cleaned by brushing with silver sand and water as far as the brush will reach, when the bottom and hollow parts of the body may be scoured with a mop made with rag or pieces of cloth and silver sand. If it is preferred to dissolve the tin from the inside of the vessel by means of potash, the hot liquid must be poured in as before, and the vessel placed where the heat can be kept up until the desired object—the removal of the tin—is attained, when the vessel must be cleaned as before. Dissolving the tin from the inside of such old plated articles should be the first preparatory process they are subjected to; indeed, the interiors of all vessels to be electro-plated should be attended to first, in all the preliminary operations, but more especially in the operations of scouring, in which the *handling* of the outside, though a necessity, is liable to cause the work to strip (especially in nickel-plating), unless the hands are kept well charged with the pumice or other gritty matter used in scouring. To remove tin from copper surfaces, a hot solution of *perchloride of iron* may also be used, for although this iron salt acts freely upon copper, voltaic action is at once set up when the two metals, tin and copper, come in contact with the hot solution of the perchloride, which quickly loosens the tin so that it may be brushed away with perfect ease. From the rapidity of its action, we should prefer to adopt the latter mode of de-tinning copper articles, but either of the former would be safest in the hands of careless or inexperienced manipulators.

Old "plated"—we use the term in reference to Sheffield ware more especially—sugar-bowls, cream-ewers, mugs, goblets, &c., which have been gilt inside, should have what gold may still remain upon the article "stripped off" before other operations are proceeded with; and since these articles were originally *mercury gilt*, in which a liberal amount of gold was often employed, it is frequently worth while to remove this by dissolving it from the insides of the vessels; and the same practice should be adopted with all silver-gilt articles which are merely required to be whitened, to which we shall refer in another place.

Stripping Gold from the Insides of Plated Articles.—The sugar-bowl or other vessel is placed on a level table or bench, and put in connection with the positive electrode of a battery. A strip of sheet copper or platinum foil is next to be attached to the negative electrode, and placed inside the vessel, without touching at any point. By this arrangement the article becomes an *anode.* The vessel must now be filled with a moderately strong solution of cyanide of potassium, consisting of about 4 ounces of cyanide to 1 quart of water. Since the metal beneath will also dissolve in the cyanide solution, the operation must be stopped as soon so the gold has disappeared from the surface. The solution should then be poured out, and bottled for future use. When the stripping solution, from frequent use, has acquired sufficient gold to make it worth while to do so, the metal may be extracted by any of the processes given in another chapter.

Old plated table candlesticks, some of which are of admirable design and well put together, may be occasionally met with, as also a very inferior article, the parts of which are mainly held together by a lining or "filling" of pitch, or some resinous compound. In treating old plated candlesticks, the removal of the *filling* should be the first consideration, since it will give the plater a vast amount of after trouble if he attempts to plate them while the resinous or other matter remains in the interior. In the first place, the silver solution will be sure to find its way into the hollow of the article, from which it will be next to impossible to entirely extract it when the article is plated, for the liquid will continue to slowly exude for days, or even weeks, after the article is finished. Again, if the article be plated without removing the filling material, this, being freely acted upon by the cyanide solution, will surely harm it. After removing the socket, the green baize or cloth should be removed from the base of the candlestick, when it should be placed before a fire until the whole of the resinous matter or pitch has run out. To facilitate this, the article should be slightly inclined in an iron tray or other vessel, so that the resinous matter may freely ooze out and be collected. In dealing with the inferior varieties of candlesticks—which may be known by *all* or nearly all the silver having worn from their surface—the plater may find, to his chagrin, that before all the stuffing has run out the candlestick will have literally fallen to pieces. The various parts, not having been originally put together with solder, but held in position merely by the filling material, readily come asunder when the internal lining is loosened. In such a case as this he should, without losing his temper (if possible), determine to prepare and plate all the parts separately (keeping the parts of each "stick" together), and after scratch-brushing, carefully put them together again. The candlestick should now be turned upside down, and held in this position by an assistant, while a sufficient quantity of pitch (previously melted in an earthenware pipkin) is poured in. The candlestick must be left in the erect position until the filling has nearly set, when the hollow formed by the contraction of this substance must be filled up with the same material, and the article then left until quite cold, when it may be handed over to the burnisher. When burnished, the surface of the pitch should be levelled with a hot iron, and then at once brought in contact with a piece of green baize, placed upon a table, and gentle pressure applied to cause the uniform adhesion of the two surfaces. When cold, the remainder of the baize is cut away by means of a sharp pair of scissors, when, after being wiped with a clean or slightly rouged chamois leather, the article is finished.

Hand Polishing.—When the electro-plater is unprovided with a proper polishing lathe and the various appliances ordinarily used in polishing metals, he must have recourse to the best substitute he can command for polishing by hand. To aid those who may be thus circumstanced, and who may have no special knowledge of the means by which the rough surfaces of old work may be rendered sufficiently smooth for replating, we will give the following hints: Procure a few sheets of emery-cloth, from numbers 0 to 2 inclusive; one or two lumps of pumice-stone; a piece of Water-of-Ayr stone, about $\frac{3}{4}$ inch square and 5 inches long; also a little good rottenstone, and a small quantity of sweet oil. Suppose it is necessary to render smooth the base, or stand, of an old cruet frame, deeply marked on its plane surface by the corrosive, or, rather, voltaic action of the vinegar dropping from the cruets upon the plated surface. The article, after being *stripped*, as before, should be laid upon a solid bench, and a lump of pumice (previously rubbed flat upon its broadest part) frequently dipped in water and well rubbed over the whole surface, that is, not merely where the cavities are most visible, but all over. After thus rubbing for some time, the stand is to be rinsed, so that the operator may see how far his labour has succeeded in reducing the depth of the "pit-marks." The stoning must then be resumed, and when the surface appears tolerably uniform, the article should be well rinsed, dried, and again examined, when if the marks are considerably obliterated, a piece of No. 2 emery-cloth may be briskly applied to the surface by being placed over a large cork or bung, after which a finer emery-cloth should be applied. The article should next be *thoroughly* rinsed, and brushed with water to remove all particles of emery; and while still wet, the Water-of-Ayr stone must be rubbed over the surface. The stone should be held in an inclined position, frequently dipped in water, and passed from end to end of the article. The effect of this will be—and *must* be—to remove all the scratches or marks produced by the pumice and emery-cloth. Until these have disappeared, the smooth but keenly-cutting stone must be applied. After having rendered the surface perfectly smooth, the article is to be again rinsed and dried. It must now be briskly rubbed with rottenstone, moistened with oil, and applied with a piece of buff, or belt (such as soldiers' belts are made of), glued to a piece of wood. When sufficiently rubbed or buffed with the rottenstone, the surface will be bright, and in order to ascertain how the work progresses, it should occasionally be wiped with a piece of rag. In very old plated articles, the pit-holes are frequently so deep that to entirely obliterate them would render the metal so thin as to spoil the article. It is better, therefore, not to go too far in this respect, and to trust to the cruets, when in their places, disguising whatever remains of the blemishes, after the foregoing treatment, rather than to endanger the solidity of the stand itself. By employing pieces of pumice of various sizes (keeping the flattened piece for *plane* surfaces), strips of emery-cloth folded over pieces of soft wood, Water-of-Ayr stone, and ordinary hand "buff-sticks" of various kinds, the "wires" of old cruet and liqueur frames may be rendered smooth enough for plating. With perseverance, and the necessary labour, many old articles may be put into a condition for plating by hand labour with very creditable results; and it may be some consolation to those living at a distance from large towns, if we tell them that during the first ten years of the electro-plating art, the numerous host of "small men" had no other means of preparing their work for plating than those we have mentioned, many of whom have since become electro-depositors upon an extensive scale.

Resilvering Electro-plate.—This is quite a distinct class of ware from the preceding, inasmuch as the articles are manufactured from what is called *white metal*, in contradistinction to the basis of Sheffield plate, which, as we have said, is the red metal copper. The better class of electro-plate is manufactured from a good quality of the alloy known as German silver, which, approaching nearly to its whiteness, does not become very distinctly visible when the silver has worn from its surface. Inferior qualities of this alloy, however, are extensively used for the manufacture of cheap electro-plate, which is very little superior, as far as colour goes, to pale brass, while the latter alloy is also employed in the production of a still lower class of work. The comparatively soft alloy, of a greyish-white hue, called *Britannia metal*, is also extensively adopted as a base for electro-plate of a very showy and cheap description, of which enormous quantities enter the market, and adorn the shop-windows of our ironmongers and other dealers in cheap electro-plated goods. To determine whether an electro-plated article has been manufactured from a hard alloy, such as German silver, or from the soft alloy Britannia metal, it is only necessary to strike the article with any hard substance, when a ringing, vibratory sound will be produced in the former case, while a dull, unmusical sound, with but little vibration, will be observed in the latter.

Characteristics of Electro-Plate.—Electro-plated articles of the best quality are invariably *hard-soldered* in all their parts; the wires of cruet and liquor frames are attached by German silver nuts to the screwed uprights, or feet of the wires, instead of pewter solder, as in plated ware, and the bottoms of the stands are coated with silver, instead of being tinned, as in the former case. The mounts are of the same material as the rest of the article, and the handles and feet of cream-ewers and sugar-bowls are frequently of solid cast German silver. With these advantages the electro-plater should have little difficulty, if the articles have received fair treatment in use, in replating them and turning them out nearly equal to new, which it should be his endeavour to do. It sometimes occurs that "ship plate"—that is, plated work which has been used on board ship—when it reaches the hands of the electro-plater exhibits signs of very rough usage; corner dishes are battered and full of indentations, while the flat surfaces of the insides are scored with cuts and scratches, suggestive of their having been frequently used as plates, instead of mere receptacles for vegetables; the prongs of the forks, too, are frequently notched, cut, and bent to a deplorable extent. All these blemishes, however, must be removed by proper mechanical treatment, after the remaining silver has been removed by the stripping-bath. It is not unusual for those who contract for the replating of ship work to pay *by the ounce* for the silver deposited, in which case they will not allow the electro-plater to reap the full advantage of the old silver removed by stripping, but will demand an allowance in their favour, which, if too readily agreed to by an inexperienced plater, might greatly diminish his profit if the cost of buffing the articles happened to be unusually heavy; he must, therefore, be upon his guard when undertaking work of this description for the first time, since, otherwise, he may suffer considerable loss, for which the present rate of payment for each ounce of silver deposited will not compensate.

After stripping and rinsing, the articles require to be well polished, or buffed, and rendered as nearly equal to new work as possible; they are then to be potashed, quicked, plated, and finished in the same way as new goods. Since there is now a vast quantity of nickel-plated work in the market, some of which is exceedingly white even for nickel, inexperienced or weak-sighted platers must be careful not to mistake such articles for silver-plated work. When in doubt, applying a single drop of nitric acid, which blackens silver while producing no immediate effect upon nickel, will soon set the mind at rest upon this point.

Electro-tinned articles, which very much resemble silvered work, may also be detected in this way. We are tempted to make one other suggestion upon this subject, which may not be deemed out of place, it is this: a considerable quantity of nickel-plated German silver spoons and forks are entering the market, which, should they eventually fall into the hands of the electro-plater to be coated with silver, may cause him some trouble if he inadvertently treats them as *German silver work*, which in his haste he might possibly do, and attempts to render them smooth for plating by the ordinary methods of hand or lathe-buffing; the extreme hardness of nickel—even as compared with German silver—will render his work not only laborious, but unnecessary, for if he were aware of the true nature of the surface he would naturally remove the nickel by means of a stripping solution, and then treat the article as ordinary German silver work. The stripping solution for this purpose will be given when treating of nickel *re*-plating. It must be understood that in making suggestions of this nature, in passing, that they are intended for the guidance of those who may not have had the advantages of much practical experience, of whom there are many in every art.

Depositing Silver by Weight.—In this country the silver deposit is frequently paid for by weight, the articles being carefully weighed both before and after being placed in the plater's hands. The price charged for depositing silver by the ounce was formerly as high as 14s. 6d.; at the present period, however, about 8s. per ounce only could be obtained, and in some cases even less has been charged. But unless dynamo-electricity be employed this would be about as profitable as giving ten shillings for half-a-sovereign. In France electro-plating is regulated by law, all manufacturers being required to weigh each article, when ready for plating, in the presence of a comptroller appointed by the Government, and to report the same article for weighing again after plating. In this way the comptroller knows to a fraction the amount of precious metal that has been added, and puts his mark upon the wares accordingly, so that every purchaser may know at a glance what he is buying. In Birmingham there is a class of electro-depositors called "electro-platers to the trade," who work exclusively for manufacturers of plated goods and others who, though platers, send a great portion of their work to the "trade" electro-platers, whose extensive and more complete arrangements enable them to deposit large quantities of the precious metals with considerable economy and dispatch.

In depositing silver at so much per ounce, the weighed articles, after being cleaned, quicked, and rinsed, are put into the bath, in which they are allowed to remain until the plater deems it advisable to re-weigh them, when they are removed from the bath, rinsed in hot water, and placed in boxwood sawdust; they are then lightly brushed over to remove any sawdust that may adhere to them, and carefully weighed. If still insufficiently coated the articles are again scratch-brushed, quicked, rinsed, and replaced in the bath; the re-weighing and other operations being repeated as often as is necessary until the required deposit is obtained. This is a tedious and troublesome method, and is sometimes substituted by the following: Suppose a certain number of spoons and forks have been weighed for the plating-bath, one of these articles is selected as a test sample, and is weighed separately; being placed in the bath with the others, it is removed from time to time and re-weighed, to determine the amount of silver it has acquired in the bath. Thus if 24 dwts. of silver are required upon each dozen of spoons or forks, when the test sample has received about 2 dwts. of silver it is known that the rest have a like proportion, provided, of course, that each time it has been suspended in the bath the slinging wire and that part of the conducting rod from which it was suspended were perfectly clean; it is obvious, however, that even this method is open to a certain amount of doubt and uncertainty, if the workmen are otherwise than very careful. To render the operation of depositing by weight more certain and less troublesome, some electro-platers in France adopt what is termed a "plating balance." The articles are suspended from a frame connected to one end of the beam, and a scale pan, with its weights from the other end; the balance, thus arranged, is placed in communication with the negative electrode of the electric generator, and the anodes with the positive electrode. When the articles, as spoons and forks, for example, are suspended from the frame, and immersed in the bath, counter-balancing weights are placed in the scale-pan. A weight equivalent to the amount of silver to be deposited is then put into the pan, which, of course, throws the beam out of balance; when the equilibrium becomes restored, by the weight of deposit upon the articles in solution, it is known that the operation is complete. The plater usually employs scales for each bath, especially when silvering spoons and forks. If preferred, the supporting frame may be circular, so that the soluble anode may be placed in the centre of the bath, and at equal distance from the articles. The centre anode need not prevent the employment of other anodes round the sides of the vessel, so that the articles receive the action of the current in front and behind them. A sounding bell may be so connected that it will indicate the precise moment when the equilibrium of the scale takes place. In working the silver baths for this purpose, the anode surface immersed in solution is much greater than that of the articles. When the solution loses its activity additions of cyanide of silver are given to it, and when the cyanide is found to have become partially converted into carbonate of potassa, hydrocyanic acid is added, which combines with carbonate, and liberates carbonic acid gas. This method is preferred to that of adding fresh cyanide, since an accumulation of the carbonated alkali retards the conductivity of the solution, as also does the hydrocyanic acid when added in excess.

Roseleur's Argyrometric Scale.—This is an automatic apparatus and is designed for obtaining deposits of silver "without supervision and with constant accuracy, and which spontaneously breaks the electric current when the operation is terminated." The apparatus is made in various sizes, suitable for small or large operations; Fig. 98 represents the apparatus to be employed for the latter purposes.

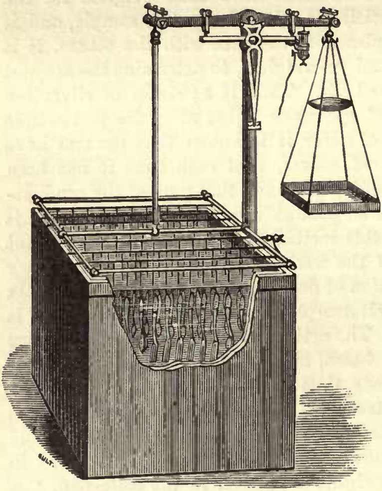


Fig. 98.

It consists of:—1. A wooden vat, the upper ledge of which carries a brass winding rod, having a binding screw at one end to receive the positive conducting wire of the battery; from this rod the anodes are suspended, which are entirely immersed in the solution, and communicate with cross brass rods by means of platinum wire hooks. These cross rods are flattened at their ends so that they may not roll, and at the same time have a better contact with the "winding rod." 2. A cast-iron column screwed at its base to one of the sides of the bath, carries near the top two projecting arms of cast iron, the extremities of which are vertical and forked, and may be opened or closed by iron clamps, these forks being intended to maintain the beam and prevent the knives from leaving their bowls when the beam oscillates too greatly. In the middle of the two arms are two bowls of polished steel, hollowed out wedge-shaped, to receive the beam knives. One arm of the pillar has at its end a horizontal iron ring, in which is fixed a heavy glass tube which supports and insulates a polished iron cup to contain mercury; beneath this cup is a small pad of india-rubber, which, by means of a screw beneath, may be raised or lowered, by which means the mercury in the cup is levelled. A second lateral binding screw connects the negative electrode of the battery. 3. A cast-iron beam, carrying in its centre two sharp polished steel knives; at each end are two parallel steel bowls, separated by a notch, intended for the knives of the scale pan and of the frame for supporting the articles. One arm of the beam is furnished with a stout platinum wire, placed immediately above and in the centre of the mercury cup, and as the beam oscillates it dips into, or passes out of, the cup. The scale pan is furnished with two cast-steel knives fixed to the metallic bar, which is connected to chains supporting the lower wooden box for the *tare;* the smaller pan, for the weight representing the amount of silver to be deposited, is placed between these two. 4. The frame for supporting the work is also suspended by two steel knives, the vertical of which is of stout brass tubing, and is equal in size to the opening of the bath, and supports the rods to which the articles are suspended. The slinging wires are formed into a loop at one end for supporting the spoons or forks, and the vertical portion of each wire is covered with india-rubber tubing, to prevent it from receiving the silver deposit.

In adjusting the apparatus, the pillar must be set perfectly upright by aid of a plumb line; the clamps are then withdrawn from the *forks*, and the beam is carefully put in its place, care being taken to avoid injuring the knives that rest in the bowls in the centre of the pillar. The clamps are now replaced, and the beam should oscillate freely upon the knives without friction. The knives of the frame are next put in their places, as also those of the scale pan; mercury is then poured into the six bowls, where the knives rest, until all the polished parts of the latter are covered. The insulated steel cup is then filled with mercury so high that the point of the platinum wire just touches it, when the beam is level; the small elastic pocket is used for raising and lowering the mercury cup, so as to place it at the proper height for bringing the mercury in contact with the end of the platinum wire. When the articles have received the amount of silver corresponding to the weight in the pan at the opposite side of the beam, the equilibrium will be established, and the platinum wire will then leave the mercury, and thus break the circuit and stop the operation. By this automatic arrangement the operation needs no attention, since the moment the platinum wire loses contact with the mercury electricity ceases to pass; if, however, the articles are allowed to remain in the bath after they have received the proper amount of silver, a portion of this metal may be dissolved by the free cyanide in the solution, in which case the end of the platinum wire would again dip into the mercury and complete the circuit, when deposition would be renewed and continue until the increased weight of silver again caused the platinum wire to lose contact with the mercury.

Solid Silver Deposits.—Although it is possible to deposit silver, from a cyanide solution rich in metal (say eight ounces of silver per gallon), upon wax or gutta-percha moulds, this method is not practically adopted. The usual method is to first obtain a copper electrotype mould or shell of the object in the ordinary way; silver is then deposited within the mould (supposing it to be a hollow object) until of the required thickness; the copper is afterwards dissolved from the silver either by boiling the article in hydrochloric acid, or, still better, a strong solution of perchloride of iron, either of which substances will dissolve the copper mould without in any way injuring the silver. The perchloride of iron for this purpose may be readily formed by dissolving peroxide of iron (commercial "crocus") in hot hydrochloric acid. The method of dissolving the copper recommended by Napier, is as follows: "An iron solution is first made by dissolving a quantity of copperas in water; heat this till it begins to boil; a little nitric acid is then added—nitrates of soda or potash will do; the iron which is thus peroxidised may be precipitated either by ammonia or carbonate of soda; the precipitate being washed, muriatic acid is added till the oxide of iron is dissolved. This forms the solution for dissolving the copper. When the solution becomes almost colourless, and has ceased to act on the copper, the article is removed, and the addition of a little ammonia will precipitate the iron along with a portion of the copper; but after a short exposure the copper is redissolved. The remaining precipitate is washed by decantation; a little ammonia should be put into the two first waters used for washing. When washed, and the copper dissolved out, the precipitate is redissolved in hydrochloric acid, and the silver article returned until the copper is all dissolved off. It is convenient to have two solutions of perchloride of iron, so that while the iron in the one is being precipitated, the article is put into the other. The persalt of iron will be found to dissolve the copper more rapidly than muriatic acid alone; persulphate of iron must not be used, as it dissolves the silver along with the copper.

"The silver article is now cleaned in the usual way, and heated to redness over a clear charcoal fire, which gives it the appearance of dead silver, in which state it may be kept, or, if desired, it may be scratched and burnished." A very simple and economical method of producing perchloride of iron is to reduce the native peroxide of iron, known as "redding," to a powder, and digest it in hot hydrochloric acid, by which the salt is obtained at a cost but little exceeding that of the acid employed, the native ore being worth only about 25s. per ton.

One great objection to solid electro-deposits of silver (and gold) is that the articles have not the metallic "ring," when struck with any hard substance, as silver ware of ordinary manufacture. "This disadvantage," says Napier, "is no doubt partly due to the crystalline character of the deposit, and partly to the pure character of the silver, in which state it has not the sound like standard or alloyed silver. That this latter cause is the principal one appears from the fact that a piece of silver thus deposited is not much improved in sound by being heated and hammered, which would destroy all crystallisation." This is quite true, but when electro-deposited silver has been *melted*, and cast into an ingot, by which its crystalline character is *completely* destroyed, and which is only partially affected by simply annealing and hammering, the characteristic "ring" of the pure metal is restored. The absence of a musical ring in electro-deposited silver is not of much consequence, however, since this method of reproduction would only be applied to rare works of art, such as antique figures, and richly chased articles kept solely for ornament.

On the Thickness of Electro-Deposited Silver.—This may be considered a somewhat delicate theme to expatiate upon when we reflect that some articles of commerce, but more especially export goods and articles sold at mock auctions, frequently receive a coating of silver which not only defies measurement by the most delicate micrometer, but also renders estimation by any other means all but impossible. This class of work includes spoons and forks, cruet-frames, toast-racks, &c., manufactured from a very inferior description of German silver or brass, while Britannia metal tea services, salt-cellars, and many other articles made from the same alloy enter the market in enormous quantities, with a mere blush of silver upon them, the thickness of which might be more readily estimated by imagination than by any practical test. As to the amount of silver which should be deposited upon articles of domestic use, to enable them to withstand ordinary wear and tear for a reasonable period, from 1 to 3 ounces per dozen for spoons and forks may be deposited. Taken as a guide, with the smaller quantity of silver upon them, such articles, with careful usage, should present a very creditable appearance after five years' use; with the larger proportion, the articles should look well, though probably somewhat bare upon those parts most subject to friction, at the end of twenty years. The same articles, if used in hotels or on board ship, would become unsightly in less than half the periods named. German silver tea and coffee services, to be *fairly* well plated or silvered, should not have less than 2 ounces of silver upon the four pieces, which may be distributed in about the following proportions: for a 5-gill coffee-pot 12 dwts.; 5-gill teapot 12 dwts.; sugar-basin 10 dwts.; cream-ewer 6 dwts.

When the same articles are required to be *fully* well plated, the proportions should be about as follows: For coffee and teapot, about 1½ ounce of silver each; sugar-basin 1 ounce, and cream-ewer about 10 to 15 dwts.

The proportion of silver which should be deposited per square foot, for plating of good quality, is from 1 to 1½ ounce. With the latter proportion the electro-silvered work would nearly approach in quality the old Sheffield plate, and would last for a great number of years without becoming bare, even at the most prominent parts, unless the article were subjected to very severe treatment in use.

Pyro-plating.—It is well known that when a silver-gilt article—as a watch-chain, for example—has been broken, and afterwards repaired by hard soldering, that the film of gold almost entirely disappears from each side of the soldered spot, under the heat of the blow-pipe flame, to the extent of 1 or 2 inches on either side of the joining. The film of gold has, in fact, sunk into the body of the silver, as though it had become alloyed with this metal. By some persons this is really believed to be the case. We are, however, disposed to think that the absorption of the gold under these circumstances is due, not to an actual alloying of the two metals in the ordinary sense, but to the expansion of the silver by the heat, by which its molecular structure becomes disturbed, and the film of gold, being thus split up into infinitely minute particles, these become absorbed by the silver as the metal contracts on cooling, and consequently disappear from the surface. We hold this view because we do not think that the heat of the blowpipe flame required to fuse the solder would be sufficient to form an alloy in the proper sense; indeed, the heat required to "run" silver solder would not be sufficiently high even to "sweat" the silver of which the article is composed. The fact of a film of metal becoming absorbed by another metal under the influence of heat has been taken advantage of, and a process termed "pyro-plating" has been introduced, and has been worked to some extent in Birmingham. The process, which has been applied to coating articles—of steel and iron more especially—with gold, silver, platinum, aluminium, copper, &c., may be thus briefly described: The article is first steeped in a boiling solution of caustic potash; it is then brushed over with emery-powder, and afterwards with a steel brush and a solution of common soda, in which it is allowed to remain for some time. It is next connected to the negative electrode of a strong battery, and immersed in a hot solution of caustic potash, abundance of hydrogen being evolved, and is allowed to remain until it has a "silvery" appearance. After rinsing, it is suspended in a silver bath, with a previously weighed metal plate of the same amount of surface placed as a cathode by its side; this plate is taken out and weighed from time to time until sufficient silver has been deposited, which indicates approximately the amount of deposit upon the article itself. The article is then removed and rinsed, and afterwards heated in a furnace until the silver is "driven" into the surface of the metal. If the steel article requires to be *tempered*, it is quenched in water, and then brought to the proper temper in the usual way.

Whitening Electro-plated Articles.—It is well known that articles which have been electro-plated tarnish more rapidly than silver goods; and while this has by many persons been attributed to the extreme purity of the electro-deposited metal, which, it was believed, was more susceptible of being attacked by sulphurous fumes and other impurities in the air, by others it is believed to be due to a small quantity of undecomposed salt remaining in the pores of the deposited metal, which undergoes decomposition, and causes the work to tarnish. In order to render electro-plate less liable to discoloration, the following method has been adopted, but, as will readily be seen, it could not be applied to all classes of work: The article is first dipped in a saturated solution of borax and then allowed to dry, when a thin layer of the salt remains upon the surface; the article is then dipped a second or even a third time (drying after each dipping) until it is completely covered with a layer of borax. When large articles are to be treated this way, the borax may be applied with a soft brush. The article is next to be heated to a dull red heat, or until the borax *fuses*. When cold, it is to be put into a pickle of dilute sulphuric acid, which rapidly dissolves the borax; after rinsing in hot water it is placed in hot boxwood sawdust, and then treated in the usual way.

Whitening Silver Work.—Articles of silver which in their original finished state were left either wholly or in part a dead white, and have lost this pleasing effect by wear or oxidation, may be restored to their original condition by the process termed *whitening*. The article is first brought to a dull red heat (not sufficient to melt the solder) over a charcoal fire—if it be a brooch, watch-dial, or other small silver article, by means of the blowpipe flame, the article being placed on a large and flat piece of charcoal. When the piece of work has thus been heated uniformly all over, it is allowed to become cool, after which it is placed in a glazed earthenware vessel (an ordinary white basin will do), containing a sufficient quantity of very dilute sulphuric acid. In a short time the acid will dissolve the oxide from the surface, together with a small quantity of oxide of copper derived from the copper with which the silver was alloyed, and which, with the silver, becomes oxidised by the heat and subsequent action of the atmosphere. When the article is removed from the pickle—in which it should remain for at least twenty minutes to half an hour—if not of a sufficiently pure whiteness it may be heated and pickled again. When the whitening is properly effected, the surface should present a beautiful pearl-white appearance, and be perfectly uniform in its lustrous dulness. Directly the article is removed from pickle, it should be rinsed in two separate waters, the last water (which should be distilled water, by preference) being boiling hot. The article, after being removed from the rinsing-bowl, should be allowed to dry spontaneously, which it will do if the water is boiling hot. It is not a good plan, though it is frequently done, to put work which has been whitened in boxwood sawdust, since if it has been much used it is liable to produce stains.

CHAPTER XX.

IMITATION ANTIQUE SILVER.

Oxidised Silver.—Oxidising Silver.—Oxidising with Solution of Platinum.—Oxidising with Sulphide of Potassium.—Oxidising with the Paste.—Part-gilding and Oxidising.—Dr. Elsner's Process.—Satin Finish.—Sulphuring Silver.—Niello, or Nielled Silver.—Pink Tint upon Silver.—Silvering Notes.

Oxidised Silver.—Soon after the art of electro-plating had become an established industry, the great capabilities of the "electro" process, as it was called, received the serious attention of the more gifted and artistic members of the trade, who, struck with the great beauty of electro-deposited silver, and the facilities which the process offered for the reproduction of antique works, induced some electro-platers of the time to make experiments upon certain classes of work with a view to imitate the effects seen upon old silver; some of the results were highly creditable, and in a short time after "oxidised" silver became greatly in vogue, and has ever since been recognised as one of the artistic varieties of ornamental silver or electro-plated work. We scarcely think we shall err, however, if we venture to say that much of the "oxidised" silver-plated work of the present time is far inferior in beauty and finish to that with which our shops and show-rooms were filled some thirty years ago. Indeed, when visiting the Paris Exhibition of 1878, we were much displeased with the very slovenly appearance of some of the plated goods which had been part-gilt and oxidised in the exhibits of some of the larger English and French firms. The specimens referred to had the appearance of having done duty as specimens in all the exhibitions since 1851, and had suffered by being repeatedly "cleaned up" for each occasion; they were certainly far from being creditable.

"Oxidising" Silver.—This term has been incorrectly applied, but universally adopted, to various methods of darkening the surface of silver in parts, by way of contrast to burnished or dead-white surfaces of an article. Oxygen, however, has little to do with the discoloration, as will be seen by the following processes, which are employed to produce the desired effect. The materials used are various, and they are generally applied with a soft brush, a camel-hair brush being suitable for small surfaces. In applying either of the materials the article should be quite dry, otherwise it will spread over portions of the work required to be left white, and thus produce a patchy and inartistic effect. The blackening substances are generally applied to the hollow parts or groundwork of the object, while the parts which are in relief are left dead, or burnished according to taste.

Oxidising with Solution of Platinum.—Dissolve a sufficient quantity of platinum in aqua regia, and carefully evaporate the resulting solution (chloride of platinum) to dryness, in the same way as recommended for chloride of gold. The dried mass may then be dissolved in alcohol, ether, or water, according to the effect which it is desired to produce, a slightly different effect being produced by each of the solutions. Apply the solution of platinum with a camel-hair brush, and repeat the operation as often as may be necessary to increase the depth of tone; a single application is frequently sufficient. The ethereal or alcoholic solution of platinum must be kept in a well-stoppered bottle, and in a cool place. The aqueous solution of platinum should be applied while hot.

Oxidising with Sulphide of Potassium.—Liver of sulphur (sulphide of potassium) is often used for producing black discoloration, erroneously termed *oxidising*. For this purpose four or five grains of the sulphide are dissolved in an ounce of hot water, and the solution applied with a brush, or the article wholly immersed if desired. The temperature of the solution should be about 150° Fahr. After a few moments the silver surface assumes a darkened appearance, which deepens in tone to a bluish-black by longer treatment. When the desired effect is produced the article is rinsed and then scratch-brushed, or burnished if required, or the blackened hollow surfaces are left dead according to taste. When it is desired to produce a *dead* surface upon an article which has been electro-silvered, the article may be placed in a sulphate of copper bath for a short time, to receive a slight coating of copper, after which it is again coated with a thin film of silver in an ordinary cyanide bath. It has then the dead-white appearance of frosted silver. Where portions of the article are afterwards *oxidised* a very fine contrast of colour is produced. In using the sulphide of potassium solution it should be applied soon after being mixed, since it loses its activeness by keeping. Fresh solutions always give the most brilliant results. Since the sulphide dissolves the silver, it is necessary that it should be applied only to surfaces which have received a tolerably stout coating of this metal, otherwise the subjacent metal (brass, copper, or German silver) will be exposed after the sulphide solution has been applied.

Oxidising with the Paste.—For this purpose a thin paste is formed by mixing finely-powdered plumbago with spirit of turpentine, to which mixture is sometimes added a small quantity of red ochre or jewellers' rouge, to imitate the warm tone sometimes observed in old silver articles. The paste is spread over the articles and allowed to dry, after which the article is brushed over with a long-haired soft brush, to remove all excess of the composition. The parts in relief are then cleaned by means of a piece of rag, or chamois leather, dipped in spirit of wine. This method of imitating old silver is specially applicable to vases, tankards, chandeliers, and statuettes. In case of failure in the manipulation, the dried paste may be readily removed by placing the article in a hot solution of caustic potash or cyanide, when, after rinsing and drying, the paste may be reapplied. To give the old silver appearance to small articles, such as buttons, for example, they are first passed through the above paste, and afterwards revolved in a barrel or "tumbler" containing dry sawdust, until the desired effect is produced.

Part-gilding and Oxidising.—To give this varied effect to work, the articles are first gilt all over in the usual way; certain parts are then *stopped off*, as it is termed, by applying a suitable varnish. When the varnish has become dry, the article is placed in the silvering bath until a sufficient coating, which may be slight, has been obtained. After rinsing, the object is immersed in a solution of sulphide of potassium until the required tone is given to the silvered parts, when the article is at once rinsed, carefully dried, and the protecting varnish dissolved off, when it is ready to be finished.

Dr. Elsner's Process.—A brownish tone is imparted to plated goods by applying to the surface a solution of sal-ammoniac, and a still finer tone by means of a solution composed of equal parts of sulphate of copper and sal-ammoniac in vinegar. To produce a fine black colour, Dr. Elsner recommends a warm solution of sulphide of potassium or sodium.

Sulphide of Ammonium.—This liquid may also be applied to the so-called oxidation of silver, either by brushing it over the parts to be oxidised, or by immersion. It may also be applied, with plumbago, by forming a thin paste with the two substances, which is afterwards brushed, or smeared over the surface to be coloured, and when dry a soft brush is applied to remove the excess of plumbago. If preferred, a little jewellers' rouge may be added to the mixture.

Satin Finish.—This process is thus described by Wahl: The sand-blast is in use in certain establishments to produce the peculiar dead, lustrous finish, known technically as *satin finish*, on plated goods; a templet of some tough resistant material, like vulcanised india-rubber, is made of the proper design, and when placed over the article, protects the parts which it is desired to leave bright from the depolishing action of the sand, while the only open portions of the templet are exposed to the blast. The apparatus employed for this purpose consists of a wooden hopper, with a longitudinal slit below, through which a stream of fine sand is allowed to fall, by opening a sliding cover. Closely surrounding the base of the hopper is a rectangular trunk of wood, extending some distance below the base of the hopper, and tapering towards the bottom, to concentrate the sand-jet. This trunk is closed about the sides of the hopper, and open below, and is designed to direct the stream of sand upon the surface of the article presented beneath its orifice. To increase the rapidity of the depolishing action of the sand, a current of air, under regulated pressure, is admitted into the upper part of the trunk, which, when the sand-valve is opened, propels it with more or less accelerated velocity upon the metallic surface below. For this purpose, either a "blower," or an air-compressor with accumulator, may be used; and the pressure may be regulated at will. The sand is thus driven with more or less velocity down the trunk by the air-blast admitted above, and, falling upon the surface of the article presented at the bottom, rapidly depolishes the exposed parts, while those protected by the templet are not affected. The articles are presented at the orifice of the trunk by the hands of the operator, which are suitably protected with gloves; and as rapidly as the depolishing proceeds, he turns the article about till the work is done. The progress of the work is viewed through a glass window, set in a horizontal table, which surrounds the apparatus and which forms the top of a large box, into which the sand falls, and which is made tight to prevent the sand from flying about. A portion of this box in front, where the workman stands, is cut away, and over the opening is hung a canvas apron, which the operator pushes aside to introduce the work. The sand that accumulates in the box below is transferred again to the hopper, as required, and is used over and over again. The satin-finish produced by the sand-blast is exceedingly fine and perfectly uniform, and the work is done more rapidly than with the use of brushes in the usual way.

Sulphuring Silver.—A very fine blue colour, resembling "blued" steel, may be imparted to silver or plated surfaces, by exposing the article to the action of sulphur fumes. For this purpose, the article should be suspended in an air-tight wooden box; a piece of slate or a flat tile is laid upon the bottom of the box, and upon this is placed an iron tray, containing a small quantity of red-hot charcoal or cinders; about a teaspoonful of powdered sulphur is now quickly spread over the glowing embers, and the lid of the box immediately closed. After about a quarter of an hour, the lid may be raised (care being taken not to inhale the sulphur fumes) and the article promptly withdrawn; if the article is not sufficiently and uniformly blued, it must be again suspended and a fresh supply of hot charcoal and sulphur introduced. It is necessary that the articles to be treated in this way should be absolutely clean.

Niello, or Nielled Silver.—These terms* are applied to a process which is attributed to Maso Finniguerra, a Florentine engraver of the fifteenth century, and somewhat resembles enamelling. It consists, essentially, in inlaying engraved metal surfaces with a black enamel, being a sulphide of the same metal, by which very pleasing effects are produced. The "nielling" composition may be prepared by making a triple sulphide of silver, lead, and copper, and reducing the resulting compound to a fine powder. The composition is made as follows: A certain proportion of sulphur is introduced into a stoneware retort, or deep crucible. In a second crucible, a mixture of silver, lead, and copper is melted, and when sufficiently fused the alloy thus formed is added to the fused sulphur in the first vessel, which converts the metals into sulphides; a small quantity of sal-ammoniac is then added, and the compound afterwards removed from the retort or crucible and reduced to a fine powder. The following proportions are given by Mr. Mackenzie:—

Put into the first crucible—

Flowers of sulphur	750 parts.
Sal-ammoniac	75 „

Put into the second crucible—

Silver	15 parts.
Copper	40 „
Lead	80 „

When fused, the alloy is to be added to the contents of the first crucible. Roseleur recommends diminishing the proportion of lead, which impairs the blue shade of the nielling, and corrodes too deeply.

To apply the powder, obtained as above, it is mixed with a small quantity of a solution of sal-ammoniac. After the silver work is engraved, the operator covers the entire surface with the nielling composition, and it is then placed in the muffle of an enamelling furnace, where it is left until the composition melts, by which it becomes firmly attached to the metal. The nielling is then removed from the parts in relief, without touching the engraved surfaces, which then present a very pleasing contrast, in deep black, to the white silver surfaces This process, however, is only applicable to engraved work.

Wahl describes a cheaper process of nielling, which consists "in engraving in relief a steel plate, which, applied to a sheet of silver, subjected to powerful pressure in a die, reproduces a faithful copy of the engraving. The silver sheet thus stamped is ready to receive the

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* The art was formerly called *working in niello.*

nielling. A large number of copies may be obtained from the same matrix. Such is the method by which a quantity of nielled articles are manufactured, as so-called Russian snuff-boxes, cases for spectacles, bon-bon boxes, &c.

Roseleur suggests the following to produce effects similar to nielling: A pattern of the design, cut out of thin paper, such as lace paper, is dipped into a thin paste of nielling composition, or into a concentrated solution of some sulphide, and then applied upon the plate of silver, which is afterwards heated in the muffle. The heat destroys the organic matter of the paper, and a design remains, formed by the composition which it absorbed.

A solution of chloride of lime (bleaching powder) will blacken the surface of silver, as also will nitric acid. For all practical purposes, however, chloride of platinum and weak solutions of the sulphides before mentioned will be found to answer very well if applied with proper judgment.

Pink Tint upon Silver.—Fearn recommends the following for producing a fine pink colour upon silver: Dip the cleaned article for a few seconds in a strong hot solution of chloride of copper, then rinse and dry it, or dip it in spirit of wine and ignite the spirit.

Silvering Notes.—1. The anodes, if of rolled silver, should always be annealed before using them. This may easily be done by placing them over a clear charcoal, or even an ordinary clear fire, until they acquire a cherry-red heat: when cold, they are ready for use. If convenient to do so, it is a good plan to hard solder a short length of stout platinum wire (say about three inches long) to the centre of one edge of the anode, which may be united to the positive electrode of the battery, or other source of electricity, by a binding screw, or by pewter solder. The object of attaching the platinum wire is to enable the anode to be wholly immersed in the bath, and thus prevent it from being *cut through* at the *water line*, which is generally the case where anodes are only partially immersed.

2. *Worn Anodes.*—When the anodes have been long in use, their edges frequently become *ragged*, and if these irregularities are not removed fragments of the metal will fall into the bath, and, possibly, upon the work, causing a roughness of deposit. It is better, therefore, to trim the edges of anodes whenever they become thin and present a ragged appearance.

3. *Precautions to be Observed when Filling the Bath with Work.*—Assuming the suspending rods to have been cleaned, the battery connections adjusted, and the preparation of the articles to be plated commenced, some means must be adopted to prevent the articles *first* put into the bath from receiving too quick a deposit while others are being got ready. In the first instance, the full force of the current must be

checked, which may be done by exposing a small surface of anode in solution or suspending a plate of brass or a small silver anode as a "stop," or check, to the negative rod, until a sufficient number of articles (say spoons or forks, for example) have been suspended, when the stop may be removed and the remainder of the articles immersed until the conducting rod is full; the rest of the suspending rods should then be treated in the same way. When magneto or dynamo-electric machines are employed, the full strength of the current is checked by the employment of the *resistance coil*, a description of which is given in Chapter XXXVI. A simple way of diminishing the amount of current, when filling the bath with work, is to interpose a thin iron wire between the positive electrode and the suspending rod, which must be removed, however, when the cathode surface (the articles to be plated) in the bath approaches that of the anode surface.

4. *Plating Different Metals at the Same Time.*—It is not good practice to place articles composed of different metals or alloys indiscriminately in the bath, since they do not all receive the deposit with equal facility. For example, if two articles, one copper or brass, and another Britannia metal or pewter, be immersed in the solution simultaneously, the former will at once receive the deposit of silver, while the latter will scarcely become coated at all, except at the extremities. Since the best conductor receives the deposit most freely, the worst conductor (Britannia metal, pewter, or lead) should first be allowed to become completely coated, after which copper or brass articles may be introduced. It is better, however, if possible, to treat the inferior conductors separately than to run the risk of a defective deposit.

5. *Excess of Cyanide.*—When there is a large excess of cyanide in the plating bath, the silver is very liable to strip, or peel off the work when either scratch-brushed or burnished; besides this, the anodes become dissolved with greater rapidity than is required to merely keep up the proper strength of the bath, consequently the solution becomes richer in metal than when first prepared. The depositor must not confound the terms "free cyanide" with "excess" of cyanide: the former refers to a small quantity of cyanide beyond that which is necessary to convert into solution the precipitate thrown down from the nitrate, which is added to the solution to act upon and dissolve the anode while deposition is going on; the latter term may properly be applied to any quantity of cyanide which is in excess of that which is necessary for the latter purpose.

In preparing plating solutions from the double cyanide of silver and potassium, great care must be taken, when precipitating the silver from its nitrate solution, not to add the cyanide in excess, otherwise a portion of the precipitated cyanide of silver will be re-dissolved, and probably lost when decanting the supernatant liquor from the precipitate. When the precipitation is nearly complete, the last additions of cyanide solution should be made very cautiously, and only so long as a turbidity, or milkiness, is produced in the clear liquor above the precipitate. Instances have been known in which not only silver, but gold precipitates also, have been partially redissolved by excess of cyanide and the solutions thrown away by ignorant operators as waste liquors. If by accident an excess of cyanide has been used during the precipitation of gold or silver solutions, the difficulty may be overcome by gradually adding a solution of the metallic salt until, in its turn, it ceases to produce turbidity in the clear supernatant liquor. Again, in dissolving precipitates of silver or gold, care is necessary to avoid using a large excess of cyanide; a moderate excess only is necessary.

6. *Articles Falling into the Bath.*—When an article falls into the bath, from the breaking of the slinging wire or otherwise, its recovery generally causes the sediment which accumulates at the bottom of the vat to become disturbed, and this, settling upon the work, produces roughness which is very troublesome to remove. If not immediately required, it is better to let the fallen article remain until the rest of the work is plated; or if its recovery is of immediate importance, the rod containing the suspended articles should be raised every now and then during about half an hour, in order to wash away any sediment that may have settled on the work. By gently lifting the rod up and down, or raising each piece separately, the light particles of sediment may readily be cleared from the surface of the work. When very large articles, as salvers, for example, are immersed in the bath, they should be lowered very gently, so as not to disturb the sediment referred to; if this precaution be not rigidly followed, especially if the vat be not a very deep one, the lower portion will assuredly become rough in the plating, which the most skilful burnishing will be incapable of removing. We have frequently known it to be necessary to strip and replate articles of this description from the cause referred to. It must also be borne in mind that when anodes become very much worn minute particles of silver fall to the bottom of the vessel, which, when disturbed in the manner indicated, rise upward, settle upon the work, and become attached, by what may be termed *electro-soldering*, to the work, causing the deposit to be rough, and when such surface is afterwards smoothed by polishing, the part exhibits numerous depressions, or is "pitted," as the Sheffield burnishers term it.

7. *Cleaning Suspending Rods.*—It is a very common practice with careless workmen to clean the suspending rods with emery cloth while they are in their places across the sides or ends of the plating vat.

This is a practice which should be strictly disallowed, for it is evident that the particles of brass, emery, and metallic oxides which become dislodged by the rubbing process, must enter the solution, and being many of them exceedingly light, will remain suspended in the solution for a considerable time, and finally deposit upon the articles when placed in the vat, while some portions of the dislodged matter will become dissolved in the bath. All suspending rods should be cleaned at some distance from the plating vat, and wiped with a clean dry rag after being rubbed with emery cloth before being replaced across the tank.

8. *Electro-silvering Pewter Solder.*—Besides the methods recommended elsewhere, the following may be adopted: After thoroughly cleaning the article, apply to the soldered spot with a camel-hair brush a weak solution of cyanide of mercury; or if it be a large surface the soldered part must be dipped for a short time in the mercury solution. In either case the article must be well rinsed before being immersed in the silver bath.

9. *Metal Tanks.*—When working solutions in iron tanks, the plater should be very careful not to allow the anodes, or the work to be coated, to come in contact with the metallic vessel while deposition is taking place, since this will not only cause the current to be diverted from its proper course, but will also cause the anodes, especially if there be a large excess of free cyanide in the bath, to become eaten into holes, and fragments of the metal will be dislodged and fall to the bottom of the vat, and possibly small particles of the metal will settle upon the work. We remember an instance in which several wooden nickel-plating tanks, lined with stout sheet lead, coated with pitch, yielded very poor results from some cause unknown to the plater. Having been consulted on the matter, the author soon discovered the source of mischief: the copper hooks supporting the heavy anodes had become imbedded in the pitch, and were in direct communication with the lead lining, from which a greater portion of the pitch had scaled off, leaving the bare metal exposed below the surface of the solution. Upon applying a copper wire connected to the negative electrode of the large Wollaston battery, at that time used at the establishment, to the leaden flange of each tank the author obtained brilliant sparks, to the great astonishment of the plater and his assistants, and subsequently caused strips of wood to be placed between the side anodes and the lead lining, after which nickel-plating proceeded without check.

10. *Bright Plating.*—Even in the most skilful hands the bright solution is very liable to yield ununiform results. When the solution has remained for some time without being used it is apt to give *patchy* results, the work being bright in some parts only; if the solution is

disturbed, by taking out work or by putting in fresh work, sometimes the latter will refuse to become bright, and the remainder of the work in the bath will gradually become dull. To obviate this the bath should be well stirred over night, and all the work to be plated at one time put into the bath as speedily as possible, and all chances of disturbance avoided. When the work is known to have a sufficient coating of the bright deposit, the battery connection should be broken and the articles then at once removed from the bath. On no account must an excess of the "bright" liquid be allowed to enter a bath.

11. *Dirty Anodes.*—When the anodes, which should have a greyish appearance while deposition is taking place, have a pale greenish film upon their surface, this indicates that there is too little free cyanide in the bath, or that the current is feeble; the battery should first be attended to, and if found in good working order, and all the connections perfect, an addition of cyanide should be made; this, however, should only be done the last thing in the evening, the bath then well stirred and left to rest until the following morning.

12. *Dust on the Surface of the Bath.*—Sometimes in very windy weather the surface of the bath, after lying at rest all night, will be covered with a film of dust; to remove this spread sheets of tissue paper, one at a time, over the surface of the liquid, then take the sheets up one by one and place them in an earthen vessel; the small amount of solution which they have absorbed may be squeezed from the sheets, passed through a filter, and returned to the bath, and the pellets of paper may then be thrown amongst waste, to be afterwards treated for the recovery of its metal.

13. *Old Slinging Wires.*—It is not a good plan to use a slinging wire, one end of which has received a coating of silver or other metal more than once, without first stripping off the deposited metal, in the first place the coated end of the wire becomes very brittle, and is liable to break when twisting it a second time, possibly causing the article to fall into the bath, or on a floor bespattered with globules of mercury and other objectionable matter; again, the broken fragments of silver-covered wire, if allowed to fall carelessly on the floor, get swept up with the dirt, and the silver thus wasted. The wires which have been used once should be laid aside, with the plated ends together, and at a convenient time these ends should be dipped in hot stripping solution, until all the silver is dissolved off, and after rinsing, the ends should be made red hot, to anneal them; the wires may then be cleaned with emery cloth and put in their proper place to be used again. These minor details should always be attended to, since they do not necessarily involve much time and are assuredly advantageous from an economical view. It is too commonly the practice with careless operators to neglect such simple details, but the consequence is that their

plating operations are often rendered unnecessarily troublesome, while their workshops are as unnecessarily untidy.

14. *Battery Connections.*—Before preparing work for the bath, the binding screws, clamps, or other battery connections should be examined, and such orifices or parts as form direct metallic communication between the elements of the battery and the anodes and cathodes should be well cleaned if they have any appearance of being oxidised or in any way foul. The apertures of ordinary binding screws may be cleaned with a small rat-tail file, and the flat surfaces of clamps rubbed with emery cloth laid over a flat file. When binding screws, from long use or careless usage, become very foul, they should be dipped in dipping acid, rinsed, and dried quickly. Previous to putting work in the bath, a copper wire should be placed in contact with the suspending rod and the opposite end allowed to touch the anode, when the character of the spark will show if the current is sufficiently vigorous for the work it has to do ; if the spark is feeble, the connections should be looked to, and the binding screws tightened, if necessary ; the hooks and rods supporting the anodes should also be examined, and if dirty, must be well cleaned, so as to insure perfect contact between the metal surfaces.

15. *Gutta-percha Lining for Plating Tanks.*—This material should never be used for lining the insides of tanks which are to contain cyanide solutions, since the cyanide has a solvent action upon it, which, after a time, renders the solution a very bad conductor. The author once had to precipitate the silver from an old cyanide solution which had remained for a long period in a gutta-percha lined bath, and soon after the acid (sulphuric) had been applied to throw down the silver, there appeared, floating upon the surface of the liquid, numerous clots of a brown colour, which proved to be gutta-percha, although greatly altered from its original state.

CHAPTER XXI.

ELECTRO-DEPOSITION OF NICKEL.

Application of Nickel-plating.—The Depositing Tank.—Conducting Rods.—Preparation of the Nickel Solution.—Nickel Anodes.—Nickel-plating by Battery.—The Twin-Carbon Battery.—Observations on Preparing Work for Nickel-plating.—The Potash Bath.—Dips or Steeps.—Dipping Acid.—Pickling Bath.

Application of Nickel-plating.—When applied to purposes for which it is specially adapted, nickel-plating may be considered one of the most important branches of the art of electro-deposition. In the earlier days of nickel-plating too much was promised and expected from its application, and, as a natural consequence, frequent disappointments resulted from its being applied to purposes for which it was in no way suited. For example, it was sometimes adopted as a substitute for silver-plating in the coating of mugs or tankards used as drinking vessels for malt liquors, but it was soon discovered that those beverages produced stains or discolorations upon the polished nickel surface, which were not easily removed by ordinary means, owing to the extreme hardness of the metal as compared with silver or plated goods. Again, nickel-plated vegetable-dishes became stained by the liquor associated with boiled cabbage or spinach, rendering the articles unsightly, unless promptly washed after using—a precautionary measure but seldom adopted in the best-regulated sculleries. It was also found that polished nickel-plated articles when exposed to damp assumed a peculiar dulness, which after a time entirely destroyed their brilliant lustre, whereas in a warm and dry situation they would remain unchanged for years, a fact which the mullers of our restaurants and taverns which were nickel-plated many years ago bear ample testimony at the present day.

While practical experience has taught us what to avoid in connection with nickel-plating, it has also shown how vast is the field of usefulness to which the art is applicable, and that as a protective and ornamental coating for certain metallic surfaces, nickel has at present no rival. Its great hardness—which closely approximates that of steel—renders its surface, when polished, but little liable to injury from ordinary careless usage; while, being a non-oxidisable metal, it retains its natural whiteness, even in a vitiated atmosphere.

The metals ordinarily coated with nickel by electro-deposition are copper, brass, steel, and iron, and since these require different *preparatory* treatment, as also different periods of immersion in the nickel bath, they will be treated separately. The softer metals, as lead, tin, and Britannia metal, are not suited for nickel-plating, and should never be allowed to enter the nickel bath.

The Depositing Vat, or Tank.—The depositing vessel may be made from slate or wood, but the following method of constructing a vat is that most generally adopted, and when properly carried out produces a vessel of great permanency. The tank is made from 2½-inch deal, planed on both sides, the boards forming the sides, ends, and bottom being grooved and tongued, so as to make the joints, when put together, water-tight; they are held together by long bolts, tapped at one end to receive a nut. The sides and ends, as also the bottom, are likewise secured in their position by means of screw-bolts, as seen in Fig. 99. When the tank is well screwed together, as in the engraving, the interior is to be well lined with *pure* thin sheet lead. It is of great importance that the lead used for this purpose be as pure as possible, for if it contain zinc or tin it will be liable to be acted upon by the nickel solution which it is destined to hold, and pin-holes will be formed, through which the solution will eventually escape. The joints of the leaden lining must not be united by means of solder, but by the *autogenous process*, or "burning," as it is called, that is, its seams are *fused* together by the *hydrogen flame*—an operation with which intelligent plumbers are well acquainted. If solder were used for this purpose voltaic action would soon be set up between the lead and the tin of the solder by the action of the nickel solution, and in time a series of holes would be formed, followed by leakage of the vat. When the lead lining is complete the vessel must be lined throughout with matched boarding, kept in its position by a rim of wood fastened round the upper edge of the tank. These tanks are usually 3 feet wide, 3 feet deep, and about 6 feet long, and hold about 250 gallons.

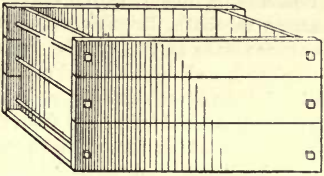

Fig. 99.

Before using the tank it should be well rinsed with clean water. It is a good plan to quite fill the tank with water, and allow it to remain therein for several hours, by which time the pressure of the liquid will soon indicate if there be a leakage at any part; it should then be emptied and examined, to ascertain if thoroughly water-tight.

We will assume that it is desired to make up 100 gallons of nickel solution—in which case the depositing tank should be capable of holding not less than 120 gallons, to allow for the displacement of liquid by the anodes and articles to be immersed, as also to allow sufficient space—say 3 inches—above the solution to prevent the liquid from reaching the hooks by which the anodes are suspended, when the bath is full of work. Although we have taken 100 gallons of solution as a *standard*, we may state that, for large operations, tanks capable of holding 250 up to 500 gallons, or even more, are commonly employed.

Conducting Rods.—These rods, which are used for supporting the nickel anodes, as also the articles to be nickeled, generally consist of 1-inch brass tubing, with a core of iron rod; they are commonly laid across the bath, lengthwise, extending about 3 inches beyond the extreme ends of the vessel. Sometimes, however, shorter rods are employed, and these are laid across the bath from side to side. For a nickel bath of 100 gallons and upwards three such suspending rods are used, one rod being laid from end to end, close to each side of the tank, upon which the requisite number of anodes are suspended by their hooks; a third rod is laid, also longitudinally, along the centre of the tank, midway between the other two, for suspending the articles to be nickeled; the anode rods are to be connected together by a stout copper wire at one end by soldering. These rods are termed respectively the *positive* and *negative* conducting rods, the former receiving the anodes, and the latter the work to be nickeled. Fig. 100 represents a cast nickel anode and its supporting hook of stout copper wire, which latter should not be less than ¼ inch in thickness. In order to insure a *perfect* connection between the copper hook and the anode, the author has found it very advantageous to unite the two by means of pewter solder, in the following way,* and which it may be useful to quote here: The holes

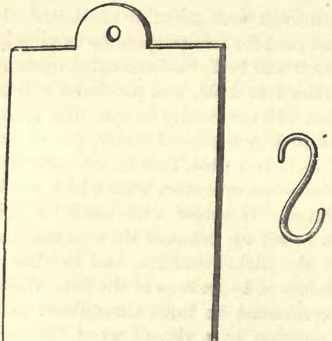

Fig. 100.

"Electro-Metallurgy Practically Treated." By Alexander Watt.

being cleaned with a rat-tail file, the hooks were dipped into ordinary dipping acid (sulphuric and nitric acid) for one instant, and rinsed. One end of each hook was then moistened with chloride of zinc, and immediately plunged into a ladle containing molten tin or pewter solder. The tinned hook was next inserted into the hole in the anode, and a gentle tap with a hammer fixed it in its place. The anode being laid flat on a bench, with a pad of greased rag beneath the hole, the next thing to do was to pour the molten solder steadily into the hole, and afterwards to apply a heated soldering iron. It is better, however, before pouring in the solder, to heat the end of the anode, so as to prevent it from chilling the metal, and a little chloride of zinc solution should be brushed over the inner surface of the aperture, so as to induce the solder to "run" well over it, and thus insure a perfect connection between the hook and the anode. The importance of securing an absolutely perfect connection between these two surfaces will be recognised when we state that we have known instances in which more than half the number of anodes, in a bath holding 250 gallons, were found to be quite free from direct contact with the supporting hooks, owing to the crystallisation of the nickel salt within the interior of the perforation having caused a perfect separation of the hooks from their anodes. It was to remedy this defect that the author first adopted the system of soldering the connections.

Preparation of the Nickel Solution.—The substance usually employed is the *double sulphate of nickel and ammonia* (or "nickel salts," as they are commonly called), a crystalline salt of a beautiful emerald green colour. This article should be *pure*. For 100 gallons of solution the proportions employed are :—

Double sulphate of nickel and ammonia . . .	75 lbs.
Water	100 gallons.

Place the nickel salts in a clean wooden tub or bucket, and pour upon them a quantity of hot or boiling water ; now stir briskly with a wooden stick for a few minutes, after which the green solution may be poured into the tank, and a fresh supply of hot water added to the undissolved crystals, with stirring, as before. This operation is to be continued until all the crystals are dissolved, and the solution transferred to the tank. A sufficient quantity of cold water is now to be added to make up 100 gallons in all. Sometimes particles of wood or other floating impurities occur in the nickel salts of commerce ; it is better, therefore, to pass the hot solution through a strainer before it enters the tank. This may readily be done by tying four strips of wood together in the form of a frame, about a foot square, over which a piece of unbleached calico must be stretched, and secured either by means of tacks or by simply tying it to each corner of the frame with string.

Nickel Anodes.—It is not only necessary that the nickel salts should be perfectly pure—which can only be relied upon by purchasing them at some well-known, respectable establishment—but it is equally important that the nickel plates to be used as anodes—which may be either of cast or rolled nickel—should be of the best quality. A few years ago there was no choice in this matter, for rolled nickel was not then obtainable. Now, however, this form of nickel can be procured of almost any dimensions, of excellent quality, and any degree of thinness, whereby a great saving may be effected in the first cost of a nickel-plating outfit. Again, some years ago it was impossible to obtain cast nickel anodes of moderate thickness, consequently the outlay for this item alone was considerable. Such anodes can now be procured, however, and thus the cost of a nickel-plating plant is greatly reduced, even if cast anodes are adopted instead of rolled nickel.

Nickel-plating by Battery.—For working a 100-gallon bath, four cells of a 3-gallon Bunsen battery will be required, but only two of these should be connected to the conducting rods until the bath is about half full of work, when the other cells may be connected, which should be done by uniting them for *intensity;* that is, the wire attached to the carbon of one cell must be connected to the zinc of the next cell, and so on, the two terminal wires being connected to the positive and negative conducting rods. If preferred, however, the batteries may be united in series, as above, before filling the bath with work, in which case, to prevent the articles first placed in the solution from "burning," as it is termed—owing to the excess of electric power—it will be advisable to suspend one of the anodes temporarily upon the end of the *negative* rod farthest from the battery, until the bath is about half filled with work, when the anode may be removed, and the remainder of the articles suspended in the solution. In working larger arrangements with powerful currents—to which we shall hereafter refer—resistance coils are employed, which keep back the force of the electric current while the bath is being supplied with work, and even when such coils are used it is usual to suspend an anode or some other "stop," as it is called, from the negative rod during the time the work is being put into the solution.

Twin-Carbon Battery.—A very useful modification of the Bunsen battery, and well suited for nickel-plating upon a small scale, is the American twin-carbon battery, introduced by Condit, Hanson and Van Winkle, of New Jersey, U.S.A., which, in its dissected condition, is represented in Fig. 101. A pair of carbon plates are united by a clamp, with binding screw attached, as shown in Fig. 1. A plate of stout sheet zinc is cut out so as to leave a projecting piece, to which a binding screw is also connected, as at 2, and the zinc is turned up into an oval form to admit the porous cell, 4. The zinc being put into the outer cell, 3 (which is made of stoneware), the porous cell is placed within the zinc cylinder, and the twin carbons then deposited in the porous cell. The exciting fluids are, for the zinc, which must of course be well amalgamated, 1 part oil of vitriol to 12 parts water. The porous cell is filled to the same height with a mixture composed of equal measures of oil of vitriol and water, to which 2 ounces of nitric acid are added. This is an exceedingly useful and compact battery, and is specially serviceable in nickel-plating upon a moderate scale. When great electro-motive force is required, strong nitric acid is used instead of the above mixture in the porous cell.

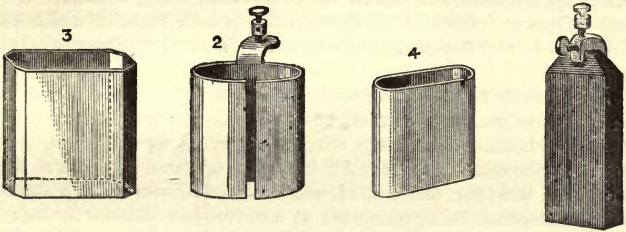

Fig. 101.

Observations on Preparing the Work for Nickel-plating.—For several reasons, it is of greater importance that the articles to be coated with nickel should be what is termed *chemically clean*, than in any other branch of electro-deposition. The excess of cyanide used in gilding, silvering, and brassing solutions is capable of dissolving from the work such slight traces of organic matter as might be accidentally communicated by the hands, and being a powerful solvent of metallic oxides, the delicate film of oxide which quickly forms upon the surface of recently scoured work becomes at once dissolved in a cyanide solution. In the case of a nickel solution, however, which is prepared from a neutral salt, no such solvent action would take place, and the slightest trace of organic matter or of oxide resulting from the action of the air upon the prepared article, would prevent the adhesion of the nickel to the underlying metal, and the work would consequently *strip*. In some establishments, to prevent the possibility of direct contact of the hands with the work while being scoured, the men are required to hold the work with a clean piece of rag, which is frequently dipped in water during the operation of scouring; a good substitute for this is to keep the hand holding the work, while brushing it with powdered pumice or other material, well charged with the substance by dipping the fingers occasionally in the powder. Before explaining the operation of scouring, it will be necessary to describe the various solutions, or "dips," as they are termed, in which the articles are immersed before and after being scoured. The first and most important of these is the potash bath, in which all articles to be nickel-plated are immersed before undergoing any other treatment.

The Potash Bath.—The vessel in which the solution of potash is kept for use generally consists of a galvanised wrought-iron tank capable of holding from 20 to 150 gallons, according to the requirements of the establishment. An iron pipe, or *worm*, is placed at the bottom of the tank, one end of which communicates with a steam boiler, a stopcock being connected at a convenient distance for turning the steam on or off; or the tank may be heated by gas jets, by means of perforated piping fixed beneath it. An ordinary form of potash tank is shown at A in Fig. 102, in which the worm-pipe is indicated by the dotted lines, &c., *a a*, the vertical pipe *b*, with its stopcock *c*, being conveniently placed at one corner of the tank, as shown in the engraving. The waste steam from the worm-pipe escapes into a second tank B, partly filled with water, which thus becomes heated, and is used for rinsing. A rod of iron, or brass tube with an iron core, rests upon the bath, longitudinally, for suspending the articles in the caustic liquor.

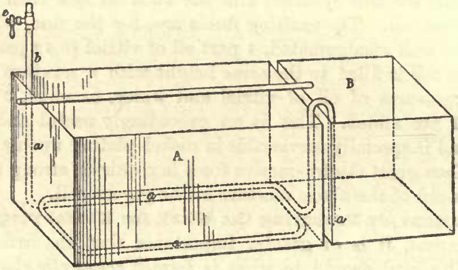

Fig. 102.

The potash solution is made by dissolving half a pound of American potash in each gallon of water required to make up the bath, and the solution is always used *hot*. The object of immersing the work to be nickeled in the potash bath, is to render soluble any greasy matter which may be present, as, for example, the oil used in the various processes of polishing. In a freshly made solution (which must always be kept hot), the work will only require to be immersed for a few minutes, by which time the greasy matter will have become converted into soap, and being thus rendered soluble, may easily be removed by the subsequent operations of brushing with pumice, &c.; but we must bear in mind that the *causticity* of the solution (and consequently its active property) gradually becomes diminished, not only in consequence of the potash having combined with the greasy matter, but also owing to its constantly absorbing carbonic acid from the air. When the bath has been some time in use, therefore, it will be necessary to add a fresh quantity of potash, say about a quarter of a pound to each gallon. It is easy to ascertain if the potash has lost its caustic property by dipping the tip of the finger in the solution, and applying it to the tongue. As the bath becomes weakened by use, the articles will require a longer immersion, and, with few exceptions, a protracted stay in the bath will produce no injurious effect. Articles made from Britannia metal, or which have pewter solder joints, should never be suffered to remain in the potash bath longer than a few minutes, since this alkali (caustic potash) has the power of dissolving tin, which is the chief ingredient of both. Again, articles made from brass or copper should never be suspended from the same rod as steel and iron articles, in case the potash solution should have become impregnated with tin dissolved from solder, &c.; for if this precaution be not observed it is quite likely (as we have frequently seen in an old bath) that the steel articles will become coated with tin, owing to voltaic action set up in the two opposite metals by the potash solution. Cast-iron work, in which oil has been used in the finishing, should, owing to its porous character, be immersed in the potash bath for a longer period than other metals in order to thoroughly cleanse it from greasy matter.

Dips, or Steeps.—Besides the potash solution, certain other liquids are employed in nickel-plating after the work has been "potashed" and scoured, which may be properly described in this place; and we may here remind the reader that the employment of these *dips*, as they are called, is based upon the fact that the *neutral* solution of nickel has no power (unlike cyanide solutions) of dissolving even slight films of oxide from work which, after being scoured, has been exposed to the air and become slightly oxidised on the surface. In order, therefore, to remove the faintest trace of oxidation from the surface of the work—the presence of which would prevent the nickel from adhering—it is usual to plunge it for a moment in one or other of the following mixtures after it has been scoured, then to rinse it, and *immediately* suspend it in the nickel bath.

The Cyanide Dip.—This solution is formed by dissolving about half a pound commercial cyanide of potassium in each gallon of water; for operations on a moderate scale, a stoneware vessel capable of holding about fifteen gallons may be supplied with about twelve gallons of the solution. Baths of the form shown in A, Fig. 103, and which are to be obtained at the Lambeth potteries, are well suited to this purpose. Another form of stoneware vessel is seen in Fig. 104, which, being deeper, is useful for certain classes of work. In applying the *cyanide dip* to articles of great length, it is commonly the practice to employ a common earthenware jug, kept near the dipping bath; this, being filled with the cyanide solution, is held above the highest point of the article (a brass tube, for instance) and tilted so that its contents may flow downward and pass all over the tube, which is then quickly taken to the water trough or tray and well rinsed, when it is at once placed in the nickel bath. On using the cyanide dip, it must be remembered that its only object is to dissolve from the surface of the recently scoured work an *almost imaginary film* of oxide, therefore the mere contact of the cyanide solution is amply sufficient to accomplish the object; on no account should brass or copper articles be exposed to the action of the dip for more than *a few seconds;* indeed, if the solution is in an active condition, the quicker the operation is conducted the better. It will readily be understood, however, that the weak cyanide bath will gradually lose its activity, when the dipping may be effected somewhat more leisurely. It is a common fault, however, to use these dips long after they have yielded up their active power, and we have frequently known them to be employed, and relied upon, when they were utterly useless.

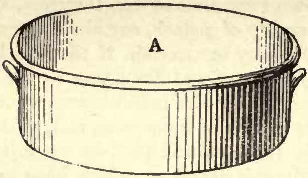

Fig. 103.

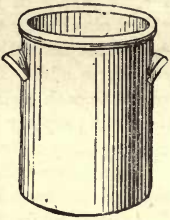

Fig. 104.

The Acid Dip.—This solution, which is used for dipping steel and iron articles after they have been scoured, is composed of hydrochloric (muriatic) acid and water, in the proportion of half a pound of the acid to each gallon of water. The solution is generally contained in a shallow wooden tub, which may conveniently be the half of a brandy cask or rum puncheon; but since the acid eventually finds its way to the iron hoops by which such vessels are held together, it is a good plan, in the first instance, to have a couple of wooden hoops, secured by copper rivets, placed over the vessel so as to prevent it from leaking in the event of the iron hoops giving way in consequence of the corrosive action of the acid liquor. Precautions of this nature will prevent leakage and the inconvenience which it involves.

Dipping Acid.—This name is given to a mixture which is frequently used for imparting a bright surface to brass work, and which is variously composed according to the object to be attained. When required for dipping brass work preparatory to nickel-plating, it is commonly composed of—

Sulphuric acid	4 lbs.
Nitric acid	2 „
Water	4 pints.

In making up the above mixture, the nitric acid is first added to the water, and the sulphuric acid (ordinary oil of vitriol) is then to be gradually poured in, and the mixture stirred with a glass rod. When cold, it is ready for use. The mixture should be made, and kept, in a *stoneware* vessel, which should be covered by a sheet of stout glass each time after using, to prevent its fumes from causing annoyance and from injuring brass work within its vicinity. The "dipping" should always be conducted either in an outer yard, or near a fireplace, so that the fumes evolved during the operation may escape, since they are exceedingly irritating when inhaled by the lungs. When it is convenient to do so, it is a good plan to have a hood of wrought iron, painted or varnished on both sides, fixed above an ordinary fireplace in the workshop, and to have a hole made in the brickwork above the mantelpiece to conduct the fumes into the chimney; this arrangement, however, will be of little use, unless there is a good draught in the chimney. It is well to ascertain this, therefore, before the *dipping* is proceeded with, which may be readily done by holding a large piece of ignited paper above the grate, when, if the flame persistently inclines towards the chimney, the draught may be considered perfect; if, however, it shows any inclination to come *forward*, it may be assumed that the draught is imperfect, owing to the chimney being filled with *cold* air. In this case lighted paper should be applied as before, until the flame and smoke of the ignited material have a *direct* tendency upward, or in the direction of the chimney. We are induced to give these precautionary hints more especially for the guidance of those who may be necessitated to work in apartments of limited space. In all cases, a vessel of clean water should be placed close to the dipping bath, into which the articles are plunged *the instant after* they have been removed from the dipping acid.

Pickling Bath.—Cast iron, before being nickeled, requires to be placed in a cold acid solution, or *pickle*, as it is called, to dissolve or loosen the oxide from its surface. The pickle may be prepared in a wooden tub or tank, from either of the following formulæ:—

Sulphuric acid (oil of vitriol)	½ lb.
Water	1 gallon.

Cast-iron work immersed in this bath for twenty minutes to half an hour will generally have its coating of oxide sufficiently loosened to be easily removed by means of a stiff brush, sand, and water.

When it is desired that the articles should come out of the bath bright, instead of the dull black colour which they present when pickled in the plain sulphuric acid bath, the following formula may be adopted:—

Sulphuric acid	1 lb.
Water	1 gallon.

Dissolve in the above two ounces of zinc, which may be conveniently applied in its *granulated* form. When dissolved, add half a pound of nitric acid, and mix well.

CHAPTER XXII.

ELECTRO-DEPOSITION OF NICKEL (*continued*).

Preparation of Nickeling Solutions.—Adams' Process.—Unwin's Process —Weston's Process.—Powell's Process.—Potts' Process.—Double Cyanide of Nickel and Potassium Solution.—Solution for Nickeling Tin, Britannia Metal, &c.—Simple Method of preparing Nickel Salts.— Desmur's Solution for Nickeling Small Articles.

Preparation of Nickeling Solutions.—Although many solutions have been proposed, we may say, with confidence, that for all practical purposes in the electro-deposition of nickel, a solution of the double sulphate of nickel and ammonium, with or without the addition of common salt, will be found the most easy to work and the most uniform in its results, while it is exceedingly permanent in character if worked with proper care and kept free from the introduction of foreign matter. The preparation of a nickel bath from the pure double salt is exceedingly simple, as we have shown, and only needs ordinary care to keep such a solution in good working order for a very considerable period. In order that the reader may, however, become conversant with the various solutions and modifications which ingenious persons have from time to time introduced, we will, as briefly as possible, explain such of these processes as may appear to deserve attention, if not adoption. Boettger's original process having been already referred to, we will now describe Mr. Adams' modification of it, for which he obtained patents in this country, in France, and the United States, and which, after much costly litigation, and consequent loss to those who had become possessed of them, were proved to be unnecessary to the successful deposition of nickel by electrolysis. When the ordinary simple methods of preparing the double salts of nickel and ammonium are taken into consideration, it seems marvellous that Adams' exceedingly roundabout process—which no one with practical chemical knowledge would dream of following—should have been considered worth contesting; not to defend the process as such, which no one infringed, but to secure the sole right to deposit nickel by electro-chemical means, by any process whatever. And what was the real "bone of contention"? It was based upon the most absurd "claim" ever allowed to become attached to a patent, which runs as follows :—

"The electro-deposition of nickel by means of a solution of the double sulphate of nickel and ammonia, or a solution of the double chloride of nickel and ammonium, prepared as [below] described, and used for the purposes [below] set forth, in such a manner as to be free from the presence of potash, soda, alumina, lime, or nitric acid, or from any acid or alkaline reaction."

According to this, if any solution of nickel, no matter how prepared, which could be proved by analysis to be free from the substances named (not one of which would be a *necessary* associate of nickel or of its double salts), such solution, if used in nickel-plating, would be an infringement of the patent! This *we know* was the impression of those who held the English patent, and we vainly endeavoured to show its fallacy. "Any solution of nickel which is free from these substances and used for plating purposes is an infringement of our patent." That was the contention, and the owners of this patent believed themselves entitled to an absolute monopoly of the right to nickel-plate within the four quarters of the United Kingdom.

Adams' Process.—In preparing the solution, the inventor prefers to use pure nickel, but commercial nickel may be used. "Commercial nickel," says the patentee, "almost always contains more or less of the reagents employed in the purification of this metal, such as sulphate of lime, sulphide of calcium, sulphide of sodium or potassium, chloride of sodium, and alumina. When any of these substances are present, it is necessary to remove them. This can be done by melting the nickel, or by boiling it in water containing at least 1 per cent. of hydrochloric acid. The boiling must be repeated with fresh acid and water until the wash-waters give no indication of the presence of lime when treated with oxalate of ammonia. When the metal is purified by melting, the foreign substances collect on the top of the metal in the form of slag, which can be removed mechanically. If the nickel contains zinc, it should be melted in order to volatilise the zinc and drive it off. The crucible in such a case must not be closed so tightly as to prevent the escape of the zinc fumes. If copper, arsenic, or antimony be present in the nickel, they can be removed, after the nickel is dissolved, by passing sulphuretted hydrogen through the solution. The acid to be used in dissolving the metal consists of 1 part strong nitric acid, 6 parts muriatic acid, and 1 part water. Nitric acid or muriatic acid may be used separately, but the above is preferred. A quantity of this acid is taken sufficient to dissolve any given amount of the metal, with as little excess of the former as possible; a gentle heat is all that is required. The resulting solution is filtered; and to prepare the solution of the double sulphate of nickel and ammonium, a quantity of strong sulphuric acid, sufficient to convert all the metal into sulphate, is added, and the solution is then evaporated to dryness. The mass is then again dissolved in water, and a much smaller quantity than before of sulphuric acid is added, and the whole again evaporated to dryness, the temperature being raised finally to a point not to exceed 650° Fahr. This temperature is to be sustained until no more vapours of sulphuric acid can be detected. The resulting sulphate of nickel is pulverised, and thoroughly mixed with about one-fiftieth of its weight of carbonate of ammonia, and the mass again subjected to a gradually increasing temperature, not to exceed 650° Fahr., until the carbonate of ammonia is entirely evaporated. If any iron is present, the most of it will be converted into an insoluble salt, which may be removed by filtration. The resulting dry and neutral sulphate of nickel is then dissolved in water by boiling, and if any insoluble residue remains, the solution is filtered. From the weight of nickel used before solution, the amount of sulphuric acid in the dry sulphate can be calculated. This amount of sulphuric acid is weighed out and diluted with four times its weight of water, and saturated with pure ammonia or carbonate of ammonia —the former is preferred. This solution, if it is at all alkaline, should be evaporated until it becomes neutral to test-paper. The sulphate of ammonia of commerce may likewise be used, but pure sulphate of ammonia is to be preferred. The two solutions of the sulphate of nickel and sulphate of ammonia are then united, and diluted with sufficient water to leave 1½ to 2 ounces of nickel to each gallon of solution, and the solution is ready for use. The object of twice evaporating to dryness and raising the temperature to so high a degree is, in the first place, to drive off the excess of sulphuric acid; and secondly, to convert the sulphate of iron, if it exists, into basic sulphate, which is quite insoluble in water.

