PRACTICAL IRON FOUNDING

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BY

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"PRINCIPLES OF FITTING," ETC.

With Two Hundred and Eighty-Three Illustrations

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PREFACE TO FIRST EDITION

THIS is an attempt to give a condensed account of the principles and practice of Iron Founding. It is written both for the student and for the practical man. I have stated and explained principles, and have also included the most recent practice, particularly as it relates to the two branches of machine moulding and the melting of iron.

JOSEPH HORNER.

PREFACE TO FOURTH EDITION

Since this volume was written great changes have been accomplished in the Iron Foundry. This is the explanation of the fact that the amount of matter in the present edition is just double that of the previous one, and that certain portions, notably that of machine moulding, have been wholly rewritten.

Additional examples of moulds have been introduced, and some new chapters prepared. It is now more than an elementary treatise, and should possess a correspondingly higher value than the previous editions.

Bath, 1914

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CHAPTER I

PRINCIPLES

In this text-book the endeavour will be to explain and illustrate in a clear and concise manner the principles and practice of iron moulding and founding. Though a dirty trade, more of technical skill and forethought are required, more difficulties have to be encountered than in many trades of more apparent importance. And as it is one the practice of which is very varied and extensive, and as a thoroughly exhaustive treatment would occupy a much larger treatise than this, judicious condensation will be necessary. But if we endeavour to go down at once to first principles, and gain clear ideas as to the fundamentals involved in iron-moulding, we shall be able to obtain such a broad grasp of the subject as will assist subsequently in the comprehension of details.

The matrices into which iron is poured in order to obtain castings of definite outlines are invariably either of *sand* or *iron*. The process in which the latter is used is a small and comparatively restricted section, known as *chilling*; the former embraces all the ordinary iron castings—those the surfaces of which are not required of a hard and steely character. Recently, however, the practice has been developing of casting pipes, wheels, sash weights, etc., in permanent moulds of iron.

Sand is eminently adapted for casting metals into. No material can take its place, because there is none which is at the same time plastic, porous and firm, adhesive and refractory. *Plasticity* is necessary in order that the matrix may be moulded into any form, intricate or otherwise. *Porosity* is essential to permit of the escape from the moulds of the air and of the gases generated by the act of casting, and *firmness* and *adhesiveness* are required to withstand the liquid pressure of the molten metal. A matrix must also be *refractory*, that is, able to resist the disintegrating influence of great heat, and the chemical action of the hot iron itself. It must, moreover, be cheap, readily available, and not difficult to manipulate. All these qualities are possessed by certain sands, and mixtures of sands, and by no other materials.

The leading branches of moulding derive their names from the different kinds of sand mixtures used, termed respectively *green sand*, *dry sand*, *loam*, to be explained directly. It will suffice just now to remark that the fact that sands differ widely in their physical qualities is apparent to any observant person, so that while one kind will be loose, open, friable, and free, another will appear as though clayey, greasy, close, and dense. Advantage is taken of these differences in quality to obtain mixtures suitable for every class of moulded work, from the thinnest, lightest rain-water pipes to the most massive and heaviest engine cylinders and bedplates. Almost invariably, therefore, foundry sand consists of mixtures of various separate kinds. By judicious mixture, grades of any required character can be obtained.

To enable the sand to take the requisite definite impressions and outlines, it is necessary to employ *patterns*, the shapes of which are in the main the counterparts of those of the castings wanted. These patterns are in some cases absolutely like their castings, but in others they resemble them only to a certain extent. Thus, if work is to be hollow, the hollow portions, instead of being provided in the patterns, may be often much better formed in *cores*:—*prints* on the patterns indicating their positions, and the print impressions affording them support. But in much large work, again, the patterns are mere skeletons, profile forms, and the mould is prepared mainly by a process of "sweeping" or "strickling" up.

In order to effect delivery of patterns, a process of loosening by *rapping* has to be resorted to, and this, together with the *lifting* or withdrawal, tends to damage the mould. To prevent or to minimize this injury, *taper* is given to patterns, that is, their dimensions are slightly diminished in their lower portions, or in those which are last withdrawn from the mould.

As iron shrinks during the process of cooling, an allowance has to be given for this "contraction," by making the pattern and mould larger by a corresponding amount than the casting is required to be. Moreover, the forms of some castings are such that they *curve* in cooling, and for this also provision has properly to be made in their patterns.

Iron when molten behaves similarly to a liquid in all respects; hence the conditions of *liquid pressure* exist in all moulds. The iron, therefore, has to be confined at the time of pouring by the resistance of large bodies of sand enclosed in boxes or *flasks*, which are weighted, or otherwise secured. Sufficient area of entry for the metal has to be provided by means of suitable *gates* and *runners*. The shrinkage of metal in mass must receive adequate compensation by *feeder heads*. Owing to the irregular outlines of cast work, flasks must be jointed, and *joints* of various kinds have to be made in the mould itself.

CHAPTER II

SANDS, AND THEIR PREPARATION

Although as stated, sand is not the only material used for moulds, yet ninety-nine one-hundredths of the moulds made are prepared in sand in some way or another, and cast into either moist or dried. Consisting, as this material does, of a vast number of distinct particles, it can readily be compelled by ramming or pressure to take any required outlines and the finest impressions of the pattern. Though friable and destitute of cohesion in its natural dry condition, it is plastic and coherent when moistened with water; so that when in this state it is capable not only of receiving but of retaining the impressions made by the pattern after its withdrawal. Further, the porosity of the sand much assists the free escape of the gases generated by casting, and which, in the absence of a free vent, would honeycomb the castings with innumerable blowholes.

But it is obvious that sands are not all alike, and a very superficial knowledge of moulding is sufficient to show that different classes of moulds must require different kinds of mixtures of sands. In their judicious choice and proper mixture lies very much of the moulder's art; so that a foreman moulder will spend several months, or even years, in studying and experimenting in various mixtures before he gets the very best possible results in his shop.

Choice of sands.—Primarily the choice depends very much upon localities. When building a new foundry one would not go to the opposite end of England to get sand to lay down his floor, which will properly be from 2 ft. to 3 ft. or 4 ft. in depth. He would purchase cheap sand in his immediate neighbourhood, and there are few localities in which the new red sandstone, the green sand, and chalk formations, or the coal measures, do not furnish suitable material for the moulder. But there are several localities which are famous for some special qualities possessed by their sands which render them more suitable for some classes of work than for others, and small quantities of these sands are often purchased at considerable expense, due chiefly to the cost of transit, for special work. Thus, though the yellow and greenish-yellow sands usually form the basis of the foundry floor, the fine red sands are chiefly employed for facing and for fine moulding.

The names and qualities of some of the best-known sands used in this country are summarized below:

Erith sand, or London sand, is largely used for green, and loam moulds. It is suitable for light work, for ordinary and moderately heavy castings, and, mixed with old loam and cow hair, for loam work. Devizes and Seend sands, used in the West of England, are of a yellow or greenish-yellow colour, and are used for general and heavy work. They are not suitable for the finest work, being coarse and close. Worcester is a fine red sand, used for fine moulds and for facing moulds, in which a coarser sand is used for filling. Falkirk sand is coarse and open, and is suitable, therefore, for casting hollow ware into, its porosity allowing free vent for the gases. Belfast sand is fine; it is used for general work, is mixed with rock sand, and affords excellent facing. Doncaster sand is suitable for jobbing work. It is of a red colour, and moderately open. Winmoor sand is very open, and used for strong moulds. Kippax, a yellow sand, is employed for cores, and for dry-sand moulds. Mansfield sand is close, and suitable for fine work. Derbyshire, Snaith, Shropshire, Cheshire, the Birmingham district, and many others, produce good sands of various qualities. Sea sand is sometimes used for cores, and rock sand—*i.e.*, rotten rock—is employed for imparting strength to weaker sands.

Moulding sands are obtained in the coal measures, the new red sandstone, and the green sand and chalk. As local foundries largely use local supplies, a knowledge of the precise mixing of sands for any one locality has to be acquired there, and the experience thus gained is modified to be of service when the sands of another locality are employed. Nevertheless, there are certain general principles to be observed in the mixing and use of sands, which apply to all alike.

The terms *green*, *dry*, *loam*, *floor*, *black*, *strong*, *weak*, *core*, *facing*, *burnt*, *parting*, *road sands*, have exclusive reference to mixtures, and physical conditions; none whatever to geological character, or to locality.

Sand is *green* when the mixture is used in its natural condition, that is, damp, or mixed with just sufficient water to render it coherent. Immediately after the pattern has been withdrawn therefrom, the mould is ready, except for the necessary cleaning and mending up, and blackening, to receive the metal. It is also termed *weak* sand to distinguish it from the other mixtures, which by comparison therewith are *strong*, *i.e.*, possessed of superior binding qualities—having more *body*—more coherence.

Floor sand.—Every time that a casting is poured, the sand in the mould becomes baked dry by the heat of the metal, and before being allowed to mingle with the floor sand it is passed through a riddle to free it from small particles of metal, lifters, nails, etc., and is then moistened with water from a bucket or can, or hose pipe, and dug over two or three times, and it is then ready for use once more. The *floor sand* or *black sand*, therefore, forms an accumulation, always damp, always ready for filling boxes, or for moulding patterns by a process of bedding-in. It possesses no strength, and is only used for box-filling.

When a mould requiring a fine sand is large, or only of moderate size, then the common sand would be used for its main body—or for *box-filling*—and only those portions which come next the pattern, and for an inch or so away from it, would be made with the more expensive sand. There are certain primary methods of preparing sands which are, however, followed in all shops, no matter what kinds or what proportions are used. Except for mere box-filling, no sand is ever used just in the condition in which it is dug out of the quarry or pit. It is mixed with other sands, or other ingredients, and with water. Omitting loam mixtures we may therefore divide all prepared moulding sands into two classes, those which are used for *box-filling*, and those employed for *facing*.

In reference to the first, little preparation is required. The floor of a foundry is composed entirely of sand, which is being used and cast into over and over again, year after year, and only such portions as become burnt by direct contact with the castings are ever removed and thrown away. This sand is receiving continual additions of new facing sand, used once in contact with the castings, and then, excepting the burnt portions, allowed to mingle with the floor sand.

Facing sand.—The actual sand which is rammed around, and in immediate contact with, the pattern, is termed facing sand, because it forms the actual faces of the mould, against which the metal is poured. This is the true moulding material, on the composition and character of which the quality of the casting itself depends in a very large measure, and which is varied by the skill and experience of the founder to suit different classes of work. Facing sands are made to vary in strength, porosity, and binding qualities, for different kinds of work, the reasons of which will be apparent as we discuss the different kinds of moulds. Some of these are more porous and sharp than others, and being *open*, are suitable for light, thin castings, being more or less self-venting. Some of the more open sands are used alone, but most kinds require tempering by admixture with those of opposite qualities, in order to fit them for their specific uses. Thus *strong sands*, or those having a good body, or closeness of texture, are mixed in variable proportions with the open sharp sands, and by varying their proportions, sand, like iron, can be obtained in any required grade.

Hence the facing sands are prepared by a careful process of due proportioning of ingredients adapted to the several classes of work for which they are specially required.

For light, and for heavy work, and for all intermediate classes, the kinds and proportions of sands used, and the quantity of coal dust intermixed, will vary, and even in different parts of the same mould. In parts subject to much pressure, the sand should be close, rammed hard, and well vented; and in sections where the opposite conditions exist, the sand may be light and open. It is therefore impossible to give any precise rules. But the broad principles upon which such mixtures are proportioned can be indicated.

For *heavy* moulds—that is, moulds for massive castings—the sand will be mixed dense and *strong* to resist the great pressure and heat; in *light* moulds it will be more porous and weak. In the first case more, in the latter less, venting will be required. In heavy moulds more, in light moulds less, coal dust will be used; because the burning action is more intense in the former than in the latter, the action of the hot metal being continued longer in the case of the first than in that of the second. In a heavy mould, the proportions of coal dust may be one to six or eight of sand; in light moulds it may be one to fifteen of sand. The reason of its use is as follows:

Molten metal slightly fuses the surface of sand with which it comes into contact, and the casting becomes roughened in consequence. A perfectly refractory sand cannot be employed, there must be a certain percentage of alumina and metallic oxides, which are binding elements, present, to render it coherent and workable, and these happen to be readily fusible. The more silica present in a sand the more refractory it is; but too large a percentage of this in a moulding sand would diminish its necessary cohesive property. The facing sand therefore is introduced into a mould to supply that which is lacking in the main body itself, and by forming a backing of an inch or two in thickness to the mould, prevents, by the oxidation of the coal dust, this burning and roughening from taking place. The carbon of the coal yields with the oxygen of the air, at the high temperature of the mould, either carbonic oxide, or carbon di-oxide, and the thin stratum of these gases largely prevents that amount of direct contact of metal with sand which would produce burning and roughening. Castings become *sand-burnt* when there is not sufficient coal dust used to prevent surface fusion from taking place.

Dry sand.—Though ordinary green sand mixtures cannot be dried and yet retain coherence, mixtures of close heavy sands are made, which when dried in the stove, are comparatively hard and firm. Only the heavier sands of close clayey texture will bear drying: green sand mixtures would become friable and pulverize under the action of heat. There is a superficial or *skin drying* practised with these. But that only affects the surface, and is quite distinct from the drying to which the present remarks have reference. Horse manure, cow hair, or straw are mixed with dry sand to render its otherwise close texture sufficiently open for venting: the undigested hay in the manure becoming partially carbonized during the drying of the mould, while the moisture also evaporates at the same time. Coal dust is added to dry sand mixtures as to green sand. It is said to be *strong* to distinguish it from *weak* or green sand. It is a mixture which is used for a better class of moulds than green sand. It is also specially adapted for heavy work. Less gas is generated by the use of dry than of green sand, and the mould is, therefore, safer. It is mixed damp, and rammed like ordinary facing or moulding sand, but is dried in the core stove previous to casting. Being dried, it is hard, and will stand a greater degree of liquid pressure, approximating in these respects, and in being mixed with horse manure, to loam. But it differs from loam in containing coal dust, and in being rammed damp, like green sand, around a complete pattern.

Core sand.—This is variously mixed. For light and thin castings it is open and porous, being chiefly or entirely moulding sand, and having just sufficient cohesiveness imparted to it by the addition of clay water, peasemeal, beer grounds, or other substances, to make it bind together. But for heavy work, and that which has to stand much pressure, strong dry sand mixtures, having horse manure, are used. It is always rammed damp, like moulding sand, and dried similarly to dry sand moulds. Cores are also made with loam by *sweeping up* or *striking up*.

Loam.—This is a mixture of clayey and of open sands ground up together in proportions varying with the essential nature of those sands. It is a strong mixture, which is wrought wet, and *struck up* while in a plastic condition, and being afterwards dried, forms a hard, compact mould. The close texture of the loam is not vented, as is usual with green and dry sand moulds, with the vent wire; but certain combustible substances are mixed and ground up with the sand, and these, in the drying stove, become carbonized, leaving the hard mass of loam quite porous. The material usually employed is horse manure, containing, as it does, a large proportion of half digested hay. Straw, cow hair, and tow are also employed; but the horse manure appears to be almost universally made use of. Loam is used in different grades, being coarser for the rough sweeping up of a mould, and for bedding-in the bricks, than for facing and finishing the surface. *Old loam*, that is, the best unburnt portions stripped from moulds which have been cast in, is also ground up again with new sands, and used both in loam and dry sand mixtures. Loam, unlike the other mixtures, has no coal dust mixed with it.

Parting sand.—This is burnt sand, used for making the joints between sections of moulds, which, without the intervention of the parting sand, would stick together. The sand is red sand, baked, or brick-dust, or burnt sand scraped from the surface of castings. A thin layer only, of no sensible thickness, is used. Its value consists in its non-absorption of moisture, so that it forms a dry, non-adhesive stratum between damp and otherwise coherent faces. Parting sand is simply strewn lightly and evenly over with the hand.

I have not given definite proportions of sands for different mixtures, because the proportions of such mixtures must depend entirely upon locality as well as upon the class of work for which they are intended. The red sand or the yellow sand of one locality will not be precisely like that of another, and therefore the practice will differ in different parts of the country. Moreover, the mixture of sands, like that of metals, is largely a matter of individual opinion and experience; each foundry foreman follows the practice which in his experience has produced the best results. And again, green sand, dry sand, and loam mixtures are each prepared in various grades to suit different classes of work, differences of strength or body being required, not only in distinct moulds, but even in individual portions of the same mould. As generally indicative only of the methods and proportions of mixing adopted, a few recipes are given in the Appendix.

Facings.—The use of facing sand is not sufficient alone to ensure a clean face or skin on castings. Hence a thin film, a facing, or a paint of a carbonaceous substance, is always brushed over moulds, excepting those intended for castings of the roughest possible character. This film will be laid on wet or dry, according to the class of work. It is comprised of different ingredients also. Formerly the facings or paints were mostly made of ground wood-charcoal and coal-dust. At that time the moulder mixed his own facings to suit different kinds of work, and the muslin *blacking-bag* was in frequent requisition. Now, various preparations are ground and mixed, and sold under different names, for specific purposes. In the best foundries now, also, nearly pure plumbago or black-lead is used almost exclusively. Though costly, it produces a finer skin than the preparations of charcoal and coal-dust, and is less troublesome to apply. It is dusted over the mould, and swept with a broad camel-hair brush, and then sleeked with the trowel. On green-sand moulds nothing more is required, because the porous face of the sand retains the plumbago. But on all dried-sand and loam moulds, and on the faces of skin-dried green-sand moulds, the plumbago is made into a wash with water and clay, or other cementing substances. But on moulds of this kind, the *paint*, as it is called, is generally made of the cheaper coal-dust mixed into a *black wash* or *wet blacking*, with the clay water, the clay in the water binding the dust and preventing it from flaking off when in the stove. Since the best plumbago costs something like £1 per cwt., or about twenty times as much as coal-dust, there is reason for such economy. It, however, always *peels* better than the coal-dust or charcoal-dust—that is, the sand can be stripped from the casting more freely, leaving a smoother face, hence for good work it has superseded the common blackings.

There is much difference in the cost of foundry blackings, the price increasing with the amount of pure blacklead present. All grades are obtainable, for green sand and loam, for light and fancy work, and for general and heavy work.

There is no need to use a large quantity of blacking or plumbago on a mould. It tends to roll up before the metal, and form streaky lines or rough patches, which are unsightly. Neither should it be sleeked much, for much sleeking is always injurious to the face of a mould. Passing the trowel over it once or twice only lightly is sufficient to make it lay to the mould. It is put on dry-sand and loam moulds after they have been dried in the stove, and while yet warm. If the moulds are allowed to get cold first, then the blacking must be dried off.

The effect of the blacking is to prevent the metal from being roughened by direct contact with the sand. The plumbago facing acts so efficiently that cften when a casting is turned out, if the fingers are rubbed on it, the plumbago adherent to its surface will come off on the fingers, showing that it has remained unaffected by the heat. This protection has nothing to do with the production of sound castings, but it improves the appearance immensely.

Chemistry of sands.—The time has not arrived when chemical analysis can displace the practical knowledge gained by experience in working in particular grades of sands. Analysis safely asserts that the purest sands should consist of little besides silica and alumina, the first the refractory element, the second the bond. Lime and iron oxide, with the alkalies—soda, potash, and sometimes traces of other ingredients—all detract from the value of a sand, lowering the fusing point and rendering it liable to flux. If the materials in a sand become fused by the molten metal the result will be the closing of the pores, so preventing the escape of the gases.

Sizes of grains.—If the grains are large and regular in size and shape the sand will be more porous than with opposite conditions. The popular objection to large grains is that they will not produce castings with smooth skins. Also grains of equal size and of angular shapes favour porosity, while grains of unequal sizes, and which have smooth surfaces, do not, though they give a strong sand.

Alumina or clay, being hydrated silicate of alumina, contains 46.4 per cent. of silica, 39.7 per cent. of alumina, and 13.9 per cent. of combined water, so that the total silica is a larger quantity than the free silica.

Mechanical analysis deals with the sizes of sand grains, and is very useful because it reveals the texture of the sand, which is passed through a succession of sieves of different meshes, and the proportions which pass through the different meshes afford data for estimating the suitability of the sand for fine and coarse work. Weak sands are fine grained and usually have least alumina. They are used for light green sand work. For heavy green sand work a larger proportion of alumina is desirable, and coarser grained sands. For dry sand, loam, and cores, the largest proportion of alumina is suitable, and fine sand. That castings with smooth skins cannot be obtained from coarse sands is negatived by experience. The coarse grains favour the escape of the gases, and the applications of facings fill up the spaces against which the metal is poured. The following are analyses of standard sands used for different kinds of work.

Sand for fine castings

Silica	81.50	per cent.
Alumina	9.88	,,
Iron Oxide	3.14	,,
Lime	1.04	,,
Magnesia	0.65	,,

(Fine grain)

Sand for average castings

Silica	84.86	per cent.
Alumina	7.03	,,
Iron Oxide	2.18	,,
Lime	0.62	,,
Magnesia	0.98	,,

(Medium grain)

Sand for heavy castings

Silica	82.92	per cent.
Alumina	8.21	,,
Iron Oxide	2.90	,,
Lime	0.62	,,
Magnesia	0.00	,,

(Coarse grain)

But Heinrich Ries has stated that there is no relation between the bonding power and plasticity, and the percentage of alumina, as determined by chemical analysis. He says that the mechanical analysis affords an approximate index of the cohesiveness of sand. In this analysis the grains, being passed through sieves of different mesh, yield percentages of the grains retained in each, while the clay group forms another percentage separated from the sand grains.

The texture of a sand has a much greater influence on its suitability for a given class of work than the chemical analysis. Heinrich Ries illustrates this fact by giving four sets of chemical and mechanical analyses of sands, as below. In these Nos. 1 and 2 agree closely in their chemical composition, but differ in their texture. Nos. 3 and 4 agree closely in chemical analysis, but differ widely in mechanical analysis. No. 1 was Albany sand used for stove plate work. No. 2, stove plate sand from Newport, Ky. No. 3, sand for general work from Petersburg, Va. No. 4, sand for general work from Fredericksburg, Va.

Chemical analyses

	No. 1	No. 2	No. 3	No. 4	
Silica	79.36	79.38	84.40	85.04	per cent.
Alumina	9.36	9.38	7.50	5.90	,,
Ferric Oxide . .	3.18	3.98	2.52	3.18	,,
Lime	0.44	1.40	0.06	0.06	,,
Magnesia . . .	0.27	0.54	0.21	0.14	,,
Potash	2.19	1.80	1.29	1.65	,,
Soda	1.54	1.04	0.65	0.83	,,
Titanic Oxide . .	0.34	0.44	0.44	0.78	,,
Water	2.02	2.50	1.49	1.57	,,
Moisture	0.74	0.80	1.76	1.11	,,

Mechanical analyses

Per Cent. Retained

Size Mesh.	1.	2.	3.	4.
20 . . .	0.26	0.06	0.09	0.19
40 . . .	0.51	0.12	0.41	0.19
60 . . .	2.53	0.32	2.21	0.39
80 . . .	0.99	0.16	2.67	0.19
100 . . .	4.19	0.83	17.37	0.98
250 . . .	79.85	23.38	58.20	81.92
Clay . . .	11.24	24.73	19.02	15.97

Other materials.—Small quantities of certain very essential articles are used in foundries, as clay, resin, flour, oil, tar, straw, hay, tow, etc. The use of the first three is chiefly that of cementing agents for cores. Small cores are cemented with these, the resin and flour binding the sand together, beer grounds and molasses being used for the same purpose. Specially prepared "core gums," the elements of which are only known to the manufacturers, are sold. Clay, mixed with water to various degrees of consistence, is a valuable cement for sticking the joints of cores together; for swabbing flasks, the better to retain the sand; for cementing broken edges of moulds and cores; for mixing with wet blacking; and for other purposes. Oil is used for pouring over the faces of chaplets, over the damp mended-up parts of moulds, and around metallic stops in order to lessen the risk of blowing occurring in those localities, the metal lying more quietly on the oil than on the bare metal or on the moist sand. Tar is used for painting over the ends of wrought-iron arms or shafts around which metal has to be cast, and for painting loam patterns to harden their surfaces. Straw and hay are used for cores, being first spun into bands, which are then wound round the core-bar. These are usually spun in the foundry, but can also be purchased ready for use. Tow is wound round those portions of bars where the spun bands would be too thick. Hay is also used in layers in cinder beds to prevent the sand from filling up the interstices of the cinders.

Sand preparation.—To prepare and mix sands various methods are made use of. For the floor sand, simply moistening with water and turning over two or three times with the shovel suffices in most shops. But all facing sands have to be thoroughly pulverized and passed through sieves of varying sized mesh, according to the class of work for which they are required. Sand as it comes from the quarry is gritty and lumpy, and is riddled to separate the lumps, which are either thrown aside, or ground and crushed and re-riddled. The suitable mixtures of sand and coal-dust having been made, they are thoroughly intermixed with water, and are then ready for use.

In reference to the watering, it is as well to remark that this must not render the sand *wet*, which would spoil any mould in which it might be used, but only moist, or damp, rendering it sufficiently coherent for moulding into. So that if a portion of such sand is taken up in the hand and squeezed, it will retain the impression imparted without falling apart of itself, which perfectly dry sand would do.

Machines.—The growth of machinery for dealing with sands has been very rapid in recent years. Old methods have been extended, new ones have been introduced. The scores of designs made may be roughly classified under four heads: Machinery for sand drying, for grinding, for disintegrating, and for riddling and sifting.

Machines for sand drying are of cylindrical form, of rotary designs, in which the wet sand fed in at one end through a hopper is conveyed to the other, the cylinder being disposed at an angle with the horizontal. During its passage it is subjected to a current of hot air. Several tons of sand can be treated thus daily.

Machines for grinding sand are usually of the type employed for grinding loam. This is essentially a mortar-mill, having two heavy grinding rollers, plain or grooved, between which and the bottom of the pan the materials are crushed and ground. The rollers rotate on their horizontal axes, and either the rollers, or the pan, revolve on their vertical axis, either being driven by bevel gears. Sands are ground dry, and loam wet in these machines. The pan is emptied by opening a door in the side near the bottom.

In the disintegrating machines the sand is knocked about between rapidly revolving prongs in the same or

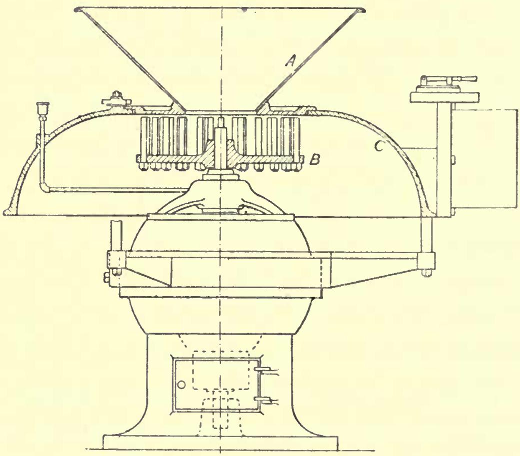

FIG. 1.—SELLERS SAND MIXER.

in opposite directions, being thrown outwards by centrifugal force. Early machines were the Schütze and the Sellers. Later ones more often have two sets of prongs, in which both sets may revolve, each in an opposite direction to the other, or one may revolve and the other be fixed. The speed of revolution is very high, and lumps are broken up effectively.

The Sellers sand-mixing machine (Fig. 1) operates centrifugally. The machine is circular, and the sand, on being thrown in through a hopper, *A*, falls among a number of vertical prongs standing up from a revolving plate, *B*. The prongs prevent the passage of stones, and disintegrate the sand in its passage outwards. By the covering plate, *C*, it is thrown to the ground beneath. The driving of the vertical shaft is done by belt pulley, set either above or below the machine, as most convenient, or by electric motor as in the Fig. The rate of revolution of the shaft is about 1,200 revolutions per minute. The hopper is hinged, and can be thrown back when necessary for the removal of obstructions. There is but little difference between Schütze's sand-mixer (Fig. 2) and that of Messrs. Sellers. In this mixer, vertical prongs on a rapidly revolving plate, *B*, break up the sand falling through the hopper by centrifugal force. *A* is the hopper, *C* the

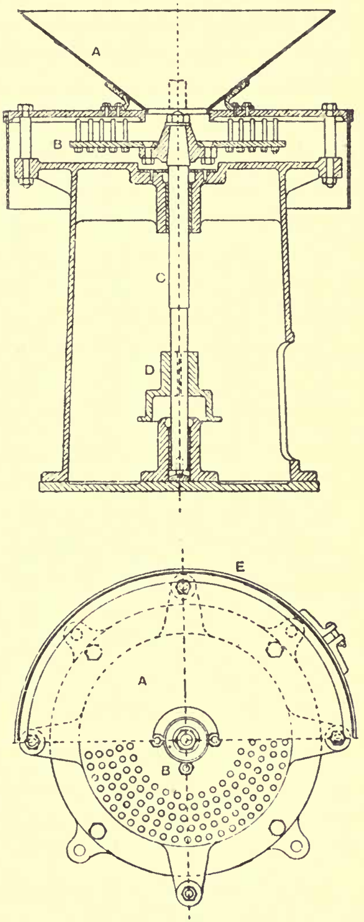

Fig. 2.—The Schütze Mixer.

shaft driven by a pulley, *D*. An indiarubber guard round the machine throws the sand downwards. The hopper and cover (attached to each other) can be thrown back on a hinge to expose the plate, *B*.

Fig. 3 illustrates a horizontal class of disintegrating mixer with double cages rotating in opposite directions, driven by separate pulleys. The hollow shaft which carries one cage runs in dust-proof ball-bearings, and the inner shaft is fitted in ring-oiling white-metal bearings.

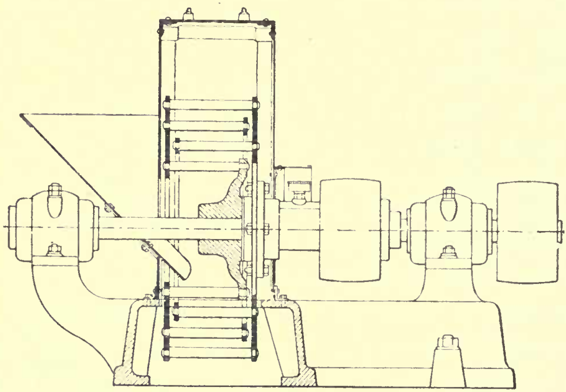

FIG. 3.—DOUBLE CAGE DISINTEGRATOR.

The sand is fed in through the shute at the side, and the hood is hinged to enable it to be thrown back for cleaning purposes. The machine is constructed by Messrs. Alfred Gutmann, A.G.

In mixing sand we seldom find moulders using weights or legal measures. It is always measured in "barrows," "sieves," "riddles," "buckets"—those being the utensils in common use in foundries.

The mixing is done by hand riddles and sieves, or by mechanisms. The first are employed in small shops.

The only difference between a riddle and a sieve is one of size of mesh. Both alike are circular, but while riddles embrace meshes down to $\frac{1}{16}$ in., sieves cover sizes below these. A screen is used only to separate the coarse lumps from the sand at the time of delivery from the quarry.

The sand is intermixed, riddled, or sieved by hand upon a rude horse formed of wrought-iron bars. The riddle or sieve is thrust backwards and forwards, along the top bars, the sand falling on the ground below, whence it is removed to the heaps, or to the sand bins, which are large recesses conveniently prepared somewhere in the sides of the shop for the storage of sand in readiness for the moulder. All the sifting and wheeling away is done by the moulders' labourers. There are several good mechanical sifters in use in foundries, operated by power mechanism, which imparts a rocking motion to the sifters.

The swinging sand sifter (Fig. 4, shown in plan and in elevation), made for driving by power, is suspended from the beams of a roof or floor above by loosely hung sling rods. The parts are as follow: *A* is the tray itself, formed of a piece of $\frac{5}{16}$ in. plate bent round to form three sides of a rectangle, the fourth side being open. There are three rows or tiers of $\frac{1}{2}$ in. round bars riveted across, so pitched out that the rods alternate with one another in the vertical direction the better to assist in breaking up the larger lumps oi sand. Over the lower row is laid the sieve bottom (not shown in this figure), the size of the mesh of which may vary from $\frac{1}{8}$ to 1 in. Screwed stay rods pass across from side to side, and by means of those which come near the ends, the straps, *B*, are fastened, to which the sling rods, *C*, are hooked. The oscillatory motion is imparted by means of the three teeth, *D*, thrusting against the pins in the slotted piece, *E*. *F*, F^1 are the fast and loose pulleys for driving, having their

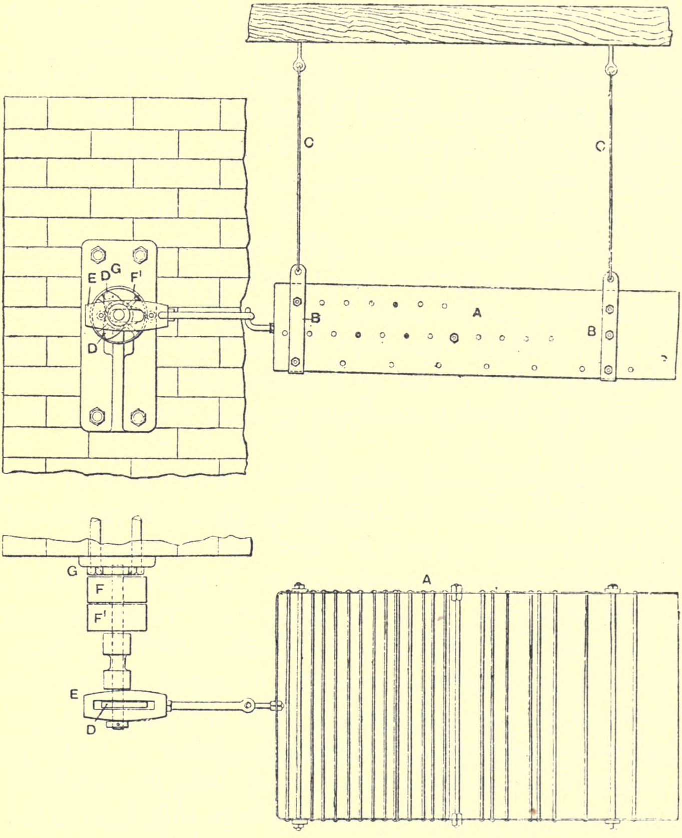

Fig. 4.—Swinging Sand Sifter.

shaft bearings in the bracket, *G*, bolted to a wall, or as convenient. The tray is suspended at a slight angle, the open end, or that farthest from the driving gear, being lowermost. The fine sand then falls vertically downwards through the sieve into a bin, while the larger lumps pass onwards and fall out at the open end.

Many sieves are of double design, with the primary

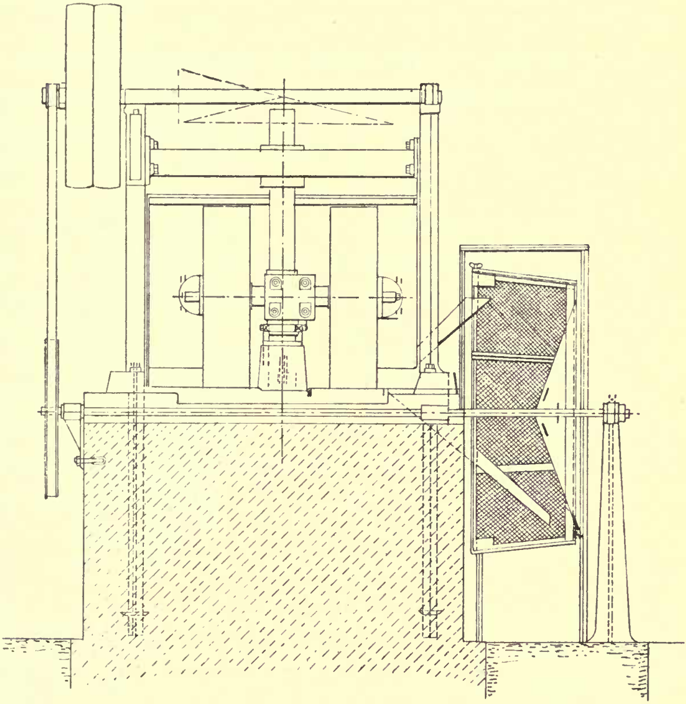

Fig. 5.—Combined Grinder and Sieve.

object of dealing with old or floor sand. Two rectangular sieves, an upper and a lower one of coarser and finer mesh respectively, separate lumps, nails, and particles of iron from the sand and discharge it, while the fine sand is dropped through the lower sieve and discharged at one end. The sieves are set at an angle in opposite directions.

Another design of sieve is rotary in action, and polygonal in outline, with a rapping device to assist the discharge. Each of these designs occurs in several modifications.

For grinding coal for facing sands, and blackening, a mill of another type is used; this is sometimes a revolving cylinder, rotating with its longitudinal axis in the horizontal position, having loose heavy rollers inside,

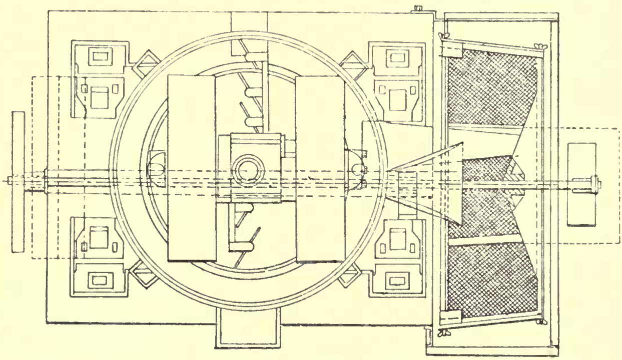

FIG. 6.—PLAN VIEW OF COMBINED GRINDER AND SIEVE.

which, as the cylinder revolves, remain in the bottom by reason of their weight, and crush the coal or coke, introduced before the mill is started through a door at the top of the cylinder. An improved form is one in which heavy balls are set revolving within a pan in an annular groove, a vertical spindle passing through the cover. The spindle is driven through bevel wheels by a belt-pulley. There is a cover of wood for the introduction of the coal, and to prevent the flying out of the dust. The ground coal is taken away through a door in the bottom of the pan.

A combined type of machine is seen in Figs. 5 and 6, comprising an edge-runner grinding pan, and an octagonal sieve, the rollers of the first named being driven by the bevel gears on the top shaft. The sieve is revolved by a belt pulley from the same shaft. When the rough lumpy sand has been ground in the pan, it passes down a shute into the sieve. If it has been ground sufficiently small it falls through the meshes and is removed; but if there are lumps of too large a size, they are carried up around the top of the sieve, and fall down the top shute into the pan again to undergo further crushing.

Fig. 7, Pl. I, represents an electro-magnetic separator in conjunction with a reciprocating sieve, built by the London Emery Works Company. The rough sand is fed into the hopper at the top, and falls on to the magnetic drum which abstracts and retains all the nails and other scraps of iron or steel present, after which the sand drops into the sieve, and is thoroughly shaken and broken by the rapid reciprocations until it is fine enough to escape through the meshes.

CHAPTER III

IRON—MELTING AND TESTING

Cast iron owes its value as a material of construction to the fact that it is not pure metal. If it were pure, it would be useless for the purposes to which it is now applied. Pure iron cannot be melted to fluidity, neither when cold is it rigid nor hard, but ductile and soft by comparison with commercial iron. Cast iron does not contain more than 93 or 94 parts of pure metal in the 100, the remaining 6 or 7 consisting of carbon, silicon, phosphorus, sulphur, and manganese, with occasional percentages of arsenic, titanium, and chromium.

The element which more than any other influences the physical character of cast iron is *carbon*, and this occurs in allotropic forms, either as graphite or plumbago, in a state of mechanical admixture, forming gray iron; or as combined or dissolved carbon, producing white iron. In most, if not all commercial irons, the carbon occurs in both forms. The proportion of combined carbon is never more than a mere trace in the gray, while the white iron is almost destitute of graphitic carbon. The mottled varieties occupy a position midway between the gray and white, and are to be regarded as mixtures of the two kinds, the mottle being more pronounced as the proportion of white increases. Here, too, the proportions of combined and graphitic carbon become nearly equalized. Gray iron is the most fluid, but is the weakest. White iron runs pasty, and is strong, but brittle. Mottled iron melts very well, and is both strong and tough.

Iron is adapted for general engineers' work in proportion to its amount of mottle, highly mottled iron being correspondingly prized by foundrymen.

There are several varieties of pig supplied by the ironmasters, ranging from the No. 1 Clyde, which is the grayest iron, to the forge pigs, which are white irons (see the Appendix). Hence it is possible to obtain pigs suited to almost any class of work, being either used alone, or by intermixture. In foundries where the same class of castings is being constantly turned out, this is what is done; but in general foundries, where all kinds of castings are required in gray, white, and mottled iron, in all their grades, usually three or four kinds of pig only are kept in stock, and the numerous grades of metal required from day to day, or during the same day, are prepared by admixture of pig with scrap. It is in these mixtures that the skill of the practical foreman or furnaceman is seen, skill which comes only after long experience. There are many moulders who would not know how to mix metals to produce definite grades, and no rules can be laid down for this work except those of a somewhat general character. Thus it is easy, having ascertained the metal which results from the mixture of certain pigs in certain definite proportions, to repeat the operation as often as required, since a grade of pig of a given brand is fairly though not absolutely constant in character. But when scrap is used, the quality of each separate piece of scrap has to be estimated by its behaviour under the sledge, and by the eye. The use of scrap, if purchased judiciously, and mixed by a competent man, is more economical than that of pig, and there is therefore advantage in its employment. Every furnaceman and foreman should therefore learn to judge of the quality of scrap and pig, and the effect of their intermixture. Afterwards he may test the results experimentally at the testing machine; but he must know how to mix, or the testing machine will record only failures.

Gray iron on being struck with a sledge fractures easily, and presents a highly crystalline structure, with a somewhat dull bluish-gray metallic lustre. If very dull, the metal is inferior, and poor in quality.

Iron follows the same law of crystallization as other substances. The slower the rate of cooling the larger the crystals produced. If a newly fractured surface of gray iron is shaded by the hand, and so viewed with reflected light only, the crystals of graphite become visible, appearing as black lustrous patches amongst the iron. If a portion of the iron is crushed and levigated, the graphite will float on the surface of the water. When the metal is molten it lies quietly in the ladle, breaking into large striations, without sparks or disturbance. After standing awhile it becomes covered with scum, composed of scales of graphite which have separated and floated to the surface. When cast, it runs fluid, and takes the sharpest impressions of the mould, being thus adapted for the finest castings. It is only moderately contractile. At the testing machine it breaks with a very moderate load, undergoing however a considerable amount of deflection first. It can be tooled easily.

If we take *white iron*, whether in the form of pig or of scrap, and fracture it, we find that it requires more force than the gray to effect fracture, but that it breaks very short and clean. An inspection of the fractured surface reveals a highly crystalline structure, but the crystals are long, fine, and needle-like in character, and of a bright, almost silvery-like lustre: no scales of graphite can be detected. The melted metal when in the ladle, though thick and somewhat viscous by comparison with gray iron, is in a state of violent ebullition; boiling, bubbling, and throwing off a quantity of sparks or jumpers. It does not run well except in considerable mass, and is highly contractile. Unlike the gray iron, it cannot be shaped with the chisel and file. At the testing machine it sustains a greater load before fracture than gray iron, but breaks with less deflection.

The *mottled iron* being a mixture of gray and white, partakes more or less of the characteristics of each, and is therefore better adapted for most castings than either of those alone. Considerable force is required to fracture a good sample of mottled iron, and when the broken surface is examined it presents that peculiar mottled appearance from which it derives its name. The crystals are of the same form as those in gray iron, but smaller, and the dull bluish lustre of that is replaced by a more silvery hue. The colour alternates, being patchy, the white contrasting with the graphitic scales still present. It melts and runs well, is tolerably quiet in the ladle, is moderately contractile, takes a high strain and a good deflection at the machine, and tools with average ease.

There are several grades of gray, mottled, and white irons, and the skill of the furnaceman consists in judging of the minute differences in these and utilizing them accordingly.

There is a grade of iron often found along with scrap, known as *burnt iron.* It is metal which, having been long subjected to an intense heat below the melting point, has lost much of its metallic character, being largely in the condition of oxide. It is of an earthy red colour, and is found in scrap containing old fire bars, sugar and soap pans, retorts, and furnace grates. In the furnace it does not melt freely, but becomes viscous or pasty, and chokes the tuyeres and the fuel. In a furnace using much of this, the slagging hole has to be kept open during nearly all the time of melting, and much of the iron mixes with and runs away to waste with the slag. It damages the furnace lining, and when poured runs very thick, and produces almost white, but rotten castings. Burnt iron can only be properly utilized by admixture in slight proportions with good open gray pig.

The largest proportion of pig used for foundry purposes is smelted either in Scotland from the Black Band ironstone; or in the Cleveland district in the North Riding of Yorkshire, from the Cleveland ironstone. Smaller quantities come from Shropshire, Staffordshire, South Wales, and a few other localities.

Pig is obtainable in five or six grades. No. 1 is the most gray and open, and as the numbers run up the iron becomes closer and mottled, or white.