"In order to give the best results, it is necessary that the solution should be as nearly neutral as possible, and it should in no case be acid. The inventor prefers to use the solution of a specific gravity of about 1·052 (water 1·000), though a much weaker or still stronger solution may be used. At temperatures above the ordinary the solution still gives good results, but is liable to be slowly decomposed. An excess of sulphate of ammonia may be used to dilute the solution, in cases where it is desirable to have it contain much less than 1 ounce of nickel to the gallon.

"In preparing the solution of double chloride of nickel and ammonium, the nickel is to be purified and dissolved in the same manner as is described for the previous solution; and it is to be freed from copper and other foreign matters in the same manner. The solution is then evaporated to dryness; it should be rendered as anhydrous as possible. The salt is then placed in a retort, and heated to a bright red heat. The salt sublimes, and is collected in a suitable receiver, the earthy matter being left behind. The salt, thus purified, is dissolved in water, and to the solution is added an equivalent quantity of pure chloride of ammonium. The solution is then ready for use; it may have a specific gravity of 1·050 to 1·100."

The repeated evaporations recommended by Adams are wholly unnecessary in the preparation of the double sulphate of nickel and ammonium or the double chloride, for if the nickel be pure (and there is no difficulty in obtaining it in this condition), the ordinary method of dissolving the metal or its oxide, and subsequent addition of the ammonia salt and careful crystallising the double salt, would give the same result, with far greater economy, both of time and trouble.

Unwin's Process.—This ingenious process, for which Mr. Unwin, of Sheffield, obtained a patent in 1877, is conducted as follows, and it will be seen that the salts of nickel and ammonia are thrown down in the form of a granular salt, readily soluble in water, by which the process of crystallisation is rendered unnecessary. He first prepares the sulphate of nickel "by taking three parts of strong nitric acid (sp. gr. about 1·400), one part of strong sulphuric acid (sp. gr. about 1·840), and four parts of water, all by measure, mixing them cautiously, and about half filling an open earthenware pan with the mixture. To every gallon of this mixed acid, I then add about two pounds of ordinary grain or cube nickel, and I heat the liquid by a sand-bath or other suitable means. If during the process of solution the action becomes inconveniently violent, I moderate it by the addition of a little cold water. If the nickel entirely dissolves (except a small quantity of black matter), I add more of it, in small portions at a time, and continue the addition at intervals until it is in excess. When the production of red fumes has nearly, or entirely, ceased, or when the liquid becomes thick and pasty, from the separation of solid sulphate of nickel, I add a moderate quantity of hot water, and boil and filter the solution; the deep green liquid so obtained is a strong solution of sulphate of nickel. If, from the circumstance of its production, I consider that it requires purification, I concentrate the solution by evaporation, until on cooling it yields a considerable percentage of crystals of sulphate of nickel; these crystals I collect, wash with a little cold water, and redissolve in a moderate quantity of hot water, filtering again if necessary. When cold, the liquid is ready for further treatment.

"I next prepare a strong solution of sulphate of ammonia, by dissolving the salt in hot water, in the proportion of about four pounds of the salt to each gallon of water, and then filter the liquid if necessary, and allow it to become cold. I then obtain the pure double sulphate of nickel and ammonia by adding the above solution of sulphate of ammonia to that of the sulphate of nickel; but I do not stop the addition of the solution of sulphate of ammonia, when sufficient has been added to combine with all the sulphate of nickel present, but I continue to add a large excess. I do this because I have discovered that the double sulphate of nickel and ammonia is far less soluble in the solution of sulphate of ammonia than in pure water, so that it is precipitated from its solution in water on adding sulphate of ammonia. I therefore continue adding the solution of sulphate of ammonia, continually stirring, until the liquid loses nearly all its colour, by which time the double sulphate of nickel and ammonia will have been precipitated as a light blue crystalline powder, which readily settles to the bottom of the vessel. I then pour off the liquid from the crystalline precipitate of double sulphate of nickel and ammonia, and wash the latter quickly with a strong, cold solution of sulphate of ammonia, as often as I consider necessary for its sufficient purification; but I do not throw away this liquid after use, but employ it at my discretion for combining with fresh sulphate of nickel, instead of dissolving a further amount of sulphate of ammonia. If I desire to make a further purification of the double sulphate of nickel and ammonia, I make a strong solution of it in distilled water, and add to the liquid a strong solution of sulphate of ammonia, by which means the double sulphate is precipitated in a very pure condition, and is separated from the liquid by filtration, or by other convenient means, and then dried, or used direct as may be desired; the liquid strained away can be employed, instead of fresh solution of sulphate of ammonia, for combining with more sulphate of nickel, or for washing the precipitate of the double sulphate."

Weston's Process.—Mr. Edward Weston, of Newark, N.J., having observed that boric acid, when added to nickel solutions, produced favourable results in the electro-deposition of nickel, obtained a patent for "the electro-deposition of nickel by means of a solution of the salts of nickel containing boric acid, either in its free or combined state. The nickel salts may be either single or double." The advantages claimed for the boric acid are that it prevents the deposit of sub-salts upon the articles in the bath, which may occur when the bath is not in good condition. Mr. Weston further claims that the addition of this acid, either in its free or combined state, to a solution of nickel salts renders it less liable to evolve hydrogen when the solution is used for electro-deposition; that it increases the rapidity of deposition by admitting the employment of a more intense current, while it also improves the character of the deposit, which is less brittle and more adherent. Mr. Wahl, after extended practical trials of Mr. Weston's formula, states that they have "convinced him of the substantial correctness of the claims of the inventor," and he adds, "Where the double sulphate of nickel and ammonia is used, the addition of boric acid, in the proportion of from 1 ounce to 3 ounces to the gallon of solution, gives a bath less difficult to maintain in good working order, and affords a strongly adhesive deposit of nickel. The deposited metal is dense and white, approaching in brilliancy that obtained from the solution of the double cyanide." The formula for preparing the solution is—

Double sulphate of nickel and ammonia	10 parts.
Boric acid, refined	2½ to 5 „
Water	150 to 200 „

Powell's Process.—This inventor claims to have discovered that benzoic acid, added to any of the nickel salts, arrests, in a marked degree, the tendency to an imperfect deposit, prevents the decomposition of the solution, and consequent formation of sub-salts. The proportion of benzoic acid to be added to the bath is said to be one-eighth of an ounce to the gallon of solution. This bath has been favourably spoken of. Powell also gives the following formulæ for nickel baths:—

1.	Sulphate of nickel and ammonia	10 parts.
	Sulphate of ammonium	4 „
	Citric acid	1 „
	Water	200 „

The solution is prepared with the aid of heat, and when cool, a small quantity of carbonate of ammonia is added until the solution is neutral to test paper.

2.	Sulphate of nickel	6 parts.
	Citrate of nickel	3 „
	Phosphate of nickel	3 „
	Benzoic acid	1½ „
	Water	200 „
3.	Phosphate of nickel	10 parts.
	Citrate of nickel	6 „
	Pyrophosphate of sodium	10½ „
	Bisulphite of sodium	1½ „
	Citric acid	3 „
	Liquid ammonia	15 „
	Water	400 „

These solutions are said to give good results, but the very complicated nature of the latter almost takes one's breath away.

Potts' Process.—In 1880, Mr. J. H. Potts, of Philadelphia, patented an improved solution for the electro-deposition of nickel, which consists in employing acetate of nickel and acetate of lime, with "the addition of sufficient free acetic acid to render the solution distinctly acid." The formula is given below:—

Acetate of nickel	2¾ parts.
Acetate of calcium	2½ "
Water	100 "

To each gallon of the above solution is added 1 fluid ounce of acetic acid of the sp. gr. 1·047. Mr. Potts first precipitates the carbonate of nickel from a boiling aqueous solution of the sulphate, by the addition of bicarbonate of soda, then filters and dissolves the well-washed precipitate in acetic acid, with the aid of heat.

"To prepare this bath, dissolve about the same quantity of the dry carbonate of nickel as that called for in the formula (or three-quarters of that quantity of the hydrated oxide) in acetic acid, adding the acid cautiously, and heating until effervescence has ceased and solution is complete. The acetate of calcium may be made by dissolving the same weight of carbonate of calcium (marble dust) as that called for in the formula (or one-half of the quantity of caustic lime), and treating it in the same manner. Add the two solutions together, dilute the volume to the required amount by the addition of water, and then to each gallon of the solution add a fluid ounce of free acetic acid as prescribed."

In reference to the above solution, Wahl says that he has worked it under a variety of circumstances, and has found it, in many respects, an excellent one. "It gives satisfactory results," he states, "without that care and nicety in respect to the condition of the solution and the regulation of the current which are necessary with the double sulphate solution. The metallic strength of the solution is fully maintained, without requiring the addition of fresh salt, the only point to be observed being the necessity of adding from time to time (say once a week) a sufficient quantity of acetic acid to maintain a distinctly acid reaction. It is rather more sensitive to the presence of a large quantity of free acid than to the opposite condition; as in the former condition it is apt to produce a black deposit, while it may be run down nearly to neutrality without notably affecting the character of the work. The deposited metal is characteristically bright on bright surfaces, and requiring but little buffing to finish. It does not appear, however, to be so well adapted for obtaining deposits of extra thickness as the commonly used double sulphate of nickel and ammonium. On the other hand, its stability in use, the variety of conditions under which it will work satisfactorily, and the trifling care and attention it calls for, make it a useful solution for nickeling."

Double Cyanide of Nickel and Potassium Solution.—This was one of the earliest solutions used for depositing nickel, and is capable of yielding an exceedingly white deposit. Though neither so economical nor so susceptible of yielding stout deposits of nickel as the ordinary double sulphate or double chloride, it may be advantageously employed when only a thin coating of a fine white colour is desired. It is stated to be somewhat extensively used in some large nickel-plating works in the United States. To prepare the solution, pure nickel or oxide of nickel is dissolved in either of the mineral acids; a mixture of hydrochloric and nitric acids, in the proportion of four parts of the former to one of the latter, may be used, an excess of the metal being taken to fully neutralise the acid. The solution is then evaporated and set aside to crystallise. The crystals, after being well drained and quickly rinsed in cold water, are next dissolved in water by the aid of heat, and when the solution has become cold a solution of cyanide of potassium is carefully added, with stirring, until all the metal has been thrown down in the form of cyanide of nickel. Care must be taken not to add an excess of cyanide. The supernatant liquor is now to be poured off, and the precipitate washed repeatedly with water. A strong solution of cyanide is next added, with stirring, until all the cyanide of nickel is dissolved. A small excess of cyanide is then to be added, when a reddish-brown solution of double cyanide of nickel and potassium will result, which, after filtering, is ready for use. The solution should be as concentrated as possible, almost to the point of saturation.

Solution for Nickeling Tin, Britannia Metal, &c.—The following formula has been recommended for coating tin, Britannia metal, lead, and zinc, as also brass and copper:—

Sulphate of nickel and ammonium . . .	10 parts.
Sulphate of ammonium	2 „
Water	300 „

The salts are to be dissolved in boiling water, and when cold the solution is ready for use. For nickeling cast and wrought iron and steel the following bath is recommended:—

Sulphate of nickel and ammonium . . .	10 parts.
Sulphate of ammonium	1½ „
Water	250 „

Simple Method of Preparing Nickel Salts.—To make the double chloride of nickel and ammonia take, say, 2 ounces of pure cube nickel, or oxide of nickel, and dissolve in hydrochloric acid, to which a little nitric acid may be added, taking care not to have an excess; apply gentle heat to assist the chemical action. When the evolution of gas has ceased dilute the resulting solution with cold water to make about 1 quart of liquor; now add liquid ammonia gradually, stirring after each addition, until the solution is neutral to test-paper; now dissolve 1 ounce of chloride of ammonium (sal-ammoniac) in sufficient water, and add this to the former solution; evaporate the mixture until crystals begin to form, then allow it to cool and crystallise gradually; next pour off the clear liquor, and repeat the evaporation to obtain a second batch of crystals; in the latter operation the solution may be evaporated to dryness. Finally, mix all the resulting products together and dissolve in about three pints of hot water, filter, and make up to about one gallon by the addition of cold water. The solution should have a specific gravity of 1·050 to 1·075.

The Double Sulphate of Nickel and Ammonium may readily be formed by dissolving oxide or carbonate of nickel in dilute sulphuric acid (1 part acid to 2 parts water). The resulting solution is then to be neutralised with ammonia and crystallised. To each pound of the dry crystals add 1 pound of pure sulphate of ammonia, dissolve the mixed salts, evaporate the solution, and re-crystallise. Cube or grain nickel may also be dissolved in a mixture composed of 1 part sulphuric acid and 2 parts water, with the addition of a small quantity of nitric acid, moderate heat being applied as before. The solution is then to be evaporated and set aside to crystallise, and to convert the sulphate of nickel into the double salt, sulphate of ammonia is to be added in the same proportion as before; the mixed salts must be dissolved, filtered, and crystallised. In making up a bath from the double sulphate prepared by either of the above methods, about 12 ounces of the dry crystals are to be taken for each gallon of bath, and the crystals should be dissolved in sufficient hot water, the solution filtered, and the requisite quantity of cold water added to make up the full quantity of the solution in the proportions given. At the temperature of 60° Fahr. the bath should have a specific gravity of about 1·52. It is necessary to state that the nickel employed should be *pure*, which can only be relied upon by obtaining it from some well-known respectable house.

Desmur's Solution for Nickeling Small Articles.—The author is indebted to M. Desmur for the following formula for coating small articles, which we recommend to the attention of those whose trade chiefly lies in nickeling struck work, such as umbrella-mounts, and the like:—

Double sulphate of nickel and ammonium .	7 kilogrammes
Bicarbonate of soda	800 grammes.
Water	100 litres.

The bicarbonate of soda must be added when the nickel solution is warm, in small quantities at a time, otherwise the effervescence which occurs may cause the solution to overflow. The bath is to be worked up to nearly boiling point. If, after working for some time, the deposit becomes of a darkish colour, add a small lump (about the size of a nut) of sulphide of sodium, which will remedy it. "Of all the solutions of nickel which I have tried," says M. Desmur, "this has, without doubt, given me the best results, both as to quickness of working and whiteness of deposit, which is equal to that of silver. Nickel deposited from this solution can be burnished. If the nature of the articles to be nickeled will not allow them to be either polished or burnished, they may be rendered bright by first dipping them in nitric acid and afterwards passing them rapidly through a mixture of old nitric acid dip (already saturated with copper), sulphuric acid, greasy calcined soot, and common salt."

CHAPTER XXIII.

ELECTRO-DEPOSITION OF NICKEL (*continued*).

Preparation of the Work for Nickel-plating.—The Scouring Tray.—Brass and Copper Work.—Nickeling small Steel Articles.—Nickeling small Brass and Copper Articles.—Nickeling by Dynamo-electricity.—Nickeling Mullers, Sausage Warmers, &c.—Nickeling Bar Fittings, Sanitary Work, &c.—Nickeling Long Pieces of Work.—Dead Work.—Nickeling Stove Fronts, &c.—Nickeling Bicycles, &c.—Nickeling Second-hand Bicycles, &c —Nickeling Sword-scabbards, &c.—Nickeling Harness Furniture, Bits, Spurs, &c.—Nickeling Cast-iron Work.—Nickeling Chain Work.—Re-Nickeling Old Work.—Nickeling Notes.

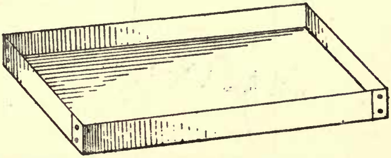

Fig. 105.

Preparation of the Work for Nickel-plating.—Since the various metals ordinarily coated with nickel require different treatment, it will be more convenient to treat them under their respective heads, by which the intending nickel-plater will become more readily conversant with the manipulation requisite in each particular case. All the preliminary arrangements of nickel bath, batteries, dips, &c., being complete, the work, as it is received from the polishing shop, should be placed in regular order upon a bench, the name of each customer being indicated by a ticket for each group of work, so as to prevent confusion. Small work is generally handed into the plating-room upon shallow trays, of the form indicated in Fig. 105. These trays are usually about 2 feet long by 15 inches wide, and about 3 inches deep; they are made of ordinary inch deal, planed on both sides, and the corners are bound with stout sheet iron. The trays are made of various sizes to suit the different classes of work to be conveyed in them. The reader is referred to another chapter for a description of the process of polishing.

The Scouring Tray.—This apparatus, which has to be subjected to much wear and tear, requires to be well put together, and must be *thoroughly* water-tight. A sketch of the scouring tray generally adopted is shown in Fig. 106. It is usually made from two-inch deal, planed on both sides; the joints are rendered water-tight by means of india-rubber, and the various parts are well bound together by screwed bolts and nuts. The dimensions may be 6 or 8 feet long (inside), 2 feet 6 inches wide, and about 15 or 18 inches deep. It is divided into two equal compartments by a wooden partition, and a stout shelf is fixed across one compartment, upon which is a small block of wood —about 7 or 8 inches long, and 2 inches square, secured to the shelf, by screws, from beneath, for scouring small articles. A water-tap, with india-rubber hose, is placed at a convenient distance above the tray, by which means either compartment may be filled at pleasure. At the corner of either compartment of the scouring tray is a flanged exit pipe, let into the bottom at the far corner, to allow the tray to be emptied when required. The second compartment is used as a rinsing trough. The exit pipes are furnished with a wooden plug, which the workman withdraws when he desires to run off the water from either compartment. A wooden shelf is generally fixed at a convenient distance above the back of the scouring tray, to hold various brushes, pumice-box, or other tools required in preparing work for the bath.

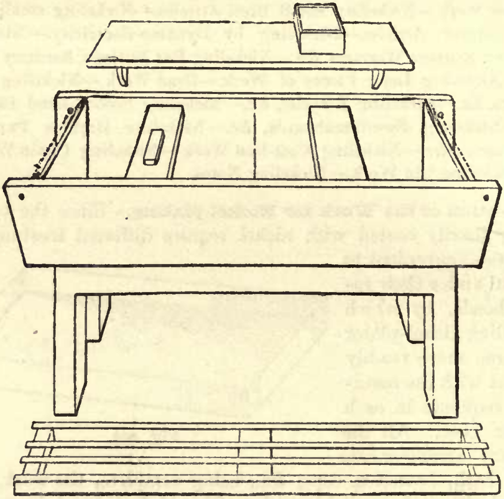

Fig. 106.

Brass and Copper Work.—The articles are first suspended, by means of short lengths of copper wire, in the hot potash bath, where they are allowed to remain until ready for scouring. The "slinging wires" for this purpose, as also for suspending the articles in the nickel bath, should be of various thicknesses, according to the weight they have to sustain, and it is a good plan to keep bundles of these wires, cut up into regular lengths, bound together by a piece of the same wire, so that they may be readily withdrawn as required. The articles being taken out of the potash bath, one by one, or a few at a time, according to their size, are at once plunged into the water in either compartment of the scouring tray. They are next subjected to the operation of *scouring*.

Scouring.—This usually consists in well brushing the work with finely powdered pumice and water, by means of hog-hair brushes. Some platers prefer a mixture of pumice and rottenstone for brass work, as being rather less *cutting*, and therefore less liable to scratch the work so severely as the pumice and water alone. The author's son, Mr. A. N. Watt, has succeeded well in employing ordinary whiting in scouring brass and copper work, which, while sufficiently cleaning the articles, enables them to come out of the nickel bath in a much brighter condition than when pumice is used, and as a natural consequence the work requires less time and trouble in finishing. We believe that recently slaked lime, either alone or mixed with whiting, would be better still, were it not for the fact that the caustic lime would be injurious to the hands of the workmen.

In scouring the work it is placed on the shelf across the scouring tray; the brush is then dipped in water and afterwards in the powdered pumice, or other material—which is kept in a wooden box upon the back shelf—and the article is well brushed all over, beginning at one end, and then turning the article round to brush the other; a final brushing is then given all over, as quickly as possible, so as to render the surface uniform. As each article is brushed it is rinsed in clean water, the slinging wire is then attached, and the article next dipped, for an instant, in the cyanide dip, again well rinsed, and immediately after suspended in the nickel bath, where it is allowed to remain from four to eight hours, according to whether the work is to be moderately or thoroughly coated with nickel.

As we have before observed, all work which is to be bright when finished must be polished before being nickel-plated. If, however, it were to be immersed in the nickel bath without any further preparation (unless a *very* slight coating of nickel were given), even if perfectly free from greasy matter and oxide upon its surface, the nickel would surely strip or peel off. Hence the operation of scouring is adopted—not alone to render the surface of the metal absolutely clean, but to give it an almost imaginary degree of roughness. It is a fact well known to electro-depositors that when a surface of metal is perfectly bright any other metal deposited upon it will readily separate. The surface may be *all but bright*, and the two metals will adhere more or less firmly; but if it is *absolutely bright*, the metals have little or no cohesion. In scouring, therefore, great care must be taken that the application of the brush and pumice has been perfectly uniform all over the work, and that the bright lustre given to it by the polisher has been thoroughly removed. To produce this result, the work does not entail laborious *scrubbing*, but is accomplished by a brisk brushing, taking care to keep the brush well charged with the pumice. We have seen men, improperly instructed in this respect, who have first dipped the brush in water, then in the pumice powder, and finally in the water again, before applying it to the work, whereby they actually washed away the material before the brush was applied! Again, it is a common error to dip the brush in the pumice before shaking the superfluous water from it, which not only causes the powder to become deluged with water, and a considerable portion of it to be wasted, but in this extremely wet condition it has little effect upon the surface to be cleaned. The brush should only be *moist* when dipped in the powder, in which state it will take up sufficient material to spread over a considerable surface, and will then do its required work effectually, with very little waste. Some scourers are very wasteful in this respect, and as a rule their work is never properly cleaned, or *pumiced.* The brushes employed in scouring are made from hog bristles, and are supplied, for the general purposes of the plater, of various widths, and are known as one-rowed, two-rowed, three-rowed, and four-rowed brushes, each terminating in a suitable handle (see Fig. 94). The brushes, in their separate sizes, may be laid upon the shelf behind the scouring tray, so as to be ready to hand when required for use, and they should on no account be used for any other purpose than scouring the work. New brushes may be dipped *for an instant* in the potash bath, and immediately rinsed, by which any greasy matter communicated to the hairs or bristles during the manufacture will be rendered soluble, and will afterwards wear away in use. This precaution is not altogether unnecessary, since these brushes have frequently been used by workmen for brushing their clothes, and sometimes even their hair.

Immersing the Work in the Bath.—When we bear in mind that the nickel anodes have a stationary or fixed position in the bath, and that consequently a very large surface of the positive electrode is exposed, it will be at once apparent that some means must be adopted, when the first batch of articles are being placed in the bath, to prevent the deposit from taking place too rapidly (owing to the excess of anode surface), and thereby causing the work to "burn," as it is called.

When dynamo or magneto-electric machines are employed, *resistance coils* are used to regulate or control the force of the current, as we shall explain hereafter; but although such coils are less necessary when depositing by battery power, some other equally effective means must be adopted. The most simple plan is to hook one of the anodes on the negative conducting rod, at its farthest end from the battery, and there to leave it until the rod is nearly supplied with work, when it may be removed and put in its proper place on the positive rod. By adopting this practice with each suspending rod in turn the "burning" of the work is entirely prevented, and deposition takes place, as it should do, gradually, which is of special importance in the earlier stages of the operation.

When work of moderate dimensions—as brass taps, for example—and very small articles are in hand for nickeling, the larger work should be put into the bath first, and the smaller work then introduced between other pieces of larger work. It is also usual to commence suspending the work from the end of the rod nearest the battery (where the power is weakest) rather than from the opposite end. Small articles—such as screws, for example—should not be slung singly, but several of them suspended from the same wire, as in Fig. 107, in such a way as not to be in contact with each other.

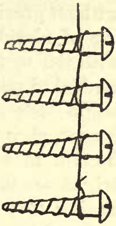
Fig. 107.

Nickeling Small Steel Articles.—This class of work, after cleaning, immersion in the acid dip, and rinsing, should be suspended in the bath, if practicable, between other articles of larger dimensions, so that deposition may take place slowly and gradually; otherwise the articles are very liable to strip. This precaution is specially necessary in nickeling small dentists' tools, as excavators, &c., which, when exposed to too strong a current, are apt to burn at the lower end and strip. In nickeling such work the rule is, after the article has become "struck" (that is, coated all over), to allow the deposit to take place very slowly, especially during the first half-hour's immersion. When battery power is used, from one to two hours' immersion will be sufficient for a serviceable coating upon the smaller dental tools, but a somewhat longer period—say, up to three hours—should be given to dental forceps. When a dynamo-machine is employed, about half this time will be sufficient. It is very important that steel work should be placed in the bath *immediately* after being cleaned, since even a few moments' exposure to the air or immersion in water will cause an invisible film of oxide to form on the surface, which will prevent the nickel from firmly adhering to the steel. After nickeling, the articles are rinsed in hot water and handed to the finisher, who gives them the necessary high polish. Small steel or iron articles which are not required to receive a stout coating of nickel are first steeped for a short time in the potash bath, and after being rinsed are dipped for a moment in the hydrochloric acid dip, again rinsed, and put into the nickeling bath, without any preparatory scouring, and given a short immersion only—say, half-an-hour. Such work is generally finished by being *dollied* only, which brings up the surface to its proper brightness.

Nickeling Small Brass and Copper Articles.—When these have to receive a good coating and afterwards to be finished bright, they must be scoured after polishing, and treated in all respects the same as larger work. Articles which are not required to be stoutly nickeled, however, but only moderately well coated with this metal, may be polished with the rouge composition referred to in another chapter, instead of with lime in the usual way, and then placed in the bath without previous scouring. When they have received a moderate coating of nickel they are rinsed in hot water, and afterwards finished with the mop, or dolly, with the aid of the same composition. This method of treating small brass work—which we believe is of American origin—is especially suitable for umbrella mounts, reticule and purse frames, cheap fancy work, and such articles as are not liable to much friction in use. Small brass articles which are not required to be bright are first put into the potash bath for a short time, and after rinsing they are dipped in ordinary dipping acid, again well rinsed in several waters, and then put into the nickel bath, in which they receive a deposit according to the nature and quality of the work and the price to be paid for it, a short immersion, in many cases, being all that is given when the price is low.

Nickeling by Dynamo-electricity.—Although a very considerable amount of work of all kinds is coated with nickel by battery current, by far the greater portion passes through the hands of those who adopt dynamo or magneto-electric machines as the source of electricity. Indeed, if it were not for the great advantages which these machines present in the deposition of this metal, the art of nickel-plating would never have attained its present magnitude. In arranging a nickeling plant upon a large scale, the baths should be placed parallel to each other, having sufficient space between each vat for the free passage of the workmen; and the dynamo-machine should be stationed conveniently near the vats, so as to be under the immediate control of the plater. The conducting wires should be so arranged that the current may be applied to one or more of the baths, as occasion may require, and this may be most conveniently effected by fixing two stout brass or copper rods, by means of insulating brackets, to the wall of the apartment nearest the nickel tanks; these leading

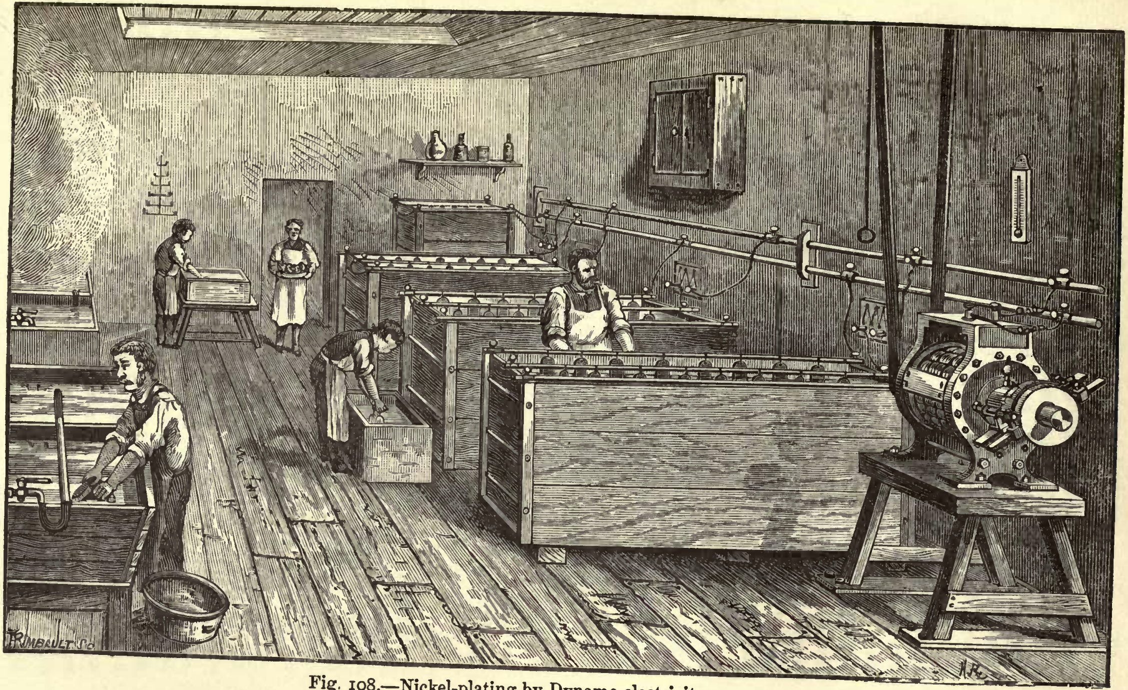

Fig. 108.—Nickel-plating by Dynamo-electricity.

wires or conducting rods must have attached to them a series of binding screws, corresponding in number to the connecting screws of the suspending rods. A large form of nickel tank, capable of holding from 250 to 500 gallons of solution, is shown in Fig. 109. To connect the machine with the leading rods stout copper wire is used, the thickness of which is regulated according to the power of the machine. For a medium-sized Weston, half-inch copper wire is generally used, but for larger machines the wire employed is usually three-fourths to one inch in thickness. To convey the current from the leading rods to the baths, the wire need not be so stout as in the former case, about one-half the thickness being sufficient. To give motion to the machine a counter-shaft is usually fixed overhead, with its driving pulley immediately in a line with the pulley of the machine, the two being connected by a belt in the usual way. The counter-shaft, an improved form of which has been introduced by Carlyle, is shown in Fig. 110, is furnished with a long iron handle within reach, by the raising or lowering of which the belt is placed on the fast or loose pulley of the shaft, according to whether the machine is required to run or stop. To regulate the amount of current entering the respective baths, a resistance coil is either attached to the end of each bath or fastened to the wall facing the end of each vat, and these coils are interposed in the circuit by means of short conducting wires. (See Fig. 108.)

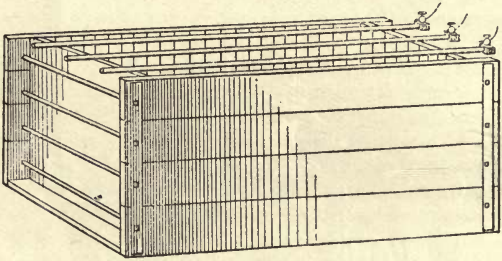

Fig. 109.

In working large tanks of nickel solution for coating articles of moderate size, as taps, spurs, bits, table lamps, &c., three rows of anodes are generally used, which are thus disposed: one row of anodes is suspended from a conducting rod on each side of the tank, and the third row is placed in the centre of the bath, midway between the other two. Two rods for supporting the work to be nickeled are placed between the side and centre rows of anodes, by which arrangement the suspended articles will be exposed to the action of two anode surfaces. The three anode rods must be united at their ends by means of thick copper wire, in which case one binding screw only, attached to the end of one of the side rods, will be necessary to connect the anodes with the positive leading wire of the machine; or a separate binding screw may be connected to the end of each rod, and the connection with the leading rods completed with short lengths of stout wire. The latter plan is the best, since one or more rows of anodes can be more readily thrown out of circuit by simply disconnecting the wire from the binding screw at the end of the rod.

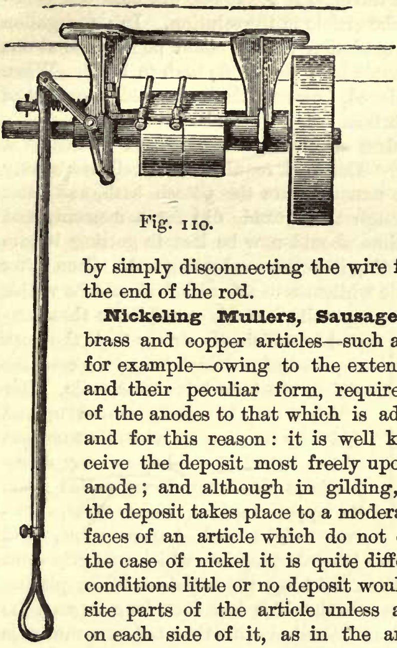

Fig. 110.

Nickeling Mullers, Sausage Warmers, &c.—Large brass and copper articles—such as beer and wine mullers, for example—owing to the extent of surface they present, and their peculiar form, require a different arrangement of the anodes to that which is adopted for ordinary work, and for this reason: it is well known that all metals receive the deposit most freely upon the surfaces facing the anode; and although in gilding, silvering, and coppering the deposit takes place to a moderate extent upon those surfaces of an article which do not directly face the anode, in the case of nickel it is quite different, for under the same conditions little or no deposit would take place at the opposite parts of the article unless an anode were suspended on each side of it, as in the arrangement we have described. Since mullers, and articles of the class to which they belong, present an extensive convex surface, it is necessary, in order to secure a uniform coating of nickel, to *surround* such work with anodes as far as is practicable. This is ordinarily done in the following manner:—The centre row of anodes is first removed; two short brass rods are then placed across the other positive rods, about 2 feet apart, and upon each of these is suspended one or more anodes, according to their width. The centre conducting rod, lately occupied by the anodes, is now used as the suspending rod for the muller. Where more than one nickel bath is employed, it is best to keep one of these specially for mullers and other large work, in which case two rows of anodes only and one centre negative rod, should be applied. The bath used for nickeling mullers should be kept covered with a frame, upon which oiled calico is stretched, to protect the work from dust. The drawing (Fig. 111) shows the relative position of the muller and the surrounding anodes. When the article has been in the bath some time, its position must be reversed—that is to say it must be *inverted*—so as to equalise the coating as far as possible, since the deposit always occurs most energetically at the *lower* surface of the article in the solution. In a 100-gallon bath only a single muller, or similar article, could be nickeled at one time; in other words, it should have the whole bath to itself. When dynamo-machines are employed, however, the baths seldom consist of less than 250 gallons of solution.

In nickeling the above class of work great care and smartness of manipulation are necessary. The work requires to be well and briskly brushed with pumice after removal from the potash bath, and after being rinsed is passed through the cyanide dip for a moment, and again well rinsed, and no time should now be lost in getting it into the nickel bath, and connecting it to the conducting rod. Soon after immersion the characteristic whiteness of the nickel should be visible upon its surface, as evidence that current is sufficiently strong to do the work required of it. Such being the case, the article must be left for awhile, after which it may be gently moved up and down by its slinging wires (but not out of the solution) to disperse any dusty particles that may have settled upon its upper surface, since these, however slight and imperceptible, will sometimes cause a rough and irregular deposit, which will give some trouble to the polisher when finishing the article. When plating work of this description in a bath which has been long in use, the anodes should be arranged as described some time before a muller is placed in the bath, so that the sediment (which always accumulates at the bottom of the vessel), if disturbed, may have time to subside; and in placing the article in the bath care should be taken to lower it gently, so as not to disturb the "mud," if we may call it so, at the bottom. The opposite of this careful treatment needs only to be tried once to make the plater exceedingly particular thereafter.

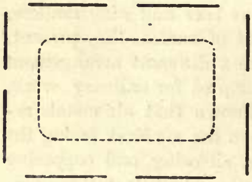

Fig. 111.

However careful the operator may be, it sometimes happens that certain parts of the article will become bare, or "cut through," as it is termed, during the process of finishing, in which case it is sent back from the polishing-room to the plater, who must in some way deposit nickel upon the exposed surface. This is accomplished by applying the "doctor," by which means a coating of metal is deposited upon the naked spot in the following way: a piece of stout copper wire, about a foot in length, is bent in the form of a hook at each end; a small piece of nickel, about an inch and a half square, is attached to one of the hooks, and this is wrapped up in several folds of rag, secured to the wire by twine. The other hook is connected by a long copper wire to the anode rod, and the article to be *doctored* connected in the same way to the negative rod. Now dip the rag-end of the wire in the nickel bath, and apply it to the bare spot (which should be previously brushed over lightly with pumice), keeping it in contact for a few seconds, then dip it in the bath again and apply as before, repeating the operation every half-minute or so, until a sufficient deposit of nickel has been given to the spot to enable the finisher to apply the "dolly," and thus render this part as bright as the rest of the article. Although this may not be considered a very conscientious method of getting over the difficulty, unless performed with patience, so as to impart something more than a mere film upon the bare place, it must be borne in mind that if the entire article were to be re-nickeled this would involve an amount of trouble and expense of labour which would never be compensated for. The "doctoring," however, should always be done *well*, and since the articles to which it is usually applied are rarely subjected to such friction as would affect so hard a metal as nickel, the defective portion of the work may cause little or no annoyance to the owner.

Nickeling Bar Fittings, Sanitary Work, &c.—Articles of this description require to be thoroughly well coated with nickel, and finished in the best possible manner. Before submitting such work to any preparatory process, the plater should carefully examine each piece to ascertain if it has been properly polished and all scratches and file marks obliterated, since if any of these be present after the article is nickeled and finished they will greatly impair the appearance of the work, while the finisher will be quite powerless to remove them without cutting through the nickel deposit. A careful examination of all work should be made by the plater before allowing it to enter the potash bath, and since in most establishments the polishing and finishing are done on the establishment, a proper understanding should exist between the finisher and plater as to the absolute necessity of having the work finished in the best possible manner. The articles, after being approved by the plater, are handed to the scourer, who connects a stout copper wire to each piece, and slings them to the suspending rod of the potash bath; after a short time these are removed, one or more at a time, according to their size, and after rinsing are taken to the scouring tray, where they are well brushed with pumice, then well rinsed in the water-trough of the scouring tray, and dipped for a moment in the cyanide dip. After being again well rinsed they are promptly suspended in the nickel bath. The articles should be thoroughly rinsed after being in the cyanide dip to prevent the introduction of this substance into the nickel bath. About two and a half hours' immersion in the bath, when a dynamo-machine is used, will be sufficient time to obtain a good deposit. It may be well to remark here, that however desirous a nickel-plater may be to give a good thick coating to his work, there is a limit, as far as nickel is concerned, which must on no account be exceeded; otherwise the deposited will strip or peel off the work, even without touching. Indeed, we have known the nickel, when the articles have been too long in the bath, to separate from the work and curl up in flakes, while a second deposit has taken place upon the parts thus deprived of metal.

Nickeling Long Pieces of Work.—Hand-rails, cornice poles, the framework of shop fronts, and other long pieces of work, require to be nickeled in a bath of suitable dimensions: for this purpose a tank of the form shown in Fig. 112 is generally used, which is supplied with a series of short anodes to suit the form of the vessel. Such a tank should be about 12 feet long, 20 inches deep, and about 18 inches wide. Since articles of this character do not very frequently come into the hand of the plater, it is unnecessary to employ special dipping baths for potash and cyanide; the hot potash liquor may be poured over the article from a jug, beginning at one end, and continuing the operation until the whole surface has been washed over with the hot liquor. After rinsing and scouring, the cyanide dip may be applied, quickly, in the same way. The article must now be well rinsed and got into the bath as promptly as possible.

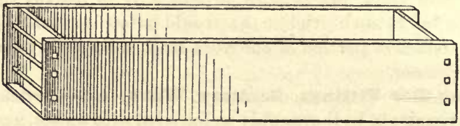

Fig. 112.

Dead Work.—Ships' deck lamps, and many other classes of work, which are not required to be polished, but left *dead*—that is, just as they come out of the nickel bath—are potashed, as usual, and after scouring and rinsing placed in the bath and allowed to remain until sufficiently coated. Since work of this kind should look as white as deposited nickel is capable of becoming, it is necessary, more especially during the last few minutes' immersion, to employ a strong current. When the articles are sufficiently coated they must be taken out of the bath, one at a time, and at once plunged into *perfectly clean* hot water for a few moments, and then placed aside to dry spontaneously. Since dead nickel is very readily stained or soiled even when touched with clean hands, the work should be handled as little as possible before being sent home to the customer. We have known instances in which dead nickel work, which from its silvery whiteness was pleasing to behold after removal from the bath, looked dirty and patchy before delivery to the customer, merely through the careless fingering to which it had been subjected by the warehouseman and others.

Nickeling Stove Fronts, &c.—These are usually nickeled in a vat specially constructed for the purpose, the form of which is shown in Fig. 113. It consists of a wooden vessel about 5 feet deep, 4 feet long, and about 18 inches wide, held together by bolts and screws, and is sometimes lined with pitch owing to the difficulty of lining such a vessel with lead. The anodes should be at least 30 inches long, and since only the fronts of stoves require to receive the coating of nickel, a single row of anodes only is necessary. This class of work is usually sent to the plating works in a polished state—that is, such parts as are to be bright are put in this condition by the manufacturers. To prepare the front for plating, it is first put into the potash bath as usual, and after a short immersion is well rinsed and scoured with pumice; it is next dipped in the hydrochloric acid dipping bath, again rinsed, and then put into the nickel vat with all possible despatch. After about two to three hours' immersion, the article is steeped in hot water, and when dry is handed to the finisher. Large pieces of ornamental iron work which have to be left dead may be also nickeled in the "stove bath."

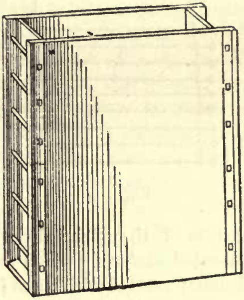
Fig. 113.

Nickeling Bicycles, &c.—When this class of work is sent to the plater in parts, these may be nickeled in the ordinary bath with the exception of the rim of the wheel, and all parts must be polished and treated in the same way as other steel work. A convenient method of suspending bicycle spokes in the bath is shown in Fig. 114. The copper slinging wire is simply coiled into a series of equidistant loops, through which the wires of the spokes pass freely, and when a sufficient number have been wired in this way the two ends of the slinging wire are pulled with both hands, by which the loops become tightened and the spokes held firmly. They are then lowered into the bath and suspended from the negative rod as shown in the engraving. After a short immersion, each spoke is shifted a little, so as to allow the wire mark to be coated, and this operation is repeated several times during their immersion in the bath, so that the coating may be as regular as possible. With a dynamo-machine a sufficient coating will be obtained in about an hour and a half. In nickeling the backbone and fork of a bicycle, and the larger parts of tricycles, these pieces should be frequently shifted in the bath to ensure uniformity of deposit, for it must be borne in mind that from the peculiar curved form of the backbone, for example, the parts farthest from the anodes will receive the least deposit. In cases where the bath is not large enough to take in the entire rim of a large bicycle wheel, it is usual to nickel one-half at a time; when this has to be resorted to, great care must be taken to well clean the line where the deposited metal and the bare steel meet, otherwise, when depositing upon the second or third portion of the rim, the nickel will strip at the junction of the separate deposits. In each case, a portion of the nickeled part should be immersed in the bath with the uncoated surface. When finishing the rim the polisher should be particularly careful with these junctions of the separate deposits, otherwise he may readily cut through the nickel and expose the underlying metal. In establishments where the nickeling of bicycles forms a special branch of the business, baths of suitable dimensions are employed for depositing nickel upon the larger pieces of bicycle and tricycle work.

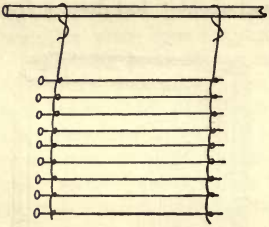

Fig. 114.

Nickeling Second-hand Bicycles.—Some few years ago, when nickel-plated bicycles first appeared in the market, the whole bicycle fraternity, who had been accustomed to plain steel or painted wheelers, looked with admiration, if not with envy, upon those who appeared amongst them upon their brilliant and elegant nickel-plated roadsters. At the time we speak of there was a rush of bicyclists at the various nickel-plating works, and anxious inquiries were made as to the possibility of nickeling bicycles which had become hideously rusty from neglect, or even those which had been more carefully treated. Could not a bicycle be popped in the solution, or whatever it was, and covered with the stuff, so as to come out bright like those in the shop windows? Questions such as these were asked, even with apparent seriousness. One firm, after consulting the foreman, determined to undertake the task of nickeling one of these second-hand bicycles, and after a good deal of trouble—since it was probably the first time such a thing had been attempted—the task was accomplished with considerable success, and the owner cheerfully paid the cost of its transmutation, three pounds ten shillings—a price that in these days of brisk competition would scarcely be thought of. Since the period referred to, the nickeling of bicycles has become an ordinary matter of detail in most nickel-plating works.

In preparing a bicycle for nickeling, the principal parts must first be taken asunder. The head nut is first unscrewed to liberate the backbone; the bolt which runs through the fork of the backbone must next be removed, by which the small wheel becomes dislodged; the bolt is next withdrawn from the hub of the large wheel, which liberates the fork; the spring is next disconnected by removing the screws at the head and back of the spring. All these parts, with the exception of the wheels, must pass through the hands of the polisher. It is not usual to remove the spokes, which in the case of a much-used machine would entail considerable risk, since much difficulty would occur not only in removing but in replacing them. The wheels are, therefore, nickeled entire, but before doing so they must be polished in the best way possible by hand, since it would not only be dangerous, but impracticable, to polish them at the lathe. The spokes and other parts of the wheel are first well rubbed with emery-cloth of various degrees of fineness, and then hand-buffed with chamois-leather, first with trent-sand, and afterwards with lime, as good a surface as possible being produced by these means. The wheels and other parts, when polished, are placed in the hot potash bath, where they are allowed to remain for a considerable time to remove the large amount of grease which invariably hangs about this class of work. To assist in the removal of this, the pieces are brushed over while in the potash tank; it is important that the potash liquor be in an active condition—that is, rich in the caustic alkali—or it will fail to *kill* the grease, as it is termed, or convert it into soap. After being thus cleansed in the potash bath, the work is removed piece by piece and rinsed, after which it is briskly scoured, and, after again rinsing, is passed through the acid dip for an instant, again well rinsed, and put into the nickel tank. When all parts of the machine are nickeled they are handed to the finisher, who "limes" them; that is, the backbone, fork, and other pieces, excepting the wheels, are polished and dollied with Sheffield lime at the lathe. The wheels, as before, are finished with lime, applied, by means of chamois-leather, by hand. The various parts are then readjusted, the machine carefully wiped all over, and it is then ready for the customer. Should the india-rubber tyre come off the wheel after being in the nickel bath, it may be replaced by fusing india-rubber cement upon the periphery of the wheel by heating over a gas-burner. While the cement is hot the tyre should be replaced in its position.

Nickeling Sword Scabbards, &c.—It not unfrequently occurs that a nickel-plater receives a sword and sheath with instruction to nickel the latter only. When such is the case, the sword should be withdrawn and placed where it cannot become moistened by the steam from the potash tank or otherwise injured. To prepare the scabbard for plating, the thin laths of wood with which it is lined must first be removed, since if the sheath were placed in the nickel bath without doing so, these pieces of wood, by absorbing the nickel solution, would become so completely saturated that much difficulty would afterwards occur in drying them. We have heard of instances in which this precaution has not been observed, and as a consequence the sword, after being sheathed for some time—probably for some months—was not only thickly coated with rust, but deeply corroded, owing possibly to voltaic action set up by the nickel solution absorbed by the wooden lining; in one such instance the sword had become so firmly fixed in the scabbard, through the oxidation of its blade, that it was unsheathed with great difficulty, and when at last withdrawn it was thickly coated with rust. The strips of wood referred to must, therefore, in all cases be removed before the sheath is immersed in either of the liquids employed. To do this, remove the screw which unites the collar to the upper part of the sheath; remove the collar, and with the blade of a knife loosen the strips of wood and withdraw them from the sheath, taking care to remove all of them. The two parts of the sheath and the screw must then be handed to the polisher, and when returned to the plating-shop they are first to be potashed, and afterwards scoured, passed through the acid dip, and after well rinsing put into the nickel bath, in which the scabbard should be slung horizontally, so as to get as uniform a deposit as possible. The collar and screw, slung upon separate wires, should then be placed in the bath, care being taken that the latter does not receive too heavy a coating, or some difficulty may arise in replacing it. To avoid this, the head of the screw only should be put into the bath. To prevent the nickel deposit from entering the screw-hole of the scabbard, a small plug of wood may be forced into the hole before the latter is put into the bath. When the several parts are sufficiently coated, which occupies about two hours, they are removed from the bath, rinsed in hot water, and *well dried;* they are then sent to the finisher, after which any lime that may have got into the screw-hole must be removed with a brush; the strips of wood and collar are then readjusted, the scabbard carefully wiped with a chamois-leather, and the sword replaced.

Nickeling Harness Furniture, Bits, Spurs, &c.—This class of work, when properly nickeled, may be considered one of the most useful applications of the nickel-plating art, but unfortunately—as is also the case with many other articles—a good deal of indifferent nickeling, the consequence, in a great measure, of unwholesome competition, has appeared from time to time, which has had the effect of shaking the confidence of manufacturers who were at one time much disposed to encourage this branch of electro-deposition. That competition may be carried too far is evidenced by the extremely low prices which are asked for nickeling articles at the present time, as compared with, say, five years ago; in many instances (if the work were done conscientiously) below the fair cost of polishing. When it is borne in mind that bits, spurs, stirrups, and all kinds of harness work are necessarily subjected to severe treatment in use, and that to nickel-plate such articles badly, for a temporary advantage, has a positive tendency, if not to close this market entirely against nickel-plating, at least to confine it solely to those who have a known reputation for doing their work properly, and can therefore be relied upon. We are led to make these remarks, *en passant*, because we have an earnest desire that nickel-plating should not lose its character for absolute usefulness for the temporary advantages of competition. We say *temporary*, because we know that much mischief has accrued to the art generally in consequence of work undertaken at prices that could not yield a profit being so badly nickel-plated, that some manufacturers have ceased to avail themselves of this branch of industry except in cases of absolute necessity.

In nickeling the class of work referred to, all the parts which are to be bright when finished must, as in all other cases, be previously well polished. Sometimes the articles are sent from the manufactory in this condition, but when such is not the case the pieces must be first handed to the polisher, and when returned to the plater they are to be potashed, scoured, and passed through the acid dip, and rinsed as before, and then placed in the nickel vat, where they should remain (with an occasional shifting) for about an hour and a half, by which time, with a good dynamo, they will have acquired as thick a coating as may be given without fear of peeling. After removal from the bath and rinsing in hot water, the articles are placed in the finisher's hands, and when finished, the lime which lodges in the crevices should be brushed away and the articles then wiped with a chamois-leather and wrapped up. The brushing of work after finishing is too often neglected, and we have known of many complaints having been made by customers of the "filthy state" in which nickel-plated work has been received, owing to the lime falling out of tubes and hollows and from other parts of articles when they have been unpacked and examined on the counter. All work, after lime-finishing, should be well brushed, and wiped with a leather; it does not occupy much time, and should be considered a necessary detail of the business.

Nickeling Cast-iron Work.—Articles of this class—as kilting machines, for example—are first potashed in the usual way, and after rinsing they are immersed in a pickle composed of half-a pound of sulphuric acid to each gallon of water used to make up the bath. In this they are allowed to remain for about half-an-hour, when they are removed, well rinsed, and scoured: for this purpose the author prefers sand to pumice powder, from the fact that when the former is used the articles have a brighter or more lustrous appearance when nickeled than if pumice be employed, besides which sand is cheaper. It frequently occurs, in cast-iron work, that numerous cavities, or "sand-holes," of greater or less magnitude, become visible after pickling and scouring the work, and since the nickel will probably refuse to enter these hollows—which is generally the case—it may be advisable in the first instance to give the article a coating of copper in an alkaline coppering bath, by which these cavities, if they are clean after sand-brushing, will become coppered with the rest of the article and the nickel will follow. Sometimes, however, the sand-holes are filled with flux or oxide of iron, in which case the former must be picked out with a hard steel point, and the hollow discoloured by oxide of iron should be scraped out with a small steel scraper. This being done, the article must be again sand-brushed and put into the coppering bath until coated all over with a slight film of copper. We have seen large iron castings in which the sand-holes have been so large and deep that the workmen at the foundry have been compelled to plug them with lead. Such defects as these should be looked for by the plater, and if any of these leaden stoppings appear it will be undoubtedly advisable to coat the article with copper before nickeling it, otherwise the nickel will not firmly adhere to the leaden stoppings. We should in all cases prefer to give a coating of copper to cast-iron work in the alkaline bath, since the cast metal is a very indifferent conductor, and requires, when not coated with copper, a very strong current; indeed, a few tolerably large pieces of cast iron uncoppered will often monopolise the whole of the current from a dynamo-electric machine, and thereby hinder the progress of the other work.

Nickeling Chain Work.—It sometimes happens that steel, iron, and brass chains of considerable length are required to be nickeled, in which case the object must be treated according to the directions given for the respective metals. A convenient method of slinging a chain in the nickel bath is shown in Fig. 115. A number of pieces of stout copper wire, of uniform length, are cut while the chain is being scoured, and both ends of the wires are dipped in dipping acid for a moment, and then well rinsed. The wires are then turned up into

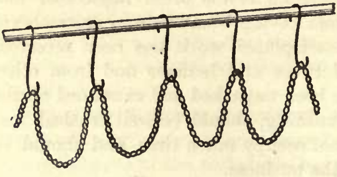

Fig. 115.

the form of a hook at one end, and when the chain is ready for slinging, the hooks are passed through the links one at a time and at equa distances apart, each portion being lowered into the bath and suspended by bending the end of the wire over the conducting rod, as in the figure ; in this way two men can immerse a chain of considerable length in a very few moments. After a short immersion, each hook may be shifted one link, to allow the wire mark to be nickeled, or the same link may be inverted, as preferred.

Re-Nickeling Old Work.—When goods which have been nickel-plated require to be re-nickeled, it is always better to first remove the old coating by means of a stripping solution, for the reason, as we have before remarked, that nickel will not adhere to a coating of the same metal. A stripping bath for nickel may be composed as follows :—

Oil of vitriol	16 pounds.
Nitric acid	4 "
Water	2 quarts.

Add the oil of vitriol to the water (not the reverse, which it is dangerous to do) gradually, and when the mixture has cooled down add the nitric acid, and stir the mixture with a glass rod. When cold, it is ready for use. The articles to be stripped should be attached to a piece of stout brass or copper wire and placed in the stripping liquid, and after a few moments they should be lifted by the wire and examined. If the articles are of a cheap class of work, the small amount of nickel upon them may become dissolved off in less than half a minute: this is generally the case with American, French, and German goods. The better qualities of English nickel-plating will sometimes occupy many minutes before the whole of the nickel will come off. This great difference in the thickness of the nickel-plating necessitates much caution and judgment on the part of the workman, for if he were to treat all classes of work alike, the metal of which the thinly-coated articles are made would become severely acted upon if left in the stripping bath while work of a better class was being *de-nickeled*, as we may term it. The operation of stripping should be conducted in the open air, or in a fire-place with good draught, so that the acid fumes may escape through the chimney. From the moment the articles are immersed in the stripping bath they should be constantly watched, being raised out of the bath frequently to see how the operation progresses, and they should not on any account be allowed to remain in the liquid one moment after the nickel has been dissolved from the surface, but should be immediately removed and plunged into cold water. On the other hand care must be taken to remove *all* the nickel, for if patches of this metal be left in parts it will give the polisher some trouble to remove it, owing to the great hardness of nickel as compared with the brass or copper of which the article may be composed. When the stripping of brass work has been properly conducted, the surface of the stripped article presents a smooth and bright surface, but little affected by the acid bath.

Nickel may be removed from the articles by means of the battery or dynamo-machine, by making them the anodes in a nickel bath ; but in this case a separate solution should be employed for the purpose ; or a bath may be made with dilute sulphuric or hydrochloric acid ; the stripping solution, however, when in good condition and used with care, is not only quick in its effect, but comparatively harmless to the underlying metal, if proper judgment and care have been exercised. Work which is in any way greasy should be steeped in the potash bath before stripping.

After the work has been stripped and thoroughly well rinsed, it should be dipped in boiling water, and then laid aside to dry spontaneously ; it is next sent to the polishing room, where it must be polished and finished in the same way as new work, and afterwards treated in the nickeling room with as much care and in the same way as new goods.

Nickel-facing Electrotypes.—In printing from electrotypes with coloured inks, but more especially with vermilion inks, which are prepared from a mercurial pigment, not only is the surface of the electrotype injuriously affected by the mercury forming an amalgam with the copper, but the colours are also seriously impaired by the decomposition which is involved. To avoid this it is frequently the practice to give electrotypes to be used for such purposes a coating of nickel, which effectually protects the copper from injury. In some printing establishments a nickel bath is kept specially for this purpose. The electrotypes, after being backed up and prepared for mounting in the usual way, are lightly brushed over with a ley of potash, and after well rinsing are suspended in the nickel bath for about an hour or so, by which time they generally receive a sufficient coating of nickel. Great care should be taken, however, not to employ too strong a current, lest the lower corners of the electrotype should become *burnt*, as it is called, by which a rough surface is produced, from which the ink, in subsequent printing, would fail to deliver properly ; this defect, however, is readily avoided with care, and by occasionally reversing the position of the plate while in the bath.

For nickel-facing electros of moderate dimensions, an oval stoneware pan, capable of holding about ten to fifteen gallons of solution, may be used. The nickeling bath should consist of about three-quarters of a pound of good nickel salts (double sulphate of nickel and ammonia) to each gallon of water. The salts should be dissolved in hot water and filtered into the containing vessel through a piece of unbleached calico. The anodes may consist of two plates of rolled nickel, each about 12 inches long by 6 inches wide, these being suspended in the bath by hooks from a brass rod laid across the vat. A Bunsen battery of about one gallon capacity will give a current sufficient for nickeling electros of moderate size. The positive electrode (the wire proceeding from the carbon of the battery) is to be connected to the brass rod supporting the anodes, and a similar rod, connected to the zinc of the battery, is to be laid across the vat in readiness to receive the prepared electros to be nickeled. The suspending rods and all binding screw connections must be kept perfectly clean.

When putting an electro in the bath, care must be taken to expose its face to the anodes, otherwise little or no deposit will take place upon this surface. If desired, a second row of anodes and an additional negative rod for supporting electrotypes may be employed, in which case the electros must be all suspended back to back, so as to face the anodes. An additional battery will be required. The faces of the electros may be placed within 3 or 4 inches of the anodes, and each should be supported by two wires passed through the nail holes in the backing metal which are nearest the corners.

Nickeling Wire Gauze.—Messrs. Louis Lang & Son obtained a patent in 1881 for a method of nickeling wire gauze, or wire to be woven into gauze, more especially for the purposes of paper manufacture. These wires, which are generally of copper or brass, are liable to be attacked by the small quantities of chlorine which generally remain in the paper pulp, by which the gauze wire eventually suffers injury. To nickel wire before it is woven, it is wound on a bobbin, and immersed in a nickel bath, in which it is coated with nickel in the usual way; it is then unwound and re-wound on to another bobbin, and re-immersed in the nickel bath as before, so as to coat such surfaces as were in contact with each other and with the first bobbin. To deposit nickel on the woven tissue, it may either be coated in its entire length, as it leaves the loom, or in detached pieces. For this purpose the wire gauze is first immersed in a pickle bath, and next in the nickel solution. On leaving the latter it is rinsed, and then placed in a hot-air chamber, and when thoroughly dry may be rolled up again ready for use.

Nickeling Printing Rollers.—Mr. Appleton obtained several patents in 1883 for coating with nickel the engraved rollers used for printing and embossing cotton and other woven fabrics, to protect them from the chemical action of the various colours and chemical matters used in calico printing, &c., by which the copper rollers become deteriorated. Nickel-plated rollers, moreover, presenting a much harder surface than copper, are far more durable. The rollers are first engraved as usual, after which they are immersed in any ordinary nickel bath. The inventor finds it advantageous, in order to secure a uniform coating of nickel, to "vibrate, agitate, oscillate, or rotate the roller continuously, or intermittently," while the deposition is taking place. He has found, however, some difficulty in obtaining a firm deposit, "owing to the formation of gas bubbles upon the surface of the roller, and the difficulty in dislodging them. To obviate this he finds it advantageous to employ "a brush, which is in contact with the roller during the plating operation, the roller being rotated continuously, or intermittently, as preferred." The brush is suspended from the cathode rod, so that the bristles may touch the surface of the roller, and thus remove any adhering bubbles. He prefers a brush made with vegetable fibre or spun glass, or other substance not liable to be acted upon by the solution.

Nickeling Notes.—1. It may be taken as a rule that only a limited quantity of nickel can be deposited upon either brass, copper, steel, or iron; if this limited amount of metal be exceeded the deposited metal will assuredly separate from the underlying metal. It has also been found in practice that a greater thickness of nickel can be deposited upon brass and copper without spontaneously peeling off than upon steel or iron. Since nickel, however, is an exceedingly hard metal, and will bear a considerable amount of friction, a very thin coating indeed is all that is necessary for most of the articles to which nickel-plating is applied. We may, however, state that too much advantage has been taken of this fact, for many articles of American and continental manufacture enter the market upon which a mere film of nickel has been deposited, and consequently they soon become unsightly from the rapidity with which the flimsy coating vanishes with even moderate wear. As a rule, the nickel-platers of this country deposit a very fair, and in many instances a very generous, coating of nickel upon their work, which has caused the home nickel-plating industry to hold a high position both as regards the *finish* of the work and its durability. It will be a thing to be regretted if price-competition should cause this useful branch of electro-deposition to become degraded by coating well-manufactured articles with a mere skin of nickel!

2. *Nickeling Steel Articles.*—When small steel work, such as purse mounts, book-clasps, &c., have to be nickeled, it is better first to suspend larger articles of brass or copper upon one end of the conducting rod, and to reserve the other end of the rod for the steel articles, or to sling them between the larger pieces of work; when it is not convenient to do this, one of the anodes should be slung from the end of the rod farthest from the battery, as a cathode, so as to take up a portion of the current. When steel articles are placed in the bath they should become "struck," as it is termed—that is, receive a slight coating of

nickel—almost immediately after immersion, but from that moment the deposition must be allowed to progress slowly, otherwise the work will surely *strip*, and this it will sometimes do even while in the bath: we have known steel work peel, when removed from the bath, by simply striking it gently against a hard substance. It is also of much importance that steel work should be placed in the bath *directly after* it has been passed through the hydrochloric acid pickle and rinsed, since even a few moments' exposure to the air—especially if there be any acid fumes given off by the batteries—will cause a film of oxide to form on the surface and render the deposit liable to strip.

3. *Rinsing the Articles.*—It will be readily understood that if articles are imperfectly rinsed after dipping, the acid or cyanide, as the case may be, which may still hang about them must be a source of injury to the nickel bath. It is therefore advisable not to depend upon one rinsing water only, but to give the work a second rinsing in perfectly clean water. It is very commonly the practice to give the final rinsing in one division of the scouring tray, the water of which can be readily changed by simply removing the plug and turning on the tap when it is replaced.

4. *Lime used in Finishing Nickel-plated Work.*—The lime used for finishing work which has been nickel-plated is generally obtained from Sheffield, and since this substance becomes absolutely useless after it has been exposed to the air—by which it attracts carbonic acid and falls to an impalpable powder possessing little or no polishing effect upon nickel—it must be preserved in air-tight vessels. For this purpose olive jars, or large tin canisters such as are used by grocers, answer well. Small quantities may be preserved in stone jars, covered with a well-fitting bung. The general practice is to take a lump of lime from the jar, cover the vessel immediately, and after breaking off a sufficient supply from the selected lump, to return it to the jar, which is again securely covered. The fragments of lime are then powdered in a mortar, and after sifting through a fine sieve or muslin bag, the powder is handed to the finisher, who informs the assistant (generally a boy) a short time before he requires a fresh supply of the powdered lime. By this arrangement the lime then always gets into the hand of the finisher in good condition for his purpose.

5. *Nickeling Dental Work.*—One of the most successful purposes to which nickeling has been applied for many years, is in coating dentist's tools, including forceps, excavators, and other implements used in dental practice. These articles, which are made from fine steel, are usually sent by the makers to the nickel-plater in a highly-finished condition, and therefore require but a moderate amount of labour in the plating and polishing shops to turn them out of hand.

To prepare this class of work for the bath, the pieces are first wired, after which they are suspended in the potash bath for a short time, or until required to be scoured. They are now removed, a few at a time, and rinsed, after which they are taken to the scouring bench, where they are brushed over with pumice and water ; each piece, after rinsing, is dipped for a moment in the hydrochloric acid dip, again rinsed, and immediately suspended in the vat. To prevent these small pieces from receiving the deposit too quickly and thus becoming "burnt" they are usually suspended between articles of a larger size which are already in the bath. When battery power is used for coating articles of this class (with larger work), from two to three hours' immersion in the bath will be required to obtain a fair coating ; with a dynamo about half that period will be sufficient. Dental forceps require a somewhat longer immersion than the smaller tools. When the work is sufficiently nickeled, it is removed from the bath, rinsed in hot water, and sent into the polishing room to be lime-finished, after which it should be thoroughly well brushed to remove the lime, especially from the interstices. Some packers, or warehousemen, are apt to be rather careless in this respect, and are satisfied with giving nickel-plated and finished work a slight rub up with a leather, so that when the articles are received by the customer, the first thing that attracts his attention, when unpacking the work, is the appearance of a quantity of dirty lime which has fallen from the goods after they were wrapped in paper. This negligence has often been the cause of complaint, and since it can be so readily avoided by a little extra care, this should always be impressed upon the packer of finished work.

6. *Recovery of Nickel from Old Solutions.*—This is most readily effected by following Mr. Unwin's ingenious method of preparing the double salts of nickel and ammonia, namely, by taking advantage of the insolubility of the double sulphate of nickel and ammonia in concentrated solutions of the sulphate of ammonia. To throw down the double salts from an old solution, or from one which fails to yield a good deposit, prepare a *saturated* solution of sulphate of ammonia, and add this, with constant stirring, to the nickel solution, when, after a little while, a granular deposit of a green colour will form, which will increase in bulk upon fresh additions of the sulphate being given. The effect is not immediate, on adding the sulphate of ammonia solution, but after a time the green deposit will begin to show itself, and when a sufficient quantity of the ammonia salt has been added, the supernatant liquor will become colourless, when the operation is complete. The additions of sulphate of ammonia should be gradually made, and the mixture allowed to rest occasionally, after well stirring, to ascertain if the green colour of the nickel solution has disappeared. The clear liquor is to be poured off the granular deposit—which is

pure double sulphate of nickel and ammonia—and this should be allowed to drain thoroughly. It may afterwards be dissolved in water and used as a nickel-plating bath. The solution of sulphate of ammonia may be evaporated, and the salt allowed to crystallise; and if the crystals are afterwards re-dissolved and again crystallised, the resulting product will be sufficiently pure for future use.

7. "*Doctoring.*"—This term is applied to a system of patching up an article which has been "cut through," or rendered bare, in the process of lime-finishing, and it is adopted to avoid the necessity of re-nickeling the whole article, which would often entail considerable loss to the plater. When the faulty article is sent back from the polishing room the first thing to do is to arrange the "doctor," which is performed as follows:—A piece of stout copper wire is bent in the form of a hook at each end; a piece of plate nickel, about one and a half inch square (or a fragment of nickel anode) is now bound firmly to one of the hooks with a piece of twine; the lump of nickel is then wrapped in several folds of calico, or a single fold of chamois-leather. The second hook is now to be connected by a wire to the anode rod of the bath, and the article put in contact with the negative electrode. The rag end is now to be dipped in the nickel bath, applied to the defective spot (which should be first lightly scoured with pumice and water) and allowed to rest upon it for a few moments, then dipped again and reapplied. By repeatedly dipping the rag in the nickel bath and applying it in this way a sufficient coating of nickel may be given in a few minutes to enable the finisher to apply the "dolly" to the re-nickeled spot, and thus render it as bright as the rest of the article. When the operation is skilfully performed, both by the plater and finisher, no trace of the patch will be observable.

8. *Common Salt in Nickel Solutions.*—Owing to the inferior conductivity of nickel baths, various attempts had been made to improve the conducting power of these solutions by the addition of other substances, but the most successful of these, of French origin, was the introduction of chloride of sodium (common salt), which is a very good conductor of electricity. The addition of this substance was subsequently adopted by a well-known London firm, the character of whose nickel-plated work was much admired for its whiteness as compared with some other specimens, of a more or less yellow tone, which appeared in the market at that time. The advantages to be derived from the addition of common salt to nickel solutions have been very clearly demonstrated by M. Desmur, who, in a communication to the author, in June, 1880, made the following interesting statement,* which he

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* Electro-Metallurgy, Practically Treated. By Alexander Watt. Eighth edition, p. 229.

deems it advisable to reproduce in this place from its importance to those who follow the nickel-plating industry:—

9. *Augmentation of the Conductivity of Nickel Baths*—M. Desmur says: "The resistance of nickel baths as they are usually prepared, *i.e.* by dissolving double sulphate of nickel and ammonia in water, is very great. I would advise persons engaged in the trade to introduce into their baths ten per cent. of chloride of sodium (common salt). I have observed, by means of a rheostat, that the addition of this salt augments the conductivity by thirty per cent., and that the deposit is much whiter and obtained under better conditions. The diminution of resistance is in proportion to the quantity of chloride of sodium added, for the conducting power of a solution of this salt increases with its degree of concentration up to the point of saturation. I mention this fact because it is not the case with all saline solutions. For example, saturated solutions of nitrate of copper, or sulphate of zinc, have the same conductive power as more diluted solutions, because the conductibility of these solutions increases as the degree of concentration reaches its maximum, and diminishes as the concentration increases."

In our own experience we have observed that not only is the nickel deposit rendered much whiter by the addition of chloride of sodium, but it is also tougher and more reguline; indeed, we have known a stout deposit of nickel upon sheet brass or copper to allow the metal to be bent from its corners and flattened without the least evidence of separation or even cracking—a condition of deposit not often obtained in plain double sulphate solutions.

10. *Nickeling Small Articles by Dynamo-electricity.*—Small steel pieces, such as railway keys, for example, should not be kept in the bath longer than an hour, or an hour and a half at the most. About twice this period will be necessary when battery power is employed. Brass and copper work, as a rule, may remain in the bath about double the length of time required for steel work.

11. *Nickeling Small Screws*—When a large number of small screws have to be nickeled, they may be placed in a brass wire-gauze basket, made by turning up a square piece of wire-gauze in the form of a tray, and overlapping the corners, which must then be hammered flat and made secure by soldering. A piece of stout copper wire, bent in the form of a bow and flattened at each end, is then to be soldered to the centre of each side of the tray, forming a handle, by which it may be suspended in the bath by the negative wire of the battery or other source of electric power. The screws, having been properly cleaned, are placed in the basket, which is then immersed in the bath, and while deposition is taking place the basket must be gently shaken occasionally to allow the parts in contact to become coated: this is espe-

cially necessary during the first few moments after immersion. When nickeling such articles in the wire basket, they should be placed in a single layer, and not piled up one above another, since nickel has a strong objection to deposit *round the corner*. It is better, however, to sling screws by thin copper wire than to use a basket; and though the operation is a rather tedious one, a smart lad can generally "wire" screws, after a little practice, with sufficient speed for ordinary demands. The simple method of wiring screws before described will be found very useful, and if the necessary twist is firmly given there need be no fear of the screws shifting; the wire used for this purpose should never be used a second time without stripping the nickel from its surface and passing it through a clear fire to anneal it. When nickeling screws, it is best to sling them between other work of a larger size, otherwise they are liable to become *burnt*, which will necessitate stripping off the deposited nickel or facing them upon an emery wheel.

12. *Dead Nickel-plating*.—Certain classes of work, as ship deck lamps, kilting machines, and various cast-iron articles, are generally required to be left *dead*—that is, just as they come out of the nickel bath. All such work, when removed from the bath, should be at once rinsed in very hot and perfectly clean water. Care should be taken not to allow the work to be touched by the fingers at any part that catches the eye, since this handling invariably leaves an unsightly stain. Cast-iron work, when properly nickel-plated, presents a very pleasing appearance, which should not be marred by finger-marks before it reaches the hands of the customer.

13. "*Dry*" *Nickel-plating*.—This method, which is of American origin, has sometimes been adopted in this country for umbrella mounts and other small work, but it is only applicable to very cheap work, upon which the *quantity* of nickel is of secondary importance. Work of this character is generally dollied with a "composition" consisting of crocus (oxide of iron) mixed up into the form of a hard solid mass with tallow. The workman takes a lump of the composition, which he presses against the revolving dolly until it has acquired a small amount of the composition upon its folds (as in lime-finishing). He now holds the piece of work to the dolly, which quickly becomes brightened. When a sufficient number of pieces have been prepared in this way, they are suspended by any suitable means and at once placed in the bath, and so soon as they have become sufficiently coated for this class of work, that is in about half-an-hour or so, the articles are removed, rinsed, and dried, and after a slight dollying are ready for market. A convenient arrangement for suspending umbrella mounts, and articles of a like description, is shown in Fig. 116.

14. *Removing Nickel from Suspending Appliances*.—When wire-

gauze trays, wire suspenders, and other contrivances by which articles have been supported in the bath have been used many times, they naturally become thickly coated with nickel, and since this metal when deposited upon itself has no adhesion, the various layers of nickel which the tray, &c., have received from time to time generally curl up and break off with the slightest touch, and the fragments are liable not only to fall into the bath, but upon any work which may be in the solution at the time. It is better, therefore, to remove the nickel from these appliances, either by means of a *stripping solution* or by connecting them to the positive electrode of a battery and dissolving the metal off by electrolysis, for which purpose a small bath may be specially kept.

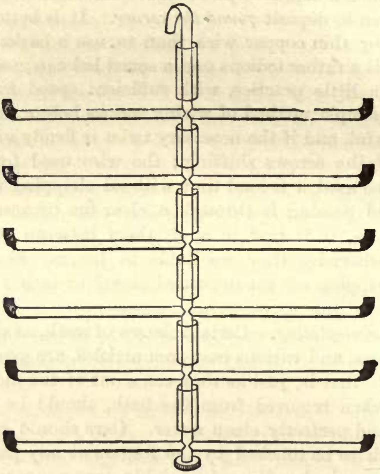

Fig. 116.

15. *Recovery of Dropped Articles from the Bath.*—When an article is accidentally dropped into the nickel vat, the workman should have at hand a ready means of recovering it without resorting to the unhealthy practice of plunging his bare arm into the solution. Many contrivances have been adopted for this purpose, amongst which may be mentioned an instrument of which a sketch is shown in Fig. 117. This simply consists of a per-

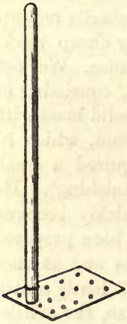

Fig. 117.

forated iron plate, fitted with a suitable handle, which may be conveniently attached by means of a socket brazed on to the perforated plate. If this tool, or *lift*, be gently lowered into the bath, in the direction in which the article is supposed to lie, and carefully moved about, so as not to disturb the sediment more than can be avoided, the lost article will probably soon come in contact with the lift, which should then be guided so as to draw the article to the side or end of the bath, when it may be shovelled on to the perforated plate and gradually lifted to the surface of the bath and taken off the plate, and the instrument hung up in its proper place ready for use another time. When small steel or iron articles fall into the bath, they may be recovered by means of a horse-shoe magnet. For this purpose a tolerably large magnet, having a cord attached to its centre and allowing the poles to hang downward, may be employed, and if allowed to drag along the bottom of the vat slowly, so as to avoid disturbing the sediment as much as possible, the lost article may generally be recovered and brought to the surface, even when the bath is full of work, without stirring up the sediment to any serious extent. When the recovery of the dropped pieces is not of any immediate consequence, this is better left till the evening, after the last batch of work has been removed.

16. *Rolled Nickel Anodes.*—The cost of a nickel-plating outfit, when *cast* anodes are employed, is in this item alone excessively heavy, since in many cases such anodes, for large operations, frequently weigh more than a quarter of a hundredweight each; and when it is borne in mind that for a 250-gallon bath from sixteen to twenty-four anodes would be required—except when a dynamo or magneto-electric machine is employed, when about half that number would be sufficient—it will be at once seen that the aggregate weight of metal would be considerable. Since *rolled* nickel anodes can now be obtained of almost any required thinness, from one-fourth to one-eighth of the quantity of metal only would be required to that of the cast metal. It is a common fault with cast nickel anodes that after they have been in use a short time they become soft and flabby while in the depositing vat, and will even fall to pieces with the slightest handling and become deposited—not in the electrolytic sense—at the bottom of the vat. It is not an uncommon circumstance, moreover, to find a considerable percentage of loose carbon—graphite—interspersed with the badly-cast nickel, and which, of course, if paid for *as nickel*, entails a loss upon the consumer. We have seen samples of such anodes containing nearly thirty per cent. of graphite, which could easily be scooped out with a teaspoon! Some very good specimens of cast nickel, however, enter the market in which neither of the above faults are to be found; indeed, we have examined samples containing 99 per cent. of nickel,

which for all practical purposes may be said to be pure. We should, in any case, give our preference to *rolled* nickel anodes; and for the following reasons:—They are less costly; they become more uniformly dissolved in the bath; they are generally more pure; they do not soften in the solution, and are less cumbersome to handle than cast anodes, which is an advantage when these require to be shifted, as in plating mullers and other large pieces.

17. *Nickeling Cast Brass Work.*—It sometimes occurs that work of this description is full of sand-holes; when such is the case, the polisher should receive instructions to obliterate these as far as possible, for nothing looks more unsightly in nickel-plated and finished articles than these objectionable cavities. It not unfrequently happens, however, that some sand-holes are too deep to be erased by the polishing process, with any amount of labour, while sometimes, in his endeavour to obliterate these defects the polisher finds that they extend in magnitude, and are found to enter deep into the body of the work. In such cases all attempts to eradicate them will be futile, and must therefore be abandoned. Polishers and finishers accustomed to prepare work for nickel-plating are fully aware of the importance of a fair face on the work, and they generally do their best to meet the requirements of the nickeling process, and many of them are exceedingly careful to prepare the work so that, when nickeled and finished, it shall look creditable.

CHAPTER XXIV.

DEPOSITION AND ELECTRO-DEPOSITION OF TIN.

Deposition by Simple Immersion.—Tinning Iron Articles by Simple Immersion.—Tinning Zinc by Simple Immersion.—Tinning by Contact with Zinc.—Roseleur's Tinning Solutions.—Deposition of Tin by Single Cell Process.—Dr. Hillier's Method of Tinning Metals.—Heeren's Method of Tinning Iron Wire.—Electro-deposition of Tin.—Roseleur's Solutions.—Fearn's Process. — Steele's Process. — Electro-tinning Sheet Iron. — Spence's Process.—Recovery of Tin from Tin Scrap by Electrolysis.