Scrap.—When a furnaceman or foreman has to provide for a general run of work, as is the case in nearly every foundry, there are usually two courses open. One is to stock various brands of pig and melt from those brands, singly or variously mixed, to suit the various kinds of work on the floor. Thus, for cylinders and for liners a different quality will be required from that for firebars or ploughshare points, or, again, for machine framings or gear wheels. Though each grade may be melted on the same day, in the same cupola, the different mixtures required will be kept apart in the cupola. The ironmasters will send pig of any given quality, suitable

PLATE I

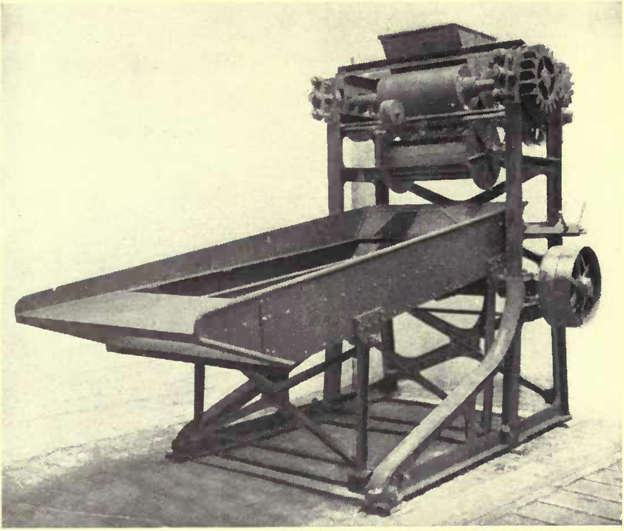

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FIG. 7.—COMBINED SEPARATOR AND SIEVE

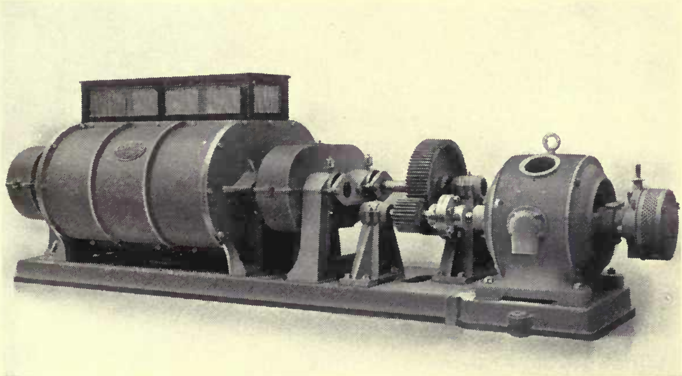

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FIG. 18.—ROOTS' BLOWER, MOTOR DRIVEN

for any class of work. Or, without a very large stock of different brands, a furnaceman who knows his business can, by judicious mixing, with or without remelting as occasion requires, make up metal to suit any job. At the two extremes there are the soft open gray, and the hard, close white pig. Between these there comes every variety of gray, mottled, and white. But in all foundries a certain proportion of scrap is used along with the pig for most classes of work. A furnaceman or foreman who thoroughly understands the mixing of scrap and pig is a valuable acquisition to a firm, for he can not only improve the quality by such mixture, but can save much money also, because scrap is often to be bought at a cheaper rate than pig. There is this further advantage, too, that scrap has been remelted once at least, and therefore the cost of such remelting—supposing pure pig would otherwise have to be used and remelted—is saved. Further, metal is improved by the mixing of several kinds of pig and scrap, very much as hammered scrap is improved by the piling and welding of all kinds of bars.

Only when a furnaceman cannot judge scrap well, is it desirable to make use chiefly of special brands of pig. There must be some scrap always used, because the runners and risers, the overflow metal, and the wasters have to be used again in any foundry. And there are few foundries that do not use one-third or one-half scrap in the mixing of metal.

Good stocks of pig and scrap should be laid in when iron is cheap. Much money can be saved by watching the markets, and purchasing heavily when prices are low. A look-out should specially be kept for good cheap scrap. A competent man should be sent to see it previous to purchase. Water and gas pipes are about the worst scrap, old engine work and machinery the best, and the older it is, almost invariably the better it is. The scrap should be roughly sorted out according to quality, and kept in separate heaps.

The quality of pig, though subject to slight variations in the same consignment, is sufficiently well known, and there is little need to look at every bar as it is broken. Not so with scrap. Every piece of this must be judged on its own merits. This is a rather tedious process, and there is only one way in which it can be done, and that is by the character of the fracture. The opinion is formed partly by the amount of work it takes to break a given piece, which is a measure of its strength and toughness; and partly by the appearance of the fractured surface, by which the nature of the iron is apparent. The broad appearances of gray, mottled, and white irons are familiar to most; the furnaceman's skill lies in judging of minute variations in these broad differences. As a rule, the rougher and more uneven and exfoliated the aspect of the fracture, and the more metallic the lustre, the stronger is the iron. If a mass of iron has draws in it, that will indicate that the iron was of a strong nature, but was not properly fed. If an iron breaks off short, and is dull in appearance, and the crystals open, it is weak and poor. Gray weak iron can be made stronger by the addition of white or mottled; and mottled can be brought back to gray by the addition of open No. 1 Scotch pig, or stove scrap. Weak iron can be strengthened by once or twice re-melting. Test bars afford a valuable aid in estimating the quality of a mixture that is required for very specific purposes, and by their aid the foreman is enabled to keep a constant check on his experimental mixtures.

Repeated *re-melting* of gray iron tends to increased strength, at the sacrifice of toughness and elasticity; the re-melted metal approaching to the white condition. Hence, after two or three re-meltings, more open pig should be added to preserve the toughness of the metal.

It is by admixture therefore that nearly all the grades of cast iron for foundry service can be obtained. The difference in the qualities of these mixtures is, as we have stated, due largely to the amount and manner of occurrence of carbon. In reference to the remaining constituents of commercial pig, and the question of their relative influences upon the metal, it will be sufficient to note very briefly the leading facts which the founder should know in relation to these, and then pass on to the tests applied to cast work.

Silicon is one of the most valuable elements found associated with cast iron. Formerly it was regarded as an enemy, producing brittle and poor metal. Now, by mixing certain proportions of silicon with white iron, it is converted into gray, the silicon throwing out carbon from the combined to the graphitic condition.

Phosphorus is always present in pig, and does no harm so long as it does not exceed 0·5 or 0·75 per cent.; a higher proportion tends to brittleness. Phosphorus however renders iron fluid, and this is an advantage for small castings, but at the same time it renders them hard.

Sulphur in small quantity produces mottled iron, separating carbon as graphite, but in excess it causes the iron to become white.

Manganese is undesirable, producing a weak and white iron.

Aluminium.—It has long been known that a very small percentage of aluminium, so little indeed as ·01 per cent., suffices to render molten wrought iron very fluid, and to prevent blow holes in steel castings. It is equally beneficial in cast iron.

It causes iron at the instant of solidifying to throw out a portion of its combined carbon into the graphitic condition, producing gray iron. The formation of the graphite is also so uniform that the thin portions of the castings are as gray as the thicker portions. In this respect it resembles silicon. Since the aluminium sets free the carbon at the instant of solidification there is less tendency to chill, which result is caused by the running of metal against a cold surface, and the consequent imprisonment of combined carbon before it has time to separate as graphite.

When aluminium causes the separation of the carbon at the instant of solidification, the scales of graphite at the surface of the casting act similarly to blackening, protecting the surface from becoming sand-burnt, and therefore producing a softer skin for cutting tools.

The presence of aluminium, by making the grain closer and finer, gives greater elasticity, and reduces the permanent set.

The shrinkage of iron is lessened by the use of aluminium. This might naturally be expected, knowing, as we do, that gray iron is less contractile than white. It is a distinct advantage, as lessening shrinkage strains on disproportionate castings.

Testing.—It is at the *testing machine* that the precise value of any mixture of metal made is ascertained, and no foundry of any pretensions can afford to be without such an instrument. Testing, in the hands of such men as Professors Unwin or Thurston, has become a scientific work, in comparison with which that of the foundry is rough and approximate only. But this is nevertheless sufficiently accurate and adequate for its purpose.

The common method of testing is to cast bars having a cross section of 2 in. × 1 in., and a length of 3 ft. 2 in. These are placed upon supports 3 ft. apart, the 2 in. being in the vertical direction, and loaded until they fracture. Fracture in a good bar should not take place with a less load than 30 cwt., in exceptional instances it goes as high as 33 or 35 cwt.; 25 to 28 cwt. would indicate a poor bar. The amount of deflection is also noted, as being a measure of the elasticity of the metal. It should not be less than $\frac{3}{8}$ in., and will in good bars be as high as $\frac{1}{2}$ in. The behaviour of bars cast from the same ladleful of metal in the same set of moulds will often be found to vary, fracture variously occurring within a range of 2 or 3 cwts.; hence it is the practice to cast several bars for testing, and take the average of the whole. Test bars should be cast from the same metal, under the same conditions of melting, as the work for which they afford the test, and should be stamped or labelled with the date, and all particulars deemed of service. They should be cast in the same manner as the work for the strength of which they are to be the index, in dry sand if the work is in dry sand, in green sand if that is in green. The relative strength of the bars is affected by difference in dimensions, a bar of small area being relatively stronger than one of larger area, the reason being that the chilling effect of the sand hardens the outer skin, and so raises slightly its tensile strength. That which is often now regarded as the standard bar is 1 in. square and 1 ft. long. This sustains about one ton before fracture. Pounds weight on this bar divided by 84 give hundredweights on the 36 in. + 2 in. + 1 in. bar; and hundredweights on the latter multiplied by 84 give pounds on the former.

Testing machine.—A machine designed for making tensile, and also transverse tests on cast-iron specimens, is illustrated by Figs. 8 and 9, being manufactured by Messrs. W. and T. Avery, Limited, of Birmingham. The construction comprises a cast-iron bed-plate, with dogs having blunt knife-edges, these dogs being adjusted along to graduations on the base, either at 12 in., 24 in., or 36 in. between centres. The base carries a cast-iron standard, fitted with hardened steel bearing blocks, upon which the fulcra knife-edges of the steelyard rest. The wrought-iron steelyard is provided with knife-edges of hardened steel, and is graduated up to the full capacity by 28 lb. divisions. It is fitted with a sliding poise by means of which it is kept in equilibrium, and the strain indicated. The poise is moved along by turning a small wheel on its front. The strain is put on by turning the hand-wheel at the top, rotating the screw, and actuating the stirrup that carries the blunt knife-edge which exerts the strain on the specimen. A spring buffer is fitted in the steelyard carrier in order to minimize the shock when the specimen breaks. A graduated deflection scale is provided, by means of which the varying deflections of a specimen under different strains can be ascertained during the test. Two series of graduations are placed on, one decimally by $\frac{1}{20}$ in. divisions up to 1 in., and the other by $\frac{1}{16}$ in. divisions up to 1 in.

Tensile specimens $\frac{1}{2}$ in. in diameter can be held in the hardened steel grip wedges, for which size the capacity of 60 cwt. allows for iron that will stand 15 tons per square inch, while bars of 2 in. by 1 in. section or less can be dealt with on the transverse testing dogs.

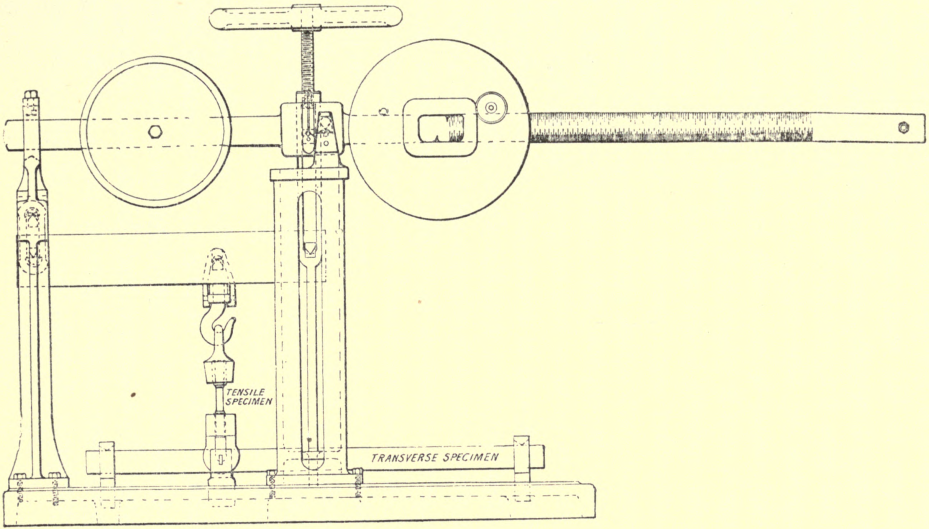


Fig. 8.—Avery Testing Machine.—Elevation.

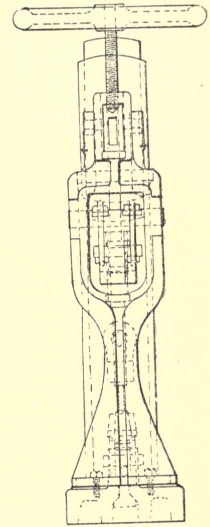


Fig. 9.—End View of Fig. 8.

Testing in the hands of an experienced foundryman reveals a great deal. For he not only notes breaking strength and deflection, but also the aspect of the fractured surfaces. He observes the extent of mottle or of graphite, the dull or lustrous appearance, homogeneity of texture or the opposite condition, the tendency to undue hardness or softness, whereby he learns how to make changes in his mixtures in order to insure the predominance of certain qualities which he desires to obtain. The iron for nine-tenths of the castings made is put together in this way. Still, the test bar tells little of real value to one who is not acquainted with foundry work, and it might tell a good deal more to the latter if used under a better method.

There are other incongruities in the commonly accepted tests of bars which strike one as rather curious. There are a few impact tests made in England. The value of impact tests is not so great as in the case of rails, because cast iron is distrusted for live loads, unless the mass of metal is so enormously in excess of that required for strength as to absorb all injurious vibration. Yet since most ironwork is liable to more or less of shock, the impact test should be of even greater value than a purely tensile test, or a cross breaking test.

There is another serious drawback inherent in foundry tests, and it is this: Little attempt is made to measure the shrinkage of iron by means of test bars. Yet many a casting is broken in consequence of excessive and unequal shrinkages. Much of this could be avoided by the use of iron selected with suitable reference to the nature of the casting. To a large extent this is done in practice by the observation of the open or close nature of the fractured surfaces of test bars, or of pig and scrap selected for making up the cast. But this is not an exact method, such as would be afforded by the measurement of a test bar. Some testing machines embody provision for the precise measurement of the shrinkage of test bars. The general adoption of this method would go far to lessen the internal stresses which frequently exist in castings, and which are a source of weakness, resulting often in serious danger.

Further, since such great emphasis is laid by metallurgists upon the influence, injurious or otherwise, of the presence of small percentages of foreign elements upon cast iron, a very distinct advance has been made in this direction by Mr. Keep, of Detroit, a brief account of whose methods follow. Not by analysis, but through physical results, can the founder learn best how to grade his irons for their specific and varied purposes.

The methods of testing adopted by Mr. Keep may be briefly summarized as follows:

Though based on chemistry, they can be applied by anyone who has no knowledge of chemical reactions or of analysis. The basis of the system is the power which silicon possesses of causing carbon in iron to pass during cooling from the combined into the graphitic condition. So that, given an iron with a sufficient percentage of total carbon, it is possible to so vary the quantities of silicon added as to produce irons in which the relative proportions of combined and graphitic carbon shall be graded to suit any classes of foundry work. Mainly, Mr. Keep makes the shrinkage of the iron the crucial test. If equal shrinkages can be produced in different mixtures of iron, then each mixture will have similar qualities as regards strength, hardness, or softness. Moderate variations in the proportions of manganese, sulphur, and phosphorus are of little or no practical consequence, provided the combined and graphitic carbons are suitably proportioned, and this is evidenced by the shrinkage. When silicon is added it changes combined carbon into graphite, and the casting occupies a larger volume than it would previously have had. All the founder has to do is to be sure that there is sufficient combined carbon for the silicon to act upon, and through. Silicon alone would increase shrinkage and harden iron, but when acting through carbon it produces an exactly contrary effect.

Making the crucial test one of shrinkage is one which is consonant with experience. Since hard white iron shrinks more than soft gray iron, and since the former contains its carbon mainly in the combined form, and the latter mainly in the graphitic form, a hard iron can be changed into a soft one by causing the carbon to separate out as graphite. Silicon effects this change, and therefore indirectly silicon added to hard white iron makes it soft and gray and diminishes its shrinkage. If, further, uniformity of shrinkage and hardness is secured in several different irons by the addition of variable proportions of silicon, the irons will be all equally graded for foundry purposes. The larger the mass in a casting, other conditions remaining the same, the less silicon will be required, because the cooling is slower, and the carbon has more time to separate out as graphite. The more carbon present, the less silicon will be required, because the presence of plenty of carbon is favourable to the separation of graphite.

It is not, however, that a certain percentage of silicon is necessary to produce a bar or casting of definite strength. It is its *influence* relatively to the mass, and not the exact proportion of silicon relatively to chemical composition, which is the essential *crux* of these methods. Irons of exactly the same chemical composition poured from the same ladle will not produce bars of precisely the same strength. But the shrinkage of a casting, which can be controlled by silicon, can be measured, and the shrinkage determines the degree of crystallization, closeness and uniformity of grain and texture, and therein lies its value. The necessary amount to be added depends not only on the percentage quantity of carbon present, but also, and much more, upon the mass of the casting. The addition of silicon retards cooling generally, producing the separation of graphite, and diminishes shrinkage. The throwing out of graphite from combined carbon removes brittleness. If shrinkage is too great, increase the silicon, and *vice versa*. In small bars and castings the silicon must be high (up to 3 per cent.), and in large bars and castings it must be low. The reason lies in the difference in shrinkage. A small casting shrinks quickly, and therefore needs more silicon to throw out the combined carbon as graphite. A large casting shrinks slowly, and therefore requires less silicon to effect the separation of graphite. Without the silicon it is possible, and would in fact occur in extreme cases, that from the same metal a small casting may be white, one of average dimensions mottled, and a very large one in the main gray.

The details of the tests are these: Bars are cast between chills or yokes in order first to ensure absolute uniformity in length, and to get a chill on the ends. The bars are of two sizes, $12 \times \frac{1}{2} \times \frac{1}{2}$ in., and $12 \times 1 \times \frac{1}{10}$ in. The thin bar is used for fluidity test, because none but very fluid and hot iron will run the whole length of the bar. The experience of the moulder soon enables him to judge of the behaviour of metal of a given quality in castings of different dimensions, made from metal which gives certain results in a test bar. And in order to furnish a ready means of comparison between bars of different dimensions Mr. Keep has constructed an ideal chart for ready reference.

Great care is taken to ensure uniform results in the testing, metal patterns being used on a bottom board, and no rapping or touching up of the mould is done. The length between the end faces is $12\frac{1}{8}$ in. There are four points noted—the amount of shrinkage of the bar, the strength under dead load and under impact, the depth of chill, and the aspect of the fractured surfaces. The dead load and impact tests are conducted in autographic recording machines. The depth of chill is ascertained by fracturing a bit out of the bar next the end. The chill will run from $\frac{1}{16}$ to $\frac{1}{2}$ in. inwards, according to quality, and is an important element in judging the suitability of an iron for a given purpose. At the same time, the aspect of the unchilled fractured surface is indicative of the open or close nature of the iron.

Chilling.—When iron is poured into metallic moulds instead of into those of sand, the result is that the surface of the casting so poured becomes of a steely character, so extremely hard that no cutting tool will attack it, and more durable, more capable of resisting the action of friction, than steel itself. It is believed that this chilling, as it is called, takes place in consequence of the combined carbon in the iron not having time to separate out as graphite. Poor irons will not chill deeply. To produce chilling of $\frac{1}{2}$ in. or $\frac{3}{4}$ in. in depth, the metal must be tough, strong, and mottled. A strong iron is also necessary, because there is tremendous stress in a chilled casting, owing to the inequality in the shrinkage strains in the contiguous portions, which are rapidly, or slowly cooled.

The iron for chilling should not be poured very hot, but dull, it will then lay more quietly in the mould. The chill should also be heated in the stove to so high a temperature that it cannot be touched with the hands. To pour metal into a cold chill is always dangerous. The surface of the chill is protected with a coat of black wash or other refractory material. In no case should the metal be allowed to beat long against a localized spot, as burning of the chill and partial fusion of the same to the molten metal is certain to ensue. The mass of metal in a chill should be large. The chill should always be much heavier than the casting which has to be poured into it; without sufficient mass, fracture is almost certain to occur.

Permanent moulds.—The experience now being gained with permanent moulds of metal promises economies in some classes of castings. If the ramming of a fresh sand mould for every casting could be abandoned in certain kinds of repetitive work, a great vista of cost-saving would be in sight. It has long been done in chilled castings; but, the chilling effect of a metal mould must be avoided in the general run of castings, such as it is desirable to produce in permanent moulds, and this tendency to chill is the principal difficulty met with in casting in these moulds. The remedy is to get the casting out before chill has formed. The time to be allowed lies within extremely narrow limits for any one shape or mass of casting, but it varies with different shapes and sizes. The chemical composition of the iron has also some influence. The difference between the chemical composition of deep-chilling, and practically non-chilling irons is vital, whether the grading is done by fracture or by analysis. But the non-chilling irons will be hardened on the surface if allowed to cool in a metal mould, and this hardening must be prevented.

Castings left to cool and chill in a metal mould have all their carbon in the form of hard, needle-like crystals, provided always that the silicon is low. If the same castings are taken out as soon as the exterior has set, the carbon will distribute itself in the graphitic form throughout the mass. This is the reason why castings are removed from permanent moulds immediately they have set, and while still at a bright yellow or orange tint. An interesting fact is that a large content of phosphorus and sulphur, sufficient to weaken a casting made in green sand, has no such result in castings poured in permanent moulds.

Attempts have been made, but with little success, to coat the interior of the metal moulds when cold with various substances to prevent chill—pulverized talc, or chalk mixed with gasolene or kerosene, and dried. When moulds are hot, heavy oils or paraffin have been used. But in the latest practice no coatings are employed.

CHAPTER IV

CUPOLAS, BLAST, AND LADLES

Although for special purposes iron is sometimes melted on the hearth of the reverberatory furnace, yet for all the usual run of work the *cupola furnace* is that which is everywhere employed. The best cupola furnaces which are in use to-day differ from those of half a century ago. Better cupolas have been designed in some respects, more economical in fuel, but many, the older ones, are retained, chiefly, it must be supposed, by virtue of their simplicity, and also because, in the hands of a careful furnaceman, fairly good commercial results can be obtained therefrom. Before noting some of the improvements which have been made in cupolas, I will briefly describe one of ordinary form (Figs. 10 and 11), and of moderate capacity, such as may be seen in daily work in many foundries.

The base *A* is of brick, covered with a cast-iron plate, *B*. The shell *C* is of boiler plate, single riveted, lined with fire-brick, arranged as headers, set in fire-clay. In small cupolas there is only one course of bricks, in large ones they are two courses deep. The vitrified slag soon forms a glassy skin over the bricks, and thus becomes a protective coating to them. A bed of sand, *D*, is beaten hard down on the bottom, and upon this is placed the bed charge, *E*, of coke; metal, coke, and flux alternating thence all the way up to the charging door,

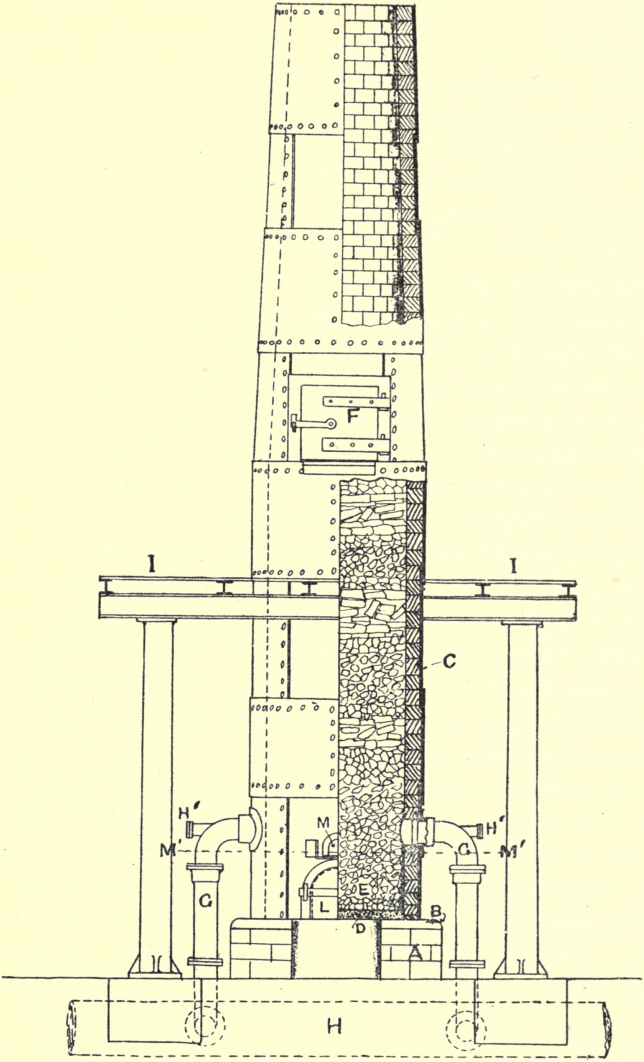
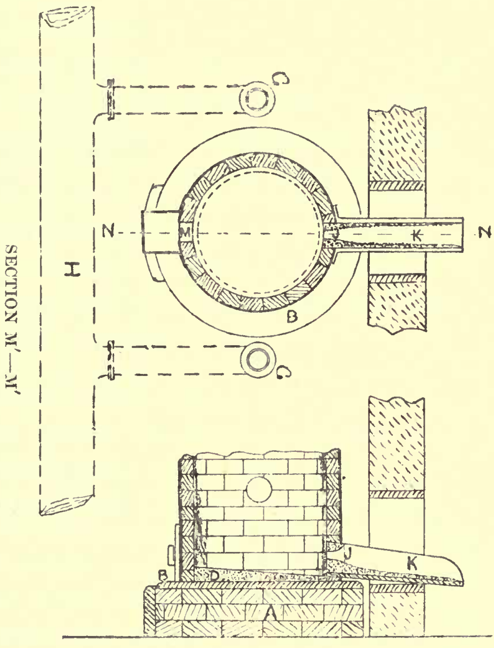


FIG. 10.—CUPOLA. ELEVATION.

F, which is about a couple of feet above the charging platform, *I*. The blast necessary for combustion is brought in at the two tuyere pipes, *G*, *G*, from the blast main, *H*, which is properly placed below the ground, as



SECTION N—N

FIG. 11.—CUPOLA. SECTIONS.

shown. The metal is tapped out at the hole, *J*, (Fig. 11), the spout of which, *K*, is usually brought through the foundry wall, outside of which the cupola is properly placed. *L* is the door closing the breast hole, through which the fire is lit, which is closed just previous to the turning on of the blast, and through which the embers are raked after the casting is done. Above the breast hole is the slag hole, *M*, placed just below the level of the tuyere openings. Through this the slag is tapped out at intervals during the process of melting.

Charging.—The method of charging is as follows. First of all, the interior up to the height of the tuyere holes is lined for a thickness of $\frac{3}{4}$ in. or 1 in. with fire-clay, or with loamy sand. The tap hole, *J*, is lined by ramming sand and fire-clay around a pointed bar inserted in the opening in the bricks. A fire is lit in the bottom, and a bed charge, *E*, of coke is laid upon this. Then follows a charge of iron and flux, and again a layer of coke, and so on alternately, as seen in Fig. 10. This is done two or three hours before the blast is put on, and in the meantime the various openings into the cupola remaining open, the fuel burns up quietly, and everything becomes warmed equably throughout. When the time arrives for the melting down of the metal, the breast-plate, *L*, is lined with sand, and wedged in place, the tuyere pipes, *G*, the bends of which are made to swivel, are put into position and luted with clay, and the tap hole, *J*, being open, a gentle blast is put on for five or ten minutes. This has the effect of hardening the clay in the tap hole. The blast is then stopped, the tap hole closed with clay by means of the bot-stick, and the full blast pressure is put on. In from ten to fifteen minutes the metal begins to run down, and presently, when the furnaceman observes through the mica sight holes, *H′*, *H′*, of the tuyeres that the metal is getting nearly to the level of the tuyere openings, he taps out a quantity into a ladle. This is done by driving the pointed end of the bot-stick through the hard-baked clay, giving the stick a rotary motion with his hands, to enlarge the hole. The metal then runs down the shoot, *K*, in a steady stream, and when the ladle is nearly filled, the tap hole is closed with a daub of clay held on the flat end of a bot-stick, the stick being held diagonally downwards towards the hole at first, and then lowered sharply until the axis of the stick is in line with the hole *J*, so closing it up without risk of spluttering of the iron.

As the metal runs down, additional quantities of iron, fuel, and flux are charged in at the door, *F*. Slag forms in quantity, and this has to be tapped out at intervals through the slagging hole, *M*. The slagging will have to be repeated more or less often according to the inferior, or superior class of the metal. As long as slag continues to run, the hole should be left open. If very inferior or burnt iron is being melted the slag may be running nearly all the while. The economy of cupola practice is largely dependent on keeping the surface of the metal free from slag.

Charges of metal of different kinds are melted in the cupola at the same time, by interposing between each charge a stratum of coke rather thicker than those used in the ordinary work of melting. The charge which is lowermost is then tapped out, as the charge above begins to melt, and the furnaceman is able to see the beginning of the melting of an upper charge at the sight holes, *H′*, *H′*.

Large quantities of metal are tapped out in detail, a ton or a couple of tons at a time, until sufficient has accumulated in the ladle. Metal in the ladle will retain its heat for a very long time if radiation is prevented by sprinkling the surface with the blowings from a smith's forge, and by allowing the oxide and scum to remain thereon.

When the melting down is done, the whole of the furnace contents are raked out through the breast hole, or, if the cupola is of the drop bottom type, like Fig. 12, p. 55, by dropping the bottom. Under no circumstances can the metal and fuel remain safely in a cupola long after the blast is shut off, since, if it sets, the mass will *bung up* or *gob up* the furnace, forming a *salamander*, and the furnace lining may probably be destroyed in the removal of the obstruction.

Economical melting.—The proper melting of metal is a task requiring a good deal of experience and caution. Economical melting is an excellent thing, but there are other points which have to be regarded besides the statement on paper that a ton of metal has been melted with a certain percentage of fuel. Iron may be melted so dull that poor, if not waster castings result, when a little more fuel would have dead-melted it thoroughly, producing good, sound, homogeneous castings. Then the size of the cupola, and the amount of work being done, has to be taken into account. A small cupola is more wasteful in fuel than a large one. A cupola running two or three hours daily is more wasteful than one running all the day. Inferior iron is more wasteful of fuel than iron of superior quality. Hence general porportions only can be given for percentages of fuel. The total percentage of fuel to iron melted may range economically from 1½ cwt. to 3 cwt. per ton, according to circumstances. Total percentage includes the fuel used in the bed charge. This always bears a large proportion to the total amount used, hence the reason why short meltings are so much more costly than lengthy casts. For a cupola like Fig. 10, 4 ft. diameter, a bed charge, *E*, of 10½ cwt. is used; for a similar cupola, 2 ft. 4 in. in diameter, a bed charge of

6 cwt. is used. But the bed charge will equal about one half the quantity of coke required for a "blow" of moderate length, say of from two or three hours.

The succession of charges in the cupolas of the two sizes above-named is as follows: 4 ft. cupola: bed charge $10\frac{1}{2}$ cwt.; each charge of iron 21 cwt., separated by $2\frac{1}{4}$ cwt. of coke; $\frac{1}{4}$ cwt. of limestone (flux) in bed charge, and seven or eight pounds on each subsequent charge. 2 ft. 4 in. cupola: 6 cwt. bed charge, each charge of iron 14 cwt., $1\frac{1}{2}$ cwt. of coke in each subsequent charge. The first cupola will melt four tons per hour, the second from two and half to three tons per hour. But in the first cupola, with heavy casts, twelve tons can be melted with twenty-five cwt. of coke, including bed charges.

In cupolas such as these, doing jobbing work, using different mixtures of iron, making many light casts, and running from two to four hours per day, the conditions for economy of fuel do not exist, and as much as two cwt. of fuel per ton of metal melted will not be an unreasonable proportion. Where contrary conditions exist, the proportions may be less by nearly one half.

The chemical conditions which govern economical working are those which relate to the purity of the fuel, and to the complete utilization of the products of combustion. The coke should be the best and purest procurable, free from sulphur, hard, columnar, heavy, having metallic lustre, and clean. The height of a cupola, the position and number of tuyeres, the density of the blast, all vitally influence the ultimate results. Height is necessary, because without it large quantities of combustible gas would escape unburnt and become lost.

Combustion.—The process of combustion is as follows: Air, under pressure, entering the cupola through the tuyeres, meets with the heated fuel. The oxygen in the air combines with the incandescent carbon in the fuel, forming carbonic anhydride, CO_2, a gas which will not burn. This gas takes up more carbon, becoming carbonic oxide, CO, equivalent to $C_2 O_2$, which is combustible. If, however, this gas does not meet with sufficient free oxygen at a high temperature, it cannot burn, but will pass away, representing a certain number of heat units wasted. But if it meets with a sufficiency of heated oxygen higher up in the furnace, it burns, giving out heat available for combustion. Hence the reason why the taller cupolas are more economical than the lower ones. Flame at, and above, the charging door represents heat lost, as far as useful work is concerned. Hence also the reason why two or three rows of tuyeres, to supply the zones of oxygen necessary for combustion, have been adopted in nearly all cupolas which have been designed to supersede the older forms, a mode of construction which is therefore seen to be quite correct in principle.

The perfect combustion of carbon to CO_2 evolves 14,647 British thermal units per pound of fuel. If only partially burned to CO, only 4,415 British thermal units are developed from each pound of carbon. A pound of carbon requires 1.33 lb. of oxygen in burning to CO, and 2.66 lb. in burning to CO_2. If the air supply is insufficient, the first oxide only is formed, and hardly a third of the heat possible is obtained. In other words, more than two thirds of the possible heat units are lost at the top of the cupola.

Even in the highest melting ratios which are obtained in practice the waste is excessive by comparison with the theoretical values. Even though the gases are burnt almost thoroughly there is much loss of heat in warming up the inert nitrogen, in warming the blast, in radiation of heat, and unavoidable heat losses in the iron and in the chimney. Actually a ratio of 10 to 1 is very good; 8 to 1 is good; 6 or 7 to 1 represents satisfactory practice.

The rapid cupola.—The embodiment of this principle is illustrated by the *Rapid* cupola, by Thwaites Bros., Ltd., shown by Figs. 12 and 13. In this there are three zones of tuyeres enclosed by an air belt, and each zone of tuyeres can be opened and closed independently of the others by means of shut-off valves. The air belt, the zones of tuyeres, and the boshes or sloping sides, are, however, of older date than this particular example. Ireland's cupolas, much used a few years since, were very tall, and were provided with boshes or sloping sides similarly to blast furnaces, by which the

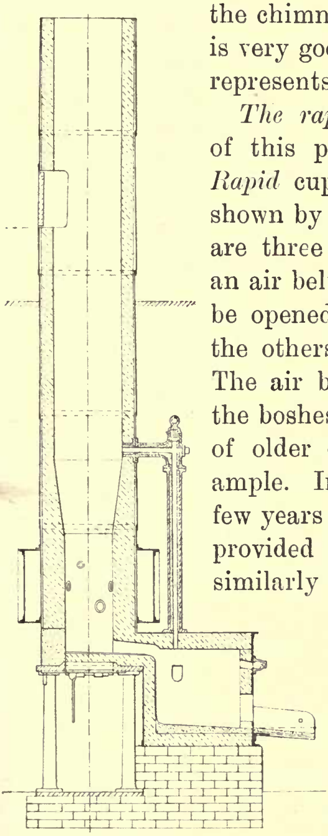


Fig. 12.—The "Rapid" Cupola.

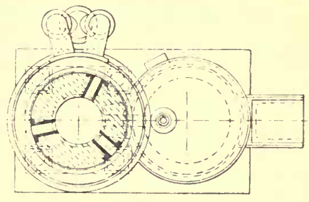


Fig. 13.—Plan of Cupola through Tuyeres.

weight of the charge was sustained. They, or at least the earlier ones, had two rows of tuyeres, but the upper row was abandoned in later structures. Voison's cupolas were made also with air belts and with two rows of tuyeres. Numbers of common cupolas, both in this country and in America, have the same arrangement. Cupolas have been made with shifting tuyeres, so that in the absence of an air belt the tuyere pipes can be moved to the zone above or below as required.

The other features of the cupola are, a brick-lined receiver for the melted metal, by which means the heat is retained and oxidation prevented, while the blast pressure maintains its surface in agitation, conducing to proper mixture and homogeneity. The waste heat therefrom is also utilized by passing up a ganister-lined pipe into the cupola, entering just above the air belt. The escape of the waste gases is regulated by a flap door at the side of the hooded top.

The efficiency of this cupola ranks high, and it has given much satisfaction where it has been erected. In blows of ordinary length it is capable of melting one ton of iron with from one, to one and a quarter hundredweight of coke. Particulars of dimensions are given in the Appendix.

The remarkable success of the air-belt design of cupola is due to the thoroughness with which theory has been translated into practice. It is based on the fact that there is no free oxygen above the tuyeres. Hence when the blast enters, its oxygen combines with the carbon in the fuel to form CO_2. This, in its ascent through the coke, unites with another atom of carbon, forming CO. This again demands oxygen for its conversion into CO_2, with development of intense heat of combustion.

In other words, the conversion of as much as possible of the carbon in the fuel into CO_2 within the melting zone is the object sought in order to develop all the heat units possible. The arrangement of supplementary tuyeres, of which there are usually half a dozen, supplies air in small volumes to the CO formed in the melting zone.

Tuyeres.—In arranging rows of tuyeres, diffusion and not concentration of blast must be accomplished, and to secure this the openings should not be arranged perpendicularly, nor be very far apart vertically. If they

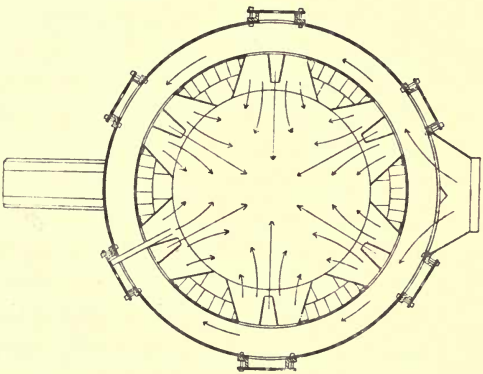


FIG. 14.—TUYERES OF NEWTEN CUPOLA.

supply a uniform and sufficient quantity of air to the melting zone, which can be judged by the working of the cupola in economy of time and in hot metal, though not necessarily in fuel consumption, their real efficiency is demonstrated.

The Newten cupola, Fig. 14, made by the Northern Engineering Works, of Detroit, Mich., has its lower tuyeres fitted with a differential device, the object of which is to send a portion of the blast right to the centre, while the larger volume is diffused more softly about the other parts of the cupola. The tuyeres are of the enlarged form, giving nearly a continuous circle of blast; but near the centre of each, two plates are set to converge, enclosing the shape of a truncated cone through which the blast, being contracted, is forced to the centre of the cupola. The remainder of the blast is diffused more softly to right and left.

Fig. 15 is a plan of the tuyere arrangements of the Whiting cupola, with a section through the wind-box.

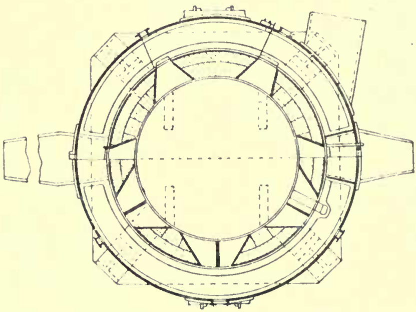


Fig. 15.—Tuyeres of Whiting Cupola.

This shows in half plan the upper and the lower tuyeres, alternated or staggered in relation to each other. They are flared, being nearly double the width of opening at the inside than where they meet the belt. The position of the upper row is fixed, but the lower row may be adjusted to different heights. And when desired, the upper row may be closed with dampers if the amount of blast has to be lessened.

Melting ratio.—Various miscellaneous arrangements of relatively minor importance contribute to the economy or durability, or facilitate the working of the cupola.

The ultimate object is to melt as much metal as possible with the smallest expenditure of fuel, consistently, of course, with thorough melting. A certain quantity of metal, say a ton, is melted by so many hundredweights of coke, say two, three, or four. The first divided by the last gives the "melting ratio," a quantity around which foundry managers are in rivalry, and concerning which no statement can be made which shall be of more than very general application.

The melting ratio must obviously be variable within wide limits, because it is under the control of so many conditions. Hence comparisons and statements can be of real value only if they are made under identical circumstances. Sometimes the ratio is stated without including the amount of coke in the bed charge, which, if included in the case of a melting of short duration, might reduce the ratio by nearly or quite one half. In a prolonged melting, running down a large quantity of metal, the bed charge will form but an insignificant proportion to the whole.

Again, in casting light work, the metal must necessarily be hotter, that is, more thoroughly melted, than for very massive work, and this requires a larger proportion of fuel; besides, a pure clean pig and scrap will require less fuel to melt thoroughly than a lot of dirty inferior scrap, with much slag, will want. But even observing these differences, and including the bed charge, in all comparisons there is much difference in cupola performances, greatly to the disadvantage of the older types.

Drop bottom.—The hinged drop bottom, though not in any way related to the efficiency of a cupola, is much to be preferred to the older solid bottom. The hinged door, on being released by a latch, allows all the contents to fall out at once. With a solid bottom they have to be raked out at the side, an operation which occupies ten or fifteen minutes, and is very hot work. It is necessary also to melt all the superfluous metal in order to run it out from a solid bottom, while it can be discharged from a drop bottom unmelted or partly melted, along with the partly burnt coke and slag. If water is thrown over it, the constituents can be separated and used again next day.

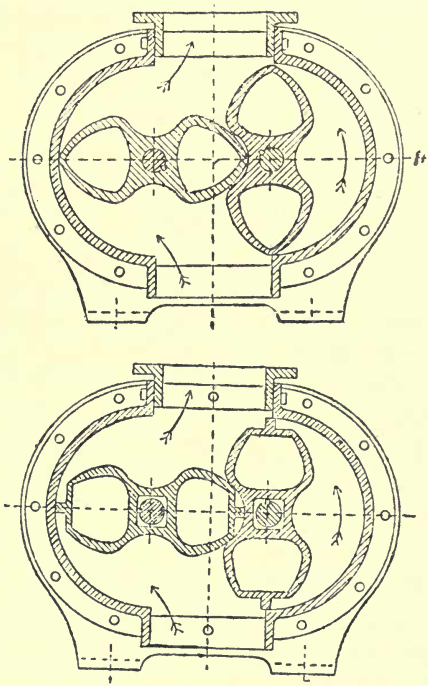
Blast.—The proper pressure of blast is a matter of great importance. A soft blast will not melt the metal quickly nor thoroughly, and will cause wasteful expenditure of fuel. A sharp blast will blow away the fuel before perfect combustion ensues. Cupolas of large capacity have been made elliptical in plan instead of circular, to enable the blast to penetrate better to the interior.

It is difficult to put in figures any rules for the blast pressure of cupolas, since it by no means follows that the pressure in a cupola is the same as that in the blast pipes; it is really less—very much less—if the pipes are not selected of suitable size, and laid properly; and it is further very variable, depending on the condition in which the furnaceman keeps the cupola, the presence of slag, dirt, and partially choked tuyeres, and too close charging, so diminishing blast pressure. The pressure in a cupola varies within several ounces from the time of putting on the blast to the period of full melting. The differences are due to the increase of resistance of the molten iron and slag, preventing that ready escape of the air which occurs through interstices of the fuel and unmelted iron. A gauge supplies the means for reading these variations of pressure. It is graduated to ounces, and reads to 2 lb. No cupola should be without one of these specially-constructed blast pressure gauges, in which the pressure or density is measured in inches of water. An inch of water gives a pressure of 0.5773 oz. per square inch. Blast pressure may range from 5 oz. or 6 oz. to 18 oz. Say we have, as an example, a pressure of 12 oz., that would be equivalent to 6.9276 in. of water, or 0.88 in. of mercury, and this may be taken as a rough average approximation to ordinary cupola blast pressure; or, putting it in round numbers, 7 in. or 8 in. of water, and 1 in. of mercury. The larger the furnace, the higher, of course, the pressure required.

Fans and blowers.—For the production of blast, fans and blowers are employed, by which the air enters the cupola under pressure. There is no virtue in mere pressure as such, but a certain rapidity of combustion is necessary in order to the efficient melting of metal. The pressure is not great, seldom more than 12 oz. per square inch, but at such a pressure an enormous volume of air passes through the tuyeres in the course of a minute. 30,000 to 40,000 cubic feet of air is necessary to melt a ton of iron, and from 20,000 to 30,000 cubic feet is necessary to consume 1 cwt. of coke. The volume of air is necessarily large, since, of the oxygen, much is lost through imperfect combustion, and the nitrogen is inert.

The difference between a fan and a blower is, that the fan acts by *inducing* a current of air, the blower produces a positive *pressure.* The fan therefore has to revolve at a very high rate of speed, causing an attendant train of evils inseparable from high speeds; the blower need only revolve at a very moderate rate. The pressure and volume are under greater control with a blower than with a fan.