THERE are three different methods of coating brass and other metals with tin in what is termed *the wet way*, in contradistinction to the ordinary method of tinning by immersion in a bath of molten metal. By two of these methods a beautifully white film of tin is deposited, but not of sufficient thickness to be of a durable character. By the third method, a deposit of any required thickness may be obtained, although not with the same degree of facility as is the case with gold, silver, and copper.

Deposition by Simple Immersion, or "Dipping."—For this purpose, a saturated solution of cream of tartar is made with boiling water: in this solution small brass or copper articles, such as brass pins, for example, are placed between sheets of grain tin, and the liquid is boiled until the desired result is obtained—a beautifully white coating of tin upon the brass or copper surfaces. Ordinary brass pins are coated in this way. Some persons add a little chloride of tin to the bath to facilitate the *whitening*, as it is termed. The articles are afterwards washed in clean water, and brightened by being shaken in a leathern bag with bran, or revolved in a barrel.

Tinning Iron Articles by Simple Immersion.—A solution is first made by dissolving, with the aid of heat, in an enamelled pan—

Protochloride of tin (fused)	2½ grammes.
Ammonia alum	75 "
Water	5 litres.*

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* Tables of French weights and measures are given at the end of the volume.

The chloride of tin (which may be obtained at the drysalters) is readily made by dissolving grain tin in hydrochloric acid, with the aid of heat, care being taken to have an excess of the metal in the dissolving flask. When the bubbles of hydrogen gas which are evolved cease to be given off the action is complete. If the solution be evaporated at a gentle heat until a pellicle forms on the surface, and the vessel then set aside to cool, needle-like crystals are obtained, which may be separated from the "mother liquor" by tilting the evaporating dish over a second vessel of the same kind. When all the liquor has thoroughly drained, it should in its turn be again evaporated, when a fresh crop of crystals will be obtained. The crystals should, before weighing, be gently dried over a sand bath.

The ammonia alum is an article of commerce, and is composed of ammonia, 3·75; alumina, 11·34; sulphuric acid, 35·29; and water, 49·62, in 100 parts. It may be prepared by adding crude sulphate of ammonia to a solution of sulphate of alumina.

When the solution of tin and alum has been brought to a boil, the iron articles, after being well cleaned and rinsed in water, are to be immersed in the liquid, when they quickly become coated with a delicately white film of a dead or matted appearance, which may be rendered bright by means of bran in a revolving cask, or in a leathern bag shaken by two persons, each holding one end of the bag. The scratch-brush is also much used for this purpose. To keep up the strength of the tinning or *whitening* bath small quantities of the fused chloride of tin are added from time to time. Articles which are to receive a more substantial coating of tin by the separate battery may have a preliminary coating of tin in this way.

Tinning Zinc by Simple Immersion.—To make a bath for tinning zinc by the dipping method, the ordinary alums of commerce (potash and soda alums) may be used. In other respects, the solution is prepared and used in the same way as the above; and it may be stated that the proportions of the tin salt and ammonia in water need not of necessity be very exact, since the solution, after once being used, becomes constantly weakened in its proportion of metal, still giving very good results, though somewhat slower than at first.

For coating articles made of brass, copper, or bronze, a boiling solution of peroxide of tin in caustic potash makes a very good bath, yielding a coating of extreme whiteness. A still more simple solution may be made by boiling grain tin, which should first be *granulated*, in a moderately strong solution of caustic potash, which in time will dissolve sufficient tin to form a very good whitening solution.

Tinning by Contact with Zinc.—Deposits of tin upon brass, copper, iron, or steel may easily be obtained from either of the following solutions by placing the articles, while in the hot tinning bath, in contact with fragments of clean zinc, or with *granulated* zinc. To granulate zinc, tin, or other metals, have at hand a deep jar, or wooden bucket, nearly filled with cold water, upon the surface of which spread a few pieces of chopped straw or twigs of birch. When the metal is melted, let an assistant stir the water briskly *in one direction only*, then, holding the ladle or crucible containing the molten metal high up above the moving water, pour out *gradually*, shifting the position of the ladle somewhat, so that the metal may not all flow down upon the same part of the vessel's bottom. When all the metal is poured out, the water is to be run off, and the granulated metal collected and dried. It should then be put into a wide-mouthed bottle or covered jar until required for use.

Roseleur's Tinning Solutions.—Roseleur recommends either of the two following solutions for tinning by contact with zinc: 1. Equal weights of distilled water, chloride of tin, and cream of tartar are taken. The tin salt is dissolved in one-third of the cold water; the remaining quantity of water is then to be heated, and the cream of tartar dissolved in it; the two solutions are now to be mixed and well stirred. The mixture is clear, and has an acid reaction. 2. Six parts of crystals of chloride of tin, or 4 parts of the fused salt, and 60 parts of pyrophosphate of potassium or sodium are dissolved in 3,000 parts of distilled water, the mixture being well stirred; this also forms a clear solution. Both the above solutions are to be used hot, and kept constantly in motion. The articles to be tinned are immersed in contact with fragments of zinc, the entire surface of which should be equal to about one-thirtieth of that of the articles treated. In from one to three hours the required deposit is obtained. To keep up the strength of the bath equal weights of fused chloride of tin and pyrophosphate are added from time to time. Roseleur gives the preference to this latter solution if the pyrophosphate is of good quality. He also prefers to use coils of zinc instead of fragments of the metal, as being less liable to cause markings on the articles than the latter, which expose a greater number of points. It is evident from this that granulated zinc should not be used with these solutions, since metal in this form would exhibit an infinite number of points for contact. For tinning small articles, such as nails, pins, &c., these are placed in layers upon perforated zinc plates or trays, which allow of the circulation of the liquid; the edges of the plates are turned up to keep the articles from falling off the zinc surfaces. These plates are placed upon numbered supports, in order that they may be removed from the bath in the inverse order in which they were immersed. The plates are scraped clean each time before being used, in order that a perfect metallic contact may be insured between the plates and the articles to be tinned. During the tinning the small articles are occasionally stirred with a three-pronged iron fork, to change the points of contact. After the articles have been in the bath from one to three hours an addition of equal parts of pyrophosphate and fused chloride is made, and the articles are then subjected to a second immersion for at least two hours, by which they receive a good deposit. Large articles (as culinary utensils, &c.) coated in the above solution are scratch-brushed after the first and second immersions. The final operations consist in rinsing the articles, and then drying them in warm sawdust.

In reference to the working of the above solutions, Roseleur says:—"If we find that the tin deposit is grey and dull, although abundant, we prepare [? strengthen] once or twice with the acid crystallised protochloride of tin. With a very white deposit, but blistered, and without adherence or thickness, we replace the acid salt, by the fused one. In this latter case we may also diminish the proportion of tin salt, and increase that of the pyrophosphate." For tinning zinc in a pyrophosphate bath, the following proportions are recommended:—

Protochloride of tin (fused) . .	1 kilogramme.
Pyrophosphate of soda	5 kilogrammes.
Distilled water	300 litres.

Deposition of Tin by Single Cell Process.—Weil makes a tinning solution by dissolving a salt of tin in a strong solution of caustic potash or soda; a porous cell nearly filled with the caustic alkali (without the tin salt), and in this metallic zinc, with a conducting wire attached, is placed, the end of the wire being put in contact with the articles to be tinned. The solution of zinc formed in the porous cell during the action is revived by precipitating the zinc with sulphide of sodium.

Dr. Hillier's Method of Tinning Metals.—A solution is prepared with 1 part chloride of tin dissolved in 20 parts of water; to this is added a solution composed of 2 parts caustic soda and 20 parts of water; the mixture being afterwards heated. The articles to be tinned are placed upon a perforated plate of block tin and kept in a state of agitation, with a rod of zinc, until they are sufficiently coated.

Heeren's Method of Tinning Iron Wire.—This consists in first cleaning the wire in a hydrochloric acid bath in which a piece of zinc is suspended. The wire thus cleaned is then put in contact with a plate of zinc in a bath composed as follows:—

Tartaric acid	2 parts.
Water	100 ,,

To this is added, 3 parts of each, chloride of tin and soda. After remaining in the above bath about two hours, the wire is brightened by drawing it through a hole in a steel plate.

Electro-deposition of Tin.—Although the deposition of tin by simple dipping, or by contact with zinc, is exceedingly useful for small articles, and may be pursued by persons totally ignorant of electro-deposition, the deposition of this metal by the direct current is far more reliable when deposits of considerable thickness are desired, besides being applicable to articles of large dimensions. There have been many different processes recommended—some of which have been patented—for the electro-deposition of this metal, and several of these have been worked upon a tolerably extensive scale. For many purposes, this exceedingly pretty metal, when properly deposited by electrolysis, is very useful, but more especially for coating the insides of cast-iron culinary vessels, copper preserving pans, and articles of a similar description. There is one drawback connected with the electro-deposition of this metal, however, which stands much in the way of its practical usefulness, and renders its deposition by separate current more costly than would otherwise be the case, namely, that the anodes do not become dissolved in the bath in the same ratio as the deposit upon the cathode, consequently the strength of the bath requires to be kept up by constant additions of some salt of the metal to the solution while deposition is taking place. If this were not done, the bath would soon become exhausted, and cease to work altogether. To overcome this difficulty, and to keep up a uniform condition of the bath, the author proposed in his former work * the following method:—Arrange above the depositing tank a stone vessel, capable of receiving a tap (Fig. 118); to this connect a vulcanised india-rubber tube, reaching nearly to the surface of the solution. Let this jar be nearly filled with concentrated solution of the tin salt employed, made by dissolving the salt in a portion of the main solution. When the bath is being worked, let the tap be turned slightly, so that the concentrated solution may drip or flow into the depositing bath. When the stone vessel has become empty, or nearly so, a fresh concentrated solution should be made, using the liquor from the bath to a certain extent in lieu of water, so as not to increase the bulk of

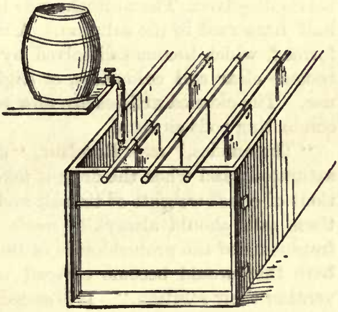

Fig. 118.

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* "Electro-Metallurgy." Eighth edition, p. 241.

the bath more than is absolutely necessary. By this method several advantages are gained—(1) By using the weakened bath each time to make the concentrated solution, there will be but trifling addition to the bulk of the solution; (2) By allowing the concentrated solution to *continually* enter the bath while deposition is taking place, there will be no necessity to disturb the bath by stirring in a larger quantity of the solution all at one time. In cases in which it is necessary to make additions of two separate substances, these may be introduced by employing two tapped vessels instead of one.

Roseleur's Solution.—The bath which this author recommends as possessing all the conditions desired by the operator, is composed of:—

Protochloride of tin (in crystals) . .	600 grammes.
Pyrophosphate of soda or potassa . .	5 kilogrammes.
Distilled or rain water	500 litres.

Instead of employing crystals of the tin salt, the fused substance is to be preferred, 500 grammes of which take the place of the former. In making up the bath, the water is put into a tank lined with anodes of sheet tin, united together, and put in connection with the positive electrode of the battery or other source of electricity. The pyrophosphate salt is then put into the tank, and the liquid stirred until this is dissolved. The protochloride is placed in a copper sieve, and this half immersed in the solution. A milky-white precipitate is at once formed, which becomes dissolved by agitation. When the liquid has become clear and colourless, or slightly yellow, the bath is ready for use. The cleaned articles are now to be suspended from the negative conducting rods as usual.

"The anodes," says Roseleur, "are not sufficient to keep the bath saturated; and when the deposit takes place slowly, we add small portions of equal weights of tin salt and pyrophosphate. The solution of these salts should always be made with the aid of the sieve, for if fragments of the protochloride of tin were to fall on the bottom of the bath they would become covered with a slowly soluble crust, preventing their solution." It is stated that any metal may be coated in this solution with equal facility, and that a good protective coating may be obtained with it, while the metal has a dead white lustre resembling that of silver, which may be rendered bright either by scratch-brushing or by burnishing. An intense current is necessary in working this solution.

Fearn's Process.—This process, for which a patent was granted in 1873, includes four different solutions, which may be thus briefly described: No. 1. A solution of chloride of tin (containing but little free acid) is first prepared, containing 3 ounces of metallic tin per gallon; 30 pounds of caustic potash are dissolved in 20 gallons of water; 30 pounds of cyanide of potassium in 20 gallons of water; and 30 pounds of pyrophosphate of soda in 60 gallons of water. 200 ounces (by measure) of the tin solution are poured slowly, stirring with a glass rod, into the 20 gallons of potash solution, when a precipitate is formed, which quickly redissolves; into this solution is poured first all the cyanide solution, then all the pyrophosphate, and the mixture well stirred. No. 2. 56 pounds of sal-ammoniac are dissolved in 60 gallons of water; 20 pounds of pyrophosphate of soda in 40 gallons of water; into the latter is poured 100 ounces by measure of the chloride of tin solution, and the mixture well stirred, when the precipitate formed redissolves as before. Lastly, the sal-ammoniac solution is added, and the whole well stirred together. No. 3. 150 pounds of sal-ammoniac are dissolved in 100 gallons of water; into this 200 ounces by measure of the tin solution are poured, and well stirred in. No. 4. To make this solution, 400 ounces of tartrate of potash are dissolved in 50 gallons of water; 1,200 ounces of solid caustic potash in 50 gallons of water; 600 ounces by measure of the tin solution are then added slowly, with stirring, to the tartrate solution; the caustic potash solution is next added, the stirring being kept up until the precipitate which forms has become entirely redissolved.

In using the above solutions, No. 1 is to be worked at a temperature of 70° Fahr., with a current from two Bunsen batteries; No. 2 is used at from 100° to 110° Fahr., with a weaker current; No. 3 is to be worked at 70° Fahr.; and No. 4 may be used cold. It is stated that solutions 1 and 4 yield thick deposits without requiring alternate deposition and scratch-brushing. Since during the working less tin is dissolved from the anodes than is deposited, the oxide or other salt of the metal must be added from time to time, except in the case of No. 3, which acts upon the anode more freely than the others. In tinning cast iron in these solutions, they require first to have a deposit of copper put upon them. For tinning zinc articles, No. 1 solution is employed.

Steele's Process.—This process is applied to coating articles of copper, brass, steel, iron, and zinc with tin. The solution is prepared thus: Dissolve 60 pounds of common soda, 15 pounds of pearlash, 5 pounds of caustic potash, and 2 ounces of cyanide of potassium in 75 gallons of water, then filter the solution; next add 2 ounces of acetate of zinc, 16 pounds of peroxide of tin, and stir the mixture until all is dissolved, when the solution is ready for use. The solution is to be worked at about 75° Fahr.

In preparing articles for electro-tinning, they must be rendered perfectly clean, either by scouring or dipping. Articles of cast iron may advantageously be first coppered in an alkaline coppering bath. Sometimes a deposit of tin is given in a boiling-hot solution by the zinc-contact method, and a stouter deposit afterwards obtained by the separate current in either of the foregoing solutions. The process of electro-tinning has been much adopted in France, and during the past few years there has been considerable attention paid to it in this country. It has yet to be developed into a really extensive industry.

Electro-Tinning Sheet-Iron.—Spence's Process.—This inventor says:—"When it is desired to make tin plates as cheaply as possible, I first place the plates in a solution of zinc, and deposit that metal on the surface; and then put them in a solution of tin, and deposit a coating of that metal. In manufacturing these plates, I coat the sheet iron with zinc, as before, and then deposit a coating of lead by electricity." By this method he reduces the quantity of tin usually required; and in regard to terne plates, he dispenses with the use of tin altogether. When removed from the bath, the electro-tinned plates are brightened by being placed in a stove heated to a temperature slightly above that at which tin melts (442° Fahr.). As the plates are taken out of the tinning bath, they are placed in a rack capable of containing 24 pieces. These racks, as they are filled, are placed in the stove, where they are allowed to remain until the tin melts on the surface. The plates are afterwards passed through rollers, with that edge first which was at the bottom of the rack. To avoid the employment of heat, one or more pairs of polished steel rollers may be used in succession, and so adjusted as to bear on the plate with some pressure. On removing the plates from the bath, they are passed through the rollers, which remove inequalities of the tin surface. To give the necessary polish, the plates are then placed on a table, on which is a pair of rolls rotating at high speed, and coated with cloth or other suitable material. These rolls are so arranged "as to rotate in the reverse direction to the transverse of the plate, and hence the plate has to be pushed through them."

Recovery of Tin from Tin Scrap by Electrolysis.—Dr. J. H. Smith, in a paper read before the Society of Chemical Industry, described a method for working up tin scrap which he found to be successful. The scrap to be dealt with had, on an average, about 5 per cent. of tin and there was a supply of some 6 tons a week, for which quantity the plant was arranged. It was designed to convert the tin into chloride of tin for dyers' use, the iron scrap being utilised as copperas. On the recommendation of Messrs. Siemens and Halske, of Berlin, one of their dynamos (C. 18), was used. The machine in question was stated to give a current of 240 ampères, with an electromotive force of 15 volts, and an expenditure of 7-horse power. Eight baths were used, made of wood lined with rubber. They were

1½ mètres long, 70 centimètres wide, and 1 mètre deep. The anodes were, of course, formed of the tin scrap, which was packed in baskets made of wood, and of a size to hold 60 kilos to 70 kilos of the scrap. There was an arrangement for constantly agitating these baskets by raising and lowering them, thus promoting circulation of the solution and regularity of action. The cathodes were copper plates 1½ millimètres thick and 120 centimètres long by 95 centimètres broad. There were sixteen of these, placed two in each tank, one on each side of the basket. The electrolyte used was sulphuric acid, diluted with 9 volumes of water. The tin precipitated was rather over 2 kilos per hour; it was very pure, easily melted when required, and in a form very suitable for solution in acid for preparation of tin salts. Dr. Smith having worked his process in a district in Germany, where probably tin scrap was obtainable at a low price, was enabled to show that a profit could be obtained upon the working. The same results might possibly be obtained in Birmingham, London, and other districts where large quantities of sheet tin are used. There have been many patents taken out for the electrolytic treatment of tin scrap, but the expense of collecting the scrap has always been the chief difficulty in rendering such processes commercially available.

CHAPTER XXV.

ELECTRO-DEPOSITION OF IRON AND ZINC.

Electro-deposition of Iron; Facing Engraved Copper-plates.—Klein's Process for Depositing Iron upon Copper.—Jacobi and Klein's Process.—Ammonio-sulphate of Iron Solution.—Boettger's Ferrocyanide Solution.—Ammonio-chloride of Iron Solution.—Sulphate of Iron and Chloride of Ammonium Solution.—Electro-deposition of Zinc.—Zincing Solutions.—Person and Sire's Solution.—Deposition of Zinc by Simple Immersion.—Hermann's Zinc Process.

Electro-deposition of Iron.—*Facing Engraved Copper-plates.*—The extreme hardness of electro-deposited iron as compared with copper and type metal has caused the electro-deposition of iron to be applied to the *facing* of printers' type and engraved copper-plates, by which their durability is greatly augmented. The importance of protecting the surface of engraved copper-plates from the necessary wear and tear of the printing operations can scarcely be overestimated, and a deposit of iron answers this purpose admirably. Another great advantage of the iron or "steel facing," or, as it is termed in France, *acierage*, is that when the deposited metal begins to wear off, the old coating is readily removed from the surface by means of dilute sulphuric acid, and another deposit given in its place in a very short time. In this way copper-plates may be preserved almost for an indefinite period, while each impression from the plate is as sharp and distinct as another even after a vast number of copies have been printed from the same plate. This system of facing printers' type and engraved copper-plates—which was originally suggested by Boettger—and the plates used for printing bank notes, has been much adopted by several large firms, including the eminent firm by whom this work was printed.

Iron may readily be deposited from a solution of its most common salt, the protosulphate, or green copperas, but for this purpose the salt should be as pure as possible. A depositing solution may also be prepared by passing a strong current through a large iron anode suspended in a tolerably strong solution of sal ammoniac. After the electrolytic action has been kept up for an hour or so, a cathode of clean sheet brass or copper should be substituted, which, if the solution has become sufficiently impregnated with metal, will at once receive a coating of iron, of a good white colour, though not perhaps quite so bright as the deposit obtained from a solution of the protosulphate of iron. An iron-depositing solution may be made in the same way by employing a moderately strong solution of either acetate of ammonium or acetate of potassium. A mixture of two parts sulphate of iron and one of sal ammonaic dissolved in water may also be employed, but the solution should not be too strong, otherwise the deposit is apt to be irregular, and of an indifferent colour. In making up iron baths for the electro-deposition of this metal, it has commonly been the practice to employ somewhat concentrated solutions, but the author, in the course of a long series of experiments, found that in most cases such a condition was far from being necessary and that weaker baths frequently yielded better results.

The author has obtained deposits of iron from most of its salts, including those prepared with the vegetable acids, as the acetate, citrate, tartrate of iron, &c., from some of which exceedingly interesting results were obtained, but possessing, however, no practical significance. The results of some of the more useful experiments are given in the Appendix.

Klein's Process for depositing Iron upon Copper.—This process, which from its successful results obtained the recognition and support of the Russian Government, is specially applicable to the production of electrotypes, as a substitute for those produced from copper, and is stated to be eminently successful in bank-note printing. The solution is prepared in a very simple way, as follows :—A solution of sulphate of iron is first made, and to this is added a solution of carbonate of ammonia until all the iron is thrown down. The precipitate is then to be washed several times, and afterwards dissolved by sulphuric acid, care being taken not to use an excess of acid. The solution is to be used in as concentrated a state as possible. To prevent the iron bath from becoming acid by working, a very large iron anode is employed—about eight times larger in surface than that of the copper cathode to be coated. After working this bath for some time, M. Klein found that the deposition became defective, and this he discovered was due to the presence of acid in the bath, owing to the anode not having supplied the solution with its proper equivalent of iron to replace that which had been deposited. To overcome this, he attached a copper or platinum plate to the anode, by which the two plates formed a separate voltaic pair in the liquid, causing the iron (the positive metal) to become dissolved, while the battery current was not passing through the bath. It is stated that the iron deposited by this process is as hard as tempered steel. but very brittle; it may, however, be rendered malleable by annealing, when it may be engraved upon as easily as soft steel. The following process is given for copying engraved metal plates in electrotype, and then giving them a surface of iron.

To Copy Engraved Metal Plates and Face them with Iron.—"If the plate be of steel, boil it one hour in caustic potash solution. Brush and wash it well. Wipe it dry with a rag, and then with one moistened with benzine. Melt six pounds of the best gutta-percha very slowly indeed, the gum being previously cut up into very small pieces. Add to it three pounds of refined lard, and thoroughly incorporate the mixture. Pour the melted substance upon the centre of the plate. Allow it to stand twelve hours, and then take the copy off.

"*Phosphoric Solution.*—Dissolve a fragment of phosphorus half-an-inch in diameter in one teaspoonful of bisulphide of carbon, add a similar measure of pure benzine, three drops of sulphuric ether, and half-a-pint of spirit of wine. Wash the mould twice with this solution, allowing it to dry each time.

"*Silver Solution.*—Dissolve one-sixth of an ounce of nitrate of silver, in a mixture of half-a-pint of strong alcohol and half a teaspoonful of acetic acid; wash the mould once with this liquid, and allow it to dry.

"*Copper Solution.*—Dissolve fifty-six pounds of sulphate of copper in nineteen gallons of water, and add one gallon of oil of vitriol. Deposit a plate of copper upon the mould in this solution.

"*Iron Solution.*—To coat the copper plate with a surface of iron, dissolve fifty-six pounds of carbonate of ammonium in thirty-five gallons of water. Dissolve iron into the liquid, by means of a clean anode of charcoal iron and a current from a battery. Clean the anode frequently, and add one-pound of carbonate of ammonium once a week. The copper plate, before receiving the deposit, should be cleansed with pure benzine, then with caustic potash, and thoroughly with water. Immerse the cathode in the iron solution for four minutes, take it out, wash, scrub, replace in the vat, remove and brush it every five minutes, until there is a sufficient deposit; then wash it thoroughly, well dry, oil, and rub it, and clean with benzine. If it is not to be used at once, coat it with a film of wax."

Jacobi and Klein's Process.—For depositing iron upon moulds for reproducing engraved surfaces and for other useful purposes, the following process is given. A bath is prepared with a solution of sulphate of iron, with the addition of either sulphate of ammonia, potash, or soda, which form double salts with the salt of iron. The bath must be kept as neutral as possible, though a small quantity of a weak organic acid may be added to prevent the precipitation of salts of peroxide of iron. A small quantity of gelatine improves the texture of the deposit. To accelerate the rapidity of the deposit, and favour its uniform deposition, the solution should be warm. The anodes employed are large iron plates, or bundles of iron wire, and since it is found that the anodes do not dissolve with sufficient rapidity to keep up the normal metallic strength of the bath, the inventors have found it useful to employ anodes of gas carbon, copper, or platinum—or any metal which is electro-negative to iron—as well as the iron anodes; or these auxiliary anodes may be placed in separate porous cells, excited by dilute sulphuric or nitric acid, or the nitrates or sulphates of potash or soda. The current employed is either from one or two Daniell cells only, or from a single Smee, the size of which is proportionate to the surface of the cathode. The Daniell cells should have a large surface, and the zinc be excited by a solution of sulphate of magnesia instead of dilute sulphuric acid. It is said to be "indispensable that the current should be regulated and kept always uniform with the assistance of a galvanometer having but few coils, and therefore offering only a small resistance. The intensity of the current ought to be such as to admit only of a slight evolution of gas bubbles at the cathode; but it would be prejudicial to the beauty of the deposit if gas bubbles were allowed to adhere to its surface." In working this process, the same moulds used for electrotyping may be employed; but it is advisable in using lead or gutta-percha moulds to first coat them with a film of copper in the usual way, and after rinsing to place them at once in the iron solution. The film of copper may be afterwards removed, either by mechanical means or by dipping in strong nitric acid.

The following formula is given for the composition of the iron bath:—

Sulphate of iron	139 parts.
„ magnesia	123 „

These substances are to be dissolved together in hot water, with the addition of a little oxalic acid and some iron shavings. This solution should be kept, in its concentrated condition, in well-stoppered glass bottles or carboys, and when required for use must be diluted until it has a specific gravity of 1·155 (water being 1·000). When working this solution, the oxide of iron which appears at the surface of the liquor must be skimmed off, with some of the solution, and shaken up in a bottle with a little carbonate of magnesia, and after settling, the clear liquor may be returned to the bath. To prevent air-bubbles from adhering to the mould, while in the bath, the mould may be first washed with alcohol, and afterwards with water; it is then to be placed in the bath before it has time to become dry. It is said that the iron deposited by this process is very hard and brittle, therefore much care must be taken to avoid breaking the electro-deposit when separating it from the mould. When annealed, however, the iron acquires the malleability and softness of tempered steel, and has a remarkably fine appearance when brushed with carbonate of magnesia.

Amongst the numerous solutions recommended for the electro-deposition of iron, we select the following :—

Ammonio-sulphate of Iron Solution.—This double salt, which was first proposed by Boettger for depositing this metal, may be readily prepared by evaporating and crystallising mixed solutions of equal parts of sulphate of iron and sulphate of ammonia ; a solution of the double salt yields a fine white deposit of iron with a moderate current, and has been very extensively employed in "facing" engraved copper-plates. When carefully worked, this is one of the best solutions for the deposition of iron upon copper surfaces.

Boettger's Ferrocyanide Solution.—This solution, which is considered even better than the former for coating engraved copper-plates with iron, is formed by dissolving 10 grammes of ferrocyanide of potassium (yellow prussiate of potash) and 20 grammes of Rochelle salt in 200 cubic centimètres of distilled water. To this solution is added a solution consisting of 3 grammes of persulphate of iron in 50 cubic centimètres of water. A solution of caustic soda is next added, drop by drop, with constant stirring, to the whole solution, until a perfectly clear light yellowish liquid is obtained, which is then ready for immediate use.

Mr. Walenn obtained good results from a slightly acid solution of sulphate of iron (1 part to 5 of water). Sulphate of ammonia, however, was found to increase the conductivity of the solution.

Ammonio-chloride of Iron Solution, made by adding sal-ammoniac to a solution of protochloride of iron, may also be used for depositing iron, a moderately strong current being employed. When carefully prepared and worked, this solution is capable of yielding very good results, but it has these disadvantages : the solution becomes turbid, and a shiny deposit is apt to form upon the electrodes. It is a common defect in iron solutions that they are liable to undergo change by absorbing oxygen from the air. To overcome this, Klein adopted the ingenious expedient of adding glycerine to the solution, by which he was enabled to keep his solution bath tolerably clear, except on the surface, upon which a shiny foam accumulated, which became deposited upon the articles in solution. To prevent the air from injuriously affecting the baths, it is advisable that the depositing vessel should be kept covered as far as practicable.

Sulphate of Iron and Chloride of Ammonium Solution.—The addition of chloride of ammonium (sal-ammoniac) to sulphate of iron solution improves the character of the deposit while improving the conductivity of the solution. Meidinger found that engraved copper-plates coated with iron in a bath thus composed were capable of yielding from 5,000 to 15,000 impressions.

Electro-deposition of Zinc.—*Watt's Solution.*—The deposition of this metal has never attained the dignity of a really practical art. In the earlier periods of electro-deposition many iron articles, including the sheet metal, were coated with zinc by this means, to protect them from rust, or oxidation, but it was soon found that the porous and granular nature of the coating, instead of acting as a preservative from rust, greatly accelerated the action of moisture upon the underlying metal (iron) by promoting electro-chemical action, by which the iron really suffered more severely than would ordinary sheet iron from which the *scale*, or coating of black oxide of iron, had not been removed. The process of *galvanising* iron, as it is fancifully termed—by which articles of this metal are dipped into a bath of molten zinc—soon proved, although not altogether faultless, so vastly superior to that of electro-zincing, that it became generally adopted to the entire exclusion of the latter. There are many purposes—gauze wire, for example—to which the process of "galvanising" is inapplicable, and for which a good electro-deposit of zinc would be specially serviceable. To obtain a solution which would give a good reguline deposit of zinc suitable for such purposes, the author, after a long series of experiments, succeeded in forming a solution, for which he obtained a patent in 1855, from which he obtained some exceedingly beautiful deposits, possessing the fullest degree of toughness which this metal exhibits when in a perfectly pure state. The most satisfactory result was obtained by dissolving the best milled zinc in a strong solution of cyanide of potassium, with the addition of liquid ammonia, by means of a strong voltaic current. The process is briefly as follows: 200 ounces of cyanide of potassium are dissolved in 20 gallons of water; to this solution is added 80 ounces, by measure, of strong liquid ammonia. The whole are then well stirred together. Several large porous cells are then filled with the solution, and these are placed upright in the vessel containing the bulk of the solution, the liquids in each vessel being at an equal height. Strips of copper are then connected by wires to the negative pole of a compound Bunsen battery of two or more cells, and these strips are immersed in the porous cells. A large anode of good milled zinc, previously well cleaned, is now connected to the positive pole of the battery, and the plate suspended in the larger vessel. The voltaic action is to be kept up until the zinc has become dissolved to the extent of about 60 ounces, or 3 ounces to each gallon of solution. To this solution is added 80 ounces of carbonate of potash, by dissolving it in portions of the solution at a time, and returning the dissolved salt to the bath. The porous cells being removed, the solution is allowed to rest for about twelve hours, when the clear liquor is to be transferred to another vessel, the last portions, containing sedimentary matter, being filtered into the bath.

Preparing Cast and Wrought Iron Work for Zincing.—The articles require to be first dipped for a short time in a hot potash bath, after which they are to be well rinsed. They are next steeped in a "pickle" composed of oil of vitriol half-a-pound, water 1 gallon. As soon as the black coating of oxide yields to the touch the articles are removed and plunged into clean cold water; they are then taken out one by one and well brushed over (using a hard brush) with sand and water; if any oxide still remains upon the surface, the articles must be immersed in the pickle again, and allowed to remain therein until, when the brushing is again applied, they readily become cleaned. They are now to be well rinsed, and at once suspended in the zincing bath, in which they should remain for a few minutes, then taken out and examined; and if any parts refuse to receive the deposit, these must be again well sand-brushed or scoured, the article being finally brushed all over, again rinsed, and placed in the depositing bath, where they are allowed to remain until sufficiently coated. An energetic current from at least two 3-gallon Bunsen cells, where a dynamo-machine is not used, is necessary to obtain a good deposit. The articles may be rendered bright by means of the scratch-brush, but large articles may be sufficiently brightened by means of sand and water, with the assistance of soap. When finished they should be dipped into hot water, and may then be further dried by means of hot sawdust. The anodes should be of the best milled zinc, and well cleaned before using.

Zincing Solutions.—For the electro-deposition of zinc, solutions of the sulphate, ammonio-sulphate, chloride, and ammonio-chloride may be employed, as also alkaline solutions prepared by dissolving zinc oxide or carbonate in a solution of cyanide of potassium or caustic potassa; the deposit from either of these alkaline solutions is generally of very good quality, and if too strong a current be not employed, the deposited metal is usually very tough.

Person and Sire's Solution.—This consists of a mixture of 1 part of oxide of zinc dissolved in 100 parts of water, in which 10 parts of alum have been previously dissolved at the ordinary temperature. The current from a single battery cell is employed, and the anode surface should be about equal to that of the articles to be coated, when, it is stated, the deposition proceeds as easily as that of copper, and takes place with equal readiness upon any metal.

Deposition of Zinc by Simple Immersion. — According to

Roque, cast and wrought-iron articles may be coated with zinc in the following way:—A mixture is first made consisting of (by measure) hydrochloric acid 550 parts, sulphuric acid 50 parts, water 1,000 parts, and glycerine 20 parts. The iron articles are first pickled in this mixture and then placed in a solution composed of carbonate of potassa 1 part and water 10 parts. The articles are next to be immersed from three to twelve hours in a mixture composed as follows:—water 1,000, chloride of aluminium 10, bitartrate of potassium 8, chloride of tin 5, chloride of zinc 4, and acid sulphate of aluminium 4 parts. The thickness of the deposit is regulated by the length of the immersion.

Hermann's Zinc Process.—By this process, which was patented in Germany in 1883, zinc is deposited by electrolysis from dilute solutions of sulphate of zinc with the aid of sulphates of the alkalies, or alkaline earths—potassium, sodium, ammonium, strontium magnesium, or aluminium—either added singly, or mixed together. The addition of these salts is only advantageous when dilute solutions of sulphate of zinc are to be treated. According to Kiliani, during the electrolysis of a solution of sulphate of zinc of 1·33 specific gravity (the anodes and cathodes consisting of zinc plates), the evolution of gas is greatest with a weak current, diminishing with an increasing current, and ceasing when on one square centimètre electrode surface, three milligrammes of zinc are precipitated per minute. The deposit obtained with a strong current was very firm. From a 10 per cent. solution the deposit was best with a current yielding from 0·4 to 0·2 milligramme of zinc. From very dilute solutions the zinc was always obtained in a spongy condition, accompanied by copious evolutions of hydrogen. With a weak current and from a 1 per cent. solution, oxide of zinc was also precipitated, even with an electro-motive force of 17 volts, when only 0·0755 milligramme of zinc per minute was deposited on one square centimètre of cathode surface. The size of the electrode surfaces must therefore be adjusted according to the strength of the current and the degree of concentration of the electrolyte.

CHAPTER XXVI.

ELECTRO-DEPOSITION OF VARIOUS METALS.

Electro-deposition of Platinum. — Electro-deposition of Cobalt. — Electro-deposition of Palladium. — Deposition of Bismuth. — Deposition of Antimony.—Deposition of Lead.—Metallo-Chromes. — Deposition of Aluminium.—Deposition of Cadmium.—Deposition of Chromium.—Deposition of Manganium.—Deposition of Magnesium.—Deposition of Silicon.

THERE are many metals which have been deposited by electrolysis more as a matter of fact than as presenting any practical advantage in a commercial sense; others, again, possessing special advantages which would render their successful deposition a matter of some importance, have been the subject of much experiment, in the hope that the difficulties which stood in the way of their being practically deposited for useful purposes could be overcome. Of these latter, the intractable but most valuable metal, platinum, may be considered the most important.

Electro-deposition of Platinum.—The peculiar attributes of this interesting metal—its resistance to the action of corrosive acids, and of most other substances, render it invaluable in the construction of chemical apparatus, while its high cost, its infusibility, and the great difficulty experienced in giving this metal any required form, greatly limit the area of its usefulness. If, however, articles of copper, brass, or German silver—metals which may be so readily put into shape by casting, stamping, or by any ordinary mechanical means—could be successfully and economically coated with platinum, this branch of the art of electro-deposition would soon meet with considerable support from the manufacturers of chemical apparatus, as also from opticians, who would gladly adopt electro-platinised* articles for many purposes of their art.

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* To contradistinguish the art of depositing bright reguline platinum upon metals from the process of *platinising*, devised by Smee for imparting a black powdery film upon silver for the negative plates of voltaic batteries, the term *platinating* has been proposed, but we would suggest that a simpler term would be *platining*. Electro-platinising would be a more correct term than platinating.

One great difficulty that stands in the way of depositing platinum economically and of any required thickness is that the anodes do not dissolve in the solutions which have as yet been adopted for its deposition; consequently, unless repeated additions of a platinum salt are made as the solution becomes exhausted, it is impossible to obtain a coating of sufficient thickness for any practical purpose. In order to meet this difficulty in some degree, the author suggested in his former work that the strength of the solution may be kept up in the same way as he recommended for electro-tinning; that is to say, a reservoir, containing concentrated platinum solution, is placed upon a shelf a little above the electro-platinising bath (Fig. 118), and the strong liquid is allowed to drip or flow out through a tap in the reservoir, and trickles at any required speed, into the solution bath, *while deposition is going on*, and in this way the strength of the bath may be kept up to any desired density. For small quantities of solution, the funnel arrangement shown in Fig. 119 may be adopted. The concentrated platinum solution being made in part from a portion of the larger solution, instead of with water, the original quantity of the liquid may be very fairly balanced. For example, if we take, say, one quart of the platinising solution and add to this a considerable proportion of platinum salt and the solvent employed in its preparation, so as to make as strong a solution as possible, when this is added and returned to the bath in the way above indicated, it will not add much to its original bulk. By weighing the articles before and after immersion, the weight of metal deposited may soon be ascertained (the time occupied being noted), and if the exact percentage of metal in the concentrated liquor is previously determined, there will be no difficulty in determining at what speed the strong solution should be allowed to flow into the bath to keep it up to the proper strength. Another suggestion we have to make is this: since the platinum anode does not become dissolved during electrolysis, a carbon anode may be substituted, which, in large operations, would add much to the economy of the process.

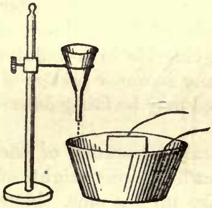

Fig. 119.

Preparation of Chloride of Platinum.—As in the case of gold, this metal must first be dissolved in *aqua regia*, to form chloride of platinum, previous to making up either of the baths about to be described. For this purpose, fragments of platinum, which may be pieces of foil or wire, are put into a glass flask, and upon them is to be poured two to three parts of hydrochloric acid and one part nitric acid; the flask is then placed on a sand bath, and gently heated until the red fumes at first given off cease to appear in the bulb of the flask. A solution of a deep red colour is formed, which must now be carefully poured into a porcelain evaporating dish, placed on the sand bath, and heated until nearly dry, moving the vessel about, as recommended in treating chloride of gold, until the thick blood-red liquor ceases to flow, at which period the vessel may be set aside to cool. Any undissolved platinum remaining in the flask may be treated with nitro-hydrochloric acid as before until it is all dissolved. The dry mass is to be dissolved in distilled water, and the subsequent solution, after evaporation, added to it. If the original weight of the platinum is known, it is a good plan to dissolve the dried chloride in a definite quantity of distilled water, so that in using any *measured* portion of the solution, the percentage of actual metal used may be fairly determined when making up a solution.

Cyanide of Platinum Solution.—Take a measured quantity of the chloride of platinum solution representing about five pennyweights of metal, and add sufficient distilled water to make up one pint. Now add of strong solution of cyanide sufficient to precipitate and redissolve the platinum; add a little in excess, filter the solution, and make up to one quart with distilled water. The solution must be heated to about 130° Fahr. when using it. A rather weak current from a Wollaston or Daniell battery should be used; if too strong a current be applied, the deposit will probably assume the form of a black powder.

Deposition by Simple Immersion.—Platinum readily yields itself up when brass, copper, German silver, &c., are immersed in its solutions, but the deposit is of little or no practical use. It may also be deposited from its solution by contact with zinc as follows:—Powdered carbonate of soda is added to a strong solution of chloride of platinum until no further effervescence occurs; a little glucose (grape sugar) is then added, and lastly, as much common salt as will produce a whitish precipitate. The articles of brass or copper are put into a zinc colander and immersed in the solution, heated to about 140° Fahr., for a few seconds, then rinsed and dried in hot sawdust.

Deposition by Battery Current.—Roseleur describes a solution from which he obtained platinum deposits of considerable thickness. The solution is prepared as follows:—

Platinum, converted into chloride . .	10 parts.
Distilled water	500 „

Dissolve the chloride in the water, and if any cloudiness appears in the solution, owing to the chloride having been over-heated during the last stage of the evaporation, it must be passed through a filter.

Phosphate of ammonia (crystallised)	100 parts.
Distilled water	500 „

Dissolve the phosphate in the above quantity of water, and add the liquid to the platinum solution, with brisk stirring, when a copious precipitate will be formed. To this is next added a solution of phosphate of soda, consisting of—

Phosphate of soda	500 parts.
Water (distilled)	1,000 „

The above mixture is to be boiled until the smell of ammonia ceases to be apparent, and the solution, at first alkaline, reddens blue litmus paper. The yellow solution now becomes colourless, and is ready for use. This solution, which is to be used hot, with a strong battery current, is recommended for depositing platinum upon copper, brass, and German silver, but is unsuited for coating zinc, lead, or tin, since these metals decompose the solution and become coated in it by simple immersion. Since the platinum anode is not dissolved in this solution, fresh additions of the chloride must be made when the solution has been worked.

Boettger's Solution for Depositing Platinum consists of a boiling-hot mixture of chloride of platinum solution and chloride of ammonia (sal-ammoniac), to which a few drops of liquid ammonia are added. The solution, which is weak in metal, requires to be revived from time to time by additions of the platinum salt.

Electro-deposition of Cobalt.—Until somewhat recently the electro-deposition of cobalt had chiefly been of an experimental character, based upon the belief, however, that this metal, if deposited under favourable conditions, was susceptible of some useful applications in the arts. The difficulty of obtaining pure cobalt anodes—as was the case with nickel until a comparatively few years ago—as a commercial article, stood in the way of those practical experimentalists who would be most likely to turn the electro-deposition of this metal to account. Moreover, the extremely high price of the metal, even if rudely cast in the form of an ingot, rendered its practical application all but impossible. That unfavourable epoch is now passed, and we have cobalt anodes and "salts" in the market, as easily procurable, though not, of course, at so low a price, as the corresponding nickel products. The author is indebted to the courtesy of the enterprising firm of cobalt and nickel refiners, Messrs. Henry Wiggin & Co., of Birmingham, for some excellent examples of their single and double cobalt salts and rolled cobalt anodes, and is thus enabled to state that those who may desire to embark in the electro-deposition of this metal can readily obtain the chief requisites, the salts and anodes, in any desired quantity from this firm at the following rates:—Rolled and cast cobalt anodes, 16s. per lb.; single cobalt salts, 5s. 6d. per lb.; double cobalt salts, 4s. 6d. per lb.

Characteristics of Cobalt.—Believing that this metal is destined to take an important position in the art of electro-deposition at no distant period, a few remarks upon its history, and the advantages which it presents as a coating for other metals, may not be unwelcome. Cobalt, like its mineral associate, nickel,* was regarded by the old German copper miners with a feeling somewhat akin to horror, since its ore, not being understood, frequently led them astray when searching for copper. Brande says, "The word *cobalt* seems to be derived from *Cobalus*, which was the name of a spirit that, according to the superstitious notions of the times, haunted mines, destroyed the labours of the miners, and often gave them a great deal of unnecessary trouble. The miners probably gave this name to the mineral out of joke, because it thwarted them as much as the supposed spirit, by exciting false hopes, and rendering their labour often fruitless; for as it was not known at first to what use the mineral could be applied, it was thrown aside as useless. It was once customary in Germany to introduce into the church service a prayer that God would preserve miners and their works from *kobalts* and *spirits*. Mathesius, in his tenth sermon, where he speaks of *cadmia fossilis* (probably cobalt ore) says, 'Ye miners call it *cobalt:* the Germans call it the black devil, and the old devil's hags, old and black *kobel*, which by their witchcraft do injury to people and to their cattle.'"

In chemical works cobalt is generally described as a reddish-grey metal, and this fairly represents the tone of its colour, though a *warm steel grey* would perhaps be a more appropriate term. When deposited by electrolysis under favourable conditions, however, cobalt is somewhat whiter than nickel, but it acquires a warmer tone after being exposed to the air for some time. Becquerel states that cobalt, deposited from a solution of its chloride, "has a brilliant white colour, rather like that of iron;" while Gaiffe says that, when deposited from a solution of the double sulphate of cobalt and ammonium, it is "superior to nickel, both in hardness, tenacity, and beauty of colour." Wahl remarks, "The electro-deposits of this metal which we have seen equal, if indeed they do not surpass, those of nickel in whiteness and brilliancy of lustre." Much of the beauty of electro-deposited cobalt depends, not only upon the electrolyte employed, but also upon the quality of the current, as is also the case with nickel, and indeed most other metals and their alloys.

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* Nickel was called, by the old German miners, *kupfernickel*, or "false copper."

According to Deville, cobalt is one of the most ductile and tenacious of metals, its tenacity being almost double that of iron. It is fused with great difficulty, but more readily when combined with a little carbon, in which respect, as in many other characteristics, it bears a close resemblance to its mineralogical associate, nickel. It is soluble in sulphuric and hydrochloric acids, but more freely in nitric acid.

Cobalt Solutions.—The salts most suitable for making up cobalt baths are:—1. *Chloride of cobalt*, rendered neutral by ammonia or potash; 2. the *double chloride of cobalt and ammonium*; and 3, the *double sulphate of cobalt and ammonium.*

Chloride of Cobalt.—The single salt (chloride) may be prepared by dissolving metallic cobalt or its oxides (the latter being the most readily soluble) in hydrochloric acid, and evaporating the solution to dryness. The residuum is then heated to redness in a covered crucible, when a substance of a bright blue colour is obtained, which is pure chloride of cobalt. When this *anhydrous* (that is without water) chloride of cobalt is dissolved in water it forms a pink solution, which, by careful evaporation, will yield crystals of a beautiful red colour. This is *hydrated* chloride of cobalt, from which various cobalt baths may be prepared according to the directions given below.

Becquerel's Solution.—This is formed by neutralising a concentrated solution of the chloride of cobalt by the addition of ammonia or caustic potash, and adding water in the proportion of 1 gallon to 5 ounces of the salt. The bath is worked with a very weak current, and the deposit is in coherent nodules, or in uniform layers, according to the strength of the current. The deposited metal is brilliantly white, hard, and brittle, and may be obtained in cylinders, bars, and medals, by using proper moulds to receive it. The deposited rods are magnetic,* and possess polarity. If an anode of cobalt be used, the solution is of a permanent character. A portion of the chlorine is disengaged during the electro-deposition, and if iron be present in the solution, the greater portion of it is not deposited with the cobalt.

Beardslee's Solution.—The following has been recommended by Mr. G. W. Beardslee, of Brooklyn, New York, and is stated to yield a good deposit of cobalt, which is "very white, exceedingly hard, and tenaciously adherent." Dissolve pure cobalt in boiling muriatic acid, and evaporate the solution thus obtained to dryness. Next dissolve from 4 to 6 ounces of the resulting salt in 1 gallon of distilled water, to which add liquid ammonia until it turns red litmus paper blue. The solution, being thus rendered slightly alkaline, is ready for use. Battery power of from two to five Smee cells will be sufficient to do good work. Care must be taken not to allow the solution

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* Faraday says that perfectly pure cobalt is not magnetic.

to lose its slightly alkaline condition, upon which the whiteness, uniformity of deposit, and its adhesion to the work greatly depend.

Boettger's Solution.—Boettger states that from the following solution a brilliant deposit of metallic cobalt was obtained by means of a current from two Bunsen cells.

Chloride of cobalt	40 parts.
Sal-ammoniac	20 „
Liquid ammonia	20 „
Water	100 „

By another formula it is recommended to dissolve five ounces of dry chloride of cobalt in one gallon of distilled water, and make the solution slightly alkaline by means of liquid ammonia. A current from three to five Smee cells is employed, with an anode of cobalt. The solution must be kept slightly alkaline by the addition of liquid ammonia whenever it exhibits an acid reaction upon litmus paper. Since these solutions are liable to become acid in working, it is a good plan to keep a strip of litmus paper floating in the bath, so that any change of colour from blue to red may be noticed before the altered condition of the bath has time to impair the colour and character of the deposited metal; if some such precaution be not adopted, the deposit may assume a black colour and necessitate the rescouring of the work.

Double Sulphate of Cobalt and Ammonia.—Cobalt is freely deposited from a solution of the double salt, of a fine white colour, provided that an excess of ammonia be present in the bath. From four to six ounces of the double salt may be used for each gallon of water in making up a bath, according to the strength of current employed. The solution of this salt and that of the double chloride more readily yield up their metal than the corresponding salts of nickel, therefore a proportionately smaller quantity of the metallic salts are required to make up a cobalting bath.

Electro-deposition of Palladium.—This metal may be deposited more freely from its solution than platinum; it is dissolved in *aqua regia* and treated in the same way as the latter metal, and the dry salt dissolved in distilled water. The palladium is then precipitated by means of a solution of cyanide of potassium, and the precipitate redissolved by an excess of the same solution. Since a palladium anode becomes dissolved in the cyanide bath, deposits of any required thickness may be obtained. This metal may also be deposited from a solution of the ammonio-chloride, using a palladium anode, and a scurrent from two or three Smee cells. M. Bertrand advises a neutral olution of the double chloride of palladium and ammonium for the electro-deposition of this metal either with or without the use of a voltaic battery. The deposition of palladium is, however, more interesting as a fact than of any practical use.

Deposition of Bismuth.—This metal may be dissolved in dilute nitric acid (2 parts acid to 1 part water) with moderate heat, and the solution evaporated and allowed to crystallise. The resulting salt is known as *acid nitrate of bismuth*, which may be dissolved in a very small quantity of distilled water; but if the solution, even when acid, be poured into a large quantity of water it becomes decomposed, and forms a white, somewhat crystalline precipitate, commonly called *subnitrate of bismuth*, *basic nitrate*, or *pearl white*. If strong nitric acid be poured upon powdered bismuth the chemical action is intensely violent, and sometimes attended by ignition. *Chloride of bismuth* is formed by dissolving the metal in 4 parts of hydrochloric acid and 1 part nitric, by measure. The excess acid is afterwards expelled by evaporation.

To deposit bismuth upon articles of tin by simple immersion, Commaille employs a solution formed by dissolving 10 grains of nitrate of bismuth in a wineglassful of distilled water, to which two drops of nitric acid have been added. After the article is immersed the bismuth will be deposited in very small shiny plates. The metal may also be deposited from this solution by means of the separate battery. The deposited metal is said to be explosive when struck by a hard substance.

Bismuth may be deposited from a cyanide solution, but since the anode is not freely acted upon by the cyanide the solution soon becomes exhausted. M. A. Bertrand states that bismuth may be deposited upon copper or brass from a solution consisting of 30 grammes of the double chloride of bismuth and ammonium, dissolved in a litre of water, and slightly acidulated with hydrochloric acid. A current from a single Bunsen cell should be used.

Deposition of Antimony.—Chloride of antimony, terchloride of antimony, or, as the ancients termed it, *butter of antimony*, is thus prepared, according to the pharmacopœias: 1 lb. of prepared sulphuret of antimony is dissolved in commercial muriatic acid, 4 pints, by the aid of gentle heat, gradually increased to ebullition. The liquid is filtered until quite clear, then boiled down in another vessel to 2 pints; it is then cooled, and preserved in a well-stoppered bottle. The solution has a specific gravity of 1·490. It is highly caustic.

A solution of chloride of antimony may also be prepared by the electrolytic method, that is by passing a moderately strong current through an anode of antimony, immersed in hydrochloric acid, employing a plate of carbon as the cathode, the action being kept up until a strip of clean brass, being substituted for the carbon plate, promptly receives a coating of antimony.

Another solution may be prepared by digesting recently precipitated teroxide of antimony in concentrated hydrochloric acid, and then adding an excess of free acid to the solution thus obtained. This solution yields a very quick and brilliant deposit of antimony upon brass or copper surfaces with a current from three small Daniell's cells, arranged in series, with electrodes of about equal surface. The fresh teroxide may be readily formed thus: Dissolve 4 ounces of finely powdered tersulphuret of antimony in 1 pint of muriatic acid, by the aid of gentle heat, by which a solution of terchloride of antimony is obtained; filter the liquid, and then pour it into 5 pints of distilled water. By this dilution a greater part of the terchloride is decomposed, the chlorine unites with the hydrogen of the water, forming hydrochloric acid, and the oxygen of the water, being set free, unites with the antimony, forming a teroxide, that is, an oxide containing three equivalents of oxygen. The teroxide thus obtained is separated by filtration, and washed, to free it from acid. It is then washed with a weak solution of carbonate of soda, which decomposes any terchloride present, leaving the teroxide free. It is then dried over a water bath, and preserved in a well-stoppered bottle.

Antimony may also be deposited from a solution prepared by dissolving oxychloride of antimony in strong hydrochloric acid, the latter being in excess. The oxychloride may be obtained by largely diluting with water a solution of the chloride of antimony, when a white precipitate falls, which is insoluble in water. The liquor is now to be poured off, and hydrochloric acid added until the precipitate is entirely dissolved. The resulting solution, which must not be diluted with water—which decomposes it—should be used with a moderate current and rather small anode surface, and the articles to be coated in it must be perfectly dry, and when the required deposit is obtained the article should be dipped in a strong solution of hydrochloric acid before being rinsed in water, otherwise a white insoluble film of oxychloride will form on the surface.

A depositing bath may also be formed by mixing equal parts, by measure, of a solution of commercial chloride of antimony and salammoniac. The solution thus formed is a very good conductor, deposits freely a good reguline metal, and is not so liable to yield deposits upon the baser metals by simple immersion as the former solution.

A very good antimony bath may be made by dissolving tartar emetic (potassio-tartrate of antimony) in 2 parts hydrochloric acid and 1 part water, by measure; or, say, tartar emetic 8 lbs., hydrochloric acid 4 lbs., and water 2 lbs., a larger proportion of water being added if desired. The resulting solution forms a very good bath for the deposition of antimony, and yields up its metal very freely. With the current from two to three Daniells the metal is deposited very quickly, and in a good reguline condition. To insure the adherence of the deposit, however, the anode surface should at first be small, until a film of moderate thickness has been obtained, after which it may be gradually increased until both electrodes are of about equal surface. The above solution is not affected by atmospheric influence nor by continual working, and would be very useful for small operations for producing thick deposits of antimony; but the cost of the mixture would preclude its adoption for any but purely experimental purposes.

Deposition by Simple Immersion.—The acid solution of chloride of antimony readily yields up its metal to brass by simple immersion, and by this means brass articles are coloured of a lilac tint. A solution is made for this purpose by adding a large quantity of water to a small quantity of chloride of antimony, when a dense white precipitate of oxychloride of antimony is formed. The mixture is boiled until this is nearly redissolved, when more water is added, and the boiling resumed. The liquor is then filtered, and the clear liquor heated to boiling; into this the cleaned brass articles are placed, when they at once receive a coating of antimony of a lilac colour, being kept in the boiling solution until the desired shade of colour is obtained. After rinsing in clean water, the articles are dried in hot sawdust, then brushed clean and lacquered.

Commercial chloride of antimony (butter of antimony) is also used for bronzing or *browning* gun-barrels, and when used for this purpose it is known as *bronzing salt.* To apply it for bronzing gun-barrels the chloride is mixed with olive-oil, and rubbed upon the barrel, slightly heated; this is afterwards exposed to the air until the requisite tone is obtained; a little aquafortis is rubbed on after the antimony to hasten the operation. The browned barrel is then carefully cleaned, washed with water, dried, and finally burnished or lacquered.

When a piece of clean zinc is immersed in a solution of chloride of antimony the metal becomes reduced to a fine grey powder, which is employed to give the appearance of grey cast-iron to plaster of Paris casts.

Deposition of Lead.—This metal is readily reduced from a solution of its nitrate or acetate—as exemplified in the production of the well-known *lead-tree;* it may also be deposited upon zinc or tin from a solution formed by dissolving litharge (oxide of lead) in a solution of caustic potash. Iron articles will become coated, by simple immersion, in a solution of sugar of lead (acetate of lead). Becquerel * deposited lead upon a bright, cleaned surface of copper, in contact with a piece of zinc, in a solution of chloride of lead and sodium. This metal may

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* "The Chemist," vol. v. p. 408.

also be deposited, by means of the battery, from dilute solutions of acetate or nitrate of lead, or from a solution formed by saturating a boiling solution of caustic potash with litharge, employing a lead anode. The deposition of this metal is not, however, of any commercial importance. The electrolysis of salts of lead under certain conditions are, however, exceedingly interesting in what is termed *metallochromy*, as will be seen below.

Metallo-Chromes.—A remarkably beautiful effect of electro-chemical decomposition is produced under the following conditions: A concentrated solution of acetate of lead (sugar of lead) is first made, and after being filtered is poured into a shallow porcelain dish. A plate of polished steel is now immersed in the solution, and allowed to rest on the bottom of the dish (see Fig. 120). A small disc of sheet copper is then to be connected to the wire proceeding from the zinc element of a constant battery of two or three cells, and the wire connected to the copper element is to be placed in contact with the steel plate. If now the copper disc be brought as close to the steel plate as possible, without touching it, in a few moments a series of beautiful prismatic colorations will appear upon the steel surface, when the plate should be removed, and rinsed in clean water. These colorations are films of lead in the state of peroxide, and the varied hues are due to the difference in thickness of the precipitated peroxide of lead, the light being reflected through them from the polished metallic surface beneath. By reflected light, every prismatic colour is visible, and by transmitted light a series of prismatic colours complementary to the first series will appear, occupying the place of the former series. The colours are seen to the greatest perfection by placing the plate before a window with its back to the light, and holding a piece of white paper at such an angle as to be reflected upon its surface. The colorations are not of a fugitive character, but will bear a considerable amount of friction without being removed. In proof of the lead

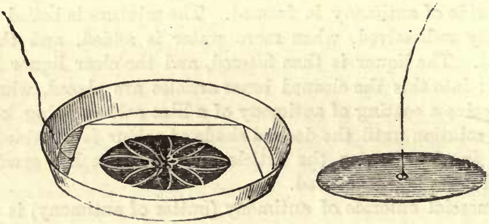

Fig. 120.

oxide being deposited in films or layers, if the deposit be allowed to proceed a few seconds beyond the time when its greatest beauties are exhibited, the coloration will be less marked, and become more or less red, green, or brown. If well rubbed when dry with the finger or fleshy part of the hand a rich blue-coloured film will be laid bare, by the removal of the delicate film above it.

The discovery of this interesting electrolytic phenomenon is due to Nobili, who in the year 1826 discovered that when a solution of acetate of lead was electrolysed by means of a current from four to six Grove cells, a large platinum anode and a platinum wire cathode being employed, prismatic colours were produced upon the anode surface; and when the platinum anode was placed horizontally in the acetate solution and the negative wire held vertically above it, a series of rings in chromatic order were produced. These effects subsequently took the name of "Nobili's rings," and the interesting discovery induced Becquerel, Gassiot, and others to experiment in the same direction by varying the strength of the current and employing other solutions than the acetate of lead.

Becquerel's Solution.—The following formula was suggested by Becquerel:* Dissolve 200 grammes of caustic potash in 2 quarts of distilled water, add 150 grammes of litharge, boil the mixture for half an hour, and allow to settle. Then pour off the clear liquor, and dilute it with its own bulk of water.

The plan recommended by Mr. Gassiot to obtain the *metallo-chromes* is to place over the steel plate a piece of card, cut into some regular device, as shown in the illustration, and over this a rim of wood, the copper disc being placed above this. We have found that very beautiful effects are obtained when a piece of fine copper wire is turned up in the form of a ring, star, cross, or other pattern, and connected to the positive electrode as before; indeed, this is one of the simplest and readiest methods of obtaining the colorations upon the polished metal. A few examples of metallo-chromes obtained in this way are shown in the frontispiece of this work. Metallo-chromy, as it is termed, is extensively employed in Nuremberg to ornament metallic toys, the solution used being that suggested by Becquerel, namely, a solution of the oxide of lead in caustic soda or potash. Metallo-chromy has also been adopted in France for colouring bells, and in Switzerland for colouring the hands and dials of watches. In using the lead solutions to produce metallo-chromes it must be remembered that metallic lead becomes deposited upon the cathode, consequently the solutions in time become exhausted, and must therefore be renewed by the addition of the lead salt.

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* "The Chemist," vol. iv. p. 457.

Metallo-chromes on Nickel-plated Surfaces.—It will be obvious that if metallo-chromy were only applicable to platinum or steel surfaces—which has generally been the case heretofore—that the usefulness of the process as a means of ornamentation for industrial purposes would be greatly restricted. While the production of these colorations upon platinum foil would only be effected for experimental purposes, the application of the process to steel surfaces would necessarily be of a limited character, owing to the unsuitableness of this metal as compared with brass, German silver, and copper, for the manufacture of many articles of utility or ornament. With a view to extend the usefulness of these very beautiful colorations, and thus, to a certain extent, open up a new field for their application, the author some time since turned his attention to polished nickel-plated surfaces, as being, of all others, the most suitable, from their extreme brilliancy, to exhibit the rainbow tints of metallo-chromy. His first experiments were upon highly-polished surfaces of nickel-plated brass, and the results obtained were exceedingly satisfactory. The experiments were subsequently pursued under varied conditions of working, until the most satisfactory method of procedure was arrived at. A few of these results, obtained upon nickel-plated brass, are illustrated in the frontispiece to the present work; but the reader is referred to the Appendix for a detailed description of the method adopted to produce these colorations upon nickel-plated surfaces, and for some particulars as to salts of lead applicable to the purpose.

Deposition of Aluminum or Aluminium.—This remarkable metal, which in an oxidised state (alumina) occurs most abundantly in nature as a constituent of all clays in combination with silica, was first obtained in the metallic state by Wohler in the following way: Chloride of aluminium and pure potassium are heated in a small platinum or porcelain crucible, the heat of a spirit-lamp being sufficient, for when the substances begin to react upon each other the temperature suddenly rises to redness. When the crucible is cold, its contents are well washed with cold water, by which a finely divided grey substance with a metallic lustre is obtained, which is pure aluminium. About the year 1854, Sainte-Claire Deville, of Paris, devoted his attention to this subject, substituting chloride of sodium for potassium, and heating the chloride of aluminium with this salt in a porcelain crucible to bright redness,* by which the excess of chloride of aluminium was disengaged, and in the middle of the resulting saline mass larger or smaller globules of perfectly pure aluminium were found. In reference to the characteristics of this metal, Deville says:

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* "The Chemist." Edited by John and Charles Watt. Vol. i., new series, 1854.

—"It is completely unalterable, either in dry or humid air; it does not tarnish; and remains brilliant where freshly-cut zinc or tin lose their polish. Sulphuretted hydrogen has no action upon it; neither cold nor boiling water will tarnish it; nitric acid, whether weak or concentrated, or sulphuric acid employed cold, will take no effect upon it. Its real solvent is hydrochloric acid. . . . It will be easily understood that a metal as white [?] and as unalterable as silver, which does not tarnish in the air, which is fusible, malleable, ductile, and yet tough, and which has the singular property of being lighter than glass, would be most useful if it could be obtained. If we consider, besides, that this metal exists in considerable proportions in nature, that its ore is argil [clay], we may well desire that it should become of general use. I have much hope that it may be so, for chloride of aluminium is decomposed with remarkable facility by common metals at a high temperature, and a reaction of this nature, which I am now endeavouring to realise on a larger scale than a mere laboratory experiment, will decide this question in a practical point of view."

Not long after the above announcement was made, Sainte-Claire Deville, supported in the practical development of his ingenious process by the late Emperor of the French, succeeded in producing aluminium in abundance, and bars of this useful metal entered the market as a commercial product to the great surprise and delight, not only of scientists, but of those workers in metals who know how to appreciate the importance of a metal possessing such remarkable characteristics as aluminium. We all know now what an important position it has taken in the arts; but its usefulness may yet receive further development, it is hoped, by some successful process of electro-deposition. That point, however, has not yet been fully reached, although the metal has been deposited with sufficient success to warrant the belief that still more satisfactory results will be obtained by a further investigation of the subject.

Speaking upon the separation of aluminium by electrolysis, Deville observes:*—"It appeared to me impossible to obtain aluminium by the battery in aqueous liquids. I should believe this to be an impossibility if the brilliant experiments of M. Bunsen on the production of barium did not shake my conviction. Still, I must say that all processes of this description which have recently been published for the preparation of aluminium have failed to give me good results. It is of the double chloride of aluminium and sodium, of which I have already spoken, that this decomposition is effected. The bath is composed of 2 parts by weight of chloride of aluminium, with the addition of 1 part of dry and pulverised common salt. The whole is

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* "The Chemist," new series, vol. ii. p. 12, 1855.

mixed in a porcelain crucible, heated to about 392° Fahr. The combination is effected with disengagement of heat, and a liquid is obtained which is very fluid at 392° Fahr., and fixes at that temperature. It is introduced into a vessel of glazed porcelain, which is to be kept at a temperature of about 392° Fahr. The cathode is a plate of platinum, on which the aluminium (mixed with common salt) is deposited in the form of a greyish crust. The anode is formed of a cylinder of charcoal, placed in a perfectly dry porous vessel, containing melted chloride of aluminium and sodium. The densest charcoal rapidly disintegrates in the bath and becomes pulverulent; hence the necessity of a porous vessel. The chlorine is thus removed, with a little chloride of aluminium, proceeding from the decomposition of the double salt. This chloride would volatilise and be entirely lost, if some common salt were not in the porous vessel. The double chloride becomes fixed, and the vapours cease. A small number of voltaic elements (two are all that are absolutely necessary) will suffice for the decomposition of the double chloride, which presents but little resistance to the electricity. The platinum plate is removed when it is sufficiently charged with the metallic deposit. It is suffered to cool, the saline mass is rapidly broken off, and the plate replaced."

Bunsen electrolysed the fused chloride of aluminium and sodium in a deep covered porcelain crucible, divided by a partition of porous porcelain, which extended half-way down the vessel. Carbon electrodes were used, and these were introduced through openings in the cover. He used a current from ten cells of his zinc and carbon battery. The salt fused at 662° Fahr. (the boiling point of mercury), and readily yielded the metal. The temperature of the liquid should then be raised to nearly the melting point of silver, when the particles of the liberated aluminium fuse, uniting together into globules, which, being heavier than the fused salt, fall to the bottom of the crucible.

Corbelli has deposited aluminium by electrolysing a mixed solution of rock alum (sulphate of alumina) and chloride of sodium or calcium with an anode of iron wire, coated with an insulating material, and dipping into mercury deposited at the bottom of the solution; a zinc cathode is immersed in the solution. Aluminium deposits upon the zinc, and the chlorine set free at the anode unites with the mercury, forming chloride of mercury (calomel).

Thomas and Tilley's Process, for which a patent was obtained in 1854, consists in forming a solution composed of freshly precipitated alumina dissolved in a boiling solution of cyanide of potassium. By another process, patented in 1855, calcined alum is dissolved in a solution of cyanide of potassium. Several other solutions are included in the same specification, and the invention includes the deposition of alloys of aluminium with silver, silver and copper with tin, silver and tin, &c.

Jeancon's Process (American) consists in depositing aluminium from a solution of a double salt of aluminium and potassium, of the specific gravity 1·161, employing a current from three Bunsen cells, the bath being worked at 140° Fahr.

M. Bertrand states that he has deposited aluminium upon a plate of copper in a solution of the double chloride of aluminium and ammonium by using a strong current, the deposit being susceptible of a brilliant polish.

Goze's Process.—Mr. Goze obtained a deposit of aluminium by the single cell method from a dilute solution of the chloride. The liquid was placed in a jar, in which was immersed a porous cell containing dilute sulphuric acid; an amalgamated zinc plate was immersed in the acid solution, and a plate of copper in the chloride solution, the two metals being connected by a copper conducting wire. At the end of some hours the copper plate became coated with a lead-coloured deposit of aluminium, which, when burnished, presented the same degree of whiteness as platinum, and did not appear to tarnish readily when immersed in cold water, or in the atmosphere, but was acted upon by dilute sulphuric and nitric acids.

Deposition of Cadmium.—This metal is readily soluble in dilute nitric, sulphuric, and hydrochloric acids, with disengagement of hydrogen, and the respective salts may be obtained in the crystalline form by concentrating the acid solutions by evaporation. The *hydrated oxide*, in the form of a gelatinous precipitate, is produced when a solution of the alkalies, soda, potassa, &c., is added to a solution of a salt of cadmium. The hydrate is white, but becomes brown from loss of water when dried by heat. Respecting the electro-deposition of cadmium, Smee states that it is difficult to obtain firm, coherent deposits from solutions of the chloride or sulphate, but that it may be easily deposited in a reguline and flexible condition from a solution of the ammonio-sulphate, prepared by adding sufficient liquid ammonia to sulphate of cadmium to redissolve the precipitate at first formed. Napier recommends the following: "A solution of cadmium is easily prepared by dissolving the metal in weak nitric acid, and precipitating it with carbonate of soda, washing the precipitate, and then dissolving it in cyanide of potassium. A battery power of three or four pairs is required, and the solution should be heated to at least 100° Fahr. The metal is white, and resembles tin; it is very soft, and does not present many advantages to the electro-metallurgist."

Russell and Woolrich's Process.—This process, for which a patent was obtained in 1849, is thus briefly described: "Take cadmium, and dissolve it in nitric acid diluted with five or six times its bulk of water, at a temperature of about 80° or 100° Fahr., adding the dilute acid by degrees until the metal is all dissolved; to this solution of cadmium one of carbonate of sodium (made by dissolving 1 lb. of crystals of washing soda in 1 gallon of water) is added until the cadmium is all precipitated; the precipitate thus obtained is washed four or five times with tepid water. Next add as much of a solution of cyanide of potassium as will dissolve the precipitate, after which one-tenth more of the solution of the potassium salt is added to form free cyanide. The strength of this mixture may vary; but the patentees prefer a solution containing six troy ounces of metal to the gallon. The liquid is worked at about 100° Fahr., with a plate of cadmium as an anode."

For depositing cadmium M. A. Bertrand recommends a solution of the bromide of cadmium, containing a little sulphuric acid, or a solution of sulphate of cadmium. He states that the deposit obtained is white, adheres firmly, is very coherent, and is capable of receiving a fine polish.

Deposition of Chromium.—In his investigation concerning the electrolysis of metallic salts Bunsen determined the causes which most influence the separation of the metal; these causes are two in number, the principal of which is owing to the *density* of the current, and the other to the greater or less concentration of the electrolyte. By density he means the concentration to a single point of "the electrical undulations, in a manner analogous to the concentration of luminous or calorific rays in the focus of a concave mirror. Let us take, for example, a charcoal crucible in communication with the positive pole of the battery, and place in it a small capsule of glazed porcelain, containing the liquid to be decomposed; the space between the crucible and the capsule is filled with hydrochloric acid, and the liquid of the small capsule is put in communication with the battery by means of a thin sheet or wire of platinum.* The current is then established between a large surface, the charcoal crucible, and a fine platinum wire, in which it is concentrated; the effects are added in this direction, and the fluid becomes capable of overcoming affinities which have hitherto resisted powerful batteries." The apparatus just described is placed in a porcelain crucible, which is kept warm in a sand bath.

By the above arrangement Bunsen succeeded in separating chromium with perfect facility from a concentrated solution of its chloride; the deposited metal, which was chemically pure, presented the appearance of iron, but was less alterable in moist air. It resisted

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* For this purpose the platinum wire must be exactly in the centre of the crucible; if not, by virtue of its tendency to take the shortest road, the current is established in preference between the nearest points.

the action of even boiling nitric acid, but was acted upon by hydrochloric acid and dilute sulphuric acid. Bunsen found that when the current was diminished, the metal ceased to be deposited in the metallic state, but appeared as a black powder consisting of protoxide and sesquioxide of chromium.*

Deposition of Manganium, or Manganese.—The same eminent chemist succeeded in obtaining metallic manganese by the method above described from a concentrated aqueous solution of chloride of manganese. The metal was separated with the greatest facility with a powerful current, but when the current was weakened black oxide of manganese was obtained.

Deposition of Magnesium.—Bunsen electrolysed fused chloride of magnesium at a red heat by the same method as that adopted for the separation of aluminium. Manganese, being a very light metal, is liable to rise to the surface of the fused mixture and ignite in the air; to prevent this, as far as possible, the carbon cathode was notched, so that the metal could collect in the notches. M. Bertrand says that from an aqueous solution of the double chloride of magnesium and ammonium, a strong current will deposit magnesium upon a sheet of copper in a few minutes, the deposit being homogeneous, strongly adherent, and easily polished.

Deposition of Silicon.—Mr. Goze reduced the metal *silicium* from a solution of monosilicate of potash, prepared by fusing one part of silica with 2¼ parts of carbonate of potash, the same voltaic arrangement being adopted, except that a small pair of Smee batteries were interposed in the circuit. With a very slow and feeble action of the current, the colour of the deposit was much whiter than aluminium, closely approximating that of silver.

We have given the foregoing details concerning the deposition of some of the less tractable metals, more with a view to show what ingenious methods have been devised for their extraction, or separation, than as presenting any absolute practical advantage. As interesting electrolytic facts they are valuable to the student, while to the more practical operator who may devote a portion of his spare time to electrolytic experiments, Chevalier Bunsen's methods of conducting the electrolysis of salts which do not readily yield up their metal from aqueous solutions will prove not only interesting but highly instructive. It will not be in accordance with the object of this work, however, to enter further into the deposition of metals which have no practical significance in the arts.

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* "The Chemist," new series, vol. i. p. 685.

CHAPTER XXVII.

ELECTRO-DEPOSITION OF ALLOYS.

Electro-deposition of Brass and Bronze.—Brassing Solutions.—Brunel, Bisson, and Co.'s Processes.—De Salzede's Processes.—Newton's Processes.—Russell and Woolrich's Process.—Wood's Process.—Morris and Johnson's Process.—Dr. Heeren's Process.—Roseleur's Processes.—Walenn's Processes.—Bacco's Solution.—Winckler's Solution.—American Formulæ for Brassing Solutions.—Thick Brass Deposits.—Brass Solution prepared by Battery Process.

Electro-deposition of Brass and Bronze.—The deposition of two metals in combination by electro-chemical means, although perfectly practical, is far more difficult to accomplish satisfactorily than to deposit a single metal. For example, the two metals zinc and copper are so widely different in all their characteristics—in their melting point, ductility, electric relation, and conductivity—that when in a state of solution great care is necessary to enable us to bring them together in the uniform condition of what is termed an *alloy*. Even when these two metals are alloyed in the ordinary way, by fusion, great care must be exercised, or the zinc, being a *volatilisable* metal, will pass away into the air instead of uniting with the copper to form *brass*. The copper, melting at a far higher temperature than zinc, is fused or melted first, and the zinc gradually added, until the desired object is obtained—a bright yellow alloy, the tone or colour of which may be varied according to the proportion of either metal.

In depositing brass from its solution, the *nature* and strength of the electric current are of the greatest importance, for if the electromotive force be too weak copper only will be deposited, and if too strong zinc alone will be precipitated upon the receiving metal. Again, if too great a surface of anode be exposed in the bath in proportion to the size of the article to be coated zinc alone will deposit, the reverse being the case, that is copper alone, if the surface of anode is too small. A medium between these conditions is absolutely necessary (all other things being equal) to ensure a coating of brass of good colour upon any given article. To make this more clear to the less experienced, we may state, for instance, that a battery composed of the two elements, zinc and copper, as the Wollaston and Daniell batteries, are far less *intense*, that is to say, they possess feebler electromotive force, than Bunsen's battery, with carbon and zinc elements. The latter battery, therefore, is more suited to the electro-deposition of brass, and is indeed preferable to any other. The quality of the deposit is also much influenced by the temperature of the solution and the materials with which it is prepared, some formulæ yielding solutions which are better conductors than others, and consequently offer less resistance to the current.

In making up solutions for the deposition of alloys, as brass, bronze, and German silver, for example, the author prefers to prepare them in what may be termed *the direct way ;* that is to say, instead of forming the depositing solution from a mixture of the metallic salts and their solvents, according to the usual method of preparing such solutions, he first dissolves the metallic alloy in its acid solvent—nitric or nitro-hydrochloric acid (*aqua regia*)—and from the acid solution thus obtained he forms the depositing bath by either of the methods given below. It may be well to remark, however, that in making up a brass bath upon this system, metal of the very best quality should be employed, and the solution should be formed from the identical sample of brass which is to be used as an anode in the depositing tank. The proportions given are for one gallon of solution, but it will be readily understood that, adopting the same proportions of the materials, a bath of any desired quantity can be prepared.

Brassing Solutions.—*No. I.*—Take of

Good sheet brass	1 ounce.
Nitric acid (by measure) about . . .	4 ounces.
Water	2 „

Cut up the sheet brass into strips, and put them carefully into a glass flask, then pour in the water and acid. To accelerate the chemical action the flask should be gently heated over a sand bath, and the fumes must be allowed to escape through the flue of the chimney. When the red fumes, liberated during the decomposition, cease to be visible in the bulb of the flask the chemical action is at an end, provided a portion of undissolved brass remains in the flask. If such be not the case a few fragments of the metal should be put into the flask and the heat continued, when, if red fumes are again given off, the heat should be kept up until the fumes disappear while a portion of undissolved metal still remains in the flask. The reasons for giving these precautionary details are—1, that it is important there should be as little excess of acid as possible in the solution ; and 2, that the strength of commercial nitric acid is very variable, and therefore chemically minute proportions cannot advantageously be given. We may say, moreover, that the *exact* quantity of brass per gallon of solution is of no consequence; if the proportion nearly approaches that given in the formula, it will be quite near enough for all practical purposes. While touching upon this subject we may also state that the active quality of commercial cyanide of potassium also varies greatly; consequently it may be necessary to apply either more or less than the quantity specified below, according to the quality of the article that may fall into the hands of the user. Upon this subject we shall, however, say more hereafter.