The common fan consists of an outer casing, cast in halves, and bolted together. Within it revolve the blades, or vanes, upon a spindle which runs in long bearings, and which is driven by belt pulleys. The



FIGS. 16 AND 17.—TYPES OF BLOWERS.

revolution of the vanes produces a partial vacuum within the casing, into which air rushes from openings at the sides of the casing, gathering momentum, like a falling body, with increase of speed, and is forced out through the nozzle of the casing into the blast main.

In the blower (Figs. 16 and 17), the air which enters the casing (from below in the figures) is forced forward under constant pressure by the revolving pistons or impellers into the outlet above, which communicates with the blast main. These impellers are of cast iron, shaped to templet, and fit so accurately into each other, and to the bored casing, that the thickness of a sheet of paper alone preserves them from actual contact. The narrow, almost pointed ends serve to sweep out any deposit of dirt or grit which may enter within the casing. Being lubricated with a very thin coating of red oxide paint, they run, though practically air-tight, with the very minimum of friction. Two examples of Roots' blowers are shown by Fig. 18, Plate I, and Fig. 19, Plate II, the first being geared direct to an electric motor, the second driven by the special type of engine which is used for these, with two connecting rods. Ordinary high-speed enclosed type engines are also employed for this function, with a heavy flywheel on the shaft, and connection to the second shaft by the usual gears. These are by Thwaites Bros., Ltd., of Bradford, Yorkshire. A table of the performances and other particulars of Roots' blowers is given in the Appendix.

In Baker's blower there are three revolvers or drums, each of circular section. Two of these are slotted throughout their entire length in order to allow the pair of radial wings in the upper drum which propels the air to clear inside them. The lower drums are so arranged that contact is never broken between one or other of them and the upper drum. The upper drum is furnished with two radial arms which alternately sweep through the hollow portions of the two drums placed beneath it In this case also the casing is bored out truly to prevent escape of air and to ensure smooth working.

Controversy respecting the relative merits of fans and blowers is perennial. Each has its advocates, but an unbiassed mind will admit that between the best of each there is little if anything to choose. The points in favour of each are these.

With the blower, practically the same volume of air which is drawn in must be forced out, for a well made machine should have no perceptible leakage. Hence the volume of air can be controlled exactly by varying the number of revolutions of the blower, an increase in which increases the melting capacity of a cupola. The volume of air supplied being uniform under similar conditions the pressure increases with resistance offered, so that a blower will force air through slag obstructions, or through charges of increasing density. So that pressure may rise from 8 oz. to 16 oz. in the course of a blow. This is all in favour of the blower. Moreover, very minute fluctuations occur in pressure during each revolution, occurring each time the arm of an impeller discharges air. This is also claimed as of value in regular melting.

The fan acts by imparting momentum to the air and not by displacing a precise volume equal to the cubic capacity of the blower. The term centrifugal denotes that the air is delivered by centrifugal force at the circumference. The rotation produces a partial vacuum about the centre, to occupy which air enters at the openings in the sides. Pressure is increased with increase in the rapidity of the revolutions, and in the ratio of the square of the speed. The speed of a fan cannot be increased beyond the proper speed for which it is rated without absorbing additional power in the ratio of the cube of the number of revolutions. So that a fan will, under these circumstances, be a wasteful machine. Actually fans

PLATE II

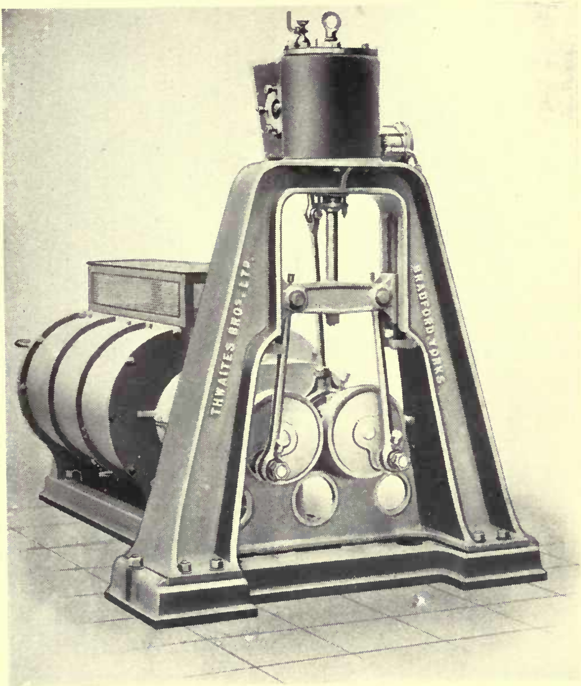


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FIG. 19.—ROOTS' BLOWER, DRIVEN BY SELF-CONTAINED STEAM ENGINE

should be selected of capacities large enough for their work, and for this the tables of manufacturers may be accepted as a working basis. And further, the pipe arrangements must be free, large, short in length, and without any quick bends, if the fan pressure is to be maintained at the cupola. The fan is not so well able to force air through dense charges of slag as the blower is. On the other hand it produces a softer blast. It is desirable with fans to have a blast gate in the main pipe for regulating the supply as the demands made upon it vary. The elasticity or flexibility of the fan, its self-adjusting capacity, is in its favour in the opinion of many foundrymen. But unless a fan is selected fully large enough for its work and run at suitable speeds, it will prove very inefficient. In its favour is that of costing less than the blower, requiring less solid foundations, and being less expensive for repairs.

The attempt has been made to employ a jet of steam to induce the blast current. This was the peculiarity of Woodward's cupola.

In the Herbertz cupola also the blast is induced by an exhausting jet of steam. The jet operates in a flue near the charging door, and the blast enters through an annular opening immediately above the hearth. The width of this opening is capable of adjustment by means of screws for the production of a cutting or of a soft blast.

Ladles.—For the pouring of metal into moulds, *ladles* of various kinds are employed. The ordinary forms are shown in the accompanying illustrations. In the group of Fig. 20, Plate III, the smallest, the second from the top, is a hand ladle holding a half hundredweight only, used for very light casts and supplying feeder heads with hot metal. Above it is seen the double handled shank ladle, made in capacities ranging from one to about four hundredweights: two, three, or four men carry these ladles, according to the weight. Thus there may be one, or two men at the cross handle; and one, or two at the straight shank. When made for two, the end of the shank is

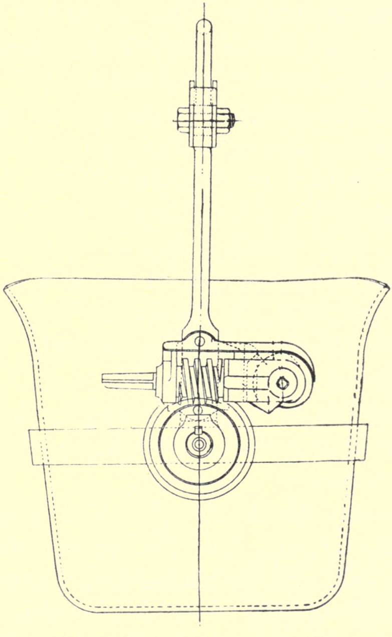


FIG. 21.—DOUBLE-GEARED LADLE.

turned down, and is supported on a cross bar, each end of which is held by a labourer. The third down in the group is a heavier, or crane ladle; it may range from ten hundredweights to a ton in capacity. It is slung in the crane hook; the catch seen on the right prevents the ladle from becoming accidentally up-tipped, and, when thrown back, a man standing at the cross handle turns the metal into the mould. The heaviest ladles are of the type shown below. These are *geared ladles*, which may range from one to twelve tons in capacity. The geared ladle was the

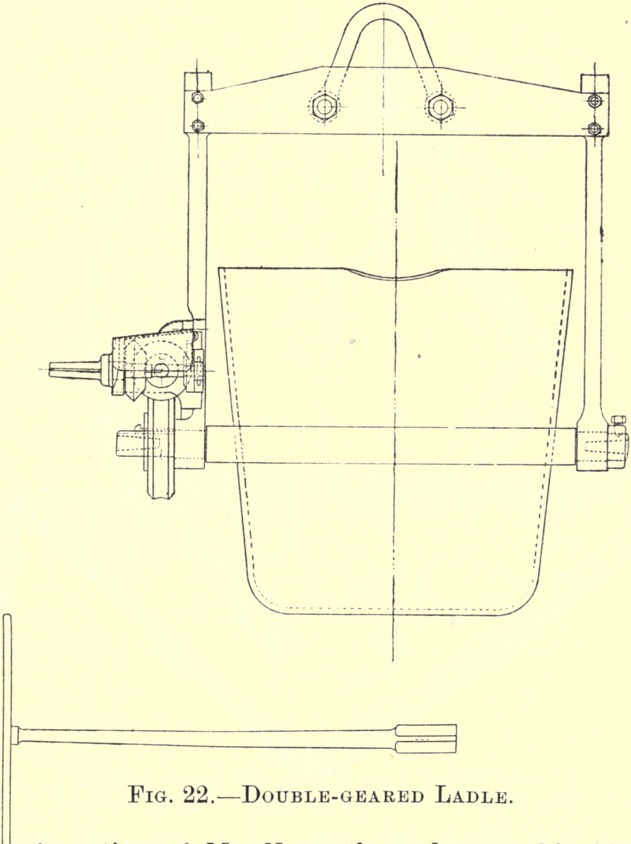


FIG. 22.—DOUBLE-GEARED LADLE.

invention of Mr. Nasmyth, and a graphic illustration of the contrast between it and the old ungeared form is given in his admirable autobiography. The ladle in the Fig. is double geared, having mitre wheels in addition to the worm gear. Many ladles have the latter only. A weight of several tons is tipped easily and steadily into the mould by means of the geared ladles.

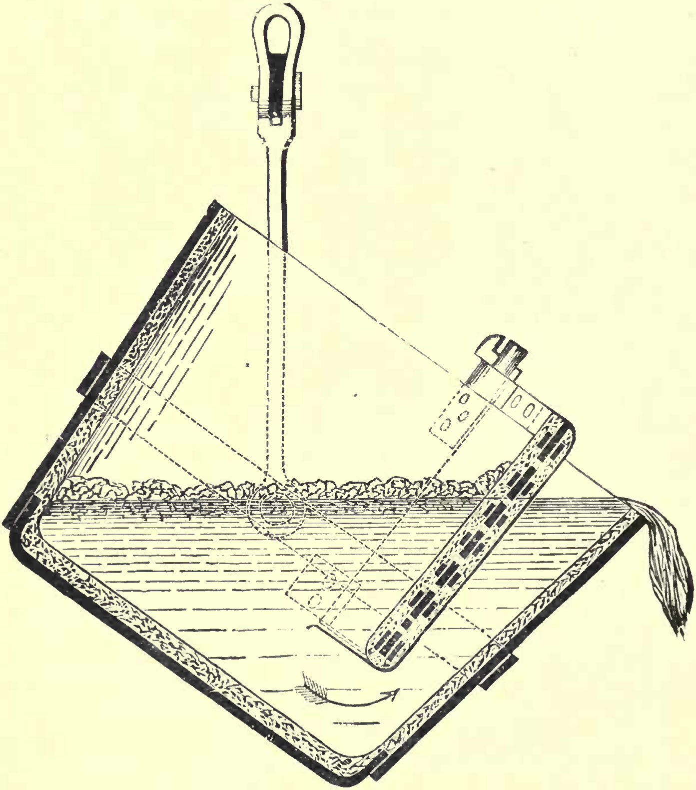


FIG. 26.—GOODWIN AND HOW'S PATENT LADLE.

Figs. 21 and 22 show the construction of a double-geared ladle by Charles McNeil, of Glasgow, of 25 cwt. capacity. The worm gear for tipping is turned by the application of the handle either directly on the square on the worm shaft, or if more convenient at right angles on the square of the mitre gear shaft. Fig. 23, Plate IV, represents a worm-geared ladle of 12 tons capacity, by

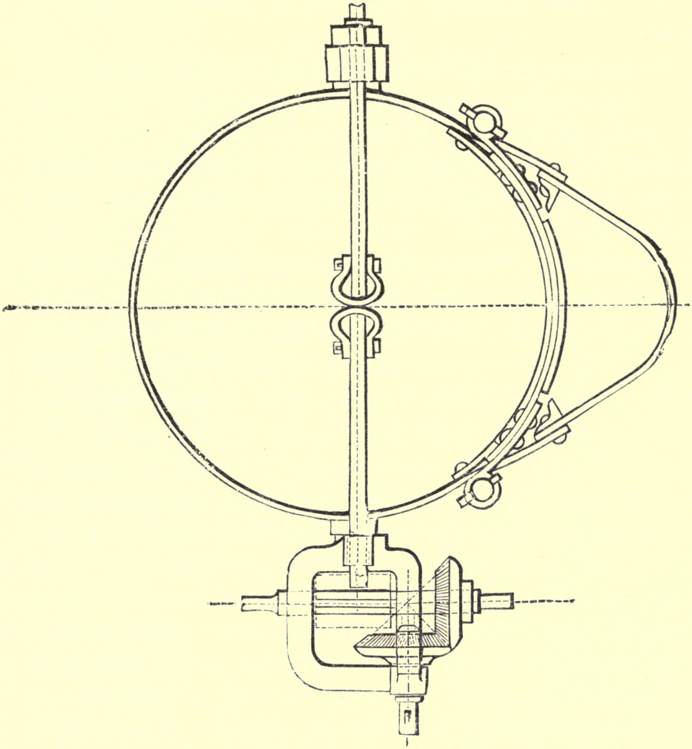


Fig. 27.—Goodwin and How's Patent Ladle.

Messrs. Thwaites Bros., Ltd., with riveted body, and Fig. 24 is a 10 cwt. ungeared ladle mounted on a four-wheel bogie. A heavier class of ladle—5 tons capacity—Fig. 25, Plate IV, is provided with a lifting bar so that it may be lifted on and off by the crane. The eight-wheel bogie carriage has ball-bearing swivels, and the wheels are flanged to run on a track. These ladles are, except the smallest, which are of cast iron, made of steel plate riveted together. The McNeil ladles are of pressed steel.

Ladles are daubed every morning before casting with fire-clay, or loamy sand, and blackwashed. This lining is dried, in the case of the smaller ladles, over a coke fire, in the larger ones by lighting a fire of wood within them. After casting, the skulls are chipped out with a hand hammer.

Skimmimg.—When metal is poured from a ladle, a boy holds a rectangular bar of iron across the mouth, to bay back the scoriae which floats on the surface, so preventing it from entering the mould, to the detriment of the casting. The method is necessarily an unsatisfactory one, but few attempts have been made to remedy it. Two forms of ladles have been patented, having a bridge or bar dividing the spout from the body; the Craven and Chapman is one; the other, Goodwin and How's, is illustrated in Figs. 26 and 27. From these it is seen that the body of the ladle is pear-shaped, the shell being extended on one side to form an external spout, which is separated from the body by a skimmer or dividing plate, projecting above the top of the shell, and descending to the required distance from the bottom. It is held in position by eyes, pins, and cotters at the top, and by finger plates at the bottom. The skimmer plate is readily removable for repairs. The principle of taking the metal from the bottom is an excellent one, and has long been adopted in the steel-casting ladles, fitted with a goose neck and plug.

CHAPTER V

THE SHOPS, AND THEIR EQUIPMENT

Situation.—When designing an iron foundry, everything must depend upon situation and upon the space available; but there are certain main considerations which may be briefly stated. In the first place, the soil ought to be dry. One of the greatest difficulties in some low-lying districts is to get a sufficiently dry site. This, which is a matter of slight consequence in the building of a machine shop or boiler shop, is of serious import when a foundry is concerned. In spongy ground, and ground liable to floods, moulds sunk in the floor are always liable to damage. In such cases new ground should be made up of a height sufficient to be above the reach of water, and especial care be taken in so lining the casting pits as to render them impervious to moisture.

The building also ought to be lofty and well ventilated, to carry off the sulphurous fumes and smoke present in all foundries. There should be plenty of light. Ventilation and light are as essential in a foundry as in a machine shop. Both should be mainly provided in the roof. A foundry cannot be too well lighted. So much of the work is, in itself, involved in shadow, as in deep lifts, setting of cores, etc., that even in the best-lighted shop the use of lamps in the daytime is frequently necessary. If the roof is well lighted, little side light is required. Still, the more the better, and, whenever practicable, side windows should be included. Further, the building should be of the same section throughout, in order that a travelling crane may run from end to end without hindrance. Again, if a large area is required, it is better to obtain that by giving increase in width rather than excessive increase in length, and this not by unduly widening a single span, but by doubling or trebling the spans, either making two of equal breadth, or flanking a main span with one or with two narrower side ones, according to circumstances. This arrangement is economical in respect of the carrying of metal and materials, flasks, and tackle; and it permits also of better overlooking and supervision. In any span there should always be clear floor room throughout, and this is of prime importance. To have cranes stuck about in the middle of a shop is a bad arrangement, because they occupy valuable room, and make the transit of metal awkward.

But these general conditions often have to be modified by circumstances, because the planning of any workshop may be hampered by the ground plan of the premises. The proximity of certain departments is desirable, and parallel bays are not always practicable.

Enlargement.—The possibility of future enlargement must be considered in laying out a new foundry. And extension can only be effected on the ground. No shops can be built over, because the heat and sulphurous fumes forbid it. Future extension must be provided for, longitudinally, or laterally, by increasing the length of a bay, or by adding a new bay or bays at the sides of the primitive building. A beginning can be made with a square building, equipped with a central crane, and one or two wall cranes. That is not a very good plan, but many small shops are constructed thus. In a future extension the shop would be made oblong, and the crane would remain to serve the heavy loam work, while the added length might be served with a traveller and light wall cranes. When starting a block of buildings, the proximity of stores, etc., must be borne in mind to save unnecessary handling of materials.

Cupolas.—Two cupolas are necessary in any foundry. The smaller will be of about 2 ft. 6 in. diameter, the larger will range up to 4, 5, 6, or 7 ft., according to the weight of work done. In a large foundry two cupolas or more of the largest capacity may be required for the day's casts. Besides these, it is often convenient to have a small one of from 16 to 18, or 24 in. diameter, having a capacity of from 10 to 30 cwt., for the purpose of making tests of mixtures, casting test bars, making a special light cast, etc.

Generally it is convenient to locate the cupolas together for convenience of charging and blowing. Inside the foundry it would often be more convenient for the tapping of metal to locate cupolas apart from one another. In the case of special departments of work, such arrangements must sometimes be made. The general rule, however, is to set cupolas together, as nearly centrally as possible, in order to lessen the distance of carriage of the metal, and the loss of blast pressure. In many foundries the practice is to locate the cupolas without the building, passing the tapping shoot through the wall into the interior. In others the lower portions are within the building, and the upper parts pass out through the roof. The latter has the advantage over the former, that the furnacemen are protected from weather, and that the foreman can observe the melting without going outside. But if the cupolas are placed without, a door at the side permits ready egress. Hydraulic hoists, or geared pulley-driven hoists, will be located at the cupola stagings for lifting iron and coke from below.

Large ladles of metal are carried away with the traveller, or with a walking crane, or swung round in a jib crane to moulds within its radius. Light casting is sometimes done from a tipping ladle on a bogle running on rails down the shop. The moulds are either poured directly from the ladle, or it is used to supply the smaller hand ladles which fill the moulds in its passage down the shop. Shank ladles, containing from 56 lb. to 4 cwt. are generally carried by hand.

Core Ovens.—The dimensions of core ovens and drying stoves depend upon the nature of the work done in a given foundry. The largest stoves run to 20 ft. or 24 ft. long, by from 10 ft. to 12 ft. wide. Height also will depend on the class of work, ranging from 6 ft. to 10 ft. Carriages will occupy from 1 ft. to 2 ft. of this height. In cases where work exceeds 6 ft. or 8 ft. in height, it is usual to effect a division in the mould, parting it into two, which are placed separately on the carriage. The largest stoves should be adjacent to the area where loam work is done. The smallest stoves are better located elsewhere, adjacent to the small core-making departments, to be used for the drying of cores, or of small moulds. The stoves, except those for very small cores, are always built outside the foundry, the doors being flush with the interior of the foundry walls. Stoves are fired with coke from the outside—that is, from the end farthest from the doors. In some cases, however, the grate is built inside in the centre of the floor. The neatest way of firing is by producer gas, or the waste gas from furnaces. The carriages containing the cores are made in cast iron, framed together, and covered with loose plates. They are run in on rails which lead from the shop into the stove. Provision is made in some foundries for drying large moulds in the foundry pits. The latter are of large area, and are heated by gas, being covered over with iron plates during the drying process.

Tracks.—Narrow bogie tracks might advantageously be used to a greater extent than they are in English foundries. The objection to their use is that they occupy some floor space that might be required, and that the ladles are apt to spill some of their contents if the track becomes temporarily obstructed. In reference to the first, a fairly clear way down the centre of the shop must of necessity be kept for the transit of materials, and of metal if carried in hand ladles. In reference to the second, mishaps need not occur if a labourer is made responsible for keeping the ways clear. Also, similar mishaps occur with hand-carried ladles. Further, too, other materials beside metal are carried on the tracks, and tackle also. The advantages are: Facility in transit, avoiding the changing of heavy ladles from one crane to another and saving in labour, one man being able to push along a load which would require three or four men to carry in shank ladles and by hand. In the light foundry more especially, the tracks are of value, since a ladle carrying 5 cwt., 8 cwt., or 10 cwt. of metal can be run over from the cupola and made to feed a dozen or twenty small moulds ranged along its track. For small moulds not in the line of track, the light 56lb. hand ladles can be dipped into the larger ladle close by, instead of running across to the cupola with them. Probably most of our readers know that one of the largest foundries in England—that at Crewe—has tiny locomotives running on its tracks. Not only for pouring, but also for running along flasks, sand boxes, and other material, is the track serviceable, saving hand-carrying for light loads and frequent waiting for the traveller to be at liberty for heavy ones.

With rare exceptions the tracks are always narrow, seldom exceeding about 18 inches gauge. The rails are either cast on plates, or they are fitted on cross-sleepers. Casting-on is a convenient device for several reasons. The rails may stand above the plates, or preferably be flush, flanked by recesses for the wheel flanges. Such tracks are arranged to connect with the yard tracks and thence with the other shops of the works.

The narrow-gauge tracks may run uniformly throughout the works, or not go beyond the shop doors, as when wide-gauge standard tracks serve the yard. These then come up to the foundry doors so that articles can be loaded and unloaded from standard to narrow and *vice versa*. Suitable trolleys are built for foundry service, being plain, or with sides to suit different classes of castings.

Casting pits.—These are either oblong, circular, or polygonal in form, and their purpose is twofold. The oblong pits are comparatively shallow, but of large area, and are used for moulding work which has to be dried, but which is so massive that it could not be dried in the ordinary core stove, or, if dried, could not be moved from the floor to the pit. Hence it is rammed, dried, and cast *in situ*. The circular and polygonal pits are usually very much deeper than the oblong pits, and the work may or may not be moulded and dried in them, but is as a rule moulded on the floor, dried in the drying stove, and only lowered into the pit finally for casting. The oblong pits being shallow, are generally lined only with brickwork, except in damp and low-lying situations where water could gain access, when they are of iron. They are covered over with movable plates of cast iron to confine the heat while drying, and are dried with gas. The deep pits, on the contrary, have no covering, being simply receptacles for finished moulds; but, being deep, they are often liable to the entrance of water, and are therefore lined throughout with iron plates, consisting either of boiler plates riveted together in the form of a

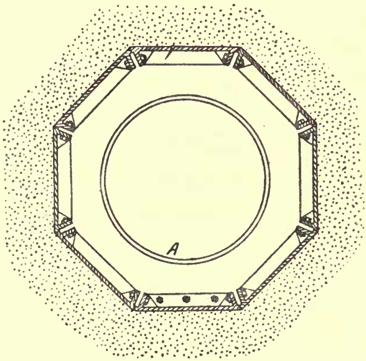


Fig. 28.—Foundry Pit.

cylinder, or of cast-iron plates bolted together with flanges like tank plates (Fig. 28). The bottom is similarly formed of iron plates.

When bricking-up work in the pit it is often necessary to erect staging at intervals for the men to stand upon while working; ladders, also, are sometimes placed in the pit, and planks laid across the rungs, but it is better to make provision when building the pit for such staging. When boiler plate is used, rings of angle iron can be riveted around at various heights for this special purpose; ribs may be cast on cast-iron plates when such are employed, or the pit itself may be constructed with rings or plates, the diameter of which increases as the series ascends, so as to form ledges at intervals all the way up.

When it is required to diminish the size of a large pit for a temporary purpose in order to put a small job in, loose rings are lowered down and the work rammed up inside them as at A (Fig. 28). Large casting pits will range from 30 ft. to 70 ft. in length, by from 18 ft. to 22 ft. in width; small ones from 8 ft. to 12 ft. or 14 ft. in diameter.

Offices, etc.—The foreman's office should overlook the entire shop, and be roomy enough to permit of the making of tests, and for the clerical work of the foundry.

The pattern bench never need be large. Patterns ought not to lie about long in the foundry. The foundry bench is not a store, but simply a receptacle for jobs wanted, and as soon as they are done with they should be cleared away from the shelving and a fresh supply of patterns sent in.

Narrow shelving—one or two rows—is arranged round the walls for the reception of small patterns after moulding, and a few moulders' small requisites—lamps, nails, etc. As soon as the castings are turned out and passed, the patterns must be removed, otherwise loose pieces will be lost and parts damaged.

Stores for the foundry, and the various machinery for the same, should be located close to the building, in such a manner that time will not be wasted in obtaining anything required Coke, sand, iron will be kept in sheds, and the machines for grinding, mixing, and breaking will be adjacent, and rails, trucks, and hoists will convey the materials whenever required. The sand and other sheds may open into the foundry, or may be located outside. There is so much dust, dirt and litter attending these, that it seems better to have them to open outside the foundry than into it, adjacent to the work of moulding.

The fettling shop must always be parted from the foundry itself. The reason is that the chips, the fins, etc., that are chipped off the castings must not be permitted to mix with the foundry sand. In the fettling shop there will be a bench with vices, small emery wheels for grinding off fins, scabs, etc., and a tumbler or rattle barrel for cleaning off sand and smoothing surfaces.

The location of the pig and scrap iron will depend on local conditions. It is not necessary that the iron shall be close to the cupolas. It may be elsewhere, provided a track is brought from the iron stores to the cupola.

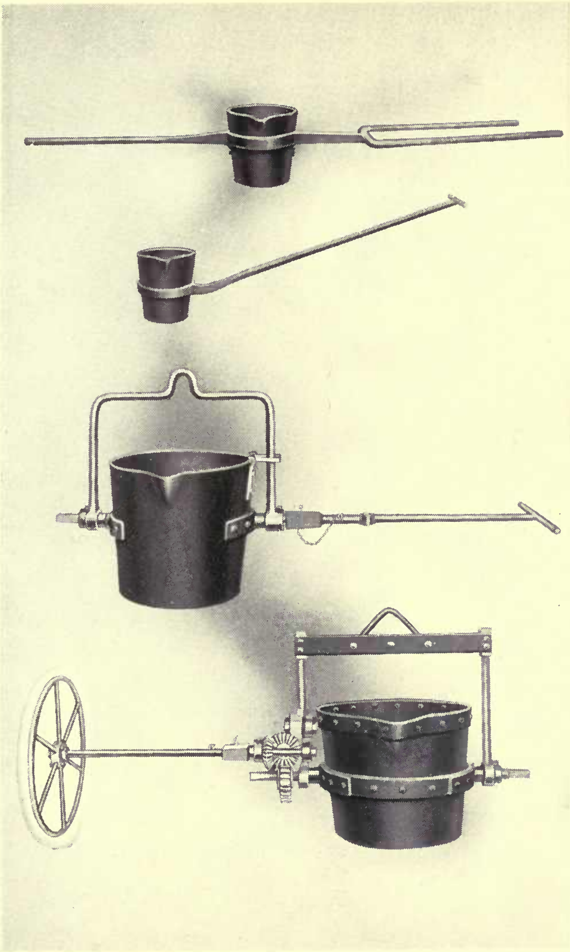
Departments.—If there are specialities in firms, as there are in most cases nowadays, each should be confined to a separate department. This is simply an extension of the principle of keeping in a general shop certain men on certain classes of jobs. Thus, wheel moulding, cylinder moulding, light green-sand, heavy green-sand, etc., will be done by men who will be kept as far as practicable each on his class of work. To keep separate classes of work in separate departments follows naturally as the volume of trade increases. Sometimes these departments will be located in separate buildings, or in different portions of a single building. It is always desirable to make a distinction between light and heavy work, because that permits of a suitable arrangement of hoisting tackle, flasks, proportion of unskilled labour required, and so on. Loam work must always be kept distinct from everything else, because of the special tackle required, the ground area occupied, the proximity of drying stoves and casting pits, and heavy hoisting tackle, and because of the dust created in filing and finishing moulds. Plate moulding, with or without the aid of machines, requires its own special area and tackle. So does railway-chair work, ploughshare work, malleable cast iron work, etc. Engine cylinders, liners, and slide valves, also, when made in large numbers, should have a separate shop, and a cupola for the melting of special metal. Brass work is always relegated to a distinct shop.

Everything which can be kept under cover should be so kept. A considerable weight of metal is lost in rust every year when tackle is left in the open. Standard grids, core bars, and the smaller flasks can all be kept in sheds without encroaching on the foundry area.

Foundry doors must be made amply large enough to pass the largest patterns or castings ever likely to be constructed. The main doors should not, as a rule, be less than 12 to 14 ft. wide, and from 10 to 12 ft. high. They are made of sheet iron to slide sideways, or vertically; in the latter case being counterweighted. Hinged doors should never be used. Smaller doors will be placed at various parts to suit various requirements.

The average foundry is almost invariably the most badly-equipped of any engineer's department in regard to labour-saving appliances. There are foundries now, considered good, in which there is no machinery and no labour-saving appliances worth mentioning—in which work is carried on by precisely the same methods which were in operation a quarter of a century ago, and where everything is still done by dint of pure physical effort; moulds made, metal carried, castings cleaned, etc., with-

PLATE III



See p. 65

FIG. 20.—LADLES, BY THWAITES BROS., LTD.

out the most obvious economies which have long been practised in the leading firms. If a fractional part of the money which is lavished in the other departments to save unskilled labour were spent in the foundry to lessen the cost of skilled labour there, the results would in time prove eminently satisfactory. The reason why this condition of things exists is that the class of work done in pattern shop and foundry is of a different character from that carried on in the boiler and machine shop, in this respect—that the work is not usually so repetitive there as in these.

There is some machinery which is indispensable in any foundry. There is much, also, of a more or less special character, the cost of which is either too heavy for small foundries, or else it is machinery which is adapted only for certain classes of work.

Indispensable machines are the coal mill and loam mill. Those which are seldom used in small foundries, but which are found in most large ones, are sand-sifters, emery wheels, rattle barrels, testing machines, and machines for breaking pig iron and coke. Machines of a special character used in special departments of large foundries doing general work, and in any shops doing special work, are the plate-moulding and the wheel-moulding machines. Articles which come under the head of appliances, and which are essential everywhere, are wheel-barrows, ladles, shovels, riddles, sieves, scratch brushes, core trestles, iron core boxes, flasks, etc.

Cranes.—These are of three kinds—post cranes, which slew completely round; wall cranes, which slew within a more limited range, generally 180 degrees; and overhead travelling cranes, the range of travel of which covers the whole of the floor area of the shop. The post cranes are very useful when the shop is of moderate size and of quadrangular form. The framework, triangular in outline, may be constructed either of steel or of wood. The post is pivoted in a toe step in the ground, and in a socket attached to cross timbers in the roof trusses. Provision is made for lifting by single and double gear, and for racking inwards and outwards; the latter being essential for the precise adjustment of the ladles in relation to the moulds, which are arranged on the floor. The power of such cranes may range from three to fifteen tons.

The wall cranes are necessarily of light construction, ranging between powers of one and two tons only. The framework consists of horizontal jib, and ties only, made in steel. The hoisting gears are attached to a bracket which is bolted to the wall, independently of the main framework. A racking carriage travels on the horizontal jib, and is worked by means of an endless rope depending from a spider wheel above. These are used for turning over and lifting the light moulds, and smaller ladles, and if ranged in series, each within range of the radius of its fellow, ladles can be passed down the shop rapidly, being transferred from crane to crane with changing hooks.

But the overhead traveller has the best arrangement for all except the very small shops. The traveller moves along the gantry beams which are supported on the stone abutments of the walls, and the crab has a transverse motion across the traveller beams. The whole area of the floor can thus be covered at will. Travellers when of small size are worked by hand from below with endless ropes, many of those of larger size by a man stationed on the crab above. Travellers of all sizes are now actuated electrically.

These will be differently arranged according to circumstances. There should be at least one overhead traveller in each bay, operated by hand or by electricity. It is well to have two travellers—one light and one heavy—in long shops where a lot of handling of flasks has to be done. In addition there must be several hand, electric, or hydraulic cranes. Columns can be utilized for the attachment of cranes which swing in a complete circle to serve adjacent bays. It is necessary to have jib cranes, as well as a traveller, in a foundry bay, because a single traveller cannot serve all the requirements of a foundry. They should not be in the middle of the shop, because they would be in the way. If a crane is placed in the centre of a bay it must be located at one end, in order not to interfere with the work of the traveller, or with the clear floor area necessary. At one end it may serve for the heavy loam work, or heavy green-sand work. Any jib crane which is adjacent to another crane should cover its radius, for the convenience of changing flasks or ladles from one to another. All jib cranes must have racking movement to cover any work lying between the post and the maximum radius, and therefore they must have horizontal jibs. Walking cranes are sometimes used in foundries, as in machine shops and turneries. They cover the whole area without remaining a permanent block. But they are not so well adapted for heavy work as the travellers.

Converted and single-motor travellers are undesirable. Each motion,—hoisting, longitudinal, and cross traverse should have its own motor, and a heavy traveller should have in addition an auxiliary hoist for light loads.

Power.—In making selection of power for a foundry at the present time, broader views have to be taken than formerly. Not only have new applications of power agencies come into the field, but the foundry itself has been radically reorganized and remodelled. Many recent foundries are machine-moulding shops; others have gone far in that direction. Human muscle—a big asset in the older shops—is of less account now than it was at one time. Mechanical aids to lift and carry are ubiquitous. As foundries have been re-designed, so also have power agencies become readapted.

One fact should seem so obvious as hardly to need stating, namely, that no single answer can be given to the question that would be of universal application. There is, for example, very little in common between a foundry doing all light work and another handling only heavy work. A foundry which deals with both classes stands in a different category from one manufacturing specialities, and so on. Each shop must be considered as an entity apart from any other. The following remarks are intended to embrace the principal conditions which exist in foundries.

The natural course to adopt in approaching the power question is to take first a brief survey of the services for which power is demanded or is desirable. These are hoisting and carrying power for the cupola, machinery for the preparation of materials, machinery for making moulds, and that for cleaning castings.

Hoisting and carrying machinery.—These are included under one heading because they are intimately related, though carrying on tracks is independent of hoisting. But all cranes carry as well as lift, and one of the principal differences in them lies in their range of action, which is least in a swinging crane, and greatest in overhead travelling cranes, and hoists on overhead tracks.

The power agencies include hand, steam, electricity, compressed air, and pressure water.

Hand power.—Hand power cannot be left out of account, because small foundries in country places depend mainly upon it. Such foundries are not able to afford an expensive power plant of any kind. The demands for crane service are too limited, too intermittent, to justify the capital outlay involved. For these the hand-operated overhead travelling crane offers a cheap source of power. It is made to be operated by a labourer on the crab, or from the floor by a dependent chain. A swinging jib crane, or two, judiciously located against walls, to cover certain areas where such help is most needed, may well supplement the overhead traveller. Such cranes must have horizontal jibs along which the jenny can be racked. Neither cranes with fixed jibs, nor derrick cranes with luffing jibs, are suitable for foundry service. In shops equipped with hand cranes the power which can be most economically installed is a steam-engine for driving the blower, the sand and coke mills, and tumblers. This is the simplest and cheapest, the driving then being done by means of belts. This machinery, small in amount, but indispensable, can be located adjacent to the blower and cupola, preferably in a shed outside the foundry wall.

Steam power.—Steam power may be ruled out entirely now in all ordinary foundries of medium and large dimensions for new installations of hoisting machines. Electricity has almost wholly superseded it, and where this is installed it serves also for the driving of the blower and the grinding mills. Overhead steam travellers and rope-driven ones were always somewhat of a nuisance, which accounts for the rapidity with which they disappeared as methods of electric driving improved.

Electric power.—Electricity is the agent which in foundries, as in other shops, is the most flexible and mobile form of power. The work of the foundry is more intermittent than that of the machine shop, and electricity is eminently adaptable to such conditions. At casting time, and when castings are being removed from their moulds, the cranes are fully occupied. During the middle of the day their service is intermittent. When electric cranes are not running they are using no power, and when in operation they absorb only the amount which corresponds with the demands made upon them. Also, nearly all cranes now built have separate motors for each motion, and for heavy and light loads, rated suitably for the different speeds and loads, thus not only economizing power, but getting the most suitable speeds for every separate motion.

The distribution of electric power from the power house entails the employment of a considerable number of motors distributed where required. But against their cost is to be set the fact that they are eminently adapted to foundry service where the cranes and machinery are scattered and used very intermittently, and they compare in this respect most favourably with any other method of power distribution. In a large foundry the average load on the motor is low, because the intermittent periods when no power is being used are frequent and long in the case of almost all machines.

In a large foundry the facilities for transmission which the electric cables afford contrast most favourably with those of steam pipes, square shafts, or cotton ropes. One power house will supply all the current required for cranes, blowers, and machinery used in the foundry. Cables supply the cranes with current, which is switched on to motors on the cranes only when required for service.

Blowers and various machines are belted preferably from short lengths of motor-driven shafting suitably disposed. Blowers are designed to suit every kind of drive. A motor is directly coupled to the blower shaft, or it is driven through one set of reduction gear, or a belt drive is taken from a countershaft above, or from a countershaft on the same bedplate as the blower, with provision for belt tightening. Or a steam-engine often drives the blower direct, being mounted on the same bedplate.

These variations are adaptable to different local conditions, and the reason why the blower is thus favoured lies in the desirability of locating it in a room by itself, away from other machines, in order to prevent access of dust to the interior. The sand and coal-grinding mills are better belted from a motor-driven countershaft. The machines in the fettling shop are similarly operated.

Compressed air.—This is a source of power which is almost indispensable in any foundry of ordinary dimensions, apart from its utilities in operating light hoisting machinery running on overhead tracks, and in some types of moulding machines. The utilities of pneumatic rammers, and of pipes for blowing loose sand away from pattern faces and out of moulds, are of much value, as also is the sand blast for fettling castings. These alone are sufficient to justify the pneumatic installation. Whether to extend the system to the operation of hoists and of moulding machines must be answered differently in different foundries.

The light pneumatic hoists on overhead tracks, covering the entire floor area, are a great help in many foundries. But since electric power has been installed so generally, electric hoists have often been preferred. The electric cable is to be preferred to air-supply pipes with their risks of leakages. The elasticity of the air lift, though not very marked in the best modern hoists, is still objectionable when withdrawing patterns, and when turning over boxes of moulds.

On the other hand, the cost of pneumatic hoists is less than that of electric ones, which have to include one or two motors, besides gears. Electric hoists are, however, better suited to the heavier loads than pneumatic types. Compressed air is used in many power-rammed machines, and its use is increasing. But many firms prefer, or are committed to, hand machines. Then the air hose should be an adjunct for blowing surplus sand out of the moulds.

Hydraulic power.—Pressure water is used very largely in German foundries. The reason of this, apparently, is that in the German shops heavy machine moulding has developed more extensively than in any other country, and for this, hydraulic pressure has no rival. But apart from this service, pressure water is now rarely installed in foundries; that is, it would seldom be used for cranes, unless already in use or contemplated for heavy moulding machines.

Formerly, in a fair number of foundries, hydraulic jib cranes were employed, and they have the advantage of being easily and minutely controlled. But there are several disadvantages incidental to the pipe connections and valves, and the liquid used, and the system is not adaptable to the other services of the foundry—the overhead travellers and the blowers and machines. The combination of steam with water, the steam-hydraulic system, has been employed rather extensively; but the disadvantages of the transmission apply to this as to the hydraulic, comparing unfavourably with the electric conductor.

Miscellaneous machines.—Cupola hoists are operated by whatever source of power happens to be installed. Direct hydraulic operation is the best if pressure water is available. But failing that, either steam or electricity are quite suitable. The latter is now predominant. Some cupolas have bucket elevation, and transportation bucket gantries.

Trolleys on tracks for transportation of materials, boxes, and castings are simply pulled or pushed by hand. In rare instances light locomotives are employed in extensive foundries.

Machinery for the preparation of materials includes pig breakers, sand grinders, sand sifters and mixers, coal mills, and loam mills. The best arrangement for these is that of short lengths of countershaft, motor-driven, with fast and loose pulleys to throw any machine into or out of action.

Machinery for making moulds includes chiefly the various moulding machines, and then all subsidiary conveying systems, which, however, are used only in shops where the output is large, and where power is available. The employment of a large installation of moulding machines need not, and often does not, involve a power plant, for the majority in use are still hand-operated. Patterns on machines of large dimensions can be dealt with thus, so nicely are heavy parts counterbalanced, and combinations of levers devised. Hand ramming and pressing is also more common than power ramming.

When power is used it is chiefly compressed air in this country, and hydraulic power in Germany.

Machinery for cleaning castings includes tumbling barrels, sprue cutters, pneumatic chisels, cold saws, emery grinders, and sand-blasting apparatus. All except the last, and the pneumatic chisels, which are operated by compressed air, are usually belt-driven. The countershaft used can be driven by a steam-engine or electric motor. The direct motor-driven unit is, however, gradually coming into favour.

In the foregoing remarks the foundry has been regarded as an isolated unit. But very often it is one department among several of equal importance in a great engineering works, and then the question of power is one which embraces the works as a whole. In such a case one large power house may supply electric current to all the shops, where it is taken up by motors located as seems most desirable.

The large works also is favourable to the best possible adaptabilities of power, because not only electricity, but also hydraulic and pneumatic plants are, of necessity, installed. The boiler shop must possess the last two. A stamping shop must have either hydraulic or steam or pneumatic power, often two of them if heavy and light work are both being carried on. In such works the foundry will be highly favoured in being able to utilize the best possible agents for its various services.

Heating and ventilation.—The heating and ventilation of foundries have too often been neglected. Modern buildings are usually lofty, the areas are large, and large end doors, which are frequently opened, are essential; and these conditions, with louvre ventilation in the roof, or alternatively swinging sashes, are frequently sufficient in foundries of large dimensions, such as those comprising two or three adjacent bays. Hence, comparatively few foundries have provision either for ventilation or for heating, where the temperature in the coldest weather seldom drops lower than about 18 degrees or 20 degrees Fahr., nor remains long at that. In the northern United States and Canada, where temperature is frequently a good way below zero for long periods, warming is imperative, and ventilation is made a part of the system.

The plenum system, using a blower circulating cold air on the outsides of banks of steam pipes which constitute a heater, and discharging it through ducts within the building just above head room, is the ideal system. The temperature within the building depends on numerous conditions which have to be weighed carefully, such as cubic capacity, amount of glass, frequency of change, difference between the outside and inside temperatures required, the latter being usually in the winter 50 degrees to 55 degrees Fahr. for foundries. Thence the temperature to be imparted to the air at the heater, the size and number of revolutions of the blower, the sizes of pipes and ducts and their numbers are calculated, being the work of engineers who make this a specialty.

Small steel converters.—Steel castings are now used instead of those of iron for so many purposes where lightness has to be sought, as well as strength, that a steel foundry has become a frequent annexe to the iron foundry. The steel firms can supply castings, but delays and expense are lessened when the iron foundries make such steel castings as are required for their own use.

This practice has been fostered and developed by the growth of the baby or small steel converters, the Tropenas being generally used. The choice lies between these small converters and the small open-hearth furnace, since the ordinary large converters handle quantities of metal too great for the small steel foundry. Moreover, the grade of metal is not so easily controlled as is that in the small converter or the open-hearth furnace.

A good deal might be said in favour of each system. The baby converter requires a rather large plant, as the metal has to be melted in a separate cupola first, and a turning or tilting gear, power-operated, is essential. The open-hearth furnace requires no such aids, but it must have regenerators.

On the whole, it appears that the small converter plant is being installed very extensively on the ground of its great utility in small castings made in small quantities, articles which have previously been forged, or made in malleable cast iron, or in one of the bronzes, or in cast steel in the regular foundries. Quantities much smaller than the contents of even a small open-hearth furnace can be melted in these converters. There are, moreover, considerable numbers of small, self-contained melting furnaces suitable either for steel or the bronzes, furnaces of tilting type and having blast pipes, as the Schwartz and others. These are extremely simple, more so than the baby Bessemer designs and therefore adapted to conditions which might not admit of the laying down of such a plant.

CHAPTER VI

MOULDING BOXES AND TOOLS

Flasks or moulding boxes are employed for enclosing either in part or entirely all moulds excepting those which are made in open sand. The lower portion of a mould may be in the sand of the floor, and its upper portion in a flask. Or the entire mould may be contained in flasks above the level of the floor sand.

The upper portion of a covered-in mould is termed the *top* or *cope*, and the flask corresponding therewith is also termed the *cope*, or often the *top part*. The flask in the bottom, or that which lies on the floor, is called the *drag*, or *bottom part*. If there is a central flask, that is named the *middle* or *middle part*. These are shown in Figs. 29 to 31. In this group, Fig. 29 is a cope, Fig. 30 a drag or bottom, and Fig. 31 a middle part.

It follows from a consideration of the obvious functions of flasks that they must fulfil these main conditions—they must be rigid and strong enough to retain their enclosed sand without risk of a *drop-out* occurring, and their joints and fittings must be coincident, so that after the withdrawal of the pattern they shall be returned to the precise position for casting which they occupied during ramming up.

Rigidity and strength are obtained by making the flasks of cast iron of sufficient thickness. Occasionally they are made in wood, this being a common practice in the United States and Canada, but the general practice here, and by far the better, is to use cast iron. The evils of a weak and flimsy flask are, springing during the process of turning over and of lifting, causing fracture of the sand to take place, and portions to fall out; and springing or straining of the cope at the time of casting, producing a thickening of the metal over the strained

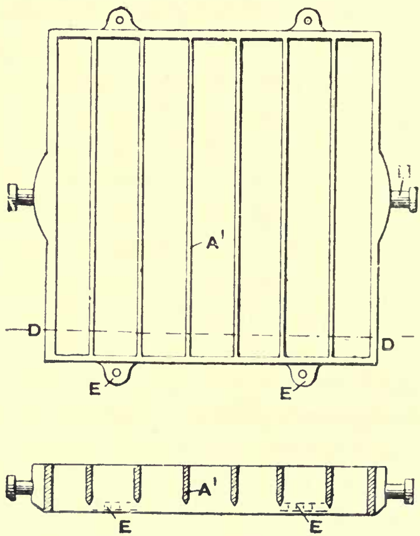


FIG. 29.—A COPE.

area. A flask should not be excessively heavy, but at least it requires to be strong and rigid.

Various devices are adopted in order to ensure the retention of the contents of flasks. Chief among these are the *bars* or *stays* by which they are bridged, A^1 A^1 in Figs. 29 and 30. These are ribs of metal usually cast with the frames, though sometimes bolted therein, to be detachable therefrom. They are arranged for the most part at equi-distant intervals. Their forms differ. Thus the typical bars for bottom or drag flasks are flat, Fig. 30, *A* [1], their function being the retention of the sand which lies thereon, and which but for the bars would mingle with the sand on the floor. Only in the case of special flasks, as for example those used for pipes,

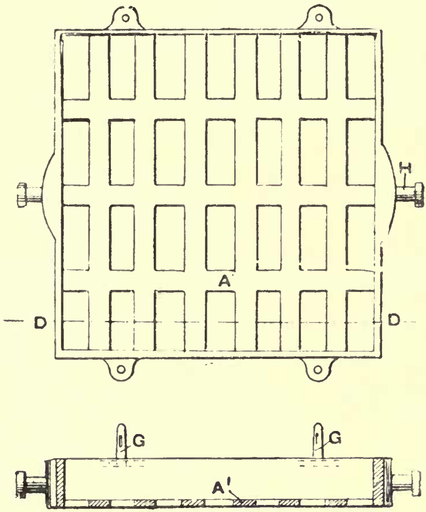


FIG. 30.—A DRAG.

columns, and for repetitive work (Figs. 32 to 34) in which the bars follow the contour of the pattern, is this practice departed from. The bars in the cope (Fig. 29, *A* [1]) are made on an essentially different plan. Here they are never flat, but always vertical, being rather of the nature of ribs than of bars. For general work they are parallel, as in Fig. 29, but for special work their lower edges are cut to the contour of the pattern which they cover (Figs. 32 to 34), but kept to a distance of $\frac{1}{2}$ in. or $\frac{3}{4}$ in. away from the patterns. They are always chamfered also, Fig. 29, because if left flat, the sand lying immediately underneath the bars would be insufficiently rammed. Being chamfered almost to a knife-edge, the full pressure of the rammer is exerted immediately underneath the bars, as elsewhere.

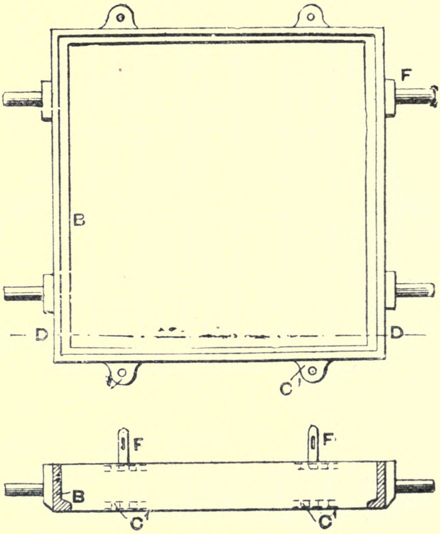


Fig. 31.—A Middle.

There are no stays in middle parts excepting for some special work. Middles for general work are always left clear of bars, as in Fig. 31, because they have usually to contain a zone of sand only, the central portions being open. To retain this zone of sand, *rods* and *lifters* are employed, the function and mode of use of which are described at p. 147. Lifters are also employed in the cope. A rib is cast around the inner bottom edge of a

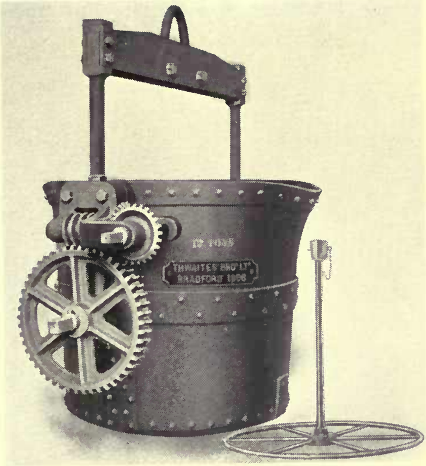


Fig. 23
Heavy Ladle

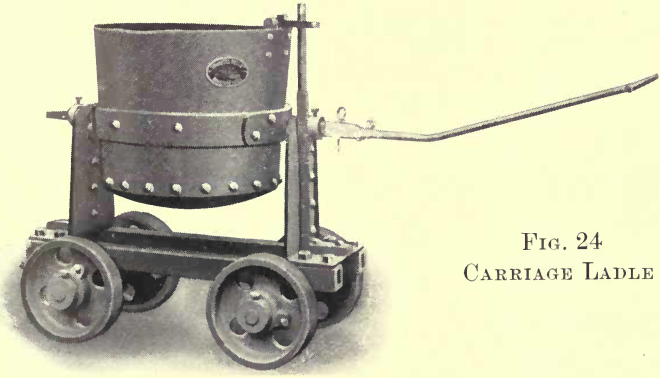


Fig. 24
Carriage Ladle

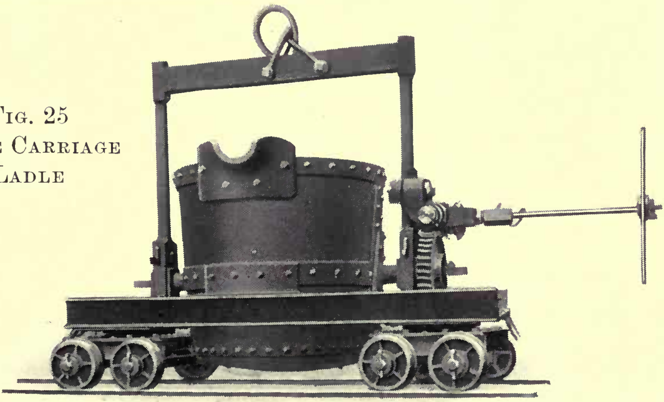


Fig. 25
Bogie Carriage Ladle

See p. 69

[*Facing p.* 96

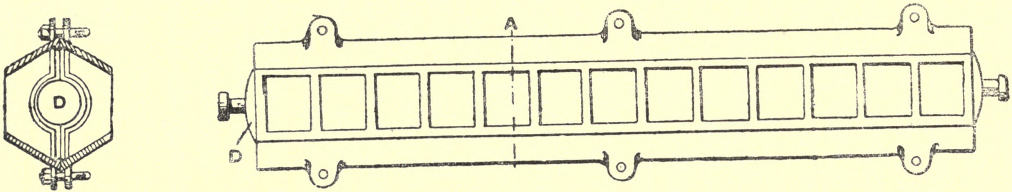


Fig. 32.—A Pipe Box.

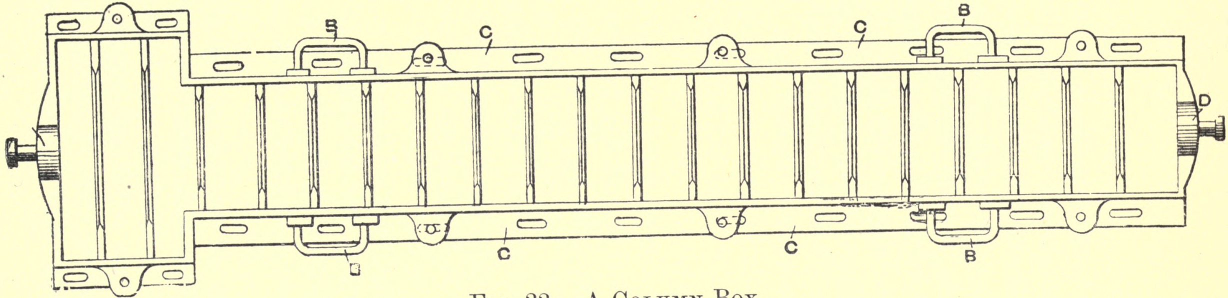


Fig. 33.—A Column Box.

Flasks.

middle, Fig. 31, *B*, to assist in the retention of the sand, and also as a convenient support for the rods which help to carry the lifters and the sand.

Flasks are always cast with a very rough skin, the better to retain their contents. They are frequently made in open moulds, no blackening is used, and their inner faces are often purposely hatched up to increase their adhesive power.

The coincidence of the joints of moulds is effected differently in the case of work which is bedded in, than in that which is turned over. Thus, the mould being *bedded* mainly in the floor, the cope is set by means of *stakes* of wood or iron; but being *turned over*, the flasks are fitted with *pins*.

In the first method, one example of which is shown on pp. 165 to 169, the pattern having been bedded in, and rammed up as far as the joint face, parting sand is strewn thereon, and the cope lowered into its position for ramming. Before being rammed, however, its permanent place is definitely fixed by the stakes, which are driven deeply down into the sand of the floor alongside of the lugs, Fig. 29, *E*, *E*, or other projections standing from its sides. See also p. 174, Fig. 97, *D*. Being then rammed, and afterwards lifted off for withdrawal of the pattern, and cleaning and finishing of the mould, it is returned and guided to its original position by the stakes in the floor.

In the second method the lugs cast upon the sides of the flask parts have holes drilled to correspond with each other, and long turned pins are bolted into the lugs which are lowermost, and pass into the corresponding holes in the lugs above. The more care which is taken with the fitting up of these lugs, the more accurately will the boxes and consequently the mould joints correspond. The length of the pins should be settled with reference to the nature of the work. In any case the pins should enter their holes before any portions of the opposite mould faces come into contact. Unless the pins guide the closing mould there is always danger of a crush of the sand occurring. In shallow flat work, therefore, the pins may measure no more than 3 in. or 4 in. in length. But in work having deep vertical or

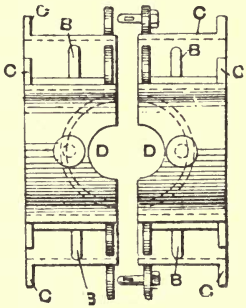


FIG. 34.—SECTION OF COLUMN BOX (FIG. 33).

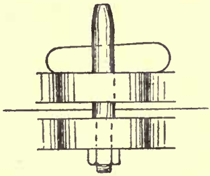


FIG. 35.—PIN AND COTTAR.

diagonal joints the pins may require to be 8 in. or even 10 in. long. The practice is usually to make the pins point upwards. Thus, in Figs. 29, 30, and 31, the parts of the flasks are represented in their correct relations for super-position at the time of final closing of the mould. The drag (Fig. 30) has its pins *G*, *G*, pointing upwards ready to enter into the lugs C^1, C^1, of the middle (Fig. 31). The pins *F*, *F*, of Fig. 31 also point upwards to enter into the lugs *E*, *E*, of the cope (Fig. 29).

The best method of securing the pins is with cottars (Fig. 35); sometimes, however, in deep moulds cast vertically, the pins are short, and the ends are screwed and the tightening is effected with nuts.

When flasks are retained in position with stakes, cottaring or screwing cannot of course be effected, yet great counter pressure is necessary to prevent a cope from being strained and lifted at the time of pouring. *Weights* are therefore employed for this purpose, the amount required being estimated roughly according to the area of the mould, and its depth from the pouring basin.

If the contact area of a cope measures four feet square, and the height of the pouring basin is one foot above it, the amount of weight required by calculation to keep it down, including its own weight, will be $48'' \times 48'' \times 12'' \times {\cdot}263$ lb., the latter being the weight of a cubic inch of iron. This would give 7,121 lb. required for loading, or over $3\frac{1}{4}$ tons. Actually, a moulder seldom attempts to calculate the weight necessary to load a flask properly, because so many other conditions have to be considered besides the simple laws of hydrostatics. There is a good deal of pressure due to momentum to be taken into account. Metal poured directly into the mould will exercise more straining action than that led in at the side. Rapid pouring again will cause more momentum than slow pouring. Hot metal will induce more strain than dead metal. Risers relieve strain. The moulder, therefore, loads according to the best of his experience and judgment, and not by calculation merely, which alone would often lead him astray.

There are numerous minor attachments to flasks, used both for general and for special purposes. All flasks require to be turned over, either for ramming, or for cleaning up of the mould. For this purpose handles are provided in the small flasks, and middles, Fig. 31, *F*, and swivels in larger ones, Fig. 30, *H*, and Figs. 32 and 33. The swivels rest in slings depending from a cross beam, the beam being suspended from the crane the while. Since handles and swivels require to be very firmly secured in place, they are not only made of wrought iron and cast in position, but the metal is increased around that portion which is cast in, as shown in Figs. 29, 30, 31, 32, and 33.

There are other attachments, as handles, Fig. 33, *B*, *B*, for turning over flasks which are too long to be slung in the crane in the manner just noted, and for lowering them into the foundry pit for vertical casts. There are also flanges, *C*, *C*, in the same figure, for the attachment of *back plates*, that is, plates of cast iron bolted to the backs of deep flasks which have to be poured vertically, and which are subject, as all deep moulds are, to enormous liquid pressure. The back plates prevent all risk of the pressure forcing out the molten metal, and so producing a waster casting.

The forms of flasks vary widely, being rectangular, both square and oblong, and having ordinary, or special bars. Or, cope and drag may be precisely alike, and bars be alike in each, as in Figs. 32 and 33, which represent pipe and column boxes, Fig. 32 being for pipes, and Fig. 33 for columns. The sides are bevelled in Fig. 32, to economize the sand, and time spent in ramming, a consideration when large numbers of casts are required. In Fig. 32, and Figs. 33 and 34 the holes *D* in the ends are for the purpose of allowing the ends of the core bars to project through. Flasks are also circular for circular work, or of irregular and unsymmetrical outlines to suit work of special character. In jobbing shops, flasks will be sometimes fitted with interchangeable bars bolted in place. Pockets also are often fitted at the ends, which are then bolted on, to be removable, the object being to increase the length of the flask. Sometimes pockets are bolted on the sides to take branches, and holes are cut

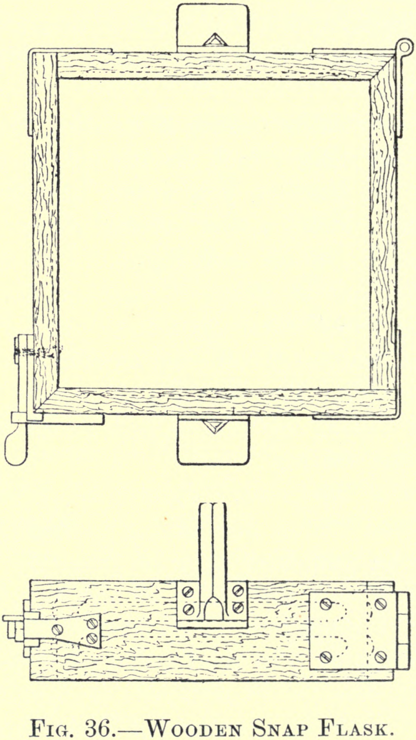


Fig. 36.—Wooden Snap Flask.

through the flask sides next the pockets. In all these cases the question to be decided is one of relative cost, as between the expense of the alterations, and that of a new flask. Flasks cost little for making, and the metal is always worth nearly its first value for re-melting. The dimensions of flasks will range from 6 in. to 12′ 0″ square, or from 1′ 6″ to 20′ 0″ long, if of oblong form.

Snap flasks.—Figs. 36 and 37 show a wooden snap flask, made up to about 14 in. square, with pins of triangular section, having provision for taking-up wear.

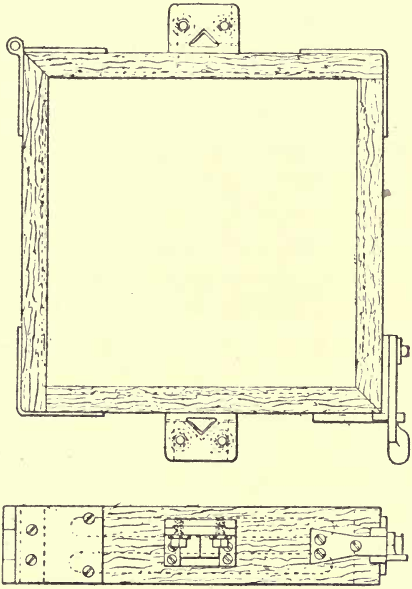


Fig. 37.—Wooden Snap Flask.

These are made of birch or other suitable hard wood, 1 in. to $1\frac{1}{8}$ in. thick, by 3 in. deep, in standard sizes. As no bars or stays can be used, each side has two concave recesses cut longitudinally, so that the boxes can be lifted without risk of the sand falling out. The fast corners are bonded with $\frac{1}{8}$ in. sheet iron running the whole depth. The hinge is made with $\frac{1}{4}$ in. straps. The snap at the opposite corner is of the latch type (compare with Fig. 38), and the latch cannot be locked in place unless the corners are in absolutely close contact. This fitting is of brass, to avoid rusting up. The pins, which are also of brass for the same reason, are seen in Figs. 36 and 38. The pin is cast on an angle bracket that is screwed to the side of the top box, and fits through a a hole in another angle bracket on the bottom box. This bracket is made in two pieces, one of which is screwed to the box side, and the other attached to the horizontal

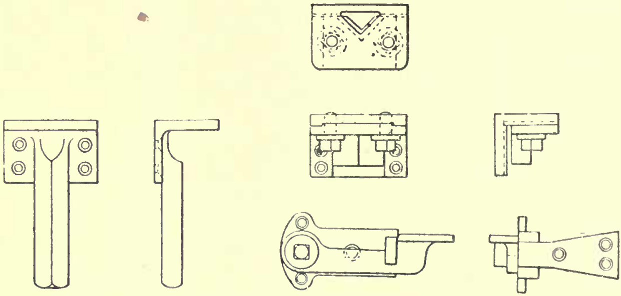


Fig. 38.—Details of Snap Flask.

portion with two set bolts, over which slot holes in the adjustable piece slide, permitting the taking up of wear.

The pattern plate, Figs. 39 and 40, has triangular holes to receive the pins, and lugs on opposite corners for the purpose of rapping and lifting it by. The plate is of cast iron, $\frac{1}{2}$ inch thick, planed on both sides. That shown in the figure has pattern parts on both sides, and ingates and runners on the top, Fig. 40. Presser boards for top and bottom, Fig. 41, stiffened with battens, fit freely inside the flask parts.

A man and a boy operate a machine and set of moulds thus: The sand being mixed and damped and thrown in a heap at the side of the machine, the man commences work by placing the complete flask on the machine upside down —that is, with the pins pointing downwards—and lifts off the upper part, Fig. 36 (the bottom part in the completely-rammed mould). The pattern plate is next laid on the joint face of the box part—with the deepest portion of the patterns facing upwards—and the upper part is replaced over the plate, the pins passing therefore through the plate and the lower one. The lad now throws sand into the box from the heap, while the man tucks the sand round the patterns with his hands. When the box part is filled, the sand is strickled off level, and the bottom board, or carrying-down board, Fig, 41, is laid upon the strickled surface.

During this time the table or platen has been standing out clear of the presser head, but now a catch on the right-hand side of the machine, which has hitherto retained the table in place, is released, and the table is moved to bring the mould under the presser head. The lever is pulled sharply once or twice, raising the table and bringing the press board in contact with the head, compressing the sand, and sending the presser board between the box sides to a depth of from $\frac{3}{4}$ in. to 1 in.

Releasing now the lever and the catch, the table moves forward and remains locked in a slot, bringing the box clear of the head. The man now turns it over, and the same operation of shovelling in, tucking, and strickling off the sand is gone through. The second presser board, now put on, carries the pattern cup for the ingate, which comes plumb over the ingate boss on the pattern plate. The same operation of running the table back and pressing is repeated.

The table is next drawn out, the pressing board lifted off, leaving the impression of the pouring cup, which is now connected to the boss beneath by removing the sand with a tubular cutter. The lad next raps the projecting lugs at the corners of the pattern plate, and the man lifts the top part of the flask and places it on edge on a stand at the left-hand side of the machine. The lad raps the plate on the top face, and the man draws it, together

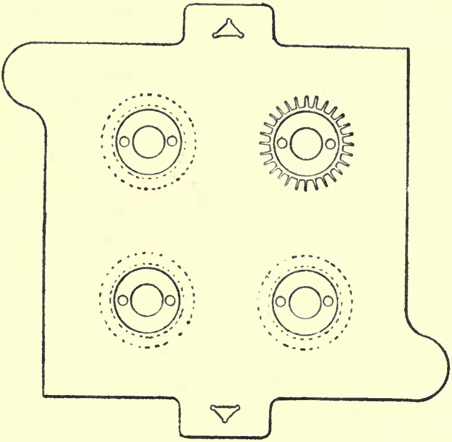


FIG. 39.—PATTERN PLATE FOR SNAP FLASK.

with the lower sections of the patterns, from the bottom part. The lugs, with their well-fitting pins, enable the man to give a steady perpendicular lift until the patterns are quite clear of the mould.

At the next stage the halves of the moulds are closed, standing on the bottom press board. The catches or snaps at the corners are released, and the flasks are opened on their hinges away from the mould, which is left standing on the board. This is then carried away bodily and laid on the floor, and other similar moulds made, so that instead of a separate flask for each mould, one flask suffices, and as many bottom boards as there are moulds in a day's work.

As there is no cottaring of pins done, the moulds are kept closed by flat weights—one to each mould. Each covers the area of the mould and has a centre hole through which pouring is done. They are lifted by

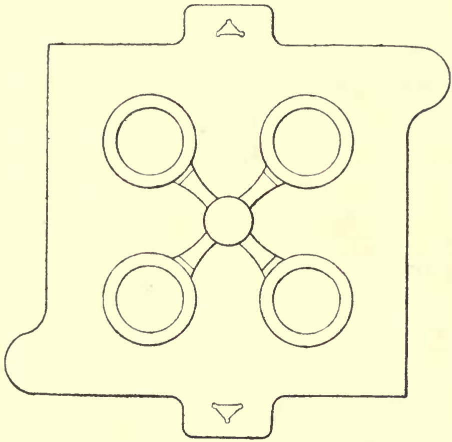


FIG. 40.—PATTERN PLATE FOR SNAP FLASK.

wrought-iron eyes cast in at opposite ends. About six weights suffice, because they are being moved from the first moulds poured as the pouring is being done on the fifth or sixth. The lad does this as the man pours.

With regard to the effect of the pressure of metal on moulds unsupported by flasks, no difficulty occurs unless the moulds contain rather heavy castings. In cases where their weight does not exceed about 12 lb. there is no trouble. In heavier ones, up to about 28 lb. weight, the moulds are enclosed with sheet-iron binders, which are slipped over the moulds. As light castings form the staple in many foundries, the saving in cost and storage room for flasks mounts up. Actually a man and a boy can put down from 150 to 200 boxes in a day, besides

Fig. 41.—Presser Board.

getting the sand ready, coring when required, casting, and knocking out the castings.

The illustration, Fig. 42, is drawn to give the relation of the box parts to the pattern plate, shown between them, and the top and bottom presser boards.

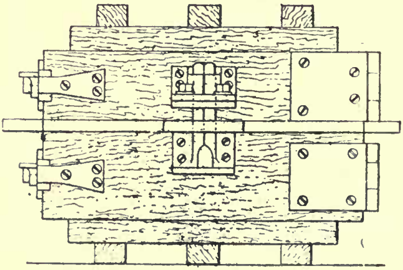


Fig. 42.—Shows Relation of Box Parts to Pattern Plate and Boards.

Tools.—The small tools used by moulders, and mostly provided by themselves, though not numerous, are very characteristic of the work done. Foremost among them is the *rammer*, varieties of which are shown in Fig. 43, *A* being the usual form of *pegging rammer*, *B* another form, *C* and *D* *flat rammers*. *A* and *B* are employed for consolidating the sand in narrow spaces, and generally for all the earlier stages of ramming, *C* and *D* being used only for final flat ramming, or finishing over of surfaces. *E* shows the manner in which the flat rammer is handled, a wedge at the lower end being driven home by the forcing down of the handle into the socket of the rammer head.

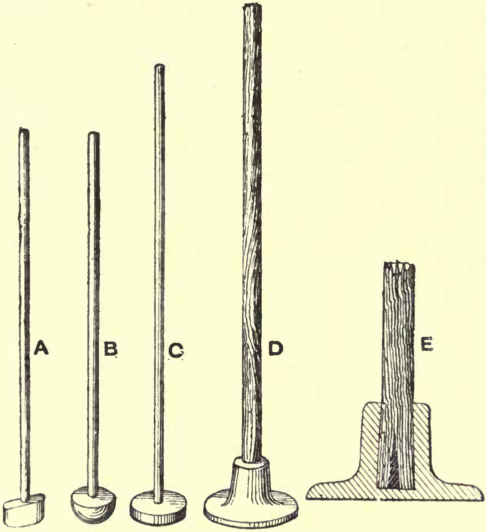


FIG. 43.—RAMMERS.

Vent wires are shown at Fig. 44, *B* being a small *pricker* or *piercer*, as it is sometimes called, the other, *A*, being larger and requiring considerable force to use. The smaller wire, which may be from $\frac{1}{8}$ in. to $\frac{3}{16}$ in. in diameter is employed for piercing the sand in the immediate vicinity of the pattern with innumerable holes, all leading into larger vents, or into the *gutters* in the joint faces. The larger wires will range from $\frac{1}{4}$ in. to $\frac{3}{8}$ in. and are used for venting down to cinder beds underneath flasks, and around the edges of deep patterns, bringing off the vents from the smaller channels.

The *trowels* (Fig. 45) are in perpetual request for

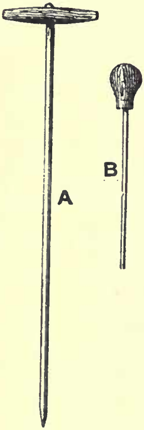


FIG. 44.—VENT WIRES.

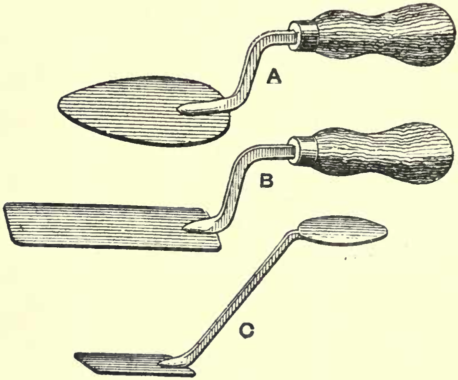


FIG. 45.—TROWELS.

smoothing or sleeking the surfaces of moulds, for spreading and smoothing the blackening, and for mending up broken sections of moulds. They are also employed for *finning* joints of dry sand moulds, for marking lines on

FIG. 46.—CLEANER.

sand faces, and are improvised for many purposes beyond those for which they are legitimately designed. *A* is the common *heart* shape, *B* the *square* trowel, and *C* the combination, or *heart and square* form.

Fig. 46 is a *cleaner*, a tool used for mending up and

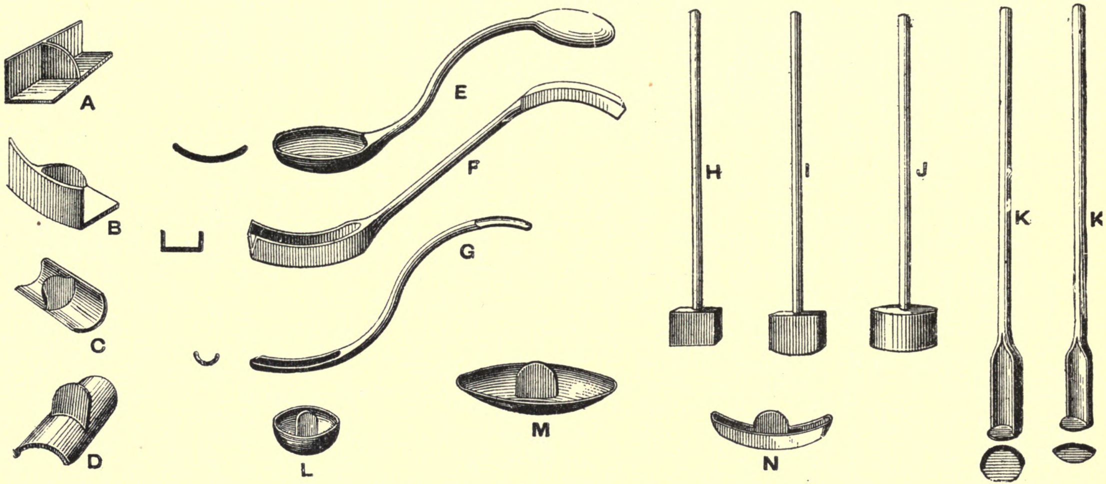


Fig. 47.—Finishing Tools.

smoothing the deeper portions of moulds which cannot be reached by the trowel.

The remaining figures (47) illustrate finishing tools. *A* is a *square corner sleeker*, also spelt *slicker*, or *slaker*. *B* is a similar tool, except that one face is adapted for sweeps, hence called *flange corner sleeker*. *C* is a *bead tool or smoother*, or *pipe smoother*, for smoothing the impressions of beads or sweeps of that section. *D* is a *hollow bead*. *E* is a *spoon tool*. *F* is a square or *flange* bead. *G* is a *bead tool* curved lengthwise. *H*, *I*, *J*, are *flange tools*, *K*, *K*, *boss tools*. *L* is a *Button sleeker* or *bacca box smoother*. *M* an *oval pipe sleeker*. *N* another pipe sleeker. These tools, with a rule and calipers, complete the private kit of a moulder.

Other aids.—The general appliances, used in moulding, omitting those of the nature of machines, and those not directly employed in moulding, are shovels, lamps, riddles, sieves, buckets, water-cans, bellows, oil-cans. Shovels are used for sand-mixing and box-filling, lamps for throwing light into the darker recesses of moulds; the uses of riddles and sieves have been described, p. 23; buckets and water-cans are used for damping sand and swabbing moulds, bellows for blowing away parting sand and loose particles generally, oil-cans for pouring oil over chaplets, and on damped corners and sections of moulds to prevent the metal from bubbling and causing scabs. These are all provided by the firm for general use.

CHAPTER VII

SHRINKAGE—CURVING—FRACTURES—FAULTS

THOUGH the laws which govern shrinkage and curving of castings are somewhat obscure and uncertain, yet little difficulty is experienced in making allowances sufficiently exact for all practical purposes. Curving, however, as a rule gives greater trouble than shrinkage.

The linear shrinkage of all ordinary iron castings is pretty constantly $\frac{1}{8}$ in. in 15 in. If, however, a casting is exceptionally light a rather greater allowance should be made, say $\frac{1}{8}$ in. in 12 in., if unusually massive a smaller allowance, say $\frac{1}{8}$ in. in 18 in. or 20 in., and in the case of a very massive solid casting the shrinkage appears to be almost *nil*. A casting will apparently shrink less in the direction of its depth than in that of its length or breadth, but this is apparent rather than real, for a very deep casting will be found on careful measurement to have shrunk to the normal extent, showing that the apparent diminution in the vertical shrinkage of shallow castings is due to secondary causes, chief of which is the springing or straining upwards of the cope by reason of liquid pressure. Castings, the central portions of which are hollowed with numerous dried sand cores, and which are rendered rigid by ribs, or which are plated over, do not, as a rule, contract so much as those in which shrinkage is unimpeded, as for example in those cases where the centre is cored with green sand, or when metal is not massed heavily about the centre. Thus, a gear wheel with arms will shrink less than a mere ring of teeth. Hard white iron also shrinks much more than the soft gray kind—roughly, twice as much—and strong mottled iron occupies a position about midway between the other two. When, therefore, it is stated that the shrinkage of iron equals $\frac{1}{8}$ in. in 15 in., that is given as a good average, $\frac{1}{8}$ in. in 12 in., as sometimes stated, is not correct for ordinary work, but only so for the lightest castings, for which it is about a proper average.

Of the curving of castings the barest summary need be given. An excess of metal in the form of a rib on one side of a *long* casting invariably induces a concave curvature on that side, the concavity increasing with the amount of disproportion. Where there are two flanges of unequal thickness in a *long* girder or girder-like casting, concavity will result on the side of the *heavy* or *thick* flange. When, in a column or pipe the metal is of unequal thickness, the casting will *go* concave on the side where the metal is thinnest—the direction of curvature being precisely the reverse of that which is witnessed in a girder or a ribbed casting. Both sets of facts are, however, consistent with one another. The explanation appears to be: that in the column the disproportion in thickness is so slight, that cooling, and the initial shrinkage, and consequent curving of the thin side remains permanent, while in the case of the girder, though the thin flange shrinks and curves first, yet sufficient heat is transmitted from the heavy flange through the web to maintain the thin flange in a semi-plastic condition. Cooling slowly therefore under restraint, its crystals remain somewhat large and its texture open, and its total shrinkage is thereby diminished. Finally, the heavy flange shrinks to its full extent, more so than the thin one, the shrinkage of which has been delayed and diminished. The heavy flange consequently becomes concave, pulling the thin flange, still at about its own temperature, convex. Figs. 48 to 51 show typical sections, which, if *long relatively* to their cross sections, will infallibly become concave in cooling on the sides marked *A*. This curvature is termed *camber*, and a pattern is *cambered* to the precise amount by which its casting is expected to curve, and in the opposite direction. It is, however, only possible to design patterns to neutralize the curvature in unsymmetrical castings by much

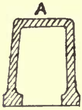


Fig. 48.

Fig. 49.

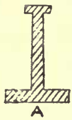


Fig. 50.

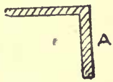


Fig. 51.

Sections liable to Curve.

observation of actual cases, experience, and very often in new work, some tentative measures being the only guides; all depends on *relative* proportions, that is on *length*, as well as on cross section, a vital point which must be ever borne in mind.

The Fracture of Castings.—Iron castings break by reason of the unequal tension which occurs between adjacent parts. As a mere statement this seems simple enough, but so many causes contribute to such a result that the reasons for fracture are not always apparent.

By unequal tension is understood the internal stress which is set up by the skrinkage of metal during its cooling down after pouring. This affects castings in two ways, one being that which results from the arrangement of the crystals, the other that of the thick and thin sections which are tied together in close proximity. The problems involved in these two cases differ, and yet they are in some degree related. The first is readily understood both in theory and in its practical applications: the second is not so easy of recognition. Castings will sometimes fracture in a manner which is not readily explained, as in frosty weather, though even then the reasons are generally traceable to a neglect of the two conditions named above, crystallization, and the proper proportioning.

There is something which almost savours of instinct possessed by the man who is able to design castings which, even though awkwardly shaped, will not fracture. It is not always practicable to produce ideal designs such as will meet with the approval of the moulder; but the latter can often secure safety even in undesirable shapes. The drawing office should always keep in close touch with the foundry when new designs are being got out. Wasters would often be avoided if this precaution were taken, apart from the unnecessary expense which is frequently incurred in the cost of moulding shapes, the designs of which could be modified without detriment to the mechanism of which they form a portion.

It is hardly necessary to remark that crystallization explains why sharp angles are or should be avoided, as far as possible, in castings. In chilled castings the planes of crystallization are most apparent. But they always exist in ordinary gray iron castings, and the sharp angles which occur in rectangular shapes (Fig. 52) invite easy fracture. In curved outlines (Fig. 53) there are no sharp planes of separation. Hence curved designs are not only more graceful, but stronger than square ones, and the larger the curves the better. But square designs, with a small radius, combined with bracketings, are also strong. But the bracketing should be continuous with the main body of metal, and not take the form of a cross-tie, which is weak. Examples of the latter occur in gratings and other objects. If the crossing-pieces are of slight section, and the surrounding portions are massive, the former are almost certain to become pulled away from the latter in some degree. The results will be similar if the ties are of large section and the sur-

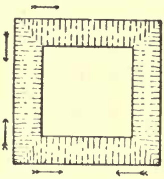


Fig. 52.

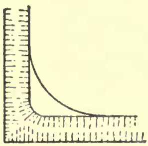


Fig. 53.

Crystallization in Castings.

roundings slight. In the direct pulls exercised by shrinkages at right-angles, the lines of cleavage of the crystals will be weak sections that will readily part in two. But if a large flowing curve is inserted, to form the union, the shrinkage will be distributed around that, and the section itself will be strengthened, because there will be no abrupt lines of crystallization present.

But a limit soon comes to the strength which a proper disposition of the crystals affords, a limit at which unequal shrinkage will tear contiguous sections asunder. Here a considerable experience becomes necessary to enable a man to design forms that will not fracture. The presence of thick and thin sections in close proximity will not alone induce fracture. The safe condition is that they are free to shrink in on themselves. They will only fracture if they are tied, and bound fast, so that their shrinkage is thereby prevented. This will happen if the casting in itself is of improper form, or if, though correctly proportioned, it is prevented from shrinkage in its mould. The first is, of course, by far the most frequent, but the latter is rather common.

A good object lesson in the causes which produce fracture is the familiar cast-iron belt-pulley. This is safe if properly designed, excepting at excessive rates of revolution; but, if disproportioned, it will fracture in the mould in cooling, or afterwards, when being turned, or when being keywayed, or while working, all these being not uncommon mishaps. The reason why pulleys in particular are so sensitive is because the metal is so slight that it cools more rapidly in rim and arms than in the boss. The boss is the chief source of danger. A slight difference in its thickness makes the difference between safety and risk. Thick bosses, therefore, should never be used on light pulleys. The extra thickness required round the keyway should be added as a keyway boss. If a boss is very long it is also risky, and then the bore should be enlarged—chambered out, at the central portion. And if the recessed pulley is a loose one it may be bushed right through, covering up the chamber or recess.

But, after the boss, a rim too thick causes risk of fracture. For if the rim is thin it will become broken and pulled inwards by the fracture of one arm or more. If, on the other hand, it is thick, it will break off an arm or arms. For this reason again, the allowance for turning must not be excessive on a rim already properly proportioned, else the pulley may fracture in cooling. And if a rim is cast of medium thickness, even though it may not fracture in the mould, it is liable to do so while being turned, when it arrives at that stage where its strength is overcome by the tension of the arms.

Lastly, the arms may be too light, in which case they will fracture under the pull exercised by the cooling boss. Or they may be too heavy, and cause fracture of the rim. In belt-pulleys, therefore, the proportioning of each part must be nicely adjusted if fracture is to be avoided.

And what occurs in a pronounced degree in pulleys happens in a less marked extent in toothed wheels, in the centre castings of crane beds, and in the castings for crane foundations. Heavy bosses next light arms are ever a source of danger, and there comes a limit to bracketing and the use of curved and filleted connections, beyond which fracture is likely to result, either during cooling, or tooling, or in service. It is certain that there are large numbers of castings in use which are always perilously near fracture, and which only await the application of some sudden and unusual stress to do so. The effects of and the amount of such tensile forces are often very apparent in the bosses of toothed wheels, fly-wheels, heavy pulleys, and beds, which have to be divided or split with plates, to be either bolted or bonded together subsequently. The divided bosses are often drawn apart in cooling, leaving the divided portions $\frac{1}{8}$ in., or even more, wider than they were at the time of casting, an ocular demonstration of the stresses which occur in cooling. This splitting is adopted as a necessary precaution against fracture, though it increases the expense and entails bonding or bolting, and is often unsightly. But it is better than a fractured casting.

Although mass in certain parts menaces the strength of some castings of the class which we have been considering, there are many examples in which mass is necessary for strength. It occurs in those cases in which large sections being unavoidably adjacent, parts must be suitably proportioned. A familiar example of this kind occurs in spur-wheel castings. When the arms of these are made of ⊥-section, as when moulded from full patterns, these are more liable to fracture than when the arms are of I-section, and the rim of the ⊏-section. In the latter case the sections are all about equally proportioned, and such wheels seldom break under severe stresses.

In the second place, if the shrinkage of a casting is artificially hindered to any important extent it is liable to fracture. This is especially likely to happen in large loam moulds, and is the reason why courses of loam bricks are inserted, and why the hard bricks must frequently be partially or entirely dislodged before the casting has arrived at the black-heat stage. Loam bricks in large cylinder cores are built in one, two, or three vertical courses. They are also laid behind top and bottom flanges. In both cases they yield to and are crushed by the shrinkage of the metal, that in the circumferential direction in the first instance, and the shrinkage in the vertical in the second. But for this precaution such castings would fracture by their own shrinkage occurring against unyielding bricks, more than one instance of which the writer remembers. And it is often necessary to remove even the loam bricks before the shrinkage has proceeded far. Sometimes nearly all the bricks are loosened and thrown down into the middle of the core while the casting is still shrinking —a hot job for the labourers, but a safeguard against the chance of fracture.

Some plated castings are exceedingly liable to fracture. If a large plate is free to shrink it is quite safe: but if it is tied with several strong webs or ribs it is not so. I remember some bed castings which were plated all over at top and bottom, with only small holes to get the cores out of, and several of these broke in succession. The trouble was got over by substituting ribs for the plates, which again were too massive, and tied too much, and being unable to yield much in any direction they fractured about the central boss. The better plan, however, is not to plate beds at top and bottom, but, even though the top is left solid, to cast ribs only on the bottom. And it is usually better not to insert dried sand-cores in such beds, but green-sand ones only, or, when practicable, to let the bed deliver its own green-sand cores. I remember some large circular bottom tank-plates for water-cranes which sometimes split in a radial direction. This was prevented by splitting them in the mould with plates and filling up the places with rust cement afterwards. The reason is clear. The major circumference was so great that the shrinkage going on round there put the metal in excessive tension, and as it could not move towards the centre on the solid metal there, it parted. Here, too, the shrinkage was partly delayed by the presence of ribs and a deep facing round the edge.

Faults and Wasters.—An engineer's specification for the quality of cast iron runs substantially as follows:

"The castings shall be clean and sound, both externally and internally, and shall be carefully fettled and smoothed. They shall be free from honeycombing, blow-holes, scabs, cold shuts, draws, and other defects. No stopping up or plugging is on any account to be permitted. No castings shall be made in open sand. Cores must be cast in accurately. No more than five per cent. variation in weight will be allowed on either side. The metal shall be remelted once in the cupola, and free from any admixture of cinder iron, or other inferior material. It shall be uniformly tough and close-grained. It shall be of such strength that a turned bar having an area of two square inches shall bear a tensile strain of not less than from 16,000 lb. to 18,000 lb. per square inch without breaking. A test-bar 3 ft. between supports, by 2 in. deep by 1 in. thick shall bear a cross breaking strain of not less than from 28 cwt. to 30 cwt., with a deflection of not less than $\frac{3}{8}$ in. or $\frac{1}{2}$ in. before breaking."

Honeycombing.—Fig. 54 is drawn to illustrate the appearance of a spongy top face of a column casting. The sponginess may be greater or less in extent than that indicated by the drawing; but the general appearance is unmistakable, and the term *spongy* or *honeycombed* expresses exactly that appearance. The holes will range from the size of a pin's head to that of a pea or a hazel-nut. When larger, they have gone past mere sponginess, and are termed blow-holes. Often, as in blow-holes, the worst does not appear on the surface—a film of metal conceals a lot of honeycombing. A foreman or an inspector will try the most minute holes with a bit of wire or a long pin, and often discover in that way that a very small hole on the surface will extend for several inches beneath the surface, opening out really into a large blow-hole. Such sponginess is almost invariably found, when present, on the upper surface of castings, where the pressure is least; seldom on the lower, where it is greatest. In some positions it is of relatively little moment; in others it should condemn the casting. Those parts which are subject wholly to tension, as the bottom flanges of girders, should never be passed if the honeycombing is at all extensive or deep. In the case of lugs subject to tension, honeycombing, such as that

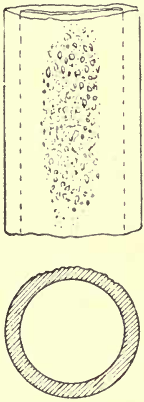


Fig. 54.

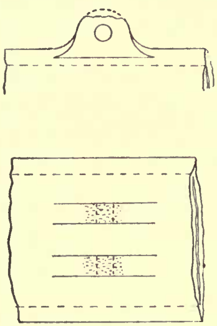


Fig. 55.