The acid solution of brass must next be poured into a vessel of sufficient capacity, and diluted with about three or four times its bulk of water. Then add liquid ammonia (specific gravity ·880°), gradually to the green solution of the metals, stirring with a glass rod, when a pale green precipitate will be formed, which will afterwards become dissolved by adding an excess of ammonia, forming a beautiful deep blue solution. This solution should become perfectly clear when the necessary quantity of ammonia has been added, but if such be not the case, a little more must be added, with brisk stirring, until the precipitate is quite dissolved and a clear solution obtained. The exact quantity of ammonia required will depend upon the amount of free acid remaining in the metallic solution first prepared. A moderately strong solution of cyanide must now be added to the blue solution, with constant stirring, until the blue colour entirely disappears. When sufficient cyanide has been added to destroy the blue colour, the solution will acquire a pinkish tinge, and on the application of a little more cyanide solution this will in its turn disappear, and the liquid will assume a yellowish tint, when a moderate excess of the cyanide must be given as "free cyanide," and the solution then made up to the full quantity (one gallon) by the addition of water. The solution should then be set aside to rest for a few hours, when the clear liquor may be poured into the depositing vessel. The last portion of the liquor should be passed through a filter, to separate any impurities (chiefly derived from the cyanide) which may be present. If convenient, the entire bulk of the solution may be filtered, which is in all cases preferable. A brassing bath always works most satisfactorily if not used for at least twenty-four hours after being prepared, although it may, if required, be used directly after being filtered. If to be used hot, the solution may be further diluted.

Solution II.—One ounce of brass being dissolved as before, the solution is to be diluted with about three pints of cold water; a solution of carbonate of potash (about half-a-pound to a quart of water) is to be gradually added, with frequent stirring, until no further precipitation takes place. The precipitate formed should next be put into a filter of unbleached calico stretched over a wooden frame, and when the liquor has ceased to drain from it, hot water should be poured on to the mass, which must be stirred with a wooden spoon, or flat strip of wood, so as to assist the *washing* of the precipitate with the water. When the precipitate is thoroughly drained, it is to be transferred to a convenient vessel, and redissolved by liquid ammonia, which is to be added gradually, and constantly stirred in until the whole is dissolved, and a dark blue solution formed. After reposing for a few minutes, the clear liquor may be poured off, and should any undissolved green precipitate remain at the bottom of the vessel, ammonia must be added to this until dissolved, when the resulting blue liquor is to be added to the bulk. A strong solution of cyanide is now to be added to the blue liquor, until its characteristic colour has entirely disappeared, after which a moderate excess of the cyanide solution is to be added, and the solution then made up to 1 gallon (according to the proportion of metal dissolved) with cold water. The repose or filtration as before should be again resorted to.

Solution III.—

Acetate of copper	5 ounces.
Sulphate of zinc	10 "
Caustic potash	4½ lbs.
Liquid ammonia	1 quart.
Cyanide of potassium	8 ounces.

The acetate of copper should be first powdered, and then dissolved in about 2 quarts of water. To this add one-half of the ammonia (1 pint). Now dissolve the sulphate of zinc in 1 gallon of water at a temperature of 180° Fahr.; to this add the remaining pint of the ammonia, constantly stirring while the liquid is being added. The potash is next to be dissolved in 1 gallon of water, and the cyanide in 1 gallon of hot water, after which the several solutions are to be mixed as follows: The solutions of copper and zinc are to be first mixed, the solution of potash then added, and lastly the cyanide. The whole must now be well stirred, and then allowed to repose for a short time, when the agitation may be resumed and repeated at intervals during a couple of hours or so. Water, to make up 8 gallons in all, is now to be added, and the solution then allowed to rest for a few hours, when the clear liquor is to be decanted into the bath. This solution should be worked with a strong current, with additions of liquid ammonia and cyanide from time to time when the anode becomes foul. It is important in working this, as in all other brassing solutions, that the anode should be kept clean, a condition which is not possible with these solutions unless there be an excess of the solvents, cyanide and ammonia.

Brunel, Bisson, & Co.'s Processes.—1. The brassing solution is formed from the following ingredients, which should each be dissolved in separate vessels:—

Carbonate of potassa (salt of tartar) . .	10 pounds.
Cyanide of potassium	1½ pound.
Sulphate of zinc	1¼ "
Chloride of copper	10 ounces.
Water	12½ gallons.

A sufficient quantity of the potash solution is to be added to the sulphate of zinc and chloride of copper solutions to precipitate all the metal in the form of *carbonates*. Liquid ammonia (specific gravity ·880°) is now to be poured into each vessel, being well stirred in to dissolve the respective precipitates, when the solutions are to be added to the cyanide solution; the remainder of the potash solution is next to be added, and the whole well stirred; water is then to be added to make up a bath of 12½ gallons. The solution is to be worked with two or more Bunsen batteries, with a large brass anode. As before recommended, the solution should not be worked until some hours after being made, and the clear liquid must be decanted, so as to separate it from any sedimentary matter that may be present from impurities in the cyanide or otherwise. After using the bath for some time, it will require moderate additions of cyanide and liquid ammonia, to keep the anode free from the white salt of zinc which forms upon its surface when the excess of these substances has become exhausted. In adding fresh cyanide, a portion of the solution may be taken out of the bath with a jug, and a few lumps of cyanide (say half a pound) added, and as this becomes partially dissolved, the liquid is to be added to the bath, and the jug again filled with the solution as before; in this way the bath may be strengthened with cyanide without employing water to dissolve it. In warm weather, however, when the bath loses water by evaporation, the cyanide may be dissolved in water before adding it to the bath. When either liquid ammonia or cyanide are to be added to the solution, this may be conveniently done overnight, and the bath well stirred, when by the following morning the disturbed sediment, which always accumulates at the bottom of depositing vessels, will have had time to settle.

Solution 2.—This is prepared from the following ingredients:—

Sulphate of zinc	2 pounds.
Chloride of copper	1 pound.
Carbonate of potassa	25 pounds.
Nitrate of ammonia	12½ "

The chloride of copper is to be dissolved in half a gallon of water, the carbonate of potash in 6 gallons of water, and the sulphate of zinc in half a gallon of hot water. These three solutions are now to be mixed, and the nitrate of ammonia added, when the whole are to be well united by stirring. Sufficient water is next to be added to make up about 20 gallons of solution, which must be allowed to rest for some hours before using it. After working this solution for some time it will be necessary to add moderate quantities of liquid ammonia and cyanide of potassium, otherwise the anode will become foul and thus incapable of becoming dissolved in the solution.

De Salzede's Processes.—1. This is prepared from the following formula:—

Cyanide of potassium	12 parts.
Carbonate of potassa	610 „
Sulphate of zinc	48 „
Chloride of copper	25 „
Nitrate of ammonia	305 „
Water	5000 „

The cyanide is to be dissolved in 120 parts of the water, and the carbonate of potash, sulphate of zinc, and chloride of copper are next to be dissolved in the remainder of the water, the temperature of which is to be raised to about 150° Fahr. When the salts are well dissolved, the nitrate of ammonia is to be added, and the mixture well stirred until the latter is all dissolved. The solution should be allowed to stand for several days before using, and the clear liquor separated from any sediment that may have deposited at the bottom of the vessel.

Solution 2.—

Cyanide of potassium	50 parts.
Carbonate of potassa	500 „
Sulphate of zinc	35 „
Chloride of copper	15 „
Water	5000 „

This solution is to be made up in the same way as No. 1.

Solution 3. *Bronzing Solution.*—This solution is the same as No. 1, except that 25 parts of *chloride of tin* are substituted for the sulphate of zinc.

Solution 4. *Bronzing Solution.*—This solution is the same as No. 2, with the exception that 12 parts of *chloride of tin* are substituted for the sulphate of zinc. This solution is worked warm, that is, at about 97° Fahr.

Newton's Processes consist in forming solutions for depositing brass or bronze. He mixes chloride of zinc with the chloride of ammonium (sal-ammoniac), chloride of sodium (common salt), or chloride of potassium, dissolved in water. Or he makes a mixture of acetate of zinc dissolved in water and acetate of ammonia, soda, or potassa. In making up a *brassing* solution, Newton adds to either of the above solutions a proportion of the corresponding salt of copper: for example, with the acetate of zinc he would unite acetate of copper, and so on. In making a *bronzing* solution, he dissolves the double tartrate of copper and potassa, and double tartrate of the protoxide of tin and potassa. He deposits an alloy of zinc, tin, and copper by employing a solution composed of the following: double cyanide of copper and potassium, "zincate" of potassa, and stannate of potassa. The *zincate of potassa* he forms by fusing oxide of zinc with caustic potassa, and the *stannate* of potassa, either by fusing oxide of tin with caustic potassa, or by dissolving it in a solution of potassa. To form a brassing bath, he also employs a solution consisting of a given quantity of oxide of copper dissolved in an excess of cyanide of potassium; oxide of zinc and a little liquid ammonia are then added, and the solution heated from 120° to 140° Fahr. Water is then added to allow the solution to contain 3 ounces of the metallic oxides to each gallon of the solution, that is, 2 ounces of zinc oxide to 1 ounce of copper oxide, being the proportions to form brass.

Russell and Woolrich's Process.—A solution is made of the following:—

Acetate of copper	10 pounds.
„ zinc	1 pound.
„ potassium	10 pounds.
Water	5 gallons.

The salts are to be dissolved in the water, and as much of a solution of cyanide added as will first precipitate the metals, and afterwards redissolve the precipitate. An excess of cyanide is then to be added, and the solution set aside to settle as before. A brass anode, or one of zinc and another of copper, may be used.

Wood's Process consists in making a solution as follows:—

Cyanide of potassium (troy weight)	1 pound.
„ copper	2 ounces.
„ zinc	1 ounce.
Distilled water	1 gallon.

When the ingredients are dissolved, add 2 ounces of sal-ammoniac. For coating smooth articles, it is recommended to raise the temperature of the solution to 160° Fahr., using a strong current.

Morris and Johnson's Process.—A solution is made by dissolving in 1 gallon of water—

Cyanide of potassium	1 pound.
Carbonate of ammonia	1 „
Cyanide of copper	2 ounces.
„ zinc	1 ounce.

The solution is to be worked at a temperature of 150° Fahr., with a large brass anode, and a strong current.

Dr. Heeren's Process.—According to this authority,* a brassing solution may be prepared by employing a large excess of zinc to a very small proportion of copper, as follows:—Take

Sulphate of copper	1 part.
„ zinc	8 parts.
Cyanide of potassium	18 „

The ingredients are to be dissolved in separate portions of warm water. The copper and zinc solutions are now to be mixed, and the cyanide solution then added, when 250 parts of distilled water are to be added, and the mixture well stirred. The bath is to be used at the boiling temperature, with two Bunsen cells. By this process it is said that very rapid deposits of brass have been obtained upon articles of copper, zinc, Britannia metal, &c.

Roseleur's Processes.—1. Dissolve in 1,000 parts of water, 25 parts of sulphate of copper and from 25 to 30 parts of sulphate of zinc; or, 12½ parts of acetate of copper and 12½ to 15 parts of fused chloride of zinc. The mixture is to be precipitated by means of 100 parts of carbonate of soda previously dissolved in plenty of water, with constant stirring. The precipitate is to be washed several times, by first allowing it to subside and then pouring off the supernatant liquor (which may be thrown away), when fresh water is to be poured on the precipitate, and after again stirring it is allowed to subside, the washing to be repeated two or three times. After pouring off all the water the last time, a solution composed of 50 parts of bisulphide of sodium and 100 parts of carbonate of soda dissolved in 1,000 parts of water, is to be added, stirring well with a wooden rod. A strong solution of commercial cyanide of potassium is now to be added until the precipitate becomes just dissolved. From 2½ to 3 parts of cyanide in excess are now to be added with stirring, when the solution is complete.

Solution 2.—To form a cold bath for brassing all metals, dissolve 15 parts of sulphate of copper and 15 parts of sulphate of zinc in 200 parts of water; now add a solution made by dissolving 40 parts of carbonate of soda in 100 parts of water, and stir the mixture well. The precipitate is allowed to subside, as before, when the clear liquor is to be run off, and fresh water added, to wash the precipitate, the washing to be repeated several times. To the drained precipitate add 20 parts of bisulphide of sodium dissolved in 900 parts of water. Now dissolve 20 parts of cyanide of potassium and two-tenths of a part of arsenious acid (white arsenic) in 100 parts of water, and add this to the former liquor. This decolours the mixture and completes the

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* "The Chemist," 1855, p. 345.

brassing solution. The effect of the arsenious acid is to render the deposit bright. We were long accustomed to employ small quantities of white arsenic with our brassing solutions, and when used with moderation considered the addition highly favourable to a good deposit of brass. Roseleur recommends, in working this bath, to add a little cyanide when the deposit looks earthy, or ochreous, and arsenic when it yields a dull deposit; if too red, a little zinc and cyanide are to be added; if too white, a little copper and cyanide; if the solution works tardily, add both zinc and copper salts, and more cyanide; and since the anode does not dissolve freely enough to keep up the strength of the solution, these additions of the metallic salts and cyanide must be made from time to time whenever the bath works tardily. The same remedy should be applied to all brassing solutions when they work sluggishly. When the above solution, by the additions of the metallic salts, reaches a higher specific gravity than 1·091, water must be added, but the specific gravity must not be lower than 1·036.

Solution 3.—The following solution is recommended for coating steel, cast iron, wrought iron and tin:—Dissolve 2 parts of bisulphite of soda, 5 parts of cyanide of potassium (of 75 per cent.), and 10 parts of carbonate of soda in 80 parts of distilled water, and add to the mixture 1 part of fused chloride of zinc and 1¼ parts of acetate of copper, dissolved in 20 parts of water.

Solution 4.—For coating zinc articles, the following solution is recommended:—20 parts of bisulphite of soda and 100 of cyanide of potassium (of 75 per cent.) are dissolved in 2,000 parts of water. Then dissolve 35 parts of chloride of zinc, 35 parts of acetate of copper, and 40 parts of liquid ammonia in 500 parts of water. The solutions are now to be mixed and the compound solution passed through a filter.

In working these solutions, if too strong a current be employed, or too large a surface of anode exposed in the solution, zinc only will be deposited; if the current be feeble, or if the articles are kept in motion while deposition is taking place, the deposit will be chiefly or wholly copper. If a white deposit of oxide of zinc appears upon the anode, a small quantity of liquid ammonia should be added to the bath.

Walenn's Processes.—A solution for depositing brass is made as follows:—Crystallised sulphate of zinc 1 part, and crystallised nitrate of copper 2 parts, are dissolved to saturation. Strong liquid ammonia is then added in sufficient quantity to precipitate the oxides and redissolve them. Cyanide of potassium is then added until the purple liquid is completely decoloured. The resulting solution should be left to repose for a day or two, and may be worked with from 1 to 3 Smee cells, using heat if a brass anode be employed. It is preferred, however, to work the solution by a "porous cell arrangement, in which the surface of the solution next the zinc or other dissolving plate is at a greater elevation than that of the external or depositing solution." In working the solution, the hydrated oxides of copper and zinc are added from time to time, and, if necessary, ammoniuret of copper also.

For a hot brassing solution, Walenn gives the following formula:—A "solvent solution" is first made, consisting of—

Cyanide of potassium (standard solution) . .	6 parts.
Nitrate of ammonium " " . .	1 part.
Sulphate of " " " . . .	2 parts.

The standard solution of each salt consists of the solid salt dissolved in five times its weight of water. The ingredients being mixed, the whole is divided into three parts:

Free solvent solution	1 part.
Solution to dissolve cupric cyanide . . .	5⅓ parts.
" " zinc " . . .	2⅔ "

When the respective cyanides have been dissolved to saturation in the above proportions, the free solution is added, and the whole well mixed; ammoniuret of copper is then added, and the solution set aside for a day or two. Walenn prevents the evolution of hydrogen (or nearly so) during deposition by adding the hydrated oxides of copper, or ammoniuret of copper and zinc, in sufficient quantity for the purpose.

By another process he employs solutions of cyanide of potassium and tartrate of ammonium, in equal proportions. In this menstruum he dissolves cyanides, tartrates, carbonates, &c. of copper and zinc, and the solutions thus formed may be worked either hot or cold. The proportions of the various salts must be varied according to the strength of the current employed.

Walenn makes the following observations on the electro-deposition of copper and brass:—"A solution containing one pound of cupric sulphate, and one of sulphuric acid to a gallon of water, deposits the metal in a solid and compact mass, with a somewhat botryoidal* surface. The addition of one ounce of zinc sulphate (as recommended by Napier) prevents this botryoidal form, and renders the deposit tough, compact, and even. From a solution containing a greater proportion of zinc, sulphate copper is deposited in tufts or needles,

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* *Botryoidal,* resembling a bunch of grapes; referring to the *nodular* or knotty form which copper assumes at the back of electrotypes.

standing at right angles to the surface of the metal. Ordinary electro-brassing liquids [deposits from] show the same peculiarity in even a more marked degree, and this makes it impossible to produce a good deposit of more than ·01 to ·03 inch in thickness. This form of deposit is owing chiefly to a copious evolution of hydrogen taking place during its formation." While not disagreeing with Mr. Walenn's views, the author may state that he has found that a small quantity of arsenious acid (previously mixed with a strong solution of cyanide) added to brassing baths had generally rendered the deposit smooth and compact; the quantity, however, must be small, otherwise the deposit is liable to be of a brittle character. About one drachm of arsenious acid to each gallon of bath will be sufficient. He has usually noticed that brassing solutions evolve hydrogen most freely when poor in metal, and when containing a large excess of cyanide. A solution richer in metal, and containing but a moderate excess of cyanide, generally yields better results, both as to colour and general character of the deposit. A great deal depends, however, upon the amount of current and its tension, and also upon the temperature of the bath. A solution rich in copper and zinc is best worked at about 130° Fahr., or even higher. When the solution becomes partly exhausted of its metals, owing to the brass anodes not becoming freely dissolved in the solution, it is always advisable to add fresh *concentrated* cyanide solutions of the zinc and copper salts from time to time, taking care, however, only to add them in sufficient quantity to obtain the desired effect—a coating of good colour with but trifling evolution of hydrogen at the negative electrode.

Bacco's Solution.—The following solution is said to yield a brass deposit upon zinc work that will stand burnishing, and the deposit may be obtained either by simple immersion or by the battery. A solution is first prepared by dissolving equal parts of sulphate of zinc and sulphate of copper in water. A strong solution of cyanide of potassium is then added in sufficient quantity to redissolve the precipitate formed; to the resulting solution one-tenth to one-fifth of liquid ammonia is added, and the solution is then diluted with water until it stands at about 8° Baumé. For a light-coloured deposit of brass 2 parts sulphate of zinc to 1 part sulphate of copper are used. In adding cyanide to the solution of the sulphates, great care must be taken to avoid inhaling the cyanogen fumes that are liberated, which are highly poisonous. A solution of this character should only be prepared by a person well accustomed to chemical manipulations.

Winckler's Solution.—Saturated solutions of chloride of zinc and sulphate of copper are first prepared, in separate vessels. A solution of cyanide of potassium, consisting of cyanide 100 parts in water 1,000 parts, is next prepared, and this is added to the solution of sulphate of copper until the precipitate at first formed is redissolved, when a grass-green liquid results; into this the solution of zinc is gradually introduced, with constant stirring, until the solution exhibits a white turbidity. The solution is then diluted with 2,000 parts of water, and heated to the boiling point in an enamelled vessel, and then allowed to cool. It is next filtered, when it is ready for use. The bath is worked at the ordinary temperature, with a brass anode.

Brass Solution for Rough Cast Iron.—The following formula has been given for brassing cast-iron work, and is said to yield a good colour:—

Soft water	14 pints.
Bisulphite of soda	7 ounces
Cyanide of potassium	17 „
Carbonate of soda	34 „

To which is added—

Acetate of copper	4½ ounces.
Neutral chloride of zinc	3½ „
Water	3½ pints.

American Formulæ for Brassing Solutions.—The *Scientific American* publishes the following formulæ for brass solutions:—1. When the ordinary commercial cyanide is employed, the following is said to answer very well:—

Sulphate of copper	4 ounces.
Sulphate of zinc	4 to 5 „
Water	1 gallon.

Dissolve and precipitate with 30 ounces of carbonate of soda; allow to settle, pour off the clear liquid, and wash the precipitate several times in fresh water. Add to the washed precipitate—

Carbonate of soda	15 ounces.
Bisulphite of soda	7½ „
Water	1 gallon.

Dissolve the above salts in the water, assisting the solution by constant stirring; then stir in ordinary cyanide of potassium until the liquid becomes clear and colourless. Filter the solution, and to improve its conductivity, an additional half-ounce of cyanide may be given.

Cold Bath for all Metals.—

Carbonate of copper (recently prepared)	2 ounces.
„ zinc	2 „
„ soda	4 „

Bisulphite of soda	4 ounces.
Cyanide of potassium (pure)	4 „
Arsenious acid	$\frac{1}{20}$ „
Water	1 gallon.

Dissolve, precipitate, and redissolve as before, and filter if necessary. The arsenious acid is added to brighten the deposit; an excess is apt to give the deposited metal a greyish-white colour.

Thick Brass Deposits.—MM. Person and Sire patented a process for obtaining stout coatings of brass upon steel or iron by depositing alternate layers of zinc and copper upon the objects, and then submitting them to heat until the metals become alloyed with each other.

Brass Solution Prepared by Battery Process.—A brassing solution may be prepared by the battery method by suspending a large brass anode in a strong and warm solution of cyanide of potassium, to which liquid ammonia is added; about 1½ pound of good cyanide and 10 ounces of strong liquid ammonia to the gallon of water will be about the best proportions. A strong current must be employed. Some persons recommend the addition of hydrocyanic acid; this will not be necessary if good cyanide be used. In preparing solutions by the battery process, or indeed by the ordinary chemical methods, it is far better to employ really good cyanide of a guaranteed strength than to call in the assistance of hydrocyanic acid, which, even in the most careful hands, is a hazardous substance to deal with in what may be termed *practical* quantities. All the best results in electro-deposition have been obtained without the direct aid of this volatile and highly-poisonous acid, and its employment should never be attempted by inexperienced persons under any circumstances whatsoever.

CHAPTER XXVIII.

ELECTRO-DEPOSITION OF ALLOYS (*continued*).

Electro-brassing Cast-iron Work.—Scouring.—Electro-brassing Wrought-iron Work.—Electro-brassing Zinc Work.—Electro-brassing Lead, Pewter, and Tin Work.—Observations on Electro-brassing.—Bronzing Electro-brassed Work.—French Method of Bronzing Electro-brassed Zinc Work. Green or Antique Bronze.—Bronze Powders.—Dipping Electro-brassed Work. – Lacquering Electro-brassed Work. — Electro-deposition of Bronze.—Electro-deposition of German Silver.—Morris and Johnson's Process.—Deposition of an Alloy of Tin and Silver.—Deposition of Alloys of Gold, Silver, &c.—Deposition of Chromium Alloys.—Slater's Process.—Deposition of Magnesium and its Alloys.—Alloy of Platinum and Silver.—New White Alloys.—Notes on Electro-brassing.

Electro-brassing Cast-iron Work.—Owing to the porous nature of this class of work, and its liability to present certain unavoidable defects of casting known as sand-holes, the articles to be coated with brass require to be prepared with some care before being immersed in the depositing bath. Moreover, it is necessary to remove the coating of oxide from the surface of the work previous to submitting the articles to the processes of scouring or cleaning. Cast-iron work should first be placed in a "pickle" composed of the following mixture, in sufficient quantity for the work in hand:—

Sulphuric acid	½ pound.
Water	1 gallon.

The articles being placed in the above pickle are allowed to remain therein for about twenty minutes to half an hour, when they are taken out, one at a time, and examined; if the oxide has become sufficiently loosened to readily rub off with the fingers, the articles are to be at once placed in clean cold water to rinse them; they are then to be scoured with a hard brush, coarse sand, and water. If after rinsing any black oxide obstinately refuses to be brushed away, the work must be returned to the pickle for a short time longer, or until the objectionable matter readily yields to the brush, leaving a clean surface beneath. Some articles require but a short immersion in the acid pickle, while others need a much longer steeping. When the articles are coated with rust (oxide of iron) this may be removed by brushing them over with strong hydrochloric acid, after which they should be immersed in the sulphuric acid pickle until it is found that sand and water, applied with a very hard brush, will clean them. A solution for brassing cast-iron work should be very rich in metal.

Scouring.—When the articles are sufficiently pickled, they are to be removed from the bath and *well* rinsed in clean water; they are then taken to the "scouring tray," and being placed on the horizontal board, are to be well rubbed with the hard brush and coarse sand moistened with water, until they are perfectly bright and clean and free from all traces of oxide on their surfaces. They are now to be thoroughly rinsed in clean water, and are then ready for the brassing-bath. Some operators prefer to give them a momentary dip in a weak and cold potash bath, and then rinse them before placing the articles in the depositing bath. The work should be suspended in the bath by stout copper wires, and in the case of large pieces of work several such slinging wires should be employed, not only to give support to the articles, but to equalise, as far as possible, the action of the current; since it must be remembered that cast iron is but an indifferent conductor as compared with other metals.

Electro-brassing Wrought-iron Work.—This class of work is more readily coated with brass (and copper) than the former, the metal being less porous and the articles generally in a smoother condition. The work is first to be pickled as before, and afterwards well scoured with sand and water, and then rinsed. The solution in which wrought-iron goods are brassed may have rather less metal (that is, zinc and copper) than is necessary for cast iron. When the articles have been in the bath a few moments, they should be tinted with the characteristic colour of brass. If, however, the colour is of too *red* a tone (showing an excess of copper in the deposit) the brass anode should be lowered a little further into the solution until the deposit is of the proper colour. If, on the contrary, the deposit is *pale*, or whitish (indicating an excess of zinc), the anode must be raised out of the solution to a slight extent. By regulating the *anode surface in solution* the colour of the deposit may be greatly varied; the current of electricity must also be regulated according to the surface of work in the bath and the character of the metal to be coated—cast iron, for example, requiring a current of greater electromotive force than wrought iron.

Electro-brassing Zinc Work.—This metal receives the brass deposit very freely, and the articles made from it are generally prepared for the bath with very little trouble as compared with iron work. Zinc goods should first be steeped in a pickle composed of dilute sulphuric acid, or the following mixture:—

Sulphuric acid	1 ounce.
Hydrochloric acid	2 ounces.
Water	1 gallon.

The work should be immersed in the above bath from ten to twenty minutes, then well rinsed, and next scoured with a hard brush, silver sand, and water; after being again rinsed, the article is to be immersed in the brass bath, and it will generally become coated all over in a few moments, providing the bath be in good condition, the current of sufficient power, and the proper surface of anode exposed in the solution. If the deposit does not take place within a few seconds after immersion, the anode should at once be lowered in the bath until the yellow colour has *struck* well over the article, after which it may be again raised, and the operation then allowed to proceed, undisturbed, until a coating of sufficient thickness is obtained. Since this class of work is not generally required to be subjected to friction (being chiefly castings of an artistic or ornamental character) a stout coating of brass is unnecessary; moreover the zinc work, when electro-brassed, is usually required either to be *bronzed*, electro-gilt, lacquered, or finished in some other way. Zinc and iron articles should not be suspended in the bath at the same time if it be possible to avoid it; if, however, this rule cannot be conveniently followed, the iron articles should enter the bath first, and when these have become coated with brass the zinc work may then be introduced. When zinc goods have received the required deposit, they should be well rinsed in hot but not boiling water, and then placed in hot mahogany or boxwood sawdust. After being well brushed with a soft, long-haired brush to remove the sawdust, the piece of work should be rubbed with a clean diaper or chamois-leather, and may then be lacquered or *bronzed*, as desired. If the article is required to be gilt, it is to be simply well rinsed after removing from the bath, and at once placed in the gilding bath.

Electro-brassing Lead, Pewter, and Tin Work.—Brass does not deposit upon lead so readily as upon zinc; but pewter, however, receives the deposit pretty freely. Lead and pewter articles should be pickled for about half an hour in a dilute solution of nitric acid, consisting of about eight ounces of the acid to each gallon of water, then scoured with silver sand and water, a *soft* brush being employed. They are then to be rinsed and placed in the brass bath, a rather large surface of anode being immersed in the solution when they are first suspended. The current should be strong, otherwise lead is very apt to receive the coating only in parts. It is also best to employ a warm solution for brassing lead and pewter, but more especially the former. Articles of tin, or tinned iron articles, should also be brassed in a warm solution, and treated in other respects in the same way as the former metals, except that the preliminary pickling (which is not absolutely necessary in either case) may be dispensed with.

Stereotype-plates may advantageously receive a deposit of brass, and, indeed, this method of producing a hard surface upon these plates has been to some extent adopted, a warm brassing solution being employed, with a strong current. For plates which have to be used for printing with *vermilion* ink neither a brass nor a copper facing should be adopted, since this colour, being a *mercury* preparation, would be liable to attack both the copper and its alloy (brass), and thus not only injure the metal facing, but also affect the colour of the ink itself.

Observations on Electro-brassing.—After an electro-brassing bath has been used for some time, its whole character becomes greatly changed, unless, indeed, it has been worked under exceptionally favourable conditions, and even with such advantages it will invariably yield results far different from those at first obtained. There are several causes for this, and when these are fully understood it will be more readily seen how tolerable uniformity of action may be secured, absolute uniformity being, so far as we are aware, impossible in the deposition of this or any other alloy. The principal causes of change in the condition of brass deposits are—(1) The anode, being composed of two metals of unequal solubility in cyanide of potassium, does not become freely and uniformly dissolved in the solution, consequently the latter becomes partially, and indeed greatly, deprived of its metallic constituents; (2) If an excess of ammonia be employed as one of the solvents, this volatile substance by constantly evaporating alters the condition of the bath in proportion to its volatilisation; (3) The oxide of zinc eliminated at the brass anode being less soluble than the oxide of copper evolved at the same electrode, the free cyanide in the solution is largely taken up by the latter to the exclusion of the less soluble zinc oxide, and as a consequence this latter substance hangs upon the surface of the anode, or falls to the bottom of the bath as an undissolved mass. In this way the solution becomes more freely supplied with copper than with zinc, and therefore becomes altered from its original condition; (4) When a current of low electro-motive force is used in depositing brass, the copper of the alloy is more readily deposited than the zinc, which requires a current of higher electro-motive force than copper for its deposition, and as a consequence the solution soon becomes altered in its constitution. For example, when a Bunsen battery is employed in the deposition of this alloy, a very good quality of brass is obtained from a well-made brassing solution; if for this battery a single Wollaston battery were substituted, all other conditions being the same, copper alone would be deposited on the cathode; (5) The amount of anode surface immersed in solution in proportion to that of the cathode affects the deposition of brass in a sensible manner. To illustrate this, a very important lesson may be learnt in a very simple way: Take a small steel article, say a pocket latch-key, for example, and connecting it with the negative electrode of a Bunsen battery, suspend it in the brass bath, having previously immersed a large surface of the brass anode. We shall at once observe that a deposit of zinc only has taken place upon the key. Let the key be scratch-brushed, and the anode raised out of the bath so that only a very small portion of one of its corners remains in the solution; if now the key be suspended in the liquid we shall soon observe that it becomes coated with copper only. If the anode be now cautiously lowered in the bath, we find that the coating gradually assumes the characteristic colour of brass; and if we take care to estimate the approximate amount of anode surface which yields the yellow alloy, we may in this way form a tolerable notion of the surface of this electrode which it is necessary to expose to a given surface of cathode with the electric power employed. As a further illustration of the caprice which attends the deposition of brass from its solutions, we have known instances in which a steel rod suspended horizontally in the bath has exhibited the following varieties of deposit: at one end zinc alone was deposited; at the opposite end, copper; and midway between the two, brass of various tints, from pale straw or lemon colour to a rich golden yellow. *Motion* also affects the character of the deposit, copper being deposited instead of brass when a brisk motion is given to the article while in the bath.

When a much-used bath has a tendency to deposit copper alone, from the cause above stated, its condition may be improved in several ways—(1) By adding liquid ammonia to dissolve the deposited oxide of zinc; (2) By adding a strong cyanide solution of zinc until the required yellow deposit is obtained; and (3) By syphoning off the clear solution, and adding ammonia to the deposit at the bottom of the depositing vat, and then returning the clear liquor, when after a few hours' repose the bath will generally work well. A moderate addition of cyanide may also be necessary. When it is found that the bath exhibits general signs of weakness owing to the anode failing to keep up its *metallic* strength, an addition of a concentrated solution of the metals, copper and zinc, must be made, in which there should be an excess of the metal most needed to bring the bath up to its proper condition. In working brassing solutions, it is always advisable to keep in hand a quantity of very concentrated brass solution, so that this may be added to the bath from time to time as required, and thus prevent the annoyance which attends the working of a sluggish and defective solution. Another way of strengthening an exhausted bath is the following: Take a large porous cell, and about three parts fill it with a strong solution of cyanide of potassium; now connect a long and broad strip of copper to the negative pole of the battery; immerse the porous cell in the brassing bath, either by standing it upright or by suspending it, according to the depth of the vessel. Now connect a large brass anode to the positive pole of the battery, and allow the current to pass through the solution for a few hours, by which time it will have taken up a considerable amount of brass if the current was sufficiently strong. Two or more 3-gallon Bunsen cells should be employed for a 100-gallon bath of brass solution. If a white deposit appears upon the brass anode, liquid ammonia should be added and well stirred into the solution.

Bronzing Electro-brassed Work.—By the term *bronzing* is meant the application of one or other of the numerous methods of *staining* brass, or imparting to the metal an antique or artistic appearance. When the electro-deposited metal is required to assume the appearance of solid brass, the process of *lacquering* is applied; but for cast zinc or iron work electro-brassed, another system of ornamentation is adopted, which is known by the name of *bronzing*. For example, if a dilute solution of chloride of platinum be brushed over a brass surface, a *black stain* is produced, the depth or tone of which may be heightened by a second application of the solution. In this case the metal platinum is reduced by electro-chemical action, and becomes deposited upon the more positive metal. The stain, however, produces an effect of contrast which, when artistically applied, is exceedingly pleasing to the eye; and by this means ornamental brass and also electro-brass work is greatly enriched by art-metal workers and others to meet the requirements of the public. Since it is important that electro-depositors of brass should be well acquainted with the methods of producing upon their work the varied effects which are applied to the solid alloy, we will now explain some of the many processes adopted.

Black Bronze.—This is produced, as before observed, by means of a dilute solution of chloride of platinum. For this purpose, the platinum salt may be dissolved in spirits of wine, methylated spirit, or distilled water, and a few drops of the concentrated solution added to a small quantity of water, and applied with a camel-hair brush or by dipping. For large pieces of work, a sufficient quantity of the dilute solution should be prepared to finish the piece in hand, so as to ensure uniformity of tone throughout the entire piece. When bronzing very large articles, as stove fronts, fenders, &c., it is sometimes the practice to mix a little of the dilute platinum solution with plumbago, made into a thin paste with water, and to brush this over the entire ornamental surface of the article, and when nearly dry, the article is well brushed with a rather soft, long-haired brush until quite bright; the *high lights*, or prominent points of the article, are then gently rubbed with a piece of chamois leather moistened with spirit of wine or rubbed on a lump of chalk, the object being to remove the black stain from these points, so as to show the yellow metal with which the work is coated. Instead of employing the platinum solution for this purpose, a small quantity of sulphide of ammonium may be mixed with the plumbago paste; this latter is most frequently adopted for the sake of economy. The platinum salt, however, produces the most brilliant and lasting effect.

Warm Bronze Colour.—When it is desired to give a warm chocolate tone to an electro-brassed article, a mixture of jewellers' rouge and black-lead, in varying proportions according to the tone required, is first made with water; to this a few drops of chloride of platinum solution or sulphide of ammonium are added and intimately mixed. This bronzing paste is spread over the article with a soft brush, and allowed to become nearly dry, as before, when the surplus powder is brushed away by polishing with a long-haired brush. The high lights are then touched up as before to expose the metal. The article should now be made moderately warm, and then brushed over quickly with a very thin, hard, and quick-drying varnish; when this is done the work is complete. A bronzing composition for imparting a warm chocolate tone to electro-brassed work may be made by mixing into a paste with water the following ingredients: black-lead, 1 ounce; Sienna powder, 2 ounces; rouge, ½ ounce. To this may be added a few drops of sulphide of ammonium. Or a mixture of black-lead and rouge or crocus may be employed. In each of these cases the formulæ may be varied at the will of the operator; indeed, the tone or bronze effect is so greatly a matter of taste that the proportions of the various materials may properly be left to the discretion of the electro-bronzer.

Green Bronze.—Mix into a paste with water the following substances, varying the proportions, as before suggested, according to taste:—

Chromate of lead (chrome yellow) . .	2 ounces
Prussian blue	2 „
Plumbago , ...	½ pound
Sienna powder	¼ „
Lac carmine	¼ „

When applying the above composition, a small quantity of sulphide of ammonium or chloride of platinum solution may be added. It should be mentioned that the particles set free by brushing off the superfluous portions of the above mixture would be unwholesome to breathe, on account of the chromate of lead present in the composition, the other substances are virtually innocuous, though the inhalation of small particles of mineral, or indeed any other substance whatever, should be avoided as much as possible. In polishing work which has been coated with bronzing powders, therefore, it would be well if the workpeople could be induced to protect the nose and mouth by a thin piece of muslin, more especially in the earlier stages of the polishing operation, when the great bulk of the superfluous material has to be brushed away.

French Method of Bronzing Electro-brassed Zinc Work.—If a warm tone is desired, the electro-brassed article is first dipped in a weak solution of sulphate of copper and then dried. It is next moistened with sulphide of ammonia or a solution of liver of sulphur; after again drying the surface is brushed over with a mixture of hematite or jewellers' rouge and black-lead, the mixture being made according to the tone required. The brush should be slightly moistened with turpentine to assist the adhesion of the powder. The parts in relief are then to be "set off," that is, well rubbed, to disclose the metal, and give it the appearance of having been subjected to wear. The object is then to be coated with a thin colourless varnish.

Green or Antique Bronze.—Dissolve in 100 parts of acetic acid of moderate strength, or in 200 parts of good vinegar, 30 parts of carbonate of ammonia or sal-ammoniac, and 10 parts each of common salt, cream of tartar, and acetate of copper, and add a little water; mix well, and smear the object with it, and then allow it to dry, at the ordinary temperature, from twenty-four to forty-eight hours. At the end of that time the article will be found to be entirely covered with verdigris, which presents various tints. It is then to be brushed, but more especially the prominent parts, with a waxed brush, that is, a brush passed over a lump of yellow beeswax. The relief parts may then be "set off" with hematite, chrome yellow, or other suitable colours. Light touches with ammonia impart a blue shade to the green parts, and carbonate of ammonia deepens the colour of the parts to which it is applied.

Steel Bronze.—This is obtained by moistening the articles with a dilute solution of chloride of platinum, and slightly heating them. Since this bronze is liable to scale off with friction, it should not be applied in successive doses, but the solution used should be of such a strength that the desired effect may be obtained, if possible, by a single application. Copper bronze, that is, electro-brass with an excess of copper, may be darkened by dipping it into a weak and warm solution of chloride of antimony (butter of antimony) in hydrochloric acid. Sometimes, however, the coloration will be violet instead of black.

Bronze Powders, as the Bessemer bronzes, for instance, are largely used for imparting a metallic appearance to plaster casts and ceramic wares, and also for ornamenting cast-iron work, to give it the appearance of bronze. The mode of application is as follows: The article, after being cleaned, is coated with a fatty drying varnish, which is allowed to become nearly dry. The bronze powder is then applied with a badger-hair brush, when it firmly adheres to the sticky varnish. After drying, the article is coated with a hard, colourless varnish, which fills up the details. This process is chiefly applied to metals for such work as cheap iron fenders, cast-iron dogs for fireplaces, umbrella-stands, and other coarse work, and is in no degree suitable for articles which have been electro-brassed, in which a more artistic finish is required.

Dipping Electro-brassed Work.—When steel or iron articles have received a good coating of brass, but of an indifferent colour, they may be greatly improved in colour by being *dipped* in the ordinary dipping liquids used for brass. The dippings, however, must be done with great promptitude, otherwise the coating will either be dissolved off, or at least much reduced in thickness. If the operation is conducted with smartness, and the articles at once plunged into cold water, the desired result may be obtained without risk—provided, of course, that a tolerably stout coating has been deposited upon the work. This method of improving the colour of the deposit we have successfully adopted, and, indeed, frequently made it a practice to give to the work an extra strong coating to allow for the reduction of its thickness in the acid dip. By this means we were enabled to produce results in electro-brassing which were acknowledged to be fully equal in colour to the finest specimens of solid brass, and not unfrequently superior.

Lacquering Electro-brassed Work.—After being worked for some time, a brassing bath is liable to give deposits which are either too red, or *coppery*, or they may assume a sickly pale colour, which, after scratch-brushing, is of too light a colour to fairly represent brass. Articles in this condition, although they may be greatly improved by a coating of good yellow lacquer, still fail to resemble ordinary brass. When zinc or steel articles are required to be lacquered after electro-brassing, it is a good plan to be provided with an extra brassing solution, capable of yielding a really good colour, in which the articles, after being coated in the ordinary bath and scratch-brushed, may be immersed, to give them a final coating of good yellow brass. Generally speaking, an immersion in the second bath of only a few minutes is sufficient to produce the desired effect, and the solution we should recommend for this purpose is one prepared from the sulphates of copper and zinc, precipitated by carbonate of potash, and redissolved with cyanide and liquid ammonia. A solution carefully prepared from these ingredients is capable of yielding a brass deposit of a very fine colour. The solution should be used only for giving a final coating to electro-brassed work which is of a bad colour, and when it ceases to yield a good coloured deposit, it may be added to the ordinary brassing bath and another solution prepared in its place. If the plan we have suggested be adopted, the work may then be lacquered in the same way as ordinary brass, after being thoroughly rinsed and dried. It may be mentioned that acid dipping, to improve the colour of the brass deposit, cannot so safely be applied to zinc work which has been electro-brassed.

Electro-deposition of Bronze.—The electro-deposition of the alloy of copper and tin known as bronze is less frequently practised than that of the more common alloy, brass; indeed, the latter with an excess of copper in the solution generally answers the purpose equally well for most of the uses to which the deposited bronze alloy would be applicable as an imitation of *real* bronze. In making up a bronzing solution, it is only necessary to substitute a salt of tin (chloride of tin by preference) for the zinc salt in the preceding formulæ, but in rather less proportion than the latter, say about one-third less. The simpler method, however, is to make up a brassing bath with a slight excess of copper, and to depend upon the artificial methods of *bronzing* previously given, or such modifications of them as may suggest themselves, for producing imitations of solid bronze. A very little practice in this direction will enable the operator to meet almost every requirement as to tone or colour. In this, as in the case of electro-brassed work, the most prominent parts of the work should be rendered bright, so as to expose the deposited metal at such points by gently rubbing away the materials used in producing the artificial bronze colour. By so doing a very pleasing artistic effect may be produced, provided the removal of the bronzing material is not carried too far, but merely confined to such points as may be assumed to have been subjected to friction in use.

Electro-deposition of German Silver.—We have succeeded in depositing an alloy of copper, nickel, and zinc, forming German silver of good quality, by making a solution of the alloy in the *direct* way, as recommended for preparing brassing solutions, thus: Cut up into small pieces sheet German silver, about one ounce; place the strips in a glass flask, and add nitric acid, diluted with an equal bulk of water. Assist the solution of the metal by gentle heat; when the red fumes cease to appear in the bulb of the flask, decant the liquor, and apply fresh acid, diluted as before, to the undissolved metal, taking care to avoid excess; it is best to leave a small quantity of undissolved metal in the flask, by which an excess of acid is readily avoided. The several portions of the metallic solutions are to be mixed, and diluted with about three pints of cold water in a gallon vessel. Next dissolve about four ounces of carbonate of potash in a pint of water, and add this gradually to the former, with gentle stirring, until no further precipitation takes place. The precipitate must be washed several times with hot water, and then redissolved by adding a strong solution of cyanide with stirring, and about one ounce of liquid ammonia. To avoid adding too great an excess of cyanide, it is a good plan, when the precipitate is nearly all dissolved, to let it rest for half an hour or so, then decant the clear liquor, and dissolve the remainder of the precipitate separately. A small excess of cyanide solution may then be added, as "free cyanide," and the whole mixed together and made up to one gallon with cold water. The solution should then be filtered, or allowed to repose for about twelve hours and the clear liquor then carefully decanted from any sediment which may be present from cyanide impurities. The bath must be worked with a German silver anode, which should be of the same quality as that from which the solution is prepared; a Bunsen battery should be employed as the source of electricity, or a dynamo-machine.

Morris and Johnson's Process.—By this process a German silver bath is prepared by the battery method. One pound each of cyanide of potassium and carbonate of ammonia are dissolved in a gallon of water, and the solution heated to 150° Fahr. A large German silver anode, connected with the positive electrode of a powerful battery, is immersed in the solution; a small cathode of any suitable metal is connected to the negative pole of the battery and also immersed in the solution. The electrolytic action is to be kept up until a considerable amount of metal is dissolved, and a bright cathode receives a deposit of good colour, when the solution is ready for use. If the deposit is too red, carbonate of ammonia is to be added; if too white, cyanide of potassium.

The electro-deposition of German silver may with advantage be substituted for nickel-plating for many articles of ornament and usefulness; a coating of this alloy looks exceedingly well upon bright steel surfaces, and is, to our mind, specially suitable for revolvers, dental instruments, and scabbards, having, when deposited of a good colour, a more pleasing tone than that of nickel.

Deposition of an Alloy of Tin and Silver.—Messrs. Round and Son obtained a patent in 1879 for a process for depositing an alloy of tin and silver, which is said to be applicable to coating brass, German silver, and copper, and, if slightly covered with a film of copper, iron and steel also. The inventors state that from their solution a white reguline metal is obtained which is easily polished, and greatly resembles fine silver. The solution is prepared as follows: Dissolve 80 ounces of commercial cyanide of potassium in 20 gallons of water in a suitable vessel; then pour in 100 ounces by measure of strong liquid ammonia, of the specific gravity of 880°, stirring well together; next add 10 ounces of nitrate of silver; any soluble *tin salt* may then be added at discretion; now add 3 pounds of carbonate of potassa, and allow the compound solution to rest until all sediment has subsided, then carefully decant the clear liquor, and the bath is ready for use. It is worked with a large anode of tin and a smaller one of silver. The articles to be plated by this process are cleaned in caustic ley, and all oxide carefully removed; they are then immersed in the bath, in connection with the negative pole of a strong voltaic battery, the two anodes being connected to the positive as usual. The articles are allowed to remain in the bath until the required thickness of deposit is obtained, when they are removed, rinsed, and dried, and may then be polished or burnished to a high degree, closely resembling unalloyed silver, but produced at far less cost.

Deposition of Alloys of Gold, Silver, &c.—These are noticed in Chapter XV. on Electro-gilding. We may, however, state that by mixing gold and silver cyanide solutions in varying proportions, gilding of various shades of colour may be obtained. The same results may be effected by blending cyanide solutions of gold and copper. The colour of the deposit is greatly influenced by the strength of the current employed, the amount of anode surface, and the temperature of the bath. With these hints to guide him, the experimentalist may obtain very interesting results by modifying the condition of the bath, strength of current, &c., at will.

Deposition of Chromium Alloys.—Slater's Process.—This process, for which a patent was obtained in March, 1884, may be thus briefly described: Anodes of chromium alloy are prepared by heating chromium compounds with charcoal in a closed crucible, and pouring upon the reduced mass 2½ parts of fused copper, and, subsequently, from 1 to 1½ parts of molten tin, and then granulating, re-fusing, and casting in moulds of the desired form. The plates thus formed are used as anodes in a solution made by dissolving 1 pound of cyanide of potassium and one pound of carbonate of ammonia in a gallon of water, heated to 150° Fahr., until a good deposit of alloy is formed upon the cathode; the bath is then ready for use. To finish the articles coated in this solution, they are "coloured" in a bath composed of chloride of tin 6 to 8 parts; chloride of copper, 20 to 25 parts; bichromate of ammonia, 10 to 15 parts; chloride of platinum, 6 to 12 parts, and water 101 to 110 parts. A very moderate current only is required.

Deposition of Magnesium and its Alloys.—Gerhard and Smith obtained a patent in December, 1884, for the following process: Ammonio-sulphate of magnesia is prepared by dissolving and crystallising together 228 parts of sulphate of magnesia (Epsom salt), and

132 parts of sulphate of ammonia. The crystals are dissolved in 35,000 parts of water, and the solution thus formed is best used at a temperature of 150° to 212° Fahr. For white metal, a nickel anode is used; for magnesium bronze, a copper anode must be employed. In the latter case, the bath is formed of ammonio-sulphate of magnesia, 360 parts; cyanide of potassium, 550 parts, and carbonate of ammonia, 550 parts, dissolved in 35,000 parts of water.

Alloy of Platinum and Silver.—Mr. Milton H. Campbell, of America, has taken out a patent for depositing this alloy, which is said to resist the action of nitric acid and sulphides. A bath is made by dissolving 30 parts of platinum and 70 parts of silver in aqua regia, and the metals are precipitated as a grey powder by means of chloride of ammonium. The compound chloride thus obtained is dissolved in a solution of cyanide of potassium, which constitutes the electrolytic bath. The anode is an alloy of 3 parts of platinum and 70 parts of silver, a feeble current being employed for the deposition of the alloy.

New White Alloys.—Many attempts have been made by refiners and metal workers to produce a metallic alloy to resemble silver in whiteness and texture, and sufficiently low in price for general manufacturing purposes; but although many excellent results have been obtained, there is no doubt whatever that the new alloy introduced by Messrs. Henry Wiggin and Co., under the title of "Silveroid," is the nearest approach to silver yet produced. This pretty alloy is not only beautifully white and of close and fine grain, but has a silvery lustre which renders its commercial name exceedingly appropriate. The new alloy, moreover, files and turns well, and is susceptible of a high polish. Being readily fusible, it is admirably adapted for ornamental castings, and produces very fine work. It is, we understand, being adopted for carriage, railway, and steamship fittings, machinery-bearings, taps, &c., and is intended as a substitute for brass, bronze, and gun-metal in all cases where a brilliantly white metal would be preferred as a substitute for the commoner alloys. A specimen of rolled "silveroid" sent to us by the above firm many months ago has undergone no change in appearance, being as white and silvery as when first received. Silveroid is an alloy of copper and nickel, to which zinc, tin, or lead in varying proportions are added, according to the purpose for which it is to be used. Another alloy has been introduced by Messrs. Wiggin & Co., under the title of "cobalt bronze," which is more steel-like in colour than the former, and is also much harder. This alloy, which takes a bright polish, is suitable for all kinds of work in which a hard, white, non-tarnishable metal is required, and would, we should say, be invaluable for steamship and railway carriage fittings, and work of that class. The cost of this alloy is rather higher than "silveroid," owing to the metal cobalt being one of its necessary constituents. Since it does not much exceed the price of ordinary German silver, however, while being much whiter, we have no doubt that it will be accepted as a valuable substitute for the former for unplated spoon and fork work. A long exposure of a sample of this alloy to the atmosphere, and also to the mingled fumes of our laboratory, by which it was unaffected, establish the fact that "cobalt bronze" will resist all ordinary atmospheric influences.

Notes on Electro-brassing.—When the brass anodes become foul, owing to undissolved sub-salts of zinc or copper, or both, forming on the surface, it indicates that the bath requires an addition of cyanide and liquid ammonia. After making these additions, it is well to remove the anodes, rinse them, and scour them perfectly clean.

Colour of Bronzes.—The tone or colour of the bronzing paste applied to electro-brassed cast-iron work (as fenders, for example) should be regulated according to the colour of the deposit. For instance, for a *yellow* brass, the black or green tones will be most appropriate, while for deposits of a more coppery hue, the warmer bronzes should be used, as those containing rouge, crocus, &c.

Bronze Tone.—To deposit metal approaching the tint of real bronze, a slight excess of copper should be added to the ordinary brass solution.

Green Bronze Colour.—To impart an artificial green bronze appearance to electro-brass, the article may be placed in a closed wooden box, having a saucer containing a little chloride of lime (bleaching powder) placed at the bottom. A small quantity of hydrochloric acid is then to be poured on the powder, the lid of the box immediately closed, and the article allowed to be subjected to the chlorine fumes which are given off, for a short time, after which the article is to be exposed to the air. The process may be repeated until the desired effect is produced. The article should be well coated with brass or bronze before being submitted to the action of the chlorine, otherwise this gas will attack the underlying metal.

Fender and Stove Work, which are generally required to be electro-brassed at a very low price, should first be pickled in dilute sulphuric acid for a short time, then rinsed and briskly scoured with coarse sand and water, again rinsed, and placed in the bath. A very strong current should be employed, so that the article may receive a sufficient coating in a few minutes. After rinsing and drying quickly the bronze paste is applied, and this is to be dried on the article as quickly as possible; when nearly dry the article is polished, its prominent parts then rubbed up with a piece of chamois leather and dry whiting, and a thin coating of hard spirit varnish laid on while the article is warm; the object is now finished.

Evolution of Hydrogen during Deposition.—A great deal has been written and said concerning the vigorous evolution of hydrogen which commonly occurs with electro-brassing baths when under the influence of the current; and, while we readily agree with much that has been said upon this subject, we must frankly confess that we have generally obtained the best results when the escape of hydrogen has been most brisk. We should certainly not consider a brassing bath, in which deposition takes place directly the articles are immersed in it (the deposit being of a good colour), a defective solution, though evolving hydrogen, since some of our best results have been obtained under such conditions. In depositing very stout coatings of this alloy, however, it is certainly desirable that the evolution of hydrogen should, as far as possible, be prevented, a result which may most readily be obtained with solutions containing a considerable quantity of the metallic constituents. Such baths, however, require a frequent addition of concentrated solution to keep up their metallic strength, which the brass anodes, under the most favourable conditions, fail to do.

Keeping up the Strength of the Bath.—To keep up the strength of brassing baths, the plan suggested by the author in respect of electro-tinning and platinising solutions may be adopted (see page 335). By this method a highly concentrated solution of brass, delivered from a tank above, may be allowed to trickle into the bath while deposition is going on, and thus its metallic strength fairly well kept up. Such an arrangement can be effected with very little trouble, a small barrel, furnished with a tap with a long piece of rubber tubing, being all that is necessary.

Solution for Cast-iron Work, &c.—The brassing bath for this class of work should be rich in metal, otherwise, even with a strong current, the deposit will take place chiefly, or only, at the corners or prominent portions of the articles. It is better to employ a solution containing a good percentage of metal and small quantity of free cyanide, than a great excess of the latter and a small proportion of copper and zinc. The current for depositing brass upon cast iron, especially in cold solutions, must be strong, and a large anode surface exposed in the bath. The same observations apply, to a certain extent, to lead, which requires a bath rich in copper and zinc to obtain successful results, especially when battery power is employed.

Brassing Different Metals.—It must be borne in mind, as we have hinted, that all metals do not receive the brass deposit with equal facility; indeed, if two articles—one composed of zinc and the other of cast iron—were placed in the bath simultaneously the former would at once become coated with brass, while the cast-iron article would either remain uncoated with the alloy, or at most a slight deposit would be visible at the points nearest the anode, or at the lower parts of the article, according to its form. This being the case, the cast-iron article should first be put into the bath, and when this has become *perfectly* coated all over the zinc articles may then be suspended in the solution. It is better, however, to deposit these metals separately. Even wrought and cast iron will not receive the brass deposit with equal readiness; the latter, therefore, should be put into the bath first, and the former only when the cast-iron piece is well coated all over.

Brassing in Hot Solutions.—When an article is first put into the bath (being connected to the negative electrode) it should be gently moved about for a few moments, to cause the deposit to take place as uniformly as possible all over the surface of the article, and when the characteristic yellow tint of the alloy appears uniformly all over the object, it may be allowed to rest in the bath for a short time, when the slinging wires should be shifted to allow the parts they have covered to become coated with the alloy. After a while the article should be inverted in the bath to equalise the deposit as far as possible. With these exceptions, it is not judicious to disturb work in brassing solutions while in circuit, as the colour of the deposit is often affected even by slight motion.

CHAPTER XXIX.

ELECTRO-METALLURGY.

Application of the Term.—Dechaud and Gaultier's Process.—Electrolytic Refining of Copper by Separate Current.—Elkington's Process of Refining Copper by Electrolysis.—Dr. C. W. Siemens' Observations on the Electro-metallurgy of Copper.—Mr. B. N. S. Keith on Refining Copper by Electrolysis.—M. Thénard's Experiments.—Dr. Higgs' Observations. —Dr. Kiliani's Observations on the Electrolytic Refining of Copper.—Gramme's Experiments with Sulphate of Copper Baths.

Application of the Term.—The term *Electro-metallurgy*, which was applied by the late Alfred Smee to the art of electro-deposition of metals generally, is now more correctly applied to the refining or purification of metals, and to their separation or extraction from ores by electrolysis. This important branch of electro-chemistry, the practical development of which had long been the dream and the hope of electricians, has during the past twenty years gradually developed into an art of considerable magnitude, while the great improvements in magneto and dynamo-electric machines which have been made within a comparatively recent date have given a stimulus to this field of enterprise which is likely to render it one of the most important in its employment of electric machinery. That these great results could never have been profitably obtained by means of voltaic electricity, is beyond all question.

An early investigation of this subject was made by Maximilian, Duke of Leuchtenberg, in the year 1847, who proved that impure copper containing precious metals could be refined so as to yield pure copper, and leave the precious metals in a condensed form ready for further treatment. He moreover recognised the great influence which his discovery would eventually have in connection with practical metallurgy. At this time, it must be remembered, electrolytic operations were, with the exception of Woolrich's magneto-electric machine, wholly conducted by means of the current from voltaic batteries, which rendered the following up of this discovery for commercial purposes practically impossible. The introduction of Wilde's magneto-electric machine in 1865 may fairly be taken as the starting-point from which success in this direction became possible as regards the means of obtaining electric power. In the same year Mr. J. B. Elkington introduced a practical process for refining copper by electrolysis, and which, worked by currents from Wilde's successful machines, soon placed the art of refining copper electrolytically upon a sound practical basis. A brief description of this process will be given farther on.

There can be no doubt that the first instance of the application of electrolysis in metallurgy was in the production of what is termed "cement" copper in the wet method of treatment. The drainage water of copper mines is frequently charged with sulphate of copper, due to the oxidation of the sulphide contained in the ore, and it is from these cupreous liquors that the cementation copper is obtained. The wet process is particularly adapted to the treatment of the poorer oxidised ores, especially where fuel is scarce. These ores are treated with acid, either hydrochloric or sulphuric, or with a solution of ammonia, all three of which are good solvents of the oxides of copper. The precipitation is effected in the copper solution by placing iron in it. The action is the result of electrolysis (*Williams*).* The cupreous solution being placed in large tanks, fragments of iron are immersed and the copper becomes reduced to the metallic state in the form of a spongy deposit to which the term "cementation copper" is applied. The first patented improvement on the above method, and which may also be considered the first application of a distinctly electrolytic process to the reduction of copper, was due to MM. Dechaud and Gaultier, of France, the patent, dated 1846, being for "Improvements in the extraction of copper from its ores, founded particularly on electro-chemical methods." The process, which we abridge from Mr. Williams's able work, is as follows:—

Dechaud and Gaultier's Process.—The inventors prepare the sulphate of copper from sulphide and oxide ores, by roasting them in a furnace, and then extracting the copper by lixiviation. The process, which exhibits much originality, is thus described by the inventors:—"If a mixture of oxide of copper and of sulphate of iron or zinc is subjected to the action of a suitable temperature, and of an air current, the resulting product will be sulphate of copper and sesquioxide of iron or oxide of zinc." The ore was first roasted and washed before being mixed with the sulphate of iron. The proportion of sulphate to ore was determined by previous experiment on a smaller scale. The inventors also found that carbonate ores of copper could be reduced in the same way. The suitable quantity of reducing sulphate having been well mixed with the dried roasted ore,

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* "Mineral Resources of the United States," by Albert Williams. Government Printing Office, Washington, 1883.

the mixture was roasted in a reverberatory furnace; it was afterwards thoroughly washed to dissolve the sulphate of copper formed. If the assay showed that the residue still contained copper, it was again mixed with sulphate and roasted. Instead of introducing iron into the copper solution in the ordinary way, by which the copper becomes deposited upon this metal and contaminated with impurities from the iron, MM. Dechaud and Gaultier proceeded as follows:—The solution was first concentrated by evaporation, and then placed in large shallow wooden tanks lined with lead. On the bottom of each tank were placed a number of flat copper plates, whose under surfaces were insulated with varnish so that the deposit could take place on the upper sides only. At the upper part of the solution, plates of iron, cast with grooves and openings like a gridiron, so as to present more surface and allow the escape of gases, were suspended in the solution of sulphate of copper by means of lugs, which rested on the edges of the tanks. All the copper plates were connected together electrically, as also were the iron plates. On connecting the two sides—*i.e.*, the combined copper plates with the combined iron plates—a battery arrangement was effected, and the deposition of copper took place upon the cathode surfaces (the copper plates), while the iron plates (acting as anodes) became dissolved into the solution. To prevent the impurities from the iron mixing with the pure deposited copper, the inventors employed a porous diaphragm of cotton cloth between the two sets of plates. Instead of employing copper cathodes, they sometimes used leaden ones, from which the copper was more readily detached. Since during the electrolytic action the solution naturally grew weaker in copper, being replaced by sulphate of iron, these ingenious inventors provided a system of automatic circulation by means of leaden pipes connected with reservoirs, whose valves were controlled by the rise and fall of hydrometers. One set of pipes delivered fresh copper solution to the bottom of the tank, which of course caused the liquid to rise in the vessel: another pipe placed at the upper part of the tank drew off some of the sulphate of iron, and in this way the solution always maintained the same density, and contained one uniform proportion of copper. The sulphate of iron liquor was afterwards evaporated, and the salt obtained by crystallisation, which could then either be disposed of as copperas, or employed in treating fresh batches of ore. It is stated that about 2,200 lbs. of copper could be reduced per day by the above process. In a subsequent addition to their patent, MM. Dechaud and Gaultier describe a method of utilising the sulphurous acid gas liberated during the roasting of the ore.

Electrolytic Refining of Copper by Separate Current.—This method of obtaining pure copper is now most extensively carried on in various parts of England, on the Continent, and in America, the amount of pure metal annually produced being enormous. One great advantage of this method of refining is that the crude coppers operated upon frequently contain considerable quantities of gold and silver, which valuable metals become entirely removed from the impure metal, and are readily recovered by ordinary refining processes. Another important feature in this system is that when the process is properly conducted the copper obtained is pure—a most important consideration when the metal is required for conducting electricity, as in the case of wire for submarine cables, telegraphs, and the wires employed in the construction of magneto and dynamo-electric machines, and other electrical apparatus. Respecting the presence of gold in copper refined by the ordinary method, or "dry way," we remember the great public excitement that occurred about the year 1844, when it was discovered that the copper coinage of William IV. contained a considerable quantity of gold. So soon as the fact became known, many persons of the Hebrew persuasion became large purchasers of penny pieces, at prices ranging from three-halfpence to twopence each, and many were those who enjoyed the luxury of collecting these coins for the purpose of reaping the advantage of their extra market value. It is well known that by the ordinary refining processes it is practically impossible to extract from copper the gold and silver which not unfrequently exist in this metal in considerable quantities. By the electrolytic method, however, not only are these precious metals recovered, as a natural part of the process, but other impurities—as bismuth, arsenic, iron, manganese, &c.—become separated, and chemically pure copper is obtained, which, from its superior conductivity, realises a higher market value than the best refined copper obtainable in the "dry way."

In the following pages we have given the views and experiences of some of the highest authorities upon the subject of electrolytic refining, from which not only the student, but the practical operator, will glean much that is instructive and useful in this important branch of electro-deposition. A few observations upon the general principles of electro-metallurgy, as applied to the refining of copper more especially, may, however, prove useful to those who have not as yet studied the subject. In the electrolytic process of refining copper, the electrolyte employed is a nearly saturated solution of sulphate of copper, contained in a series of tanks, which are placed in electrical communication with each other by copper connections, as many as forty baths or even more being electrolysed by the current from a single magneto or dynamo-electric machine, which, however, is usually an exceedingly powerful generator of the current, or more properly converter of heat into electricity. The wires which form the coils of the dynamo machines* employed in the electrolytic treatment of copper are usually drawn from the chemically pure copper obtained by the eletrolytic method, and therefore possess the highest conductivity of which this metal is susceptible. In the best constructed machines to be used for depositing copper, the thickness of the coil wires is so regulated that a current of low electric-motive force—frequently from one to three volts only—is obtained, by which the purity of the copper deposit is insured, and the deposition of metallic impurities upon the cathode (which require a higher E.M.F.) prevented. In most electrolytic copper refining works the anodes consist of cast slabs or plates of *crude* copper, containing not more than from 3 to 4 per cent. of impurities. The cathodes are thin sheets of *pure* copper, presenting the same surface as the anodes. To diminish the resistance of the bath as much as possible, the anodes and cathodes are arranged as close to each other as practicable without danger of coming in contact. When the current passes through the series of tanks, the sulphate of copper solution becomes decomposed, its copper being gradually deposited upon the cathodes, while the liberated sulphuric acid dissolves an equivalent proportion of copper from the anodes, forming sulphate of copper, by which the strength of the solution is kept uniform—that is to say, so far as the impurities of the copper will allow. If pure copper anodes were employed, the solution would keep in a perfectly uniform condition, excepting as regards loss of water by evaporation; but with impure anodes the bath gradually becomes charged with iron and some other soluble metallic impurities, which in course of time render the bath too foul, if we may use the term, to be further worked, in which case the solution is removed and replaced by a fresh solution of sulphate of copper. The deposit or "mud" which collects at the bottom of the tanks is removed from time to time, and the gold and silver afterwards recovered by the ordinary processes of refining.

In arranging an electrolytic copper refining plant, the resistance of the bath is diminished by increasing the anode and cathode surfaces, by which the cost of the electricity—and consequently of the motive power—is greatly reduced. If, however, this is carried to the fullest extent, it necessarily involves the employment of a costly stock of copper as anodes; it is therefore preferred by some electro-metallurgists (especially in districts where coal is cheap, or where water power can be obtained) to increase the expenditure of power rather than absorb interest on capital by increasing the quantity of copper in the baths, which would in many cases absorb a large proportion of the profits. When a quantity of copper is refined with a given power,

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* In speaking of dynamo-electric machines in connection with this subject, we wish to be understood as including magneto-electric machines also.

and it is desired to double the production without increasing the expenditure of power, it becomes necessary to quadruple the quantity of metal to be treated, which greatly increases the cost of the original establishment. The interest of the capital thus absorbed must therefore greatly reduce the annual profit. One hundred and fifty baths joined in series and worked with two powerful dynamo-electric machines, also joined in series, is considered by some an economical arrangement. The views of electricians, however, differ greatly in this respect, and we believe that the system adopted in this country and that pursued on the Continent are widely different in many essential features. We have been informed that some Continental machines require 10,000 square feet of copper surface (as anodes) per machine, which necessarily involves a very large amount of capital where a large number of machines are employed. With some of our English machines only 2,000 square feet of copper surface as anodes (or say 10 tons of copper) are required for a plant of the same out-putting capacity, which greatly reduces the amount of capital required for copper in stock. It must also be borne in mind that with the larger anode surface tanks of greater capacity are required, and consequently a larger bulk of copper solution, besides a proportionate increase in the cathode surface, and in the number of conducting rods.

Elkington's Process of Refining Copper by Electrolysis.—The impure copper, as it comes from the smelting furnace, is cast into slabs or plates, about 18 inches square and $\frac{3}{4}$ inch thick, with lugs projecting from their corners at one end. These plates are placed in troughs, each sufficiently long to take two plates, end to end; three such rows of plates, or six in all, are placed in each trough, a space of about 6 inches being left between the rows. The lugs of the plates rest on the ends of the trough, and upon a cross-bar fixed midway of its length, to which part strips of copper are attached, and these are all placed in metallic contact with each other. Cathodes of pure thin sheet copper (about $\frac{1}{32}$nd of an inch in thickness) are arranged between the rows of slabs or positive plates, the cathodes being about the same size as the cakes required for the market, or about 12 by 6 inches. There may be four such plates (cathodes) in each row, or sixteen in each trough. These negative plates are each cut with a projecting tongue, by which they are fixed to a frame made of copper rods, the tongue of each plate being lapped round the frame and thus connected and held. The frame has arms at its four corners, which rest on the sides of the trough, on which are copper strips insulated from the strips at the end of the trough. In this way a series of twenty-five troughs are made, the negative plates of one trough being connected with the positive plates of the next, and so on throughout the whole series, the positive plates being at one end of the series and the negative at the other. Care is taken that all metallic connections are clean and the contacts perfect. The troughs are charged with a nearly saturated solution of sulphate of copper. The negative and positive plates are then connected to the corresponding poles of a large magneto-electric machine, having, say, fifty permanent magnets weighing 28 lbs. each, and fully magnetised.* When the positive plates have become so far dissolved and corroded that fragments are likely to fall from them, they are replaced by others, and the old ones recast. The negative plates may be kept in the baths until they are ¾ inch in thickness.

The sulphate of copper solutions are kept at work until they become so charged with sulphate of iron that their further use is inconvenient, when they are changed, and the copper recovered by the usual means. The residue which accumulates at the bottom of the troughs is removed from time to time, and since it frequently contains a considerable percentage of silver, some gold, and also tin and antimony, it has a certain market value, and may be sold to the refiners. Mr. Elkington prefers to work with crude copper known as "blister" or "pimple copper," rather than with that obtained from the earlier stages of the smelting process, which contains higher percentages of impurity.

Dr. C. W. Siemens' Observations on the Electro-metallurgy of Copper.—In his address to the Society of Telegraph Engineers, in January, 1878, Dr. Siemens said, "The dynamo-electric machine has also been applied with considerable success to metallurgical processes, such as the precipitation of copper, in what is termed the 'wet process of smelting.' The effect of 1 horse-power expended in driving a dynamo-electric machine of suitable construction is to precipitate 1,120 lbs. of copper per 24 hours, equivalent to an expenditure of 72 lbs. of coal, taking a consumption of 3 lbs. of coal per horse-power per hour." It is stated that even this startling result has been surpassed, owing in a great measure to the important improvements in dynamo-electric machines which have been effected since the above gratifying statement of the great electrician was made.

Mr. B. N. S. Keith on Refining Copper by Electrolysis.—In a very able paper upon this subject, Mr. Keith proposes the following experiments to show under what conditions an increase of copper deposit may be obtained from a given value of electric power, and the important results obtained will prove invaluable to students and to those who are engaged in depositing copper either in electro-

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* The machines referred to have been greatly improved by Mr. Wilde since, as will be noticed on referring to page 26.

typing or in the process of refining by electrolysis. We extract the following from this interesting paper, but refer the reader to the journal in which it appeared * for more elaborate details. Mr. Keith says: "Take a Smee cell, having 5 Volt. electro-motive force, ·5 ohm. resistance, and connect with a copper electrolysing cell having a resistance of ·5 ohm. The result will be a current of ·5 Veber; one Veber current causes the solution of 18·0 grains of copper from the anode, and deposition of the same amount of copper per hour upon the cathode of an electrolysing cell. An equivalent quantity of 18·46 grains of zinc is dissolved in the Smee cell. So the amount of copper deposited by this arrangement is 9·0 grains per hour. Next take a Daniell cell, having an E.M.F. of 1 Volt., resistance of ·5 ohm., and connect with the same electrolysing cell. The current will be 1 Veber. The amount of copper deposited by this arrangement is 18·0 grains per hour, and 18·46 grains of zinc are dissolved in the Daniell cell. Next take a Bunsen cell, having say 2 Volts. E.M.F. and resistance of ·5 ohm., connect with the electrolysing cell, and we have a current of 2 Vebers. The copper deposited is now 36 grains per hour, and 36·92 grains of zinc are dissolved. In these three cases we observe that increased E.M.F. increases the speed of the deposition, *i.e.* more copper is deposited per hour. We also observe that the relative quantity of zinc dissolved remains the same in the three cases—*i.e.* an equivalent of zinc for an equivalent of copper. We cannot well change the E.M.F. of these cells, but we can their resistance, by making them larger for less resistance, and smaller for more resistance. We can in the same way change resistance of electrolysing cells. For less resistance, make the anode and cathode larger. Having made two electrolysing cells, twice as large as the one we have been using, they have each then a resistance of ·25 ohm. Connect in succession the several galvanic cells with the electrolysing cells, as by the accompanying diagram, Fig. 121, in which the arrows show the direction of the current." 1 is the battery cell, Z and S signifying the zinc and silver elements, 2 and 3 are electrolysing cells, A C representing the anodes and cathodes respectively.

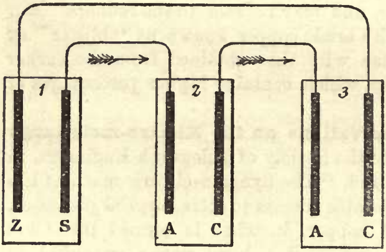

Fig. 121.

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* *Engineering and Mining Journal*, New York.

By the above arrangement the E.M.F's., the resistance, and the current are the same, and the same amount of copper deposited in each of the electrolysing cells, or twice as much in the aggregate as before, while no more zinc is consumed. It is the same when 3, 4, 10, or more electrolysing cells are used, their size being increased 3, 4, 10 times, as the case may be, so as to preserve the same resistance, and it is found that 3, 4, 10, &c., times as much copper is deposited, with no increase in the consumption of the zinc. It will be observed that the speed of the deposit with the Daniell cell series was twice as much as in the case of the Smee, and with the Bunsen four times as much as the latter. "This relation continues throughout," says Mr. Keith, "as the character of the deposit changes with increased cathode surface, the tendency being to form crystals of metallic copper, not coherent; the practical limit of number of electrolysing cells is sooner reached with the battery of lowest E.M.F." Mr. Keith gives the following table of his experiments:—

1. Galvanic Cell.	2. Electro-motive force in Volts.	3. Resistance of cell in ohms.	4. No. of electrolysing cells.	5. Resistance of each electrolysing cell in ohms.	6. Total resistance in ohms.	7. Zinc dissolved per hour, grains.	8. Grains of copper deposited in each electrolysing cell per hour.	9. Total copper deposited per hour in grains.	10. Current in Vebers.
Smee . . .	0·5	0·5	1	0·50	1·00	9·23	9·01	9·01	0·5
„ . . .	0·5	0·5	2	0·25	1·00	9·23	9·01	18·03	0·5
„ . . .	0·5	0·5	3	0·166	1·00	9·23	9·01	27·04	0·5
„ . . .	0·5	0·5	4	0·125	1·00	9·23	9·01	36·06	0·5
„ . . .	0·5	0·5	10	0·05	1·00	9·23	9·01	90·15	0·5
Daniell . .	1·0	0·5	1	0·50	1·00	18·46	18·03	18·03	1·0
„ . .	1·0	0·5	2	0·25	1·00	18·46	18·03	36·06	1·0
„ . .	1·0	0·5	4	0·125	1·00	18·46	18·03	72·12	1·0
„ . .	1·0	0·5	10	0·05	1·00	18·46	18·03	180·30	1·0
Bunsen . .	2·0	0·5	1	0·50	1·00	36·92	36·06	36·06	2·0
„ . .	2·0	0.5	2	0·25	1·00	36·92	36·06	72·12	2·0
„ . .	2·0	0·5	4	0·125	1·00	36·92	36·06	144·24	2·0
„ .	2·0	0·5	10	0·05	1·00	36·92	36·06	360·60	2·0

The foregoing figures are not given as exact, but near enough to illustrate the principles involved.

Refining Copper by Dynamo-electricity.—The dynamo-electric machines employed in refining copper by electrolysis are constructed to yield currents of low E.M.F., because the soluble anodes, being of the same material as that deposited upon the cathode, no force is absorbed during the solution and reduction of the metal. Dynamo machines of high E.M.F. and low resistance require smaller anode and cathode surface in the electrolytic bath for a given amount of copper deposited, while those of low E.M.F. and low resistance, yielding currents of great quantity, require much larger anode and cathode surfaces for the same amount of copper deposited. The latter type of machine is less costly than the former.

Copper, regulus, blue metal, black metal, &c., vary in their constitution from say 74 to 98 per cent. of copper, with varying proportions of sulphur and iron as the chief impurities. The impure metal is made the anode in a bath of sulphate of copper, and sheet copper is employed as the cathode. During the electrolysis copper and iron are dissolved, and copper is deposited on the cathodes at the same rate as it is dissolved. Sulphur will remain undissolved, and will rise to the surface of the solution in flocculent masses, which may be collected. Iron and zinc remain in the solution, and lead falls down as sulphate of lead. If gold and silver be present, the former will fall to the bottom as a metallic powder, and if small quantities of chlorides (as common salt, for instance) are added to the solution, the latter will also fall to the bottom in the form of chloride of silver. The insoluble residues may be collected, and the precious metals recovered by the usual processes. When the solution becomes surcharged with iron, zinc, &c., a portion of the solution is removed from time to time and replaced by water and sulphuric acid, by which means it may be kept in working condition for an indefinite period. The sulphuric acid is added to dissolve the iron, zinc, &c., and no more than is necessary for this purpose need be employed. The purer the copper under treatment, the less acid will be required, and also smaller proportions of the solution will require to be removed.—(*Keith*). The economy of the operation, says the same author, "consists in using a proper dynamo-electric machine, with large vats, large surfaces of the impure metal, large surfaces of copper to receive the deposits composing each electrolysing cell, and many of the cells placed in series."

M. Thénard's Experiments.*—This famous chemist made some investigations concerning the advantages of the compound bath in electrolysis, the source of the current being a Gramme magneto-electric machine, having a permanent Jamin magnet, and driven by a Lenoir engine. The liquid used was composed of 125 parts of sulphate of copper, the same amount of sulphuric acid, and 1,000 parts of water. The number of revolutions was from 1,200 to 1,300 per minute; the electrodes immersed in each bath were three plates of

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* *Scientific American Supplement.* 1877.

64·7 inches in area, each placed parallel and facing each other. The outer plates of each group, distant from the middle one 0·78 inch, worked positively, the inner plate negatively, so that the latter, on its two faces, became charged with the copper from its neighbours. Sixteen baths were so arranged, and the current established. At the end of one hour the exact weights of the middle cathodes were determined, there being upon each a regular [reguline ?] and strongly adherent deposit. Then, at intervals of twenty minutes thereafter, one bath was removed, so that the current might first pass through sixteen, then fifteen, and so on, until all the baths had been taken out of action. The middle cathode of each bath in turn, on stoppage, was removed, washed, dried, and accurately weighed. The following table exhibits in grains the result of the investigation :—

No. of Baths.	Period of immersion.		Augmentation of weight of each cathode.	Gain per cathode per twenty minutes.	Total weight of copper deposited in twenty minutes.
	h.	m.			
16	0	20	1·210	1·210	19·360
15	0	40	2·445	1·222	18·330
14	1	00	3·725	1.241	17·374
13	1	20	5·085	1·271	16·523
12	1	40	6·495	1·299	15·588
11	2	00	7·995	1·332	14·652
10	2	20	9·535	1·362	13·620
9	2	40	11·155	1·394	12·546
8	3	00	12·775	1·419	11·352
7	3	20	14·535	1·453	10·171
6	3	40	16·270	1·480	8·880
5	4	00	18·040	1·500	7·500
4	4	20	19·990	1·540	6·160
3	4	40	22·000	1·570	4·710
2	5	00	24·140	1·610	3·280
1	5	20	26·290	1·640	1·640

It will be seen from this that the quantity of copper deposited in a given time augments with the number of baths, although the cathodes of each one of the latter is charged with a less amount of metal. The mechanical effort, on the other hand, was found to increase very sensibly with the diminution in the number of baths. These experiments were many times repeated with uniform results. The electrodes were then connected for quantity, instead of for tension, and it was found that the sum of all the deposits was constant, regardless of the number of electrodes. The quality of the deposit was moreover improved in proportion to the augmentation of the latter.

These results "demonstrate," Mr. Keith observes, "that less power (in proportion of 1·210 to 1·640) was required to produce a deposit of 19·360 in 16 vats in 20 minutes than to deposit 1·640 in a single vat in the same time, thus saving about 94 per cent. of the power. If the size of the electrodes had been increased, so as to keep the total resistances the same, the result would have been 1·640 × 16 = 26·240 for the same power used. If the vats had been increased in number to thirty-two, without increasing their size, the power used would have been about one-half what was used with one, and the total deposit about 26·200. If they had been increased in size as well as number to thirty-two, so as to have the total resistances the same, the result would have been 52·480 for the same amount of power expended on one, a saving of 97 per cent. in power."

It will thus be seen that the economy of the electrolytic process of refining crude copper depends upon the employment of a large number of depositing vats, large anode and cathode surfaces in each vat, and an uniform electrolyte; the amount of deposit per hour, or per day, will, however, depend greatly upon the percentage of impurities in the crude copper anodes. The system adopted at different refineries varies considerably, as also do the machines employed for producing the current; for example, Wilde's improved 32-magnet machine (Fig. 26) requires a series of 130 vats, each having 40 square feet of anode and cathode surface respectively, with which arrangement an aggregate weight of upwards of 900 lbs. of copper will be deposited in twenty-four hours, with an expenditure of 12 horse-power. With a Siemens C_{12} machine only 40 baths are required, and several other machines are worked with the same number of baths. At the North German works at Hamburg one installation consists of 40 baths, while in two other series 120 baths are employed.

Dr. Higgs's Observations.—At a meeting of the Institute of Civil Engineers in 1878, Dr. Higgs made the following statement upon this subject: "For the deposition of large quantities of metal, where, by arranging baths in succession, little change was made in the total circuit-resistance, the dynamo-electric machines gave much greater economy. With one of these machines and a proper succession of vats, as much as 3 tons of copper have been deposited daily. It is to be observed that the amount of power applied is not stated. I am informed that 1,500 depositing cells are in use. One set of 327 are placed 109 in series, and three in 'multiple arc.' It is without question the cheapest mode of solution of metals, and so little acid is used. In fact, none is necessary after the first solution is made, unless the impure metal contains iron, zinc, &c., which it may not be desirable to save; then only enough acid to dissolve them is necessary."

Dr. Kiliani's Observations on Electrolytic Refining of Copper.—Dr. Martin Kiliani, of Munich, recently published a long paper in the German *Berg-und Hüttenmännische Zeitung*, which in an abridged form is reproduced in *Engineering*,* from which journal we will make the following extracts. Referring to Elkington's process before described, Dr. Kiliani observes, "But however simple this process seems in outline, there are many points which would bring great difficulties to an inexperienced person attempting the use of it, if he desired to get, not only silver and gold, but also a good quality of copper. These points depend on the presence of such impurities as arsenic, antimony, bismuth, &c., and on the necessity of carefully observing certain conditions as to strength of current, composition, and circulation of the solution, &c. Elkington, in his patents, does not deal with those points, and this is perhaps the reason, together with the lack of suitable dynamo machines, why the electro-metallurgy of copper did not make much progress beyond Elkington's works till within the last few years. It is really only during the last decade [more particularly within the past three or four years] that the immense progress of electro-technics has extended also to metallurgy, and enabled great successes to be realised in the working of copper, and opened up the prospect of equal successes in other directions." As to the nature of the process itself, Dr. Kiliani begins by saying that the basis of the whole matter consists in the simple fact that when an alloy of several metals forms the anode in the bath, the electric current does not cause the solution of all the component metals at the same time, but that it makes a selection, and takes one metal after the other in a certain order; and similarly, when several metals are in solution in a bath, the current selects them in a certain order for deposition on the cathode. A fully satisfactory scientific explanation of these facts cannot be attempted, because the whole matter is even yet too little studied, and the materials for a full explanation have not yet been collected. Even as concerns the order of this solution and deposition there are only full materials published concerning silver, copper, iron, zinc, and lead, and then only so far as concerns some few electrolytes. About those elements which are specially troublesome and important in the metallurgy of copper, arsenic, antimony, bismuth, &c., the published information is very superficial and scanty, and in some instances quite incorrect.

With regard to the selection of the different metals by the current, Dr. Kiliani says that this "takes place, in general, on the principle that as much energy as possible is created (*erzeugt*) and as little energy as possible is consumed;" that is to say, under conditions that metal will be first dissolved from the anode, the solution of which causes the development of the greatest amount of energy (electro-

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* *Engineering*, July 3, 1885.

motive force); and that the metal will be first deposited from the solution on to the cathode, the separation of which requires the least consumption of this same energy. A comparative measure of the energy required in these cases is obtained by taking the heat of combination of the metals with oxygen to form oxides or salts. The combination heat of the metals with oxygen to form oxides is taken by the author to form a tabular list in the order in which they are dissolved, as follows:—Manganese, zinc, iron, tin, cadmium, cobalt, nickel, lead, arsenic, bismuth, antimony, copper, silver, gold. Of this list it may be said that all those metals which precede copper, when they are present in the anode metals (not oxides) together with copper, will be attacked by the current before the copper; whereas silver and gold will only be dissolved after the copper, or if they are present in very small amount, they will fall from the anode as powder, and be found in the "mud" of the bath. In practice this order is fully maintained, and all the above metals dissolve before the copper, and are found in solution in the electrolyte, unless they form insoluble compounds, for example, with lead, when the bath is a sulphate, as in refining copper. When the metals are once in solution, their deposition on the cathode takes place in the reverse order, beginning with gold and ending with manganese. But the correctness of these rules is dependent upon several conditions which must be observed in order that the work may go on in a normal manner. The chief of these conditions concerns the strength of the current, the nature of the electrolyte, the proportions of the metals alloyed together in the anode, and the physical condition of the anode itself.

If the current exceeds a certain strength, all the metals may be dissolved and deposited together. The more neutral the electrolyte is, the more easily will the more electro-negative metals be dissolved, and the more easily will the electro-positive metals be deposited. The same may be said of the electrolyte, the poorer it is in copper solution. If the anode consists of copper containing a large amount of impurities, these will be dissolved more easily than from a copper containing but little impurity. The less dense and compact the anode is, the better the process will go on. This all applies only to copper containing the other metals in the metallic form. If oxides or sulphides are present, the first question is as to their conductivity for the current. Most oxides may be classed as non-conductors under the conditions of the bath, and have nothing to do with the action of the current; they simply go into the insoluble mud, or are dissolved by the purely chemical action of the electrolyte.

The sulphides are mostly good conductors, but not nearly so good as metallic copper. If, therefore, but a small amount of sulphides is contained in the copper anode, the current will act only on the copper and the sulphides will be found in the mud unacted upon, unless by the acid of the bath; if much sulphide is contained in the copper, the current will be more or less divided between the copper and sulphide, and a portion of the latter will be decomposed, with separation of sulphur. In addition to the above secondary reactions of the bath, there are others, some of which are good and some bad, for conducting the process. The current is always striving to decompose the electrolyte into metal (or oxide) and acid; whilst the liberated acid is striving to redissolve the deposited metal or oxide. These two forces are always opposed to one another, and under varying conditions either may gain the upper hand. The resolvent action of the acid, in cases where the components of the electrolyte have a strong chemical affinity, may overpower the action of a weak current.

In the case of copper this secondary reaction is not of much importance, copper not being acted upon by dilute sulphuric acid in the absence of air, but still it is quite noticeable in presence of good circulation of the liquor, and more or less access of air in the cathodes. A favourable effect of this secondary action is that any cupreous oxide which may be deposited at the cathode with the copper owing to weakness of current, is dissolved again.

Respecting the presence of foreign metals and oxides in the anodes, Dr. Kiliani says, "Cupreous oxide, being a bad conductor, is not affected by the current and goes first of all to the mud of the bath. It is then, however, dissolved by the free acid, more or less, according to the time the acid is allowed to remain in the tank. Therefore any cupreous oxide contained in the anodes diminishes the free acid of the electrolyte, and increases the amount of copper in solution." As to sulphide of copper, if it does not exceed in quantity that usually present in "black copper," it deposits in the mud. If there be a high percentage of copper sulphide in the anode, it is decomposed with liberation of sulphur. Gold, silver, and platinum all remain undissolved in the mud when they are not present in considerable quantity, and so long as the electrolyte retains its normal composition as to free acid and dissolved copper. If the liquor becomes neutral the silver dissolves and becomes deposited on the cathode. Bismuth and its oxide go partly to the mud, as insoluble basic salt, and partly into solution, eventually precipitating as basic salt. The presence of metallic bismuth in the anode causes the liquor to become poorer in copper, while the presence of its oxide causes a reduction in the amount of free acid. Bismuth does not become deposited upon the cathode, even when large quantities of the basic salt accumulate in the mud, provided the bath be kept in its normal condition as to copper and acid. Tin dissolves in the bath and after awhile is partly deposited again as basic salt. If the anode contains very much tin, the greater portion remains as basic sulphate, adhering to the anode itself in the form of a deposit of a dirty grey colour while moist, but becoming white when air-dried, increasing rapidly in weight even after long drying at 212° Fahr.; it contains sulphuric acid, and the tin oxide in it is mostly of the variety soluble in hydrochloric acid. The presence of tin, therefore, reduces the amount of copper in the bath without replacing it by any appreciable amount of tin in solution. The tin in solution exercises a surprisingly favourable influence on the copper deposit on the cathode. Copper deposited from a neutral solution of pure copper is rough, irregular, and brittle, but if tin be present the deposits are excellent and tough, even though the deposits give no trace of tin. The resistance of the bath is also much reduced by the presence of tin in the anodes. If arsenic be present in the metallic state, it enters the solution as arsenious acid, and only appears in the mud when the solution is saturated with it. Arsenic in the form of arsenic acid combined with oxide of copper, or other oxides, is at once deposited as mud in neutral solutions, since these oxide combinations are non-conductors. Metallic arsenic thus reduces the amount of copper, and increases that of the free acid in the bath, because it goes into the solution without combining with an equivalent of acid, while at the same time a proportionate amount of copper is deposited with liberation of acid. Arsenic does not enter into the copper deposit in the cathode while the bath remains normal as to copper and free acid; in a neutral bath, or one in which the copper is insufficient, arsenic is deposited with the copper.

In reference to the above experiments, it must be borne in mind that they were conducted only upon a laboratory scale, at the Technical High School at Munich, and, therefore, should not be accepted as ruling operations conducted on a large commercial scale. We may assume, moreover, without questioning their value as facts, that the results were obtained by means of voltaic batteries, and these we know are not so reliable as dynamo or magneto-electric machines properly constructed to yield large currents of low electro-motive force, suitable for the deposition of copper. In the electrolytic treatment of copper, it is undoubtedly of the greatest importance that not a trace of arsenic, bismuth, or any foreign metal should be present in the deposited copper, since it is well known that even one-fifth per cent. of iron depreciates the conductivity of copper by 25 per cent., while a mere trace of arsenic reduces its conductivity by 66 per cent. The uniform character of the deposit and its absolute purity will depend upon the keen observation of the electro-metallurgist, who, while taking care that the machines he employs yield the exact quality of current necessary for the reduction of copper, will also devote special attention to the condition of his electrolytes, and the removal of the mud so soon as its accumulation in the baths involves risk of partial re-solution. As far as the nature of the current is concerned, it will be seen, by the foregoing remarks, that the requirements of electrolytic copper refiners have been fully met by those of our electrical engineers who have paid special attention to this subject. There has been much said about the "secrecy" observed at some of the British and Continental works in respect of their electrolytic operations; it must be borne in mind, however, that although the principles of the electrolytic art are common property, *practice* may vary considerably, and special advantages may arise from the suggestiveness or keenness of observation of an expert in one establishment, which, if known to competitors, would reduce their value. These technical advantages often represent extra profit. We need say no more.

Gramme's Experiments with Sulphate of Copper Baths.—With a view to determine the proper conditions under which electrolytic copper refining should be conducted upon economical principles, M. Gramme carried out a series of important experiments, the results of which he communicated to the Academy of Science, in August, 1877, from an abstract of which, by M. Fontaine, we take the following (see pp. 412, 413):—

First Series of Experiments.—These experiments were conducted with a continuous-current dynamo-electric machine, with a varying number of baths, all placed parallel, and the results showed that, with one or thirty-six baths the deposition is the same with a constant intensity, which confirmed Faraday's law upon a commercial scale. Each bath contained one anode and one cathode only, each having a surface of 16 square decimetres. The intensity [strength?] of the current was 6·3 ampères. With one single bath the deposit was found to be at the rate of 7 grammes per hour; with 12 baths it was 7·1 grammes, and with 36 baths (that is with a surface of anodes equal to 6 square metres) it was 7·1 grammes, about 2 decigrammes per bath.

Second Series.—Table 1 gives the results of experiments conducted with baths connected in a chain, as in arranging a voltaic battery for tension; the number of these baths varied from one to forty-eight, each having electrodes of the same surface—namely, 16 square decimetres. The speed of the machine was increased as the number of the baths grew larger, and the electro-motive force varied from 1 to 8 volts. The figures of the tables show that the deposition of copper increased with the number of baths, not only in absolute quantity, but also in a ratio to the work expended in the operation. The weight of copper per kilogrammetre varied from 1·58 gramme up to 33·18 grammes, and even up to 140 grammes, if the loss of motive-power which was found to occur be taken into account; whereas in the first series of experiments the weight of the deposited copper did not

TABLE No. 1. SOLUBLE ANODES.—BATHS IN TENSION.—INVARIABLE SURFACE OF ANODE FOR EACH BATH.

Baths.								Work in kilogrammetres.				Deposition in grammes.				
					Temperature C.											
Nos. of the experiments.	Number.	Electromotive force.	Deviation of the galvanometer.	Total weights of the liquid in action.	Initial.	Final.	Rise due to the current.	Total.	Absorbed by the frictions.	Absorbed by the rising of the temperature.	Remainder.	Total in 3 hours.	Per hour.	Per bath and per hour.	Per kilogrammetre of the total work and per hour.	Per kilogrammetre of the remainder.
			°	Kilos.	°	°	°									
1	1	—	10.25	6.600	9.0	11.0	0.7	4.455	1.041	0.162	3.242	21.00	7.00	7.00	1.58	2.16
2	3	1.3	10.0	19.800	9.9	9.9	0.7	4.438	1.050	0.485	2.903	63.00	21.00	7.00	4.73	7.23
3	6	2.5	9.25	39.600	9.8	10.8	0.6	5.203	1.203	0.832	3.163	118.00	39.33	6.66	7.55	12.43
4	9	3.4	8.50	59.400	9.0	9.6	0.6	4.996	1.311	1.247	2.438	155.50	51.83	6.42	10.37	21.26
5	12	4.2	8.0	79.200	9.0	9.8	0.5	5.478	1.832	1.386	2.270	204.00	68.00	5.66	12.41	30.00
6	18	5.0	7.50	118.100	12.0	12.6	0.4	6.588	2.934	1.653	2.001	269.00	89.60	5.00	13.60	44.57
7	20	5.6	7.25	132.000	12.2	12.8	0.4	7.548	3.343	1.848	1.562	298.00	99.33	4.96	13.15	63.60
8	24	6.2	6.50	158.000	10.8	11.4	0.4	6.753	3.147	2.212	1.394	311.00	103.70	4.32	15.35	74.10
9	33	7.0	6.0	217.000	12.8	13.6	0.3	5.754	2.598	2.278	0.868	372.00	124.00	3.75	21.55	142.85
10	36	8.0	6.25	237.000	13.8	14.2	0.3	6.439	2.810	2.488	1.141	425.70	141.90	3.94	22.04	124.45
11	45	8.2	5.25	297.000	13.0	13.6	0.2	6.082	2.982	2.079	1.021	429.60	143.20	3.20	23.54	140.25
12	47	8.2	4.50	310.000	12.3	12.7	—	5.963	3.181	—	—	423.00	141.00	3.00	23.18	—
13		7.0	1.75	316.800	12.7	12.9	—	3.328	1.430	—	—	217.73	725.76	1.51	21.80	—

OBSERVATIONS.—1. The tension of the bath in experiment No. 1, and the rises of temperature in experiments Nos. 12 and 13, could not be determined. 2. The specific heat of the liquid was 0.89 3. In the calculation of the rise of temperature due to the current, the ambient temperature of the laboratory has naturally been taken into account. 4. No. 13 experiment had been made with a machine having much more tension than the one used for the twelve first ones. 5. The resistance of the machine used for the twelve first experiments was equal to that of a copper wire of 1 millimetre diameter and 27.58 metres long.

TABLE No. 2. SOLUBLE ANODES.—BATHS IN TENSION.—VARIABLE SURFACE OF ANODES.

Nos. of the experiments.	Baths.							Work in kilogrammetres.				Deposition in grammes.			
	Number.	Surface of each bath in square centimetres.	Deviation of the galvanometer.	Weight of the liquid in action.	Temperature C.			Total.	Absorbed by friction.	Absorbed by the rising of the temperature.	Remainder.	Total in one hour.	Per Bath.	Per kilogrammetre of the total work.	Per kilogrammetre of the remainder.
					Initial.	Final.	Rise due to the current.								
			°	Kilos.	°	°	°								
1	3	8·26	7·5	19·8	13·04	13·9	0·3	3·397	1·722	0·624	1·051	15·75	5·25	4·63	15·00
2	5	16·52	7·5	33·0	12·5	12·9	0·2	3·452	1·765	0·693	0·994	29·00	5·80	8·43	29·17
3	7	33·04	7·5	92·4	12·0	12·2	0·1	3·520	1·837	0·969	0·714	37·38	5·34	10·62	52·35
4	9	49·56	7·5	178·2	13·0	13·1	0·1	3·279	1·613			48·00	5·33	14·63	
5	11	66·08	7·5	280·4	12·9	13·1	0·1	3·449	1·788			61·60	5·60	17·85	

OBSERVATIONS.—1. The surface of the baths have been increased so as to obtain a constant deviation of the galvanometer. 2. The rise of temperature due to the current could not be determined in experiments Nos. 4 and 5.

TABLE No. 3. INSOLUBLE ANODES.

Nos. of the experiments.	Baths.							Work in kilogrammetres.				Deposition in grammes.			
	Number.	Deviation of the galvanometer.	Total weight of the liquids in action.	Temperature C.				Total.	Absorbed by friction.	Absorbed by the rising of the temperature.	Remainder.	Total in one hour.	Per Bath.	Per kilogrammetre of the total work.	Per kilogrammetre of the remainder.
				Initial.	Final.	Rise due to the current.									
		°	Kilos.	°	°	°									
1	1	11·00	6·6	10·3	11·5	0·9		7·615	2·459	0·627	5·529	7·0	7·0	0·92	1·26
2	3	8·25	19·8	10·2	11·1	0·5		8·504	4·302	0·044	3·158	16·0	5·33	1·88	5·06
3	6	5·00	52·8	10·1	10·6	0·2		7·840	4·370	1·114	2·356	18·0	3·00	2·28	7·64
4	12	11·00	79·2	11·6	11·9	0·2		7·615	2·459	0·835	4·321	7·5	0·62	0·98	1·66

OBSERVATIONS.—1. In the first three experiments the baths were rejoined in tension; in the fourth one, they were all joined in quantity. 2. The secondary current was 70° (vertical galvanometer), with six baths in tension, 40° with three baths, and 10° with one. 3. In No. 4 experiment the secondary current was 60°. 4. The duration of the first three was one hour; that of the fourth was two hours.

exceed 1·96 gramme. The practical fact to be deduced from these experiments is that when dynamo-electric machines are employed considerable economy is effected by joining the baths in series.

Third Series.—In this series of experiments Gramme determined to maintain constant the intensity of the current in a series of comparative trials, which induced him to increase the surface of the anodes and cathodes, as also the number of baths united in series, so as to maintain constant the total resistance of the circuit. In Table 2 it will be seen that the quantity of copper deposited in a bath is about the same in all the experiments. The speed of the machine and electro-motive force did not vary, and the work expended remained practically invariable.

"These experiments," says M. Fontaine, "are in perfect accordance with all the known theoretical notions except on one point; it will be at once observed that M. Gramme was driven to increase the sections of the liquid in a greater ratio than the number of baths joined in tension. However this may be, various circuits are seen here, with uniform resistance and invariable electro-motive force and intensity of current; it is therefore not surprising to see that in each part of these various circuits the quantity of deposited copper practically remains constant. But it will be observed that the total quantity of copper deposited in the complete circuit is proportional to the number of baths; from which it might be concluded that with a fixed expenditure of work it is possible by means of suitable arrangements to almost indefinitely increase the total deposition."

Fourth Series.—In these experiments M. Gramme substituted insoluble lead anodes for the copper anodes in the sulphate of copper baths, and found, as was to be expected, that the polarisation was considerable, while the deposition of copper was much less than before, owing, of course, to the lead anodes not keeping up the strength of the bath. M. Gramme thus sums up the results of his experiments: "I have placed myself in conditions which I believe to be favourable for the measurement of the work expended in each experiment; the constancy of the work was nearly perfect during the three hours which each experiment lasted; I constantly verified it by galvanometric observations. At the termination of the experiment I opened the circuit and placed a Prony brake on one of the fly-wheels of the gas-engine, bringing it back to the speed at which it ran during the electrolytic operation, and I concluded from it what had been the expenditure of work. I could easily afterwards, by disconnecting the gas-engine from the dynamo, ascertain what proportion of the motive-power was absorbed by the passive resistances of the latter. This quantity is given in the above three tables. I wished to go further and ascertain the loss of work corresponding to the heating of the baths, and have arrived at the results by the following means:—

"In every experiment I took both the initial and final temperature of the baths; an inactive bath placed near at hand served as a means of comparison. The difference between the final temperature of the active baths and of the inactive one represented the rise of temperature due to the current. Taking into account this difference, as also the quantity of the liquid operated upon, and the specific heat of the liquor, which I have found equal to 0·80, I obtained the number of calorics supplied to the baths by the passage of the current; multiplying them by the mechanical equivalent of heat, I obtained the quantity of work represented by this apparent heat. It will be understood that it is only the apparent and sensible heat of which I have thus been able to calculate the value; and that the results which I have obtained are inferior to the real figures. Deducting from the total work performed by the motor in each experiment the work corresponding to the friction of the electric machine and to the heating of the liquids, I obtained the quantity which I call remainder in the columns of my tables. In the experiments of the third series (Table No. 2), we have the irrefutable proof of the fact that the expenditure of work with soluble anodes in electrolysis can be taken as *nil;* for the deposition is seen to pass from 15 to 60 grammes, without giving rise to an increase of work which could be measured. If the experiments of Table No. 1 show everywhere a remainder of work, the use of which cannot be precisely determined, it must be observed that this remainder grows smaller as I realise some better conditions, and becomes as low as ·868 kilogrammetres, and so less than one-sixth of the total work. It is explained by calorific work in the other parts of the circuit."

The foregoing exhaustive experiments, conducted as they undoubtedly were with the utmost precision and care, not only confirm accepted theories, but also support the view that with a definite amount of current the deposit of copper may be increased almost *ad infinitum* by increasing the number of the baths in series—an important consideration in districts where fuel is dear and the cost of electricity proportionately high.

CHAPTER XXX.

ELECTRO-METALLURGY—(*continued*).

Progress of Electrolytic Copper Refining.—Copper Refining at Hamburg—Copper Refining at Biache.—Copper Refining at Marseilles.—Electrolytic Refining at Oker.—Electrolytic Refining at Birmingham.—Electrolytic Refining in America.—Electrolytic Treatment of Copper in Genoa.—Cost of Electrolytic Refining.—Arrangement of the Baths for Electrolytic Refining.

Progress of Electrolytic Copper Refining.—It is now about twenty years since the first practical development of the electrolytic method of refining copper was established by Mr. J. B. Elkington, with the aid of Mr. Henry Wilde's magneto-electric machines, and for many years the process was exclusively practised by this firm. Since that period, however, the method has been very extensively adopted, not only in this country, but on the Continent, more especially in Germany, Saxony, and France. The North German Refining Works at Hamburg have adopted the electrolytic method for upwards of ten years, the machines of M. Gramme being used. More recently it has been practised at the Oker Foundry, near the mines of Mansfeldt, Germany, with Siemens' large machines; by MM. Oeschger and Mesdach, at Biache (Gramme machines); by M. Hilarion Roux, at Marseilles, (Gramme); by MM. Lyon-Allemand, at Paris, and by M. André, at Frankfort (Gramme); by the Mansfeldt Mining Company, at Eisleben, and by Messrs. Sterne & Co., at Oker (Wilde's machines). Besides Messrs. Elkington's extensive works at Pembrey, South Wales, where Wilde's large machines are employed, the electrolytic refining process is carried on by Sir Hussey Vivian at Swansea (Gülcher and Crompton machines); by Mr. W. H. Hills at Chester (Gülcher machines); by Messrs. Williams, Foster, & Co. at Swansea (Crompton machines); Messrs. Charles Lambert & Co. (Gülcher machine); and by the Elliott Metal Refining Company at Selly Oak, near Birmingham, where Wilde's machines are employed. It will thus be seen that the electrolytic method of copper refining is gradually but surely making considerable progress; indeed, the important improvements which have recently been made in dynamo-electric machines have greatly influenced this result. From information which has been conveyed to us, we have no doubt that in a very short period the art of electrometallurgy will attain a far greater extent of development, both at home and abroad; and to this end manufacturers of dynamo-electric machines are devoting much attention to the construction of machines specially suited to electrolytic copper refining.

As we have before remarked, there is much difficulty in obtaining information as to the precise methods adopted at the various electrolytic refining works, nevertheless certain points of detail concerning the general system adopted at the respective establishments gradually find their way to the public by some occult means, as is usually the fate of all secret processes sooner or later. The following particulars concerning the principal refineries will give the reader a general idea of the special features of each system of working, and guide his judgment as to which is the most effective and economical. It must not be forgotten, however, that where water-power is not available for driving dynamo machines, the cost of fuel in the various districts is greatly different, often in the proportion of one to four. Besides this, the coppers refined at the various works differ considerably in the nature and proportions of their impurities, by which their conducting power as anodes is greatly influenced, and the cost of electricity increased or lessened accordingly.

Copper Refining at Hamburg.—The North German Refinery is under the control of Dr. Wohlwill, who has made the electro-metallurgy of copper his special study. To carry out his system at the above works, six large No. 1 Gramme machines are employed, besides which a still more powerful machine, constructed under his own direction, is used. The principal features of Dr. Wohlwill's method consist in keeping the various baths at a uniform strength, and always at the same temperature; the machines are made to revolve at regular speeds, and are kept in perfect order; all the coppers to be treated are subjected to analysis both before and after the electrolysis. It is by thus keeping all things equal that he is enabled to produce copper of very fine quality.

The first Gramme machine constructed for Dr. Wohlwill for the chief electrolytic installation at the North German Refinery is provided with two collectors and four brushes; each collector has twenty sections. The spirals of the bobbins are each composed of seven strips of copper 10 millimetres (0·4 inch) wide and 3 millimetres (or about $\frac{1}{8}$ inch) in thickness. Forty groups of copper ribbon correspond to the forty sections of the two collectors, so that each spiral is composed of two identical half spires juxtaposed, and soldered at their extremities to a radiating piece which connects them to one of the sections of the double collector. The inducted ring is therefore composed of forty partial bobbins, of which twenty are connected to the right-hand side, and a corresponding number to the left-hand side collector. The total resistance of the induced bobbin is ·0004 ohm; when the two parts are joined in parallel this resistance is reduced to ·0001 ohm. The E.M.F., with a speed of 500 revolutions per minute, is equal to 8 volts for the coupling in series, and to 4 volts for the coupling in parallel. The eight electro-magnets of this machine have iron cores 120 millimetres (or $4\frac{3}{4}$ inches) in diameter, and 410 millimetres (16·5 inches) in length. On these cores are wound thirty-two turns of sheet copper, corresponding in width to the length of the electro, and 1·1 millimetre in thickness. The resistance of the eight conductors in one single circuit is ·00142 ohm; when the electros are joined in two series their resistance becomes ·00038 ohm. The total resistance of the machine is therefore ·00038 ohm in quantity and ·00182 ohm in tension. The total weight of copper is 1,620 pounds, and that of the entire machine about 49 cwt. The normal output of current of this machine is said to be 3,000 ampères for 4 volts, and 1,500 ampères for 8 volts electro-motive force.

At the North German works there are forty baths arranged in two series of twenty; the anode surface in each bath is nearly 325 square feet, giving a total of 13,000 square feet of surface for the whole of the baths. The anodes and cathodes, or receiving plates, are arranged at about 2 inches apart. The copper is deposited on the cathodes to the thickness of about $\frac{1}{25}$ inch, and at the rate of about 64 pounds per hour, in all the baths, or 1,760 pounds per day of twenty-four hours. The motive power absorbed is about 16 horse-power, giving a production of 1 pound of pure copper with the consumption of 0·4 horse-power per hour. At the same works two other series of baths are employed, the number of which is 120, and these are connected in succession. Each bath is furnished with anodes exposing about 160 square feet of surface, and the entire series of 120 baths has a resistance of 0·1 ohm. The current for these baths is obtained from two No. 1 Gramme machines, connected together in series of 300 ampères, with an electro-motive force of 27 volts. The amount of copper deposited per day of twenty-four hours is 2,000 pounds, at an expenditure of 12 horse-power, or say $\frac{1}{7}$ horse-power per pound of copper per hour. The nature of the electrolyte employed at these works appears to be a secret. It has been affirmed that nitrates are used.

The cost of fuel being an important consideration at Hamburg, Dr. Wohlwill has specially designed his baths to economise motive power as far as possible. After an extensive series of practical trials, he found that considerable advantage was obtained by working with large cathode surfaces, and allowing only thin deposits to take place upon them. In his first installation the rate of deposit is only about 0·005 pound per square foot per hour, or only 0·00012 inch per hour in thickness; in the other installations referred to, the deposit is still further reduced, with, as will be seen, a considerable reduction in the expenditure of motive power. The value of copper under treatment in one of the installations at Hamburg is said to be equal to about £8,000.

Copper Refining at Biache.—Messrs. Œschger, Mesdach, & Co., of Biache-Saint-Waast, near the English Channel, have an installation in which a large Gramme machine, similar to that constructed for Dr. Wohlwill for the Hamburg works, is employed. Twenty baths are used, from which the daily production of copper is about 800 pounds. The baths are each about 10 feet long, 2 feet 6 inches wide, and 3 feet deep, and are constructed of wood nearly 3 inches thick, and lined with lead. These vats are coupled in series, and are charged with a solution of sulphate of copper maintained at a density of 19° Baumé. Each bath is furnished with 88 anodes and 69 cathodes of equal total surfaces; the anodes, which are 28 inches long, 6 inches wide, and $\frac{1}{3}$ inch thick, are arranged in 22 rows of 4. The cathodes, which are 34 inches long, 7 inches wide, and about $\frac{1}{10}$ inch thick, are placed in 23 rows of 3. The total surface under action represents, therefore, about 10,800 square feet. The copper is deposited upon the cathodes of sufficient thickness to be taken directly to the rolling-mill. The production of copper at these works is about 1,540 pounds per day of twenty-four hours, the thickness of the deposit being equal to about ·00012 inch per hour. The silver and gold (if any) are deposited in the "mud" at the bottom of the baths, and this is removed from time to time and washed, and after being dried is fused with litharge or with a reducing agent, the product in the former case being treated as argentiferous lead. When the electrolyte becomes heavily charged with iron and other impurities, it is evaporated and allowed to crystallise.

Copper Refining at Marseilles.—M. Hilarion Roux has an installation at his refinery in Marseilles, in which a No. 1 Gramme machine is employed. There are 40 baths, having a total anode surface of about 10,000 square feet, or about 250 square feet for each bath. There are 115 plates in each vat, each being 2 feet 3 inches long, 6 inches wide, and $\frac{4}{10}$ inch in thickness. Each plate weighs about 26 pounds. The plates are immersed about five-sixths of their length, the anodes and cathodes being placed at a distance of about 2 inches from each other. The total weight of copper under treatment is 54 tons, of which 23 pounds are refined per hour, or about 550 pounds per day, with an expenditure of 530 pounds of coal per day for driving the Gramme machine, which revolves at a speed of 850 revolutions, and absorbs about 5 horse-power. The bath is worked at a density of 16° to 18° Baumé,* and is maintained at a temperature of 25° C. (77°

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* Or about 18·267 per cent. of sulphate of copper.

Fahr.), the deposit being at the rate of 70,002 pounds per square foot of cathode.

Electrolytic Refining at Oker.—At these works, five large C_1 dynamo-electric machines furnished by Messrs. Siemens and Halske, of Berlin, are employed, one of which has been at work for upwards of four years. The machines have been constructed to give low internal resistance and great power in ampères, which has been effected by surrounding the soft iron and the bars of the electro-magnets with copper bars of rectangular section, instead of winding them with wire as in electric-light machines. The induced bobbin is provided with a series of bars with the Hefner-Alteneck system of winding; the corresponding bars are joined together by means of large spiral bands, placed on the face of the bobbin, opposite the collector. On the anterior face of the bobbin, on the collector side, the bars are connected to the latter by means of strong copper angle pieces. The inductor also consists of a single layer of copper bands coiled by series of seven on each branch, or twenty-eight in all. The bars are insulated by means of asbestos, which being a non-conductor, allows the machine to become heated without doing harm. Each machine works twelve large vats, and is driven, we understand, by water-power of from four to five horse-power, and deposits 1 kilogramme (2·2 lbs.) of copper per hour, or about 300 kilogrammes (6 cwt.) per day.

Electrolytic Refining at Birmingham.—The Elliott Metal Refining Company, of Selly Oak, near Birmingham, employ five large Wilde machines, which refine about ten tons of copper per week. The vats are arranged in five series of forty-eight in each, one Wilde machine being employed for each group of forty-eight baths. The vats are 2 feet 9 inches long, by the same width, and are 4 feet deep; each vat contains 16 anodes, which are each 2 feet long by 6 inches wide, and ½ inch thick, and weigh 26 pounds. There are only ten cathodes in each vat, each cathode being 1 foot 4 inches long, 22 inches wide, and ·03 inch in thickness, and weighing 2·86 pounds. The total weight of copper per bath is about 450 pounds, and in a series of forty-eight baths about ten tons. The anodes and cathodes are arranged at about 3½ inches apart. The anodes are immersed only to the extent of 20 inches of their length, so that the surface under action, including both surfaces of the anode, is only 1¾ square feet, or 30 square feet in each bath. The yield of copper for the forty-eight baths approximates 30 pounds per hour, or about ·65 pound per bath per hour, which corresponds to a current of 235 ampères. The anodes are replaced every five weeks, and the operation progresses for 156 consecutive hours per week. The temperature of the electrolytic department is uniformly maintained at 68° F.), and the density of the bath kept up to 16° B. The particulars concerning the improved Wilde machine adopted at these works are given in Chapter II.

Electrolytic Refining in America.—It is stated that the Balbach Refining Works in Newark, N.J., are probably the largest in the world, the daily production of copper being about six tons. The current is obtained from four dynamos, furnished by the Excelsior Electric Company, of Brooklyn, New York. Each of the dynamos is driven by an independent Westinghouse engine. The three larger dynamos produce a current of 30,000 watts each, while the fourth is a smaller machine of 15,000 watts capacity, which was put down for the firm about two years and a half ago, to enable them to ascertain whether the electrolytic method of refining was remunerative before embarking in the business upon a large scale. The work goes on day and night, with a short intermission each day for cleaning and oiling the engines and dynamos. The foundry for casting the anodes, the mechanical appliances for handling and transporting them and the finished plates, are all designed with the object of saving manual labour as far as possible. There is another large establishment in the States for the production of electrolytic copper and the separation of the precious metals, namely the St. Louis (Mo.) Smelting and Refining Company. Besides the two principal works above referred to, there are some other less important works, and the great interest taken in the results obtained shows that electro-metallurgy is making rapid strides on the other side of the Atlantic, where, of all places in the world, a successful process is sure to command attention, and when once taken in hand, pushed forward until it acquires the highest state of development that enterprise and a due appreciation of the advantages of labour-saving machinery can bestow upon it.

Electrolytic Treatment of Copper in Genoa.—A somewhat recent addition to the list of firms adopting the electrolytic treatment of copper is the Italian Mining and Electro-metallurgical Company of Genoa, whose works are at Casarza, but the system adopted differs considerably from that pursued by most other firms. The process may be thus briefly described:—A portion of the ore is melted to a crude metal, or matte, consisting of copper, 34·7; iron, 38·6; sulphur, 25·3, as given by a representative analysis. Another portion of the ore is roasted and lixiviated, to obtain a solution containing as much sulphate of copper as is required to render the ferrous sulphate of the anode available for the electrolysis of the copper salt. The anodes are formed of the matte obtained after the fusion of the mineral, being cast in iron moulds into plates 32 inches square by 1¼ inch thick. The melting is effected in a small furnace fed by a fan, 15 tons of ore being operated upon in twenty-four hours, yielding 50 plates weighing 176 pounds each; bands of copper are cast into the plates for connecting with the source of electricity. To prevent these bands from being acted upon by the solution, the liquid is kept about $\frac{3}{4}$ inch below the upper edge of the plates. The residues from the anodes, after the extraction of the sulphur, are returned to the furnace. The cathodes consist of thin plates of red copper, 28 inches square by $\frac{1}{64}$ inch in thickness, supported by a wooden frame. Upon these plates the copper is allowed to deposit to the thickness of $\frac{1}{4}$ inch. Dr. Higgs, from whose paper in the *Engineer* we obtained the above extract, says that, "by employing anodes of iron, copper, sulphur, such as ordinarily result from the first melting, the copper may be removed from the solution with an electrical efficiency comprised between 50 per cent. when there is no copper in the anodes, and of 100 per cent. where, on the contrary, there is no iron. With the use of metallic sulphides in the anodes, all the sulphur contained in the mattes may be regained in a metalloidal state. The deposit is of good quality as long as the baths contain in solution about 0·1 per cent. of copper. After exhaustion of the copper, the solution contains basic persulphate of iron, protosulphate of iron, and sulphuric acid."

The electrolyte, or sulphate of copper, bath is obtained by roasting very rich ores and mattes in a reverberatory furnace, the roasting being so conducted as to yield more oxides than sulphides; oxide of iron not being soluble in dilute sulphuric acid very little sulphate forms in the solution. The electrolyte is kept up to a normal strength of copper (about 4 per cent.) by circulation over roasted minerals. When the bath from excess of iron yields a pulverulent deposit of copper, with evolution of hydrogen, it is renewed. The baths are 6 feet 9 inches long, 3 feet wide, and 40 inches deep, made from wood and lined with lead. About twelve of these baths are required to yield 2 cwt. of copper per day, for which twenty dynamo machines, arranged in two groups of ten each, are employed, and each machine is connected with twelve baths arranged in chain. The dynamos yield a current of 250 ampères at 15 volts, and each bath is furnished with fifteen anodes and sixteen cathodes arranged two inches apart. The motive power is obtained from turbines.

Cost of Electrolytic Copper Refining.—When it is borne in mind that the electrolytic method of refining copper is pursued at the various works under totally different conditions, and that it is evidently not to the advantage of the respective competitors to make publicly known the special means by which they secure economy in the cost of their production, it will be at once seen that any published data in this connection must be received with caution. It is true that the capabilities of the leading dynamo-electric machines are well known, and that a given current will do a certain amount of work; the coppers operated upon at different refineries, however, vary considerably in the nature and extent of their impurities, which of course influences their conductivity; again, the systems of working are different, some employing larger anode and cathode surface than others, while, again, the condition and strength of the electrolytic is varied according to the judgment and experience of each electro-metallurgist, according to the particular metal which he has to treat. That electrolytic copper refining has proved to be a profitable method of obtaining pure copper in large quantities at several large works may be considered as proved, by the fact that the process has been carried on without intermission for a great number of years.

To arrive at an approximation of the cost of electrolytic refining of copper, it will be necessary to refer to Mr. Sprague's experiments on the deposition of copper which were conducted with a bath composed of saturated solution of sulphate of copper, 3 parts; sulphuric acid, 10 parts, diluted with ten times its volume of water. The source of electricity employed was a Daniell cell, and the current was varied by varying the resistances, so that a given thickness (·0035 inch) was obtained in thirty hours as the slowest, and forty-five minutes as the quickest rate. Between a thickness of ·00012 inch—determined by repeated weighings—and ·00144 inch deposit per hour, the deposits were good, up to the limit of the last; beyond this all quicker rates yielded defective deposits. Mr. Sprague concluded from these results, that the limit of current of 1 ampère to 33 centimetres, or about 5 square inches, could not be exceeded with advantage. This rate, from one to twelve, corresponds to 300 ampères per square metre, or nearly 30 ampères per square foot of anode. These results, however, would not be obtained in practice from the causes previously indicated (impure anodes, &c.); indeed, even under the most favourable conditions and with pure anodes, the deposit of copper in electrotyping seldom exceeds one-third of this rate. The following table shows the thickness of deposit obtained in a working week of 156 hours, including the results obtained by Mr. Sprague and M. Gramme.

	Inches.
Maximum deposit (chemically pure anodes) .	·067
Sprague's results (good deposits) . . .	·02 to ·24
Gramme's results	·0036 to ·025
Hamburg Works	·02 ·006
Biache Refinery	·02
Marseilles Works	·007
Selly Oak Works, Birmingham	·06

The purity of the deposited copper obtained by electrolysis depends upon several important conditions, either of which will greatly influence the character of the deposits; these are: the strength and tension of the current; the percentage of impurities in the anodes; the altered condition of the electrolyte after dissolving out impurities from the anodes; the distance between the anode and cathode surfaces; and the temperature and density of the solutions. To these points Dr. Wohlwill appears to have paid special attention, and as a consequence is accredited with producing copper of great excellence. The quality of copper is found to be uniformly pure when Mr. Sprague's limit is not exceeded.

In estimating the cost of electrolytic copper refining, we have to take into consideration the interest on the capital embarked; the cost of fuel absorbed in driving the dynamos; the cost of labour; the cost of recovering sulphate of copper, &c., from the baths; and the general expenditure of the establishment. Since many refiners are also dealers in the metal, the amount of copper in stock, as anodes, is not of so much consequence, since it is a matter of indifference to them whether it be employed as anodes or otherwise, except in the event of sudden fluctuations in the market prices, when important losses might result. The cost of fuel on the Continent is considerably higher than in Birmingham or Swansea. Upon this point M. Fontaine says: "We can estimate the cost of fuel at twenty francs per ton, although that price would be too high in the case of Birmingham, sufficiently approximate for Hamburg, and quite insufficient for Marseilles. However, as we are only making a comparison, we will maintain an uniform price; it will always be easy afterwards to recalculate the cost, taking as a basis the actual cost of fuel in the locality considered.

"An engine from 4 to 5 horse-power consumes 20 kilogrammes of fuel per hour; the wages of the driver being estimated at 60 centimes per hour, and the necessary expenses of waste, grease, &c., at 40 centimes per hour; the total hourly cost of the motive power is, therefore, approximately 1·60 francs. A 20 horse-power engine consumes 50 kilogrammes of fuel per hour; the driver's wages being about 70 centimes per hour, and the accessory expenses 60 centimes; total 2·30 francs per hour. The cost of maintenance and the wear and tear of the apparatus in use represent a minimum of 10 per cent. of the purchase price; those of the building 5 per cent. The electric conductors which convey the current in the baths do not alter in price. The labour in a factory of forty baths amounts to 75 centimes per hour, or 18 francs per day; it is double this amount in a factory of 120 baths. The general expenditure can be estimated at 100 per cent. of the cost of labour in large installations of 200 or 300 baths, for example, and at 150 per cent. of the cost of labour in installations of only 40 or 50 baths."

The foregoing figures (which are only approximate) enabled M. Fontaine to compile the following comparative table, which is not to be taken as absolutely correct, but as serving as a basis to a project. The figures "convey an exact idea of the elements which constitute the cost of the electrolytic of refining, and their true interest consists in the comparison which they allow of being established between various factory installations:—

Factories taken as examples.	Expenditure per ton of refined copper.					
	Interest on capital.	Motive power.	Maintenance.	Labour.	General expenditure.	Total.
	frs.	frs.	frs.	frs.	frs.	frs.
Hilarion Roux, Marseilles	78·80	112·00	18	72·00	108·00	388·80
North German Refinery, Hamburg	64·65	39·50	12	40· 0	40·00	196·05
Elliott Metal Company, Birmingham . . .	35·95	180·06	30	57·75	57·75	361·45

"The cost of fuel in Birmingham," says M. Fontaine, "is much lower than we have taken as a basis; but, taking it at 6 francs (5s.) per ton at the works, we find that the motive power still costs 1·20 francs per hour, or 125 francs per ton of copper. If we leave all the other figures unaltered we obtain a total of 306·45 francs, that is to say, a much greater expenditure than at the Hamburg works. The interest on the capital engaged represents a small proportion only of the cost price, whereas at Hamburg it constitutes the main expenditure. As it was easy to foresee, two factories—those of Hamburg and Marseilles—established with the same elements, and on the same lines, give essentially different results in their working, owing to their respective magnitude. At Hamburg, where the operations are conducted on a large scale, the cost price of refining is about 200 francs, whereas at Marseilles, where the works are not of much importance, this cost is nearly doubled. The arrangement of 120 baths in tension, and the considerable surface of anodes, is much to be preferred to that of 48 baths of small surface, notwithstanding the enormous capital sunk in the first case. If water-power instead of steam-power were used it would still be necessary, for economically refining the copper, to adopt the disposition in use at Hamburg."

We are quite willing to endorse M. Fontaine's views as to the economical advantage of working with large anode surfaces, no matter from what source the motive power is obtained, and the observations of Keith and others clearly indicate that in this direction is to be found the chief element of economy in electrolytic refining, all other conditions being duly fulfilled. There can be no doubt, however, that a great deal depends upon the character of the dynamo machines manufactured for this special purpose, and their construction should undoubtedly be based upon the quality of copper which it is intended to refine by their agency. A dynamo that would fulfil all the requirements of electrolysis for one variety of copper would be quite unsuited for refining metal of higher resistance. In taking advantage of this knowledge lies the secret of Dr. Wohlwill's well-known successes.

Respecting the cost of electrolytic refining, the following particulars have been handed to us, from which it will be seen that there is a wide difference when compared with the estimates of M. Fontaine.

Twenty indicated horse-power will deposit 3 tons of copper in 144 hours, the current being generated at a cost of 2 lbs. of coal per horse-power per hour, thus: 20-horse power consumes 40 lbs. of coal per hour; $144 \times 40 = 5{,}760$ lbs. of coal per 144 hours, or, say, less than 3 tons of small coal, which can be purchased anywhere near a coal-pit at 3s. a ton, delivered, or in other districts (as in Birmingham) at, say, 5s. per ton. Thus the total cost of fuel for depositing 3 tons of copper by one large dynamo-electric machine amounts to only about 15s.

An important consideration in the electrolytic method of refining copper is, that the gold and silver—which are often present in considerable quantities in crude coppers—are entirely and easily recoverable, since these metals, during the electrolysis of the impure material, are deposited in the mud at the bottom of the vats, from which they can be readily extracted by the ordinary processes of refining. As evidence of the importance of this process over the dry method of refining copper, by which small traces of gold and silver would not be recoverable—we have been told that in one case, in which a trial sample of 6¾ tons of crude copper were operated upon by the electrolytic method, the mud from the bottom of the baths yielded 5½ ounces of gold and 123 ounces of silver, of the aggregate value of about £54, a sum that would leave a handsome profit after paying the cost of the operation. It is unnecessary to say that in refining this sample of copper by the dry method both the gold and silver would have been practically lost.

Another important consideration in the electrolytic method of refining copper is, that the pure metal obtained, from its high conductivity, is invaluable for all electrical purposes, while by its aid dynamo machines may now be constructed of infinitely greater power than would have been practically possible some twenty years ago. In electrotyping, also, the pure metal presents advantages which all practical electrotypists will readily acknowledge. In telegraphy, pure electrolytic copper presents advantages from its high conducting power which cannot well be overestimated, since even a mere trace of impurity in copper wire reduces its conductivity to a considerable extent.

Arrangement of the Baths for Electrolytic Refining.—A writer in the *Engineer* makes the following observations on the arrangement of the baths, which will be read with interest: "It is a recognised fact that when the electro-chemical action at the anode is the converse of that taking place at the cathode, an almost unlimited quantity of metal may be dissolved and deposited by the expenditure of a given quantity of electrical energy—a single dynamo machine often precipitates over 10 kilogrammes (22 lbs.) of copper per hour. It may be well to exemplify the fact above stated. Let us suppose that a current of 1,400 ampères is passing through an electrolytic tank, in which the anode and cathode are both of lead, and the electrolyte a suitable solution of the same metal. Nearly 12 lbs. of lead will then be deposited at the cathode per hour. If we now connect another electrolytic tank, similar to the former, in series with it, the resistance of the circuit may be nearly doubled. But if we then connect another series of two tanks in multiple arc with the former, the resistance will be reduced to its original value. Assuming that the electromotive force is not altered—an assumption which is not strictly correct, but is practically nearly so—if the comparatively small 'back electromotive force' be reduced by the circulation of the electrolyte, the current will now be 1,400 ampères, as before, and the electrical energy expended will also remain constant. But as the current is now passing through two electrolytic (double) cells *in series* the quantity of lead deposited will be double, *i.e.* 24 lbs. nearly. Calling I current in ampères, n number of tanks in series, E electro-motive force in volts, and R resistance in ohms, the expression for weight of lead deposited per hour, applicable under the assumption above mentioned, is—

$$\mathrm{P}b = \frac{\mathrm{I}n}{117} - \frac{\mathrm{E}n}{\mathrm{R} \times 117} \text{ lbs. per hour.}$$

CHAPTER XXXI.

ELECTRO-METALLURGY—(*continued*).

Electrolytic Refining of Lead.—Keith's Process.—Electrolytic Treatment of Ores.—Becquerel's Process for Treating Gold, Silver, and Copper Ores.—Lambert's Process for Treating Gold and Silver Ores.—Electro-chlorination of Gold Ores; Cassel's Process.—Electro-metallurgy of Zinc.—Létrange's Process.—Luckow's Zinc Process.—Electrolytic Treatment of Sulphides.—MM. Blas and Meist's Process.—Werdermann's Process.

Electrolytic Refining of Lead.—Keith's Process.—Professor Keith, of New York, in 1878, devised a process for the electrolytic refining of impure lead, with the object of extracting the silver and at the same time separating the lead in a pure metallic state. The process, so far as the arrangements of the baths and the disposition of the anodes and cathodes, is the same as in Elkington's copper-refining process. In base bullion the chief constituent is lead, which forms at least 90 per cent. of the mass. To separate this from the silver, antimony, arsenic, &c., by electricity, many electrolytes were tried, including nitrate of lead; but since the nitric acid set free would also dissolve the silver from the bullion anodes, this was not found to be a suitable electrolyte; sulphuric acid, which dissolves lead in small quantity, but the sulphate of lead formed became precipitated in the solution, while no metallic lead was deposited upon the cathode. After having tried all the known salts of lead in varying combinations, Professor Keith finally obtained several solutions which would serve as more or less perfect electrolytes for lead, and it was to his success in this direction that the apparent practicability of his processes was due.* The electrolyte which he found most successful, and which was accepted as the best for the electrolytic treatment of lead, consisted of acetate of soda, about 1½ pounds to the gallon, in which 2½ to 3 ounces of sulphate of lead were dissolved. The bullion-plates or anodes were thinner than those used in electrolytic copper refining, being only from ⅛th to $\frac{3}{16}$ths of an inch in thickness. A plate of bullion 15 by 24 inches of this thickness weighs about 20 pounds. Before being put into the vats a muslin bag is drawn over each bullion-plate, the object being to prevent the residues (silver, &c.) from falling to the bottom

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* This process was carried on by the Electro Metal Refining Company, New York, but has since been discontinued.

of the vat. The lead is intended to accumulate on the bottom of the vats, and by the above arrangements the impurities are prevented from mixing with the deposited metal.

The muslin employed to enclose the anodes is fine enough to prevent the fine particles of residue from being washed through by agitation of the solution, while the liquid is freely diffused between the inside and outside of the bags, and the resistance not perceptibly increased. The diffusion of the liquid by agitation is absolutely necessary, since the lead becomes dissolved as sulphate by electrolysis, and this sulphate must diffuse itself in the liquid to replace the sulphate decomposed at the cathode to deposit metallic lead. If the diffusion were to take place too slowly, in a short time the amount of lead present in the solution outside the bags would be too little to satisfy the depositing power of the current, and hydrogen would be evolved, followed by polarisation. If the solution be constantly agitated, therefore, a much stronger current may be employed without danger of polarisation. Heating the solution also favours the diffusion, while at the same time it materially reduces the resistance; it is, therefore, usually heated to about 100° Fahr. On working the solution it is maintained in a neutral state; if allowed to become alkaline, the alkali (in this case soda) becomes decomposed, furnishing oxygen to the anode and peroxidising the lead thereon, while hydrogen is evolved at the cathode and produces polarisation, irrespective of the diffusion of the solution.

In working the above solution there is no polarisation, provided the liquid is kept in a normal condition; the lead is dissolved from the anodes, and an exact equivalent of metal is deposited on the cathodes, and gathers as a crystalline coherent layer. In some cases, after the layer becomes sufficiently thick, it rolls off the surface of the cathodes and falls to the bottom of the vat; sometimes, however, the cathodes require to be gently scraped to remove the deposited metal. When the lead is all electrolysed from the bullion-plates (anodes), the impurities alone remain in the bags, and these usually constitute about 5 per cent. of the whole mass. If the bag containing the anode be carefully removed, it will be found that the anode has changed but little in appearance; it has a bright metallic aspect with a display of iridescent colour, and appears as if it had undergone no action; if the plate be touched, however, it yields to the finger like blue clay, to which it bears some resemblance. This is the residuum, in which may be seen here and there small fragments of lead which had become detached from the anode as it grew thinner. The residuum is immersed in water, when the scraps are washed from the "mud," which then deposits in a clayey mass, leaving the water perfectly clear; the scraps are afterwards remelted and recast into plates. The lead is drawn out from the vats at convenient intervals, and after washing to free it from the solution which attaches to it, it is dried quickly, and either pressed into "slugs," or otherwise melted at a low heat and cast into pigs. The residue, which contains the silver and gold besides the impurities, as arsenic, antimony, &c., is treated by a special process, which is thus described by Professor Keith:—

"In laying out our plan of procedure, we must first consider the conditions and liabilities. These may be formulated thus:—

"1. It is a wet powder, and must be dried.

"2. The oxidisable constituents must be oxidised.

"3. It must be mixed with fluxes and fused.

"4. Antimony and arsenic are volatile, and carry off in vaporising, mechanically or otherwise, silver, and perhaps gold. It is absolutely necessary to get all the gold and silver, and as pure as possible, though they may be alloyed together. It is obvious that drying the powder and roasting it in a reverberatory furnace will cause a great loss in silver from volatilisation with arsenic and antimony, besides loss of powder carried off by the draught. Its roasting needs most careful treatment, as from the easy fusibility of antimony, masses of alloy may be formed which cannot be practically oxidised. Recognising these conditions and difficulties, the plan of proceeding is this: After having removed the powder from the filters while it is still wet, it is mixed with the proper quantity of nitrate of soda, when it may be dried without loss of dust, as the nitrate cements the whole together. When sufficiently dry it is placed in crucibles for fusion. These are cautiously heated: the nitrate decomposing gives oxygen to the antimony, arsenic, copper, iron, &c., thus forming teroxide of antimony, arsenious acid, and oxides of copper, iron, &c. The soda combines with the teroxide of antimony and the arsenious acids, forming antimoniate of soda and arsenite of soda, which are fusible; a little borax added makes the slag more liquid when the oxides of iron and copper are present. A button of pure gold and silver collects at the bottom of the crucible. Now, though antimony, arsenic, and arsenious acid are volatile, antimoniate of soda and arsenite of soda are not, so there can be no loss from their volatilisation. Nitrate of potash may be substituted for the soda salt with the same effect. This slag of antimoniates and arsenites can be utilised in the following manner: When treated with hot water the arsenite of soda or potash is dissolved, and the antimoniate remains undissolved, together with the oxides of copper and iron. The arsenite of soda or potash is obtained by crystallisation, and finds its use in dyeing, colour-making, &c.; or metallic arsenic may be obtained from it by sublimation. Antimony may be obtained from the residue by mixing it with charcoal and melting in a crucible. No copper or iron need be reduced with the antimony with proper care, but if they are, they may be removed by subsequent fusion with some teroxide of antimony. Perhaps it will not be found profitable to carry the utilisation farther than to save the antimony and arsenic."

In this process the anode plates are cast thin, because the speed at which the electrolysis can be pushed is limited by the rate of diffusion of the sulphate of lead through the bags, as before explained. In practice it was found that with plates 15 by 24 inches, the rate of the electrolytic transfer of lead was from 1½ to 2 ounces of lead per hour, and a plate of this size, weighing 20 pounds, would therefore require from six to eight days. With plates twice as thick, or ¼ of an inch, it would last twice as long, and to make a given return per day, the amount under treatment would require to be greater. Larger and thinner plates would be electrolysed more rapidly. The electrolyte does not become changed by continued use. Iron and zinc, if present in the bullion, become dissolved and remain in solution, but this does not impair its efficiency. A small quantity of sulphate of lead added to the bath will correct any defect from this cause; moreover, the sulphate of iron becomes gradually oxidised, and sesquioxide of iron rises to the surface, which may be skimmed off.

The chief object in the treatment of lead base bullion is the separation of the silver from the lead, which by the old or dry method is not only costly but imperfect, while the presence of antimony and other impurities greatly influences the facility of such treatment. Indeed, some varieties of bullion, containing antimony in large proportions, are so refractory that in many cases they cannot be separated with profit. By this process, however, the silver and lead are directly separated, whether antimony be present in the bullion in large or small quantities, while at the same time this metal is also saved, and can be sold at the market value. All the lead is recovered with the exception of a trifling percentage lost by vaporisation, oxidisation, &c., because the bullion is only heated sufficiently to be melted and cast into plates, instead of being repeatedly heated, as in the old process. Again, all the gold and silver are saved, while the lead is obtained in an almost perfectly pure state—an important advantage in the electrolytic method of treatment. A sample of Keith's electrolytic lead was found on analysis to contain only ·000068 per cent. of silver, or ·02 ounce per ton, while only traces of antimony and arsenic could be detected, though a large quantity was used for analysis; there was no copper, though there had been some in the bullion. The presence of the small quantity of silver was believed to be due to carelessly handling the bags covering the anodes, by which small particles of the residue washed out into the bath, and finally deposited with the lead at the bottom of the vat. The bullion from which this lead was electrolysed was also submitted to analysis, with the following result:—

Lead	96·36
Silver (161·7 ounces per ton)	·5544
Copper	·315
Antimony	1·07
Arsenic	1·22
Traces of zinc and iron, undetermined matter, and loss	·4806
	100·0000

Although this ingenious process is not now being worked, there is much in its details that is instructive, and may serve as a guide to the experimentalist in his researches in the electrolytic treatment of lead—a successful process for which we may yet hope will be discovered. Mr. Williams* thus describes the arrangements formerly adopted for carrying out the process by the Electro Metal Refining Company of Rome, New York, who were the owners of Professor Keith's patents. The process was first developed on a comparatively moderate scale as follows:—"In this plant there were 4 vats 10 feet long, 2 feet wide, and 3 feet 6 inches deep, made of wood, and covered with pitch without and within to make them watertight. Copper rods 1 inch square, resting on the edge of each tank, served as conductors for the current. The anodes and cathodes rested on these conductors by means of hooks projecting from their upper margin. A piece of paper was placed between the hook of each anode and the conductor on one side, so as to prevent contact, while the cathodes were also insulated in like manner from the other conductor. There were about 40 anodes and as many cathodes in each tank. The tanks were connected in series to a Weston dynamo-electric machine for electro-deposition, having an electromotive force of about 1 volt, and a very low resistance. A circulating and heating apparatus was also provided as follows: The solution was allowed to run off from a gutter at one end of each tank, and was thence conveyed to a tub, from which it was pumped up into a cask placed higher than the tanks. From the bottom of this cask was a delivery-pipe which subdivided into four smaller pipes, one extending along the bottom of each tank. These small pipes were perforated with numerous holes, through which the solution entered the tank. In the cask a copper still-worm was placed, which was heated by steam. Thus the solution was agitated and heated at the same time. The weight of each plate (15 by 24 by $\frac{1}{8}$ inches) being about 20 pounds, the amount under treatment was consequently 160 (plates) × 20 = 3,200 pounds. At the rate of $1\frac{1}{2}$ ounces per plate per hour, which was the average of working, the

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* "Geological Survey of the Resources of the United States."

deposit was 360 pounds per day of twenty-four hours. It will be readily understood that the machine can be worked by night as well as by day. At this rate a plate would be exhausted in somewhat less than nine days. In practice the plates are not all exhausted, however; there always remain small pieces which become detached from the rest of the plate. The weight of these scraps would average about 1 pound, though in this case many of the plates were cracked to begin with, and did not hold out well for this reason.

The company subsequently fitted up a more extensive plant at Rome, New York, which is thus described: "The works are in a one-storey building, 150 feet by 50 feet, of which the working capacity (three tons per day) requires only one-third the space. The casting of the bullion-plates is done by means of a casting machine, or system of mechanical moulds rotating around a centre, and passing successively under the spout of tho melting furnace. There are twelve moulds, each holding at its upper part two thin strips of copper perforated with holes. When the lead is poured into the mould it fills these holes, and the strips form suspension lugs and connections at the same time. At the side of the revolving system opposite from the furnace, the plates are taken away by a boy, who replaces other copper strips and closes the mould again for another round. A man and a boy will make 180 plates per hour. Each plate is 24 inches by 6 inches by $\frac{1}{8}$ inch, and weighs 8 pounds. The plates are hung from a frame and carried by an overhead railway to the vats. There are thirty circular vats, made of a kind of concrete mixture. Each vat is 6 feet in diameter, 40 inches high, and has a central core or pillar 2 feet in diameter, and equal in height to the vat.

"The cathodes consist of thirteen circular hoops or bands of sheet brass, two feet high, and arranged concentrically two inches apart. The plates of bullion are lowered between these circular cathodes. The anode frame or bullion carrier has twelve consecutive rings of brass, 2 inches wide and $\frac{1}{8}$ inch thick, also arranged two inches apart. Rivet heads of copper project from these rings, and the bullion-plates are suspended to these by the eye-holes in the suspension lugs. Each frame will receive 270 bullion-plates, making a total weight of bullion about 2,100 pounds per vat, or slightly over one ton. The carrying power of the overhead railway is 3,000 pounds. The solution is allowed to overflow from the vats by a small gutter to the floor, which is of concrete, and grooved with gutters that lead to cisterns at the end of the building, which have a capacity of 3,000 gallons, whence it is pumped by a centrifugal pump to an overhead tank, where it is heated by a system of steam pipes to 100° Fahr., automatic electrical regulation of the temperature being secured by a special device. From this tank the solution is distributed to the vats by a system of pipes. An Edison dynamo-electric machine, constructed specially for this purpose, is used to furnish the current. This machine has an electromotive force of ten volts, and an internal resistance of ·005 ohm, and produces the enormous volume of current of 2,000 ampères. This current will nevertheless be entirely safe to the employés on account of its very low electromotive force.

"The vats are connected in series, and the power used by the machine does not exceed 10 horse-power for 30 vats. The vats are charged in rotation, three per day, and on the tenth day the first three are renewed, after which the renewal is kept up in the same order. In this way three tons are put under treatment every day, and three tons refined and returned. The anode carriers can be rotated around the core of the vat as a centre, and they carry mechanical fingers which scrape the surface of the cathodes by the motion. By removing a plug, each vat may be rapidly emptied, and the crystalline lead shovelled out. This lead is washed in water and placed in a centrifugal dryer, after which it is melted under oil or other reducing material, to expel the remaining traces of moisture without oxidation, and it is then ready for the market. In this establishment there are ovens and muffles, &c., for assay purposes and for reducing residues. These residues are washed in water, and the water run through a sieve to take out the scraps of bullion; they are then allowed to settle, after which the water is decanted and the residuum dried."

Electrolytic Treatment of Ores.—During the past forty years many attempts have been made to extract metals from their ores by electrolysis, and many ingenious processes have been devised, but few of these, so far as we are aware, have proved successful. Some of the earlier investigations of Bunsen, Sainte-Claire Deville, and Becquerel are of special importance as indicating the general principles upon which such electrolytic operations may be conducted; there is little doubt, however, that much has yet to be done before the separation of metals from their ores will attain the position of a really practical branch of electro-chemistry. We have noticed in the case of copper refining by the wet way, that many attempts were made in this direction long before a commercially successful application of the electrolytic method was arrived at, and we still hope and believe that electricity will yet be practically employed in extracting metals from their ores; indeed some trials which we have recently made in this connection are at least of a very hopeful character.

Becquerel's Process for Treating Gold, Silver, and Copper Ores.—This process, discovered by the famous French chemist upwards of thirty years ago, is based on the property possessed by chloride of silver and sulphate of lead to dissolve in a saturated aqueous solution of chloride of sodium (common salt) and sulphate of copper. The chlorination of the silver by the wet way is applicable to ores in which the silver occurs either in the metallic state or as a simple sulphide; when in the form of double sulphide, the dry method must be adopted. To chlorinate a silver ore, it is first reduced to an impalpable powder, upon which much of the success of the process depends. The substances employed for the chlorination are chloride of sodium, sulphate of copper, or sulphate of peroxide of iron, the proportions depending on the composition of the ore and the percentage of silver present, ten per cent. of the chloride and twenty per cent. of sulphate being mixed with the pulverised ore.

Copper exists in the ores either in the metallic state, in the form of oxide, or chloride, or as carbonate (malachite), sulphide (copper pyrites), &c. The sulphide is usually associated with sulphide of iron. When copper occurs in the metallic state, it is separated from the *gangue*, or earthy matter, by washing; if in the state of oxide or carbonate, it is treated with sulphuric acid; and when in the state of simple or double sulphide or a combination of sulphides, it is cautiously roasted, care being taken not to convert any portion of it into oxide. The copper pyrites being roasted by a sustained but not too high a heat, the sulphide of iron, which becomes reduced at a lower temperature, is converted into peroxide, while the sulphide of copper changes into soluble and hydrous sulphate. The importance of careful roasting will therefore be at once apparent.

Lead occurs chiefly in the form of sulphide, as *galena;* it is also found associated with silver (argentiferous galena), in which ores it is generally combined with sulphide of antimony, arsenic, &c. Galena is *sulphated*, as it is termed, by the dry method, by careful roasting, when sulphurous acid is liberated, the lead becoming oxidised and sulphate of lead formed. By the wet process, the sulphatation of galena is effected by causing a solution of sulphate of copper to react upon the plumbic sulphide by the aid of a solution of common salt.

Having chlorinated or sulphated the silver, copper, and lead ores, solutions of the metallic compounds are made, salt water being used for silver and lead, and water for the copper salt. From these solutions, Becquerel deposited the respective metals by voltaic electricity, employing couples of zinc, iron, or lead connected by copper strips to tin plates or to fragments of carbon immersed in the solution bath. The oxidisable metals, however, were placed in porous cells filled with salt water. When adopting this "single cell" arrangement, he found that by grouping six baths together the chloride decomposed more rapidly without increasing the cost. In the first few hours three parts of the silver became extracted, but the remainder required a much longer period, owing to the conductivity of the bath being diminished, and consequently offering greater resistance to the current, which also decreased in strength. With dynamo-electricity, however, these difficulties of the process would be more readily overcome.

In another arrangement, Becquerel employed a wooden case lined with lead, covered with wax, to hold the solution of sulphate of iron; in this case there were two openings, one at the top for receiving the normal liquor, and another at the bottom through which the denser liquor escaped by a siphon. In the interior of the wooden case, leaded sheet-iron boxes were immersed, the end walls and bottom of which were of metal, and the lateral walls of open work lined with sheets of cardboard. Concentrated solution of sulphate of copper was allowed to enter at the bottom of these boxes, by means of siphons, while the weaker liquid was allowed to pour from the opening at the top. In one of these boxes the metal which was to receive the copper deposit was placed, and between each were cast-iron plates for generating the current. By this ingenious arrangement, a quantity of concentrated copper solution and weak iron liquor entered the boxes exactly proportionate to the weak copper liquor and strong iron liquor run out, which, occurring automatically, necessitated no personal attention, the only labour required being for the removal of the copper sheets when sufficiently thick, and replacing the iron plates when worn out. Becquerel thus sums up the advantages of his process: "From the facts set forth it evidently results that silver ores can be treated without difficulty by the electro-chemical process when sea salt is at a low price and there is enough wood in the locality for roasting the ore, if the chloridising cannot be done by the wet method; that this process is particularly applicable to very complex ores, that is to say sulphuretted ores; and that although it is simpler than the Mexican or Freybergan amalgamation, there are, nevertheless, instances in which it will be preferred to this last method, which would not be suitable for the treatment of argentiferous galena and argentiferous copper pyrites. It is most probable that the electro-chemical method, by means of which silver, copper, and lead ores can be treated, will be adopted in practice when the principles upon which it rests shall have become familiar. It will more particularly be adopted in countries where mercury is only found with difficulty, and where wood is too scarce for treating the ore by melting, and where common salt is abundant."

The above process was carried on by Becquerel for a considerable time at his works at Grevelle, many years before the introduction of dynamo-electric machines; and although the process was not a commercial success at that time there is much reason to believe that if practised in districts where fuel is cheaper than in France, and by the aid of dynamo-currents, far more satisfactory results could be obtained than were possible when the great scientist pursued his ingenious method.

Electrolytic Extraction of Copper from Ores—Marchese's Process.—This process relates to the electrolytic treatment of copper ores, by which the inventor is "enabled to prevent the precipitation of iron or its compounds, and to obtain a very pure copper." For this purpose a portion of the ore to be treated is smelted into the condition of a matt, or regulus, consisting generally of copper, iron, and sulphur, which is cast into anodes. Another portion of the ore is roasted and lixiviated, sulphuric acid being added to dissolve out the oxides. The resulting liquid, chiefly sulphate of copper, with sulphate of iron, is transferred to the electrolytic baths, where it is decomposed by the current, metallic copper being deposited on the cathodes, while the sulphides of the anodes are dissolved, producing sulphuric acid and iron sulphates, so that none of the iron is deposited on the cathodes. To keep the liquor at the proper strength a considerable portion of it is caused, by pumping or otherwise, to circulate from the baths to the lixiviating tanks, and after becoming enriched therein, to return to the baths. "A large part of the electric power necessary to decompose the sulphate of copper being generated by the oxidation of the iron in the anodes, very little extraneous electric power is required for the operation. The exhausted anodes are used for the production of sulphur and sulphuric acid, and the sulphate of iron contained in the spent liquor may be crystallised in the usual way. In cases where the liquor contains excess of iron a little granulated matt of copper is added to it. This is acted upon by the sulphuric acid present, causing evolution of sulphuretted hydrogen and production of sulphate of copper ready for depositing." This reaction may be promoted by applying moderate heat.

Lambert's Process for Treating Gold and Silver Ores.—The ore is dissolved by nascent chlorine, obtained by the decomposition of a soluble chloride by means of the current, by which the metals of the ore are converted into chlorides which become dissolved in the bath either as a consequence of their own solubility, or owing to the salts which enter into the composition of the bath. These chlorides are afterwards decomposed by electric action, and the metals deposited upon the cathodes. The three principal conditions necessary to the success of this process are: 1. Polarisation at the anodes and cathodes must be avoided; this is counteracted by keeping the mass of ore in motion, whereby the adhering gas is liberated. 2. The continuous collection of the deposits at the cathode prevents polarisation. 3. To secure a complete attack of the ore, all its parts must be subjected to the action of the nascent chlorine, which result is obtained by keeping the mass in constant motion, by which all its points are put in contact with the conductors of the current. The apparatus used by Mr. Lambert in his experiments consisted of a box divided into two compartments by a porous diaphragm. In one of these compartments was put the solution for receiving the cathode, which consisted of a strip of copper, which was cleaned and replaced at regular intervals. In the other compartment the ore was placed with a plate of carbon facing the cathode; other plates of carbon were also placed in this compartment, so that the ore was surrounded by this conducting material. The stirring was effected by means of a current of water specially adapted for the purpose.

Electro-chlorination of Gold Ores—Cassel's Process.—This process, which promised well from trials carried out in London, has some features of interest which render its retention in these pages desirable, since the electrolytic treatment of ores is as yet in its infancy. In one trial of the process several tons of antimonial gold concentrates, which had been obtained from Queensland, were treated, and, according to the assay of Messrs. Johnson, Matthey, and Co., it showed that by this process 91 per cent. of the gold was extracted. The process, which is purely one of chlorination, is based upon the readiness with which chlorine in the nascent state—that is, at the moment of its elimination from a compound—attacks gold, in which state it has a far greater combining capacity than when generated by the ordinary chemical methods. The apparatus which has been most successfully employed consists of a large drum, within which are arranged a number of dense carbon rods; these rods form the anodes, or positive electrodes, and are metallically connected with the positive pole of the dynamo, while the negative pole of the dynamo is connected with the hollow iron shaft of the drum, which serves both as axis to the drum and also a negative electrode of the apparatus. The shaft referred to terminates through stuffing-boxes in hollow standards or tanks, where finally the gold accumulates. In working the apparatus, which, as will be seen, is of an exceedingly simple nature, the drum is charged with about 2½ tons of ore, and salt and water added thereto; it is then set in motion by suitable gearing, at a speed of about eight revolutions a minute. The current is then passed through, which decomposes the salt solution, and nascent chlorine and oxygen are evolved at the anode. As the drum revolves the ores are constantly brought in contact with the carbons, where both these elements are set free, and the metals become readily dissolved. Since the most refractory gold ores generally contain iron, which would naturally enter into solution with the gold, Mr. Cassel hit upon the idea of adding caustic lime to the mixture of crushed ore and salt, which earth, by reason of its alkaline properties, at once combines with any hydrochloric acid as fast as it is formed, and effectually neutralises it, so that no iron can be taken up by the gold solution. At the same time a hypochlorite of lime is formed, which again, being decomposed by the water present, affords additional nascent chlorine for the gold; the ultimate products of the reaction being chloride of sodium in excess, chloride of calcium, terchloride of gold, and undecomposed gangue at the anode, and chloride of sodium and caustic soda at the cathode. In the iron shaft are bored a number of holes, and the shaft itself is covered with asbestos cloth, which, while preventing the gangue from entering the shaft, allows the dissolved gold to penetrate through the cloth. After the addition of the lime—which precipitates all other dissolved metals present except the gold—the latter metal is rapidly dissolved, and deposited by the electrical action in the interior of the pipe in a finely divided metallic state, and is carried thence into the hollow standards by means of an Archimedean screw fixed in the pipe. The standards are provided with movable doors, from which the gold "slime" is from time to time withdrawn, when, after drying, it is ready for melting. In the above process it will be seen that the presence of the lime not only checks the formation of iron salts, but instantly precipitates them when formed, as also all other metals which may be present in the auriferous pyrites.

Electro-metallurgy of Zinc.—Many attempts to extract zinc from its ores by electrolysis have been made from time to time, but without success. Well knowing the importance of the subject, and believing that the difficulties which had hitherto stood in the way were surmountable, the author pursued a long series of experiments in this direction, and eventually succeeded in obtaining a suitable electrolyte, from which the metal deposited in a highly satisfactory condition. The process was subsequently submitted to a long series of practical trials, in which the extraction of zinc by the electrolytic method was proved to be thoroughly successful and susceptible of practical application on the large scale. A description of the process, which has been patented, is briefly given in the Appendix, and a company is being formed to carry out the process on a large commercial scale. It may be mentioned that the zinc obtained from its ores by this method is exceedingly pure. The process is also applicable to the refining of zinc from crude or impure metal.

Letrange's Process is thus described by Hospitalier:* "Létrange transforms the insoluble blende into a soluble sulphate by a very simple

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* "Modern Applications of Electricity," by E. Hospitalier. Translated by Julius Maier, Ph.D.

process, in which the sulphuric acid necessary for the formation of the sulphate is supplied by the ore itself. It is well known that by the roasting of the sulphur ores part of the sulphur forms a sulphate, whilst the remainder is given off in the form of sulphurous acid. This latter can be converted into sulphuric acid in the usual way, and the acid thus obtained can be used as a solvent for the ore.

"The ore, consisting of a mixture of blende and calamine, is roasted at a moderately high temperature, so as to obtain the largest possible quantity of zinc sulphate. The sulphurous vapours, converted into sulphuric acid, are used either for the solution of the calamine or of the roasted ore. After the ore has been converted into sulphate it is placed in large tanks, and treated with water. The solution of zinc sulphate passes slowly into another series of tanks, when it is exposed to the action of the electric current. The liquid sulphate sinks slowly to the bottom of the tank, and the sulphuric acid liberated at the positive electrode gradually rises to the top, from whence it flows into another tank containing roasted calamine. A continuous reaction is thus established; the liquid current first passes through the dissolving tanks, where the acid dissolves the zinc contained in the ore to exhaustion, then passes into the precipitating tanks, where it deposits the zinc, and changes back into acid, only to be again employed as a solvent. The same liquid, however, *cannot be used ad infinitum*, because the ores contain oxides—lime, for instance—which do not part with their acids by electrolysis.

"The electrodes employed in this method are not identical, the negative electrode consisting of a thin plate of zinc, the positive electrode being formed of a leaden plate. On this latter the iron contained in the liquid is deposited in the form of oxide, which detaches itself and sinks to the bottom of the tank. As regards the lead, the silver, and the other metals insoluble in sulphuric acid, they remain in the residue, from which they can be extracted. The electric current necessary for these operations is supplied by the dynamo-electric machine, and Létrange uses, as much as possible, natural forces for driving them. In this latter case the operations are reduced to placing the roasted ore in the dissolving tanks, removing the residue, and replacing the electrodes charged with deposited zinc by fresh plates. When a steam motor is required, the quantity of coal used for the production of 2 cwt. of zinc is the same as for 1 cwt. by the ordinary method. There is an enormous saving, too, in the original outlay, which for the ordinary method amounts to £40,000 for the production of 20,000 tons of zinc. The new process only requires, for the same production, from 200 to 300 horse-power, a corresponding number of dynamo-electric machines, and a certain number of dissolving tanks. The outlay in this would not exceed £20,000."