Honeycombing.

shown in Fig. 55, is quite condemnatory, even though all the rest of the casting is perfectly sound. Honeycombing on column flanges is also serious, because the stability of a column largely depends on flanges, and the strain of the bolts is liable to pull such flanges off. Sponginess down one side of a column may or may not be serious, dependent on its extent and depth. A practised observer can usually form a correct opinion about that by probing, and by general appearance; but when columns have to be subjected to severe stress, it is better to condemn all which show any traces of sponginess. They can be cast well if the mould is properly vented, the metal clean, and sufficient risers put on. Minute cracks in columns have sometimes been pened over with a hammer. The same practice is resorted to when there are honeycombed surfaces, the hammer-blows closing them, and smoothing the surface over. The most satisfactory test for the closeness of grain and freedom from sponginess of a column is the hydraulic, just as it is used in the case of water- and steam-pipes.

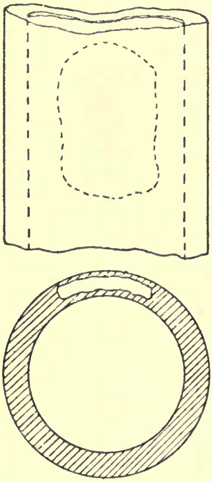


Fig. 56.—A Blow-hole.

Blow-holes.—The utmost care does not always suffice to prevent these. They are due to insufficient venting of the mould or core, to moisture, and to the entanglement of air in the molten metal. Ample venting and steady pouring, with the use of risers, are the best preventives of blow-holes. Unfortunately, they are very often concealed by a film of metal, as in Fig. 56. Hence the top faces of all castings—which can always be known by the marks left from cut-off runners, risers, and chaplets—should be tested with hammer-blows, when hollow sounds will indicate the existence of concealed blow-holes, and a sharp blow will break through the thin film. Another way to detect them is to thrust a fine wire in some of the suspicious-looking small holes when such are present, when it will often penetrate several inches, revealing the fact that there is a blow-hole beneath. A smooth skin will often conceal hidden faults of this kind. Fig. 56 illustrates an extensive blow-hole in section below, and its locality and extent are indicated by dotted lines in plan above. Such blow-holes seldom occur, except on the upper portions of castings. These often extend over large areas without any external indication of their presence, because a thin film of metal so frequently covers and encloses them. They exist either with, or without association with general sponginess. As they generally occur on the top, and as they are often completely hidden, it is necessary to test all castings along their top faces with smart blows from a hand-hammer. Such blows do no harm to a good casting; but they will either return a hollow sound or break through the skin, if large blow-holes are underneath.

Blow-holes in castings are less serious when they occur in those portions subject to compression than in those subject to tension. A few blow-holes occurring at intervals in the former would not sensibly increase the risk of crushing; but in the latter they would be highly dangerous. Blow-holes in the neutral axis of a casting are of no moment. This is illustrated by the fact that holes may be drilled in the neutral axis of a test-bar, and the drilled bar will sustain the same load as a solid bar: on the other hand, if the bar were turned upside down, bringing the thinner metal into tension, it would fracture quickly. The fact is also illustrated by the practice of lightening out a girder along the neutral plane. Sponginess on the compression side of a casting will slightly increase its deflection; but, all the same, it is risky to pass work in which blow-holes occur, even in localities subject to little or no tensile stress; because if a casting is blown in one place, it may also be so in another, of which no indications are visible.

Scabs.—An extensive scab is shown in Fig. 57 at A. These occur on all parts of castings—top, bottom, and sides. They are due to the washing away of sand caused by hard ramming, to weak sand, and bad venting. The fettlers may chip them off; but an inspector can see where such extensive chipping has been done, and all castings that show signs of much scabbing should be condemned. It is not because the scab has been cut off, but because its presence is a sure indication that there are masses of sand, corresponding in size with the scab, im-

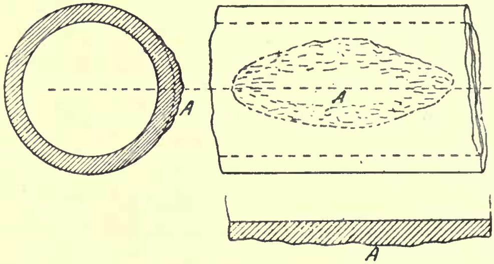


FIG. 57.—SCABBING.

bedded somewhere in the body of the casting. Such masses may or may not come to the surface. If invisible, they constitute a hidden source of danger. It is quite likely that the corresponding hole or holes are not to be found, being perhaps covered with films of metal, but there is no doubt about their existence somewhere. So that the presence of extensive scabbing is quite sufficient to condemn the castings in which it occurs as unsound.

The causes of scabs are various. As just stated, hard ramming is liable to cause them. So also is using sand of too close texture, or working it too wet. When ramming a mould, regard must be had to the nature of the casting, and the particular section of the mould which is being rammed. Metal will not lie kindly on a hard bed, but will bubble, the air not getting away with sufficient rapidity, and bubbling will result in the detachment of flakes of sand, and consequent scabbing. If, on the contrary, the sand is rammed too softly, the pressure of the metal will produce lumpy castings. The moulder has therefore to ram the sand sufficiently hard to resist the pressure of metal, yet so soft that bubbling shall not take place. The practical result is a kind of compromise. The lower stratum of sand is rammed hard, and freely vented, and an upper stratum of an inch or two in thickness is rammed more softly. The metal, therefore, lies upon a comparatively soft cushion, which is supported by a firm, well-vented backing. The lower portions of moulds are not as a rule rammed so hard as the sides and top, since the gas can escape more readily from the latter than from the former. A hard-rammed mould will be productive of less risk in the case of a heavy than in that of a light casting. Another cause of scabbing is the leaving of risers and feeder heads open during the actual pouring of metal.

Choking of vents will produce scabbing, hence the reason why the vent openings are always closed against the face of a mould. Excessive moisture in a mould will produce scabbing by the generation of steam in quantity. The moisture may be due to overmuch watering of the sand in the first place, or to the abuse of the swab at the time of mending up in the second. The amount of moisture in a mould should be just so much as is necessary to effect the consolidation of the sand—anything in excess of that is injurious. Too much sleeking with the trowel also is injurious, and too thick an application of blackening, whether wet or dry, followed by hard sleeking, is a fruitful cause of scabbing, the blackening and the sand beneath flaking off at the time of pouring.

Cold Shuts.—Fig. 58 illustrates the defect which is termed a *cold shut.* Its presence should condemn any casting, no matter where it occurs. The casting is really as good as fractured where the cold shut occurs. It means this: that the metal has been poured cold and dead, or that the metal has had so far to travel in the mould that it has become chilled; consequently, when opposing currents meet, they do not mix as perfect liquids, but only to a partial extent. Being so cold, they form a joint or imperfect union, much like a bad weld. These are also caused by using poor iron with no life in it, or by using iron badly melted, as well as by allowing iron to remain too long in the ladle before pouring. When only a moderate stress comes on the casting, the cold shut becomes the weak link in the chain. These shuts can usually be recognized by the rounded appearance of the edges along the irregular groove or fissure where the metals have met.

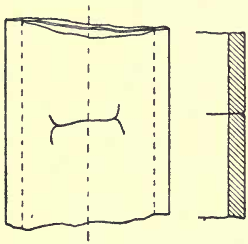


Fig. 58.—A Cold Shut.

Draws.—These must not be confounded with blowholes, or with general honeycombing. Draws are, of course, sources of weakness; but they differ from blowholes and sponginess, in cause and in characteristics. They are not due to the presence of air or dirt, and they are not, as a rule, visible on the surface. The better—that is, the stronger—the metal is, the more liable is it to draw. And the draws occur in the heart of the thickest parts of the casting. They are due to unequal rates of cooling, and to crystallization; the outside of the casting sets firmly while the interior is still molten, or, at least, viscous. As the interior shrinks, the outside will not yield, and so the interior metal shrinks on itself, becoming drawn towards the outside metal. Then one of two things, or both, must happen: the crystallization will be large, coarse, "open grained," and proportionately weak, or a cavity will be left about the centre. Given a tough, strong iron, and great disparity in thickness of metal, favourable to the more rapid cooling of some sections than others, and the metal is certain to become drawn. Hence, what some people think must be a good strong casting is a weak and uncertain one. As a blow-hole and a draw are due to entirely different causes, so their appearances are quite different and quite unmistakable. A blow-hole is bounded by smooth concave faces or edges. A hole caused by a draw always has sharp, jagged boundaries, generally of very irregular outline. As there are great differences in the dimensions of blow-holes, so there are in the dimensions of holes caused by drawing. Blow-holes merge into mere sponginess; draws diminish down to mere openness or extreme coarseness of crystallization. Some holes due to drawing are so large that two or three fingers may easily be inserted in them; others will barely admit a pin between the coarse crystals. Draws, like many blow-holes, are generally concealed until the casting fractures; but their presence is often indicated by a slight depression of the surface adjacent, or by the presence of a small hole leading from the surface adjacent into them. Blow-holes generally occur on or near the upper surface of castings; draws may occur anywhere, in the bottom as well as in the top of the mould; in fact, they are often more likely to occur in the bottom. Thus, if a mould is of no very great depth, and it is fed during the period while the casting is setting with fresh supplies of molten metal over the parts where the metal is thickest, drawing will be prevented. But if there is thick metal in the bottom, the chances are that drawing will take place there. On the other hand, in a deep casting not fed, heavy metal in the bottom will not be likely to draw, because the superincumbent liquid mass will feed it; but the top metal will be likely to draw.

All draws are preventible by some method or another, either by alteration of design, or by the adoption of certain precautions on the part of the moulder. Engine cylinders are capital object-lessons in the drawing of castings. They are always made of tough, stiff metal, and invariably in localities where there is much excess of metal some may be confidently looked for. So, too, are large weights, such as are often cast for test loads and for foundry use. In such weights there is always a depression on the top face, due to the internal shrinkage, and if such weights are broken, there is always a central cavity also, or else very open crystallization. Again, supposing a girder made like Fig. 59, and the light and heavy flanges are tied with ends or with cross ribs, the probability is that in the vicinity of the union of the ribs with the thick flange there will be a draw, as at *a*, and depressions at *b*, *c*, *c*. In the case of this girder, having a very heavy bottom flange, and pockets, *A*, for trimmer girders cast on one side, and brackets, *B*, on the other, there is every chance of a draw occurring in the thickest part. Or, if an actual open space does not occur, the crystallization will be very open, as shown at *a*. The obvious alternative is to lessen the mass of the bottom flange and to put smaller radii in the angles. In the case of the column head, Fig. 60, putting a straight core

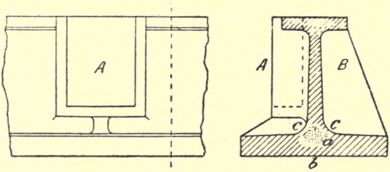


FIG. 59.—A DRAW.

through, the side *A* masses too much metal at that locality, and there will be a draw at *a*, with probably a very slight circular depression of metal on the outside or inside, and the column will not be any stronger—prob-

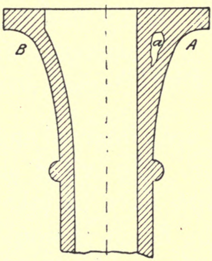


FIG. 60.

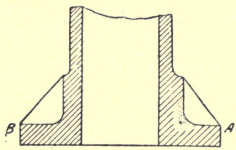


FIG. 61.

DRAWS, AND HOW TO AVOID THEM.

ably weaker—than as if it were cored out to an equal thickness, as shown at *B*.

Fig. 61, side *A*, shows the effect of a heavy belt and thick bracket in combination, in producing a draw. At side *B*, with the belt shown and bracket made no thicker than the thickness of the metal in the body of the column, no draw will occur.

In these instances there would not be any appreciable risk of fracture, because the top flange is free to shrink inwards; but in some cases the risk of fracture becomes serious. It is serious when thick and thin adjacent parts are so tied that they are not left free to shrink. Heavy mouldings on columns ought, therefore, always to be cored out, to leave approximately the same section everywhere.

The tendency to draw is lessened, and the strength of

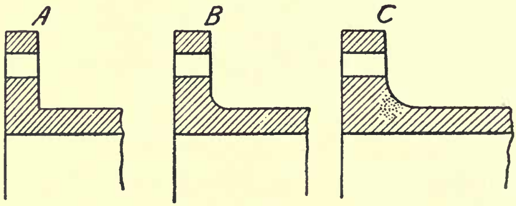


FIG. 62.—EFFECT OF A RADIUS.

castings increased, by abolishing all keen internal angles. This rule is of universal application. The evil of sharp angles is seen chiefly in flanges which have to take the pull of screw-bolts. In Fig. 62 the flange *A* would be almost certain to fracture when under moderate stress only. The flange *B* would possess the maximum of strength. In the flange *C* the radius would be rather overdone, and the flange too thick. The two extremes—a very thick flange and a very large radius—would probably cause the draw shown, and produce fracture under less strain than that which would be required to fracture *B*. There is no advantage in a very large radius. A small radius, even less than that shown at *B*, adds immensely to the strength. The mere strength is not that chiefly due to the increase of metal, but indirectly to the regular or symmetrical arrangement of crystals when cooling, which occurs when there are no abrupt re-entering angles. When such sharp angles do occur, there is an abrupt break in the arrangement of the crystals, and it is along that line of abrupt break that fracture will occur. Hence it is a rule that no iron castings to stand stresses should ever be made with keen internal angles. They should be filled up and obliterated with radii, hollows, or fillets, as they are variously termed. In some positions the omission of these is not of much importance; but in others their omission will certainly ensure fracture.

It is rather fortunate that the moulder's instinct prompts him to insert those radii in moulds when they are not put on the pattern; but as he will not incur too much responsibility, he generally *breaks the edge* with a hollow sleeker, which is much better than nothing at all. And many a flanged casting would be broken in the mould before ever it saw the light of day but for the precaution the moulder takes of digging away sand from between adjacent flanges or ribs, and from between flanges and box-bars, and so permits free shrinkage to take place. Without this precaution, the hard sand in the mould would prevent the full shrinkage from occurring, and the tension put on the casting by shrinkage stresses would be greater than the tenacity of the red-hot or black-hot casting.

Lapping joints.—A column which has been chipped heavily along the flask joints should be carefully examined, because that is due to the shifting of the flasks on one another, or to the bad mending of a broken mould.

It means that the metal will be thinned along the joints by the amount of overlap which has been chipped off. Lapping-joints like those shown in Fig. 63 are unsightly, besides detracting from the strength of the casting. The strength being measured by the diminished section at *a*, instead of at *b*, lap to the extent shown in the figure ought to condemn a casting, even though a sound one. In Fig. 63, *A* is a section through a true column, and *B* a section through one which has overlapped. Some very slight amount of overlap is almost unavoidable in jobbing work, for which special flasks and patterns are not made. But it should never exceed, say, $\frac{1}{32}$ in., or $\frac{1}{16}$ in.,

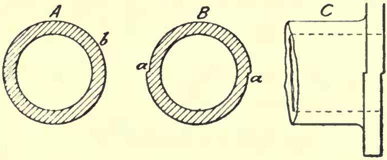


FIG. 63.—LAPPING JOINTS.

at *a*. When it becomes $\frac{1}{8}$ in. or $\frac{3}{16}$ in., it is too much to be passed. If, in addition to the overlapping, the core happens to be out of centre sideways, then the thickness of metal will be still further diminished. Sometimes flanges overlap, as shown at *C*. Then, if they are faced, their thickness is reduced by the amount of overlap. If they have to bed on stone without facing them, they look unsightly.

Pressure in top and bottom.—Owing to the marked difference in the strength of cast iron in tension and compression, it is usual, when practicable, to cast those portions of work which are to be in tension in the bottom of the mould. All the advantage to be derived from closer metal is thus secured. This is practicable in the case of girders subject to uniform stress in one direction only. But it is not applicable to columns on which the stresses are either uniform, or, if variable, acting in all directions indifferently at different times. Thus, for instance, in columns sustaining the girders of a bridge subject to side wind pressure, the opposite sides of the columns will in turn be in compression and tension. This will be due to the varying directions of the wind against the girders, producing bending of the columns to one side or the other. Such columns should in theory be cast upright, with heads. But it is seldom done, because more costly than the usual method of casting horizontally. Horizontal casting is prolific of several evils, unless very great care is exercised in moulding, coring up, and pouring, and in subsequent testing and inspection. A test-bar will give the strength of the iron in the column, but it tells nothing at all about the evils above alluded to.

The reason why more porous metal occurs at the upper part of a casting than at the bottom, is because it is subject to little pressure, while that in the bottom is subjected to a considerable liquid pressure, which effects its consolidation, making it closer and stronger. The deeper the mould the greater the pressure, and the sounder will be the lower parts of the casting. This is the chief reason why the supplementary metal termed "head" is cast upon much work that has to be tooled, such as engine cylinders, hydraulic cylinders and rams. All the spongy metal is in the head, and when this is turned or sawn off, the casting below is uniformly sound at top as well as at bottom. This sponginess is always present in some degree on the top parts of all castings, and that is why founders always try to cast parts which have to be planed or otherwise machined bright, in the bottom. If the top part of a casting is machined, it almost always turns out spongy unless special precautions are taken, such as running through a skimming chamber, or allowing an extra thickness to be machined off, or casting several risers or flow-off gates. The first-named consists of a circular chamber set right in the way of the course of the metal, and which is so arranged as to impart a swirling motion to the metal, sending the lighter matters upwards into a riser above, and leaving only clean metal to pass on into the mould (see p. 155). The third named means that there is a slight flow-through of metal in the mould permitted, the lighter matters passing out into vertical channels or risers (see p. 160). But these devices do not wholly prevent sponginess. They do, however, effect removal of the scurf, and that is something, since the presence of this is a fruitful source of sponginess. But the greater natural porosity of the metal on the top of a casting cannot be wholly removed.

CHAPTER VIII

PRINCIPLES OF GREEN SAND MOULDING

This branch embraces much the largest proportion of cast work done, being not only cheap, but sufficiently good for all except some few special purposes. The meaning of the term *green sand* was explained on p. 6. The methods of moulding in green sand are broadly classified under three great divisions, namely, moulding in *open sand*, by *bedding in*, and by *turning over*. By one or another of these, all work which is made in green sand is accomplished.

Moulding in *open sand* signifies that the mould is uncovered on its upper face. In the *closed* moulds, the metal when poured is arrested at a certain definite stage by the face of the sand in the top or cope. This face may have any contour, irregular or otherwise, but the upper face of a casting made in open sand can only be truly horizontal, which fact at once limits the utility of open moulds. But in addition to this, the upper surface of a casting made thus is always irregular, rough, porous, unsound: irregular and rough, because the hot bubbling iron is not confined against a face of sand, but begins to set before the commotion due to the evolution of its heat, and of the gases and air, has subsided—porous and unsound, chiefly for this reason, and partly because it is not cast under pressure, as are all closed moulds; the pressure in these being due to the height of the pouring-basin above the surface of the mould. Castings made in open sand are therefore only employed for very rough work, never for ordinary engineering constructions. Moulding flasks, back plates, foundation plates, core plates, rough weights used only for loading, and similar articles are made in open sand.

The main essential in this class of work is to have the mould perfectly level, a matter comparatively unimportant in closed moulds. Hence, either a level bed of sand is first prepared, and the pattern or skeleton of the pattern, or sectional portion of the pattern, as the case may be, is laid upon this and rammed, or the pattern is *bedded in* and levelled during the process of ramming. Venting is seldom done except when the sand happens to be of very close texture, but the air comes away partly from the upper face of the casting, partly through the bottom sand.

Usually an open sand mould is made $\frac{3}{8}$ in. or $\frac{1}{2}$ in. deeper than the casting is required to be, and overflow channels are cut around the edges to carry off the superfluous metal, and to indicate the proper time for the cessation of pouring. A good deal of work in open sand is shaped by the moulder himself with the aid of a few strips and sweeps only, but then it is the roughest class of moulded work done.

Bedding in.—This signifies the moulding of patterns in the sand of the foundry floor, the position of the mould being in no respect changed from the commencement of operations until the time of casting. In this method it is obvious that the lower faces of the mould—those which are formed underneath the pattern—will not be easily rammed, and may be harder and softer in places.

When work is *bedded in*, the sand is dug up and loosened to a sufficient depth, and into this the pattern is beaten with heavy wooden mallets, its top face, when practicable, being tested by the spirit level—usually in conjunction with winding strips. As soon as a very rough impression of the mould is thus obtained, an inch or two of facing-sand is strewn or riddled over the whole area, and the pattern is beaten down again. This hammering down of the pattern causes the sand to become harder in certain sections than in others—becoming hard, it also offers a certain resistance to the further bedding down of the pattern. This consolidated sand is therefore hatched up and loosened, and if need be, portions are removed with the trowel, or with the hands, until the pattern has been made to bed pretty nearly alike all over. Recesses, pockets, ribs, flanges, and such like, when present, have to be filled in, by *tucking* the sand underneath and around them with the hands, the smaller rammer following afterwards where possible. When the sand is thus rammed and brought up level with the top edge of the pattern, it is scraped and sleeked off, and the joint face made ready for the cope. The face is then strewn with parting sand, and the cope put on, set with stakes, and rammed.

Though these operations are in general outlines very simple, yet in their practical details they call for the exercise of as much skill on the part of the moulder as those involved in turning over. The difficulty in bedding in lies chiefly in the proper consolidation of the sand. If the sand is of unequal consistence, scabs and blowholes in the harder portions will result, and swellings on the castings over the softer portions.

Turning over.—This signifies that the face of the mould which is lowermost at the time of casting, is uppermost at the commencement of ramming, being subsequently turned over. By this method it is clear that the portion of the mould which is finally lowermost will be rammed as evenly and well as the upper portion, since it has already been in the top at the earlier stage of ramming: and it is evident that the consolidation of the sand over any given area will be more perfect when it has been rammed directly *against* a pattern, than when the pattern has been simply *beaten down* into a bed of sand. But it is also clear that since in turning over, the whole of the mould is contained in flasks, this method requires more *box parts* or flask sections, and increases the *weight* which has to be lifted by men, or with cranes, or travellers; and is therefore more expensive than bedding in. The larger and heavier the work, the greater the reason then why bedding in should be adopted in preference to turning over. In massive work, therefore, the preference is usually given to bedding in, but in moulds of small and of moderate size, and generally for work of the best class, turning over is the method usually adopted.

Figs. 64 to 67 illustrate the moulding of a trolly wheel by turning over. The pattern is first laid with its upper face downwards on a temporary cushion of sand in the flask, *A*, Fig. 64, which is presently to form the top or cope. A joint face is made, which may or may not be in the same plane as the joint edge of the flask, being dependent on circumstances. It is often convenient to slope the sand joint up or down when the relative depths of pattern and flask require it. The joint is strewn with parting sand. Upon this the flask *B*, which is presently to form the drag, is laid, Fig. 65, and rammed permanently. The two flasks then cottared together, are turned over, and the bottom or drag *B* is laid in its

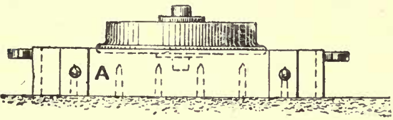


Fig. 64.

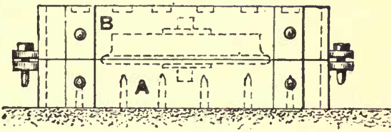


Fig. 65.

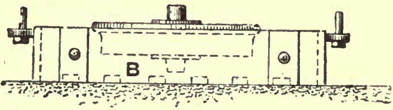


Fig. 66.

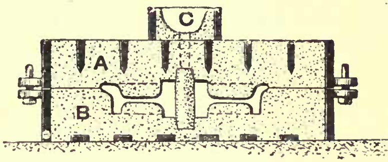


Fig. 67.

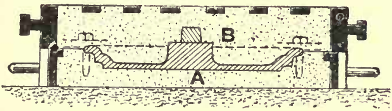


Fig. 68.

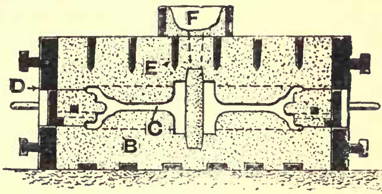


Fig. 69.

Fig. 70.

Examples of Turning over.

permanent position upon a bed of levelled sand. The cope is lifted off, its loose cushion of sand knocked out, and the upper joint face of the drag smoothed over, and strewn with parting sand. Fig. 66 represents the mould at this stage. The cope is then placed on, swabbed, liftered, and rammed permanently with the runner pin in place. The flasks are then parted at the joint, the mould mended and blackened, cored, closed, and cottared, and the pouring basin *C* made. Fig. 67 represents the mould closed ready for pouring.

The next illustrations, Figs. 68 to 70, are those of a *three-parted mould*. It is obvious that the groove of the sheave wheel there shown must effectually prevent delivery if moulded in the same manner as the trolly wheel —that is, with a cope and drag only. Two parting joints are necessary to enable the pattern to deliver, and in addition the pattern itself has to be divided through its middle plane. Fig. 68 shows that stage of the mould which corresponds with the stage in the moulding of the trolly wheel seen in Fig. 64. The sand in *A*, Fig. 67, forms a temporary bedding only for the half-pattern, over which the drag *B* is rammed for permanence. The flasks *A* and *B*, then cottared together, are turned over, *A* is removed, and the sand knocked out, the exposed joint face of *B* is sleeked, and strewn with parting sand, the middle part rodded and liftered, swabbed with clay-water, and rammed approximately level with the pattern joint, Fig. 69. To sustain the weak narrow zone of sand which forms the pulley-groove, nails dipped in clay-water are rammed in—*nailing*—with the sand, as seen in Fig. 70. The upper half-pattern is then put on the lower half and weighted, the sand rammed to the middle plane *D* of its flange, Fig. 69, the joint sleeked over, parting sand strewn thereon, and the cope *E* put on, liftered and rammed. The flasks are then parted, the pattern withdrawn, the mould cleaned, blackened, cored, and closed, the pouring basin *F* made, and all is ready for casting, as in Fig. 69.

Figs. 71 and 72 show in vertical section and in plan respectively the mould through a column which has been made by turning over. Here the top and bottom boxes are alike. The sand in the top is liftered, the mould

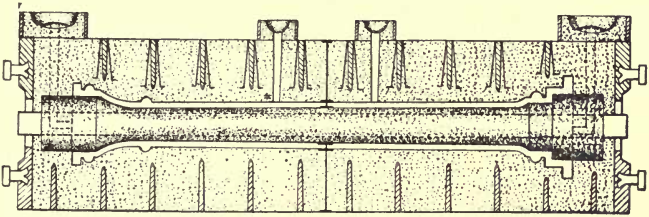


FIG. 71.

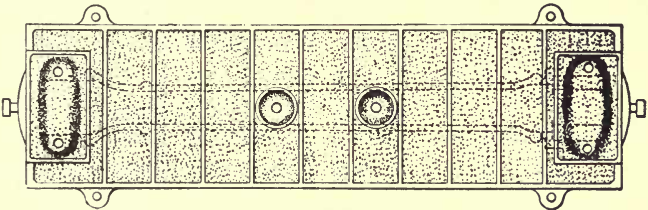


FIG. 72.

A COLUMN MOULDED BY TURNING OVER.

being long, is poured from both ends simultaneously, and strain is relieved by risers or flow-off gates placed about the central portions of the mould. Chaplets will be noticed by which the core is maintained centrally in the middle part away from the core prints.

These, in bare outline, are the general processes of bedding in, and of turning over. I have purposely, in order to avoid confusing the mind of the student, omitted to explain certain important items essential to safe moulding, which we must now consider.

Venting.—Vents are variously made, according to circumstances. When a pattern is being rammed, the sand by which it is surrounded is pierced with innumerable small *vent-holes* of about $\frac{1}{8}$ in. in diameter, more or less. These do not properly come quite close, but only to within $\frac{1}{8}$ in. or $\frac{1}{4}$ in. of the pattern. When vent-holes come out on the actual mould surface, there is always risk of the metal entering the vents and *choking* them, and, by preventing the escape of air and gas, causing a waster casting. All the small vents are brought into larger ones, and the positions of the larger ones will depend on the nature of the mould. For instance, when a pattern is bedded in, and the area of the mould is large, all the lower surface vents are carried directly downwards into a large porous reservoir of cinders, clinkers, or coke—hence termed a *coke-bed* or *cinder-bed*. In this, layers of hay alternate with layers of cinders, and the whole is covered with a final stratum of hay. This bed is laid at a depth of 10 in. or 12 in. beneath the lower face of the mould, and has a total thickness, including cinders and hay, of 10 in. or 12 in. Into this the vents are carried, and from it the air is led away, and escapes through vent-pipes. Fig. 88, p. 167, illustrates a mould having a cinder-bed and vent-pipes. The larger vent-holes are made with a vent-wire of $\frac{1}{4}$ in. or $\frac{3}{8}$ in. diameter, usually at an early stage of the bedding in of the pattern, or as soon as the general contour of the mould is obtained, and before the pattern is put back for final ramming up. But after the pattern is withdrawn, the vent openings, if not already closed by the bedding in, are filled up by the consolidation of the surface sand with the hands of the moulder, which invariably follows upon the withdrawal of a pattern that has been bedded in. By exerting gentle pressure with the fingers over the whole of the surface in detail, the moulder ascertains what sections are not sufficiently firm, and adds fresh sand in those parts, using the rammer for the purpose. At the same time he closes vent-holes which may yet remain open. On first thoughts it may seem strange to make vents and then close their openings, but the air and gas will force their way under the liquid pressure existing in the mould, through an inch or thereabouts of intervening sand, to the vents, while the metal itself will be unable to do so.

Diagonal vents are brought from the sides of a mould into shallow channels or *gutters* which are cut in the sand, forming the joints of the mould, and are thus carried away at the box joints. The vents from the *upper surface* of a mould are brought off directly through the whole area of the upper surface of the cope sand. In Figs. 67 and 69, the upper surface vents are brought out over the tops of the copes *A* and *E* respectively, covering the whole area. The venting is therefore direct. Vents in the drag, in work which is turned over, are first made directly to the pattern face before turning over, and are then brought out at the joint which the under surface of the drag makes with the levelled bed of sand on which it rests. The necessary connection with the outside of the flasks is made by passing a long vent wire from the outside between those faces in all directions. The vents therefore in Figs. 65 and 67 pass from the lower faces of the mould perpendicularly through the drags *B* and *B*, and then out at right angles herewith, on a level with the sand floor upon which the drags rest.

The vents from the peripheries of these moulds are brought out diagonally into gutters cut into the mould faces, and the air escapes through the joints of the flasks.

Sand which is rammed hard will require more venting than loosely rammed sand. Free open sand will require less than close loamy sand. The red sands are so free and open that for many kinds of light work no venting is required at all, their natural porosity being sufficient to allow of the escape of the air. In heavy work the vents may be kept farther from the surface than on light work. The more moisture present in a mould the greater the quantity of venting necessary.

Retention of Sand.—Another important matter in moulding is the artificial binding together and retention of large quantities of sand in their boxes. It is clear that the mere ramming of a large mass of sand in a flask, with no other support than that afforded by the sides, and the bars or stays, would not prevent the tumbling out of portions of that sand by concussion, or even by reason of its own weight. Numerous devices are therefore resorted to in order to bind or secure it, both during moulding and at the time of casting. These methods are *rodding*, *liftering*, and *sprigging*, signifying that rods, lifters, and sprigs or nails are used in different moulds, or in different portions of the same mould, as binding agents.

Rodding.—This means that masses of sand which by reason of their large amount of overhang cannot be supported and stayed by the bars of the flask, are sustained by means of iron rods. Thus, as a typical example, a mass of sand overhanging a flange will be supported by rods, the opposite ends of which are either sustained by the main body of sand in the mould, or upon a *drawback* plate, or on any ordinary cast iron ring or frame, such as those which are often used for lifting the middle sand in some kinds of bedded-in moulds. Rods are used also in turned over moulds, in the middle flasks, which are destitute of bars. The general mode of rodding and liftering middle parts is shown in Fig. 87, p. 165, rods of square bar iron being placed across the flask and supported by the ledge (see Fig. 31 *B*, p. 96) that runs round the inside face. The lifters depend from, and are supported upon these. Similar rods are seen in the middle part in Fig. 69, p. 141.

Lifters.—These are bent rods made both in wrought and in cast iron, the size of cross section and length varying with the dimensions of the work. They may range from $\frac{1}{4}$ in. to $\frac{3}{4}$ in. in diameter, and from 4 in. to 24 in. in length. They rest upon the rods as in Fig. 87, p. 165, or are suspended from the box bars as in Fig. 92, p. 170, and are set and laid in all possible positions wherever sand requires support. In some few cases they are not themselves supported, but simply act as binders within the sand, their bent ends resisting the tendency to dislodgement of the sand in mass. But when practicable they should be suspended from, or rest upon, rigid supports. Judgment is required even in the apparently simple matter of the putting in of lifters, since if improperly supported, a tumble-out of the sand and lifters *en masse* will probably occur.

Sprigging or nailing.—Common cut nails are employed for strengthening weak sections of sand which are too small to be sustained by lifters. Or the sprigs may be considered as auxiliary to lifters, strengthening in detail the sand the principal mass of which is carried by the lifters. In all work where there are small isolated bodies of sand, narrow weak edges, projections, etc., long nails are inserted in quantity to bind those to the main body. The nails are not only inserted at the time of moulding, but also after the pattern has been withdrawn. Should the mould crack or show signs of giving way, nails are thrust in to strengthen it, and to prevent risk of the sand becoming washed away by the rush of metal. In the economy of mending up, these nails are indispensable. An example of sprigging occurs in Fig. 70, p. 141.

Mending up.—This is necessary in most cases excepting those in which the patterns are made for standard use, regardless of expense, and those in which patterns are moulded by machine. The causes of moulds breaking down are numerous, as, for instance, badly made patterns destitute of taper, of rough construction, having overlapping joints in the wood of which they are composed; the leaving those pieces fast which ought properly to be loose, too soft or too hard ramming, imperfect rodding or nailing, insufficient or excessive rapping, uneven or jerky lifting. These are the principal causes of the fracturing of moulds.

At the time of withdrawing, or *delivery* of a pattern, the joint edges of the sand are *swabbed*, in other words, they are just damped or moistened with the swab or water brush in order to render the sand around the edges of the pattern as coherent as possible. Then the pattern is *rapped*, that is, a pointed iron bar is inserted in a rapping plate let into the pattern, or otherwise into a hole bored into the pattern itself, and the bar is struck on all sides in succession with a hammer, so loosening the pattern from actual contact with the sand in its immediate proximity. A lifting screw, or else a spike, is then inserted, several screws or spikes being used in work of large dimensions, and the pattern is lifted gently, moderate rapping with wooden mallets on its surface and edges being continued the while.

After the pattern has been removed, the mould is carefully overhauled to note the extent of the damage, if any, which it has sustained. If the lift has been very bad and the work is very intricate, it is better not to attempt mending up at all, but to ram the pattern over again. If the edges chiefly are broken, it is in some cases desirable, as, for instance, in moulds taken from loam patterns, to put the pattern into place again, and make good the sand around the edges, pressing it down with the trowel and increasing its coherence by means of sprigs and the use of the swab. If the damage is of quite a local character, that portion of the pattern corresponding therewith can often be taken off and put back in the mould as a guide by which to mend up.

In sections which are inherently weak, a stronger sand should be employed than that which is used for the general facing of the mould; core sand may in certain sections be used with advantage. In most broken parts it will be necessary, where the main pattern or portions of the pattern are not utilized for the purpose, to use *mending up pieces*. These are strips of wood cut to the outlines, curved or otherwise, of the broken sections, and held against those sections while the broken sand is being repaired and made good.

In green sand moulding there is a process termed *skin drying*, which is serviceable as a means of slightly stiffening an otherwise weak section or area of sand. It consists in partly drying the surface of the mould, not in the stove, but with *devils* or open cages containing burning coke or charcoal. Or a red hot weight, or other mass of hot iron, is suspended in close proximity to the mould for the same purpose. This skin drying slightly stiffens and hardens the sand, enabling it the better to resist the pressure of metal.

The mould is not finished at this stage. Its surface has to be protected with *blackening* or *blacking*. When a mould is skin dried this is laid on before the drying is done. The use of blackening is similar to that of the coal dust in the sand, namely, as a protection against the fierce heat of the metal. But the coal dust being mixed in small proportions is scattered finely among the facing sand, while the blackening continuously covers the face of the mould. The blackening being made either of ground oak charcoal, or prepared from plumbago, is essentially carbon, and the immediate effect of contact of the molten metal therewith is the formation of a gaseous film of one or of both of the oxides of carbon. Thus smoothness of surface is preserved, because the metal is prevented from coming into actual contact with, and entering into the interstices of, the sand, and fusing its surface, with the production of a hard skin of silicate. The action is further assisted by the coal dust in the facing sand. Hence the reason why heavy castings require a thicker coat of blackening, and a thicker stratum of facing sand, than lighter ones.

Wet blacking is often used on moulds of large size, and on those which are to be skin-dried. This is blacking mixed with water, thickened with clay, and laid on wet with a brush. Blacking in its ordinary state is applied as powder and sleeked with a camel hair brush and trowel.

Pouring.—The methods of *pouring* or *running* a mould are varied. Much depends on this apparently simple matter. But in truth there is nothing in moulders' work which is insignificant or unimportant. From first to last care in little, and to a casual observer, trivial things, has to be scrupulously exercised. A trifling neglect may, and often does, ruin the work of several hours, or of days.

Since the conditions of liquid pressure exist in moulds, several things become self-evident. The pouring basin must be higher than the highest part of the mould. The liquid pressure on any given portion of the mould will be statically equivalent to head $\times$ area $\times$ sp. gr. of metal. The pressure on a mould of large area will in any case be very great, and must be resisted by equal and opposite forces. The area of the *ingates* must be sufficient to fill the mould before the metal has time to become chilled or pasty. Also there are other matters of a purely practical character, which must be illustrated to be properly explained.

Various methods of pouring are shown in Figs. 73 to 76, pp. 155-156. A mould may be poured direct from the top, or from the bottom, or from both top and bottom simultaneously, or it may be poured from one side. Most moulds are poured from the top direct, Figs. 67, 69, p. 141. When they are of considerable depth, or when it is desirable that their surface or skin shall be clean and smooth, that is, not roughened or cut up by the action of the metal, they are run from the bottom or from the sides. For it is evident that metal rising quietly in a mould will not cause such damage to surfaces as that which, falling from a considerable height, strikes the sides in its descent, and beats heavily on the bottom of the mould. When it is necessary that metal shall be poured from the top into a deep mould, its cutting action is often diminished either by making the mould in dry sand, or by placing a piece of loam cake at the area where the beating action is most intense, or by inserting a number of flat-headed chaplet nails in close proximity at that area, and allowing the metal to fall upon them.

As a general rule it may be stated that, unless good reasons exist for the contrary practice, moulds should be poured from the top. Iron falling upon liquid iron remains hotter and in greater agitation than iron rising slowly. The latter will carry up the scum and dirt which it gathers from the sides of a mould, allowing these foreign matters to lodge under projecting portions: but the metal falling from above cuts up the dirt and scurf, keeping them in such perpetual movement that they can scarcely effect a lodgement in the mould. Running from the bottom, the metal becomes chilled as it rises; but running from the top, the last iron poured is as hot as the first. When running from the top and the bottom at once, the first metal is led in at the bottom, and after a portion of the mould is filled, the top metal is introduced, falling upon metal. The dirt is thus cut up and the iron is kept hot until the mould is filled. No set rules can be laid down for the most suitable method of pouring, the matter is entirely one for the exercise of the moulder's judgement.

Examples of the simplest forms of pouring basins and runners occur at p. 141. These are only adapted for the smallest moulds. For those of moderate and of large dimensions, the forms of the basins and the modes of running are modified. The shape of a typical pouring basin and runner is shown in Figs. 86 and 89, pp. 165 and 169. Though a rough-looking affair, every detail is a matter of design. First there is a depression at *O*. This receives the first inflow of the metal. If there were no such depression the metal on being poured from the ladle would flow at once into the mould, and as some slight adjustment of the ladle is necessary before it is ready for emptying a full stream, a few drops would be running in during the making of such adjustment. These would form *cold shots* in the casting. Also, the iron falling for a considerable time upon a bed of sand would cut it up, and wash portions into the mould. But the depression in the basin receives and retains the first few droppings of metal, and forms a shallow reservoir into which all the remaining metal falls as in a bath, preventing the cutting up of sand. Only when the depression is filled does the iron begin to flow off in a quiet stream into the mould. As soon as the depression is full the remaining metal is poured very rapidly into the basin until it is nearly level with the brim, and is *kept filled* until the mould is quite full. This is necessary in order to prevent any dirt or scurf which may happen to pass the skimmer from entering the mould with the metal. As long as the basin is full, the dirt floating on the surface will not be carried into the ingate. For a similar reason the surface *area* of the depressed portion is made sufficiently large. If it were small it would not hold much metal, and the scurf would be more likely to become sucked into the ingate.

These pouring basins are made chiefly by hand. A small middle flask, or a frame only, is laid upon the cope, and swabbed with clay water, the runner pin put in place, the sand rammed with a pegging rammer, central portions dug out and then rounded and moulded to the proper form with the hands. All sharp corners which might become washed down by the rush or pressure of metal are scrupulously avoided.

In spite of every precaution in the manner of pouring, particles of dirt which accumulate from the metal in the ladle, and from the sand in the basin, gain access to the mould. In castings which are not turned or planed, the slight contamination thus caused is not of importance; but on turned or planed faces the slightest specks have an unsightly appearance, and in such work various devices are made use of to obtain the cleanest faces possible.

In steam and hydraulic cylinders, in pumps, and work of this class, a belt of *head metal* is cast on, into which the lighter matters rise, and this is subsequently turned off. On large flat upper surfaces an extra thickness of metal is allowed, to be planed off afterwards. Or, several *risers* are placed over the surface, and cut off. Lastly, the mode of running is modified, the metal being led in through a *skimming chamber*. This method is shown in Fig. 73. Here *B* is the ingate, and *C*, *D*, the runner. Right in the course of the runner, which is purposely made of the indirect form shown in plan, there is a capacious chamber, *A*, made by ramming up a ball or a disc in the mould. Over the chamber is a riser, *E*. As the metal obtains entry through the first portion, *C*, of the runner into the side of this chamber, *A*, it receives a rotary motion, as shown by the arrows in plan view. The effect is to throw the heavy metal to the outer part of the sphere, leaving the scurf and inferior lighter metal at and about the centre. The outer metal passes into the mould by the ingate *D*, *F*, and the lighter matters float upwards into the riser *E*. This riser need not be added in very small moulds, the chamber in itself being sufficiently capacious; but in large moulds enough dirt will accumulate to fill it up to the brim. Fig. 74 is drawn to show by contrast with Fig. 73 the wrong way to make a

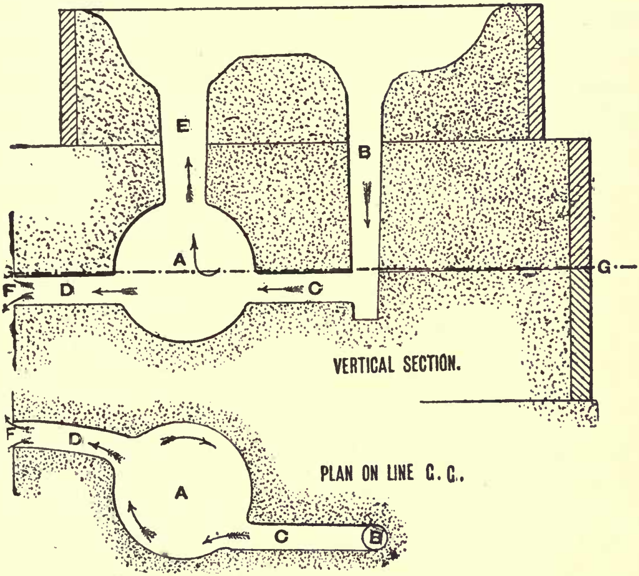


FIG. 73.—SKIMMING CHAMBER.

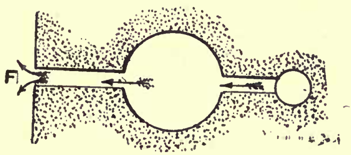


FIG. 74.—INCORRECT FORM OF SKIMMING CHAMBER.

skimming chamber. The runner entering and leaving the chamber in a *straight line*, *F*, there is no rotary motion set up in the metal, and the chamber is useless.

Sometimes a disc is used in the smaller moulds instead of a ball. The workmen usually speak of the employment of skimming chambers as *running with a ball*, or *running with a disc*. Figs. 75 and 76 show the pouring of a cylinder cover through a disc, *A*. *B* is the ingate, *C* and *D* risers, *C* being over the disc and *D* over the casting.

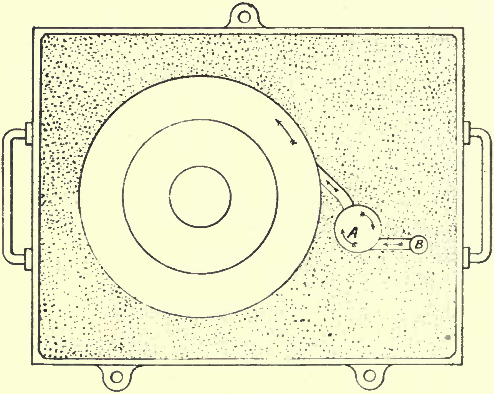


Fig. 75.