To simplify his process, Létrange causes the sulphurous acid to act directly upon the oxidised ore and the carbonate without previously converting it into sulphuric acid, by which he obtains sulphite of zinc instead of sulphate; this salt, however, is as readily decomposed by the current, and, moreover, becomes gradually transformed into sulphate by the action of the air. This exceedingly ingenious and well-devised process certainly deserves the fullest attention, and if placed in the hands of experienced persons, possessing a thorough practical knowledge of electrolytic operations, there can be little doubt, we should think, as to its success. Much, however, will depend upon the arrangement of the baths, and the amount of anode and cathode surface employed, so as to diminish the resistance of the baths to the fullest extent attainable. The chief difficulty in the way, however, is in the electromotive force required for the decomposition of sulphate of zinc, which, if it exceeds 1·5 volt, involves the decomposition of water, and consequent loss of power.

Luckow's Zinc Process.—In this process zinc ore mixed with coke is used as the anode, and a zinc plate forms the cathode. A large rectangular bath is used for the operation. The mixture of ore and coke is placed in an openwork case, and a wooden frame weighted with lead and covered with a thick cloth is placed under the cathode to collect the precipitated zinc. During the electrolytic action froth is formed, which must be skimmed off as it occurs. When a solution of sulphate of zinc is employed, care must be taken to keep the solution neutral; although this is not so necessary when chloride of zinc is used, this latter solution has the disadvantage of disengaging chlorine at the anode, the fumes of which are exceedingly irritating to the lungs. Luckow recommends for the direct separation of zinc from blende a solution of sea salt slightly acidulated.

Electrolytic Treatment of Natural Sulphides.—There have been several attempts to treat native sulphides electrolytically, and indeed the subject is being followed up at the present moment in more than one quarter. It appears from the following communication * that M. Deligny turned his attention to the sulphides in 1881, for he then wrote to the journal mentioned below:—"I started from this fact, that the various natural cupric sulphides, and their compounds or mixtures with iron pyrites, are tolerably good conductors of electricity, and are more or less rapidly attacked by an acid in the presence of nascent oxygen. It was therefore to be expected that one of these compounds, taken as the positive electrode in any electrolytic action, should throw off, at least slowly, a certain portion of its metal to the solution, from which the electrical action would afterwards withdraw

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* *La Lumière Electrique*, 1881.

it. In order to realise these conditions, I have placed in a rectangular vessel either a weak solution of sulphate of copper, or some ordinary acidulated water, such as is used in voltameters. I then place in the solution a copper plate as a negative electrode, and for a positive electrode a piece of carbon surrounded by pulverised ores and contained either in a linen bag or in a porous cell, or even at the bottom of the electrolytic cell, and without any diaphragm. With the electromotive force of one or two Bunsen cells, the reaction takes place rapidly enough, and especially when the ores are not separated by a resisting diaphragm; in the case of the linen bag, the action is immediate. I have successively operated on two qualities of ores. The first one was cupriferous iron pyrites containing 4·60 per cent. of copper, and in which the yellow copper pyrites with the iron pyrites forms a homogeneous mass. In the second ore the cupreous pyrites formed little agglomerations or spots disseminated in the mass; the percentage was 3·60 per cent. of copper. After a few days' action of the battery, a notable proportion of the two ores was attacked, and the copper resulting from it was partially deposited on the negative electrode. But the attack, as I had anticipated, was attended with different results on the two ores. The first one, of homogeneous composition, had all its elements parallelly dissolved, so that the residue still gave 4·57 per cent. of copper after the action. The combination of cupreous pyrites with the iron pyrites had, therefore, been dissolved in greater proportion than the martial pyrites."

MM. Blas and Meist's Process.—This process, which is too evidently based on the foregoing, was made known in the following year, namely in 1882. It is based on the following facts:—1. The natural sulphides are, in certain degrees, conductors of the voltaic current. 2. The sulphuretted ores (mixtures of sulphides and gangues) are conductors of the current, even when the proportion of gangue is large. 3. If a solution of a salt, the acid of which attacks the natural sulphides, is electrolysed by using the latter as anodes, the metal of the sulphide is dissolved, whereas the sulphur remains deposited on the anode. It is with the nitrates that this operation is more easily conducted, and in this case without the formation of sulphate. The inventors describe the reactions which occur in a bath of nitrate of lead, in which a galena anode and insoluble metal cathode were used. The lead under the action of the current passes to the cathode, and the acid is liberated at the anode, where it attacks the galena, and regenerates the nitrate of lead, the bath remaining neutral and permanent in action. The sulphur being separated can be readily removed. In carrying out their process, MM. Blas and Meist first agglomerate the ores by heat and compression. The ore being crushed into small grains, is introduced into copper moulds, and submitted to a pressure of 100 atmospheres, the mould is then closed and heated in a furnace to about 600° C.; it is again pressed on removal from the furnace, and afterwards rapidly cooled to facilitate the removal of the ore plates. Thus prepared, the ore plates are attached to iron bars, which are connected by means of iron conductors to the positive pole of a dynamo-electric machine, and suspended in the bath, which consists of a solution of a neutral metallic salt suitable to the nature of the ore under treatment: nitrate of lead being used for galena; nitrate, sulphide or chloride of zinc being used for zinc blende. In treating a compound ore, the bath is formed in accordance with the various metals of which it is composed. The cathodes employed consist of plates of metal insoluble in the bath, and connected by iron conductors to the negative pole of the dynamo-electric machine. The baths may be joined for tension or quantity, but preferably the former, whereby the fullest metallic deposit is obtained with a minimum of current.

It must be borne in mind that in treating ores by either of the above processes, the bath must of necessity become impregnated with soluble earthy matter, which in time must seriously affect its conductivity, to overcome which a great expenditure of electricity would be necessary. It has yet to be seen whether this insuperable objection to the direct treatment of metallic ores by electrolysis can be overcome. It will naturally suggest itself that a preliminary roasting would be advantageous. In the case of copper, there can be little doubt that the combined processes of smelting and electrolytic refining are by far the most certain and practical, if not the most economical, method of treatment, more especially as the gold and silver are by this method entirely recovered, while the copper itself is obtained in a chemically pure state when the process is properly conducted.

Werdermann's Process.—This process, which was submitted to trial in America some years ago, consisted in passing a powerful current into the furnace while the ores were in a state of fusion; the process, however, was not successful, and the inventor subsequently devised the following process. The ores containing some precious metals associated with antimony, arsenic, sulphur, and other substances, were first subjected to oxidation by means of ozone; after oxidation and lixiviation, the silver was deposited from the solution by electrolysis; the gold and silver remaining in the deposit were recovered by amalgamation, which was facilitated by moistening the ore with a solution of caustic alkali, and by connecting the agitating apparatus of the amalgamating vessel to the negative pole of a battery, the positive pole being connected to the vessel itself.

Electric Smelting.—The great success which has attended the electrolytic method of refining metals, but more especially copper, is believed by many to be but the forerunner of a still wider application of the electric current, namely, the reduction of metals from their ores, in the "dry" way, by means of electricity. The fact that sulphides are known to be conductors of electricity, and, moreover (as lately shown by Mr. Bidwell), are capable of accumulating or storing up the current, lead some persons to believe that the reduction of ores by electricity may at some future period supplant the ordinary processes of furnace smelting. Be this as it may—and which time alone will determine—a very interesting result in this direction has lately been achieved in the United States, which is likely to prove of great importance in the production of one or two refractory but important substances—aluminium and its alloys, and silicon bronze.

Cowles' Process.—The following account of the methods adopted by the Cowles Electric Smelting and Aluminium Company, of Cleveland, Ohio, was given in the New York *Engineering and Mining Journal*,* and will be read with considerable interest. The Company referred to is, it appears, carrying on electric smelting commercially, but at present are chiefly devoting themselves to the production of aluminium and silicon bronze. The system, however, may hereafter be extended to other metals, and the operations be conducted upon a more extended scale. The Messrs. Cowles have succeeded in greatly reducing the market value of aluminium and its alloys, and thereby vastly extending its uses; they are said to be the largest producers in the world of these important products. As described in their patents, the Cowles process consists essentially in the use, for metallurgical purposes, of a body of granular material of high resistance or low conductivity, interposed within the circuit in such a manner as to form a continuous and unbroken part of the same, which granular body, by reason of its resistance, is made incandescent, and generates all the heat required. The ore or light material to be reduced—as, for example, the hydrated oxide of aluminium, alum, chloride of sodium, oxide of calcium, or sulphate of strontium—is usually mixed with the body of granular resistance material, and is thus brought directly in contact with the heat at the points of generation. At the same time the heat is distributed through the mass of granular material, being generated by the resistance of all the granules, and is not localised at one point or along a single line. The material best adapted for this purpose is electric light carbon, as it possesses the necessary amount of electrical resistance, and is capable of enduring any known degree of heat, when protected from oxygen, without disintegrating or fusing; but crystalline silicon or other equivalent of

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* *Engineering and Mining Journal.* New York. August 8th, 1885.

carbon can be employed for the same purpose. This is pulverised or granulated, the degree of granulation depending upon the size of the furnace. Coarse granulated carbon works better than finely pulverised carbon, and gives more even results. The electrical energy is more evenly distributed, and the current cannot so readily form a path of highest temperature, and consequently of least resistance, through the mass along which the entire current or the bulk of the current can pass. The operation must necessarily be conducted within an air-tight chamber or in a non-oxidising atmosphere, or otherwise the carbon will be consumed and act as fuel. The carbon acts as a deoxidising agent for the ore or metalliferous material treated, and to this extent it is consumed, but otherwise than from this cause it remains unimpaired.

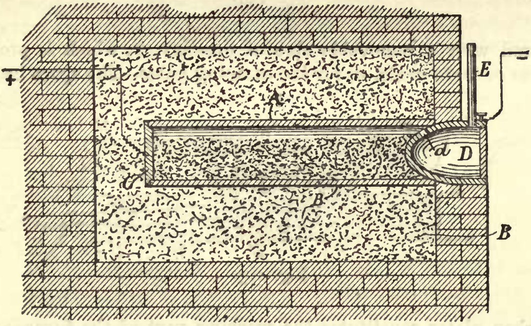

Fig. 122.

Fig. 122 of the accompanying drawings is a vertical longitudinal section through a retort designed for the reduction of zinc ore by this process, and Fig. 123 is a front elevation of the same. Another form of the electric furnace, which is illustrated by Fig. 124, is a perspective view of a furnace adapted for the reduction of ores and salts of non-volatile metals and similar chemical compounds. Figs. 125 and 126 are longitudinal and transverse sections respectively, through the same, illustrating the manner of packing and charging the furnace. The walls and floor, L L, of the furnace are made of fire-bricks, and do not necessarily have to be very thick or strong. the heat to which

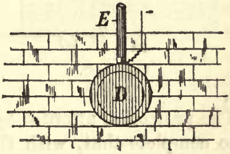

Fig. 123.

they are subjected not being excessive. The carbon plates are smaller than the cross-section of the box, as shown, and the spaces between them and the end walls are packed with fine charcoal. The furnace is covered with a removable slab of fire-clay, N, which is provided with one or more vents, *n*, for the escaping gases. The space between the carbon plates constitutes the working part of the furnace; this is lined on the bottom and sides with a packing of fine charcoal, O, or such other material as is both a poor conductor of heat and electricity—as, for example, in some cases silica or pulverised corundum or well-burnt lime—and the charge, P, of ore and broken, granular, or pulverised carbon occupies the centre of the box, extending between the carbon plates. A layer of granular charcoal, O, also covers the charge on top.

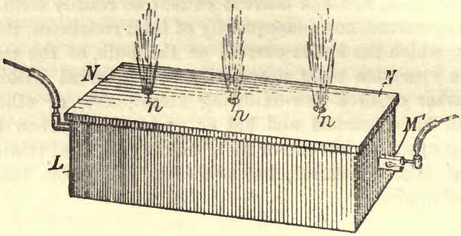

Fig. 124.

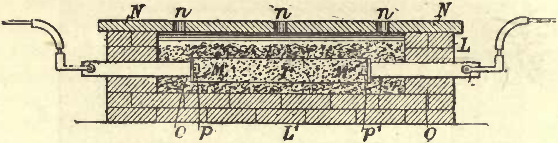

Fig. 125.

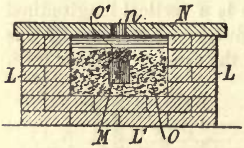

Fig. 126.

The protection afforded by the charcoal jacket, as regards the heat, is so complete that, with the covering slab removed, the hand can be held within a few inches of the exposed charcoal jacket; but with the top covering of charcoal also removed, and the core exposed, the hand cannot be held within several feet. The charcoal packing behind the carbon plates is required to confine the heat, and to protect them from combustion. With this furnace aluminium can be reduced directly from its ores, and chemical compounds from corundum, crysolite, clay, &c., and silicon, boron, calcium, manganese, magnesium, and other metals are in like manner obtained from their ores and compounds.

In a paper read before the American Institute of Mining Engineers at Halifax,* Dr. T. Sterry Hunt, who had devoted two entire days at the experimental works at Cleveland, furnished some additional particulars concerning this interesting and valuable process, from which we make a few extracts, feeling confident that this important application of electricity will receive the fullest attention on this side of the Atlantic. Dr. Hunt says, "If alumina, in the form of granulated corundum,† is mingled with the carbons in the electric path, aluminium is rapidly liberated, being in part carried off with the escaping gas, and in part condensed in the upper layer of charcoal. In this way are obtained considerable masses of nearly pure fused aluminium and others of a crystalline compound of the metal with carbon. When, however, a portion of granulated copper is placed with the corundum, an alloy of the two metals is obtained, which is probably formed in the overlying stratum, but at the close of the operation is found in fused masses below. In this way there is got, after the current is passed for an hour and a half through the furnace, from 4 to 5 lbs. of an alloy containing from 15 to 20 per cent. of aluminium and free from iron. On substituting this alloy for copper in a second operation, a compound with over 30 per cent. is obtained. . . . . The reduction of silicon is even more easy than that of aluminium. When silicious sand, mixed with carbon, is placed in the path of the electric current, a part of it is fused into a clear glass, and a part reduced, with the production of considerable masses of crystallised silicon, a portion of this being volatilised and reconverted into silica. By the addition of granulated copper, there is readily formed a hard brittle alloy holding 6 or 7 per cent. of silicon, from which silicon bronzes can be cheaply made.

"The direct reduction of clay gives an alloy of silicon and aluminium, and with copper, a silico-aluminium bronze that appears to possess properties not less valuable than the compound already mentioned. Even boric oxide is rapidly reduced, with evolutions of copious brown fumes, and the formation, in presence of copper, of a boron bronze that promises to be of value, while, under certain

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[*] *American Engineering and Mining Journal*, September 19th, 1885.

[†] *Corundum* is a very hard genus of aluminous minerals, to which the gems sapphire, ruby, salamstein, and adamantine spar belong. *Emery* is an impure, compact, amorphous, and opaque variety of corundum, and consists, according to Tennant, of alumina, 80; silica, 3; iron, 4 parts.

conditions, crystals of what appear to be the so-called *adamantoid boron* are formed. In some cases also crystalline graphite has been produced, apparently through the solvent action of aluminium upon carbon."

By another improvement in the Cowles furnace, the copper or other metal used for the alloy is in the form of rods running across the furnace, it having been found that where grains of copper were used, they sometimes fused together in such a manner as to short circuit the current. The new electric smelting furnace is shown in Fig. 127.

Since the publication of the earlier editions of this work the Cowles electric smelting process has been, as we anticipated would be the case, introduced into this country, with the result that the Cowles Aluminium Syndicate have established extensive works at Stoke-upon-Trent, where operations were commenced, for the manufacture of aluminium bronze, in February of the present year, with a dynamo-electric machine built by Messrs. R. E. Crompton & Co., of Chelmsford, of a capacity of 300,000 watts. With this powerful machine the Cowles Syndicate reduce from its oxides, in a run of about one hour, upwards of 20 pounds of metallic aluminium in its most valuable alloyed state—that of aluminium bronze—at a cost far below that at which it could be produced by any other known means. The raw material generally used by the Cowles Company, at their works in Lockport, U.S.A., is corundum, but for carrying out the manufacture in this country it is found that they can use not only corundum, but also bauxite, wochleinite, and other aluminous ores which are plentifully distributed in various parts of the world.

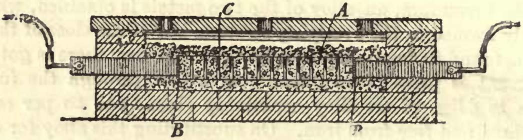
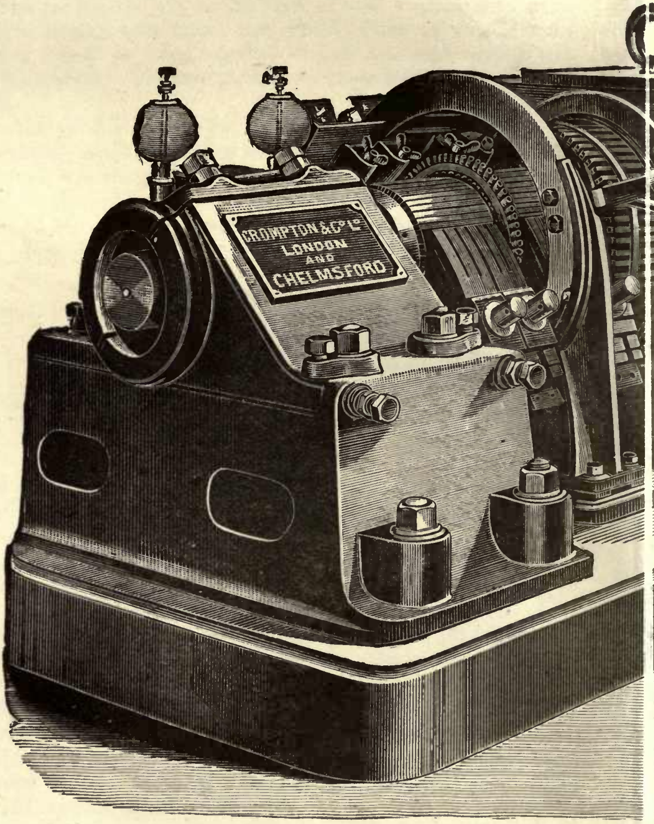


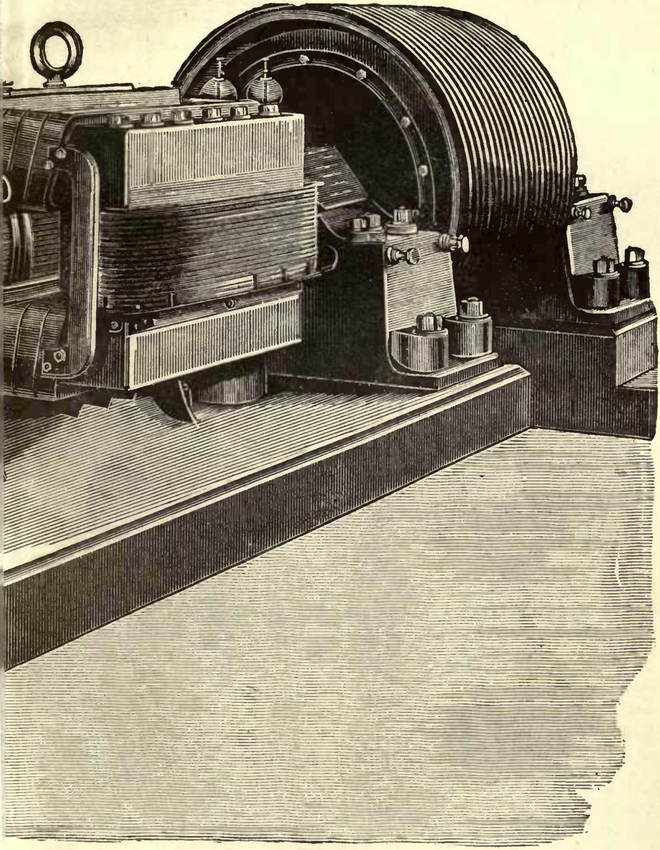
Fig. 127

In Fig. 128 a view is shown of a series of electric furnaces erected at the new works at Stoke-on-Trent, the current being supplied by the large Crompton dynamo referred to.

The production per machine of the capacity above named at the Stoke works is stated to be considerably above one ton of ten per cent. aluminium alloy per day. With this machine, which is rather more than one-fourth larger than the Brush "Colossus" machine running at the Lockport works in America—the production is proportionately



DYNAMO-ELECTRIC MACHINE OF 300,00
STOKE-U



ATTS, IN USE AT THE COWLES WORKS,
TRENT.

very much greater, and evidences also that the Cowles process is capable of operating dynamos of almost any magnitude. We understand that a second dynamo, having a guaranteed capacity of 402,000 watts, is in course of construction and will shortly be put down at the Stoke works. The production of aluminium alloys by this process has recently been much simplified, with a proportionate reduction in cost, and it is believed to be probable that these alloys will soon be marketable at prices competing with the common metals and alloys.

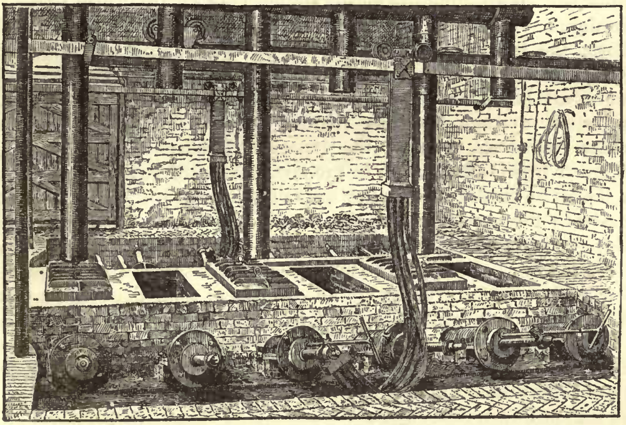


Fig. 128.

The Cowles Syndicate are also making a ferro-aluminium alloy, with a new continuous furnace, from which the product runs direct in its fluid state.

When we consider the enormous importance of aluminium alloys—aluminium bronze, perhaps, more especially—and the numerous purposes for which they are particularly applicable, a few details concerning the alloys manufactured by the Cowles furnace may not be uninteresting. One of the most important purposes to which aluminium bronze — if obtainable in large quantity and at a moderate cost—could be applied, would be in the manufacture of heavy ordnance. Indeed, Mr. J. W. Richards, Instructor in Metallurgy in the Lehigh University, Bethlehem, Pa., U.S.A., has stated that "the most recent action of the Italian Government in the artillery line is the replacement of 4,000 steel field-pieces by bronze or gun-metal pieces, the advantage of the latter being that while as safe from bursting, and as effective as steel guns of equal weight, they can be cast at much less expense and to greater perfection than steel guns. Such being the advantages in using ordinary gun-bronze, let me ask if it is not in the power of our Government to take a step in advance of the best and most recent artillery practice by undertaking to cast its heavy guns of aluminium bronze?" Following up Mr. Richards' sensible suggestion to the American Government, may we express a hope that our own Government will seriously consider the advisability of turning its attention to the same alloy for our own naval and military ordnance? Respecting the tensile strength per square inch of Cowles' aluminium bronze as compared with that of some other metals and alloys, the following data are given by the manufacturers:—Cast copper, 24,000; gun-bronze of copper and tin (cast), 39,000; cast gun-metal (U.S. Ordnance), 30,000; steel plates (rolled), 81,000; cast steel, average Bessemer ingots, 63,000; Cowles' aluminium bronze, *in castings*, 100,000; the "special" grade of the same has, *in castings*, a tensile strength up to 130,000. It should be mentioned that in the latter grades of this alloy a small percentage of silicon—about one-tenth the percentage of the aluminium—is combined with the alloy, that is to say about 11·3 per cent. of aluminium and silicon are added to pure Lake Superior copper to form this special alloy. Messrs. Cowles state that every ingot of alloys made at their works has a test bar made from it, which is tested in a machine built by Tinius Olsen & Co., of Philadelphia, a trustworthy machine, and one used in many of the colleges and ironworks in the States, and the record of all tests is carefully preserved. The grade, tensile strength, and elongation are stamped upon each ingot.

The beautiful golden-yellow colour of the ten per cent. aluminium bronze renders it highly suitable for the manufacture of art metal work, since it has not only a richer colour than brass, but it is also much less liable to corrosion. We have seen some very pleasing specimens in the form of salvers, candlesticks, sugar-bowls, salt-cellars, &c., manufactured from this bronze, which by contrast would really form very pretty table ornaments when mingled with articles of silver or electroplate.

CHAPTER XXXII.

MECHANICAL OPERATIONS CONNECTED WITH ELECTRO-DEPOSITION.

Metal Polishing.—Brass Polishing.—The Polishing Lathe.—Brass Finishing. —Lime Finishing.—Nickel Polishing and Finishing.—Steel Polishing. —Polishing Silver or Plated Work.—Burnishing.—Burnishing Silver or Plated Work.—Electro-gilt Work.

Metal Polishing.—All articles which are required to be bright when finished are submitted to the process of polishing before they undergo the preliminary operations of cleaning, dipping, quicking, &c., to prepare them for the depositing vat. If the articles were not to be rendered perfectly smooth before being coated with other metal, it would be exceedingly difficult, if not impossible, either to polish or burnish them after being plated to such a degree of perfection as is necessary for bright work. This preliminary polishing is more especially necessary in the case of nickel-plated work, for unless the work is rendered bright and absolutely free from scratches or markings of any kind, these defects will inevitably show when the articles are finished. The extreme hardness of nickel renders the operation of polishing and finishing nickel-plated work at all times laborious, but more especially so if the work has been badly polished before it enters the nickel bath. It is also the fact that every scratch, however minute, which a careless polisher leaves upon brass, copper, or steel work, becomes plainly visible after it has been finished by the nickel-polisher. In large work, such as mullers, sausage-warmers, &c., the preparatory polishing should be of the most faultless character, since any attempt to remedy defects *after* nickel-plating would be fruitless, and probably result in *cutting through* the nickel, necessitating the replating of the article, which should under all circumstances be rigidly avoided. It should be the nickel-plater's *first* duty to examine every piece of work, to see if it has been properly polished, before placing it in the potash bath ; if badly polished, it must be sent back to the polisher again.

Brass Polishing.—These operations are performed at a lathe set in motion by steam-power. It is usually the practice for metal polishers to fix their lathes in workshops supplied with steam-power from adjacent premises, the cost of power per lathe being generally moderate.

The Polishing Lathe.—This machine ordinarily consists of a stout wooden bench set firmly in the floor. In the centre of the bench is a solid cast-iron standard—secured in its position by screwed bolts—in which runs a long double spindle, working on brass or gun-metal bearings. In the centre of the spindle are two pulleys, one fast and the other loose, by means of which it may be set in motion or stopped at will. The spindle revolves at a very high speed. A leather belt, connected to a revolving shaft, by preference below the lathe, passes over these pulleys, and either workman, by means of a stick kept for the purpose, can, by pushing the belt to left or right, set the spindle in motion or stop it as occasion may require. This arrangement is not only convenient, but absolutely necessary, since the spindle is generally worked by two men—one at each end; and when either of them requires to change one circular buff, or "bob," for another, which very frequently happens, he takes up the short stick and pushes the belt from the *fast* pulley, which is attached to the spindle, to the *loose* pulley, which runs over it. An improved polishing lathe, with shaft-carrier and standard combined, has been produced in Birmingham, and the design is shown in Fig. 129. This arrangement obviates the necessity of fixing a wooden bench.

The polishing tools, or "bobs," as they are usually called, consist of discs of various kinds of hard leather, the stoutest of which are about three-fourths of an inch thick, and are made from walrus or hippopotamus hide; other bobs are made from bull-neck leather, felt, &c. The materials used for brass polishing are glass-cutters' sand and Trent sand; the former, having a sharper cut than the latter, is generally used for very rough work, such as comes direct from the founders, with the file marks extensively visible upon its surfaces. Before commencing his work, the polisher, after removing his coat and hat, envelops himself in a long, loose garment, made of brown holland, which buttons at the neck from behind, and its sleeves are secured at the wrists in the same way.

Previous to setting the lathe in motion, each polisher spreads a square piece of calico upon the bench, immediately under the point of each spindle, upon which each workman places a quantity of the sand he intends to use. The first operation, called roughing, or *rough sanding*, is generally performed by the workman standing at the right-hand end of the spindle, and the work is then passed to his mate on the left, who treats it with a finer quality of sand, or "old sand," that which has been repeatedly used, by which a much smoother surface is produced. In the process of *sanding*, as it is called, the workman, holding a piece of work in his right hand, takes up a handful of sand with his left, and holding the work up to the lower part of the revolving bob, presses it against it, while he dexterously allows the sand in his left hand to continually escape, by which it passes on to the bob while the work is being pressed against it; the moment the handful of sand is paid out, he takes up another handful, almost involuntarily, and keeps up this movement, at intervals of a few seconds only, with mechanical regularity. The operation of rough sanding is sometimes very laborious, as the workmen have to press with all their force upon the work, in order to obliterate deep file marks and other irregularities.

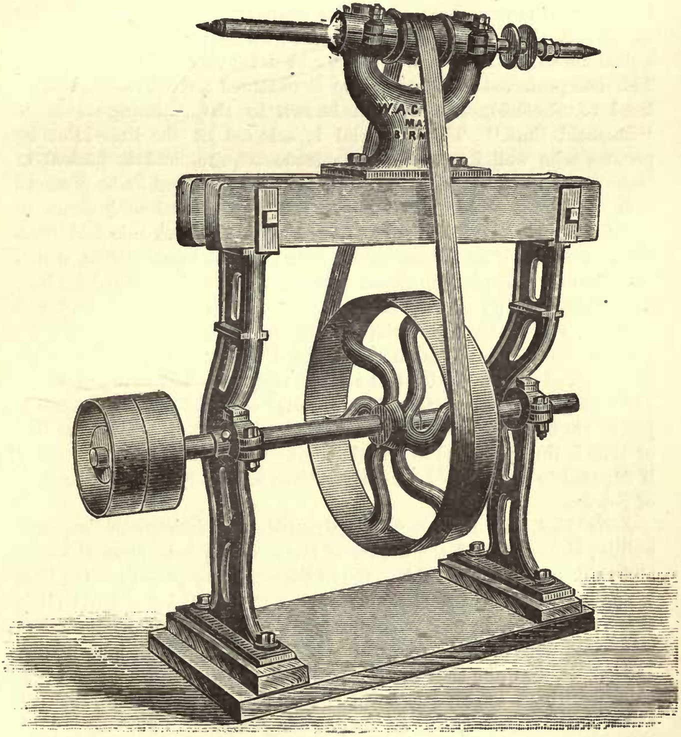


Fig. 129.

Brass Finishing.—After the work has been rough and fine sanded, it is transferred to the *finisher*, in whose hands it receives the highest degree of polish of which the metal is susceptible. As in all other branches of trade, there is much difference in the skill and judgment of those who follow the art of brass finishing. While some workmen take great delight in turning their work out of hand in the most creditable condition, others are exceedingly careless and indifferent as to whether the work be good or bad, having, perhaps, a preference for the latter. The material generally used for finishing brass work is quicklime reduced to a fine powder, and sifted through a muslin sieve. The lime preferred for this purpose is obtained from the neighbourhood of Sheffield, and is well known in the polishing trade as "Sheffield lime." This material is selected at the lime-kilns by persons who well know what the trade require, and is packed in casks and sent to the polishers in London or elsewhere, who preserve it in olive jars, or large tin chests, carefully covered with cloths to exclude the air; if the lime be allowed to extract carbonic acid from the atmosphere it soon becomes converted into *carbonate of lime*, which is useless for polishing purposes. When the lime is required for use, a boy takes a lump or two from the jar, and removes all dirt and impurities by first scraping the lime all over, after which he breaks the lime up into small fragments, a few of which he puts into an iron mortar, and with a pestle of the same metal reduces it to a powder. He next passes the powdered lime through the sieve and hands the fine powder to the first workman who requires it. Only a small quantity of lime is thus prepared at one time, since it loses its *cutting* property if exposed to the air even for a short time, especially when in the state of powder.

Lime Finishing is generally entrusted to workmen of superior ability, since much of the beauty of the work depends upon the care and skill bestowed upon this stage of the polishing process. The lime is applied to the bobs in the same way as the sand, but a little oil is also used; by being used over and over again, the lime becomes impregnated with particles of metal, which increases its polishing power. Indeed, we may say that the bright *polish* which metals acquire when rubbed with an impalpable powder, such as jewellers' rouge, lime, or other material, is only due to the polishing medium indirectly; it is the metal which becomes removed from the surface of the work which produces the brilliant effect termed *finish*, or *high polish*. When the workman has carefully gone over every part of the work, changing the bobs from time to time to suit the various surfaces—plane or hollow, as the case may be—he removes the lime-bob from the spindle, and fixes a "dolly" in its place. The dolly for this purpose commonly consists of a large disc, composed of many layers of unbleached calico—the whole being about half to three-quarters of an inch in thickness. The folds of calico are first cut into a circular form by means of a chisel and mallet, and these are braced together by two discs of leather or metal, secured by copper rivets. A hole is formed in the centre to admit the screwed point of the spindle. The dolly is worked with dry lime, which is applied by frequently holding a lump of fresh lime against the revolving calico disc, by which it becomes sufficiently charged for the time. The high speed at which the dolly revolves causes the frayed edges of the cloth, when charged with dry lime, to produce an exceedingly brilliant surface in a very short time, but much judgment on the part of the finisher is needed to produce the highest finish attainable, a point which good workmen never fail to reach.

Nickel Polishing, or Finishing, is performed by aid of Sheffield lime, a little oil being applied to the bobs occasionally. Rouge and crocus compositions are used by preference by some polishers. If the work has been properly polished before plating, the nickel-finisher's task, although requiring much skill and care, is tolerably straightforward. The dull nickel deposit readily yields to the pressure upon the lime-bob, presenting to the eye of the workman that degree of brightness which he knows full well will come up to the highest possible brilliancy under the operation of the dolly. He takes good care, however, not to trust too much to the latter tool, but gives the work a brilliant surface before it is submitted to the dolly. It is his special care, moreover, by using small and thin bobs, specially reserved for such purposes, to well polish every interstice or hollow that can be reached by the smallest of his bobs, some of which are about the size of a crown piece.

Steel Polishing.—The articles are first ground upon a grindstone or emery wheel, and are afterwards *glazed*, as it is termed, which consists in submitting the steel articles to the action of round discs of wood covered with leather or metal—a mixture of lead and tin—applied with emery powder of various degrees of fineness, moistened with a little oil. By this means the work is rendered as smooth as possible, and afterwards receives a bright finish with leather-faced buffs charged with finely powdered crocus (peroxide of iron), which imparts to the surface the brilliant lustre for which good steel, as a metal, is so justly famed. Cow-hair or bristle brushes charged with crocus and oil are also used for steel polishing.

Polishing Silver or Plated Work.—The preliminary stages of the process are performed at a lathe set in motion by steam-power, or by a suitable foot-lathe; the ordinary form of the latter machine is shown in Fig. 130. The tools used are a series of circular buffs or bobs consisting of discs of wood, faced with hard and soft leathers to suit the several stages of the process, the softer buffs being applied after the articles have received a preliminary treatment with the harder and more active tools. Circular brushes, formed of bristles set in discs of wood, are also employed, and for some purposes bobs made from bull-neck leather, &c., of various sizes and degrees of thickness, are used. The polisher is generally provided with the various kinds of leather required in his work, from which he cuts out his bobs to suit the particular work he may have in hand. The polishing is effected with the material known as rotten-stone, or tripoli, moistened with oil; the former is usually kept in a shallow tray, and the latter in a conical tin can with small tubular opening at the top; by gently pressing upon the bottom of the can with the thumb, the oil escapes slowly, so that a single drop may be applied if necessary. Having set the lathe in motion, the workman applies a little rotten-stone and oil, in the form of a paste, to the revolving bob, and then presses the article with moderate force against it, shifting the article continually, until the entire surface has been buffed. The work is carefully examined from time to time, and when sufficiently smooth for finish-

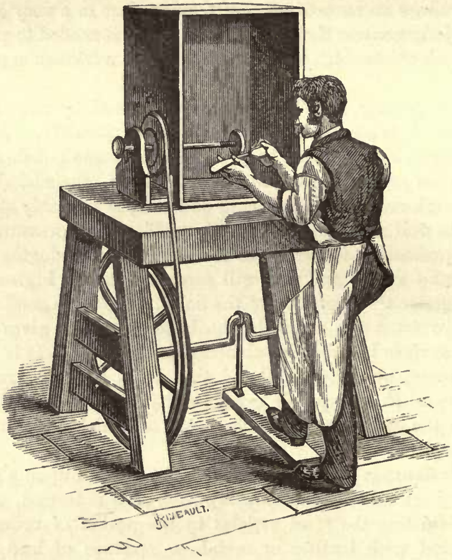


Fig. 130.

ing, it is sent to the finishing room, where it is first cleaned by well washing with warm soap and water, with the addition of a little soda.

Finishing, or Colouring, is performed either by lathe or by hand, according to the nature of the work. When the lathe is employed, a a mop or "dolly," made from the fabric called *swansdown*, is used, in which several layers of this material, cut into a circular form, are united by discs of wood or metal held together by screws or rivets. In the centre of these discs a hole is punched, to receive the screwed point of the spindle. The material used for finishing is the finest quality of jewellers' rouge (peroxide of iron), which is made into a paste with water, and applied, in small quantities at a time, to the face of the dolly-mop, which, by revolving at a very high speed, quickly produces a remarkably brilliant lustre. The rouge "compo" before referred to is also used for silver polishing.

Hand-Finishing, or Colouring.—This operation is best conducted by men or women whose hands are of a soft texture, or have a "velvet-hand," as it is sometimes termed in the trade. The colourer is provided with a shallow porcelain vessel, in which he puts a quantity of rouge, and pours upon it sufficient water to form a pasty mass; after having thoroughly cleaned the articles, and wiped them dry with a soft piece of diaper, he dips the tip of his finger in the rouge-paste, and smears it over a part of the work, and rubs the article briskly with the side of the hand below the little finger, or the large muscle below the thumb, according to the surface he has to treat, using moderate pressure at first, and this he diminishes as the work approaches the finish. As soon as the silver surface has acquired the black lustre for which this metal, when highly polished, is so remarkable, it is examined to ascertain if there are any scratches or other imperfections visible; if an appearance of *greyness* is noticeable upon any part of the work, such portions are again gone over until the uniform black lustre has been produced. It is of the highest importance that neither dust nor grit should get into the rouge or upon the work while being coloured, otherwise scratches difficult to obliterate will be produced. When the work is finished, the rouge is washed out of the crevices, or ornamental parts of the work by means of soap and water and a very soft long-haired brush kept specially for this purpose. The articles are then wiped dry with a soft piece of old diaper or linen, and afterwards with a soft chamois leather.

Articles which have been electro-plated should only be submitted to the process of polishing when they have received a stout coating of silver, for if but a moderate deposit has been put upon the work, the severe operation of buffing with rotten-stone will most probably cut through the silver and expose the metal beneath, more especially at the edges.

Burnishing.—Although many stoutly plated articles of electro-plate—especially spoons and forks—are rendered bright by *polishing*, by far the greater proportion of this class of work is *burnished*. Burnishers are an important class of female operatives, who have regularly served an apprenticeship to the trade from an early age, and many of whom perform their allotted tasks with exquisite care and finish. The tools employed in burnishing silver and plated work are very numerous, and are made of steel for the preliminary operations of *grounding* as it is termed, and blood-stone, a hard compact variety of hæmatite (native oxide of iron) for *finishing*. A few examples of burnishing tools are shown in the accompanying engravings (Fig. 131), the cuts being about half the actual size of the tools they represent. The steel tools, which are made in various forms to suit the different surfaces to which they have to be applied, are of various degrees of thickness, the thinner or keener implements being first used to *ground the work*, as it is termed, before the stouter tools are applied. The blades of the steel burnishers are fixed into wooden hafts or handles provided with a brass or iron ferrule, to prevent the wood from splitting. The blood-stones are fitted into iron tubes, and secured by means of pewter solder, a wooden handle being inserted in the other end of the tube. Blood-stone burnishers are of several qualities, the finest material being used for *finishing*. These implements are also of different sizes, so as to be suitable for large or small surfaces.

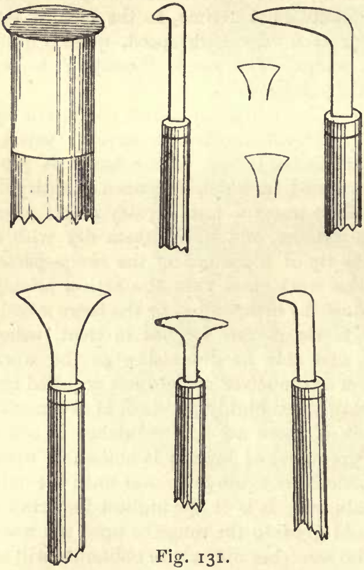


Fig. 131.

Preparing the Tools for Burnishing.—To impart a perfectly smooth and bright surface to the steel and blood-stone burnishers, each workwoman provides herself with two flat buffs, one for the steel tools and the other for the blood-stones. The steel buff consists of a piece of *buff* (Fig. 132) or belt leather, such as soldiers' belts are made from, about 10 inches long and 2½ inches wide. The leather is first boiled for some time in water, after which it is dried as speedily as possible, by which means it becomes excessively hard; the leather is next glued to a flat piece of wood, about three-fourths of an inch larger than itself each way, and about three-quarters of an inch in thickness. To secure the leather in its position until the glue has become hardened, a heavy weight or clamps are used. When ready for use, the burnisher forms a groove from end to end, by rubbing one of the stouter tools upon the surface of the leather, leaning with all her weight upon it, so as to form as deep a hollow or groove as possible. Having done this she places a little jewellers' rouge in the groove, and passes the tool up and down the hollow with all her force, until its face has acquired a bright black lustre. It is usually the practice to form about three such grooves in the leather with tools of various thicknesses, these being applied to stout or thin burnishers, as the case may be. The buffs for polishing the bloodstone tools are prepared in the same way as the former, a single groove or channel only being formed as evenly as possible in the centre of the leather. The material employed in polishing the face of the bloodstone is putty-powder (oxide of tin), which is used in the same way as the rouge for the steel tools.

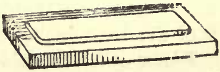


Fig. 132.

Preparation of the Work for Burnishing.—The plated articles, after being scratch-brushed, rinsed, and dried, are transferred to the burnisher, who first scours them all over with fine silver-sand and warm soap and water, applied with a piece of soft flannel; the work is then thoroughly well rinsed in warm water, then wiped dry with soft diaper or old linen rag. When thus prepared, the article is ready for burnishing.

Burnishing Silver or Plated Work.—After scouring the work the burnisher makes a small quantity of warm soap-suds, in a gallipot or other small vessel, by putting a few thin slices of yellow soap in the vessel, and pouring hot water over them, stirring for a few moments with one of the steel tools, until the "suds" are in a condition for use. She next selects the tool she intends to commence with, and rubs it upon the buff until the requisite surface is obtained. Having wiped the tool, she dips it in the suds, and holding it in her right hand, with the handle resting on her little finger, near the knuckle, the other three fingers being above the handle, while the thumb presses upon the top of the handle, by which means the tool is held firmly, and can be applied with the necessary pressure. The first tool employed for a large flat surface is one of the larger and thinner burnishers, whose face is of an elliptic form; this is held in a slanting direction, and passed to and fro over the work with sufficient pressure to produce a certain degree of brightness, and every now and then the tool is wiped dry, re-buffed, and again applied, until the whole surface of the article has been gone over. A stouter steel tool is next applied, which has the effect of considerably erasing the marks left by the first implement. After going over the surface several times with steel tools of increasing thickness, the first blood-stone is next applied, and which, having a broad and highly polished surface, nearly removes all traces of the marks produced by the steel tools. The work is afterwards gone over with a *finishing stone*, which is of the finest quality of blood-stone that can be procured.

Electro-gilt Work is burnished in the same way as the preceding, but some burnishers prefer using vinegar instead of soap-suds for moistening their tools. We suggested the employment of weak ale for this purpose, and the workwomen having tried it, used it constantly with much satisfaction at our own works for many years.

CHAPTER XXXIII.

RECOVERY OF GOLD AND SILVER FROM WASTE SOLUTIONS, ETC.

Recovery of Gold from Old Cyanide Solutions.—Recovery of Silver from Old Cyanide Solutions.—Extraction of Silver by the Wet Method.—Recovery of Gold and Silver from Scratch-brush Waste.—Recovery of Gold and Silver from Old Stripping Solutions.

Recovery of Gold from Old Cyanide Solutions.—Since the precipitation of gold (and silver) from cyanide solutions, which is effected by means of mineral acids, involves the liberation of hydrocyanic acid (prussic acid) the operations must always be conducted with the utmost caution, and should always be carried on in the open air. It is well to remark here that when acid is added to a cyanide solution, not only hydrocyanic acid but also carbonic acid is liberated; and since this heavy gas cannot escape through the flue of an ordinary chimney, owing to its gravity, but flows over the vessel in a dense white vapour, the operator should be careful not to disturb these fumes, so as to cause them to rise upward, but to allow them to flow over the sides of the vessel and escape into the open air, where they will be dispersed by the wind. The reduction of the gold by the *dry way* is, however, less hazardous, not so offensive, and fully as economical.

To precipitate gold from cyanide solutions, hydrochloric acid is to be gradually added, until no further precipitation takes place; the solution should then be boiled and the vessel set aside to cool. The precipitate (cyanide of gold), which is of a yellowish colour, must then be separated from the supernatant liquor by decantation, and then filtered. Since a small portion of gold, however, still remains in the liquor, it must not be thrown away, but should be heated, and zinc filings added, which will throw down the remainder of the gold; the clear liquor is now to be poured off, and the residue boiled with dilute hydrochloric acid, to remove excess of zinc, and after washing, the deposit is to be added to the other portions. Ignite and fuse the mixture in a platinum or ordinary crucible, with an equal weight of sulphate of potassium. Dissolve the saline residue in boiling sulphuric acid, then wash it with water, when perfectly pure gold will remain.—(*R. Huber.*)*

Böttger recommends the following method for recovering gold from old solutions:—The solution should be evaporated to dryness, the residue then finely powdered, and intimately mixed with an equal weight of litharge (oxide of lead) and fused at a strong heat; the lead is extracted from the resulting button of gold and lead alloy by warm nitric acid, when the gold will remain as a loose brown spongy mass. The same author says, "If we pour hydrochloric acid into a pure solution of gold in cyanide of potassium, there is slowly formed at ordinary temperatures, and immediately on the application of heat, a yellow precipitate, which is cyanide of gold; the filtered liquid which has given this precipitate still contains a little gold in solution. On evaporating the liquid to dryness, fusing, dissolving, and filtering afresh, there remains upon the filter the remainder of the gold. Crystallised double cyanide of gold and potassium fuses and effervesces by heat, and is resolved into cyanogen gas, ammonia, and cyanide of potassium, if air be present; its complete decomposition requires a strong heat. When it is strongly ignited, mixed with an equal weight of carbonate of potash, a button of metallic gold is obtained."

Cyanide gilding solutions, when mixed with sulphuric, nitric, or hydrochloric acid, slowly deposit cyanide of gold; and when boiled with hydrochloric acid, it is completely resolved into cyanide of gold and chloride of potassium. The same result is obtained with nitric and sulphuric acid, and even with oxalic, tartaric, and acetic acids. When heated with sulphuric acid, it gives off hydrocyanic acid gas, and after ignition, leaves a mixture of gold and sulphate of potassium. Iodine sets free cyanogen gas, forms iodide of potassium, and throws down the cyanide of gold.—(*Böttger.*)

Gold may be precipitated from washing waters containing traces of the precious metal by adding a solution of protosulphate of iron, when a brown deposit of pure gold is obtained; the subsidence of the metal may be hastened by heating the liquid.

Recovery of Silver from Old Cyanide Solutions.—Elsner made a series of important researches upon the extraction of gold and silver from cyanide solutions, the results of which he communicated in a valuable paper, from which the following extracts are taken. He prefaced his description of the practical methods recommended, by mentioning the results of some of his experiments upon which they were based.

1. "If we add hydrochloric acid to a solution of silver in cyanide of

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* *Chemical News*, vol. viii. p. 31.

potassium until the liquid exhibits an acid reaction, we obtain a white precipitate of chloride of silver, which, when submitted to heat, melts into a yellow mass. If this was cyanide of silver, the application of a red heat would have left a regulus of silver. The addition of the hydrochloric acid precipitates all the silver present in the liquid in the form of chloride of silver.

"If we evaporate a solution of silver in cyanide of potassium to dryness, and heat the residue to redness, until the mass is in a state of quiet fusion, and has assumed a brown colour, there remains, when we wash the mass with water, metallic and porous silver. The wash waters, when filtered, still contain a little silver in solution, because, if hydrochloric acid is added to them, it produces a precipitate of chloride of silver. In evaporating and calcining a solution of gold in cyanide of potassium, the result is similar, *i.e.* we obtain metallic gold. The wash waters, acidulated with hydrochloric acid, give, when treated with sulphuretted hydrogen, a brown precipitate of sulphide of gold; and with the salt of tin a violet precipitate (purple of Cassius), a proof that these liquids still contain a little gold in solution.

"*Extraction of Silver by the Wet Method*—Add hydrochloric acid until the liquid exhibits a strongly acid reaction. The precipitate of chloride of silver which is thus obtained, will be, as we have already said, of a reddish-white colour, because of the cyanide of copper which is precipitated with it when the solution has been used a long time for silvering objects containing copper. In this precipitation by hydrochloric acid, there is hydrocyanic acid gas set free, therefore the operation should only be performed in the open air, or in a place where there is good ventilation; if the precipitate is very red, it must be treated with hot hydrochloric acid, which will dissolve the cyanide of copper. The chloride of silver, having been washed with water, must be dried and then fused with pearlash in a Hessian crucible coated with borax, in the ordinary manner for obtaining metallic silver.

"This method is very simple in its application, and very economical, considering that by the aid of the hydrochloric acid all the silver contained in the solution of cyanide of potassium is precipitated, and there remains no trace of it in the liquid. But the quantity of hydrocyanic gas which is disengaged is a circumstance which must be taken into serious consideration when operating on large quantities of silver solution, the vapour of which is most deleterious, and nothing but the most perfect ventilation, combined with arrangements for the escape of the poisonous gases, will admit of the process being carried on without danger to the workmen; when, however, we have taken the precautions dictated by prudence, the method in question may be considered as perfectly practical. The liquid should be poured into very capacious vessels, because the addition of the acid produces a large amount of froth.

"*Extraction of Silver by the Dry Method.*—The solution of cyanide of silver and potassium is evaporated to dryness, the residue fused at a red heat, and the resulting mass, when cold, is washed with water. The remainder is the silver in a porous metallic condition. There still remains in the wash waters a little silver, which may be precipitated by the addition of hydrochloric acid."

Recovery of Gold and Silver from Scratch-brush Waste.—The sludge or sediment which accumulates in the scratch-brush box frequently contains a considerable quantity of gold and silver, removed by the brushes from articles which have stripped in parts owing to defective cleaning of the work. This waste, with other valuable refuse of a similar description, should be collected every few months, and after being dried, should be mixed with a little dried carbonate of potash and fused. The resulting button, being an alloy of gold, silver, copper, &c., may be treated as follows to separate the gold and silver:—Remelt the alloy, and granulate it by pouring the molten metal into cold water. Place the grains in a flask and pour on them a mixture of 2 parts nitric acid to 1 part water, and apply moderate heat, when all but the gold will be dissolved, the latter remaining as a brown powder at the bottom of the flask. The liquid must then be carefully poured into another vessel, and strips of clean copper immersed in it, which will cause any silver present to be thrown down in the metallic state. The gold and silver deposits must afterwards be well washed with warm water, and after drying, be mixed with dried carbonate of potash or soda, and fused as before. In fusing these fine deposits, after they have been intimately mixed with the dried alkali, which is to act as a flux, the mixture should be compressed as much as possible when placed in the crucible, or melting pot, by means of an iron pestle or other suitable tool, and the heat allowed to progress slowly at first, and after a short time this may be increased until the contents of the crucible assume a semi-fluid condition; when in this state, the heat should be moderated, to allow the metal to "gather," as it is termed, by which the molten globules will gradually subside and unite in the form of a liquid mass at the bottom of the pot. It is very important at this stage to keep the fused mass in as liquid a state as possible, taking care also not to apply too great heat, or the contents may rise up and overflow. Should this be likely to occur, a pinch of *dried* common salt may be thrown into the pot, which will cause the fused mass to subside. When the operation is complete, the pot is to be withdrawn from the fire and placed aside to cool; the pot is afterwards broken at its lower part, by a blow from a hammer, and the button extracted. This may then be plunged into a dilute sulphuric acid pickle to remove any flux that may attach to it.

Recovery of Gold and Silver from Old Stripping Solutions.—The gold may be recovered from exhausted stripping baths by evaporating them to dryness and fusing the residue with a little carbonate of potash or soda There are several methods of treating old silver stripping solutions, of which the following are the simplest: 1. Dilute the liquid with three or four times its bulk of water; now place in the liquid several stout plates of clean zinc, which will rapidly become covered with a spongy layer of reduced silver; the plates should be occasionally shaken in the liquid to remove the deposited metal, which will fall to the bottom of the vessel. When the zinc plates, after having been immersed for a few hours, cease to become coated with silver, the liquid may be decanted into another vessel, and a few drops of hydrochloric acid added, when, if a white cloudiness is produced, more acid should be added (or a solution of common salt) until it produces no further effect. The white precipitate, which is chloride of silver, may afterwards be collected and treated separately. The reduced silver in the first vessel should be well washed, to free it from sulphate of zinc, and afterwards dried and fused as before. 2. The silver stripping solution may be treated with a strong solution of common salt, which will throw down the metal in the form of chloride, and this, after being *well washed*, may be employed for making up a silver bath, or the chloride may be decomposed and the silver reduced to the metallic state, with or without the aid of heat, by immersing in the deposit several stout pieces of clean zinc, which after awhile will convert the deposit into metallic silver in the form of a grey powder. To facilitate the action, a few drops of sulphuric acid should be added. After well washing with hot water, this powder may be dissolved in nitric acid, to form nitrate of silver, which can then be used for making up silver baths. Or the grey powder may be dried and mixed with *dried* carbonate of potash and fused as before directed. After putting the mixture of reduced silver and carbonate of potash into the crucible, it should be compressed as much as possible, by pressing it with an iron pestle, which will greatly facilitate the "gathering" of the globules of fused silver; indeed it is a good plan, when the crucible has become fully heated, to gently press the *crust* of unfused matter with an iron rod, so as to force it to the lower part of the vessel where the heat is greatest. When the gathering of the metal is complete, a small quantity of nitre may be occasionally dropped into the crucible, which will remove any traces of iron or copper that may be present, and thus render the silver button more pure.

CHAPTER XXXIV.

AUXILIARY OPERATIONS CONNECTED WITH ELECTRO-DEPOSITION.

Stripping Metals from each other.—Stripping Solution for Silver.—Cold Stripping Solution for Silver.—Stripping Silver from Iron, Steel, Zinc, &c.—Stripping Silver by Battery.—Stripping Gold from Silver Work.—Stripping Nickel-plated Articles.—Stopping-off.—Applying Stopping-off Varnishes.—Electrolytic Soldering.

"Stripping" Metals from each other.—Old articles which have been gilt, silvered, or nickel-plated, or new work which has been unsuccessfully coated with these metals by electro-deposition, generally require to be deprived of the exterior coating before a proper deposit can be obtained by electrolysis. The operation of removing the exterior layer of metal is technically termed *stripping*, and the various solutions applied for the purpose are termed *stripping solutions.* It may be well to remark here that metals of a like character do not adhere firmly to each other; thus electro-deposited gold will not adhere to a gilt surface, silver to a silver-plated surface; nor will nickel attach itself to a nickel-plated article; this fact is most conspicuously observable when an attempt is made to re-nickel a nickel-plated article without previously removing the old layer of this metal, when the second coating will generally rise up from the underlying coat, even without subjecting it to any provocation by mechanical means, such as buffing. Indeed, so persistent is this metal in refusing to accept a second coating that we have known a brass rod (placed in the bath as a "stop," to check the force of the current when first filling the bath) which had remained *in the bath* for many weeks, to become coated with countless layers of nickel, which had partially separated from each other, giving the lower end of the rod the appearance of a metallic mop. The author's impression was that every time the circuit was broken, by the stoppage of the dynamo machine, that the layer next deposited, when the machine was again in motion, *did not adhere* to its predecessor, but became a distinct and separate layer. Although this refusal to attach itself to a metal of its own kind is not so marked in the case of silver and gold as with nickel (and we might say copper also), it is unquestionably the case that the latter metals will more firmly adhere, when electro-deposited, to copper, brass, or German silver, than they will to articles composed of or coated with the same metals. The solutions employed for removing or stripping the precious metals and nickel from articles which have been coated with them will be given under separate headings, since the materials employed differ in each case.

Stripping Solution for Silver.—A quantity of strong oil of vitriol is put into a stone jar or enamelled saucepan, heated on a sand-bath or in any convenient way, and to this is added a small quantity of saltpetre (nitrate of potash). Sometimes nitrate of soda, called *Chili saltpetre*, is used in place of the other salt. When the saltpetre has become dissolved, which may be accelerated by stirring the mixture with a stout glass rod, the articles to be stripped, attached to a copper wire, are dipped into the hot liquid, and allowed to remain, with occasional motion up and down, until the whole of the silver has become dissolved off. If the operation be carefully watched, it will be observed that the silver quickly disappears from the parts where it was thinnest, and gradually appears to fade away until not a trace is left upon the article. The chemical action of the solution upon the German silver, brass or copper, of which the article may be composed, is very slight if the articles are withdrawn directly the silver has been removed. It is very important that no water should be allowed to enter the stripping bath; therefore the articles should be perfectly dry before being immersed. In stripping spoons and forks, it will generally be noticed that the last portions of silver to leave the articles are at the points of the prongs and upper part of the handle of forks, and the lower portion of the bowls and extremity of the handle of spoons, which establishes the well-known fact that these parts receive a greater thickness of deposit than other portions of the article. The same observation applies to all projecting parts, and in order to remove the last traces of silver from such portions, when the silver has been dissolved from the main body of the work, the article should be raised out of the bath, and the projections or points dipped in separately, which will save the bulk of the article from being severely acted upon by the acid mixture. When the solution begins to work tardily, after a certain number of articles have been dipped in it, more saltpetre must be added from time to time, and the liquid kept well heated. Since oil of vitriol attracts moisture from the air, every time the bath is done with the vessel should be covered with a stout plate of glass.

When a stripping bath has been much used, it works slowly, and the addition of saltpetre fails to invigorate it. When in this condition a mass of crystals will deposit at the bottom of the vessel as the liquid cools. The bath must now be put aside and replaced by a fresh mixture. The process for recovering the silver from old stripping solutions is described at page 465.

Cold Stripping Solution for Silver.—A large quantity of strong sulphuric acid is poured into a sound and deep stoneware vessel; to every two parts of the acid by measure one part of strong nitric acid (also by measure) is added, and the mixture is employed in its cold state. The process of stripping in this solution is much slower than in the former bath, and therefore requires less attention; since, however, the thickness of silver upon plated work varies considerably, from a mere film to a good stout coating, the progress of the work must be carefully watched from time to time, and the operator's judgment will soon guide him as to the quality of the plated work under treatment. The articles to be stripped are suspended from stout copper wires, or preferably by means of glass hooks, which may readily be formed from stout glass rods by simply bending them to the required form over an ordinary gas jet or Bunsen burner. It is very important that no water should be allowed to enter the stripping bath, otherwise the metal of which the articles may be composed, as brass, copper, German silver, &c., will be acted upon by the acid mixture. When the liquid begins to act tardily, after being worked for some time, a small quantity of strong nitric acid must be added, and this addition must be made whenever the liquid shows signs of weakness.

When stripping silver from articles which have been plated, it is necessary to remove *all* the silver, otherwise, when the work is replated, the second coating may strip or peel off such parts as may have small portions of the old coating adhering to them. After the articles have been stripped, rinsed, and dried, they should be polished, or buffed, to render them uniformly smooth for replating, after which they are treated in the same way as new work preparatory to being placed in the depositing vat.

Stripping Silver from Iron, Steel, Zinc, &c.—Articles made from these metals, as also lead, Britannia, and pewter, must not be stripped in the acid stripping solutions, but the silver upon their surface may be removed by making them the *anode* in a cyanide of silver bath, and, as we have before suggested, it is better to keep a small bath for this special purpose than to risk injuring the usual plating bath by the introduction of other metals, which will surely occur when the silver is partially removed from the plated article by the solvent action of the cyanide.

Stripping Silver by Battery.—Make a strong solution of cyanide of potassium, say about one pound to the gallon of water. Attach the article to be deprived of its silver to the positive electrode of the battery or dynamo-electric machine, and suspend a strip of platinum foil to the negative electrode. When the bath has acquired a certain amount of silver (dissolved from the plated articles) the platinum will become coated, and if the current be powerful, the silver may become deposited in a granular state, and be liable to fall from the cathode in minute grains. To prevent these from falling to the bottom of the bath, the platinum cathode may be enclosed in a muslin bag, which by retaining the particles will enable them to be readily collected. A plate of gas carbon, German silver, or brass may be employed as a cathode instead of platinum, if desired.

Stripping Gold from Silver Work.—If done with great care, the gold may be readily dissolved from the surface of solid silver articles (not electro-plated) by means of warm aqua regia, composed of 4 parts of hydrochloric acid and 1 part nitric acid. The article may be either dipped in the aqua regia, or the acid may be applied to the article by pouring it over a part at a time, from a small porcelain ladle, and allowing the liquid to flow into the vessel containing the bulk of the acid. When this method is adopted, a vessel of clean water should stand by the side of the acid bath, in which the articles should be rinsed occasionally, and then allowed to drain before again applying the acid. The operation should be conducted over a sand bath, above which is a hood to conduct the fumes given off to the flue of the chimney. As we have hinted, the operation requires care, but if properly conducted it is expeditious. It may be as well to state that silver articles which have been mercury gilt—probably more than once—cannot be wholly deprived of their gold without injury to the article, for the reason that a considerable portion of the precious metal, in the primary stages of the amalgam process, becomes *alloyed* with the silver base. Electro-gilt silver articles, on the other hand, may readily be de-gilded, or stripped, by the above plan, or by making the articles an anode in a strong cyanide bath such as we have recommended for stripping silver, and employing an active current. To remove gold from silver articles by another method, they are first brought to a cherry-red heat, and then thrown into a weak solution of sulphuric acid, by which the gold scales off in spangles, and falls to the bottom of the vessel. The process of heating and plunging into the acid pickle is repeated until all the gold is removed; after removing from the pickle each time, the article should be rubbed with a hard brush to remove any loosened particles of gold, and rinsed before being again heated.

Stripping Nickel-plated Articles.—Bearing in mind what we have urged, that nickel will not adhere to a nickel-plated surface, it is necessary to remove the old nickel coating from all articles which have to be re-covered with this metal. In the case of German, French, and American nickel-plated articles which are largely imported into this country, the removal of the nickel coating is by no means a troublesome task;* trifling though the film may be, however, as, indeed, it frequently is, the film must be removed before any attempt is made to replate the article, otherwise the new coating will assuredly strip from the old one during the process of finishing, if not while it is in the bath. The stripping acid, which may be used either cold or tepid, is composed of: strong sulphuric acid, 4 lbs.; nitric acid, 1 lb.; water, about 1 pint. The water should first be put into a stoneware jar, and the sulphuric acid added cautiously and a little at a time, since considerable heat is generated when this acid is mixed with water. When the entire quantity of sulphuric acid is added, the nitric acid is then to be poured in, when the bath is ready for use. In making up the stripping bath, the proportion of the acids may be varied, but the foregoing will be found to answer every purpose.

When stripping nickel-plated articles in the above bath, it is necessary to watch the operation attentively, since, as we have observed, some articles are very lightly coated, and a momentary dip is frequently sufficient to deprive them of their nickel. Other articles which having been thoroughly well nickeled require, from some accidental cause, to be stripped and re-nickeled, will need immersion for several minutes—indeed, we have known well-nickeled articles to occupy nearly half an hour in stripping before the underlying brass surface has been entirely free from nickel. The operation of stripping should be conducted in the open air, or in a fire-place, so that the acid fumes, which are very pernicious, should escape freely. The articles should be attached to a stout copper wire, and after a few moments' immersion should be removed from the bath occasionally, to ascertain how the stripping progresses, and the moment it is found that the nickel has *quite* disappeared from every part, the article must be plunged into clean cold water. It is absolutely necessary that the work should not remain in the stripping solution one instant after the nickel is removed. When the stripping has been properly effected, the underlying metal exhibits a bright, smooth surface, giving little evidence of the mixture having acted upon it.

Nickel may be stripped from brass and copper articles, by electrolysis, in a dilute solution of sulphuric acid, making the article an anode, as in other arrangements of a similar kind; or a small nickel bath may be kept specially for this purpose.

Stopping-off.—This term is applied to various methods of protecting certain parts of an ornamental article which are required to be part gilt and part silvered, or otherwise varied, according to taste. For this

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* We allude only to *imported* articles; doubtless those retained in these countries for home use are, like our own, better treated.

purpose, certain varnishes, called "stopping-off" varnishes, or "stopping," are employed. The materials vary in their composition according to whether they have to be used with hot or cold solutions, more especially when cyanide of potassium is the active ingredient in the depositing bath. A formula which has, with modifications, been much employed for protecting plated work, to be gilt in the hot cyanide bath, from receiving the gold deposit upon certain ornamental parts of the work, is composed of—

Clear resin	10 parts.
Yellow beeswax	6 "
Best red sealing-wax	4 "
Jewellers' rouge	3 "

The three first-named substances are to be thoroughly melted, with gentle stirring, and the rouge, which is the peroxide of iron, gradually added, and incorporated by stirring.

A solution of red sealing-wax, of the finest quality, in alcohol, forms a very useful varnish for warm gilding solutions, if allowed to become thoroughly hard by drying before the article to which it is applied enters the gilding bath. Good, quick-drying copal varnish, mixed with a small quantity of jewellers' rouge, or ultramarine, is also employed for hot cyanide solutions ; the same varnish, mixed with chromate of lead (chrome yellow), may be used with cold solutions. Almost any quick drying and tough varnish may be used with cold solutions, and for the sake of recognising more freely the parts to which the varnish has been applied, the addition of a little mineral colouring matter, as red lead, chrome yellow, or ultramarine, should be added to the varnish. The article to which the stopping-off varnish has been applied, should never be placed either in a hot or cold bath, until it has become thoroughly dry and hard. The stopping-off varnishes will generally become sufficiently hard in from three to four hours in warm weather, or even in less time if the articles, after stopping, are placed in a lacquering stove moderately heated.

Applying Stopping-off Varnishes.—The article to be "stopped, off" must first be carefully well scratch-brushed, rinsed in hot water, and well dried by wiping with soft diaper. The parts which are to retain the silver colour (for example) are to be very carefully and neatly brushed over with the varnish, special care being taken not to spread it beyond its proper boundary, otherwise, when the article is gilt, the outlines of the various parts will exhibit a ragged and unsightly appearance ; the work should be done by the steady hand of a skilful workman. In gilding the articles which have been stopped-off the temperature of the gold solution should be as low as possible, even when the most resisting varnishes are used. It is not advisable to employ too strong a current, otherwise the bubbles of gas evolved are liable to dislodge the thinner layers at the extreme edge of the varnish, whereby such parts, being denuded of the material, become coated, giving a ragged appearance to these portions of the object.

After the articles have received the required deposit, they are well rinsed and dried, and the varnish is dissolved off (if an oil varnish, like copal, for example) with warm spirit of turpentine or benzole; sealing-wax varnish may readily be removed by methylated spirits, with the addition of heat, supplied by a hot-water bath. Another way to remove the varnish is to destroy it by plunging the article for a short time in cold concentrated oil of vitriol. In ornamenting articles, it is sometimes necessary to produce various coloured effects upon the same object, as orange yellow gold, pink and green gold, bright and dead silver, oxidised silver, &c., in which case the stopping-off needs the utmost artistic skill and delicacy of manipulation.

Electrolytic Soldering.—The late Frederick Scott Archer, shortly before the illness which terminated his useful career, consulted the author as to the possibility of electro-soldering the joints of a photographic dipping bath, constructed with pure sheet silver. The object which the inventor of the famous collodion process had in view was to produce a bath to contain nitrate of silver solution, in which collodionised plates could be excited without being liable to "spots," as in gutta-percha baths. The plan we suggested, if we remember rightly, was to submit one joint at a time (the vessel having but two joinings) to the action of a double cyanide solution, rich in silver, using a Wollaston battery of one zinc and two copper plates, and allowing the deposition to take place until the parts to be united were perfectly closed by the deposited metal. Respecting the application of electro-soldering generally, we are inclined to believe that, while it might be adopted for more effectually closing two metallic surfaces brought in close contact by covering the junction with deposited metal, we are doubtful whether an electro-soldered joint would bear any severe strain without separating. If we bear in mind that electro-deposited metals, as a rule, do not adhere firmly to their own kind, as silver to silver, copper to copper, and so on, two silver surfaces, united by a deposit of the same metal, can hardly be expected to form such a perfect union as would be required for a sound joint, such as is obtained with fused silver solder, for example.

Some years ago M. Elsner made a series of experiments in the electro-soldering of copper, employing the Daniell battery as the source of electricity. The plan he adopted was as follows: A strong ring of sheet copper was connected to the negative electrode of the battery, the ring being cut asunder at one point, leaving a gap of about $\frac{1}{16}$th of an inch. The ring was immersed in a solution of sulphate of copper, and at the end of a few days (during which the battery was kept renewed from time to time) the gap was found to be completely filled up with reguline copper. When this deposit was partially cut with a file, and the part examined with a lens, it was found to be equally filled with solid, coherent copper. Another copper ring was then cut in two parts, and the two semicircular pieces thus obtained were placed, with the faces of the sections opposite each other, in a bath and subjected to the action of the current. At the end of a few days the segments were united by the precipitated copper, again forming a perfect ring. On again applying the file to the deposited metal, so as to remove a portion of the thickness of the ring at the junctions, it was found that the spaces had been completely filled up by the copper deposit. On examining these points with a lens, the reguline deposit of copper could be clearly traced between the filled-up spaces of the ring. A third experiment was made in the following manner: Two strong rings of sheet copper were laid with their freshly-cut faces one above the other, so that the two rings constituted a cylinder; these rings were surrounded by a band of sheet tin, coated with a solution of wax, so that the two rings were equally surrounded by a conducting material. Thus disposed, these rings were connected to the battery, and placed in the sulphate bath. At the end of a few days the interior surface of the rings was coated with copper, the contact surfaces of the two rings being also coated with copper. These rings had only been submitted to the electrolytic action to such an extent as to cover their interior surfaces with a thin coating of copper, and yet they were completely united, and formed a cylinder in one piece. The outer rim of sheet iron was, of course, removed before testing the cohesion of the deposit. It was remarked that these rings, after being for a certain time in the bath, in contact with the plate of copper upon which they rested, became so encrusted with copper that some force was required to detach them from the conducting wire. From these results it was concluded that two pieces of metal may be firmly united with copper by electro-deposition. To this we fully agree, provided that the united parts are not required to be subjected to a heavy strain. If a chain, for example, were composed of copper links, each united by electro-soldering, we have no hesitation in saying that, if a moderate weight were hooked on to such a chain that one or other of the links would give way, even before the copper (owing to the softness of the metal) had become stretched to any considerable extent. We do not go so far as to say that a perfect union of two copper surfaces by electro-soldering is impossible, for that such is not the case may be readily proved by trying to pull asunder the copper guiding wires from the back of an electrotype, to which they frequently adhere with great tenacity. But where a really strong joint is required we should certainly refuse to depend upon an electro-soldering, for the reason we have given, namely, that the adhesion of two electro-deposited surfaces cannot be relied upon.

Elsner states that while conducting the above experiments, he found that when too powerful a current was employed the negative electrode, the ring, and even the copper plate upon which it rested, became covered with a dark brown deposit. After several unsuccessful attempts to prevent the formation of this brown coating, he found that it was possible to remove it entirely by dipping the article for a few seconds in a mixture of sulphuric and nitric acid, when it at once assumed the characteristic colour of pure copper.

The theory of electro-soldering is thus explained: "The article is, in fact, in an electro-negative state of excitation, whilst the zinc operates positively; the result is that the faces which are placed opposite each other when the ring has been cut are negative. During the progress of the electrolysis of the copper salt, the electro-positive molecules of copper, which are set free simultaneously, arrange themselves upon the two opposite faces and in the direction of the break. Now from the moment these molecules are deposited, they constitute, with the piece, a homogeneous mass, and from that time act negatively upon the copper of the electrolyte, and again precipitate copper in the reguline state. This method of operation continues until the space which existed between the two separate pieces of metal is filled up with metallic copper. In fact, the layers of copper which become deposited in an equal manner upon the contiguous faces of the metal gradually diminish the distance which separated the latter, until at length the metallic layers, which cross in the opposite direction, meet each other, the result being that the whole of the break which originally existed becomes filled with copper." Elsner says, with respect to the cohesiveness of the voltaic soldering, that it is the same as that of copper or other metal deposited by electrolysis; that too strong a current must have an injurious influence on the cohesion of the deposit, as in all other cases of electro-deposition.

CHAPTER XXXV.

MATERIALS USED IN ELECTRO-DEPOSITION.

Acetate of Copper.—Acetate of Lead.—Acetic Acid.—Aqua Fortis.—Aqua Regia.—Bisulphide of Carbon.—Carbonate of Potash.—Caustic Potash.—Chloride of Gold.—Chloride of Platinum.—Chloride of Zinc.—Cyanide of Potassium.—Dipping Acid.—Ferrocyanide of Potassium.—Hydrochloric Acid.—Liquid Ammonia.—Mercury, or Quicksilver.—Muriatic Acid.—Nickel Anodes.—Nickel Salts.—Nitric Acid.—Phosphorus.—Pickles.—Plumbago.—Pyrophosphate of Soda.—Sal-ammoniac.—Sheffield Lime.—Solution of Phosphorus.—Sulphate of Copper.—Sulphate of Iron.—Sulphuric Acid —Trent Sand.

SINCE many persons enter into the art of electro-deposition, in one or other of its numerous branches, who have not the advantage of chemical knowledge, or even an intimate acquaintance with the substances employed in the various processes, a brief description of the chief characteristics of some of the more important materials may prove serviceable. It is frequently the case, too, that lads who have been for some time occupied as subordinate assistants in the plating room, ultimately succeed to more responsible positions, and in their turn become practical platers; to these also some information as to the nature of the substances used in the art may prove useful, and tend to guard them against error. For the sake of easy reference, the various materials will be noticed alphabetically.

Acetate of Copper, or *Crystallised Verdigris.*—This beautiful salt of copper is in dark green crystals, which are soluble in water. The common verdigris of the shops is in the form of a powder, or soft lumps of a bluish-green colour, and is insoluble in water; it is, however, soluble in dilute acetic acid, when it forms the same solution as that produced by the dissolved crystalline salt; being richer in copper than the latter, it may be used with greater economy in making up copper solutions, or for other purposes in which the acetate of copper is employed.

Acetate of Lead, or *Sugar of Lead.*—This is a crystalline salt having somewhat the resemblance of crushed loaf sugar. The pure salt is wholly soluble in distilled water, but the ordinary commercial article frequently produces a slightly *milky* solution, which may be rendered clear by the addition of a small quantity of acetic or pyroligneous acid. This salt is highly poisonous.

Acetic Acid. *The Acid of Vinegar.*—A colourless liquid, having a pungent but agreeable odour. The carbonates and oxides of most bases, as those of the metals and alkalies, are soluble in the dilute acid, forming *acetates*, as acetate of copper, acetate of soda, &c. Its usual adulterant is *water*.

Aqua Fortis. *See* **Nitric Acid.**

Aqua Regia, Nitro-hydrochloric Acid.—This acid mixture, which is employed for dissolving gold and platinum, is made by mixing from two to three parts of hydrochloric acid, to one part nitric acid, by *measure*. Since aqua regia decomposes spontaneously, it should only be prepared when it is required for use.

Bisulphide of Carbon.—This highly volatile and inflammable substance must be kept in a well-corked or stoppered bottle, in a cool place, and its vapour, when the stopper is removed from the bottle, must not be allowed to approach the flame of a candle or lamp, otherwise it may take fire and ignite the contents of the bottle, even at a considerable distance, if the apartment be very warm.

Carbonate of Potash, *Pearlash, or Salt of Tartar.*—A white granular salt employed in the preparation of cyanide of potassium, in making brassing and coppering solutions, &c. It is very *deliquescent*, that is, absorbs moisture from the air, and should therefore be preserved in closely stoppered jars or bottles.

Caustic Potash.—The ordinary commercial article, used for cleaning metal work to be coated with other metals by electro-deposition, also for making up tinning solutions and for various other purposes connected with the art, is the substance known as *American potash*. This article is in the form of hard, brownish lumps, and since it readily attracts carbonic acid and moisture from the air, it must be preserved in stone jars, closed by a well-fitting bung. Caustic potash has a powerful action upon the skin, and must not therefore be handled carelessly; when it is necessary to remove one or more lumps from the jar in which it is kept with the fingers, this should be done quickly, and the hands immediately plunged into cold water, then for a moment into a weak acid pickle, and again rinsed. A small pair of spring iron tongs should be used for taking up lumps of this caustic alkali.

It may be prepared as follows: Reduce to a powder 56 parts, by weight, of fresh lime, by slaking with water. Make a cream of the powder by adding sufficient water and stirring well. Now dissolve 138 parts of pearlash in hot water, and add the cream of lime to the solution. Boil the mixture for about half an hour, or longer, and then allow it to repose. The lime will deposit in the form of *carbonate* *of lime*, leaving a strong solution of caustic potash, which may be preserved in a carboy until required for use.

Chloride of Gold.—The preparation of this substance is described in the Chapter on Gilding.

Chloride of Platinum.—Small fragments of platinum are placed in a glass flask, and a mixture of three parts hydrochloric acid and one part nitric acid (by measure) added; the flask is then to be placed on a sand bath, moderately heated, until red fumes cease to appear in the upper part of the flask. The solution is next poured into a porcelain capsule, or evaporating dish, and evaporated to near dryness, the vessel being moved about until the red mass formed sets into a solid condition. It may then be dissolved in distilled water, and bottled for future use.

Chloride of Zinc.—Granulated zinc is dissolved in hydrochloric acid; the liquid is then evaporated, when a semi-solid hydrated mass results, which, by continuing the heat, becomes anhydrous, and may be poured on a slab to solidify. A solution of zinc, commonly called "tinning salt," which is much used in *soft soldering*, is prepared by pouring muriatic acid upon small fragments of zinc, when, after the effervescence has ceased, the solution is ready for use.

Cyanide of Potassium.—In many respects this may be considered the most important substance used in electro-deposition, it being a powerful solvent of metallic oxides and salts. The ordinary commercial article is of exceedingly variable quality, and frequently contains but a small percentage of pure cyanide. Its chief adulterant is *carbonate of potash*, one of its essential constituents, and therefore readily introduced in excess. In order that the user of cyanide of potassium may be fully acquainted with its composition, we will briefly explain the methods of preparing it; and to enable him to determine the true value of the commercial article which may fall into his hands in the course of business, we will describe simple methods by which he may estimate the proportion of true cyanide in any given sample. Knowledge of this kind is of the utmost importance to those whose necessities or duty may require them to make up solutions of the various metals in which cyanide of potassium forms a necessary constituent.

Preparation of Cyanide of Potassium.—There are several methods of preparing this useful salt, but the process recommended by Baron Liebig is usually adopted, and is conducted as follows: 8 parts of ferrocyanide of potassium (yellow prussiate of potash) are first reduced to a powder, and then placed in a shallow iron pan, and dried at a heat not exceeding 260° Fahr., with stirring, until perfectly dry. The dry powder is next mixed with 3 parts of dried carbonate of potash, and the mixture then thrown into a red-hot crucible, and the heat kept up, with occasional stirring with an iron rod, until the whole is fused; the fusion must be continued until the product appears perfectly white at the end of the rod, after cooling. The crucible is then removed from the fire, the contents again stirred, and after a few moments' repose the liquid salt is poured into a clean, cold, and dry iron tray, in which it quickly sets in the form of a hard cake, which should be broken in lumps while still warm. While pouring out the clear fluid salt, care must be taken to keep back the sediment, which is chiefly iron in a finely divided state (derived from the ferrocyanide). The sedimentary matter should be knocked out of the crucible, while still hot, upon a separate slab, and the residue of cyanide which is attached to it may be separated by dissolving it out with water. Cyanide, thus prepared, contains a portion of *cyanate* of potassium, but this is not injurious to the solutions of silver or other metals in which cyanide is employed. The article prepared in this way represents ordinary commercial cyanide of good quality, and it will be readily seen (since carbonate of potash is the cheapest ingredient) that a large excess of this salt may be employed without in any way affecting the general appearance of the product; its activeness as a solvent of metallic oxides and salts, however, will be diminished in proportion to its excess in an uncombined state. Cyanide carefully prepared by the foregoing method should contain from 70 to 75 per cent. of pure cyanide.

A pure cyanide is obtained by the following process. The requisite quantity of yellow prussiate of potash, of good quality, is powdered and dried as before; an iron crucible, having a lip, is then made red hot; a small quantity of the powder is now introduced into the crucible, and when this is fused, more of the powder is added, and so on, until the vessel is about three parts filled; the iron lid of the crucible must be put on after each addition of the powdered ferrocyanide. During the fusion of the salt there is a free evolution of gas, and the fusion must be maintained for about fifteen minutes, or until a sample on the end of an iron rod dipped into it is perfectly white on cooling. The vessel should now remain undisturbed for a few minutes, to allow the iron and other impurities to subside. The clear and colourless fluid, which is nearly pure cyanide of potassium, is now to be poured upon a cold iron slab, or into an iron pan, and the black sediment, which still retains a considerable proportion of cyanide, must be scooped out of the crucible, while still in a soft and pasty condition, and carefully preserved; the cyanide may be dissolved from this residue whenever the salt is required for future use.

It sometimes happens that the cyanide, from imperfect settling while in a fused state, assumes a grey shade instead of being purely white; this is of no consequence, however, since the small proportion of insoluble impurities which cause this greyness will readily subside when the cyanide is dissolved in water for use. To prevent the formation of *cyanate* of potassium in the above process, some persons put a few small pieces of charcoal, and also a little powdered charcoal, into the crucible before the ferrocyanide is thoroughly fused. The cyanide obtained by this method usually contains about 96 per cent. of the pure salt. This process, however, is not so economical as the one previously given, inasmuch as a considerable proportion of the cyanogen escapes in the gaseous state, whereas, when the ferrocyanide is fused with carbonate of potash, the cyanogen unites with the potassium (the base of this salt), and carbonic acid is liberated instead.

Grey Cyanide, as it is sometimes called, is commercial cyanide from which the reduced iron has not been perfectly separated; this article is frequently preferred by some persons, since it is supposed to contain a smaller excess of carbonate of potash; it has generally a crystalline fracture, when broken, while cyanide containing a large preponderance of the carbonate is of a more homogeneous structure.

To Determine the Active Strength of Commercial Cyanide.—The following method was suggested by the late Thornton Herapath, in *The Chemist*, vol. iii. p. 385: "The first thing to be done in testing cyanide of potassium is to prepare a standard solution of ammonio-sulphate of copper or ammonio-nitrate of copper.* A certain known quantity of pure crystallised sulphate of copper, made by crushing the pure crystals of the shops in a mortar, and pressing the powder so obtained between folds of bibulous paper, is taken and dissolved in water. The solution so prepared is then to be diluted with water so as to measure 2,000, 3,000, or more water grain measures at 60° Fahr. Supposing 390·62 grains of the pure sulphate to have been taken and diluted to 2,000 grain measures, every 100 grains of such solution will, of course, represent 5 grains of metallic copper, or 6·25 grains of the protoxide of copper; 100 grains of each of the samples of cyanide of potassium to be tested are then dissolved in a sufficient quantity of water, and introduced into the colorimeters; an excess of ammonia is added, and the standard solution of copper is added (out of a graduated burette), to the contents of each colorimeter in turn, until a faint blue coloration makes its appearance in each of the solutions. The quantities of copper or of the solutions taken then indicate the relative strength and money value of the samples of cya-

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* *Ammonio-sulphate of copper* is formed by adding liquid ammonia to a saturated solution of the sulphate until the precipitate at first produced is redissolved, when a rich dark blue solution is obtained. *Ammonio-nitrate of copper* is produced by adding ammonia to a concentrated solution of nitrate of copper.

nide examined. Suppose, for instance, one specimen took 100 measures, and a second 150 measures, of the copper solution, the relative strengths and values of such specimens are, therefore, as 100 to 150, or 2 to 3." To render the above process available in the determination of the actual strength of, or proportion by weight of, pure cyanide of potassium existing in the commercial cyanides, it is only necessary to procure a small sample of *pure* cyanide, and to ascertain how much of this is required to decolorise 1 grain of copper in the form of ammonio-nitrate.

Another method of determining the proportion of pure cyanide in a given sample of cyanide of potassium is that proposed by Glassford and Napier, which is as follows: Prepare two solutions, one of cyanide, and another of nitrate of silver, each containing known weights of the respective salts, say 1 ounce of cyanide dissolved in distilled water, in a graduated glass, so as to make exactly six ounces of solution by measure; then dissolve 175 grains of crystallised nitrate of silver in about three ounces of distilled water; add the cyanide solution gradually and carefully to the nitrate solution, stirring continually, until the precipitate at first formed is all dissolved without any excess of the cyanide solution. The amount of the cyanide solution required to effect this, with the above quantity of nitrate of silver, will have contained 130 grains of pure cyanide, and from the quantity used may be calculated the amount of pure cyanide in the entire ounce. The authors state that "when nitrate of silver is added to a solution of cyanide of potassium, so long as the precipitate formed is all redissolved, we obtain *the whole* of the cyanide of potassium in combination with the silver; none of the other salts in solution take any part in the action, even though they be present in a large proportion. This enables us to test the exact quantity of cyanide of potassium in any sample."

A very simple way of testing commercial cyanides where extreme accuracy is not necessary is as follows: Reduce to fine powder in a mortar about half an ounce of pure sulphate of copper; weigh out 100 grains of the powder, and dissolve (in a half-pint vessel) in about two ounces of water; now add liquid ammonia of sp. gr. ·880° until the precipitate first formed is all dissolved. Next dissolve 1 ounce, troy (480 grains), in about 8 ounces of water; pour the latter solution into a tall and narrow hydrometer glass, previously *graduated* by pasting a strip of paper on its exterior surface, divided into ten equal divisions, and these again accurately subdivided into tenths; the solution must be diluted, if necessary, until it exactly reaches the top line or *zero* of the scale. Suppose we wish to determine, roughly, the comparative value of two samples of cyanide of potassium, we prepare two copper solutions as above, each containing 100 grains of sulphate of copper, and dissolve 1 ounce of each of the cyanide samples to be tested, and, taking the first sample, dissolved and poured into the graduated glass as above, we pour it gradually into one of the copper solutions, stirring after each addition, until the blue colour of the copper solution has disappeared, and has been succeeded by a pinkish tinge; the cyanide must now be added, drop by drop, until the pink tint disappears, when the operation is complete. Now read off the balance of cyanide solution left, and make a note of it; and after emptying the vessel and rinsing it, introduce the solution of the second sample and proceed as before, and when the decolorisation of the second copper solution is effected, note the proportion of cyanide solution which has been exhausted, and compare the two results.

Dipping Acid.—This name is given to a mixture of nitric and sulphuric acids and water, with sometimes the addition of a little hydrochloric acid, nitrate of potash, &c. The composition of various dipping acids is given in another part of the work. Fuming nitric alone is frequently used for dipping articles of copper and brass, by which they assume a bright lustre suitable for certain classes of work.

Ferrocyanide of Potassium, or *Yellow Prussiate of Potash.*—This useful salt, which is chiefly used in the preparation of cyanide of potassium, occurs in large transparent crystals of a yellow colour. The crystals must be powdered and dried at a low heat before being mixed with carbonate of potash, for the preparation of cyanide.

Hydrochloric Acid, or *Muriatic Acid.*—For most purposes the commercial acid is employed, but in making aqua regia for dissolving gold and platinum, the pure acid should by preference be used.

Hydrocyanic Acid, or Prussic Acid.—This volatile and highly poisonous substance, as obtained in commerce, is in reality a solution of the acid in water (hydrated hydrocyanic acid). The strongest form of the commercial acid, known as *Scheele's Acid,* contains 5 per cent. of real acid; the dilute acid of the *London Pharmacopœia* is intended to contain only 2 per cent. of real acid. Even in its diluted forms, it is an exceedingly dangerous substance to inhale, and must therefore be used with the utmost caution. Its powerful odour, resembling the flavour of the bitter almond or young laurel leaf when chewed, always indicates its presence, and the bottle in which it is kept should be very distinctly labelled, and on no account allowed to approach the nostrils when the stopper is withdrawn. The acid is affected by light, and should therefore be kept in a stone bottle, or a glass bottle covered with yellow or brown paper, and in a cool place.

Liquid Ammonia, commonly called **Ammonia.**—This highly volatile liquid, which consists of water saturated with gaseous ammonia, should have a specific gravity of ·880. It is usually contained in Winchester bottles, which must be handled with great care, since the accidental breaking of a bottle of this capacity (about ½ a gallon) might involve most serious consequences. Ammonia should *always* be kept in a cool place; and when pouring it from the bottle, the user should take care to stand in such a position that the full stream of its vapours may not approach his nostrils.

Mercury, or Quicksilver.—This fluid metal, when pure, is brilliantly white, and from this circumstance was called by the ancients *argentum vivum* and *quicksilver*. It emits vapour at all temperatures above 40° Fahr., and should therefore be kept in a closed bottle. It is entirely volatilised by heat, and should therefore leave no residue when evaporated from an iron spoon. If adulterated with lead, and exposed to the air, it becomes covered with a dull film of oxide, whereas if it remains bright after such exposure, the metal may be adjudged pure, since mercury in its pure state is not affected by exposure to the atmosphere.

Muriatic Acid.—Spirit of Salt.—See **Hydrochloric Acid.**

Nickel Anodes.—When we state that cast-nickel anodes, containing about 5 or 6 per cent. of added iron and a very large percentage of carbon, cost about fifteen years ago the enormous sum of 16s. 6d. per pound, and that almost pure anodes of nickel, either cast or rolled, may now be obtained for 3s. per pound, the reader will see what a great change must have taken place to bring about so marvellous a difference in the price of an article so indispensable to the nickel-plater. At the time we refer to, nickel was a comparatively scarce commodity, and was chiefly obtained from Bohemia and Germany. Since that period, however, nickel ores exceedingly rich in this metal were discovered in the French Colony of New Caledonia, and important improvements have taken place both in its extraction from the ore and in its purification from the crude metal. It is, indeed, a remarkable fact in the history of the electro-deposition of this metal, that just at the time when nickel-plating was developing into an important industry, both in the United States and in this country, New Caledonia should have given up her long-hidden treasures, and supplied our markets with an abundance of this useful metal.

While, a few years ago, even *cast* pure nickel anodes were difficult to procure, we are now able to obtain *rolled* nickel of any convenient thickness—a most important advantage to those who desire to embark in nickel-plating upon a small scale. To Dr. Fleitmann is due the credit of having been one of the most successful in this direction, and specimens of his rolled nickel which we have had in our possession were remarkable for their purity and perfect homogeneity. Being desirous of acquainting our readers with some data respecting English rolled nickel, we communicated with Messrs. H. Wiggin & Co., who kindly furnished us with the following particulars concerning this form of nickel anode, which will be useful to those who may wish to embark in the art of nickel-plating. The advantages claimed for rolled nickel anodes over the cast metal are:—"The constant and steady way in which they give off the metal; they never become soft or fall to pieces while in the bath, as cast anodes do; they may be light and thin to begin with (of course being far less costly in consequence); and they last a very long time."

Nickel Salts.—This term is applied to the double sulphate of nickel and ammonium, and the double chloride of nickel and ammonium, from which nickel-plating baths are usually prepared. The former "salts," however, are generally preferred, and may be considered the best for all practical purposes of nickel-plating. Nickel salts are, like everything else in commerce nowadays, of very variable quality and price. The finest product we have yet seen was imported from the United States about 1877—78, the price of which, however, was very high. Since that period, however, the manufacture of these salts has greatly progressed in this country, and the marvellous reduction in the cost of nickel has brought the selling price of the double sulphate of nickel and ammonia down to an exceedingly low figure. In reply to our inquiry upon this point, Messrs. H. Wiggin & Co., the eminent cobalt and nickel refiners of Birmingham, favoured us with the following quotations, which will serve as a guide to purchasers in large quantities. Single nickel salts, per pound, 1s., and double nickel salts, 9d. When we state that seven or eight years ago the price of these salts was 6s. or 7s. per pound, or even more, it will be readily seen what a remarkable change has taken place in so short a period of time in this most important item of a nickel-plating outfit.

In purchasing nickel salts, great care is necessary to avoid procuring an impure article, since this would involve the user in a great deal of trouble, either by yielding a deposit of a bad colour, or one that will not firmly adhere to the work coated with it. The double salts should be in large prismatic crystals of a fine dark green colour, and perfectly dry. A solution of the salt should not be acid to litmus paper. The double salt consists of 1 atom of sulphate of nickel, 1 atom of sulphate of ammonia, and 8 of water. When the commercial article is of doubtful quality, it may be improved by dissolving it in hot water, evaporating the liquor, and recrystallising.

Nitric Acid.—Ordinary commercial nitric acid has usually a slightly yellow tinge, but the pure acid is colourless. It is a highly corrosive acid, and freely acts upon the skin, producing yellow stains wherever it touches. This acid should never be kept in a *corked* bottle, since it readily acts upon this substance, but in a stoppered bottle, and in a cool and dark place.

Phosphorus.—This substance must be preserved *under water*, to prevent it from coming in contact with the air, in which, even by a few moments' exposure, it is liable to inflame. The sticks of phosphorus should be kept in a wide-mouthed, stoppered bottle, filled with water, and placed in a dark and cool cupboard. It should not be handled in the fingers nor cut in the open air, but when small pieces are required for use, it is a good plan to thrust the point of a penknife into one of the sticks, carefully withdraw it from the bottle, and lay it in a small dish containing sufficient cold water to cover the lump. The required piece or pieces may then be cut from the stick, and the remainder returned to the bottle by thrusting the point of the knife into it as before.

Pickles.—This term is applied to dilute solutions of the mineral acids, by means of which oxidation is removed or loosened from the surfaces of iron, silver, and other metals. The preparation of the various pickles, and the mode of using them, are described in the treatment of various articles for plating, nickeling, &c.

Plumbago, or *Graphite*, commonly called *Black Lead.*—This material, when required for electrotyping purposes, should be of the very best quality procurable. Its powder is of a dead black colour until rubbed, when it acquires a bright metallic lustre. It is commonly the practice to improve the conductibility of this substance, for electrotyping purposes, by intermixing metallic bronze powders, as copper and tin bronzes, for example, or by gilding or silvering the plumbago powder. The former is accomplished by dissolving 1 part of chloride of gold in 100 parts of sulphuric ether; this is then to be intimately mixed with 50 parts of plumbago, and the mixture exposed to sunlight, being frequently stirred, until quite dry. It is then applied as ordinary plumbago, but is a very superior conductor.

Pyrophosphate of Soda.—This salt, which has been much used, especially in France, in the preparation of gilding baths, may be readily prepared by heating common phosphate of soda to redness in a crucible, when it parts with its waters of crystallisation, and becomes *anhydrous pyrophosphate*. Dissolved in hot water this *anhydrous* (that is, free from water) salt yields permanent crystals on cooling, which contain 10 atoms of water. These crystals are not so soluble as the common phosphate, and their solution precipitates nitrate of silver *white* (pyrophosphate of silver), and has an alkaline reaction. All the insoluble pyrophosphates, including that of silver, are soluble to a certain extent in the solution of pyrophosphate of soda, hence the usefulness of this salt in preparing gilding solutions.

Sal-Ammoniac, or *Chloride of Ammonium.*—This salt occurs in the form of crystalline lumps, which being exceedingly tough, are more readily broken by forcing a sharp steel point through the mass by means of a hammer than by the ordinary means of crushing or pulverising. When broken into small fragments in the way indicated, the salt may more easily be reduced to a more or less powdery condition.

Sheffield Lime.—This material, which is preferred by brass and nickel-plate finishers to any other kind of lime, is obtained from the neighbourhood of Sheffield, from whence the lumps are carefully selected and transported in wooden casks to London and other parts of the kingdom. The lime must be kept rigidly excluded from the air, otherwise it attracts carbonic acid, forming *carbonate of lime*, by which it loses its *cutting* property and becomes useless. Small quantities may be preserved for any length of time in stone jars, closed by a tight-fitting bung, but for larger quantities olive jars and grocers' large tin canisters have been used with advantage.

Solution of Phosphorus, or *Greek Fire.*—This preparation, which consists of phosphorus dissolved in bisulphide of carbon, is not only highly inflammable, but if any of it be accidentally dropped upon the clothes or floor, it is very liable to take fire spontaneously. It should only be prepared in small quantities, and the bottle in which it is kept should be partly immersed in sand in an earthenware vessel, covered with a metal lid, and placed in a cool situation.

Sulphate of Copper, or Bluestone.—It is of the greatest importance that this substance, whether employed in electrotyping or for any other purpose connected with electro-deposition, should be perfectly pure. The pure sulphate occurs in large crystals of a rich deep blue colour. If there be any green salt in the interstices of the crystals, this is due to the presence of sulphate of iron, or copperas, and the article should therefore be rejected. The "bluestone" of the shops is frequently contaminated with copperas. To determine the presence of iron in a sample of sulphate of copper, dissolve a small quantity of the salt in distilled water, then add liquid ammonia, stirring with a glass rod until the precipitate formed becomes entirely dissolved. Allow the blue liquid thus obtained to rest for a short time, then pour off the clear liquor and add distilled water to the sediment; after a while pour off the water and add a little hydrochloric acid to the residuum; allow the acid to react upon the deposit for a few minutes, then pour into the acid liquor a few drops of a solution of ferrocyanide of potassium, when, if a blue colour is produced (prussian blue), this proves the existence of iron in the original sample of sulphate of copper.

Sulphate of Iron, *Copperas, or Green Vitriol.*—A bright sea-green crystalline salt, readily affected by exposure to the air; it should therefore be kept in a well-corked bottle or jar. The crystals should be bright, perfectly dry, and free from red or brown powder (peroxide of iron). The presence of this powder, however, is not of much consequence, since, being insoluble in water, it will readily deposit to the bottom of the vessel when the crystals have been dissolved.

Sulphuric Acid, or *Oil of Vitriol.*—The ordinary commercial acid has usually a somewhat brownish tint, owing to small quantities of straw or other organic matters accidentally falling into the carboys in which it is conveyed. The pure acid is, however, colourless. This acid should be kept in a perfectly dry situation, since it attracts moisture from the air; and when making a dilute solution of the acid, it should be added gradually to the water, and *not the water to the acid*, since this might cause the mixture to explode with very disastrous results.

Trent Sand.—Glass Cutters' Sand.—These materials are used by brass polishers in the earlier stages of the polishing process, to remove file-marks and other irregularities from the metal work, the latter substance being used for articles in which a very keen-cutting material is necessary.

CHAPTER XXXVI.

USEFUL INFORMATION.

Driving Belts.—Chutter's Dynamo-electric Machine.—Quantity of Electricity and Electro-motive Force.—Management of Dynamo-electric Machines.—Management of Batteries.—Relative Power of Batteries.—Constancy of Batteries.—Relative Intensity of Batteries.—The Resistance Coil.—Speed Indicator.—Binding Screws.—Characteristics of Metals.—Test for Free Cyanide.—Oxidising Copper Surfaces.—Alloys.—Soldering.—Soldering Liquid.—To remove Soft Solder from Gold and Silver Work.—Platinising.—Steel-facing Copperplates.—Antidotes and Remedies in Cases of Poisoning.

Driving Belts.—Most users of dynamo machines, polishing lathes, and other machinery driven by steam-power or gas-engines, will have experienced some trouble from the breaking, slipping, or slackening of the driving belts. Since a few hints upon these matters may prove acceptable, we give the following extracts from an exceedingly interesting and thoroughly practical paper, by Mr. John Tullis, of St. Ann's Leather Works, Glasgow.*

Main Driving Leather Belts should be manufactured so that when the joint is made while the belt is in its place, it ought to present the appearance of an endless belt. After having been taken up once or twice during the first year, good belts such as these require very little attention during the subsequent years of their long life. If the belt is driving in a warm engine-room, it ought to get a coating of curriers' dubbing three times a year. All belts having much work to do ought to present a clammy face to the pulley, and this condition can be best maintained by applying one coating of dubbing and three coatings of boiled linseed oil once a year. This oil oxidises, and the gummy surface formed gives the belt a smooth, elastic driving face. A belt looked after in this way will always run slack, and the tear and wear will be inconsiderable. On the other hand, dry belts have to be kept tighter, because they slip and refuse to lift the work. The friction of the running pulley "burns the life" out of the belt while this slipping is going on.

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* *Scottish Leather Trader*, July, 1885.

Fixing the Belt.—As to which side of the leather ought to be placed next the pulley, Mr. Tullis says, "It is well known that by running the *grain* or smooth side next the pulley, there is considerable gain in driving power. However, by using boiled linseed oil, as before mentioned, the *flesh* side will soon become as smooth as the grain, and the driving power fully as good. A belt working with the grain side next the pulley really has a much shorter life than the belt running on the flesh side. The reason is, the one is working against the natural growth of the hide, while the other is working according to nature. . . . If you take a narrow cutting of belt leather, pull it well, and lay it down, you will at once observe that it naturally curves flesh side inwards. Nature, therefore, comes as a teacher, and tells us to run the flesh side next the pulley, and practice proves this to be correct."

Jointing Belts.—"Whether the belts are new or old, a properly made joint is of the first importance to all users of belting. . . . A well-made butt joint, with the lace holes punched in row of diamond shape, answers the purpose fully as well as any. Care should be taken that the holes do not come in line across the belt. A good lace, properly applied, with all the strands of the lace running lengthwise of the driving side of the belt, will last a long time and costs little. If a lap joint is made, time should be taken to thin down the ends of the lap. Joints of this sort should be made to the curve of the smallest pulley over which the belt has to work."

Accumulation of Lumps on Pulleys and Belts.—Dust should never be allowed to gather into a cake either on pulley or belt, for if so, the fibre of the leather gets very much strained. The belt is prevented from doing its work because this stranger defies the attempts made by the belt to get a proper hold of the pulley.

Belts and Ropes coming off Pulleys.—When a bearing gets heated, the shaft naturally becomes heavy to turn. The belts or ropes, having already the maximum of power in hand they are designed to cope with, they refuse this extra strain, and will leave the pulleys at once, or break. This accident directs the attention of those in charge to the belts or ropes, when time is taken up in consulting as to what is to be done. Meanwhile the cause of all the trouble gets time to cool, and the source of annoyance is never discovered. Before a new start is made, all bearings are well lubricated. All goes smoothly, yet some one is blamed for the break down.

The above hints, coming as they do from an experienced manufacturer of leather, and who is also an extensive user of belting, will be invaluable to those who, though constantly using driving belts, may be unacquainted with the principles of their action.

Chutter's Dynamo-electric Machine.—Since the earlier portion of this work was written, we have been favoured by Mr. Samuel Sykes, of Birmingham, with some particulars concerning Mr. George F. Chutter's dynamo-electric machine, which we feel bound, in the interest of our readers, to publish, more especially since the new machine appears to have been used somewhat extensively, giving great satisfaction, by platers and gilders, and also by nickel-platers in Birmingham and its neighbourhood. The principal features of this machine, and its capabilities, are stated as follows :—

The small machine (No. 3 size), Fig. 133, which absorbs about ½ horse-power, will, under favourable conditions, deposit about 20 ounces of silver per hour.

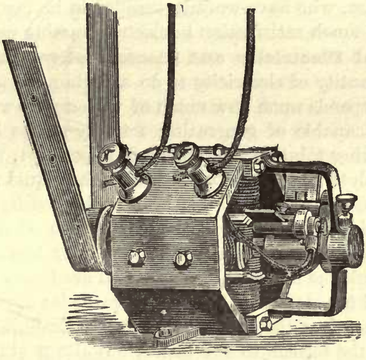

Fig. 133.

"The armature, spindle, and commutator are made in one malleable casting, and very great care is exercised in the selection of these castings, any one casting which may be found to be harder than the best wrought iron being rejected. The bearing extents of the spindle are cased with hardened steel sleeves, which, as they are made interchangeable, can be renewed at a small cost, thus saving the weakening effects of wearing down and tearing up the spindle itself. The total height of this small machine is 10 inches; extreme length, 17 inches, and weight, 63 pounds. The commutator is cased in phosphor bronze, which is found to be more durable than copper, which is generally used. The machine being of open structure, allows a free circulation of air through it, which prevents undue heating, while its compactness allows it to occupy a small space." The efficiency of the machine is said to lie in its simplicity, and the careful balancing of the parts in the design.

Amongst those who have applied the No. 3 size machine, above referred to, is Mr. Smith, of Branston Street, Birmingham, who employs 220 feet main leading circuit round his plating shop, wires being taken off to gilding and silvering vats every few feet along its length, by which arrangement the smallest article of jewellery can be gilt, and heavy deposits of silver put upon cruet-frames, salvers, &c. at the same time—each workman using the current from the main leading wires with perfect steadiness, irrespective of what is being done in other vats. The Chutter machine has also been adopted by Mr. James Fenton, Mr. J. M. Davis, Mr. Daniel Griffin, and others, of Birmingham, who have warmly testified in its favour. It appears to have given much satisfaction in electro-brassing cast iron.

Quantity of Electricity and Electromotive Force.—The power of a given quantity of electricity to do a certain amount of work in a given time, depends upon how much of the current which the battery or machine is capable of generating actually passes into the electrolyte or depositing solution, and this will depend—1, upon the nature of the electrolyte; 2, the temperature of the liquid; 3, the distance between the anodes and cathodes; and, 4, the density of the solution. As a rule, acid solutions are better conductors of the current than alkaline solutions, or, in other words, they offer less resistance to its passage through the liquid. Hot solutions are better conductors than cold ones, and the closer the anodes and cathodes approach each other the less distance has the current to traverse through the liquid in its passage from the former to the latter. While a single battery cell would be sufficient to deposit copper freely from a solution of the sulphate, three such cells would be required to deposit an equivalent of silver from a cyanide bath, and double that number, coupled in series, to deposit brass or copper from cyanide solutions. When the battery cells are arranged in series, that is, the positive element of one cell connected to the negative element of the next cell, and so on, the power of the current is greatly augmented, because it can pass more freely, that is, the electromotive force of the combined series urges forward the current generated in each cell, and thus enables the compound battery to do more work than if the negative and positive wires were separately grouped in "multiple arc," as in Fig. 134.

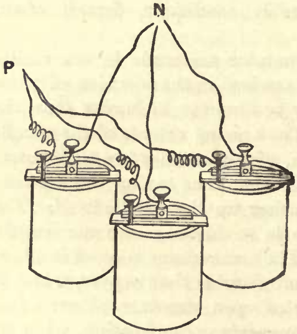

Fig. 134.

The amount of current which a battery is capable of generating, however, depends upon the surface of the positive element (zinc) immersed in the exciting fluid of the cell, and the weight of zinc dissolved in a given time, which is exactly equivalent to the weight of metal deposited in the bath; moreover, the amount of zinc dissolved in a given time is exactly the same in each cell, and if one zinc element in a series of six cells were smaller than the other five, the actual amount of available power of each cell of the series would be reduced to the capacity of the smallest zinc element.

Management of Dynamo-Electric Machines.—In working a dynamo or magneto-electric machine, it is of the greatest importance that, as far as may be possible, it should be allowed to run at an uniform speed. This important point is seldom reached when steam-power is obtained from a source which supplies power to other premises or parts of the same building, as is frequently the case, both in London and the provinces. Moreover, when the same engine which gives motion to the polishing lathes also drives the dynamo machine, irregularities of speed frequently occur, more particularly when there happens to be some especially severe strain upon the polishing spindles, as in sanding rough and heavy pieces of work. There can be little doubt that gas-engines, from the uniformity of their action and the readiness with which power can be obtained from them, regardless of their superior economy, are most suitable for driving dynamo machines; indeed, if it were not for these useful motors, it is doubtful if the applications of dynamo-electricity to the deposition of metals and electric lighting would have attained their present development.

Being of opinion that the gas-engine and dynamo-electric machine form the most perfect combination for obtaining electricity for the purposes of electro-deposition under the most favourable conditions of economy, convenience, and regularity, we applied to Messrs. Crossley Brothers, of Manchester, for some particulars of their "Otto" engine, which we had frequently seen driving dynamos, while performing other work, such as driving polishing-spindles, scratch-brush lathes, &c., and through the courtesy of those gentlemen we are enabled to give the following details, which will be useful to such of our readers as may contemplate adopting magneto or dynamo-electric machines as substitutes for voltaic batteries, or those who may desire to possess economical motive-power of their own rather than bear the ills of an irregular and often costly supply of hired steam-power from adjacent premises. An illustration of a 6 horse-power "Otto" gas-engine is given in Fig. 135.

Advantages of the Gas-Engine in driving Dynamo Machines.—These may be briefly summed up as follows:—The engine can be started in a minute's time; the lubricating being done by a self-acting arrangement, little or no further attention is required until the engine requires to be stopped, which is effected by simply shutting off the gas. The attendance required seldom exceeds one hour a day, and this is only needed for oiling, cleaning, and starting the engine. There being no risk from boiler explosion, the leading insurance companies do not charge extra insurance where gas-engines are employed. Mr. F. T. Linton, of the Leith Gas Works, in a paper upon this subject,* says, in reference to a 3½ horse-power "Otto" engine, which had been adopted at the works: "It is employed to drive various machines in our workshops, such as Root's blower for three smiths' fires, a large screw-cutting lathe, a screwing machine, a drilling machine, a circular saw, two smaller lathes, and two grindstones. The amount of power required varies considerably, as at one time nearly all these machines may be in use, and at another time not more than two or three of them. In all cases, however, the smoothness and regularity with which the engine works are very noticeable—there being no sensible diminution or acceleration of speed as the different machines are put in or out of action." This important feature in these machines renders them, as we have before observed, specially applicable to the purposes of the electro-depositor, who requires not only to drive his dynamo, but also his polishing spindles, emery-wheels, scratch-brushes, &c., and this without interfering with the steady speed of his most important appliance—the source of elec-

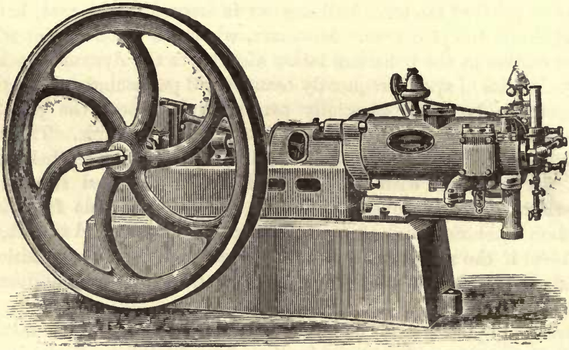

Fig. 135.

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* *Engineering*, July 30th, 1880.

tricity. Regarding the comparative cost of working gas and steam engines, Mr. Linton's paper contains some very interesting data, from which we extract the following:—Taking a gas-engine and a steam-engine of the same horse-power—that is, each being of 3½ nominal horse-power—after estimating the working expenses of each, as also the wear and tear and depreciation, the total annual charge would be—

For the gas-engine . . , .	£52	8	6
For the steam-engine . . .	79	6	0

Showing a considerable advantage in favour of the gas-engine, irrespective of the other advantages we have endeavoured to point out.

Overheating of Dynamos.—Some dynamo machines are so constructed as never to become heated while at work; others, on the contrary, are kept cool by means of a stream of water passing through such parts as are liable to become heated. In this latter case the plater should occasionally place his hand on the machine to ascertain if it be overheated, through failure of the water supply or other cause; on no account should this be neglected, otherwise the machine may suffer serious injury.

Lubrication, Cleanliness.—The bearings must be kept well lubricated with oil, and great care taken to prevent dust working into these parts of the machine. The divisions between the segments of the commutator of a Weston machine should also be kept clean, by passing a strip of card along these grooves to clear away the particles of metal which wear off the brushes and the commutator itself. When the brushes consist of layers of thin sheet copper, the ends should be trimmed with shears occasionally when much worn.

Slipping of Belts.—It sometimes happens that the driving belts are liable to slip off the pulley of the machine, owing to the belt being slack or not running perfectly true; sometimes this will occur when the machine is put on short circuit either accidentally or to exhibit its spark. When liable to this defect—more especially if it arises from imperfect fixing of the machine, or want of truth in either its own pulley or the driving pulley—it is a safe plan to fix an iron fork in such a position that it will keep the band from slipping off the machine pulley under any circumstances.

Acid Fumes.—Wherever dynamo machines are employed it should be strictly forbidden to allow any fuming acid, as nitric and hydrochloric acids or dipping acids, to be used in the room in which the machine is placed, of course excepting the hydrochloric acid dip, which, being used in a diluted form, will be unobjectionable. The machine should not be fixed in such a position as to be near the polishing shop (as we have frequently known to be the case), since the floating particles of lime, cotton from the dollies, and other floating matter will probably find its way into the interior of the apparatus and eventually do mischief.

Management of Batteries.—The zinc plates must always be kept well amalgamated; if the operator feels a tickling sensation in the throat, causing him to cough frequently, he may generally attribute this to the excessive evolution of hydrogen from one or more of his battery cells, which is very irritating to the air passages of the lungs. In such a case he should at once look to his batteries, and the defective cell, which will exhibit a brisk action or effervescence, with evolution of heat, must be disconnected, and the zinc withdrawn and reamalgamated. Before doing so, however, he should examine his connecting wires, to see if the battery is "short circuited" at any point by the accidental contact of the electrodes or other conductors. It is also very necessary that all binding screws or other connections should be scrupulously clean at the points of contact, as also the ends of the connecting wires which are adjusted to the binding screws. The upper ends of the carbons used in Bunsen batteries should be varnished, or coated with melted paraffin wax to prevent the nitric acid from attacking the brass clamps, and thus not only injuring them, but causing defective connection. The copper plates of Wollaston batteries should be kept *clean;* if accidentally spotted with mercury, from contact with the amalgamated zinc plates, the sheet copper should be heated to expel the mercury, then pickled in dilute sulphuric acid, and, after rinsing, be well scoured. The zinc rods of Daniell batteries should never be allowed to rest on the bottom of the porous cells, or a deposit of copper may take place both inside and outside the cell and render it useless. Porous cells often crack from this cause. When porous cells which have been used are laid aside until again required for use, they should first be well rinsed and then filled with clean water. They should never be allowed to become dry, otherwise any sulphate of zinc remaining in their pores will crystallise, and probably in doing so crack the vessel in many places.

Relative Power of Batteries.—The following experiments, made with electrodes double the size of the zinc plates of the batteries, all at equal distances (one inch) apart, will show the relative power of batteries. The time in action was one hour each; only one pair of plates constituted the battery:—

	Deposited		Deposited
Grove battery . .	104 grains.	Smee battery . .	22 grains.
Single-cell apparatus .	62 „	Wollaston . . .	18 „
Daniell battery . .	33 „		

Constancy of Batteries.—The action of most batteries differs after the first hour, so that one kind of battery may be useful for a short period, and another kind if the action is to be sustained for any length of time. This is illustrated by the following table, the conditions being the same as in last experiment, or on this being continued and the results taken every hour for seven successive hours :—

	One hour.	Two hours.	Three hours.	Four hours.	Five hours.	Six hours.	Seven hours.	Total.
Grove battery	104	86	66	60	54	49	45	464 grs.
Single-cell .	62	57	54	46	39	29	4	311 „
Daniell .	33	35	34	32	32	30	31	227 „
Smee . .	22	16	14	11	12	11	10	96 „
Wollaston .	18	14	15	12	11	10	10	20 „

To make this comparison more practical, larger plates were used for the battery, and proportionately larger electrodes, and the battery was kept in operation until one pound of copper was deposited, the acid being renewed and the zincs brushed every twenty-four hours. The time taken to effect this was :—

Grove battery . .	19½ hours.	Smee battery . .	147 hours.
Single-cell . .	45 „	Wollaston. . .	151 „
Daniell . . .	49 „		

Relative Intensity of Batteries.—Different batteries have different degrees of power to overcome resistance, that is, greater intensity, or higher electromotive force. To demonstrate this a single pair of Wollaston, Smee, and Grove batteries were fitted up as nearly equal in circumstances as the different arrangements would allow. Each cell exposed the same surface of zinc, and was connected with electrodes immersed in a solution of sulphate of copper, first one inch, then two, then three and four inches apart for half an hour in each case. They were then reversed, beginning with the electrodes at four inches, and coming to one inch. These experiments were repeated several times, and a mean of the whole taken. The results were :—

Electrodes.	Deposited.		
	Wollaston	Smee.	Grove.
One inch .	8·8 grains.	12·0 grains.	31·0 grains.
Two inches . .	6·6 „	6·8 „	26·0 „
Three „ . .	4·7 „	6·0 „	17·0 „
Four „ . .	3·0 „	4·6 „	14·0 „

From this it will be seen that Wollaston stands lowest in intensity, which is more apparent as the distance of the electrodes is increased

Smee is one-third more than Wollaston at one inch, and one-half more at four inches, while Grove is three-and-a-half more than Smee at one inch, but four-and-a-half more than Wollaston and three more than Smee at four inches. Taking the mean results as a comparison of batteries, their value will stand as under:—

	One pair.	Two pairs.	Four pairs.	Six pairs.	Nine pairs.
Grove battery	55	72	93	97	98
Daniell . .	15	35	60	77	86
Smee . .	11	19	29	41	58
Wollaston .	8	15	24	33	48

The above table gives results approaching to and in principle the same as the others; it will be observed that one pair of Groves is equal to nine pairs of either Wollastons or Smees. It is also noticeable that Grove's increases slowly in quantity above four pairs, the intensity being sufficient at four pairs to overcome the resistance offered to the current of electricity. For ordinary electrotyping, intensity arrangements are unnecessary, except when the article upon which the deposit is being made is of such a character as will not allow the positive electrode to be brought close to it, or when there are deep-cut objects, or any circumstance which increases distance or requires power to overcome resistance.

The Resistance Coil.—Where magneto or dynamo-electric machines are employed, it is absolutely necessary to have at command some means of controlling the current, especially while the baths are being filled with work. For this purpose various contrivances have been suggested, but the simplest form of apparatus, and at the same time one of the most effectual, is that shown in Fig. 136. It consists of a mahogany or cedar board, about 18 or 20 inches by 12 inches, or even of larger dimensions, upon which a coil of brass or German silver wire is stretched by means of brass nails or pins. A movable key, furnished with a handle, is screwed to the lower part of the board, and which, when turned to the left or right, traverses the semicircular row of pins, by which the force of the current is allowed to enter the coil of thin wire to a greater or less extent according to the direction of the movement. For example, by moving the key to S (strong), the full current passes into the plating vat; if the key be moved from peg to peg to the right, in the direction of W (weak), the current enters the thin wire, which resists its passage in proportion to the length of wire which is thus interposed in the circuit. The two binding screws at S and W are for connecting the resistance coil with the machine and the plating vat, which is done by attaching a short length of stout copper wire to the binding screw at s, the other end being connected to the cathode suspending rod of the bath. A similar piece of wire connects the binding screw w with the negative pole of the dynamo-electric machine. When the key is shifted to w the current entering the bath is reduced to a minimum. In starting the instrument, therefore, especially when small articles are to be put into the vat, the key should be placed on the first peg at w, and this must be shifted on to the next peg, and so on, as the bath becomes filled with work. It is very important that the wires of the coil should be placed and kept at some distance from the board, otherwise, when the full amount of resistance to the current is effected, the heat of the wires—which become red-hot—are liable to burn the board, a circumstance which has frequently occurred. The brass pins, or screws, for supporting the wire, should be long enough to keep the wire at least three-quarters of an inch from the surface of the board. If the wires become shifted at any time, so as to approach the board, they must be readjusted by being brought up close to the heads of the pins. The heads of the lower pegs should be cleaned with emery cloth each morning before the resistance coil is put into use, so as to insure a clean connection for the movable key.

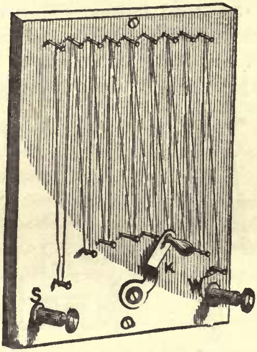

Fig. 136.

Speed Indicator.—A very useful and, indeed, necessary instrument for those who employ power-driven machinery, as dynamo-electric machines, for example, is the speed indicator, Fig. 137, by the employment of which the number of revolutions made by the armature per minute may be readily determined. The instrument being held in the right hand, its point is inserted in the small hollow at the end of the spindle to which the small pulley of the dynamo is attached, the time being taken by the seconds hand of a watch, held in the left hand. These indicators may be obtained from any machinist at a moderate price, and may be had to indicate up to 1,000 revolu-

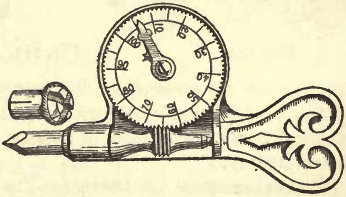
Fig. 137.

tions. The instrument shown in the figure indicates, as will be seen, up to 100. For pointed centres, such as polishing spindles, the little cap on the left of the cut is adjusted to the point of the indicator. This handy instrument can be conveniently carried in the waistcoat pocket.

Binding Screws.—These useful and necessary appliances are usually made from cast brass, and may be obtained in a great variety of forms. A few examples are shown in the accompanying engravings. Fig. 138 is used for connecting the platinised silver of a Smee battery to the wooden cross-bar, or for casting in zinc bars for Daniell's battery; Fig. 139 is used as a connection for a zinc or flat carbon plate; Fig. 140 is a binding screw for zinc plates, or for the cylinders of a Bunsen battery; Fig. 141 is for uniting the poles of dynamos with leading rods; Figs. 142, 144 are for connecting flat copper bands to zinc and platinum plates, as in Grove's battery; Fig. 143 is a clamp for large carbon blocks, for uniting the zincs of a Smee, or the copper plates of a Wollaston battery.

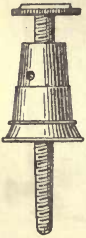
Fig. 138.

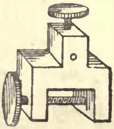
Fig. 139.

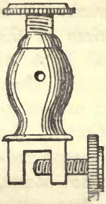
Fig. 140.

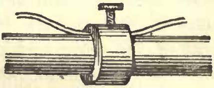
Fig. 141.

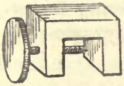
Fig. 142.

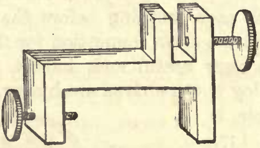
Fig. 143.

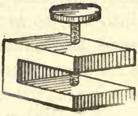
Fig. 144.

Characteristics of Metals.—To those who are engaged in manipulating metals, a knowledge of their chief attributes is always useful, and sometimes absolutely necessary. The subjoined data will therefore, it is hoped, prove acceptable.

Malleability.—When plates or bars of metal are hammered or passed between heavy rollers, they exhibit variable powers of retaining their cohesion as the metal passes into the form of a thin sheet or "leaf."

Of all metals, gold is the most malleable, being capable of being beaten out so thin that the leaf is only 1-280,000th of an inch in thickness, while a square foot weighs only 3 grains.

Ductility.—The property of being capable of extension by being drawn into wire, is greatly different in the various metals, gold being not only the most malleable, but also the most ductile of all metals. A single grain of gold can be drawn into a wire 500 feet in length, and the diameter of the thinnest platinum wire does not exceed 1-30,000th of an inch. In drawing these fine wires of gold or platinum, the metals are covered with a cylinder of silver, and both are drawn together, and thereafter the outer silver coating is dissolved away by nitric acid.

Tenacity.—The strength or cohesive power of the metals, which enables them to sustain greater or less weights, is spoken of as their tenacity. A bar or wire of the metal is securely suspended from a vice or other fixture, and weights are attached to the lower end till the wire parts or breaks. Iron possesses the greatest tenacity, and the following table gives the relative weights which several of the metals will suspend :—

Most Malleable.	*Most Ductile.*	*Most Tenacious.*
Gold.	Gold.	Iron.
Silver.	Silver.	Copper.
Copper.	Platinum.	Palladium.
Platinum.	Iron.	Platinum.
Palladium.	Copper.	Silver.
Iron.	Palladium.	Zinc.
Aluminium.	Cadmium.	Gold.
Tin.	Cobalt.	Tin.
Zinc.	Nickel.	Cadmium.
Lead.	Aluminium.	Lead.
Cadmium.	Zinc.	*Least Tenacious.*
Nickel.	Tin.	
Cobalt.	Lead.	
Least Malleable.	*Least Ductile.*	

Test for Free Cyanide.—It is sometimes useful to have at command some ready way of determining the actual quantity of free cyanide in a solution. For this purpose Mr. Sprague devised the following system, "based upon the ordinary decimal measures obtainable anywhere, and upon the basis of one ounce of cyanide per gallon of solution, from one to two ounces being the proper working strength." The method is thus described :—" One ounce per gallon is equal to 62·5 grains in 10,000 ; the equivalent of cyanide of potassium is 65, and it takes two of these to precipitate and redissolve cyanide of silver from nitrate of silver, the equivalent of which is 170. The test solution, therefore, is prepared from pure nitrate of silver, 81·72 grains, dissolved in a 10,000 grain flask of distilled water; 8·172 grammes in a litre make the same solution, which is equivalent, bulk for bulk, to a solution of one ounce of cyanide in a gallon, and may be used in any measure whatever, properly divided. I prefer to take 1,000 grains of it, and make it up to 10,000 again; to take 100 grains of the solution to be tested, by means of a graduated pipette, and then add this weaker solution to it from an ordinary alkalimeter. As soon as the precipitate ceases to redissolve on shaking, the test is complete. A slight cloudiness in the liquid marks this point.

"To test a sample of cyanide, dissolve 62½ grains in the 10,000 grain flask, and treat this in the same way. Thus, if a sample is so treated, 100 grains placed in a small flask or bottle, 1,000 grains of the test put into an alkalimeter and dropped into the flask as long as the precipitate disappears, and if upon adding 520 grains in this way, a permanent faint cloudiness is produced, the sample contains 52 per cent. of real cyanide. If the original test solution is preferred, 1,000 grains of that to be tested must be used, and the result is the same."

Oxidising Copper Surfaces.—To produce a *deep black* coloration upon a cleaned copper surface, dissolve from 100 to 150 parts of hydrous carbonate of copper in a sufficient quantity of liquid ammonia. The cleaned articles are promptly immersed in this solution, when they immediately become coated with a fine black deposit, which, when burnished, has the appearance of a black varnish.

Sulphide of Barium.—We have found that a rich coloration may be given to clean copper articles by immersing them for a longer or shorter period, according to the effect desired, in a dilute solution of sulphide of barium. About 4 or 5 grains of the salt to each ounce of water produces an instantaneous coloration, of a warm bronze tint, which increases in vigour by longer immersion. The action is of so permanent a character that the articles will bear much friction before the coating will yield, while the warm chocolate tone which the metal assumes has a bright metallic lustre which, for some surfaces, is exceedingly pleasing.

Alloys.—In pursuing the art of electro-deposition the operator has greatly to deal with alloys of metals; and since the various kinds of alloy, as brass, gilding metal, German silver, and bronze, for example, differ considerably in their composition, it will be useful to the electro-depositor to have some general knowledge of the constitution of the various alloys which may come into his hands to be coated with gold, silver, or other metallic deposit. Formerly the term alloy signified a compound of gold and silver combined with some inferior metal; it is now understood to mean a compound of two or more metals of any kind. For example, brass is an alloy of copper and zinc, and bronze an alloy of copper and tin. An alloy composed of metals which differ in their fusibility are usually malleable when cold, and brittle when hot, as is the case with brass. Many alloys consist of the definite or *equivalent* proportions of the metals, while other alloys seem to form in any proportion; the finest quality of brass is obtained when the respective metals, copper and zinc, are combined in their *atomic or equivalent* proportions. One metal does not alloy itself indifferently with every other metal, but is governed in this respect by peculiar affinities: thus silver will hardly unite with iron, but it combines readily with gold, copper, and lead. In comparing the alloys with their constituent metals, the following differences may be noted; in general, the ductility of the alloy is less than that of the separate metals, and sometimes in a very remarkable degree; on the contrary, the alloy is usually harder than the mean hardness of its constituents. The mercurial alloys, or amalgams, are, perhaps, an exception to this rule. The specific gravity is rarely the mean between that of each of its constituents; but is sometimes greater, and sometimes less, indicating, in the former case, an approximation, and in the latter a recedure, of the particles from each other in their act of union.—(*Ure.*)

When there is a strong affinity between the two metals, the density of their alloy is generally *greater* than the calculated mean, and *vice versâ*, as illustrated in the following table:—

Alloys having a Density

Greater than the mean of their constituents.	*Less* than the mean of their constituents.
Copper and bismuth.	Gold and copper.
,, palladium.	,, iridium.
,, tin.	,, iron.
,, zinc.	,, lead.
Gold and antimony.	,, nickel.
,, bismuth.	,, silver.
,, cobalt.	Iron and antimony.
,, tin.	,, bismuth.
,, zinc.	,, lead.
Lead and antimony.	Nickel and arsenic.
Palladium and bismuth.	Silver and copper.
Platinum and molybdenum.	Tin and antimony.
Silver and antimony.	,, lead.
,, bismuth.	,, palladium.
,, lead.	Zinc and antimony.
,, tin.	
,, zinc.	

Dr. Ure says, "Every alloy is, in reference to the arts and manufactures, a *new metal*, on account of its chemical and physical properties. A vast field here remains unexplored. Not above *sixty* alloys have been studied by chemists out of many hundreds which have been made; and of these very few have yet been practically employed. Very slight modifications often constitute very valuable improvements upon metallic bodies." Since those words were written, however, many important alloys have been introduced, while at the present time the subject is receiving considerable attention not only in this country but also in the United States.

When it is desired to alloy three or more metals, as in the manufacture of German silver, which is composed of copper, nickel, and zinc, much difficulty would arise if we attempted to fuse all the metals together at one time, since the zinc, being more readily fusible than the other metals, and at the same time volatile, would simply pass away in vapour: the least fusible metal (nickel) should therefore be first brought to a state of fusion, the copper then gradually added, and the zinc finally introduced in the same cautious way. Again, in forming certain kinds of brass, in which a small quantity of lead forms a constituent, the copper should be melted separately, the zinc and lead then melted together, and the alloy next added to the copper, or *vice versâ*, the combined metals being then fused together until the combination is complete. In combining zinc with copper, to form brass, the metals are first melted separately, and then quickly mixed while in a state of fusion. Brass is sometimes formed by adding strips of copper to molten zinc, until an alloy, not easily fused, is formed. This is afterwards broken up into fragments, and remelted under a layer of charcoal, with the addition of either metal to bring the alloy up to the colour and standard required. It appears that the best proportion of metals to form fine brass is one prime equivalent of copper $= 63\frac{1}{2} +$ one of zinc $= 32\cdot3$, or very nearly 2 parts of copper to 1 part of zinc. The bright gold-coloured alloy called Prince's or Prince Rupert's Metal consists of 2 parts zinc to 1 part copper. The principal alloys of metals employed in commerce are shown in the following table:—

Names.	Combining Metals.
Albata, or German silver	Copper, nickel, and zinc, with, sometimes, a little iron and tin.
Aluminium bronze	Aluminium and copper.
Amalgams	Mercury and other metals.
Bath metal	Copper and zinc.
Bell-metal	Copper and tin.
Brass	Copper and zinc.
Britannia metal	Tin, with antimony, copper, and bismuth.

Names.	Combining Metals.
Bronze	Tin and copper,
Gun-metal	Tin and copper.
Dutch gold	Copper and zinc.
Fusible metal	Bismuth, lead, and tin, with, sometimes, cadmium.
Gold, *Standard*	Gold with copper.
„ *Old Standard*	Gold with copper and silver.
Mosaic Gold	Copper and zinc.
Ormoulu	Copper and zinc.
Pewter, common	Tin and lead.
„ best	Tin, with antimony, bismuth, and copper.
Pot metal, Cock metal	Copper and lead, with, sometimes, a little zinc.
Queen's metal	Tin with antimony, bismuth, and copper.
Silicon bronze	Silicon and copper.
Shot metal	Lead, with a little arsenic.
Silver, Standard	Silver and copper
Solder, hard	Silver and brass.
„ soft	Tin and lead.
Speculum metal	Tin and copper.
Stereotype metal	Lead, antimony, and bismuth.
Tombac, Red tombac	Copper and zinc.
Type metal	Lead and antimony.
White Copper	Copper and arsenic.

Of the various kinds of brass the following are the most important:—

Finest Quality of Brass.—Copper, 2 parts; zinc, 1 part.

Prince's Metal.—Zinc, 2 parts; copper, 1 part.

Fine Malleable Brass, for sheets, tubing, &c., is made from various formulæ. I. Copper, 7 parts; zinc, 3 parts. II. Fine copper, 4 parts; zinc, 1 part. III. Copper, 33; zinc, 25 parts. IV. Copper, 3; zinc, 2 parts. These alloys are malleable whilst hot.

Red Brass contains only a small percentage of zinc, and sometimes as little as 8 or 10 per cent.

Brass for Castings.—The alloy for fine brass is sometimes used for castings, or either of the following are employed:—I. Copper, 62; zinc, 35; lead, 2 parts; tin, 1 part. II. Copper, 60; zinc, 36; tin, 4 parts. These alloys are rather brittle and of a palish colour. III. Copper, 90; zinc, 7; tin, 2 parts; lead, 1 part.

Gilding Metal.—I. Copper, 64; zinc, 32; lead, 3 parts; tin, 1 part. II. Copper, 82; zinc, 18; tin, 3 parts; lead, 1 part.

Brass for Turning.—I. Copper, 64; zinc, 33; lead, 2 parts. II. Fine brass, 98; lead, 2 parts, melted together. III. Copper, 61; zinc, 36; lead, 3 parts.

Brass Solder.—I. Brass, 3 parts; zinc, 1 part. This is used for soldering tubes and joints, and for all purposes where great strength is required. II. Fine brass, 12; zinc, 6 parts; tin, 1 part, melted together.

Brass for Wire is made from copper 72, and zinc 28 parts; or copper 64, and zinc 34 parts.

Button Brass, or Platin of the Birmingham manufacturers, is composed of 8 parts of brass and 5 parts of zinc, while their cheaper button metal is composed of copper, tin, zinc, and lead.

Soldering.—*Hard Soldering.*—It not unfrequently happens, while scratch-brushing an article of jewellery or other small article, that some portion of the work will accidentally break away; under such circumstances it will be well if the gilder can himself repair the article instead of being compelled to return it to his customer or send it out to be repaired. With a view to furnish the operator with the means of doing repairs of this nature, the author introduces the following extract from his former work;* and if the instructions herein given are carefully followed, the operator will have little difficulty in repairing accidental breakages. He should, however, first make himself master of the use of the blowpipe, and practise upon pieces of thin brass or copper wire before venturing to solder delicate articles of jewellery:—

"Hard soldering" consists in uniting any two metals, or parts of the same metal, by means of an alloy composed of two parts of silver to one part of brass. The silver and brass should be melted together as follows:—Having obtained a broad piece of good charcoal, scoop out a slight hollow on the flattest surface to receive the alloy. Now place the metals in the hollow, and fuse them by means of a blowpipe, using either a jet of gas or an oil lamp with a good broad wick. As soon as the metals become hot, touch them with a crystal of borax (borate of soda), which will immediately fuse and act as a flux. The jet of flame must now be vigorously employed until the metals are completely fused. The fusion may be continued for a few moments in order to insure perfect amalgamation. When the "button" of solder is well melted, the flat surface of a hammer should be placed quickly upon it, by which means it will become flattened; in this form it may be readily beaten out (unless a pair of steel rollers are at hand) until sufficiently thin to cut with a pair of jewellers' shears. The solder can be hammered out upon an anvil or any solid iron surface; but as each time the blow is given the alloy becomes harder, it will be necessary from time to time to *anneal* it, *i.e.* place it again upon the charcoal and apply the blowpipe flame until the alloy is of a "cherry-red" heat; it is then to be plunged into cold water, and is ready for

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* "Electro-metallurgy," by the Author, 8th edition, p. 159.

beating out or rolling as the case may be, the object being to make the solder as thin as an ordinary card, or even thinner. When the operator is without a pair of rollers he must use the next best substitutes—a hammer and patience. The solder before being used must be scraped with a keen steel edge, and then partly cut into thin strips, and these again cross-cut into small pieces or pellets about one-sixteenth of an inch square. These pellets may be cut when required for use, or kept in a clean box used for the purpose.

The operator should next provide himself with a clean piece of slate, say about three inches square, and a small phial filled with water, and having a cork with a small groove cut in it from end to end. The bottle is used to apply moisture a drop at a time, whilst a large crystal of borax is rubbed upon the slate. By this means a thick creamy paste of borax is obtained upon the slate, which will be used as presently directed. The parts to be united or soldered must now be scraped clean *wherever the solder is expected to adhere*, and with a camel-hair brush or feather of a quill dipped in the borax paste brush over the parts to be soldered. A few pellets of the solder may be placed on the dry corner of the slate, and with the extreme point of the brush moistened by the paste one pellet at a time may be readily taken up and placed upon the prepared surface of the article. The article should be placed upon a flat piece of charcoal (made flat by rubbing on a flagstone), and, if necessary, tied to it by thin "binding wire." A gentle blast of the blowpipe will at first dry the borax, and the flame must then be increased (holding the blowpipe some distance from the flame in order to give a broad jet), and in a few moments, if the jet is favourable, the solder will "run," as it is termed, into every crevice, when the blowpipe must be *instantly* withdrawn. A very little practice will make the operator expert in this interesting art, and it will be advisable for him to practise upon articles of little value until he has not only acquired the use of the blowpipe, but also the proper kind of flame to make the solder run freely. After an article has been hard soldered it is allowed to cool, or may be at once placed in a weak solution of sulphuric acid (a few drops of acid to an ounce of water), which, after a few moments, will dissolve the borax flux which remains after the soldering is complete. The article should now be rinsed in water and dried.

Soft Soldering.—This consists in uniting articles made of sheet tin (tinned iron), lead, zinc, and sometimes iron, with an alloy of tin and lead. It is usually performed with a tool called a *soldering-iron*, which consists of an ingot or bar of copper, riveted to a cleft iron stem terminating in a wooden handle; the operation may, however, in some cases be accomplished by means of the blowpipe flame. In soldering, the first thing to do is to well clean the parts to be united, which is most conveniently done by *scraping*, a three-edged tool termed a *scraper*, or the edge of a penknife, being used for this purpose. In applying the solder to the two first-named metals, a little powdered resin is first sprinkled over the cleaned surfaces to be united; the soldering-iron must be well *tinned* by first moderately heating it in a clear fire, then filing the bevelled surfaces of its point until bright and clean; it must next be at once made to touch a lump of black resin, and then brought in contact with a strip of solder; care should be taken that all surrounding parts of the point of the tool are well coated with solder. When about to apply the soldering-iron to the prepared surfaces, it must be first made moderately hot, not on any account *red* hot; its point should then be wiped on a piece of cloth having a small piece of resin upon it, and then touched with the strip of solder, when a small globule of the metal will attach itself, and the tool may now be applied to the object to be soldered; at the same time the strip of solder, being held in the other hand, should be brought in contact with the soldering-iron and a sufficient quantity of the solder allowed to melt while the tool is being applied. As the soldering-iron cools, it must be re-heated and cleaned as before. Sometimes powdered sal-ammoniac is employed in soft soldering, and it is a good plan to press the point of the hot tool upon a lump of this salt occasionally, by which the oxidation of its surface becomes removed. In passing the soldering-iron along the parts to be joined, the solder should *run*, as it is termed, freely and form a bright and even layer.

In soldering iron with soft solder, the surfaces, after being well cleaned, must be brushed over with a solution of *chloride of zinc*, or "tinning salt;" this is made by pouring a little muriatic acid upon a strip of clean zinc; vigorous effervescence at once takes place, and when this has nearly subsided the solution is ready for use. The solution may be applied to the cleaned iron surface by means of a camel-hair brush or the feather of a quill, when the soldering-iron is to be employed as before; it should, however, be rather hotter for this purpose than for soldering the more fusible metals. In soldering zinc the tinning salt is also used, but a little muriatic acid spread over the surface is better, since it cleans the surface of the zinc, forming, of course, chloride in doing so. When it is desired to solder a wire upon a stout zinc plate for battery purposes, it is a good plan to moderately heat the end of the zinc to which the wire is to be attached, then to apply a few drops of the acid, and immediately apply the solder as before; the end of the copper wire, being previously cleaned and tinned, is then to be put in its place, and the hot soldering-iron and sufficient solder applied until the end of the wire is imbedded in the material; a cold hammer may then be pressed on the wire, which, by chilling the solder, will complete the operation.

Sheet lead, such as is used for lining nickel and other tanks, should not be united by soldering, since the two metals, tin and lead, when in contact with the solution (especially a nickel salt) would slowly undergo chemical action, probably resulting in perforation of the lining. It is usual, therefore, to unite the sheet lead by the *autogenous* process, or "burning" as it is called, which consists in first scraping the surfaces clean, when a jet of hydrogen gas, or this gas mixed with common air, is applied, by which the two surfaces become fused together. This method of securing the joints of lead-lined tanks is now universally applied, and is unquestionably the best system that can be adopted.

Soldering Liquid.—As a substitute for the solution of chloride of zinc ordinarily used as a tinning salt, the following has been recommended:—Make a neutral chloride of zinc by adding strips of the metal to muriatic acid, taking care to employ an excess of the former. Then add, while the liquid is still hot from the chemical action, as much powdered sal-ammoniac as the fluid will dissolve. Instead of using water to dilute the solution, use alcohol, keeping the liquid in a well-stoppered bottle until required for use. If crystals appear when the solution is placed in an open vessel for use, add a little alcohol, which will liquefy them again.

To Remove Soft Solder from Gold and Silver Work.—This may readily be effected by placing the soldered article in a hot solution of perchloride of iron, made by dissolving crocus or jewellers' rouge in muriatic acid and diluting the solution with four times its bulk of water, and there leaving it until the solder is removed. A formula recommended by Gee* for this purpose is composed of protosulphate of iron (green copperas), 2 ozs.; nitrate of potassa (saltpetre), 1 oz.; water, 10 ozs. Reduce the protosulphate of iron and nitrate of potassa to a fine powder, then add these ingredients to the water, and boil in a cast-iron saucepan for some time; allow the liquid to cool, when crystals will be formed; if any of the liquid should remain uncrystallised, pour it from the crystals, and again evaporate and crystallise. The crystallised salt should be dissolved in muriatic acid in the proportions of one ounce of the salt to eight of acid. Now take one ounce of this solution and add to it four ounces of boiling water in a pipkin, keeping up the heat as before. In a short time the most obstinate cases of soft solder will be cleanly and entirely overcome and the solder removed without the work changing colour.

Platinising.—This name is applied to coating thin silver foil with platinum, in the form of a black powder, whereby a vast number of fine points are produced, which facilitate the escape of hydrogen in

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* "The Goldsmith's Handbook," by George E. Gee, p. 144.

the Smee battery. This ingenious method of favouring the escape of hydrogen, instead of allowing it to accumulate on the surface of the battery plates, was suggested by Smee, and was the means of rendering his admirable battery one of the most useful and popular voltaic batteries known. To platinise silver plates for the Smee battery, a solution is made by first adding to the necessary quantity of cold water one-tenth part, by measure, of sulphuric acid; after mixing these by stirring with a glass rod, add crystals of chloride of platinum with stirring, until the liquid assumes a pale yellow colour; it is then ready for use. Several Smee cells are now to be connected in series, and a couple of platinum or carbon anodes, attached to the positive pole of the compound battery, suspended in the electrolysing cell. The sheet of silver foil to be platinised should have a copper wire soldered to its upper end, and be enclosed in a frame of wood; it is then to be connected to the negative pole, and suspended between the pair of platinum or carbon plates; all being now ready, the platinum solution is to be poured into the vessel until it reaches the upper surface of the silver foil. In about fifteen or twenty minutes, the silver will become coated with a deep black film of platinum in a finely divided state, when it may be withdrawn and rinsed, and is then ready for employment as the negative element of a Smee cell. To prevent the exciting fluid of the battery from attacking the solder which connects the wire to the silver, this, and a few inches of the connecting wire, should be coated with sealing-wax varnish.

Steel-facing Copper Plates.—A very good solution for coating copper plates with iron—commonly termed *steel-facing*—may be prepared by the battery process as follows:—The depositing vessel to be used for coating the plates is to be nearly filled with water, in which is to be dissolved sal-ammoniac, in the proportion of 1 part by weight of the latter to 10 parts by weight of the former, that is 1 lb. of the salt to each gallon of water used to make up the bath. A stout plate of sheet iron, previously pickled, scoured, and rinsed, is to be connected to the positive electrode of a battery, and immersed in the solution; a second plate of iron, about half the size of the former, and also rendered perfectly clean and bright, is to be connected to the negative pole of the battery, and suspended at a short distance from the anode, or larger plate. The battery is allowed to continue in action for two or three days, at the end of which time the iron cathode may be removed, and a strip of clean brass or copper suspended in its place, when, after a short immersion, this should become coated with a bright deposit of iron, provided that the solution has acquired a sufficient quantity of this metal during the electrolytic action. If such is not the case, the iron cathode must be again immersed, and the action kept up until a brass or copper plate promptly receives a coating of iron. When the bath is found to deposit iron freely, the copper plate to be faced with iron is to be connected to the negative pole and immersed in the bath, where it is allowed to remain until sufficiently coated. A bright deposit of iron should appear upon the plate immediately after immersion, and the plate should become quickly coated all over if the bath is in proper condition and a suitable current employed. If, after the copper plate has been in the bath a short time, the edges assume a blackish appearance, it must be at once withdrawn, and well rinsed with clean water, and this is most effectually done by holding the plate under a running stream delivered from a flexible tube connected to a water tap. The plate must then be quickly dried, and afterwards washed over with spirit of turpentine; it is then ready to be printed from.

Antidotes and Remedies in Cases of Poisoning.—Since some of the substances employed in electro-deposition are of a highly poisonous nature, and the mineral acids with which we have to deal (especially nitric and sulphuric acids) are exceedingly corrosive in their action upon the skin, as also are the caustic alkalies, soda and potash, a few hints as to the best antidotes or remedies to be applied in cases of emergency will, it is hoped, prove acceptable; indeed, when we take into consideration the fatal promptitude with which hydrocyanic acid, cyanogen vapours, and cyanide of potassium will destroy life, it becomes the duty, not only of employers, but their foremen, to make themselves acquainted with such antidotes as can be applied at a moment's notice in cases of accidental poisoning or injury from corrosive substances. In the course of a long experience, the author has more than once narrowly escaped serious consequences, not only from accidental causes, but (in his youthful days) from careless disregard of the dangerous nature of cyanogen vapours. In the latter case his system was at one time so seriously affected by inhaling the vapours of cyanide baths as to partially reduce the power of the lower extremities. His esteemed friend, Mr. Lewis Thompson, a gifted scientific chemist and surgeon, having casually paid him a visit, upon observing the author's condition, and well knowing its cause, promptly prescribed *six glasses of hot brandy and water.* The advice was quickly followed, to the extent of half the prescribed dose, and by the following day the symptoms had almost entirely disappeared. Upon another occasion, the author inadvertently swallowed a quantity of old gold solution, which he had placed in a small teacup for an experimental purpose, in mistake for some coffee without milk, which it was his custom to drink when at work in his laboratory. Having discovered his mistake he at once desired his assistant to get some lukewarm water without delay; in his absence, however, he thrust his finger to the back of his throat, and by tickling the *uvula*, quickly induced vomiting; copious doses of warm water, assisted by again irritating the *uvula*, soon emptied the stomach, after which warm brandy and water completed the remedy, no ill effects from the accident being afterwards observable. Upon one other occasion, the author was ascending a spiral staircase leading to a plating room, when he suddenly felt a sensation of extreme giddiness; promptly guessing the cause, he retreated as speedily as his trembling limbs would permit, and sought the open air, and as quickly as possible obtained a glass of brandy from the nearest tavern, which had the effect of checking the tremulous motion of the limbs and feeling of intense nervousness. The cause of the sensation above referred to was this: some old silver solutions had been treated with sulphuric acid, to precipitate the silver, a short time before, in an upper apartment, and the carbonic acid and cyanogen vapours liberated were descending to the base of the building at the time he ascended the staircase; it was the remembrance of this fact that prompted him to retrace his steps as quickly as the shock to his system would allow.

In mentioning the above incidents our chief object is to illustrate, from what has actually occurred, not only the sources of danger which callousness and inadvertence may invite, and to point out how such accidents may be avoided, but also to indicate how by promptitude more serious consequences may be averted.

General Treatment in Cases of Poisoning.—The first important step, in all cases of poisoning, is to *empty the stomach* with all possible dispatch. This may generally be done (and should always be tried first) by thrusting the finger towards the throat, moving it about so as to tickle the parts until vomiting supervenes. While this remedy is being tried, a second person, if at hand, should hasten to procure some lukewarm water, which the sufferer should be made to swallow, whether vomiting has or has not occurred; warm mustard and water may also be tried. If these remedies fail, the stomach-pump should be applied. The vomiting should be kept up and the stomach well washed out with some bland *albuminous* or *mucilaginous* liquid, as warm milk and water, eggs beaten up in milk or water, barley-water, flour and water, or any similar substances ready at hand. After the vomiting, a brisk purgative or *enema* may be administered, and nervous irritability or exhaustion alleviated by means of opium, ether, wine, or warm spirit and water, as the case may require; only the "domestic remedies," however, should be applied, except under proper medical advice.

Poisoning by Hydrocyanic Acid, Cyanogen, or Cyanides.—When hydrocyanic acid has been inhaled, the vapour of ammonia or chloride of lime should be at once applied, cautiously and moderately, to the nostrils; indeed, this highly poisonous acid should never be used, especially by inexperienced persons, without the presence of a second person, holding an uncorked bottle of liquid ammonia or chloride of lime in moderate proximity to his nostrils. In case of poisoning by this acid, *cold* water should be *at once* poured upon the head, and allowed to run down the spine of the sufferer. In the case of hydrocyanic acid or cyanides having been swallowed, four or five drops of liquid ammonia, in a large wine-glass full of water, may be administered. Mialhe recommends spreading dry chloride of lime upon a towel, folding it up in the form of a cravat, and moistening it with vinegar; this is then placed over the mouth and nostrils of the patient, so that he may inhale the chlorine which is gradually liberated. In cases of poisoning by swallowing cyanides—as gold and silver solutions, for example—emptying the stomach by every means would undoubtedly be the most important step. The application of *very* cold water to the head and spine should not, however, be neglected in severe cases. As antidotes for cyanide poisoning, iron salts are recommended, which convert the deleterious acid into the comparatively innoxious prussian blue.

Poisoning by Corrosive Acids.—In case of either of the mineral acids —nitric, sulphuric, or hydrochloric—having been swallowed, copious doses of lukewarm water, mixed with magnesia, chalk, carbonate of soda, or potassa, should be administered at once. Milk, broth, salad oil, or oil of sweet almonds may also be given.

Poisoning by Alkalies.—Vegetable acids—as vinegar and water, dilute acetic acid, lemon-juice—should be given by preference, but if these are not at hand, very dilute hydrochloric, nitric, or sulphuric acid (about ten drops in half a pint of water) may be substituted. When the painful symptoms have subsided, a few spoonfuls of salad oil should be administered.

Poisoning by Metallic Salts.—The sufferer should be caused to drink tepid water copiously and repeatedly, vomiting being also urged by tickling the throat with the finger or a feather; copious draughts of milk and the white of eggs (albumen) may also be given; but flowers of sulphur or sulphuretted waters are recommended in preference, since these transform most of the metallic salts into insoluble sulphides, which are comparatively inert.

Cyanide Sores.—These painful affections may arise from two principal causes: first, from dipping the hands or arms into cyanide baths to recover articles which have dropped into them—a very common practice, and much to be condemned; and second, from the accidental contact of the fingers or other parts of the hand, on which a recent cut or scratch has been inflicted, with cyanide solutions. In the former case, independent of the constitutional mischief which may arise from the absorption by the skin of the cyanide salts, the caustic liquid acts very freely upon the delicate tissue of the skin, but more especially upon the parts under the finger nails. We have known instances in which purulent matter has formed under the nails of both hands from this cause, necessitating the use of the lancet and poulticing. Again, when cyanide solutions come in contact with recent wounds—even very slight cuts or abrasions of the skin—a troublesome and exceeding painful sore is sure to result, unless the part be at once soaked in warm water; indeed, it is a very good plan, after rinsing the part in cold water, to give it a momentary dip in a weak acid pickle, then soak it for a few moments in warm water, and after wiping the part dry with a clean rag or towel, apply a drop of olive oil and cover up with a strip of thin sheet of gutta-percha.

Poisoning by Acid Fumes.—When the lungs have been affected by inhaling the fumes arising from dipping baths, stripping solutions, &c., or chlorine gas, the sufferer should at once seek the open air; he may also obtain relief by inhaling, in moderation, the vapour of ammonia from *the stopper*, not from the bottle itself; or a little water may be put into a glass measure and a few drops of ammonia mixed with it, which may be inhaled more freely. When an apartment has become oppressive from the fumes of acid, it is a good plan to pour *small* quantities of liquid ammonia upon the floor in several places, but the acid fumes should be expelled as quickly as possible by the opening of all windows and doors.

Caution.—Never add an acid to any liquid containing cyanide, or ferrocyanide, in a closed apartment, but always in the open air, taking care to keep to windward of the liberated gases, which are *poisonous in the highest degree.*

APPENDIX.

Electro-deposition of Platinum (*Thoms' Process*).—This process, which has for some time past been carried out by the Platinum-plating Company, has for its object the "deposition of platinum with greater economy, solidity, and greater perfection than in the methods hitherto adopted," and the inventor claims, as an advantage over all other processes, that he obtains "a deposit which is so bright that it requires no subsequent polishing. This feature constitutes in itself an important advantage, as the cost of polishing is entirely abolished." In the preparation of his bath the inventor prepares a solution of chloride of platinum in the usual way, which is subsequently rendered neutral by any ordinary method. To this solution of platinum he adds a weak solution of common phosphate of soda, to which is next added a weak solution of phosphate of ammonia, and the whole are then boiled for several hours, during which operation a solution of chloride of sodium is added. The proportions of the above ingredients which it is preferable to use are as follows:—Chloride of platinum, 1 ounce; phosphate of soda, 20 ounces; phosphate of ammonia, 4 ounces; chloride of sodium, 1 ounce. The whole of the ingredients may be varied, but the proportions given have been found to produce good results. The solution may be worked at any suitable temperature, but it is preferable to work it above the ordinary temperature of the atmosphere. A strong current of electricity must be employed, and the cathode should be kept in motion while the deposition of the platinum is going on. The same bath may be used for a considerable time by adding fresh platinum solution and chloride of sodium solution as required, to keep up the original strength of the bath. When it is desired to coat surfaces to which platinum will not adhere directly, they must be first coated in any suitable manner with a substance to which platinum will adhere.