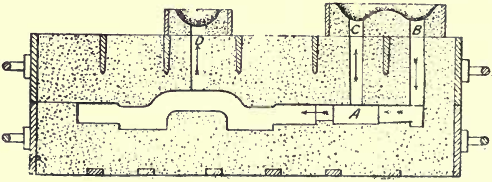


Fig. 76.

Pouring a Cylinder Cover.

The area of ingates should be in proportion to the size of the castings. Castings are light or heavy, thick or thin, machined or left rough, and all these points have to be considered in determining the sizes, positions, and character of runners. Thin and light castings should be poured from several thin runners, or from a spray. Fig.

77 shows a thin *runner stick* of the type which is employed for pouring thin pipes, etc. A heavy runner would *draw* a light casting, and probably cause fracture. The great length of runner is given to compensate for its narrowness, a large area being necessary for quick running of thin castings. Fig. 78 shows a pattern *spray* of runners, *A*, ready for ramming *in situ*, against pattern *B*, also used for the pouring of thin light castings, the total area of entry being large, while the spray itself is readily

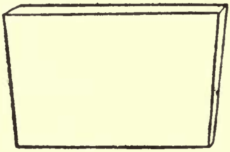


Fig. 77.—Runner Stick.

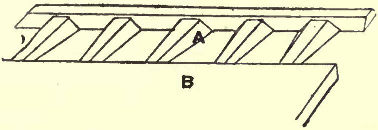
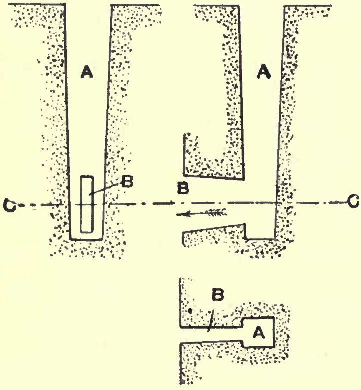


Fig. 78.—Spray.

Fig. 79.—Runner Pin.

detachable after casting. Although heavy castings will require runners of large area, it is better, as far as practicable, to employ several runners of moderate area rather than one or two of large size. Thus the runner pin shown in Fig. 79, which is the most common form, is not so good as the oblong ones in Figs. 80 to 82, being liable to cause a *draw* in its immediate vicinity. Runners of circular section are most often used, but those of flat and oblong section are in many, perhaps in most cases, preferable to the round ones, because they are more easily and safely knocked off and chipped from the casting. There must in any case be sufficient area, because a casting poured too slowly will probably show *cold shuts*, that is, imperfect union of the metal in some sections. A mould poured too rapidly will become unduly strained, and perhaps blown and scabbed. A light thin casting cannot be poured too rapidly or the metal be too hot; a



SECTION ON LINE. C. C.

FIG. 80.

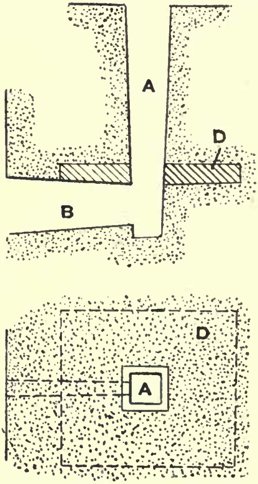


FIG. 81.

INGATES AND RUNNERS.

heavy casting must be poured slowly, and the metal must be *dead*.

In cases where castings have to be machined the runners should be kept as far away as possible from the machined parts, as the metal is always dirty and spongy in the immediate vicinity of a runner.

Figs. 80 to 82 illustrate two examples of running at the side of a mould. In each case *A* is the ingate and *B* the runner. The pattern ingate, and the pattern runner are each rammed up in place, and the runner *B* in Fig. 80 is then withdrawn into the mould in the direction of the arrow. In Fig. 82 the runner stick is drawn in the opposite direction, the sand being temporarily dug away behind for the purpose. Fig. 81 shows a loam cake, *D*, rammed in the mould, being better adapted than green sand in a heavy mould, to withstand the cutting action of the iron as it passes from *A* into *B*.

Fig. 170, p. 251 illustrates the pouring of a large mould, suitable also for cylinders cast on end, through an annular pouring basin. The metal is poured in the depression *L* at the right hand, whence it overflows into the annular basin, and then falls through the runner passages disposed around the basin. After the mould is filled, any surplus metal runs off at *M*.

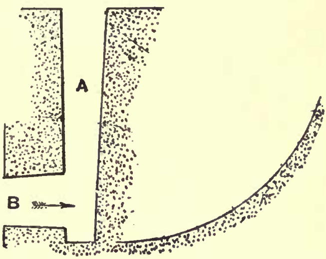


FIG. 82.—INGATE AND RUNNER.

Fig. 83 shows the external appearance of a mould after it has been poured. Here *A*, *A* are the pouring basins for the ingates, *B*, *B* are the flow-off gates. The drawing shows the blue hydrogen flames all over the top and at the joint.

Feeding.—A *draw* (see p. 128) occurs because the sum total of shrinkage will be greatest where the greatest mass of metal is situated. Since the outer skin becomes chilled by contact with the sand and sets first, nearly all the later shrinkage goes on within the mass, and this naturally will produce a spongy and open casting. To prevent this, the casting is *fed*. In some cases the head cast on to receive the scurf or sullage is made sufficiently large and massive to do duty as a *feeder head*. The mass of metal which it contains must then be sufficient not only to remain liquid until after the metal in the mould has set, but also to exert considerable pressure upon the mould, feeding and consolidating at the same time.

A *feeder head* proper, however, is distinct from head metal, consisting of a basin or cup of metal somewhat

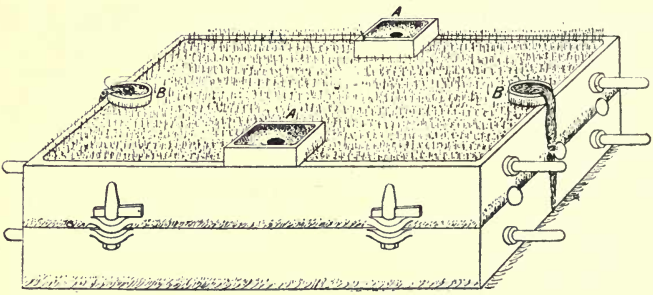


Fig. 83.—Runners and Risers.

like a pouring basin, in fact a pouring basin is often utilized as a feeder head, as in Fig. 84. A feeder head must be placed directly over that particular portion, boss, lug, etc., the shrinkage of the mass in which it is intended to compensate, and its capacity must be so great that its metal shall remain fluid after that in the boss, lug, etc., has set.

The *feeding* or *pumping* is performed by getting a $\frac{1}{4}$ in. or $\frac{3}{8}$ in. iron rod red hot in the molten metal in the ladle, and immediately the pouring has taken place the rod is inserted into the feeder head, Fig. 84, and a vertical up-

PLATE V

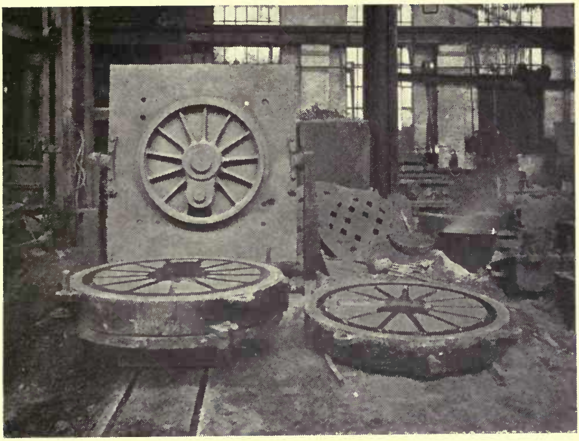


Fig. 187.—Pattern Plate and Moulds of Railway Wheel. Lancashire and Yorkshire Railway

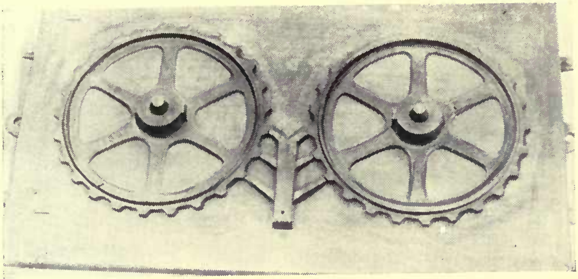


Fig. 188.—A Pattern Plate

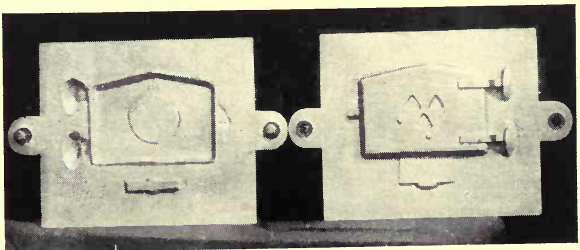


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Fig. 189.—McPhee Pattern Plates

and-down movement of the rod in the metal is commenced, taking care not to touch the actual mould. The effect is to create an agitation or movement in the molten metal, and to keep a passage clear into the heavy and still molten central mass, in order that until it becomes actually set, fresh and ample supplies of hot metal shall enter from the feeder head to compensate for the loss due to interior shrinkage. In large masses it is necessary to supply added hot metal from a hand ladle to the feeder head. The pumping continues until the metal thickens and clings to the rod, when the latter is struck sharply with a bar of iron or hammer to effect the detachment of the clinging portions.

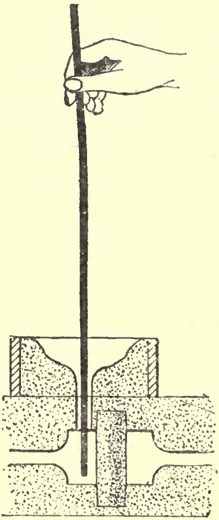


Fig. 84.—Feeding.

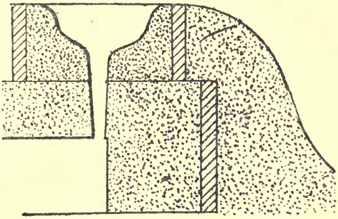


Fig. 85.—Flow-off Gate.

Finally the metal becomes so viscous that little more shrinkage will take place, and the feeding ceases.

Risers.—In moulds of considerable area, *risers* or *flow-off gates* are employed. Their function is mainly to relieve the cope of excessive strain, which in their absence would cause injury to the mould. There is an enormous pressure on a cope of several square feet in area, and though the flasks are made stiff and strong, and well loaded, this pressure would, and often does, cause a thickening of the central portions of the castings to an extent of $\frac{1}{4}$ in. or $\frac{3}{8}$ in., due to the rising up or springing of the cope under pressure. Risers relieve it partly, though not entirely, of pressure, but they also allow of free exit of the air and gas, which would otherwise be confined in the mould, and cause scabbing. The risers should properly be kept closed with plugs of clay or sand until the mould is just upon the point of filling, when the plugs are instantly removed, and the pouring still continuing, the excess of metal is allowed to flow off quietly outside the flask. Fig. 85 shows one of these flow-off gates, the metal flowing away over the sloping bank of sand.

CHAPTER IX

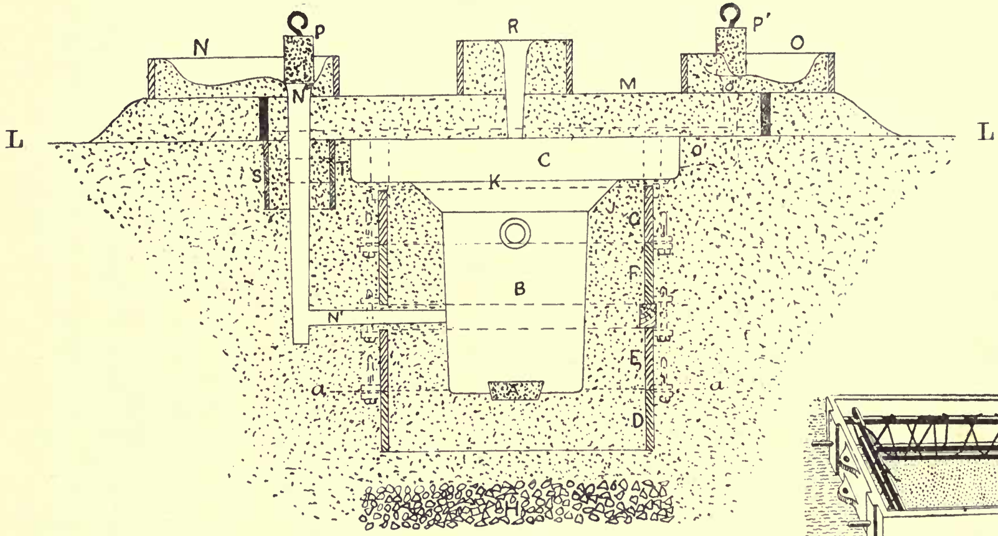
EXAMPLES OF GREEN SAND MOULDING

We are now in a position to consider some examples of green sand moulding affording illustrations of the varied work which calls forth the best judgment of the jobbing moulder. Figs. 86 to 89 are illustrations of the mould made for an anvil block of four tons weight. It is an example of a deep and heavy mould. Though this is not a case of bedding-in, pure and simple, it illustrates the manner in which methods are modified in order to suit individual and special jobs.

To begin, the top of the block must be sound, and that is therefore cast in the bottom. It is a deep mould, and there is a core, *A*, in the bottom for the anvil, there is also a great discrepancy in the dimensions of the smaller part of the block *B*, on which the anvil rests, and the base *C*, which is embedded in concrete. For these reasons the method of making the mould which is here shown was adopted. The whole of the stem *B* was made in flasks in dry sand. The method of supporting the sand in middle-part boxes by means of rods and lifters is shown in perspective in Fig. 87. The flask *D* was parted from *E* at the joint *a—a*, for convenience of placing the core *A* in position, but *E*, *F*, *G* were permanently cottared together to form one *middle*. Blocks of wood were necessarily interposed between *E* and *F*, to allow of the entrance of the runner *N′* to the mould. This portion of the mould was made, dried, cored, and finished first. Then a pit was dug in the foundry floor, a coke bed, *H*, laid down at the proper depth, sand rammed and vented over it, and the box parts *D*, *E*, *F*, *G* all cottared together, were bedded down level thereon, their vents passing down to the coke bed *H*, and thence out through the vent pipes *I*, which are rough pieces of cast iron pipe of 3 in. or 4 in. diameter, reaching from the bed to the surface of the floor. The space encircling the flasks was then filled with sand, and flat-rammed level with the top edge *L*. The pattern being jointed at *J* and at *K*, as a matter of convenience, the portion from *J* to *K* was placed back in the mould, and the base *C*, dowelled by the face *K*, was laid in position for ramming, which ramming was continued to the top edge *L*.

The cope *M* being perfectly plain was not rammed in place, but upon a levelled bed of hard sand, being liftered and vented all over its depth and area. A few lifters depending from their bars are shown in section at *M′*, to illustrate the method of liftering. While the vents from the stem *B* go down into the coke bed *H*, those from the base *C* pass out through the cope *M*.

The manner of pouring was as follows. There was one pouring basin, *N*, for running near the bottom, and one, *O*, for the main running at the top. The purpose of the runner *N′* is simply to fill the lower part of the mould, so that the metal falling from the top at *O′* shall not cut up the sand, but fall into a pool of metal. A four ton ladle was used at *O*, and a one ton at *N*, thus allowing a ton for heads and basins. The pouring commenced at *O*, but merely to steady the ladle in position, and fill the hollow, *O*, of the basin. As soon as this was done, the ladle at *N* was poured, the plug *P* being kept in place until the



VERTICAL SECTION Y—Y

FIG. 86.—MOULD FOR ANVIL BLOCK.

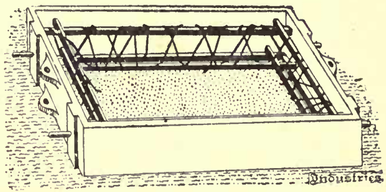


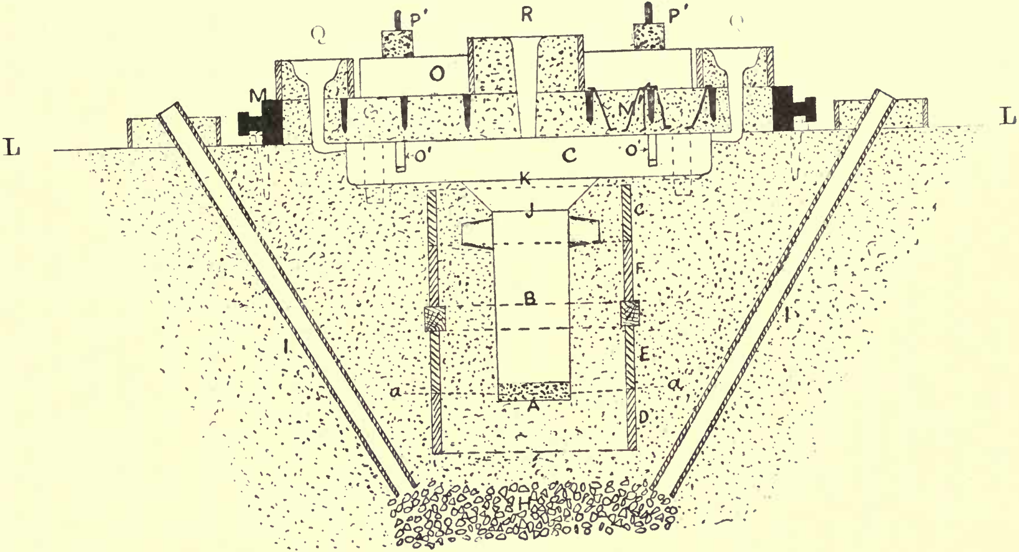
FIG. 87.—RODDING AND LIFTERING.

basin was nearly full, when P was removed, and the metal entered the mould. Immediately it had entered, the filling of pouring basin O began, and when nearly level, its plugs, P', were removed, and the metal was run into the mould rapidly. The fact of its being filled was indicated by the flow-off at the risers Q, the plugs for which (not shown) were removed at that instant. After the cast, feeding was performed at the feeder head, R. The area of the runner N' was 3 in. × 1 in., that of O', O', 6 in. × $1\frac{1}{4}$ in. At the opening of each ingate, N'' and O'', loam cakes were imbedded in the pouring basins to sustain the pressure of the metal, sand being liable in heavy casts to become cut up and washed away. The object of the flasks S, enclosing the ingate N'', at the section where the ingate comes in very close proximity to the base, is to prevent a probable washing away of the intervening sand, T, which is a casualty to be guarded against. The pressure is in such cases enormous.

To avoid confusion, no weights are shown on the cope. By calculation the pressure on the cope should be as follows:

Area of surface C, Figs. 86 and 88, 5 ft. 0 in. × 4 ft. 6 in. Height from face of cope to level of pouring basin, about 18 in. Then 60 in. × 54 × 18 = 58320 in. 58320 in. × ·263 = 15338 lb. 15338 lb. = 6 tons 18 cwt., statical load required, including cope. Actually 8 tons of weights were used.

The flywheel mould shown in the succeeding figures is an example of a type of work by which the cost of pattern-making is much lessened. Instead of making a complete pattern, a process of sweeping up and of sectional moulding is adopted. It cannot properly be called bedding in, because there is no pattern, neither does it



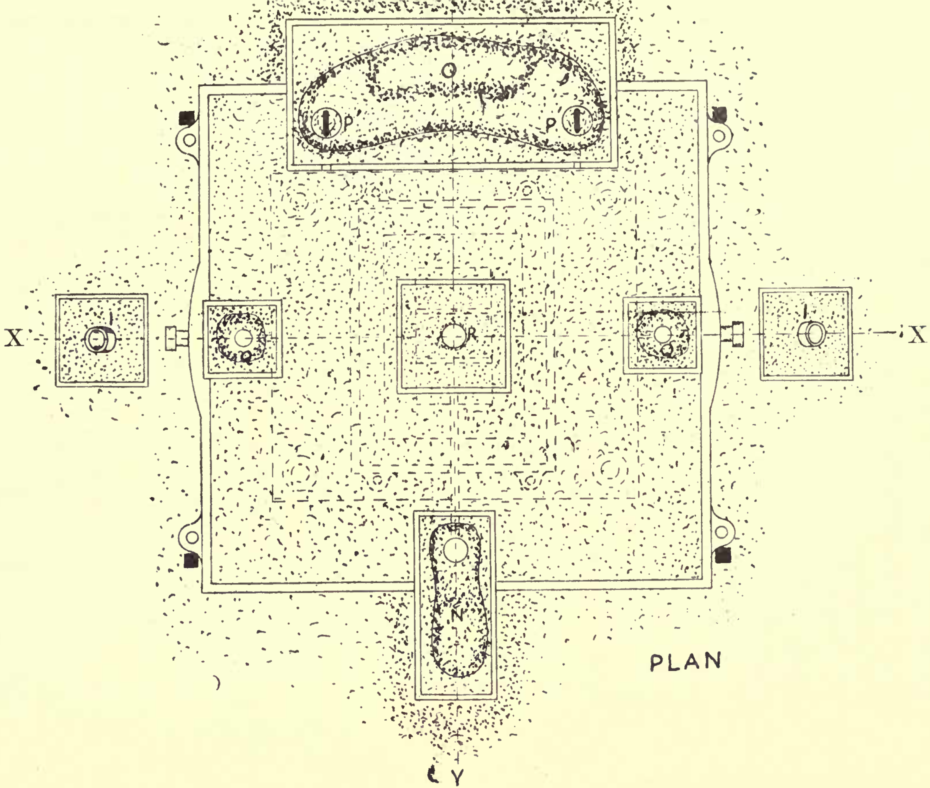
VERTICAL SECTION X—X

FIG. 88.—MOULD FOR ANVIL BLOCK.

come under the head of turning over. It resembles in the main bedding in, even though there is no complete pattern used, because the work is moulded in the floor, and a cope is the only flask used. The method is one which is often adopted in heavy work of this general type, such as rectangular bed plates, and circular bases, even when the internal portions happen to be somewhat intricate, intricate portions being readily formed by means of cores.

A coke-bed should properly be laid down for this, unless the rim happens to be narrow, in which case venting over the bottom, and diagonal venting therefrom to the mould joint will answer the purpose. In any case the cope is rammed before the lower face is touched, as follows:

A bed of sand is rammed hard, and levelled with the foundry floor, and the striking board *A*, Fig. 90, is attached to the strap *B* and the striking bar *C*, the socket *D* of which is bedded in the floor. By comparing the edge of this board with the pattern segment, Fig. 91, its coincidence with the edge of the segment is apparent. The board therefore strikes a *reverse mould*, upon which the cope, Fig. 92, is laid and rammed, a stratum of parting sand intervening. The reason why this method is adopted, instead of striking the cope direct, is that the precise ultimate position of the cope for casting is secured thereby. If the cope were struck separately, and put in place by measurement, it would be much more troublesome to set it with accuracy than when it is rammed in place; for it is not a case of fitting of flasks with pins. The cope has to be laid upon the floor, and then the only setting which is available is that done with stakes of iron driven into sand, Fig. 97, *D*. Returning the cope to



PLAN

its original position by means of the stakes with which it was set for ramming, is simpler and far more accurate than striking it first and setting it afterwards. Before

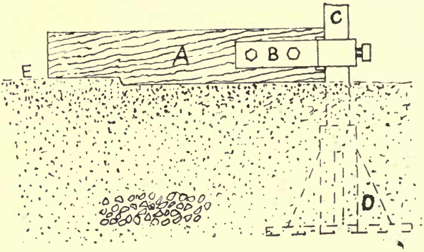


Fig. 90.—Top Striking Board for Flywheel.

the cope is rammed upon the bed several things have to be noted.

Looking at the section through the flywheel rim, Fig.

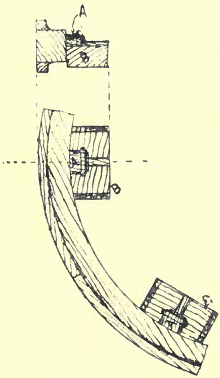


Fig. 91.—Pattern Segment.

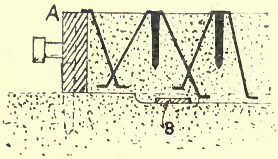


Fig. 92.—Cope.

93, it is clear that the formation of the face of the cope must take one of two directions. It must either coincide with the upper face, *A*, of the rim, and with the horizontal central plane, *B*, of the bosses, or it must remain entirely continuous with the rim face, *A*, *A′*. The choice between the two methods is determined by the formation of the upper halves of the bosses, and of the prints which carry the arms. If the mould joint were shouldered down to be continuous with the centres, *B*, of the bosses, then Fig. 94 would show the joint face in section, and then it is evident that as many half bosses and half prints as there are bosses and arms in the wheel would have to be laid upon the reverse sand bed struck by the board *A* in Fig. 96, and in precise coincidence with the positions which the lower halves of the bosses and prints are afterwards to occupy, and that the cope would be rammed over them. It would not be easy to set these bosses correctly. Nor is it advisable to lift the cope sand away from a deep shoulder, *A*, Fig. 94, such as that against which the

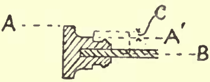


FIG. 93.—SECTION OF RIM.

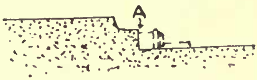


FIG. 94.—ALTERNATIVE JOINTING OF COPE.

bosses would have to abut. Hence the reason for the adoption of the method illustrated in these figures.

The lower halves of the bosses within the rim are formed by ramming directly from the pattern segment, Fig. 91. The upper halves are made in cores, the outlines of which are shown dotted in Fig. 93. In this case, to give sufficient sand in the core above the beading on the boss, it happens to be necessary to increase the height beyond that of the top face of the rim. This slightly complicates matters, because the thickness of the core *C*, Fig. 93, standing above that face, has to enter into a corresponding print in the cope. Hence six prints of thickness *C*, and of the same length and breadth as the core, have to be measured carefully into place on the reverse bed struck by the board *A*, Fig. 90, in order that their impressions may be imparted to the cope sand at the time of ramming the latter. These prints are shown in section, Fig. 92, *B*, and in plan, Fig. 95. They are set by a circle corresponding in diameter with that of the inside of the rim, and their centre lines are made to coincide with the intended centre lines of the arms marked upon the bed. They are prevented from

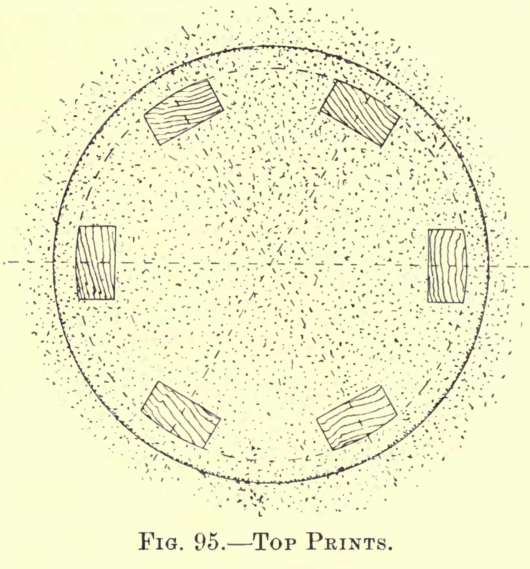


Fig. 95.—Top Prints.

becoming shifted during the process of ramming, by means of common cut nails driven down alongside of them into the sand. In this position they are rammed and their impressions obtained in the cope. The cope is liftered, Fig. 92, rammed, and vented precisely as though it were above a pattern, and it is then lifted off, taken away, turned over, and any broken edges mended up.

Then the second striking board *B*, Fig. 96, is bolted to the strap at such a height that its joint edge *A* coincides with the joint edge *E* in Fig. 90. The lower edge *C* coincides with the lower face of the rim, so forming the bed upon which the pattern segment, Fig. 91, is to rest. The corner *D* coincides with the external diameter of the rim, as shown dotted; or it may, if preferred, be of a larger diameter. The edge of which *D* is the termination, is made diagonal, because if made perpendicular the sand would tumble down—being made as it is, the segment pattern, Fig. 91, rests upon the bed struck by *C*, and the sand is rammed both on the external and internal sweeped

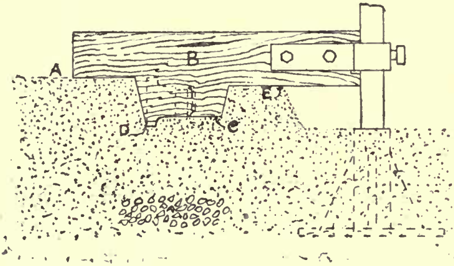


FIG. 96.—BOTTOM STRIKING BOARD.

faces of the segmental pattern. The position which the segment has to occupy in relation to the swept-up bed is shown by its dotted outline given in the figure. The edge *E*, it will be seen, corresponds with the upper face of the rim.

The bed is made as though for a bedded-in mould. The sand is rammed hard in the lower portions and well vented, and the vents closed with the fingers. A more open stratum of about an inch in thickness is lightly rammed over this surface and consolidated with the fingers, the board being swept around several times until an evenly rammed, well-vented, and smooth bed is produced underneath those portions which will be occupied with the rim, and to a little distance without and within the same. Then the board is removed and the pattern segment laid down for ramming. This segment, Fig. 91, has the same section as the rim. Two half bosses, *A*, *A*, are fastened upon it very exactly at one-

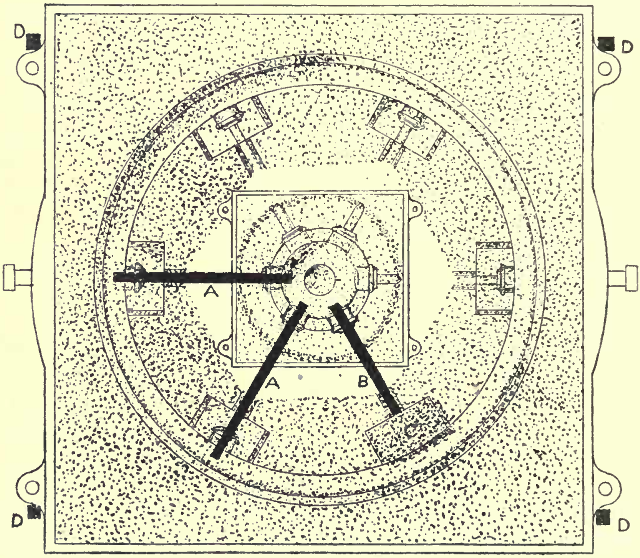


FIG. 97.—PLAN OF MOULD.

sixth of the circumference. Prints *B*, *B* occupy the positions of the complementary halves. Ample taper is given to these prints, as shown. The segment is laid in the position seen dotted in Fig. 96, and rammed. The circumferential position of the segment at each remove is governed by the bosses, the boss near one end being dropped into the impression just made by its fellow at the end opposite. The precise length of the segment extending beyond the bosses is not of importance. It is not at all necessary to ram the sand over the whole of the internal area, but only sufficiently far inwards to afford a backing for the rim mould, and for the bosses and their prints. This is seen in Fig. 97. At, and near the centre also, a space must be left for the small flask containing the boss mould.

We now leave the rim for awhile, to note the prepara-

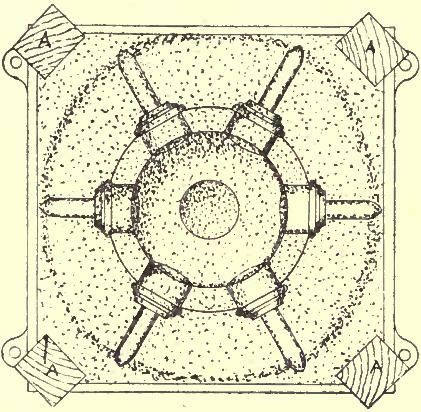


FIG. 98.—BOSS MOULD.

tion of the boss. This is rammed from a complete pattern in a small flask by itself. Fig. 98 shows the joint face of the lower half of this flask in plan. As the arms, which are cast in, have to come through the flask joints, these joints are left open to an amount sufficient for that purpose, blocks of wood, *A*, being inserted at the corners at the time of ramming, to keep the flasks at the required distance apart. The sand therefore stands above the joint faces of the flasks in both top and bottom parts, reaching to the centre of the arms. This explains the reason of the sloping joint indicated by the shading. The ramming up is quite simple, and is done in dry sand.

After the boss mould is dried, it is set in the centre of the rim mould, Fig. 97, its position being checked both radially and horizontally, the rule, straightedge, and spirit-level being used, and the print impressions for the arms in rim and boss are all brought in line.

The cores which form the upper halves of the bosses are made in the box, Fig. 99.

The arms are formed of malleable iron bar cut off in suitable lengths, and either jagged, or fullered, Fig. 100,

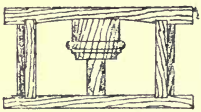


Fig. 99.—Core Box.

Fig. 100.—Fullering of Arm.

near the ends, to render their hold more secure than it would be if left smooth.

They are now set in their places, both in the boss and rim, Fig. 97, *A*, *A* showing the relative positions of arms and mould at this precise stage. All being thus set in, the cores forming the top halves of the bosses are laid in their prints, Fig. 97, one, *C*, being shown in place over the arm *B*. Then the cope being returned to the position in which it was rammed, by means of the guidance afforded by the stakes, Fig. 97, *D*, these cores are confined securely, their upper portions, of the thickness *C* in Fig. 93, entering into the impressions formed by the prints in Fig. 92, *B*, and in Fig. 95. This particular example illustrates a 7 ft. flywheel, of 14 cwt., and six tons of weights were used on the cope. The pouring

PLATE VI

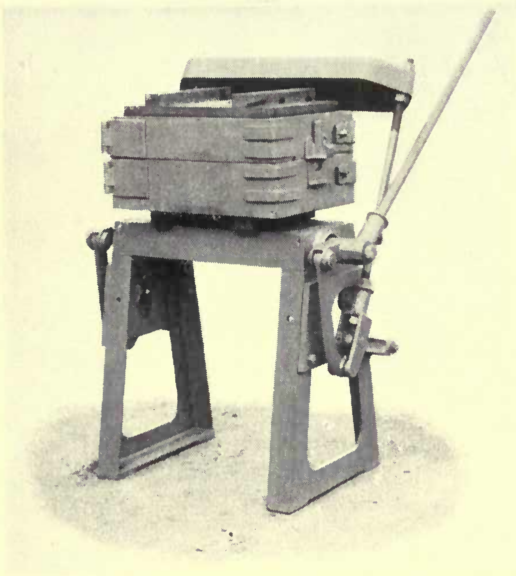


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FIG. 190.—HAND MACHINE, SAMUELSON AND CO., LTD., BANBURY

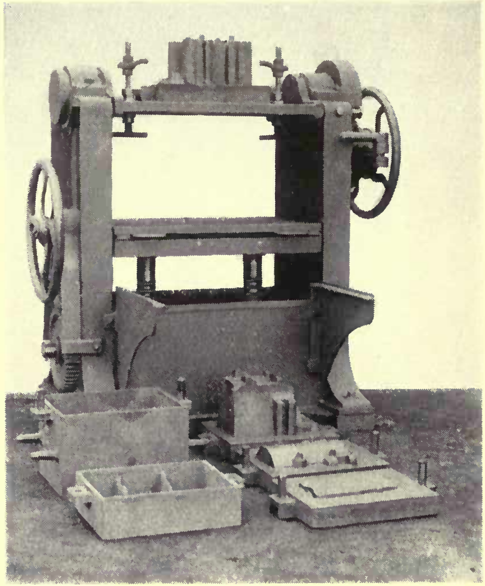

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FIG. 191.—DARLING AND SELLERS' HEAVY MOULDING MACHINE

took place at two basins, and the metal was fed at four risers.

The casting of the boss must not be done at the same time as that of the rim. If it were, the boss being small

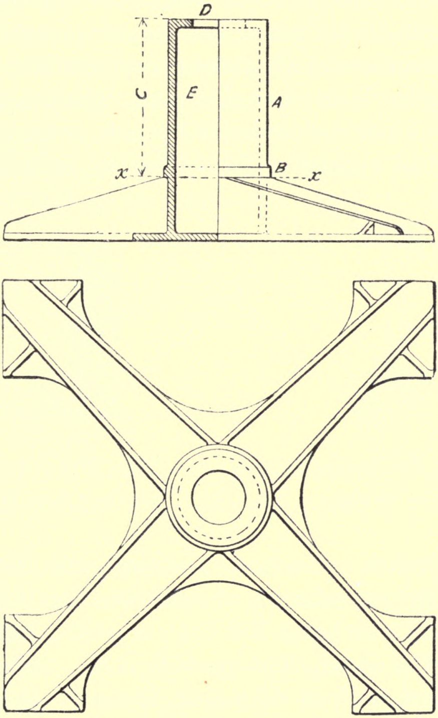


FIG. 101.—CENTRE CROSS CASTING.

would cool at once, and, setting firmly, oppose the inward shrinkage of the rim by setting up the resistance of the rigid arms thereto; and the consequence would be that, since shrinkage must occur somewhere, the rim would become fractured. In this case the rim was cast twenty-four hours before the boss, and when its shrinkage had very nearly ceased the boss was poured. It was both poured and fed through the ingate.

The casting in Fig. 101 was moulded without a complete pattern, three of them being made by the methods to be described. It formed the base or pivot upon which the superstructure of a big crane revolved. Fig. 101 shows the casting in elevation and in plan. The central boss *A*, being large, 2 ft. in diameter by 4 ft. 8 in. long, would have been an expensive job to lag up in wood. It was

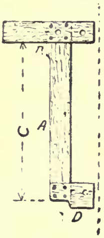


Fig. 102.—Sweeping Board for Boss.

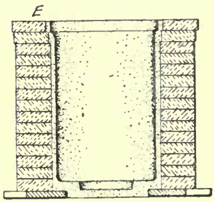


Fig. 103.—Loam Mould for Boss.

therefore struck up in loam and sunk into the floor previously to the ramming up of the cross. Fig. 102 shows the board used for striking the boss, and Fig. 103 the loam mould of the same. The part *A* in Fig. 102 strikes the straight part 2 ft. in diameter, the part *B* strikes the collar; the length of *C* is equal to the length *C*, 4 ft. 8 in. in Fig. 101, and *D* strikes a print for the end *D* of the central core *E*.

The loam mould of the boss is built up of bricks laid radially. One course is sufficient, because although the strain on the mould when pouring is great, the bricks are rammed tightly round with sand. When the mould of the boss is struck and dried, it is set in its permanent position, and before it is rammed around, the top is levelled. A parallel straight-edge is placed across the face *E* and a level is tried upon it. The straight-edge is laid in different directions in turn, and adjustments of the mould are made, until it is horizontal. If this were not done carefully, the boss would be cast out of truth.

Before commencing to ram the cross, coke beds have to be laid down underneath the horizontal flat-plated portions of the pattern (see Fig. 108, p. 183). Coke or cinders are laid down there to a depth of, say, 5 in. or

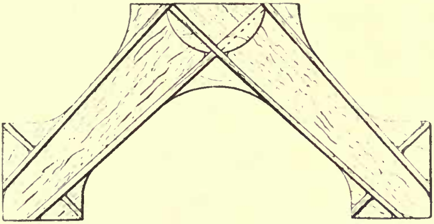


Fig. 104.—Half Pattern.

6 in., and covered with an inch or two of hay. It is not necessary to lay these down beyond the area of the plates. Their purpose is to receive the vents that go down from the flat webs. Vent pipes are brought up obliquely from the beds, one from each bed at the outer end. These details are seen in Fig. 108.

The half pattern from which the cross is moulded is shown in plan in Fig. 104, the timber shading indicating how it is constructed. The vertical ribs are screwed upon the plated portion, the screws passing through the plate so that they can be removed when the pattern is rammed up. The strips that form the plate are halved together next the boss. The pieces which form the broad feet are glued and screwed on separately, and their brackets also. The half boss is formed of two pieces fitted between the vertical ribs. The top face of the boss on the pattern terminates with the line $x—x$ in Fig. 101, which is coincident with the top face of the loam mould.

The coke bed having been laid down, sand is thrown

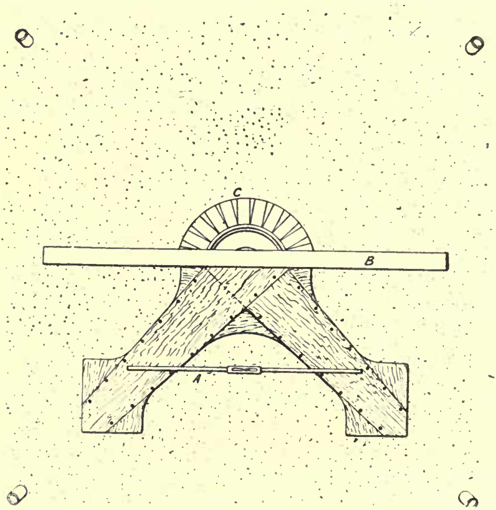


Fig. 105.—Setting Pattern into Mould.

loosely all over it with the shovel, up to about a suitable level for bedding the pattern into. The latter will have to be tried in two or three times until it has a good bedding in the sand, and with enough sand around its edges to hold it securely in place. At this stage, and before the bulk of the ramming is done, it is levelled carefully and set centrally upon the loam mould of the boss. It is levelled by laying a parallel straight-edge A,

Fig. 105, across it in various directions in turn, and placing a level upon the straight-edge. According to the indications of the level, one portion of the pattern is beaten down and another raised up by tucking sand underneath, until, in whatever direction the straight-edge and level are placed, the level shows the horizontal truth of the pattern.

The half pattern is set centrally by laying a straight-edge *B* along the centre of the loam mould *C* of the boss, and bringing the central joint edge of the half pattern up to the edge of the straight-edge. The half pattern is now ready to be completely rammed.

Obviously, in a case like this the sand cannot be rammed underneath the flat plate. The latter is therefore unscrewed from the vertical ribs at an early stage of the ramming, which is easily done, because all the screws which hold the two together are put in through the plate into the ribs. This plate is unscrewed as soon as sufficient sand has been rammed around the ribs and the boss, in order to prevent the possibility of their being moved out of place by further ramming. The ramming is then completed in detail up to the level of the under face of the plate, the sand being strickled off level with that, the top edges of the ribs furnishing the guides for the operation. Before the strickling off is done, the vents are carried down to the coke bed beneath, a long $\frac{5}{16}$ in. or $\frac{3}{8}$ in. vent wire being used. These vents are pierced pretty thickly, say 1 in. apart, going from the top of the mould down to the cinders. These are carried all over the area covered by the plate, and some are taken down a little way outside the ribs. Then the sand is finally tried over with the fingers, the damaged faces made good, and the whole strickled over level with the tops of the ribs. Finally the plate is screwed on in place, and the ramming is carried up to its edges and to its top face. As there is a good depth of sand, in consequence of the depth of the ribs, rods are driven down, going well into the bed below to support the sand.

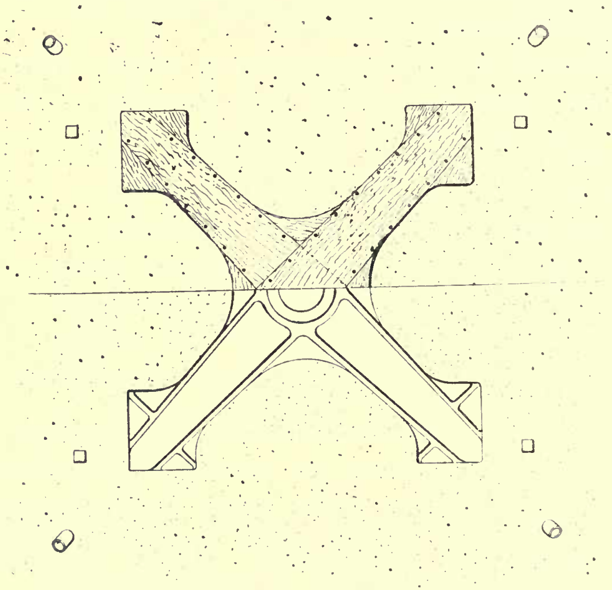


FIG. 106.—SETTING PATTERN FOR SECOND PORTION OF MOULD.

At this stage it is most convenient to ram the cope. This is perfectly plain, so that it might be rammed on any levelled bed away from the pattern; but it is better to ram it over the half pattern, because the cope can be returned into its position, guided by the stakes, with the top print impression central. To ram the cope in position, it is necessary to fill with sand all the area not occupied by the half pattern, for the temporary purpose of affording a perfectly level bed to ram on. This sand is strickled off level with the half pattern which has just been rammed, the top face of the pattern affording a suitable guide for the levelling. Parting sand may be strewn over the face so obtained; but it is better to lay sheets of brown paper over a large surface of sand which has to be rammed on, because it does not yield so readily as the sand beneath the rammer, and the surface therefore comes out more free from inequalities. The cope is well liftered, and vented over the areas occupied by the cross. After it is taken off, and turned over, the surface of the

Fig. 107.—Board for Striking Central Core.