Electro-deposition of Aluminium and its Alloys (*Burghardt and Twining's Process*).—The inventors prepare a solution containing cyanides of aluminium and copper in the following way:—A solution of chloride of copper is first formed by dissolving copper in nitro-hydrochloric acid and afterwards expelling the acid by evaporating the solution to dryness, hydrochloric acid being added if necessary. Hydrated oxide of aluminium is next prepared by adding an excess of liquid ammonia to a solution of sulphate of aluminium, the precipitate being washed to free it from foreign salts; this is then mixed with the chloride of copper solution. The mixture is then boiled and sufficient hydrochloric acid added to insure a perfect solution of the hydrated oxide of aluminium. The free hydrochloric acid is next expelled by evaporation. In this way the inventors obtain what they term a double chloride of copper and aluminium. To prepare a bath containing, say, 24 ounces troy of metal, the ingredients would be compounded in about the following proportions: 20 ounces of metallic copper are converted into chloride as described; 32 ounces of commercial sulphate of alumina are converted into hydrated oxide of aluminium, and the resulting products are then mixed, boiled, and freed from excess of hydrochloric acid by evaporation. "The resulting solution is now diluted with a suitable quantity of water and mixed with about 24 lbs. troy of solid caustic soda dissolved in water, the mixture being gently heated for some time. The caustic soda precipitates out the copper as hydrated oxide of copper, and also the aluminium as hydrated oxide, which at once redissolve in the excess of caustic soda." [The patentees describe a method of determining whether the aluminium oxide has been completely dissolved.] "We now add to the bulk of the solution," say the inventors, "about 16 ounces of solid cyanide of potassium (containing about 95 per cent. of potassium cyanide) to each ounce of metal in the solution, and heat the mixture until all the suspended hydrated oxide of copper is dissolved. We then add 8 ounces of solid bicarbonate of potassium to each ounce of metal present in the solution, and boil the solution continuously for about 24 hours, or as long as is found necessary, until the solution has cleared itself, after which it may be filtered if necessary. When it is wished to make the solution deposit the metal in a clear and bright condition, we add to the solution, whilst cold, about half a pint of a solution of hydrocyanic acid gas of the so-called 'Scheele's strength.'" If the solution, after being worked some time, becomes sluggish in its action, from excess of saline matter in the bath, an addition of cyanide is made, and the solution then boiled for some hours; but "if the solution already contains an excess of cyanide and carbonate of potassium—which is apt to be the case when it has been at work for some time—we consider that the addition of hydrocyanic acid gas solution, or the passing of hydrocyanic acid gas into the solution preferable to the addition of more cyanide. The action of the hydrocyanic acid consists principally in the formation of cyanide of potassium from the carbonate of potassium in the solution, it being a well-known fact that cyanide of potassium in the course of time decomposes into carbonate." The solution above described "may be used in the plating of metal objects, or in the depositing of the alloy upon surfaces, for which purpose a dynamo-electric machine or battery of suitable power may be employed, a platinum or other suitable anode being used." The bath is worked at a temperature of about 180° Fahr. during the deposition; but if it is wished to obtain a deposit of lighter colour, the bath is worked at a lower temperature. "When the object is to obtain the alloy as a precipitate," say the inventors, "we use the electric current to throw down the alloy without putting into the bath any object to receive the deposit or coating."

Electrolytic Treatment of Zinc and its Ores (*Watt's Process*).—This process, for which the author obtained a patent in April, 1887, has for its object the purification of crude or impure zinc, and the extraction of metallic zinc from its ores, by electrolysis. To accomplish the first aim of this invention, namely, the production of pure zinc, a solution of a vegetable acid (preferably acetic acid) is first obtained, which is placed in a suitable tank. Slabs or thick plates of impure zinc are then suspended as anodes in the depositing vessel, and thin plates of good sheet zinc, sheet copper, iron, or other suitable metal, are used as cathodes or receiving plates, the surfaces of which may have a coating of plumbago, or be slightly greased to prevent the adhesion of the deposited metal. When the required series of anodes and cathodes have been suspended in the acid solution, the current of electricity is allowed to pass, and in a short time the acid solution becomes impregnated with zinc, and the metal deposits in a state of great purity upon the receiving plates, in the form of a bluish white film: at the same time the impure zinc anodes gradually assume a discoloured or even blackish appearance, due to the metallic impurities with which impure zinc is more or less contaminated, forming an insoluble film on their surfaces. This film increases in thickness as the operation progresses, and the insoluble matters eventually become dislodged, and fall from the anodes in flakes or masses to the bottom of the tank; or they may be removed mechanically by occasionally scouring the plates with a hard brush. During the electro-chemical action, and until the acid solution becomes well charged with zinc, a good deal of gas is liberated at the surface of the plates, to check or moderate which carbonate or oxide of zinc may be introduced in small quantities at a time, until the evolution of gas nearly or almost entirely ceases, when the deposition proceeds more favourably. The solution, however, improves by continual working, and the deposit becomes more uniform than when the bath is newly prepared. When the receiving plates have become sufficiently coated with the purified zinc, they are removed from the baths and replaced by fresh plates, and the zinc-coated plates are then well rinsed and dried. If the receiving plates are of pure, or nearly pure, zinc, they may be at once melted and cast into ingots in the usual way; but if copper or other metal be employed for the cathodes the deposited zinc must be stripped off with the aid of suitable tools, and the zinc then collected for melting.

Instead of employing a solution of a vegetable acid direct as the electrolyte, a solution of zinc in a vegetable acid may be employed, preferably acetate of zinc, which is found to be most effectual. This may be prepared by digesting the carbonate or oxide of zinc, or clean scrap zinc, in acetic acid, with the aid of such agitation as may be necessary to hasten the solution of the zinc. The solution is then allowed to settle, and the clear liquor is afterwards drawn off as required, and is by preference employed in a moderately diluted condition. In refining impure zinc with the solutions prepared by either of the foregoing methods, the insoluble metallic impurities, which are liberated at the anodes, eventually form a black slime, or mud, at the bottom of the tank, and from which the several foreign metals may be recovered by ordinary processes. The refined zinc is specially serviceable for voltaic batteries, since, from its extreme purity, the "local action" which occurs even with the best commercial zinc, from the presence of negative metals, is reduced to a minimum, if not absolutely avoided. Pure zinc is also available for alloying with pure electrolytic copper, to form brass of a high quality for various purposes in the arts, but more especially for cartridge cases, the metal for which is required to be absolutely free from lead to prevent the cartridge from "jamming," as it is termed.

In treating zinc ores for the extraction of the zinc by this process, the ore (if it be calamine, or native carbonate of zinc) is first finely ground and sifted, and then introduced, in small quantities at a time, into a strong solution of a vegetable acid, say commercial acetic acid, containing about 15 or 20 per cent. of real acid. The operation is assisted by agitation, and the powdered ore introduced gradually in order to allow the liberated carbonic acid to escape without causing the contents of the tank to overflow. The supply of powdered ore is kept up until the required quantity (which may be approximately estimated by previous calculation) has been introduced. The contents of the tank will then be subjected to continuous agitation until the liquor has become neutral, or nearly so, which can be ascertained by testing with litmus paper. When the solution is found to be sufficiently neutral for the electrolytic bath (a slight excess of acid not being objectionable) the contents of the tank must be allowed to settle, and the clear liquor is afterwards drawn or pumped off for the extraction of the zinc, in the manner above described. The anodes may be of carbon or platinum, or other metal insoluble in the acid, but flat plates of carbon answer very well for the purpose. For the cathodes plates of thin sheet zinc of good quality may be used; otherwise copper or iron, slightly greased to prevent the adhesion of the deposited metal, may be employed. The acetate of zinc solution (more or less impure) may be used in its concentrated condition, that is, as it comes from the dissolving tank, or it may be moderately diluted with water; but it is found that a liquor which has a specific gravity of about 1,150 to 1,160 (water being 1,000), yields very good results as an electrolyte for the extraction of the metal. As the metal becomes deposited upon the receiving plates, an equivalent proportion of acid is set free in the liquor, and in order to prevent an accumulation of this free acid in the electrolyte, and to keep up the normal metallic strength of the solution as far as possible, and also to prevent polarisation, which an excess of free acid would tend to set up, it is necessary that a continuous supply of fresh neutral, or nearly neutral, zinc solution should constantly enter the baths, and also that a corresponding proportion of the exhausted acid liquor should be removed from the baths during the entire period when the electrolytic reduction of the zinc is going on. To accomplish this, a system of circulation must be adopted, which may be effected by any well-known method applied in similar processes. The exhausted liquor from the electrolytic tanks is conveyed into a suitable vessel or tank, and is there re-saturated with zinc from the ore, in the manner before described. In treating blende, or "black jack" (native sulphide of zinc), by this process, the ore is first roasted in the usual way, to expel the sulphur, and the roasted ore is afterwards pulverised and sifted. The finely powdered ore is then digested in a solution of a vegetable acid (acetic acid by preference) as before. When the solutions of zinc are found to contain any considerable proportion of lead, iron, &c., these may be precipitated as sulphides, by passing a stream of sulphuretted hydrogen through the liquors while in an acid condition.

Electro-deposition of Cobalt.—In the autumn of 1887 the author, believing that cobalt, as an attractive and serviceable coating for other metals—but more especially for articles of brass, copper and steel—deserved more attention than had hitherto been accorded to it by electro-depositors, pursued a long series of experiments with a view to ascertain the behaviour of certain salts of cobalt under the action of the electric current, hoping that the results obtained* would not only be instructive to the student of electro-chemistry, but also in some degree useful to those who pursue the art of electro-deposition as a business. It had often struck the writer as being somewhat remarkable that cobalt should have received so little attention from

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* *Vide Electrical Review,* Nov. 18th and 25th, and Dec. 2nd, 1887.

those who are engaged in depositing metals upon each other for the various purposes of art, since it is not only whiter than nickel, when deposited under favourable conditions, but it also requires but a very feeble current for its deposition as compared with that required by the former metal. It is true that cobalt is a dearer metal than nickel, but since a cobalt bath requires only about one-third of the quantity of "salts" required to make up a nickel bath, the actual cost of the electrolyte in each case would be about the same. The price of cobalt anodes is also higher than the corresponding plates of nickel, but when we consider the small quantity of metal that is usually required to be deposited upon ordinary work, the relative cost of the respective metals need scarcely be seriously considered. In the series of papers referred to the author endeavoured to show that the adoption of cobalt-plating, or cobalting, would probably be accepted by the public as a novelty, and thus give a fillip to the electro-plating industry, but more especially to that branch of it which is devoted to coating metal work with nickel. On making inquiries as to the probable reason why cobalt-plating had been so little adopted, it soon became apparent that the subject had hitherto been treated chiefly in an experimental way, and that the information furnished by writers on the subject was scarcely sufficient to guide those who were willing to turn their attention to the deposition of this metal as a new industry. Moreover the difficulty of obtaining anodes of cobalt, and reliable cobalt salts, also militated against the adoption of cobalt-plating for practical purposes. Since both these necessaries can readily be obtained from Messrs. Henry Wiggin and Co., of Birmingham, at the present time, there is no practical obstacle in the way of those who may feel disposed to try their hands at cobalting as an addition to their present routine of operations.

Of the many cobalt solutions which the writer tried, the following were found to be the most effective and reliable, namely, the sulphate of cobalt, the double sulphate of cobalt and ammonia, the chloride, the double chlorides of cobalt and ammonium, and the chlorides of cobalt and sodium. These salts were employed in the proportions, and with the results, given below.

Sulphate of Cobalt.—In each gallon of water required to make up a bath, 5 ounces of crystals of sulphate of cobalt are to be dissolved, which is most conveniently done by dissolving the crystals in sufficient hot water, and finally adding cold water to make up the necessary quantity of solution. The bath should be allowed to rest until cold, and be worked with rolled or cast cobalt anodes, either of which may be obtained from the firm above named. The current density should not exceed 2 to 4 ampères per square foot of cathode surface, and the articles to be coated (if required to be bright) should be previously well polished, potashed, and scoured, as for nickel-plating, before being put into the bath. As in the case of nickeling, it is also absolutely necessary that the most scrupulous cleanliness be observed, since carelessness in this respect might cause the work to strip at such parts as may have been badly prepared. Brass, copper, and steel are readily cobalted in this bath.

Double Sulphate of Cobalt and Ammonium.—To prepare a bath from this salt, 5 ounces of the crystals are dissolved in each gallon of water, and the current should be of about the same density as before; it may, however, be somewhat diminished when coating steel articles. After a time, articles coated in this bath assume a rather dull appearance, but since electrolytic cobalt is somewhat softer than nickel, the dull burr may readily be rendered bright by scratch-brushing, an operation which would have but little effect on a corresponding surface of nickel. If carefully worked, this solution should yield very good results, and may be considered a good practical bath. It must, however, be used with a feeble current, otherwise the metal will deposit too rapidly and consequently be liable to strip off before a sufficiently stout film is obtained. In cobalting with this solution, and indeed with most of them, it is absolutely necessary that the deposit should progress slowly at first; if the film has "struck" a few seconds after immersion, that is all that is needed to ensure adhesion, and the current may be gradually, but moderately, increased after a few minutes. In other words, if the deposit be allowed to *jump on*, it will most assuredly jump off when the film thickens.

Chloride of Cobalt.—A bath may be prepared from this salt by dissolving about 5 ounces, or even less, of the crystals in each gallon of water. With a very feeble current brass and copper readily receive a fine white and bright film of cobalt, which, however, becomes dull after a time. If worked with care, keeping the current low, very good deposits may be obtained from this solution.

Chlorides of Cobalt and Ammonium.—In making up a bath from this double salt, from 4 to 5 ounces of chloride of cobalt crystals are dissolved in each gallon of water, and to the solution is added about 3 ounces of sal-ammoniac, the whole being stirred until the latter is dissolved. This bath must be worked with a still more feeble current than the last, otherwise the deposited metal will be liable to strip from the articles coated. The deposit from this solution is very bright, and of a fine white colour.

Chlorides of Cobalt and Sodium.—To a solution of chloride of cobalt, containing 5 ounces of the salt per gallon of water, 3 ounces of common salt are added and dissolved. With a weak current, articles of brass or copper promptly become coated in this bath, the deposit generally remaining bright for a longer period than in either of the previous solutions. The anodes keep very bright and clean in working this bath.

Double Sulphates of Cobalt and Ammonium, with Chloride of Sodium added.—Well knowing, from his own experience, and that of others, the great advantages which are derived from the addition of common salt to nickel baths prepared from the double sulphates of nickel and ammonium, by which not only is the conductivity of the solution greatly increased, but the character of the deposited metal materially improved, the author determined to ascertain whether similar advantages could be obtained by adding common salt to a bath prepared from the double sulphates of cobalt and ammonium. For this purpose a solution was formed by dissolving crystals of the double salts, in the proportion of about 5 ounces to the gallon of water. About 5 per cent. of common salt was then added and dissolved in the liquor, and a clean brass cathode immersed and allowed to remain until fairly coated. The addition of the salt, however, did not present any apparent advantage; an additional 5 per cent. was therefore given, after which the deposit—a feeble current being used—became more prompt, and a satisfactory film of cobalt was obtained in about half an hour. A third portion of salt—making 15 per cent. in all—was next added, and a fresh plate immersed, which received a white but somewhat dull film of cobalt, but, however, very uniform in character. Although the deposits obtained in the *salted* solution were much less bright than those from the plain solution of the double sulphates, it may be mentioned that the dull bloom, which had a pearly hue, was readily brightened by the scratch-brush or by scouring with moist silver sand. It would therefore be easily rendered bright by the ordinary process of polishing. When comparing the results obtained from nickel solutions to which common salt has been added, with those in which the saline material has been added to cobalt solutions, it became evident that the advantages derived from the addition of salt were more marked in the case of nickel baths.

In depositing cobalt from its solutions, although it is necessary, in order to obtain a firmly adherent film, to employ weak currents of electricity, the colour of the deposit is never so good—that is, the film never acquires its full degree of whiteness—when the current is below a density that will yield a prompt deposit; that is to say, the article to be coated should become covered with metal *almost* immediately after immersion.

Professor Silvanus Thompson's Cobalt Process.—This process, for which Professor Thompson obtained a patent in 1887, has for its object "the deposition of cobalt in films of greater tenacity, density, and brilliance of tint, than have heretofore been obtainable with certainty. The solution for depositing cobalt may consist of sulphate or chloride of cobalt, or of the double sulphate or chloride of magnesium, or other suitable soluble salt of magnesium, or a mixed soluble salt of magnesium and ammonium may be added to the solution of cobalt salts. The citrate of magnesium is a useful salt, and it may be formed in the solution by adding citric acid and magnesia, or carbonate of magnesium, to the solution, citrate of ammonium, or simply citric acid may be added to the solution." As an example of one way of carrying out the invention, a bath may be prepared by adding to 10 pounds of pure water* 1 pound of the double sulphate of cobalt and ammonium, ½ pound of sulphate of magnesium, ½ pound sulphate of ammonium, 1 ounce of citric acid, and 2 ounces of carbonate of ammonium. The solution may be used warm or cold, but if heated to at least 35° C. (95° Fahr.) gives a brilliant deposit with greater readiness than when used cold. Another method of carrying out the invention is as follows:—Half-a-pound of sulphate of cobalt is dissolved in 4 pounds of pure water; ¼ pound of sulphate of magnesium is dissolved in 4 pounds of water; these solutions are mixed, and water added to make up 1 gallon. A quantity of sulphate of ammonium, not exceeding ½ pound, may with advantage be added. In carrying out this process, the author states that good deposits of cobalt are obtained, when either of the above solutions is diluted with an equal bulk of water, but in that case a stronger current in proportion to the surface of deposition must be employed. "The best current density," says the inventor, "I find to be not less than 1 ampère, nor more than 4 ampères per square foot of depositing surface, but a somewhat stronger current may be advantageously employed during the first few minutes of deposition, so as to secure a rapid striking film on the surface, the current density being diminished so soon as the surface is once covered with a film." The work to be coated by this process must be scrupulously clean, and otherwise prepared in the same manner as for nickel-plating.

Removing Tin from Tinned Iron.—The recovery of the tin from tin scrap, preserved fruit and meat tins and other waste of a similar character, has long occupied the attention of experimentalists, both at home and abroad, and several ingenious processes have been devised and patented, and, we believe, carried out with some success. When experimenting upon this subject a few years since, the author tried, amongst other solvents, perchloride of iron—a material which, for another purpose, he had prepared in very large quantities, and was therefore well acquainted with the most economical method of prepar-

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* By pure water, the inventor explains, is meant simply newly-boiled and filtered water, or preferably distilled water.

ing it. In stripping tin from tinned iron scrap with the perchloride of iron, the solution of the salt was employed hot, and the scrap then introduced and kept constantly in motion until the whole of the tin was dissolved from the surface of the fragments, which was generally effected in a few minutes. After a time the characteristic orange-yellow colour of the perchloride disappeared, leaving a green solution of protochloride of iron, in combination with the corresponding salt of tin. It was now found necessary to again peroxidise the iron solution, which was effected by trying various ordinary agents in succession, nitric acid being found to answer the purpose readily. Since the perchloride of iron as a de-tinning agent has somewhat recently formed, in part, the subject of a patent, it will be well to give the inventor's description of his method of applying it. The process referred to, which is given below, does not, however, depend exclusively upon the employment of perchloride of iron, as will be seen from the abridged details given.

Garcia's Process.—This process, for which a patent was granted in 1886, consists more especially of "an improved method of treating cuttings, or waste, of tin plate in order to remove the metallic tin, but is also applicable to the separation of tin combined with metals, such as copper, zinc, or lead, or in combination with oxygen. The process consists first in making solutions of tin, preferably protochloride of tin, slightly acid, and afterwards extracting the tin in a metallic state by means of the simple apparatus used in the ordinary process of electrotyping." This consists in applying the "single cell" arrangement, as it is called, in which a plate of zinc is immersed in a porous cell filled with a saline solution, or acidulated water, and which is placed in a larger vessel containing a solution of tin in lieu of the sulphate of copper, as in electrotyping. The zinc plate is connected by a suitable conducting wire to sheets of tin plate, placed round the porous cell, upon which plates the tin becomes deposited. "Supposing," says the inventor, "cuttings of fresh tin plate are to be used, as often happens, I place them in vessels of material unaffected by the chemical agents employed, and keep them in movement by any convenient mechanical means, so as to prevent them from adhering together, since if left at rest they would remain adherent, and to a great extent escape the action of the acid liquids. These acid liquids may vary according to the character of the tin cuttings, or fragments, but I prefer to use a mixture of hydrochloric and nitric acids, in about the following proportions, namely, 250 to 300 kilogrammes of hydrochloric acid, and 8 to 12 kilos, or even less, nitric acid." The vessels employed for this purpose may be constructed of stoneware, glass, slate, &c., and the mixed acids diluted with about 1,000 litres of water, the acid liquor being heated by steam passing through coils, or otherwise, to the temperature of about 80 to 100 degrees. [Centigrade ?] "While the process of solution is going on a certain proportion of iron is also dissolved in removing the last particles of tin, the fragments being removed when the further solution would cease to be economical." It is stated that the foregoing proportions of acids and water are sufficient to effect the separation of the tin from one ton of tin scrap, as, for example, preserved food cans. "Instead of nitric acid," says the patentee, "perchloride of iron may be used, by which the tin is effectually separated. The perchloride is preferably produced by dissolving 80 to 90 kilogrammes of peroxide of iron in 300 to 350 kilos of hydrochloric acid, this quantity being sufficient to separate the tin from a ton of tin plate, the quantity of water being the same as before, so as to completely cover the metal from which the tin is to be removed." The patentee next states that "the use of perchloride is new for the purpose and in the manner described, and forms an important part of the invention." As to the *novelty* of perchloride of iron being applied as a "stripping" solution for tin, we can scarcely agree to this, since this salt has long been used for the purpose by jewellers and others in common practice, and indeed has been recommended by various writers as a useful solvent not only of tin, but also of lead and copper.

Montagne's Processes.—The first of these two processes—both of which are protected by patent—consists of a method and apparatus for separating tin from tinned sheet metal, such as empty tin boxes, tin scrap, &c. "Broadly speaking," says the inventor, "the method consists in conveying hydrochloric acid gas into a closed vessel containing the material the separation of the tin from which it is desired to obtain. After the closed vessel containing the tinned sheet metal has become completely saturated [charged ?] with hydrochloric acid gas, whereby the latter combines with the tin, a shower of water is allowed to fall over the sheet metal, and instantaneously the said gas is converted into liquid protochloride of tin; the tin, entirely removed from the sheet metal, is dissolved in the protochloride of tin." The solution of tin is afterwards drawn off from the closed vessel and the metal precipitated either by means of zinc, "lime wash," or otherwise. It is obvious, however, that the metal would be more economically recovered by electrolysis. In the accompanying drawing, A is a retort into which is placed a charge of sulphuric acid and chloride of sodium for producing, with the application of heat, hydrochloric acid gas in the usual manner. The gas is conveyed by a pipe, B′, into a closed vessel, B, containing a charge of tinned sheet metal scrap or cuttings, the latter material being heated to a temperature of 150° to 160° Fahr. by a jet of steam supplied by a generator, D′, and pipe, D. After the tinned sheet metal cuttings, or scrap, have become saturated with hydrochloric acid gas, a shower of water, supplied by a pump, F, and a pipe, C, is conveyed into the closed vessel, B, by a perforated pipe, E, so as to completely wash over the tinned metal scrap. The solution thus produced is protochloride of tin, which is drawn off into a pan, H, by a tap, G. The tin, precipitated by zinc or otherwise, is placed under a press, M, to remove the liquid attached to it, and is afterwards melted in a crucible, P, and cast into ingots.

By a second patent, dated May 2nd, 1887, M. Montagne introduces an improvement on the foregoing process, which may be thus briefly described :—The tinned scrap is placed in a series of brickwork chambers lined with any suitable material capable of resisting the action of acids, and sufficiently thick to retain heat for a long time. These chambers are put into communication by a system of piping, provided with suitable valves capable of allowing the acid gas to pass successively into several chambers before passing to the exit or chimney, completely exhausted by its passage through material less and less attacked by acid. "Let it be supposed for the sake of clearness," says the inventor, "that three chambers are employed, and that the gas passes successively through chambers 1, 2, and 3. The gas first

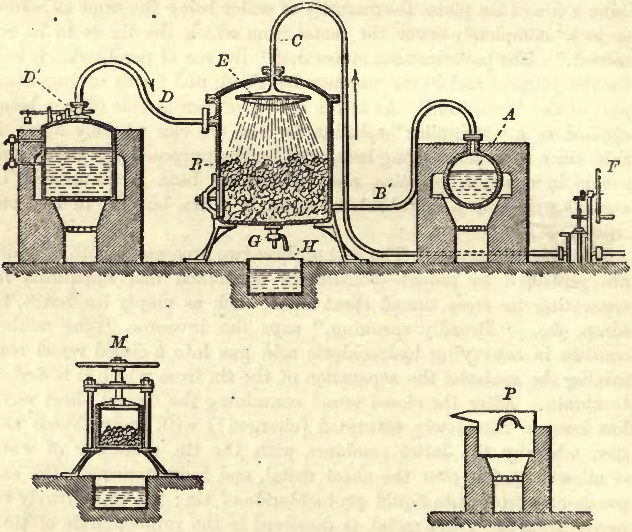

Fig. 145.

reaches chamber 1 (through a pipe and valve), in which the extraction [dissolving of the tin] will be soonest completed. When the extraction has been effected, chamber 1 is completely shut off by closing the valve of the gas supply pipe, and the valve which puts chamber 1 in communication with chamber 2 is opened. The acid gas will then first enter chamber 2 by its valve and be led into chamber 3, and thence to the chimney. While chamber 1 is shut off a spray of water is allowed to fall into the same from a perforated coil or otherwise. At the same time, in order to reach the parts which are least accessible, a jet of steam is supplied from a generator by pipes, the same being cooled by the spray of water, and forming vapour which settles on all the surfaces covered with protochloride of tin, and carries it off in solution. The condensation of all the hydrochloric acid gas is thus certain to be effected, and chamber 1 can be opened for removing the metal deprived of its tin, and recharging the same with a fresh batch of tinned scrap without being inconvenienced by the acid vapours. When this is done the chamber is closed, and placed again in circuit by opening the valve, and thus making this chamber the last in the series; that is to say the gas entering through chamber 2 passes into chamber 3, and then into chamber 1, whence it escapes through the chimney. The order of circulation thus becomes reversed, as will be readily seen, and it is obvious that the number of chambers may be varied at will. To recover the tin from the solutions thus obtained, the inventor employs zinc or iron, or otherwise lime; but the electrolytic method would doubtless be more economical.

Electrolysis of Lead Salts.—Having made a long series of experiments in the deposition of lead from the solutions of its various salts,* the author is enabled to give the details of a few results which may possibly be useful to the practical operator. Of the numerous lead salts from which solutions were prepared for the purposes of his experiments, the following were found to yield the most satisfactory results: the tartrate of lead; the same prepared by electrolysis, and phosphate of lead dissolved in caustic potassa. The tartrate of lead bath was prepared by digesting recently-precipitated, and moist, hydrated protoxide of lead in a strong and hot solution of tartaric acid, in which the oxide dissolved very freely. The solution was then allowed to cool and the clear liquor afterwards poured off and moderately diluted with water. With the current from two small Daniell cells, in series, and a sheet lead anode, a brass plate received a prompt and bright deposit of lead, of good colour, and it was noticed that no hydrogen was given off at the cathode. The film of deposited metal continued bright for a considerable time, and maintained a

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* *Vide Electrical Review*, April 6th, 13th, and 27th, 1888.

perfectly uniform and reguline character, while being also firmly adherent. It was also observed that the lead anode, which kept clean and bright, had been freely acted upon during the electrolytic action. In this solution, brass, copper, and steel were rapidly coated with lead, which firmly adhered to the respective metals. In order to determine whether the solvent action of tartaric acid, under the influence of the current, was sufficient to maintain the tartrate bath in an uniform condition, the following method was tried. A strong solution of tartaric acid was first prepared, in which was placed a sheet lead anode and a brass cathode, the current from two Daniells, as before, being used. Shortly after the respective electrodes had been immersed, hydrogen bubbles appeared all over the surface of the negative plate, from which they had little disposition to remove until the plate was briskly shaken in the bath. In about half an hour a bright film of lead formed upon the negative plate, at which period it was observed that the hydrogen bubbles ceased to be evolved at its surface. Since only one-half of the brass plate had been immersed in the acid liquor up to this period, the remaining portion of the plate was now lowered into the bath to ascertain whether the hydrogen would again show upon the brass surface only, and not upon the lead-coated half of the plate, and such actually proved to be the case, for while the brass surface instantly became covered with gas bubbles, the lead coating was entirely free from them. It thus became evident that when forming a lead bath by electrolysis, from a solution of tartaric acid, that both electrodes should be of lead, or that the negative plate should first be coated with a film of that metal. Having thus determined the solubility of lead in the tartaric acid, under the influence of the current, it became still more apparent that the tartrate of lead could be employed with advantage in the preparation of a lead-depositing bath, and there is little doubt that a solution of this salt, of moderate strength, if worked with a feeble current, is very suitable for the electro-deposition of this metal. It was noticed, however, that the deposited metal had no disposition to assume the crystalline or spongy form in the foregoing solutions, which is too commonly the case with most solutions of lead salts.

Phosphate of Lead in Caustic Potassa.—A bath was prepared from this combination as follows:—A quantity of chloride of lead was first obtained by adding a strong solution of common salt to one of nitrate of lead, the resulting precipitate being afterwards well washed with cold water. The precipitate was next dissolved in boiling water, and to this solution was added cautiously, so as to avoid excess—as recommended by Mitscherlich, to prevent the formation of a subphosphate—a hot solution of phosphate of soda. The white precipitate of phosphate of lead thus formed was next washed repeatedly with cold water, and a strong solution of caustic potash then gradually introduced until the phosphate was entirely dissolved. The concentrated solution was next diluted with about eight volumes of water, and electrolysed with the current from a single small Daniell cell, when on immersing a clean brass plate as a cathode, this at once became coated with a bright film of lead, but after a few seconds' immersion the deposit assumed a dull appearance, while there was a copious evolution of hydrogen at the negative plate. To check this, the liquid was still further diluted by the addition of nearly an equal bulk of water, after which the subsequent deposits retained their brightness for a long period, while the anode exhibited a perfectly clean surface. The metal deposited from this bath adhered very firmly to the cathode, and there was very little disposition to sponginess—a very common characteristic of electro-deposited lead.

Peroxide of Lead Colourations.—When electrolysing the various salts of lead, the writer frequently repeated experiments obtained with lead anodes by substituting platinum, steel, or a polished nickel-plated surface, with a view to observe the variations of colour which the peroxide of lead might assume when formed upon the positive electrode under certain conditions of the electrolyte. Since some of the results obtained were exceedingly beautiful, and might be susceptible of practical application for ornamental purposes, a few details obtained may probably prove interesting. In electrolysing a solution of the basic nitrite of lead with a platinum anode (3 Daniell cells in series being used), a yellow deposit of peroxide was first formed upon its surface, which was quickly followed by superb iridescence on both sides of the plate. After about a minute, two rainbow bands appeared on the upper part of the anode, the remaining surface assuming a deep crimson colour, changing to a purple. In a solution of sulphate of lead in caustic potash, platinum and steel anodes received a golden yellow film, which, even after a long immersion, did not undergo further change. In a solution of lactate of lead a platinum anode at first received a golden yellow film, succeeded by a steel grey at the lower part of the plate; in a few seconds a deep orange colour began to appear at the lower corners, followed by the primary colours in succession, which rapidly blended as in the prism, producing a remarkably fine effect, which could be modified at will by increasing or diminishing the cathode surface. In a solution of sulphocyanide of lead a platinum anode received a rich golden yellow film, which did not undergo further change of colour. Similar results were obtained from solutions of pyrophosphate of lead, and salicylate of lead. In a moderately strong solution of nitrate of lead a very brilliant iridescent film was obtained upon a platinum surface instantaneously; when this solution was considerably diluted with water, and a small cathode surface—say about three square inches—immersed, the effects were still more striking, though developing more gradually. In a solution of benzoate of lead, a pale yellow colour was first obtained, succeeded by orange, then deep orange, with a slight tendency to iridescence. When the film was rubbed with the finger, while still wet, the prismatic colours at once became visible.

Crystalline Deposits of Lead.—When electrolysing the various salts of lead, the author frequently met with crystalline deposits of the metal of remarkable beauty, which he was desirous of preserving if practicable. Having found that such metallic crystals could be most satisfactorily obtained for this purpose upon flat surfaces, and when formed upon a transparent material, as glass for example, that impressions of the crystals could be obtained by the ordinary process of photographic printing, he will now briefly explain the method adopted, which it is hoped may prove not only interesting but, possibly, useful. In producing crystals of lead upon plane surfaces, solutions of the acetate or nitrate of lead may be employed, and the crystalline forms may, to some extent, be varied by employing solutions of various strength, and also by increasing or diminishing (within certain limits) the density of the current. If we take a solution of the acetate of lead, for example, the bath may be a half-saturated solution of the salt, rendered slightly acid by the addition of a few drops of acetic acid. A plate of glass (say about 4½ × 6 inches) is then to be laid in a flat dish, and a lead anode—a strip of sheet lead about 2 × 3 inches—connected to the positive electrode of a 2-cell Daniell battery, is allowed to rest on one end of the plate, and a strip of sheet brass, attached to the negative pole, is to be placed on the glass at the opposite end. The solution of lead salt is next to be carefully poured into the dish until the glass plate is completely immersed. In a few moments crystals of lead will form upon the brass plate, and extend forward (and also backward to some extent) and gradually spread over the surface of the plate until the anode is nearly reached, when this latter electrode should be removed. The brass cathode must now be held firmly and steadily between the fingers, and the crystals attached to it gently removed with the blade of a penknife or thin strip of wood, but great care must be taken not to shift the position of the main group of crystals, which a little awkwardness would readily do. When the cathode is detached the glass plate should be gently raised at one end, which may be conveniently done with the forefinger and thumb of both hands, and the liquid allowed to flow from its surface *very* gradually, otherwise the crystalline film will slide off the plate; with ordinary care, however, this need never occur. The plate bearing the crystals may next be laid on a pad of blotting paper, supported at one end by a piece of wood, so as to allow the liquid to freely drain from the crystals. The fingers of the operator should be well rinsed after dipping in the lead solution. The solution is next to be poured out of the dish, and the vessel well rinsed, after which the glass plate is to be again laid in the dish, and water gradually and slowly poured in until the crystals are well covered, the object being to wash away all the lead solution that surrounds them. In doing this, however, much care is needed to avoid disturbing or shifting the crystals. It may here be remarked that since water produces a white precipitate in solutions of acetate of lead (unless very acid), it is necessary to remove the plate of crystals before the white precipitate has time to settle. The glass plate therefore should be removed, as before, almost immediately after the water has covered the plate, the liquid then thrown away, and the washing operation resumed, the process being repeated several times to remove all traces of the lead salt, otherwise the salt will re-act upon the delicate crystal film during the subsequent drying, causing it to become dull and brittle. When well washed the crystals should be perfectly bright and metallic. After the final washing the plate should be well drained upon blotting paper, after which it may be held before a clear fire until the crystals are perfectly dry. When the plate has afterwards cooled, so as to feel merely warm when touched with the back of the hand, a thin chloroform varnish (such as is used by photographers) should be poured on the plate, and allowed to flow all over, the surplus being conducted to the varnish bottle by tilting the plate. The plate should then be again gently warmed to prevent the varnish from *chilling*.

A photographic print of the crystals is obtained by treating the plate of crystals precisely in the same way as a photographic *negative*. The plate being laid in a suitable printing frame, crystals upward, a piece of albumenised paper, sensitised in the usual way, is laid upon it, and above this several folds of blotting-paper. The jointed back of the printing frame is then laid over all, and the springs of the frame adjusted as usual. To obtain a perfect impression, or print, of the crystals, the glass of the frame must be exposed to strong sunlight for at least half an hour, and it is probable that even double that time may be necessary to secure all the finer details of some of the more fibrous crystals. When the printing is complete, the photographic print is removed, and fixed and toned in a solution of hyposulphite of soda, to which a small quantity of chloride of gold has been added in the usual way, and it is afterwards to be well washed and dried, when it may be trimmed and mounted on a suitable card. The accompanying engravings from the *Electrical Review* are reproductions of three photographs obtained in the manner described. Fig. 146 is from a photo of crystals produced with a solution of nitrate of lead, and Figs. 147 and 148 respectively represent those produced from a solution of the acetate of lead. It should be mentioned that in producing crystals of lead upon plates of glass to be printed from, from solutions of nitrate of lead, several precautions must be observed to insure success. The bath which yielded the best results was a rather weak solution of the nitrate, and the current employed was obtained from three small Daniells in series. As it was found that the crystalline deposits obtained with this salt had a constant tendency to grow *upward*, instead of lying flat on the glass, as is more generally the case with the acetate solution, an attempt was made to deposit the crystals between two plates of glass, for which purpose the electrodes were laid flat on the receiving plate, and a second glass then laid over all; but though a slight crystalline deposit occurred at the extreme edge of the cathode, the crystals positively refused to continue their growth beyond that point, from which it became evident that the thin stratum of liquid between the two

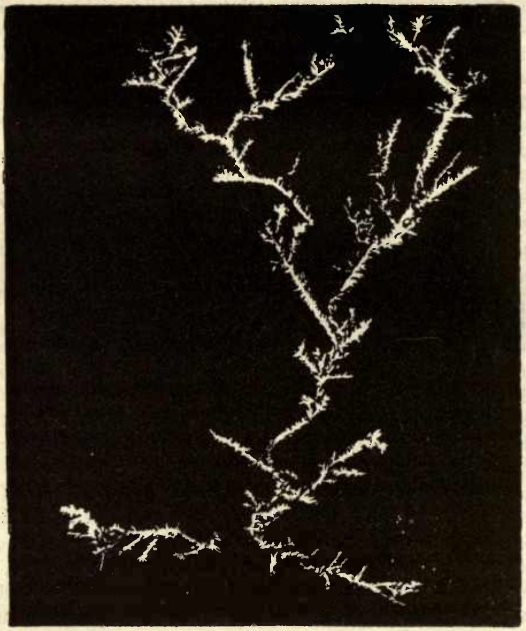

Fig. 146.

glasses offered great resistance to the passage of the current. This method was therefore abandoned, and in order to render the printing of crystals obtained from the nitrate of lead solution practicable, it was found necessary, after the crystals had been varnished, to gently bend the more upright crystals downward, by pressing them with the flat end of a lead pencil, by which means the group shown in Fig. 146 was placed fairly under control.

Electro-deposition of Iron.—Since the publication of the former editions of this work the author made a great number of experiments in the electrolysis of iron salts, the results of which were recorded in the *Electrician*.* The object of these experiments was to ascertain the behaviour of solutions of the various iron salts under electrolytic action, with a view to assist those who are engaged in depositing iron for practical purposes, and at the same time to furnish the student with information which might prove useful to him when studying this branch of electro-deposition. After having tried a considerable number of baths prepared from various salts of iron, and worked at different degrees of strength, it was found that weaker solutions almost invariably yielded more uniform results than stronger ones, and it also

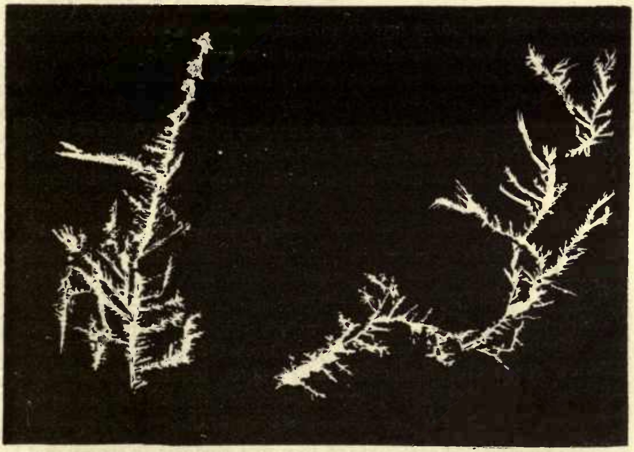

Fig. 147. Fig. 148.

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* *Electrician,* Nov. 11th and 25th, Dec. 16th and 30th, 1887, and Jan. 13th, 1888.

appeared that when the iron baths were so adjusted as to the proportion of metal per gallon of solution that the anode and cathode surfaces required to be about equal, that under such conditions the most favourable results were obtained. Of the many solutions tried, those given below were found to yield the most uniform and satisfactory results.

Protosulphate of Iron Bath.—The solution was prepared from recrystallised sulphate of iron, in the proportion of 4 ounces of the salt per gallon of water. The bath was first tried in its neutral condition, with electrodes of about equal surface, and the current from a single small Daniell cell, but as the deposit upon the copper receiving plate was of a rather dark colour, a few drops of sulphuric acid were added, and an extra cell connected, when the character of the deposit was greatly improved. A third cell was now added—the whole being connected in series—when the subsequent deposit became exceedingly white and bright, which character was maintained. At the end of about a couple of hours the copper plate was withdrawn from the bath, when its brilliant appearance resembled that of copper which had been dipped into mercury. The iron anode, which had been freely dissolved, presented a perfectly clean surface.

Ammonio-Sulphate of Iron.—For an iron-plating bath, the following proportions were found to give favourable results: ammonio-sulphate of iron, 10 ounces; water, 1 gallon. To this solution was gradually added a small quantity of acetic acid, which greatly improved the character of the deposit. It was found that with the current from 2 small Daniell cells in series a solution prepared as above gave very uniform deposits of good white colour, though not quite so bright as those obtained from the simple protosalt.

Citrate of Iron.—A solution of this salt was prepared by digesting recently precipitated carbonate of iron in a moderately strong and hot solution of citric acid, the carbonate being added a little at a time when the neutral point was nearly reached, which became known by the liquid remaining turbid after the last addition of the carbonate had been given. A moderate excess of citric acid solution was then added, when the liquid at once became clear. The solution was then set aside to cool. With the current from 3 small Daniells in series, a very white and perfectly bright film was instantly obtained upon a copper plate, the deposit retaining this character during a prolonged immersion. The anode was found to have been freely and uniformly dissolved. The iron deposited from this bath was exceedingly white and brilliant.

Double Sulphate of Iron and Potassa.—A bath was prepared from a mixed solution of the respective salts, the iron salt being somewhat in excess, say about 4 ounces of sulphate of iron and 3 ounces of sulphate of potash to the gallon of water. With the current from 3 Daniells, a fine white and very bright deposit of iron was obtained upon a copper plate immediately after immersion, and the deposition proceeded very uniformly for about half an hour, when the film became somewhat streaky; this was remedied, however, by adding more sulphate of potash. After this latter addition, deposition took place very freely, and the anode was considerably dissolved in the course of an hour. There is no doubt that this would be a very good working bath for the deposition of iron, and if rendered faintly acid, it appears to be less susceptible of oxidation in the atmosphere than the ammonio-sulphate of iron solution.

Persalts of Iron.—It had always been held by experimentalists that metallic deposits could not be obtained from solutions of the persalts of iron; for instance, Gore states on page 245 of his book that "solutions of persalts of iron yield no metallic deposit, but are reduced to protosalts by the passage of an electric current." The incorrectness of this statement the author fully established by a series of experiments with the persalts of iron, from each of which he succeeded in obtaining deposits of metallic iron—in some cases in a perfectly reguline condition. Thus, from a weak solution of pernitrate of iron, the metal deposited in a highly comminuted condition upon the cathode, being in the form of a black gelatinous mass, which, when washed and rapidly dried, was found to be highly magnetic—iron in a state of very fine division in fact. From a solution of peroxalate of iron a reguline deposit of iron of tolerably good colour was obtained. From a weak solution of perchloride of iron (1 drachm of concentrated solution of the perchloride to 3 ounces of water) a fairly bright deposit of metallic iron was obtained, upon a copper plate, with the current from 5 small Daniells in series. A solution of persulphate of iron in about the same proportions was next tried, when a bright deposit of iron at once took place at the corners and lower edges of the cathode, which gradually extended upward in the form of a horseshoe, which character it maintained until the plate was withdrawn. Deposits of iron were also obtained from solutions of the following persalts of iron, with and without the addition of other substances: sesquicitrate of iron; sesquicitrate of iron and acetate of soda; persulphate of iron and sulphate of potassa; pertartrate of iron; persulphate of iron and sulphate of ammonium; persulphate of iron and sulphate of soda; perphosphate of iron; perlactate of iron, &c. All these solutions were used in an extremely dilute state, and it was not until this condition of the electrolyte was reached that the metal would deposit in a reguline form—if at all. It thus became evident, from the results referred to, that under suitable conditions of the electrolyte persalts of iron will yield up their metal, and that if such results had hitherto been unattainable, it is clear that such necessary conditions had not been fulfilled by those who had previously experimented with these salts.

Electro-deposition of Alloys.—In the summer of 1887 the author tried a great number of experiments in the electrolysis of mixed solutions of neutral, or faintly acid, salts of various metals, with a view—*first*, to determine whether alloys could be deposited from such solutions at all as a matter of fact; and *second*, whether, if alloys could be deposited from such solutions, baths could be prepared from neutral or slightly acid solutions which might be employed, as a substitute for cyanide solutions, for the practical purpose of coating metals with alloys. The results of these experiments were published from time to time in the *Electrical Review*,* and since several of the compound solutions which were tried yielded results of a somewhat promising character, so far as relates to their application for practical purposes, it may be well to direct attention to them in the present work. It was generally understood, prior to the publication of the results of the experiments referred to, that the deposition of alloys from acid solutions was not only practically impossible but contrary to the generally accepted theory, which holds that from a solution of mixed metals the least electro-positive metal is deposited first; that is to say, the simultaneous deposition of electro-negative and electro-positive metals had always, up to the time referred to, been considered theoretically impossible, although in the case of cyanide solutions (as those of brass and German silver) the accepted law of electrolysis, propounded by Berzelius, had in the case of these *alkaline* solutions been actually upset in practice. When experimenting with mixed solutions of neutral or acid metallic salts, the first aim of the writer was to determine whether a film of brass—an alloy of zinc and copper—could be deposited from a solution of the mixed metals under any, and if so under what, conditions. For this purpose a mixed solution of the acetates of copper and zinc was first prepared, the latter salt being in excess. The bath was tried at various degrees of strength, with the current from five small Daniell cells in series, until the desired object was obtained, the deposit of a film of unmistakable alloy in the form of brass of very good colour. In the course of this first experiment it was found that when the solution was too strong a powdery deposit of copper alone appeared upon the cathode; the solution was then weakened by gradual additions of water, and it was noticed that a marked improvement in the character and colour of the film occurred after each successive addition of that fluid, until finally the characteristic yellow deposit of brass was obtained

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* *Electrical Review*, Aug. 26th, Sept. 2nd and 9th, 1887.

upon a steel surface. It was found necessary, however, in order to obtain a film of brass of good colour with the solution thus prepared to immerse an exceedingly small surface of anode, that is to say, less than one-fourth of an inch of anode surface only was required to secure a coating of the alloy upon a cathode surface (a steel plate) of at least five square inches. Indeed, when the anode was allowed to merely touch the surface of the solution a steel plate of five square inches of surface instantly became coated on both sides with brass of a good yellow colour, except at the extreme end farthest from the anode, which was tipped with zinc only. In order to modify this, and place an anode of small surface opposite the entire length of the steel plate, a piece of thin brass wire was next employed as an anode, and answered the purpose admirably, for a fresh steel plate became uniformly coated with brass of very good colour, on both sides, almost immediately after immersion in the bath. Under these conditions the deposition of a true alloy was far more prompt than with any ordinary cyanide solution. A steel plate in contact with a strip of zinc immediately became coated with brass in this bath on the contact side, but copper alone was deposited on the opposite side. By simple immersion, a clean strip of zinc became immediately coated with a film of brass in the same solution. It thus became apparent that when once the proper condition of the electrolyte was reached, the deposition of an alloy from an acid solution was an exceedingly simple operation, and that an electro-negative and an electro-positive metal could be deposited conjointly from an acid bath as a veritable alloy.

If the above results had been obtainable only with mixed solutions of zinc and copper salts, while solutions of other mixed metals failed to yield similar results, an inexplicable problem would have presented itself. But that this was not the case was amply established by further experiments, in which, amongst other alloys, the following were deposited, in some cases with remarkable facility: copper and tin, copper and lead, copper and antimony, copper and silver, copper and nickel, and even copper and platinum. In preparing a series of solutions for depositing brass, the author tried the following with success amongst others which were less successful: the sulphates of zinc and copper, citrates of zinc and copper, chlorides of zinc and copper, tartrates of zinc and copper, from each of which combinations he obtained satisfactory films of brass of a good yellow colour, but for all practical purposes he would give the preference to a solution composed of the acetates of copper and zinc. An endeavour was also made to produce a working bath from the double acetates of copper and zinc by the battery process, as it is termed, as follows:—A mixture of about equal parts of commercial acetic acid and water was first prepared, and in this was immersed a clean plate of good sheet brass, connected to the positive pole of a 5-cell Daniell battery; a rod of carbon, connected to the negative pole of the battery, was then immersed in the liquid, which soon assumed a greenish tint near the anode, which electrode kept very bright and clean, indicating that it was being freely dissolved into the solution. The liquid was kept frequently stirred while the electrolysis was proceeding, and at the end of about twenty minutes the carbon, which exhibited traces of deposited metal upon its surface, was withdrawn, and a steel plate substituted, which became partially coated with a yellow film of brass in less than half a minute. The steel plate was then withdrawn, and the carbon again immersed, in order to allow the solution to acquire sufficient metal to form a practical working bath. In about three-quarters of an hour from the commencement of the operation the bath was found to have become sufficiently charged with the respective metals—zinc and copper—to yield a ready deposit of brass of very good colour. The plate was allowed to remain in solution for a few minutes, when it was taken out and well scoured with silver sand, moistened with soap and water, which operation it withstood without stripping in the least degree, showing that the deposited alloy was thoroughly adherent. The film was next scoured with sand and water only, with as much force as possible, to test the tenacity of the film in the severest manner, and it was found that even this severe treatment failed to remove the film, except by wearing it away by long-continued friction. The plate was next replaced in the bath and allowed to receive a fairly good coating; it was then well scoured with sand, soap and water, and after being well rinsed was burnished with a steel burnisher, but without blistering or stripping in the least degree. It was noticed, when applying the burnishing tool, that the deposited metal felt exceedingly soft under the pressure of the tool; the deposit was therefore reguline in the highest degree, while its colour was equal to that of the finest quality of brass. Since the foregoing results were published in the *Electrical Review* the author was shown by a correspondent some specimens of steel coated with brass, in a solution of the acetates of copper and zinc, as recommended by him, and these certainly gave promise that, with a little further development, the electro-deposition of brass from acid solutions would eventually become practical, in the hands of skilful manipulators, for the purposes of art. Although the author's present engagements deter him from pursuing the subject of alloy deposition for awhile, he hopes to resume his experiments at an early date, and to make known some further results which may prove interesting, if not indeed practically useful, to the electro-metallurgist.

Coloration and Staining of Metals.—In the finishing of ornamental brass work, metal buttons, and various kinds of fancy metal goods, it is often necessary to produce certain artificial effects of colour or tone, to render the work attractive to the public eye. These effects are produced by several well-known means, but modifications are constantly sought for, with a view to giving variety to manufactured articles. From some experiments which the author tried in this direction some time ago he is now enabled to suggest one or two processes which may be found useful to persons engaged in the various branches of trade in which metal-colouring and staining are necessary operations in the workshop. The processes to which attention is now called may be best treated under separate headings, since they are each applicable to different branches of trade.

Colouring Nickel-plated Work.—The production of prismatic colours, called *metallo-chromes*, upon steel and platinum surfaces, by depositing films of peroxide of lead thereon, is described at page 358. In the experiments referred to it was the writer's desire to obtain similar effects upon polished nickel-plated surfaces, believing that the colorations would show more effectively upon the white surface of nickel-plated brass than upon steel, while at the same time the process could be applied to fancy articles which could not be conveniently made from the latter metal. In carrying out the experiments a series of polished brass plates, well nickel-plated, were employed. A nearly saturated solution of acetate of lead was next made and carefully filtered. Three small Daniell cells, in series, were used for the current, to the positive pole of which one of the nickel plates was attached, and then laid upon the bottom of a flat dish. The filtered acetate solution was next poured into the dish until the plate became immersed to the depth of about half an inch. The end of the negative wire of the battery was now brought as close to the plate as possible without touching, and there held steadily, when in a few seconds the coloration commenced, in form of the familiar ring, and quickly extended in a series of brilliant iridescent circles. Pieces of thin copper wire, formed into various designs, as a cross, an anchor, a star, &c., were subsequently used, by which very varied and pleasing effects were obtained, which looked exceedingly effective in the nickel-plated surface, more especially when a sheet of white paper was reflected upon it. To render metallo-chromy practically applicable to nickel-plated articles of ornament, there are several points that must be considered: the coating of nickel must be something more than a mere film, otherwise, when placed in the acetate of lead bath voltaic action will set up between the nickel film and the underlying brass surface, and the nickel will peel off; a fair coating of nickel therefore is absolutely essential. The process, moreover, is only effectual on plane surfaces. In producing the colorations care must be taken not to suffer the particles of spongy lead, which deposit upon the end of the negative wire, to fall upon the plate, otherwise they will cause a series of white spots, by preventing the formation of peroxide upon the surface beneath them. It is also important to prevent dust or particles of any kind from depositing upon the plate during the operation. After the bath has been worked for some time it naturally becomes acid, therefore when in this condition the articles should be quickly removed when the desired effect is obtained, and at once plunged into clean water, for if allowed to remain in the acid bath the peroxide film will rapidly dissolve. When the bath has become slightly acid it is better to pour it into a bottle containing a little carbonate or oxide of lead, and shake it frequently, when, after an hour or so, it may be filtered and again used. The end of the negative wire should be dipped into water and the deposit of lead which attaches brushed off, after each design has been produced, by doing which the chances of particles falling upon the plate are greatly diminished.

When electrolysing a series of solutions of lead salts recently, the author noticed some very interesting varieties of peroxide of lead, which formed upon the various anodes employed, and which it will not be out of place to mention here. When electrolysing a solution of the basic nitrate of lead with a platinum anode, the current from three small Daniells, in series, being used, a yellow deposit of peroxide of lead was at first formed upon its suface, which was quickly followed by a superb iridescent film on each side of the plate. After about a minute, two rainbow bands appeared upon the upper part of the anode, while the remaining immersed surface assumed, first, a deep crimson colour, which gradually changed to purple. The film was found to be very adherent. In a solution of sulphate of lead in caustic potash, platinum and steel anodes received a golden yellow film, which, even after a prolonged immersion, did not undergo any change of colour. In a solution of lactate of lead, a platinum anode at first became coated with a golden yellow film, which was succeeded by a steel grey at the lower part of the plate; in a few seconds a deep orange colour began to appear at the lower corners, followed by the primary colours in succession, which rapidly blended as in a prism, producing a remarkably fine effect, which could be modified at will by increasing or diminishing the cathode surface. In a solution of sulphocyanide of lead a platinum anode received a rich golden yellow film, which was sustained without further modification in colour during a long immersion. In a moderately strong solution of nitrate of lead a very brilliant iridescent film was produced upon a platinum anode instantaneously; when the same solution was considerably diluted with water, and a small cathode surface only immersed, these effects were still more striking, though developing more gradually. In a solution of pyrophosphate of lead a golden yellow film only was obtained upon a platinum anode. A solution of salicylate of lead yielded a precisely similar result. In a solution of the benzoate of lead a pale yellow colour was first produced upon a platinum plate, but this was soon succeeded by orange, then deep orange, followed by a slight tendency to iridescence. When the plate, while still wet, was rubbed with the finger, the prismatic colours at once appeared.

Colouring or Staining of Brass Surfaces.—To give a black stain to brass, a solution of chloride of platinum is usually employed, but since the platinum salt is an expensive one, its employment would necessarily be restricted to work of a special character, or to articles of a superior quality. With a view to obtain a black colour, which would be applicable to large pieces of brass work, and at the same time be less costly than the platinum salt, the author made a series of experiments, the results of which may, it is hoped, be found useful in a practical sense. Being aware that brass was far more difficult to *stain*, as it is termed, than copper, the following method was adopted to give the effect of a black stain upon brass work, as also varying shades of brown, from a warm chocolate colour to a deep sepia tone. Having tried many different substances, and solutions of various degrees of concentration, the process given below was finally hit upon, and the results obtained were exceedingly satisfactory, both from an artistic and economical point of view. Knowing that the black deposit, or *stain*, as it is improperly termed, which is produced upon brass—more especially by optical instrument makers—is very easily rubbed off, it was determined, if possible, to obtain a firm adherent film which would resist ordinary rough usage, so that the staining process would be applicable to ornamental brass of all kinds, but specially so for chandelier work. Since these results could not be obtained upon brass direct, it was resolved to first give the brass work operated upon a slight coating of *copper*, in the sulphate of copper bath, and to take advantage of the ready susceptibility of this metal to become *stained* by means of solutions of alkaline sulphides. To carry out this plan, the following routine was adopted:—The brass article, after being dipped in the ordinary dipping-acid and well rinsed, was immersed in a sulphate of copper bath composed of 1 pound of sulphate of copper dissolved in 1 gallon of water, to which was added 1 pound of sulphuric acid. In from five to ten minutes, with the current from a Daniell cell, the deposit of copper was sufficiently thick for the purpose intended, when the article was removed from the bath and plunged into boiling water, the object being to allow it to dry spontaneously. A solution of sulphide of barium (5 grains of the sulphide to each ounce of water) was next poured into a deep vessel, and the coppered brass article, being held by its suspending wire, was immersed in the liquor, when it at once assumed a light brown tone, which gradually deepened, until, after a few moments' immersion, the surface acquired an intense but brilliant black. The article was then withdrawn and plunged into hot water, then into boiling water, and afterwards set aside to dry spontaneously, which occupied but a few moments. The black film thus obtained was firmly adherent, and when the smooth surfaces were rubbed with a clean chamois leather they soon acquired a brilliant polish. Other articles of various forms were subsequently treated in the same way, and when it was desired to give a chocolate brown tone to the piece of work, it was simply immersed in the sulphide bath for about half a minute or so, when a very pleasing brown tone was produced, possessing quite a metallic lustre. Solutions of the sulphides of ammonium, potassium, and sodium respectively were also tried, but in some respects the barium sulphide is to be preferred. It was next resolved to treat a specimen of ornamental brasswork in the following way. The bright surfaces, or parts which were to be burnished and remain yellow, were coated with a film of paraffin, to prevent the copper from being deposited upon such parts. The piece of work was then placed in the coppering bath until a sufficient coating of the red metal was obtained; it was then plunged into hot water as before, being afterwards dipped in boiling water, which effectually removed the paraffin. When the work became sufficiently cool to handle, certain ornamental parts were painted over with a mixture formed by mixing blacklead and oxide of iron into a paste, with a rather strong solution of the sulphide of barium. Soon after the last coating of the above paste had been applied the piece of work was placed under a tap of running water, and a soft long-haired brush briskly passed over the surface until the whole of the sulphide paste was removed. As it was found that even with such brisk washing the diluted sulphide had slightly discoloured the copper surfaces which had not been treated with the sulphide, a moderately strong solution of cyanide of potassium was quickly brushed over the whole piece, a portion at a time, each part thus treated being at once placed under the tap, which was kept running for the purpose. In this way the bright red of the copper became speedily restored, while the blackened surfaces were unaffected. The article was next rinsed in hot water, and finally in boiling water, as before. The plain surfaces of the article were next burnished, and a thin, colourless lacquer finally applied, when the operation was complete. It will be readily seen that ornamental brasswork—chandeliers, finger-plates and fenders, for example—may readily be treated in the manner described, and exceedingly beautiful and artistic effects produced, without involving much more cost than that of skilled workmanship.

Crystals of Metallic Tin.—While making some experiments upon the electro-deposition of tin from solutions of its various salts, the author determined to ascertain how the tin crystals so readily obtained from a solution of the protochloride by the simple immersion of a piece of metallic zinc (as in the formation of the well-known "tin-tree"), would arrange themselves when allowed to form upon a flat horizontal surface—a plate of glass, for instance—as adopted in the case of lead salts as explained on page 528. To produce the tin crystals a moderately strong solution of the protochloride was first prepared, which was rendered slightly acid by the addition of a few drops of hydrochloric acid, and the liquid then filtered for use. A plate of glass, about 7 by 5 inches, was then laid in a flat dish, and a tin anode, connected to the positive pole of a small 3-cell Daniell battery, was allowed to rest on the glass plate. A strip of brass, about half an inch in width and attached to the negative electrode, was then placed on the opposite end of the glass plate, and the protochloride solution afterward carefully poured into the dish until the plate was completely immersed. In less than half a minute crystals of tin formed upon the cathode, which soon radiated right and left, and gradually extended in the direction of the anode, until (in about two hours or so) they nearly reached that electrode, which was then removed. While the crystals were thus forming, it was noticed that as they approached the anode—say within one-third of the whole distance from the cathode—they formed with increasing rapidity; so rapidly, indeed, as to render their growth almost visible to the eye. The group of crystals, which laid flat upon the glass, presented a remarkably fine appearance, the various ramifications spreading over the plate somewhat like seaweed which has been allowed to expand in water upon a flat surface. The cathode was next carefully removed by separating the brass plate from the crystals attached to it with a penknife, and the brass plate bearing the crystals was gently and cautiously removed and allowed to drain upon a pad of blotting paper. The tin solution was then poured out of the dish, and the vessel well rinsed, after which the glass plate was again laid in the dish and water very gradually poured in (so as not to disturb the crystals) until the plate was well covered; the plate was then carefully taken out and allowed to drain for about half a minute and the washing operation then repeated several times, so as to thoroughly wash away all traces of the tin salt. When the last washing had been effected the crystals were allowed to drain thoroughly, and were afterwards dried before the fire. A coating of photographic varnish was then poured over the plate, which was subsequently mounted in a frame without a backboard, so that the crystals might be examined both by reflected and transmitted light. Crystalline deposits of tin may readily be obtained in the way indicated upon suitable surfaces and applied to decorative purposes, while, on the other hand, photographic copies of the crystals may be readily obtained, as directed at page 529, and such impressions might be available as designs for art decoration in some of its numerous applications.

The Gülcher Rheostat.—This useful resistance coil, of which an illustration is given in Fig. 149, is manufactured by the Gülcher Electric Light and Power Company, and is constructed to carry any current, from 1 to 1,000 ampères, and will be found very useful to electro-platers, since it will enable them to vary the E. M. F. or current at will. By simply moving a readily adjustable slide, the current density can be regulated to suit the dimensions of the articles in the bath, and thus the rate of deposit may be kept well under the control of the operator. Being mounted upon a slab of slate, there is no combustible material to suffer from the heating of the coil, as is the case with resistance coils mounted upon wood. The author, having frequently had occasion to use the Gülcher rheostat, may say that he found it to answer its purpose admirably.

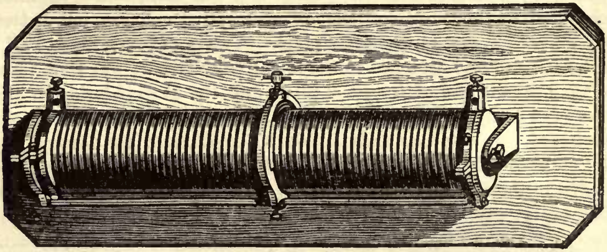

Fig. 149.

Seamless Metal-coated Tubes.—Mr. F. Madeley, of Stafford, produces jointless tubes in the following way: a strip of soft steel, of suitable width and thickness, is turned up into a skelp or tube by any known method, care being taken to make the joint as close as possible. The closed jointed tube is then polished by means of emery bobs in the usual way. The polishing being completed and the joint made quite close, the tube is next placed in an alkaline copper bath and allowed to receive a film of copper ; it is afterwards immersed in a cyanide brassing solution until a sufficient coating of brass is deposited. When a stouter casing of metal is required, the tube, after having been coated with copper in the alkaline bath, receives a further deposit of copper in a sulphate of copper bath prior to its immersion in the brassing solution. The tube is then finished by polishing and lacquering. By this process is produced what is known in the trade as a "close joint."

USEFUL TABLES.

TABLE I.—ELEMENTS, THEIR SYMBOLS AND ATOMIC WEIGHTS.

Name.	Symbol.	Atomic Weight.	Name.	Symbol.	Atomic Weight.
Aluminium	Al.	27·5	Mercury	Hg.	200·
Antimony	Sb.	122·	Molybdenum	Mo.	96·
Arsenic	As.	75·	Nickel	Ni.	59·
Barium	Ba.	137·	Niobium	Nb.	97·5
Bismuth	Bi.	210·	Nitrogen	N.	14·
Boron	B.	10·9	Osmium	Os.	199·
Bromine	Br.	80·	Oxygen	O.	16·*
Cadmium	Cd.	112·	Palladium	Pd.	106·5
Cæsium	Cs.	133·	Phosphorus	P.	31·
Calcium	Ca.	40·	Platinum	Pt.	197·
Carbon	C.	12·	Potassium	K.	39·1
Cerium	Ce.	92.	Rhodium	Ro.	104·3
Chlorine	Cl.	35·5	Rubidium	Rb.	85·
Chromium	Cr.	52·5	Ruthenium	Ru.	104·2
Cobalt	Co.	59·	Selenium	Se.	79·5
Copper	Cu.	63·5	Silicon	Si.	28·
Didymium	D.	96·	Silver	Ag.	108·
Erbium	E.	(?)	Sodium	Na.	23·
Fluorine	F.	19·	Strontium	Sr.	87·5
Gallium			Sulphur	S.	32·
Glucinum	G.	9·3	Tantalum	Ta.	138·
Gold	Au.	196·6	Tellurium	Te.	129·
Hydrogen	H.	1·	Thallium	Tl.	204·
Indium	In.	113·4	Thorinum	Th.	119·
Iodine	I.	127·	Tin	Sn.	118·
Iridium	Ir.	197·	Titanium	Ti.	50·
Iron	Fe.	56·	Tungsten	W.	184·
Lanthanum	La.	92·	Uranium	U.	120·
Lead	Pb.	207·	Vanadium	V.	137·
Lithium	L.	7·	Yttrium	Y.	(?)
Magnesium	Mg.	24·3	Zinc	Zn.	65·
Manganese	Mn.	55·	Zirconium	Zr.	89·5

* The combining *weight* of oxygen is 8.

TABLE II.—RELATIVE CONDUCTIVITY OF METALS.

By L. WEILLER.

Names of Metals.	Conductivity.	Observations.
1. Silver, pure	100·	These experiments have been conducted with a series of bars especially prepared for the purpose. These said bars have been molten at a uniform diameter of about 13 millimètres. They have been cut so as to show the grain of the metal, and the detached portions have then been drawn into wires. It is on the wires so obtained that the said experiments have been carried out, and of which the results are given in the table. As regards those alloys which can neither easily be drawn nor rolled, such as certain phosphides or silicides, the measurements have been taken direct from the bars according to the method of Sir W. Thomson. The measurements have been taken by means of a Wheatstone bridge with a sliding index, a differential galvanometer and a battery of four cells.
2. Copper, pure	100·	
3. Copper, pure super refined and crystallised	99·9	
4. Silicium bronze (telegraphic)	98·	
5. Copper and silver alloy at 50 per cent.	86·65	
6. Gold, pure	78·	
7. Silicic copper (with 4 per cent. of silicon)	75·	
8. Silicic copper (with 12 per cent. of silicon)	54·7	
9. Aluminium, pure	54·2	
10. Tin, containing 12 per cent. of sodium	46·9	
11. Silicium bronze (telephonic)	35·	
12. Plombiferous copper, with 10 per cent. of lead	30·	
13. Zinc, pure	29·9	
14. Phosphor bronze (telephonic)	29·	
15. Silicious brass, with 25 per cent. of zinc	26·49	
16. Brass, with 35 per cent. of zinc	21·15	
17. Phosphide of tin	17·7	
18. Gold and silver alloy, 50 per cent.	16·12	
19. Swedish iron	16·	
20. Pure tin of Banca	15·45	
21. Antimonous copper	12·7	
22. Aluminium bronze, 10 per cent.	12·6	
23. Siemens' steel	12·	
24. Platinum, pure	10·6	
25. Amalgam of cadmium, with 15 per cent. of cadmium	12·2	
26. Mercurial bronze, Drosnier	10·14	
27. Arsenical copper, with 10 per cent. of arsenic	9·1	
28. Lead, pure	8·88	
29. Bronze, with 20 per cent. of tin	8·4	
30. Nickel, pure	7·89	
31. Phosphor bronze, with 10 per cent. of tin	6·5	
32. Phosphide of copper, with 9 per cent. of phosphorus	4·9	
33. Antimony	3·88	

TABLE III.—SPECIFIC RESISTANCE OF SOLUTIONS OF SULPHATE OF COPPER.

By Fleeming Jenkin.

Sulphate of copper.	Temperature. Fahrenheit.	57°	61°	64°	68°	75°	82°	86°
	Water.							
8 parts.	100 parts.	45·7	43·7	41·9	40·2	37·1	34·2	32·9
12 „	100 „	36·3	34·9	33·5	32·2	29·9	27·9	27·0
16 „	100 „	31·2	30·0	28·9	27·9	26·1	24·6	24·0
20 „	100 „	28·5	27·5	26·5	25·6	24·1	22·7	22·2
24 „	100 „	26·9	25·9	24·8	23·9	22·2	20·7	20·0
28 „	100 „	24·7	23·4	22·1	21·0	18·8	16·9	16·0

TABLE IV.—SPECIFIC RESISTANCE OF SOLUTIONS OF SULPHATE OF COPPER AT 50° FAHR.

By Ewing and MacGregor.

Density.	Specific resistance.	Density.	Specific resistance.
1·0167	1·644	1·1386	35·0
1·0216	1·348	1·1432	34·1
1·0318	9·87	1·1679	31·7
1·0622	5·90	1·1823	30·6
1·0858	4·73	1·2051 (saturated).	29·3
1·1174	3·81		

TABLE V.—TABLE OF HIGH TEMPERATURES.

Degrees. Fahr.	Description.	Degrees. Fahr.	Description.
977	Incipient red heat.	1700	An orange red heat.
980	A red heat.	1873	A bright red heat.
1000	A dull red heat visible in daylight.	1996	A dull white heat.
1140	Heat of a common fire.	3000	A white heat.
1200	A full red heat.	3300	Heat of a good blast furnace.
1310	Dull red heat.		

TABLE VI.—COMPARATIVE FRENCH AND ENGLISH THERMOMETER SCALES.

French, or Centigrade. Cent. or C.	English, or Fahrenheit. Fahr. or F.	Cent.	Fahr.	Cent.	Fahr.
Degrees.	Degrees.	Degrees.	Degrees.	Degrees.	Degrees.
0	32	33	91·4	67	152·6
1	33·8	34	93·2	68	154·4
2	35.6	35	95	69	156·2
3	37·4	36	96·8	70	158
4	39·2	37	98·6	71	159·8
5	41	38	100·4	72	161·6
6	42·8	39	102·2	73	163·4
7	44·6	40	104	74	165·2
8	46·4	41	105·8	75	167
9	48·2	42	107·6	76	168·8
10	50	43	109·4	77	170·6
11	51·8	44	111·2	78	172·4
12	53·6	45	113	79	174·2
13	55·4	46	114·8	80	176
14	57·2	47	116·6	81	177·8
15	59	48	118·4	82	179.6
16	60·8	49	120·2	83	181·4
17	62·6	50	122	84	183·2
18	64·4	51	123·8	85	185
19	66·2	52	125·6	86	186·8
20	68	53	127·4	87	188·6
21	69·8	54	129·2	88	190·4
22	71·6	55	131	89	192·2
23	73·4	56	132·8	90	194
24	75·2	57	134·6	91	195·8
25	77	58	136·4	92	197·6
26	78·8	59	138·2	93	199·4
27	80·6	60	140	94	201·2
28	82·4	61	141·8	95	203
29	84·2	62	143·6	96	204·8
30	86	63	145·4	97	206·6
31	87·8	64	147·2	98	208·4
32	89·6	65	149	99	210·2
		66	150·8	100	212

TABLE VII.—BIRMINGHAM WIRE GAUGE FOR SHEET COPPER AND LEAD.

Thickness by B. W. G.	Diameter in Inches.	Weight per Square Foot.		Thickness by B. W. G.	Diameter in Inches.	Weight per Square Foot.	
		Sheet Copper.	Sheet Lead.			Sheet Copper.	Sheet Lead.
No.	inch.	lbs.	lbs.	No.	inch.	lbs.	lbs.
0000	·454	20·566	26·75	19	·042	1·93	2·48
000	·425	19·252	25·06	20	·035	1·61	2·04
00	·380	17·214	22·42	21	·032	1·47	1·89
0	·340	15·6	20·06	22	·028	1·29	1·65
1	·300	13·8	17·72	23	·025	1·14	1·47
2	·284	13·	16·75	24	·022	1·01	1·30
3	·259	11·9	15·26	25	·020	·918	1·18
4	·238	11·	14·02	26	·018	·826	1·06
5	·220	10·1	12·98	27	·016	·735	·945
6	·203	9·32	11·98	28	·014	·642	·826
7	·180	8·25	10·63	29	·013	·597	·767
8	·165	7·59	9·73	30	·012	·551	·708
9	·148	6·8	8·72	31	·010	·480	·600
10	·134	6·16	7·90	32	·009	·420	·532
11	·120	5·51	7·08	33	·008	·370	·472
12	·109	5·02	6·42	34	·007	·323	·413
13	·095	4·37	5·60	35	·005	·262	·309
14	·083	3·81	4·90	36	·004	·194	·236
15	·072	3·31	4·25				
16	·065	3·00	3·83				
17	·058	2·67	3·42				
18	·049	2·25	2·90				

TABLE VIII.—NEW LEGAL STANDARD WIRE GAUGE

Issued by the Standards Department of the Board of Trade.
Came into force March 1st, 1884.

Descriptive No. B. W. G.	Equivalents in parts of an inch.	Descriptive No. B. W. G.	Equivalents in parts of an inch.	Descriptive No. B. W. G.	Equivalents in parts of an inch.
7/0	·500	13	·092	32	·0108
6/0	·464	14	·080	33	·0100
5/0	·432	15	·072	34	·0092
4/0	·400	16	·064	35	·0084
3/0	·372	17	·056	36	·0076
2/0	·348	18	·048	37	·0068
0	·324	19	·040	38	·0060
1	·300	20	·036	39	·0052
2	·276	21	·032	40	·0048
3	·252	22	·028	41	·0044
4	·232	23	·024	42	·0040
5	·212	24	·022	43	·0036
6	·192	25	·020	44	·0032
7	·176	26	·018	45	·0028
8	·160	27	·0164	46	·0024
9	·144	28	·0148	47	·0020
10	·128	29	·0136	48	·0016
11	·116	30	·0124	49	·0012
12	·104	31	·0116	50	·0010

TABLE IX.—CHEMICAL AND ELECTRO-CHEMICAL EQUIVALENTS.

Name of Substance.	Symbols.	Equivalents.		Weights decomposed by one ampère in one hour.
		Chemical.	Electro-Chemical.	
			mgr.	grammes.
Hydrogen	H	1	0·01036	0·0375
Aluminium	Al	13·7	0·1425	0·5137
Antimony	Sb	122	1·2688	4·575
Arsenic	As	75	0·7800	2·8125
Barium	Ba	68·5	0·7124	2·5687
Bismuth	Bi	210	2·184	7·875
Boron	B	11	0·1144	0·4125
Bromine	Br	80	0·832	3
Cadmium	Cd	56	0·5824	2·095
Calcium	Ca	20	0·208	0·75
Carbon	C	6	0·0624	0·2250
Chlorine	Cl	35·5	0·3692	1·3312
Chromium	Cr	26·2	0·2725	0·9825
Cobalt	Co	29·5	0·3068	1·1062
Copper	Cu	31·8	0·3367	1·1925
Fluorine	F	19	0·1976	0·7125
Gold	Au	98·3	1·0223	3·6862
Iodine	I	127	1·3208	4·7625
Iron	Fe	28	0·2912	1·05
Lead	Pb	103·5	1·0764	3·8812
Magnesium	Mg	12·2	0·1269	0·4575
Manganese	Mn	27·5	0·286	1·0312
Mercury	Hg	100	1·036	3·75
Nickel	Ni	29·5	0·3068	1·1062
Nitrogen	N	14	0·1456	0·5250
Oxygen	O	8	0·0832	0·3
Palladium	Pd	53·2	0·5533	1·9947
Phosphorus	P	31	0·3224	1·1625
Platinum	Pt	98·6	1·0254	3·6975
Potassium	K	39·1	0·4066	1·4637
Selenium	Se	39·8	0·4139	1·4925
Silver	Ag	108	1·1232	4·05
Silicon	Si	14	0·1456	0·5242
Sodium	Na	23	0·2392	0·8625
Strontium	Sr	43·8	0·4555	1·6425
Sulphur	S	16	0·1664	0·6
Tin	Sn	59	0·6136	2·2125
Zinc	Zn	32·7	0·3401	1·2243

TABLE X.—CHEMICAL AND ELECTRO-CHEMICAL EQUIVALENTS OF SOME COMPOUND SUBSTANCES.

Name of Substance.	Symbols.	Equivalents.		Weights decomposed by one ampère in one hour.
		Chemical.	Electro-Chemical.	
			mgr.	grammes.
Acetic acid	$C_4H_4O_4$	60	0·6240	2·25
Hydrochloric acid (gas)	HCl	36·5	0·3796	1·3687
Nitric acid (monohydrated)	NO_6H	63	0·6552	2·3625
Oxalic acid	$C_4H_2O_8$	90	0·936	3·375
Phosphoric acid (hydrated)	$PO_5 3HO$	98	1·0192	3·675
Sulphuric acid (monohydrated)	SO_4H	49	0·5096	1·8375
Tartaric acid	$C_8H_6O_{12}$	150	1·56	5·625
Iron sulphate	$FeSO_4 7HO$	139	1·4456	5·2125
Nickel ,,	$NiSO_4 7HO$	140·5	1·4612	5·2687
Potassium ,,	KSO_4	87·1	0·958	3·2662
Sodium ,,	$NaSO_4$	71	0·7384	2·6625
Zinc ,,	$ZnSO_4$	80·7	0·8393	3·0262
Ammonia	NH_4O_1,HO	35	0·3640	1·3125
Ammonium chloride	NH_4Cl	53·5	0·5564	2·0062
„ cyanide	$C_2N_2H_4$	44	0·4576	1·65
„ sulphate	$N_2H_8SO_4$	84	0·8736	3·15
Nickel chloride	$NiCl$	65	0·676	2·4375
Gold perchloride	Au_2Cl_3	303·5	3·1564	11·3812
Silver cyanide	AgC_2N	134	1·3936	5·025
Potassium cyanide	KC_2N	65·1	0·667	2·4412
Copper sulphate (anhydrous)	$CuSO_4$	79·7	0·8289	2·9887
„ „ (crystallised)	$CuSO_4 5HO$	124·7	1·2969	4·6762

XI.—TABLES OF WEIGHTS AND MEASURES.

Apothecaries' Weight.

1 pound	*equals*	16 ounces.
1 ounce	,,	8 drs. (480 grains).*
1 drachm	,,	3 scruples.
1 scruple	,,	2 grains.

Troy Weight.

1 pound	*equals*	12 ounces.
1 ounce	,,	20 pennyweights (dwts.) or 480 grains.*
1 pennyweight	,,	24 grains.

Imperial Measure.

1 gallon	*equals*	8 pints.
1 pint	,,	20 ounces.
1 ounce	,,	8 drachms.
1 drachm	,,	60 minims.

French or Metrical System.

French Weight.

Kilogramme, 1,000 grammes	*equals*	2 lbs. $3\frac{3}{4}$ ozs. *nearly.*
Gramme (the unit)	,,	15·432 grains.

French Measure of Volume.

1 litre (the unit)	*equals*	34 fluid ounces *nearly.*

Long Measure.

Mètre (the unit)	*equals*	39·371 inches.
Decimètre (10th of a mètre)	,,	3·9371 ,,
Centimètre (100th of a mètre)	,,	0·3937 ,,
Millimètre (1000th of a mètre)	,,	0·0393 ,,

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* An ounce Avoirdupois is only 437·5 grains.

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