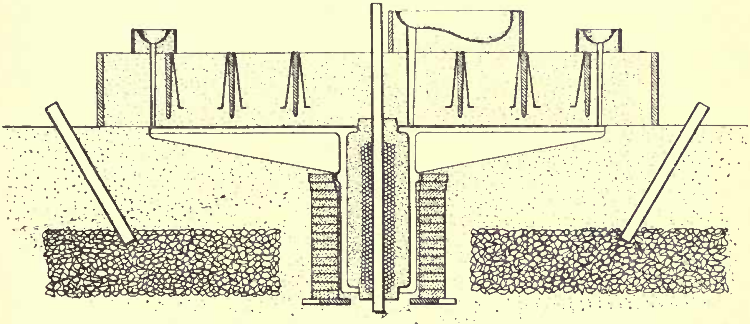


Fig. 108.—Vertical Section through Completed Mould.

sand is tried with the fingers, and portions that happen to be too loosely rammed are consolidated, and the surface is properly smoothed, finished, and blackened.

The other half of the mould is now made. The half pattern is withdrawn from the portion just rammed and turned around into its new position, the temporary sand on which the cope was rammed being mostly dug away and removed to receive the half pattern, which is set by the same methods as before. The joint face across the centre is set over the centre of the mould of the boss, and the top face of the plate is levelled in all directions. At the locality where the ribs come against the ribs already moulded, the moulded portion is filled in with pieces of wood to prevent the sand from being pushed into the mould. After this is done, the ramming, venting, and rodding proceed precisely as the same operations were performed on the first half of the mould. Fig. 106 shows the mould as it appears at this stage, one-half being finished, and the half pattern lying rammed in the other portion.

The central core is struck against the board, Fig. 107, with a core bar, hay bands and loam. The core is stood in the bottom print in the pin mould, it enters the top print in the cope, and the core bar projects through the cope to bring off the vent from the core. The mould is poured at the central boss, and one riser or flow-off gate is brought up from the end of each arm. The mould, as thus completed, is shown in Fig. 108.

CHAPTER X

DRY SAND MOULDING

Whether the metal is poured into green sand or dry sand does not affect the essential *methods* of moulding adopted, since the same processes of turning over, liftering, rodding, and sprigging are employed in each case. But the classes of work done by each method, and the mixtures of sand used, are different. Heavy work, and that which is wanted specially sound and free from blow-holes, is cast in dry moulds. Strong mixtures of sand alone can be dried.

A dried sand mould must be *dry*. This may seem a needless truism, but the point is one of very great importance. Since the mould depends for its venting on its porosity, the presence of moisture even in small quantity implies that the vents are impeded.

If green sand mixtures were dried in the stove, they would pulverize and fall to pieces. And the strong mixtures also which are used for dried moulds, though hard and sufficiently firm to resist great pressure of metal, are very tender when edges are concerned. For this reason the joint edges of such moulds are always *finned*, that is, their immediate faces are pressed down with the trowel while the mould is yet green, so that when the joints are brought together the edges remain slightly asunder, as in Fig. 109, *A*. A fin or thin film of metal of course forms here, but this is of no consequence; while, on the other hand, a crushed joint edge with the consequent falling of the sand into the mould would, if extensive, result in a waster casting.

Another point to be noted in connection with dried sand moulds is, that they will bear harder ramming than those in green sand, since they become porous in drying. For the same reason, less venting with the wire is required. The very close nature of the sand demands that its venting be perfect, and it can only be properly vented by the drying out of the moisture, and the carbonization and desiccation of the hay in the horse-manure. As long as steam, even in small quantity, is seen coming from the mould, pouring is unsafe, and the mould should properly be returned to the stove. But a steaming mould poured while warm, that is, soon after removal from the stove, is less risky than one which is allowed to become cold first. There is also this advantage in the use of dry sand, that less gas is generated than in moulds made in green sand. This is a consideration in large moulds involving a great deal of work, because the presence of gas in quantity is apt to cause blow-holes and scabs, and any arrangement by which its amount can be reduced is a distinct advantage.

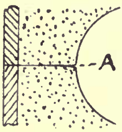


FIG. 109.
FINNED JOINT.

Dried sand moulds will also bear more swabbing than those made in green sand. Too much moisture in green sand is always a source of danger. But the swab may be used freely in dry sand, and this is often advantageous at the time of withdrawal of the pattern or of mending up, and the heat of the drying stove removes the moisture.

As in green sand moulding, so in dry, stronger facing mixtures are used in the vicinity of the pattern than in the body of the mould. The floor sand, either alone or mixed with slight proportions of stronger sand, is used for mere box filling. The cost of dry sand moulding is in excess of that done in green sand because of the extra cost of coke for drying. But this depends partly upon the system of the shop. When drying is extensively employed the percentage of expense is comparatively small, especially when the superiority of the castings and the lower ratio of wasters are taken into account.

Moulding Cylinders.—In this work two cardinal matters are the durability of wearing surfaces, and the elimination of injurious shrinkage strains. The first is got by the employment of a liner of harder metal than that which is used in the cylinder body: the second by avoiding much excess of metal in any one locality. Neglect of the first results in excessive and rapid wear of the bore, due to the friction of the piston and the hot steam; neglect of the second results in blow-holes, internal strains and possibly fracture. The simpler a casting can be made the better for the moulder, who cannot ensure a sound casting if big masses of metal are lumped in proximity to thin parts. And if the latter are those which have to be tooled, the most careful feeding from head metal will not ensure clean, sound surfaces.

In carrying out the work of cylinder making, two important details have to be considered. One is the question either of using a pattern, or of striking up the mould in loam; the other is whether to cast horizontally, or on end. Neither admits of an absolute decision, but must be settled by special conditions. In brief, the choice of the first method in work of medium size is generally determined less by dimensions than by numbers required off. For small castings, however, a pattern would almost invariably be made, even though one or two castings only should be required. Some saving even then might be effected by striking up the pattern body in loam, instead of building it in timber lagging, and then fitting the valve casings, flanges, etc., in wood, to the loam, and moulding then from that composite pattern, in green or in dry sand, exactly as in the case of a full timber pattern. In the largest work, loam moulding is invariably adopted. That is, the mould is swept round against its brick backings, and the valve seatings and small attachments are made as pattern parts in timber, to be embedded in the loam by measurement.

The question of casting horizontally or vertically seldom arises except in the case of the smaller cylinders, which are moulded from full patterns. A goodly number of firms make their cylinders horizontally, and with satisfactory results. Many men think the vertical pouring, with head metal, the safer, and would prefer that to the other; although admitting that by using clean hot metal, and by extended experience, excellent results are obtained in the other way in shops which deal with cylinder work in large quantities. And, after all, the cost of turning moulds up on end and fixing cups, etc., for vertical pouring, does not amount to much, and it gets rid of all risk of open metal on the upper portion of the cylinder bore. Certainly it is much the safer plan in the average class of shop.

The annexed figures represent a double cylinder made in dry sand, cast with circular guides for the crosshead, having a foot for bolting to a convenient base, and with steam-chests, all in one. It is a good example of rather

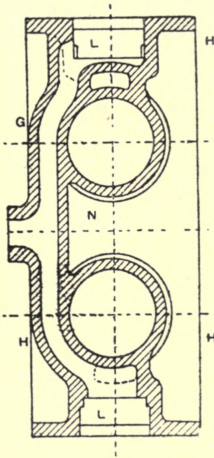


FIG. 111.

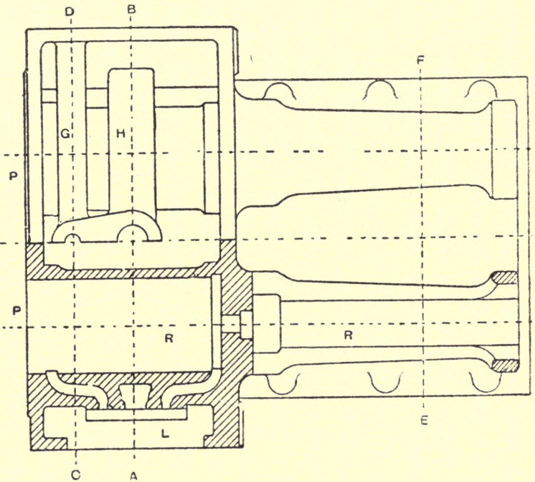


FIG. 110.

DOUBLE CYLINDER.

elaborate coring-out. Figs. 110 to 113 show views of the casting. Fig. 110, right hand, gives a plan view of the cylinder and guide, and a section through the same. Fig. 111 is a half cross section through the cylinders on the line A-B—that is, through the exhaust passages, and a half cross section through the cylinders on the line C-D—that is, through the steam inlet passages. Fig. 112 is a longitudinal elevation; Fig. 113 a half section through the guides on the line E-F in Fig. 110; G, Fig. 110 is the steampipe in plan; H, the exhaust ditto.

We see at a glance that this can only properly mould in one way—and that is as in the plan view Fig. 110. There are several troublesome features about that method of moulding, but not nearly so many as there would be with any other method. We settle instinctively that it must part along the line I-J, Figs. 112 and 113; and a glance now at the lifts shows us that several coreboxes are absolutely essential. Thus, I-J representing the joint alike of the pattern and mould, the overhanging parts at K will not lift; hence they must be cored, or the overhang must be formed with loose strips, which in this case, at least, are not desirable. Then (see Figs. 110 and 111) the steamchests must evidently be cored, and their cores must carry those also for the various passages. The hollow space M beneath the foot in Fig. 113 would deliver very well, but cutting it out in the pattern would involve considerable trouble, and be rather weakening to the pattern itself, while it offers every facility for simple coring. So, not of necessity, but for convenience, we core that out. The cylinder bores and the guides are necessarily cored. The space N, Fig. 111, between the pattern joint, and under the passages G to H, must also be cored. There is a space O, Fig. 113, which reaches from the pattern and mould joint to the plate or web which connects the two crosshead guides, and this also must be cored. Being cast on end, the necessary head metal will be put at P, P. These considerations settle the essential methods of construction.

To mould the cylinder, the half containing the steam and exhaust passages is first rammed up in a mixture of dry sand, the joint face being laid on a joint board, and the drag or top part placed around the pattern. There is nothing about the ramming of this that calls for any special comment. The sand is rammed hard in detail and vented, all its weak corners and angles are well strengthened with nails and rods, and the mass of overlying sand is properly liftered. Then the drag is turned over, the other half pattern laid on, and the top rammed, the flasks parted,

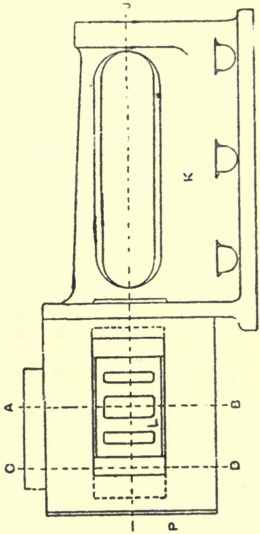


Fig. 112.

Double Cylinder.

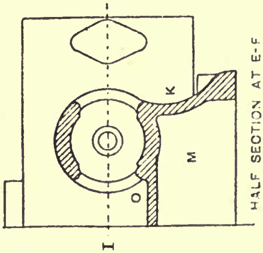
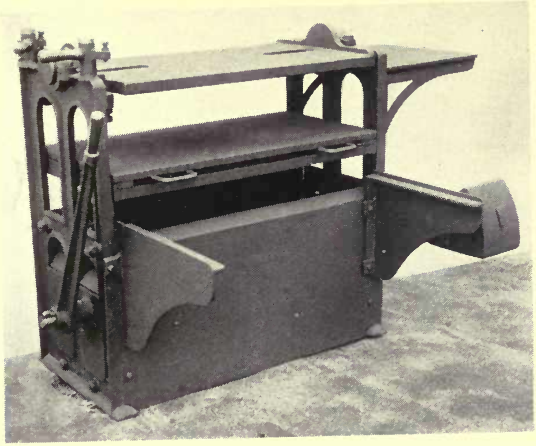


Fig. 113.

the mould cleaned, the joints finned, and the boxes run into the stove to dry. But the real work—that which presents difficulty, or at least that which demands especial care—has yet to be done, and this will now be illustrated in detail:

The two great requisites in cylinder work, after the usual and ordinary precautions common to all moulds, are the proper venting of the cores, the proper securing of the same, and the making of safe and sufficient provision for carrying off the air away from the mould. The making of the cores is accomplished precisely on the same lines as any ordinary dried cores, but since some of them are flimsy, rather more caution has to be exercised in their case. Taking the port cores first, there are two usual modes of venting—one with rods, the other with strings,—each of which is practised indifferently, the latter being most suitable for the smallest cores of all. For the smallest curved passage cores, fine string soaked in tallow may be used, and when the cores are dried, the tallow melting away, leaves the string slack. When strings are used for cores of moderate size they are either drawn out while the core is green, or after it has been dried. When drawn out while green there is a tendency of the string to cut through the cores at the corners. But if rods are rammed up crosswise, as shown at *a*, *a*, Fig. 114, which illustrates a section along a core in the plane of one of the strings, the strings can be pulled out without much risk. When the strings are greased and allowed to dry in the stove, their charred fragments can usually be blown out of the dried core with the bellows. The extreme end of the vent at A is filled up with sand to prevent the entry of the metal—all the air being brought away at the opposite end of the core, coming off, therefore, into the print impressions.

When rods are used, there are corresponding numbers of holes bored in the corebox, as shown in Fig. 115, and



See p. 280

FIG. 192.—THE DARLING AND SELLERS LIGHT MACHINE

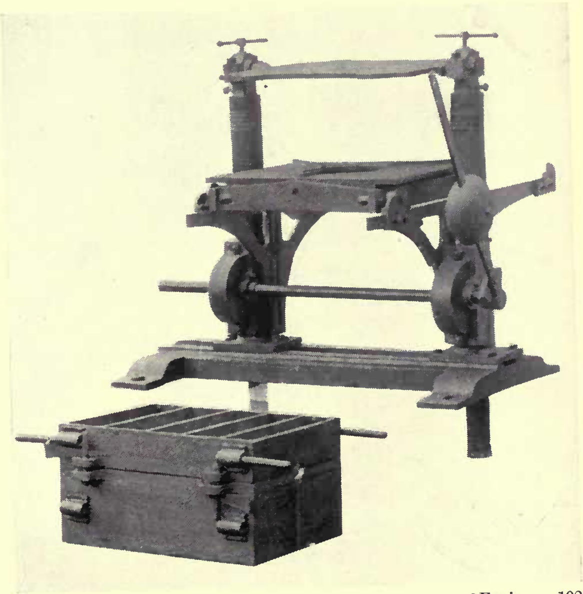


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FIG. 193.—WOOLNOUGH AND DELMER MACHINE

these rods are thrust through the holes into the box, and the core is rammed around them, taking care to keep them central with the thickness. If they get much out

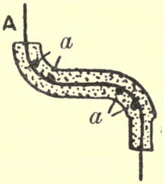


Fig. 114.

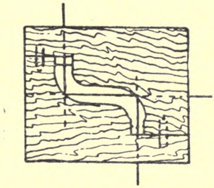


Fig. 115.

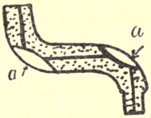


Fig. 116.

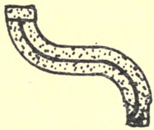


Fig. 117.

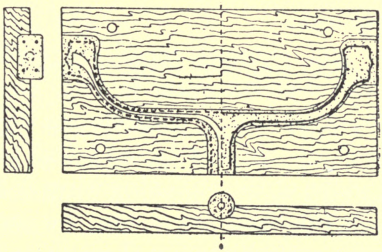


Fig. 118.

Passage Cores.

of centre there is a danger of the metal bursting into the vents, and causing a blown casting. The figure shows the corebox with the rods *in situ*, in readiness for ramming. After the core is dried, at the corners opposite each rod, Fig. 116, *a*, *a*, a narrow groove is filed, going down to meet the terminations of the holes formed by the rods. A string is inserted a little way into one hole, and carried round the curve, and through the other hole at right angles with the first. Now the portion filed out is filled up again round the inserted string with core sand, and the string drawn out, thus leaving a clear passage round the curve. The continuity of the vents should always be tried with the bellows for security. In the smaller cores it is not usual to carry the vents right round—the air striking away readily from the short unvented portion. The extreme end of the vent is of course always filled up with a plug of sand.

In addition to the rods for venting, a rod or rods have to be rammed in to stiffen the core and to furnish the means of its attachment or anchoring, a hook being formed on the core rod or rods for the purpose, as shown in Fig. 117, which illustrates a core cut through in the plane of a core iron.

The steam and exhaust cores are made somewhat differently. The corebox parts in two, one-half of the exhaust box being shown in plan, etc., in Fig. 118. Each half is rammed up separately, and the two stuck together. The shape of the stiffening wires is seen in plan, in full lines on the right-hand side, the core being supposed to be only partially rammed up there. The vent is cut out with the trowel in the joint, as shown in the left-hand side, which illustrates the half-core finished; so that when the halves are cemented together, a central, rudely circular vent traverses the whole length of the core. The appearances of the ends of the complete core when cemented are shown in side and end views.

The steam-chests are cast with the cylinders, the covers then being plain plates. Hence the prints for the port, and exhaust cores, are placed in the steam-chest corebox. Also, since it is an advantage to be able to drop the port cores down from the top rather than to thrust them into their prints horizontally, the prints are continued up to the top, *a*, Fig. 119, and the cores stopped over when finally in place.

Fig. 120 shows the core finished. The central portion is filled with ashes, and a few rods are placed about to stiffen the body. Since the exact distance between the port and exhaust cores where they pass out at the valve facing is important as affecting cut-off, $\frac{1}{16}$ in. is allowed

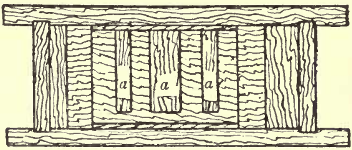


FIG. 119.

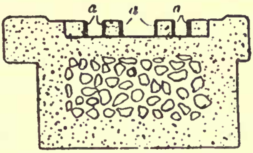


FIG. 120.

STEAM CHEST BOX AND CORE.

for machining along their edges. Hence the reason of the shoulders in the cores, Figs. 114 and 117, which are the reduced widths, giving the tooling allowance. Further, to avoid broken print edges and mending up, careful moulders often ram up strips of hoop iron against the sides of the prints, *a*, *a*, *a*, Fig. 120, which, when embedded in and forming a portion of the core, are an absolute and secure guide. An eye, or a couple of eyes, are rammed in the core for lifting it into place, and an eye projects from the back for securing it bodily against the side of the flask.

The main core R in Fig. 110 may be made either in a box or from a board. If several castings have to be made—say over three or four—a box pays for its first cost; if only one or two castings, then a board is cheaper. If a board is used, as in Fig. 121, it is evident that the cored-out openings in the sides of the guides (see Fig. 113) cannot be struck, but must be made with a corebox. The section of this box will then be that shown in Fig. 122; and the cores may then be made separately from the

Fig. 121.—Striking Board.

main core, being rammed on a bedding of sand struck to the contour of the box; or else on a bottom board, and nailed to the main core after they are dried. Or, they can be rammed directly on the main core, as in Fig. 123,

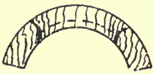


Fig. 122.

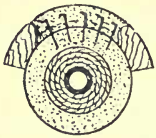


Fig. 123.

Guide Cores.

after the main core has been wholly or partially dried, the surface being cut up a little with the trowel and moistened with clay water, and nails stuck in at intervals to assist adhesion.

The section of the main core is shown at Fig. 123, a small bar being used to go through the narrow neck which carries the bush. This bar cannot be large, but must be as large as convenient. Thus, if the neck were cored to 2 in. diameter, the bar might be $1\frac{3}{4}$ in. to allow just a thin layer of tow between the bar and the loam. But the portions which form the cylinders and the guides being much larger, the $1\frac{3}{4}$ in. bar must either be wedged into two larger bars—one at each end—or the increased size must be covered with core plates and hay bands. The first plan is not desirable in this case, through lack of rigidity, so the second is to be preferred. The section of this core, then struck on such a small bar, and taken through a layer of hay bands, is that represented in Fig. 123.

When a corebox is used, a half-box will suffice, by

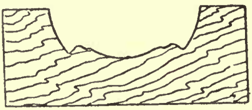


Fig. 124.

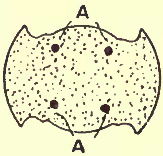


Fig. 125.

Half Box and Core.

making two half-cores, and cementing them together. Each half is stiffened with rods, and a vent passage is cut through the joint. Fig. 124 shows a section through the half-corebox, taken through the centre of one of the guides, and Fig. 125 is a section through the finished core in the same position, *A* being the rods. These, of course, are not straight, since they have to pass through the narrow neck, but are bent beyond the neck to occupy the positions in the large diameter shown at *A*.

The remaining cores call for no comment, their construction being quite apparent from the figures.

We now suppose that the mould is completed, dried, and ready for coring up. Before the cores are blackened, they are all tried in place to see that they fit properly and leave the proper amount of metal everywhere. Then

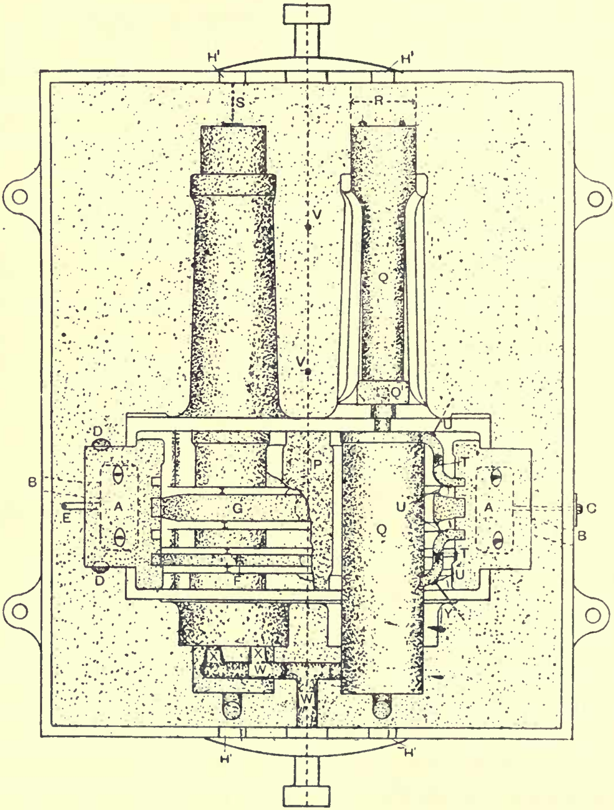


Fig. 126.—Mould Cored up.

they are blackened, put back in the stove for a few hours, or for a night, and are ready to go finally into place. Even more care has to be exercised in this particular with cylinders than with work of ordinary character, when the cylinders are not cast in the position in which they are cored, but vertically, when any insecure fixing will make itself manifest, to the great grief of the luckless moulder when he comes to his work on the following morning.

In the first place, then, that portion which was first

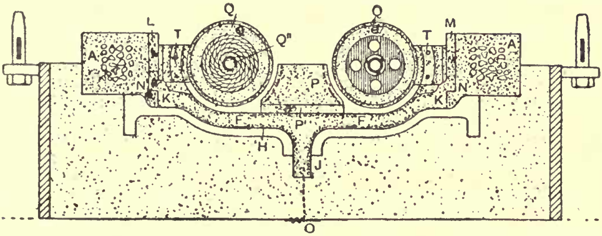


Fig. 127.

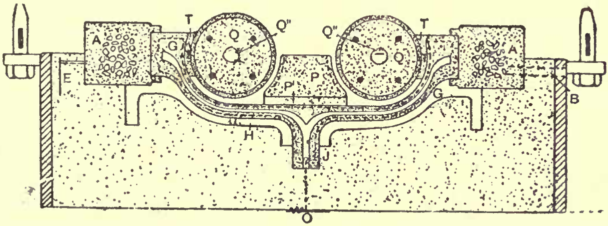


Fig. 128.

Mould Cored up.

rammed, the bottom part—though actually the cylinders are cast vertically,—is laid on blocking or any convenient support, joint face upwards. Then the steam-chest cores are laid in their print impressions—see Fig. 126 (*A*, *A*), which gives a plan view of the mould, representing it as it appears at certain stages of the work; and Figs. 127 and 128 (*A*, *A*), which are sectional views across the mould through the centre of the steam passage cores *F*, and exhaust cores *G*, respectively.

The vents from the cores *A*, *A* are brought away through holes *B* in the sides of the box part; a channel also, shown in Fig. 128, being cut in the sand from these holes to the back of the cores, which cores may be fastened with or without screw bolts. If they were heavy, and their overhang very considerable, they should properly have been attached with a screw bolt, passing from an eye in the core through a hole in the box side, as shown at *C*, Fig. 126. But in this instance the core is well supported in its print impression, and is not of very large size. Hence a little dodge, such as that shown at *D*, *D*, Fig. 126 is sufficient to hold the core. A shallow groove is filed on each side of it, vertically, and grooves in the mould sides in corresponding positions; and while the core is held back, bedding against its print, this is filled up with damp core sand, which, when dried, becomes an interlocking key or dovetail, holding the core securely in place. Another simple way is that shown at Figs. 126 and 128 at *E*, where a loop of wire is slipped through the eye of the core, and carried out through a channel cut for it in the sand, and a short bit of rod is pushed through the loop and down into the body of sand, thus holding the core securely back in place.

Afterwards, the steam and exhaust cores *F* and *G*, which (Figs. 126-128) connect their pipes with the two steam-chests, are placed in. These, when laid in, have to fit their bottom print impressions, and also the impressions in the steam-chest cores, and to allow the correct thicknesses in bottom *H* and sides *I*; which thicknesses will have been tested at the first trying-in of the cores, both by measurement and by the use of clay thickness pieces in the bottom where direct measurement is not available. The vents from these cores are not brought into the steam-chest cores at all, but through the round prints *J* in Figs. 127 and 128. There is a difference in the way of fitting these to the steam-chest cores. The exhaust core, Figs. 126 and 128, *G*, fits the steam-chest through nearly the whole depth of the latter. But this is not the case in the steam-passage core, Figs. 126 and 127, *F*; for it enters the chest at one corner, the bottom corner as the mould lies (see Fig. 127), *K*. Hence it is necessary to make provision for its support. To trust to chaplet nails only when the mould has to be up-ended for casting is not safe. A ledge therefore is formed on core *A*, as shown at *K*, on which the steam-passage core rests. This may then be either stopped over with a small rectangular core *L*, as in Fig. 127—left-hand—nailed on; or the box may be so formed as to continue core *F* to the top, and so stop itself off, as shown at *M*, on the right-hand side of the same figure. In either case the result is the same—the leaving a steam entry of width *N* into the steam-chest.

Each core is secured in its bottom print by means of a wire carried from it through the box, and twisted fast round a bit of iron rod, Figs. 127 and 128, *O*, *O*.

There is now the core which forms the inter-cylinder space, seen at *N* in the drawing of the actual casting, Fig. 111. This might deliver itself as part of the mould by leaving the portions of the steam and exhaust pipes which bridge across it, *G* and *H*, in Figs. 110 and 111 loose. It is better, however, to core it, and this is shown in Figs. 127 and 128. The core *P*, therefore, is shown fitting in its print impression P^1 in both views (Figs. 127 and 128), the print thickness P^1 happening to coincide with the thickness of the metal in the steam and exhaust pipes. This shouldering of the print takes place beyond the pipes, hence the appearance of the core in Figs. 127 and 128. The vent from this core is carried out at the back, in a line with *O*, and beyond it, of course, in the figures. The main cores *Q*, Figs. 126 and 128, are next placed in their print impressions, one only being shown in Fig. 126 to the right. The precautions to be observed here are to see that the cores do not sag in consequence of the narrowing of the diameter at the neck which forms the stuffing box, and that the thicknesses of metal are equal all round, the equal thicknesses being dependent first on the truth of the cores, and second on the concentricity of the prints with the pattern cylinders. Clay thickness pieces will be placed underneath the cores for this purpose, and measurement will be also taken at the sides. When the thicknesses are obtained, chaplets will be driven in to sustain the weight of the cores about the central portions, avoiding those parts which have to be bored. The proper position for the chaplet in this case is at Q^1, Fig. 126, under the shouldered or stepped portion lying between the cylinder bore and the guide.

Again, when ramming up cylinders the vents of which have to be brought away at the ends in the fashion to be noted immediately, it is necessary to cut away the sand in continuation of the print beyond the front end—that is, the space enclosed between the dotted lines *R* in Fig. 126—which sand is made good after the cores are finally set in place. Since the mould has to be up-ended for casting, there is just the slightest chance of the cores shifting downwards slightly, and a careful moulder will leave nothing to chance. Hence at this stage it is desirable to ram up two rods, or pieces of flat or round iron, against the core end, cutting away and letting it go down a little into the body of hard sand below, as shown at Fig. 126 in the space *R*. Or, if there is sufficient room above the vent, a small flat, square piece can be rammed in, and kept in place with a rod bearing at the other end against the inside of the flask, as shown at *S*. The holes $Q^{1\,1}$ in the centre of the cores, in Figs. 127 and 128, are the vents through which the air strikes away from these cores, and they pass completely through from end to end.

If the box is specially constructed for moulding cylinders of one particular size, it will be made with holes in its joint face opposite the air channels in the main cores, as shown at H^1, H^1, Fig. 126; and the air will then be taken directly away. But in cases where ordinary flasks are used, the air is readily taken off at the back, between the bars, in the manner shown in Fig. 129, which gives a part section through the corner of the box. Here *A* is a diagonal passage cut in the end of the core *B*, establishing a communication between the main channel in the core, and the vent passage to be formed between the bars, the sand passage being made by ramming up a piece of rope *C* in the end of the mould, from which the sand has been removed, as just now noted, thrusting first one end a little distance into the core vent, and bringing the free end outside the flask, as shown. After the sand has been rammed, the rope is drawn out,

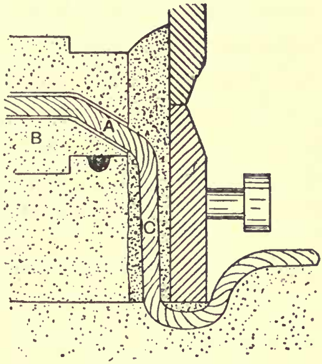


Fig. 129.—Vent Rope.

leaving a free communication between the core and the outside. The newly-made sand is shown darker than the rest in the figure, and this is dried now with a piece of red-hot iron.

The difference in the core sections *Q* in Figs. 127 and 128 is given to show the different appearance which the cores would have in section if made in the two ways previously described. Fig. 128 illustrates the cores as rammed in a box, with the four stiffening irons in section. In Fig. 127 two sections of a struck up core are shown, that on the right hand being against the face of a coreplate, that on the left through the haybands, which come intermediately with the coreplates.

Taking the port cores *T*, *T* in the figures, one fits against the cylinder bore, and one against the ring which forms the recess terminating the bore, and a corresponding difference for the lengths is made in the corebox. Unless the cores are very deep, they can be readily put in without disturbing either the steam-chest or the cylinder core, by simply sliding them round the body and down into their places. If they are very deep, as in some low-pressure cylinders of compound engines, this cannot be done, and then the prints in the steam-chest core must be made $\frac{3}{8}$ in. or $\frac{1}{2}$ in. too long, to allow the passage cores to pass the extra space, which is filled up with sand after they are in position. Fig. 130 shows a good plan to adopt in such cases as these, being an example taken from a double-ported compound cylinder, 14 in. bore, and having ports 9 in. wide. Each single port opening being narrow, the core would be weak and flimsy. Hence these weak sections are rendered rigid by connecting them together at the otherwise free ends with a continuation piece of core, fitting into the print, so that they can be handled without risk of fracture. The spaces A, A are necessary in order to be able to get the wide port cores in, and they are filled up afterwards with sand.

The vents from the cores T, T are taken off into the steam-chest core, no vents passing into the cylinder core at all. Sometimes, though seldom, they are secured into the steam-chest core. But the chaplets, Fig. 126, U, and the claywash daubed around the print joint, and the sand by which they are stopped over, are usually quite sufficient to retain them in place. The core which is

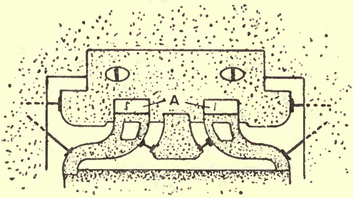


FIG. 130.—STEAM CHEST AND PASSAGE CORES.

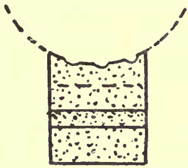


FIG. 131.—VENTS.

uppermost in the mould is grooved on the face which abuts against the body core, in order to allow the air to pass up freely at the time of casting, Fig. 131.

There now remain the cores which form the foot of the casting underneath the guides. These are three in number, and are shown in Fig. 132, which gives a plan or face view of the opposite half of the mould to that shown in Fig. 126; and Fig. 133 is a sectional view of the same—showing, however, the central guide cores in dotted outline, in order the better to illustrate the relative positions of the cores. The same reference letters are used in both figures, but the guide cores are entirely omitted from

Fig. 132. Each of these cores A, A is well guided by its print, at surfaces on the outside, end, and bottom; and B by a shallow print all round. They are all, therefore, screwed up with bolts passing through holes made temporarily through the sand between the bars, to the back of the flask, and there screwed against long flat washer plates bridging across the bars, as shown in Fig. 133. The flask is turned over in order that the holes may be filled in with sand, rammed around the bolts.

The cores being of considerable bulk, have cinders rammed in them to collect the air; and the body of sand in the box outside of the cores A, A is also vented with cinders, into which the air from the cores is conveniently brought, and out through holes in the flask sides, or downwards between the bars to the back. The courses of the vents are indicated by the dotted lines at C, C, C. Core D, though shown in its position relatively to the dotted cylinder cores, is not actually fixed in this half of the flask at all; but after both the cylinder cores are finally set in place in Fig. 126, D occupies the position marked V, V in that figure between the guides, and is secured in place by means of two rods shown at V, V, which pass up into two corresponding holes in the core D, Fig. 133, of slightly larger diameter, which permits of sand being rammed around to lock the core fast. Chaplets, shown at E, Fig. 133, keep the cores at the proper distance apart as required for the thickness of metal in the foot.

Very few chaplets are wanted about this cylinder. The outer corners of the port cores are assisted with chaplets, and the thicknesses of metal between the ports themselves are secured by two spring chaplets or by double-headed ones. Those at the outer corners of the ports have their stalks inserted in shallow grooves cut in the sand with the trowel, and are covered up and fixed with moist sand. It would often be desirable to secure the cores still further

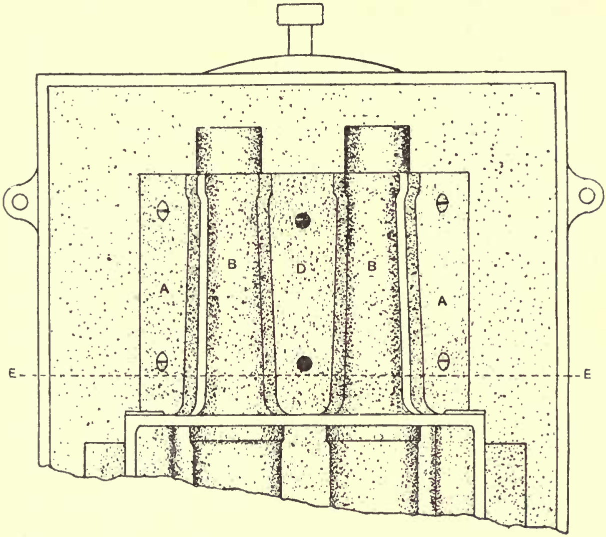


Fig. 132.

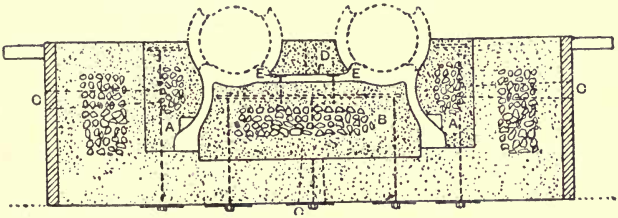


Fig. 133.

Mould Cored up.

with chaplets abutting against the base of the cylinder, but the necessity for this should, when practicable, be prevented, because the metal becomes chilled round a chaplet, and there is always more risk of a blow in its vicinity than elsewhere. In all places where cores have been stopped over, or chaplet stalks inserted, or any mending-up done, the damp sand must be dried before the closing of the mould, by placing red-hot blocks of iron over or against the made-up portions, and a little oil poured over and around them will lessen the generation of gas.

We now consider what provisions have to be made for casting. The mould has to be poured on end—cylinders and head metal uppermost. The runner is shown in Fig. 126 at *W*; ingates at *X*, *X*, two or three of the latter to each cylinder, dependent on its size. A plan view of the runner is shown in Fig. 134, where *A* is the runner and *B*,*B* are the ingates. These are cut out while the mould is green. At *C*, in the latter figure, the risers are shown, through which feeding takes place. All the vents are examined to see that they open out clear; the fastenings of the cores are all made sure of. If the main cores have been made in a box and cemented together with clay-wash, there is just a fear lest the halves should slide one over the other on up-ending, unless they fit properly in the ends of their prints. It is scarcely possible to exercise too much care in all these minutiæ before finally closing and up-ending the mould, because should anything shift it cannot be remedied after the metal is poured in.

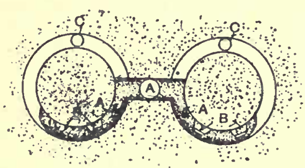
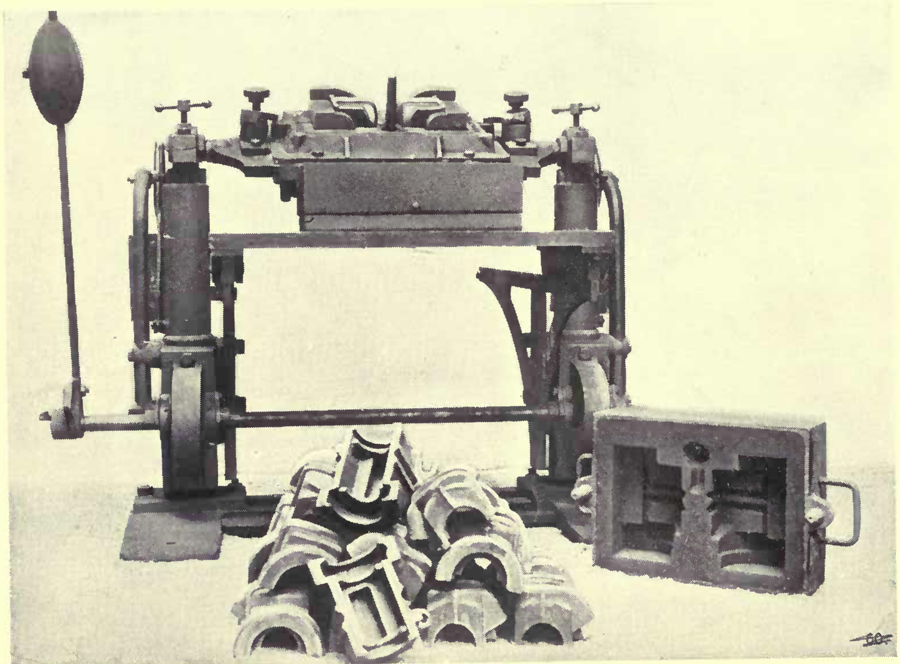


Fig. 134.—Ingate and Runners.

The flasks, well cottered or screwed together, are now lowered into a pit in the floor, of such a depth as to

PLATE VIII



See p. 284

[Facing p. 208

FIG. 196.—HAND-MOULDING MACHINE, WITH PATTERNS FOR TRAMWAY AXLE BOXES. THE LONDON EMERY WORKS CO.

bring the top at a height convenient for pouring. A pouring basin and risers are formed in the usual way. Vent pipes are brought up from the cores *A*, *B* in Fig. 133, while the vents from the body cores come out at *C*, Fig. 129; and all down the open sides the vents from the mould surfaces come out.

Head-metal.—The necessity for putting head-metal on castings which must, when machined, have perfectly clean faces, has often been a point at issue between the foreman moulder and his employer. Generally, a moulder considers head-metal indispensable in engine cylinders, hydraulic cylinders, and rams, while the employer grudges the cost of cutting off the head, and maybe thinks that it is a moulder's fad, especially when he learns that there are shops in which cylinders are cast without heads.

There is much more in this than can be settled off hand. There is no doubt that, under some conditions, it is safe to cast without heads; but these conditions do not exist in jobbing-shops doing general work, and mixing metal at random for all the work of the day. In such shops, when it is desired to turn out good sound work, it is not safe to cast cylinders without head-metal, and the cost of sawing, or slotting, or turning off a head is but a trifle compared with that of a waster casting. In foundries in which cylinders are a speciality it is often the practice to dispense with heads; by mixing special brands of metal, pouring it hot and clean, and using flow-off gates freely, heads are not found requisite. Often, then, in the case of cylinders moulded, *i.e.*, not bricked up, the practice is to mould and cast them horizontally instead of in a vertical position.

The function of head-metal is essentially two-fold: It acts as a receptacle for all the dirt, scurf, air (which would otherwise be arrested on the face of the top flange), and it also becomes a feeder to supply hot metal to the shrinking casting. In a very minor degree it fulfils a third function—that of producing liquid pressure, which tends to consolidate the metal below; but, if that were all, the result could be more easily secured by increasing the height of the pouring basin than by massing a relatively shallow head of large area over the casting. Increasing the depth of a head within reasonable limits increases the soundness of a casting; but that result follows much less from the increased hydrostatic pressure than it does from the function of the head as a feeder of hot metal. The latter function is so very important that it is usual to supplement it by the practice of mechanical feeding, with a rod through the runner, see p. 161, and two or three risers besides.

This function, therefore, of mechanical feeding is actually the most important one which the head has to fulfil. The first-named, that of collecting dirt, sullage, and air is very important only when due care has not been taken to exclude the first two from the mould altogether. Many a head is cut off with scarcely a trace of dirt apparent, or an air-hole visible in it when broken up for remelting. A careful moulder and furnaceman will generally keep dirt out of the mould, so that, if this were all, the top flange of a cylinder would face up clean even though no head metal were cast on it. Hence the chief, and almost the only, function of head which is worth consideration is that of a feeder to the casting. It is to this, therefore, that we will give attention.

It is well known that, when the metal in adjacent parts of a casting is very disproportioned, draws, or hollow and open spaces will occur in the heart of the heavier metal, see p. 128. This is caused by the thinner metal cooling and setting before the heavier. Since the latter continues to shrink for some time after the former has congealed it becomes drawn away from the central parts, leaving cavities there; the nature and extent of these will depend on the relative disproportion of the masses and on the character of the metal itself. The greater the disproportion present, and the stiffer and stronger the iron, the greater will be the extent of the drawing. It may take the form of large open cavities, or it may consist of very coarse open crystallisation with minute rifts between small masses of crystals, or it may partake of both characters—holes and coarse crystallisation and rifts combined; when such drawing occurs it is a sure indication that there is disproportion in adjacent masses of metal. Draws, it must be remembered, are not to be confounded with blow-holes and general sponginess; which occur in castings regularly proportioned. Blow-holes are due to the entanglement of air in the metal when liquid, and occur chiefly in the upper portions of castings, while drawing may occur anywhere, and has no relation whatever to the pressure of air. The two are totally distinct in cause and in appearance.

It is not easy to fix the most suitable amount of head-metal for a given job right off without experiment; usually, however, previous castings of a similar character afford some guide, but every one must stand on its own merits. A difference in design necessitates a difference in head-metal; the more disproportionate the sections of a casting the heavier should the head-metal be.

Since the head-metal becomes the dirt receptacle—the feeder for its casting, that determines its mass in relation to the casting: it must be large enough, but there is no advantage in increasing its mass unduly. But if it is insufficient, some of the dirt, instead of passing up into the head, will become lodged against the face of the casting. If the mass of metal in an annular section of the head is considerably less than that in a corresponding annular section of the body of the cylinder it will cool down before the cylinder cools, and will thus be unable to fulfil its function of a feeder of hot metal, viz., to fill up the cavities caused by shrinkage stresses. One sometimes sees head-metal put on in this fashion; but it is of so little value that the casting would be as well, probably better, without it.

The proper form for head-metal is shown in Fig. 126, p. 198, where its diameter is as large as that of the cylinder body, and where there is a good radius which facilitates the passage of dirt upwards from the flange, and there is sufficient height and mass in the head to cause it to remain hot after the body of the cylinder has ceased to remain liquid, and so the head becomes an efficient feeder as well as dirt collector. Another example occurs in Fig. 172, c, p. 254.

The idea might suggest itself that the head would be more efficient if made as large as a cylinder flange, but the adoption of such a method would cause the whole flange to become drawn, or open-grained, due to the metal becoming drawn away from the interior portions towards the outside faces, causing then either holes, or coarse crystallisation, by either of which the flange would become weakened, and the making of a steam-tight joint rendered difficult. The heads illustrated are fully efficient, practically no dirt can lodge on the portion of the flange uncovered with head, because during the movements of the molten metal any light matters which do hitch there become moved again and buoyed up into the head round the curved edges. The practice of feeding or *pumping*, which is done through the head, see p. 161, also assists in such movements, besides fulfilling its main function of carrying down supplies of hot metal from the head into the shrinking body of the casting below.

The diameter of a head is easily settled: it is not so easy to settle its height, and no rule can be given. It often becomes necessary in standard work, in order to secure the best results, to increase the height of a head, so that this becomes a matter solely for judgment and experiment; speaking generally, heads of from 4 in. to 6 in. deep are suitable for cylinders from 6 in. to 12 in. bore; from 12 in. to 18 in. or 20 in. bore, the heads should be 8 in. or 9 in. deep. Over these sizes the heads may average a foot deep, there or thereabouts, an inch or two more or less in height being of little moment. I should say that heads of 10 in. or 12 in. deep are sufficient for any cylinders, no matter how large. Heads of 15 in. to 16 in. deep are put on hydraulic cylinders, but then they have to stand very heavy pressures. For engine cylinders, the heights given represent good safe practice.

Head-metal will not feed a casting properly if the casting is badly proportioned; if there are very thick and very thin parts adjacent, the metal in the thicker portions will inevitably become drawn and open. It has sometimes been necessary to enlarge the areas in certain localities in cylinder passages solely to reduce the amount of metal adjacent and so prevent drawing. Many draws are never seen until cylinders have leaked and been broken up; but they often show on the face of a flange, and may even run from the flange into the passage adjacent. If the best results are to be obtained from head, cylinders must be so proportioned that there shall be no great disparity in adjacent thicknesses of metal. Thus, lumps of metal massed in the vicinity of passages or flanges should always be lightened out; this is not a question at all of saving a bit of metal, but possibly of saving a casting.

CHAPTER XI

CORES

THE term *core*, used in a general way at least, is almost self explanatory. Any central portion, or a portion removed from central parts, is a core. But in foundry work the term has several distinct meanings, defined by the prefixes, *green sand* core, *dry sand* core, *loam* core, *chilling* core.

The term *green sand core* simply denotes the central portions of those moulds which are made directly from the pattern itself, without the aid of a separate core box. Thus, the central portion of a plain open rectangular frame, like the surface boxes used for hydrants in the streets, would yield a green sand core, because moulded from the pattern itself, and the sand employed would be of precisely the same character as that encircling the pattern, and would be connected therewith by rods, nails, or grids, and undergo no process of drying whatever. These portions, though termed cores (often termed *cods* also), do not come properly under the present heading. Metal cores for chilling the holes in the hubs or bosses of wheels may also be disregarded in this connection, and also those loam cores which are bricked up, see Chapter XII, so that all we have to consider in this chapter is the cores made in dry sand in core boxes, and loam cores which are *struck-up* or *swept up* on bars.

Cores are required when (*a*) there would be extreme difficulty in so constructing a pattern that an impression could only be taken of the central portions by making a large number of joints in pattern and mould; (*b*) when the central sand would be so weak that it would not retain its form and position against the rush and pressure of metal; (*c*) when the cutting out of the internal portions of patterns would render them excessively weak as patterns; and (*d*) generally, when it would either be impossible or extremely difficult to make or put the mould together, or vent it without the aid of cores. Thus, if we take almost any pump clack box or valve box with seatings we could make a pattern precisely like the casting, making as many joints as would be required to allow of drawing the parts separately from the mould. But we should then meet difficulty (*a*) and also (*c*). But the substitution of a simple core or cores enables us to make a strong pattern, and to employ one or two joints only, instead of several, in the mould. Or, if holes of small area, but of considerable length, are required in castings, green sand would not deliver freely from similar holes made in the pattern, but would become cracked and broken away, even if a considerable amount of taper were imparted; neither would they withstand the rush of metal. Then the conditions (*b*) necessitate the use of dry hard cores. And no more familiar example of condition (*d*) could be given than that of any engine cylinder with its passages and feet, and often other attachments beside.

It is clear that the same conditions must exist in cores as in the moulds themselves. The substance of cores must be stiffened with rods, grids, or nails, precisely on the same principles as moulds, though the conditions and details are somewhat different. Vents of sufficient area must be provided to carry off gas and air, and the cores must be secured against the pressure of liquid metal. These are all points of fundamental importance, and we will consider them in detail.

First, in regard to the stiffening of cores. In a plain round core made in a box, a rod of iron is rammed up with it, and this is the simplest plan. In crooked cores

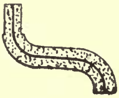


Fig. 135.—Steam Passage Core.

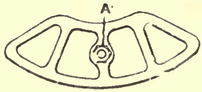


Fig. 136.—A Grid.

the rods are either bent, as in Fig. 135, which illustrates the passage core of an engine cylinder, or grids are formed of wires or rods fastened together with solder. In large cores, grids are always used, like Figs. 136 and 137, having nuts or eyes by which to lift them. These grids may be of any outline, being adapted to their cores.

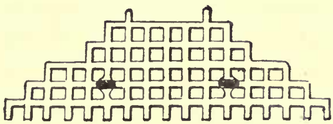


Fig. 137.—A Grid.

Fig. 136 shows one of a sweeped outline adapted to a sweeped core, Fig. 137 one of triangular outline; Fig. 136 has a nut, *A*, cast in to take the screw used for lifting, Fig. 137 has a couple of eyes cast in for the same purpose. These are usually cast in open sand, the moulder using a standard pattern grid, having excess of length, and stopping it off to length and outline required. In large and intricate work several distinct grids may be bolted together, the bolts being so placed that they may be readily taken out after the casting is made, through openings in the cored out sides of the casting itself.

Fig. 138 shows a grid used for a pipe core made in a core box, a grid being used in each half core. Similar grids, curved, are used for bend pipes of large diameter, the longitudinal portion stiffening the core, and the offsets or prongs giving local support to the sand. Stiffeners and grids of this kind are used both for cores rammed in core boxes, and for those strickled up on plates. But there is a large class of cores which are not made in boxes, but struck up on revolving bars. The bars then act as stiffeners longitudinally, and the core is made in *loam*, the adhesion of which to the bar is assisted by the use of hay bands or hay ropes, twisted and wound around the bar. When cores are very large the bar is not increased directly in proportion, except for certain standard work, but is selected simply with a view to sufficient stiffness, and the size of the core is increased by the addition of hay bands and loam alternating with each other, and sustained with core plates *A*, Figs. 139 and 140. In standard pipe and column work, collapsible core bars are used.

FIG. 138.—PIPE GRID.

There is thus a very wide range in the size and character of the bars employed. The smaller ones are made of gas piping; for those over about 3 in. in diameter, cast iron cylinders are employed, and these may be either parallel or tapered, according to the character of the work. The bars are invariably hollow, and pierced with numerous small holes, Fig. 139, for the air vents, which pass from the encircling core through the holes to the interior of the bar, whence they find exit at the ends. The bars are turned next the ends, Fig. 139, *B*, to form journals, which revolve in vees on the cast iron trestles used for their support. A boy turns at a winch handle

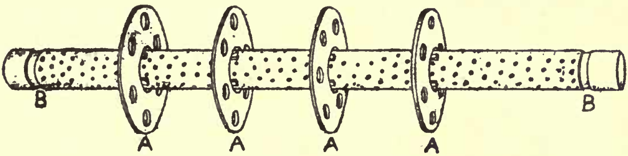


Fig. 139.—Core Bar and Plates.

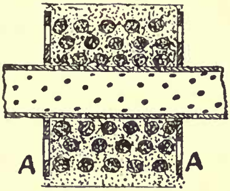


Fig. 140.—Section through Finished Core.

inserted in one end of the bar, while the core maker winds on the hay bands, and daubs the loam. This is work requiring the exercise of judgment. If the bands are not pulled taut, and laid on close, and the loam well worked into the interstices, the core will *sag*, or become baggy, will be out of truth, and dry unequally in different parts, and portions of the loam may flake off after drying. A layer of rope is laid on first, and stiff loam well worked over and between it as the bar revolves, then another layer of rope and more loam, Fig. 140. The core is partially dried before putting on the final coat, which is thinner than that first applied. Fig. 141 shows a section through a core bar *A*, hay bands *B*, and finishing coat of loam, *C*. *D* indicates vent holes. When plates are employed, as in Figs. 139 and 140, they are cast as thin as possible, and pierced with holes, as shown, to permit of their ready fracture and withdrawal after casting. When very large, the various plates are, in addition to the usual fastening to the bars by means of wedges, united and stiffened with bolts passing through them all, the bolts being inserted when the final course of hay bands is being wound round, and the nuts are brought for convenience of withdrawal opposite suitable vent holes in the ends of the casting.

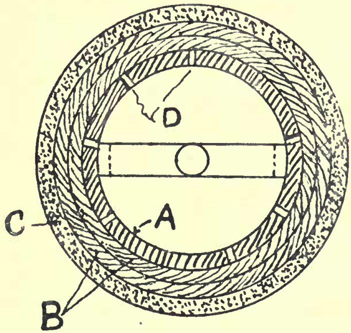


FIG. 141.—SECTION OF CORE AND BAR.

These core bars when of small diameter are used for light work, and when large, mainly for jobbing work. In regular or repetition work of large diameter, as in many pipes and columns, the cost of hay bands and of rigging up core plates would bear too great a proportion to the value of the castings. In standard pipe work therefore, and in other work of that character, the *collapsible bars* are employed. These are only $\frac{1}{2}$ in. or 1 in. less in diameter than the finished cores which they carry, and are therefore necessarily made collapsible, that is, they are so constructed as to fold, or fall inwards, and so deliver freely from the cored holes. Much ingenuity has been displayed in their design, and several forms are in use. The general principle of their action is this: The shell is usually formed of three longitudinal segments of cast iron, two of which are hinged loosely upon the third or rigid piece. The movable segments are retained in their expanded condition during the making of the core, and pouring of the casting, by various devices, as by circular discs, or by wedge-shaped bars and links, adapted to similar fittings. By means of cottars, levers, and links, the movable segments are released, falling inwards after the casting is made. The body of the bar is pierced with vent holes. The outside of a collapsible bar is, like an ordinary bar, left rough, the better to ensure the adhesion of the loam, which is daubed on directly, without the intervention of hay bands.

The *vents* of cores are variously contrived, and are of the first importance, since many a casting is ruined for want of proper venting and securing of the core vents.

The simplest vent is that formed in a plain core by means of a rod of iron rammed therein, and withdrawn, leaving a round hole, into which the air and gas generated within the core collects, and from which it finds exit through the prints. In large cores numerous rods will be rammed in, and withdrawn thus; and in addition to these, a quantity of smaller vents will be made with the vent wire, as in making moulds. In curved cores (Figs. 142 and 143) a different method has to be adopted. *Core strings* or *core ropes* have to be used, being common string or rope rammed up in the core, and either withdrawn while the core is yet green, or allowed to remain while the core is being dried; which process of baking chars the string, and allows of its fragments being blown out with the bellows. The latter method is rather uncertain, so that the better plan is to withdraw the string, the core being green, in which case two bits of wire rammed in the core, Fig. 142, prevent the string from cutting the corners by its tendency to straighten under tension. An alternative plan which is often adopted is that shown in Fig. 143, where three straight rods are rammed up in the core, drawn out, and the core dried. Then the connection is made round the curve by filing, a string inserted, and daubed and covered

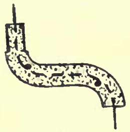


FIG. 142.—CORE STRING.

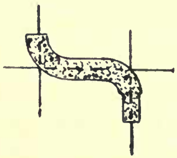


FIG. 143.—VENTING RODS IN CORE.

over with loam. This is then dried, and the string finally withdrawn.

In the case of large cores the central portions are formed of cinders, to act as reservoirs for the air and gas, precisely as in the bulkier sections of green sand and dry sand moulds. A vent hole or holes of sufficient area is then made, connecting this body of cinders with the outer air.

In cores struck on bars, the hay is porous, and conducts the air into the central core bar, which is invariably made hollow and pierced with numerous holes for that purpose. But there is no venting done with the wire in struck-up cores, as there is with those made in boxes. The latter are pierced with vent holes similarly to moulds, but the hay bands and loam are, when dried, sufficiently porous in themselves.

Cores are fastened and their vents secured in several different ways. In most cases they are set in *print* impressions, but not invariably. If a core is large and heavy, prints are not necessary. Still, in the vast majority of cases they are employed.

The *forms of prints* are various, depending on the position and mode of support required. Cores may rest in the bottom of a mould, or be carried in the top, or at the sides, or be bridged across from one portion to another. They may be carried by print impressions made in other cores. A core may be carried by one print only, or it may have several points of support.

Generally the rule is this. A core laid in the bottom is sustained by the bottom print only, the exception occurring when the core is so long relatively to its area that a bottom print alone would not afford it sufficient steadiness of base. In that case a top print will be used, or chaplet nails, or perhaps both in combination. But if the core, though long, has a broad base sufficient to afford steadiness, than neither top print nor chaplet nails are required. A core carried at the side, if short relatively to its area, will need no other support than the side print. If long, it also must be supported by chaplet nails, or if it passes right across a mould, by a print on each side. Cores carried at the sides may be either sustained by prints of the same kind as those used in top and bottom, or in *pocket or drop prints*, dependent on circumstances. Pocket prints are employed when the joint of the mould does not coincide with the centre of the hole. In such a case as Fig. 144, if a round print were used it would have to be skewered on loosely, and the core thrust in afterwards, which in this case could not be done, the core being unable to pass down by *A*; or the cope sand would have to be jointed down around the dotted line *B*, to the centre of the print, which in deep or in moderately deep lifts would be very inconvenient. Using a pocket, or 'drop print,' the lift takes place to

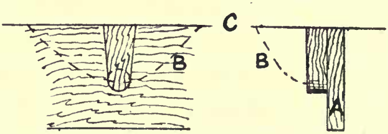


FIG. 144.—POCKET PRINT.

the cope joint *C*, leaving a clear open space into which to drop the core, which is then filled over with sand, a stopping over board, Fig. 145, *A*, cut to clip the core, being held against the mould face while the space, *B*, above the core is rammed with sand. The core is then permanently secured as though in a round print.

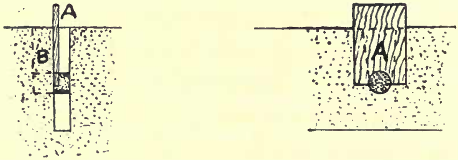
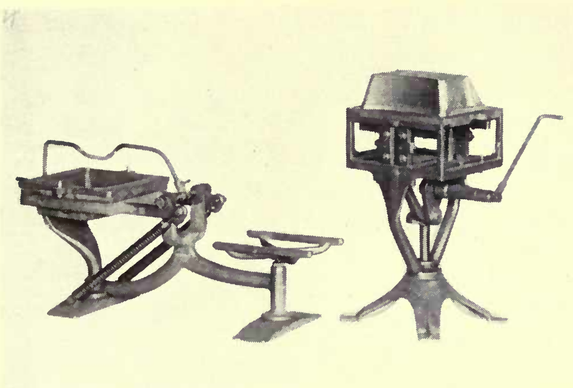


FIG. 145.—STOPPING OVER.

But core setting embraces very much besides this. It is not always sufficient in large cores to trust to the pressure of contiguous sand for security. There is an enormous liquid pressure in large moulds, and this would, in the absence of due precautions, force the cores bodily out of place in their central portions, even if well secured at the ends in their prints; or would carry them

PLATE IX



See p. 286

FIG. 197.—PRIDMORE MACHINES

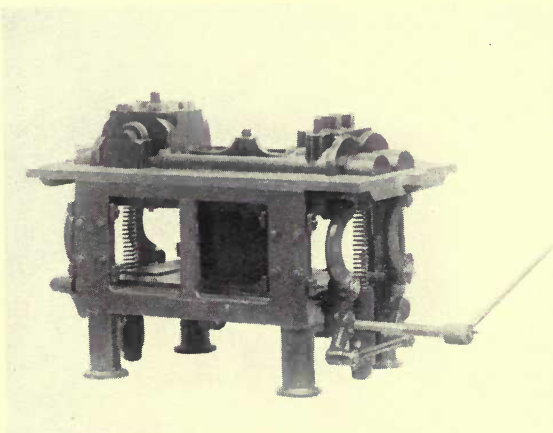


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FIG. 201.—A PRIDMORE MACHINE, FITTED WITH STEAM PUMP PATTERN

away from their prints if simply laid therein. A pipe core, or a column core, for example, would be bent and curved upwards until it would nearly or quite touch the top of the mould. A flat core with metal over its top face, and having therefore open space between it and the cope sand, would be floated up by the metal, and cause a waster casting. *Chaplet nails*, *chaplets*, and *stops* are therefore employed to steady cores in their proper positions. The forms and sizes of these vary with their position and function. Figs. 146 to 153 show chaplets *in situ*. In Fig. 146, *B′*, is a chaplet nail driven into a block of wood, *A′*, to afford breadth and steadiness of base in the yielding sand. The height of this nail is adjusted to the thickness, *B*, of metal required. Upon the flat head, *C′*, of the nail rests the core, *C*. Fig. 147 shows another chaplet made by riveting a bit of iron rod, *B′*, into a flat plate, *A′*, and used for a heavier class of work than the common chaplet nail. Here *A* is the core the upward thrust of which is sustained by the flat, *A′*, of the chaplet, which passes through the cope sand, *B*, being supported either against the inside face of a flat bar of the flask, or a bar of iron, *C*, placed temporarily across, as shown, to fulfil the same purpose. *D* is the thickness of metal between the upper face of the core, *A*, and the lower face of the cope, *B*. Fig. 148 shows another chaplet which lies entirely between core and mould faces, and having a thickness equal to the thickness, *A*, of the metal. In large heavy moulds these chaplets will be of correspondingly large area, so that two or three stalks may be required to connect the plates, Fig. 149. In light work not subject to much pressure, spring chaplets are used, consisting of pieces of hoop iron bent round. These are retained in place by their elasticity, and are mostly used against vertical or nearly vertical faces, Fig. 150.

Chaplets have their faces curved when they abut against

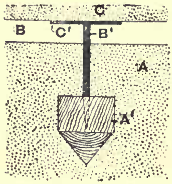

Fig. 146.—Chaplet.

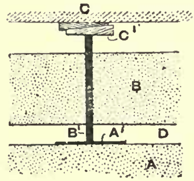

Fig. 147.—Chaplet.

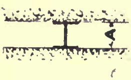

Fig. 148.
Chaplet.

Fig. 149.—Triple
Stud Chaplet.

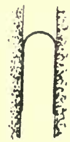

Fig. 150.
Spring Chaplet.

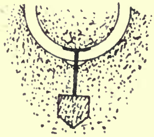

Fig. 151.—Pipe
Chaplet.

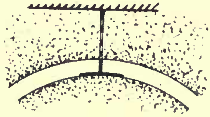

Fig. 152.—Pipe
Chaplet.

Fig. 153.
Stop.

curved faces. Figs. 151, 152, show two such forms, modifications of Figs. 146, 147. The core rests upon the stud in Fig. 151, but in Fig. 152 the stud is introduced to resist the upward pressure of the core. Fig. 153 shows a stop employed when the mould is subject to very great pressure. It is made of cast or wrought iron, and turned bright, or ground.

The evil of stops and chaplets is their tendency to cause blow holes in their vicinity. Should they become rusty the mould is absolutely certain to blow very badly, owing to the formation of gaseous compounds from the rust. Chaplet nails are often tinned to prevent rust. With the same object wrought iron chaplets, made by the foundry smith, are heated to redness in the fire and brushed over with tar or oil. Oil is also poured around and over chaplets while in place to prevent formation of rust during the time intervening before casting, and to cause the iron to lie quietly on the cold metal. In all but the thinnest castings the chaplet stalks become more or less fused by the metal surrounding them. But the heads usually remain visible, and do not amalgamate properly. Hence chaplets should never, if it can be avoided, be placed against faces or parts which have to be bored or turned.

It is not only necessary to fix and properly vent cores, but to *secure the vents* as well, that is, to see that adequate provision is made for the escape of the air and gas from the interior of the core to the outer atmosphere. The vent openings must be so secured that there shall be no chance of the entry of the molten metal into them. If it gets in, the gas will not come out, and the casting will blow, and become a *waster*. A chapter could well be entirely devoted to this subject of securing of vents, so important is it, and so many are the methods adopted to attain this end, but we must be content to note a few leading points bearing thereon. Thus, it is risky to bring core vents off against an abutting face simply, unless means are taken to prevent any possibility of the pressure of metal causing an opening between the faces to occur. There is less risk, however, in horizontal than in vertical faces, and of the two, a lower horizontal face stands less risk than an upper one, because the cope is liable to, and does usually, lift slightly. Where vents are carried down through the bottom, they are taken into a coke bed, as already explained, p. 164, and thence out through a vent pipe or pipes. When they are brought into the cope, they are usually carried into one or two large holes cut through the cope sand.

But prints afford the best means of securing cores, because if any slight separation of the core and mould occurs under pressure, the metal cannot, if the core and print are mutually good-fitting, run between them into the vents. Properly the cores should be cemented into their prints by means of core sand, or of black wash. This is usually done only in the most important work. In most cases it is sufficient, after the core has been thrust into its print, to press and consolidate sand around and into the joint.

When distinct cores meet each other in the mould, vents should only be carried from one into the other when they can be secured through a print impression, one thus being checked into the other. When the joint is only a butt joint, then the core vents must be filled with sand immediately against the abutting faces, and the air be brought away at the opposite ends, where the cores fit the print impressions of the mould itself.

In the case of cores struck upon revolving core bars, the air, after being brought into the bars, is carried out at the ends.

Cores are dried in *stoves* or *ovens* heated with coke fires or gas. The smaller cores are dried in ovens having a capacity of a few cubic feet only; for the larger ones, stoves of from 18 ft. to 24 ft. long, 10 ft. to 14 ft. wide, and 10 ft. to 12 ft. in height, are employed. These are built of brickwork, and furnished with folding or sliding doors. The cores are laid upon a core carriage, which is

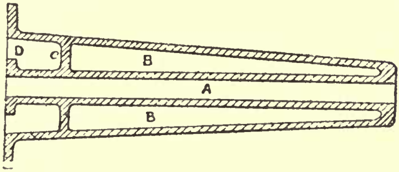

FIG. 154.—TUYERE CASTING.

a low iron carriage running on tram rails, and provided with suitable supports for the ends of the core bars, and with flat plates for cores made in boxes, and those formed with strickles. A temperature of about 400° is suitable

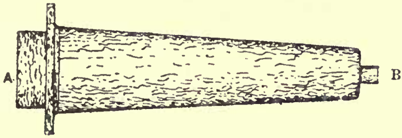

FIG. 155.—PATTERN OF TUYERE.

for the drying of cores: excess of heat burns the hay, and makes the sand or loam rotten and friable.

The illustrations show the pattern-work and moulding for a small tuyere, selected because it is an example of double coring.

Fig. 154 shows the tuyere casting in longitudinal section, and the pattern-work and moulding are illustrated in subsequent Figs. Looking at Fig. 154 it is seen that there are two cores entirely unconnected, *A* being that for the blast passage, *B* that for the water chamber. The tube containing *A* is cast to the outer body at the fire end; at the other it is connected to the body with a shallow bridge of metal, *C*. In moulding this a plain pattern is used, Fig. 155, having a print at each end, and two separate cores are employed for taking out the interior. As these cores must be maintained concentrically, provision is made for this in the manner shown in Figs. 156 and 157.

Fig. 156 is a plan view of the core-box in the joint-face. As the core is absolutely symmetrical, one half-box only

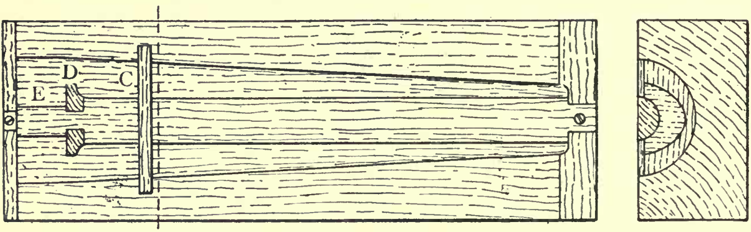

Fig. 156.—Core Box for Tuyere.

is made. The main portion is cut through with planes to the bounding lines of the body core, and the ends are screwed on separately, as indicated by the direction of the grain of the timber. The large end of the core-box is extended to correspond with the core print *A* in Fig. 155, which insures the concentricity of the body core in the mould (see Fig. 157). The similar disposition of the water tube and its core is determined by cutting holes, one at each end of the core-box, by which the tube piece is centred and its core by the print *B* on the pattern, Fig. 155, and by the print *E* turned on the tube-piece in Fig. 156. The bridge-piece *C*, Fig. 154, which connects the tube to the body, is rebated into the tube-piece in Fig. 156, and drops into shallow recesses in the sides of the core-box. The flange *D* in Fig. 154, to which the blast-pipe is bolted, is seen shouldered over the tube-piece in Fig. 156. Everything, therefore, is central, and nothing can become displaced during ramming of the core.

The two half-cores made from the box in Fig. 156 are not cemented together. Each is vented separately, the vents being brought out through the print ends at *A*,

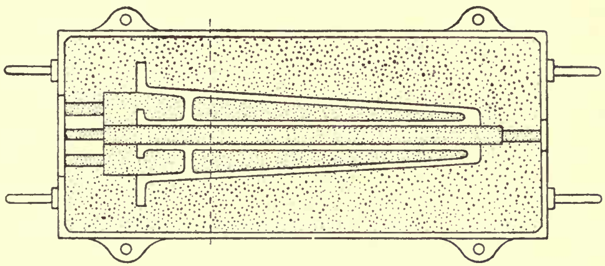

Fig. 157.—Open Mould of Tuyere.

Fig. 155. The main cores are carried at one end only in a print impression—at the end *A*. At the opposite end, chaplets are inserted to support them centrally. The middle core for the water passage is perfectly straight, and is lowered into its print impressions in core and mould in the bottom box. The top half-core and mould are lowered over it.

The same principles which govern the construction of patterns must be regarded in the construction of core boxes. Thus, regard must be had to taper and such arrangements of loose pieces as permit of ready withdrawal, strength of parts, economy of material, and so forth.

Further, it is always best when practicable to avoid the turning over of heavy cores, which is apt to cause their fracture. In most cases it is quite as easy to make the box so that the core shall be rammed up just as it has to stand in the mould—that is, top side up—as in any other way. Especially is this precaution necessary when grids and eyes are in question, the eyes being required uppermost for lifting the cores by. The patternmaker should bear this in mind when making his boxes.

There are many cores rammed in boxes which are symmetrical; and in these cases a half-box suffices, and a considerable saving is effected in material and cost of work in the pattern shop. Take a core like that shown in Fig. 157 as typical of a numerous class in which both halves are precisely alike; hence two halves are rammed separately, the joint faces sleeked level and united either while green or dry. In such cases each half of the core requires its separate grid. Taking a core which is united while green one half is first rammed in the box, bedding in during the process the "grid" or "core iron"; and in cases where there are thin sections of sand, nails are put in precisely as in the weak portions of moulds. The sand is made complete to the joint face, and then a vent channel, rudely semicircular in section, is cut with the trowel. If the core is of large size—or when small, if the sand is close—vents are driven from this channel radially to the inside faces of the box. But if the core is small and the sand is open, there is no need to do so. The half-core is now lifted out with the grid and laid with its convex face downwards upon a bed of soft moulding sand. The corresponding half-core is then similarly made, turned over, and pressed down on the joint face of the first, the moisture and slight pressure causing adhesion. The union is frequently assisted by sticking nails upward in the joint and allowing them to enter at equal distances into both halves. When the cores are made in halves, and united after drying, they are stuck with a wash of clay-water or of "slurry" made of thin loam and water. When cores which are unsymmetrical, but of circular section, are made in complete boxes, they are, if of moderate or considerable length, rammed in halves and squeezed together with or without a thin wash of clay-water intervening. Such cores must be turned over and laid while green on a bed of soft moulding sand before being put into the stove to dry.

A convenient mode of turning a core over without damaging it when a large number are required is to use a light frame of wood, or preferably of iron, which is placed upon a quantity of loose green sand thrown upon the finished core, thus confining the sand in place. The frame, core and half-box are turned bodily over, and the half-box, then uppermost, is lifted away, leaving the core resting upon the soft cushion of sand confined by the frame. It is very simple, and often saves the fracture of delicate cores.

CHAPTER XII

LOAM WORK

The advantage of loam moulding consists in the facilities which it affords for making castings of the most massive character without incurring much expense for pattern making. The apparatus used is of the most simple description, consisting of spindle, bar, and striking boards; the materials being loam, bricks, and cinders: with the aid of these the largest and heaviest castings are made.

Loam work is a specialized branch, which all moulders have not had an opportunity of acquiring, hence its exclusiveness; but it is not more intrinsically difficult than the other branches. I am inclined to think it easier of acquisition; but here, as in many other instances, the question is one of supply and demand, rather than of special difficulty. Also, large loam moulds are costly, and men are paid then for their care, as well as skill and special knowledge. The mould for a condenser, or for a large cylinder, will often occupy a couple or three men for nearly a month, hence the matter of two or three days' time, more or less, is of small account in comparison with the soundness of the casting.

The art of loam moulding, after the first principles are mastered, lies in the exercise of the inventive faculty, the ability to scheme the best methods, to elaborate the safest, and on the whole the cheapest tackle: to conceive the main plan, and to execute the lesser details with a clear head, guided by the lessons born of experience. Loam moulding is an art in itself, and a man who can undertake any job, large and small, devise, and make, and rig up his tackle, and produce uniformly safe results, need never swell the ranks of the unemployed—he is indispensable.

It is a great advantage to a loam moulder to be able to read a drawing correctly. If he cannot do so, he has, in intricate work, to depend on the explanations of the pattern maker before he can set about his task, or even decide how to do it, or line out his centres. Some loam moulders are quite independent of the pattern maker in this respect, doing all the lining out themselves.

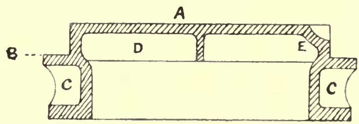

FIG. 158.—BASE FOR ENGINE CYLINDER.

So much may be said about loam work, so many different cases may arise in practice, that the best way will be to take some concrete and plain examples and make them the vehicle for remarks on loam moulding in general.

The example selected in Fig. 158 is the base which forms the bottom cover of the cylinder of a condensing beam engine. The top face *A*, as the casting stands when in position, is moulded and cast downwards, to ensure soundness.

The apparatus used is as follows: in Fig. 159, *A* is the *striking bar*, *B* its *socket*. The socket, of cast iron, is firmly embedded in the floor and levelled, its broad bracketed face maintaining it sufficiently steady. It is bored out to receive the turned tapered end of the bar, or it is cast around the turned tapered end, in either case making a close, yet working fit. The tapered end is long, so that as the bar revolves, its top end shall not diverge sensibly from the perpendicular. Over the bar slides freely the *strap C*, which is pinched at any required height with its set screw. To the strap is bolted the *striking board* or *loam board D*, the profile of the edges of which corresponds in the main, though not in all details, with the sectional shape of the casting required. *F* is the *loam plate* or building up plate, made of cast iron in open sand, without a pattern, by means of sweeps only.

Fig. 159 represents an early stage of operations. The socket, *B*, is set in place, the loam plate, *F*, levelled roughly on blocking pieces, *G*, or other convenient supports, the loam board, *D*, notched out to clear the boss of the strap, and bolted thereto. The breadth of the sides of the bar *A* is definite, being usually $1\frac{3}{4}$ in., 2 in., $2\frac{1}{4}$ in., or $2\frac{1}{2}$ in., so that the radius of the board *D* is less than the radius of the casting by an amount equal to *H*, the radius of the bar. It is easy to see the coincidence of the board with the outside of the casting by comparing Figs. 158, 159, the only point of difference being the strip, *I*, which is screwed on temporarily to make a parting joint, *J*, for convenience, and the step or check, *K*, which makes the top or cope joint. The edge of the board is chamfered, as shown at *L*, to avoid dragging up and tearing out of the loam. It is evident that loam boards should be truly level in order to ensure the striking of a level mould. Hence the top edge should, in shallow moulds, be planed square with the end which abuts against the bar, and a level tried upon it, as shown at *Z*.

Plan.

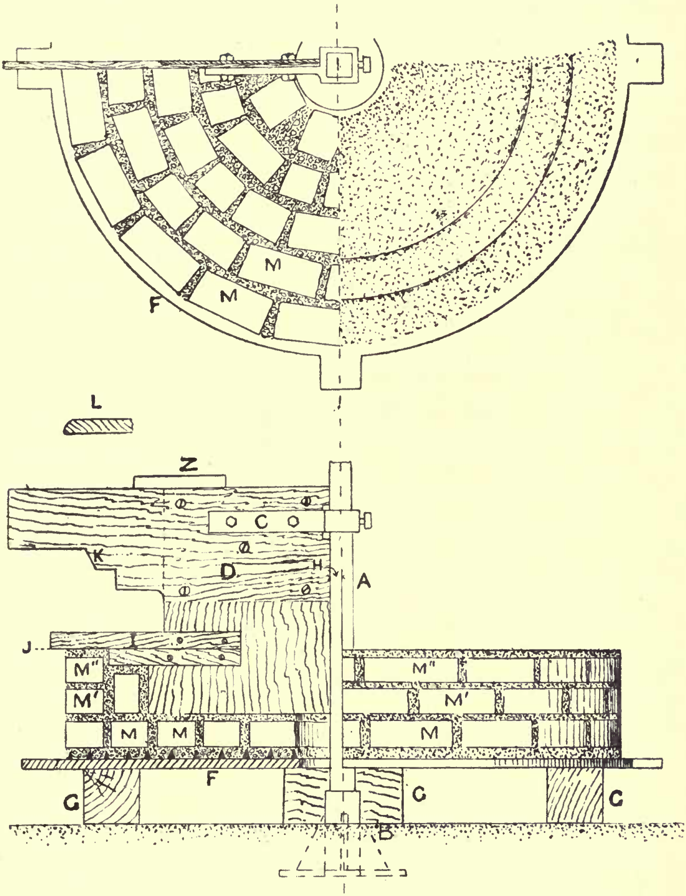

Fig. 159.—Loam Moulding.

When moulds are deep, the bar is apt to sag at the top, and to cause the diameter to alter. For this reason, and partly also to check any error in the cutting of the board, diameter strips and calipers are used for measurement of the mould. Fig. 160 shows the strip used for testing the interior of a mould, being made to clip the bar; and Fig. 161 the wooden calipers for the exterior. Their purpose is so obvious that they require no explanation.

A thin coating of stiff loam is first spread over plate *F*, Fig. 159, and upon this the bricks, *M*, *M*, are bedded. The bricking up is a vital matter, since the bricks must

Fig. 160.—Diameter Strip.

Fig. 161.—Wooden Calipers.

bind one another by being made to break joint, just as in masonry. Since moulds are irregular, and bricks are pretty uniform in size, the value of the broken bricks from previous moulds is apparent. These should be utilized as much as possible instead of breaking new bricks. It is not possible nor necessary to maintain such regularity as in masonry—the appearance of a bricked up mould is rather that of Fig. 159 (plan). In building up cylindrical work the general rule is to keep the broken bricks next the mould face, and the whole bricks as a backing. The broken bricks conduce to better venting than the whole ones would do.

When a mould is over 18 in. or 24 in. in depth, a cast iron ring is built in at about every six courses, to assist in binding the bricks together.

The joints of the bricks are not only wide apart, but large quantities of fine cinders are interspersed with the loam in the joints. These are introduced for the purpose of venting, which is a better and more certain method than venting with the wire, though the wire is sometimes used in some sections where the loam happens to be massed in quantity in a mould. There must be sufficient coarse loam intermixed with the ashes to bind the bricks together. The layers of brick M' and M'' are then built up in like fashion, with loam and ashes intermixed. A space of about 1 in. is left between the bricks and the edge of the board, and about $\frac{5}{8}$ in. of this is daubed well over with stiff coarse loam—coarse loam because it affords a better vent to the gases and air, than finer and therefore closer loam would do. The work is then left standing for a few hours in order that the loam may stiffen. Afterwards the final coat of loam, passed through a fine sieve, is struck on, and finished by the edge of the board. Several sweepings around of the board are necessary to impart the final smoothness to the surface; then the mould is put into the stove to be dried. At this stage therefore the mould is completed up to joint J, which coincides with the lower face of the flange B in Fig. 158, the mould being made, as just now remarked, to pour the casting upside down.

Fig. 162 illustrates the next stage. A cast iron plate, G, is made, a thin coating of loam swept over one face and dried. The flange space N, already struck, as in Fig. 159, is filled up temporarily with moulding sand level with the joint J, and then the loamed face of G is turned over thereon, parting sand intervening. The strip I, in

Fig. 159, is unscrewed from the board, and the second stage of bricking up is done on plate *G*, Fig. 162.

Sometimes ring plates are used similar to *G*, merely for the convenience of parting a mould which is too deep to go into the drying stove entire. The upper portion of the mould is then lifted off on its ring before being put into the stove, and is replaced after it has been dried. The ring is like *G*, but its function is different, *G* in Fig. 162 being necessary because the under face of flange *N* could not be struck at the same time as the lower portion of the mould in Fig. 159, without much difficulty, due to falling down of the loam.

There are four ribs, *C*, Fig. 158, cast between the flanges. These are made by imbedding four pattern ribs, *O*, Fig. 162, in corresponding positions, and spaces are cast out of the plate, *G*, to receive these. Whenever ribs, facings, brackets, flanges, which cannot be struck, occur in loam moulds, patterns of these have to be made as in ordinary work. In some cases where the work is intricate this becomes a source of trouble to the moulder. In the first place it is not easy to set sectional portions of wood very accurately in yielding loam. Then the wood remains in the loam for several hours, more often for days, and is liable, by its distortion, to produce inaccuracy. Again, it is not so easy to secure a homogeneous face of loam by building bricks against wood as it is by striking loam upon bricks. The wood has to remain in the mould either until the loam has become stiffened or until after it has been baked in the stove. In either case the withdrawal of the wood tends to damage the mould—more when it is baked, because the loam then absorbs some of the oily matter from the wood. This makes mending up of the faces troublesome, the oily surface not taking

PLATE X

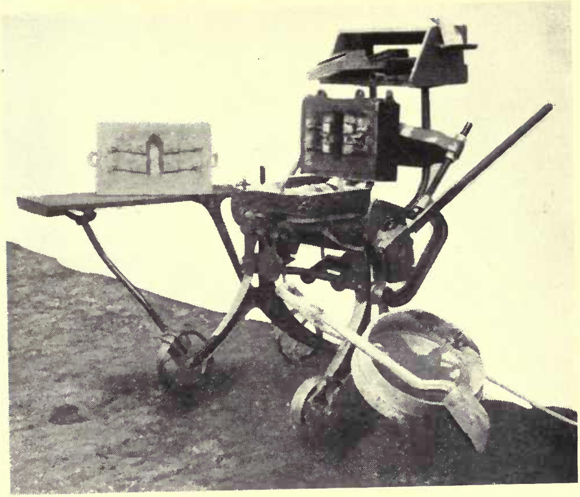

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FIG. 203.—THE FARWELL HAND PORTABLE MACHINE

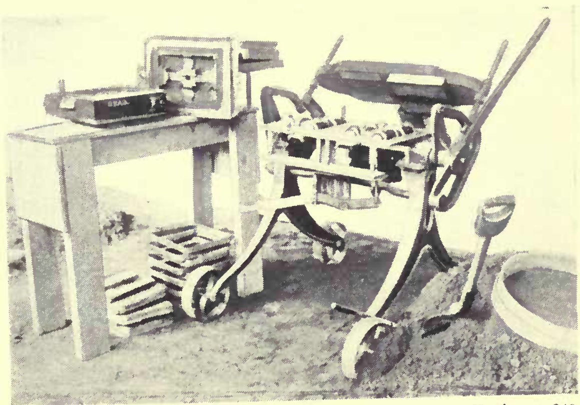

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FIG. 204.—FARWELL UNIVERSAL MACHINE

PLAN.

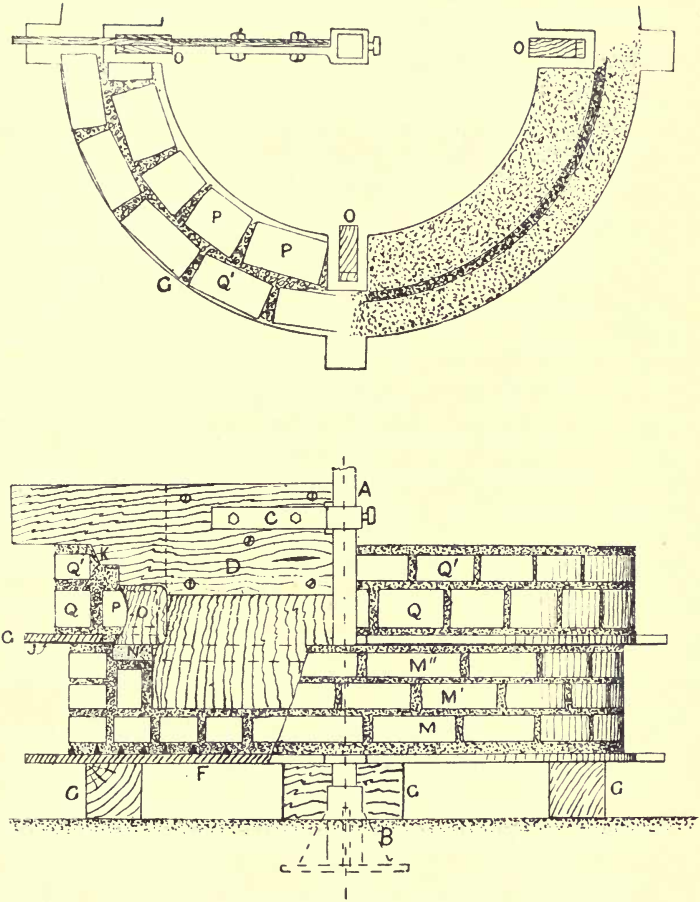


FIG. 162.—LOAM MOULDING.

kindly to the wet loam used in mending. In such cases the surfaces should be scraped before being mended. It is the usual practice to oil the surfaces of the woodwork imbedded in loam; but this only partially assists the stripping. The ribs in the illustration, though suggesting these remarks, are so plain that they would cause no trouble. It is in work of a more intricate character that trouble occurs.

At *P* in Fig. 162 are bricks which are made of loam, moulded into the shape of bricks, and dried. These occupy the spaces between the ribs. *Loam bricks*, as they are termed, are frequently used in moulds of this character wherever there are narrow spaces between flanges, or brackets, or ribs. One reason is, that if the shrinkage of the casting takes place against hard unyielding bricks, the iron is liable to fracture. If loam bricks are used, they crush and yield before the shrinking metal. They have, moreover, the additional advantage of forming a good medium for venting, and this is an important point. In intricate portions of moulds it is safer to use loam bricks and an extra thickness of loam vented with the wire, than to bring the common bricks very near the surface. A thin body of loam against common bricks is always liable to become detached, and to cause scabbing by reason of the bubbling of the metal thereon.

Outside the loam bricks *P*, a layer of common bricks, *Q*, is built, and over this again another similar course *Q'*. The thickness of loam is daubed and swept over the faces of the bricks according to the profile of the board *D*.

The cope, and the central core yet remain. A plate, *R*, Fig. 163, is cast, studded over with *prods* to hold the loam which is swept over its face, as shown—the check *K*

PLAN.

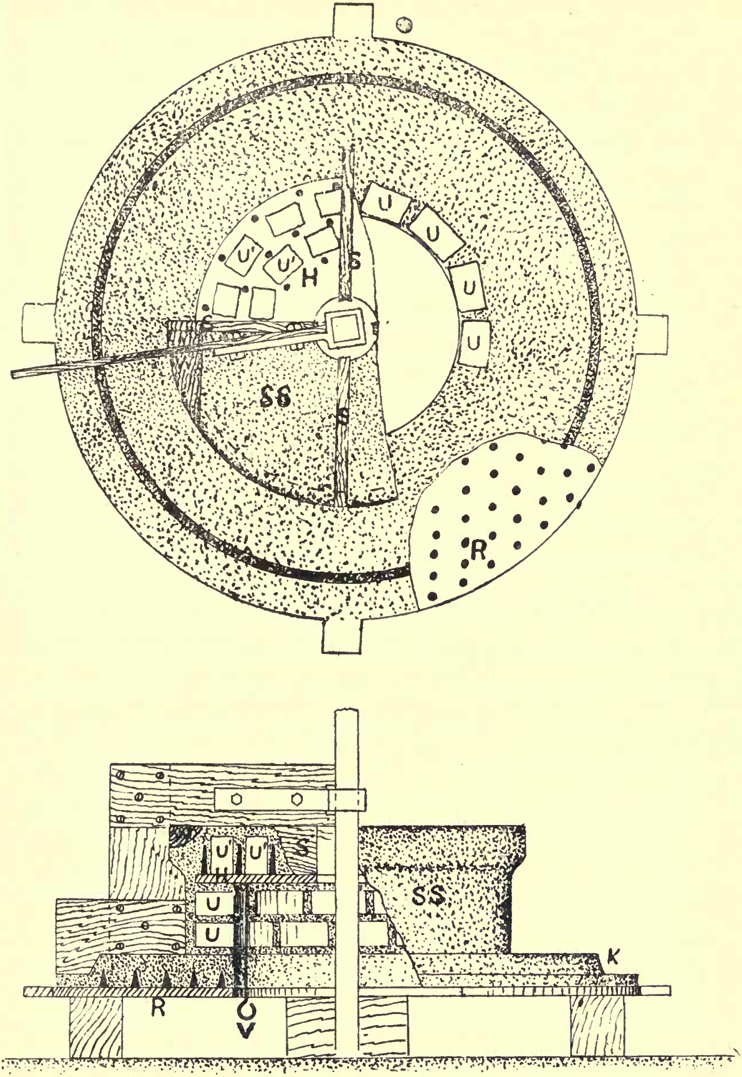
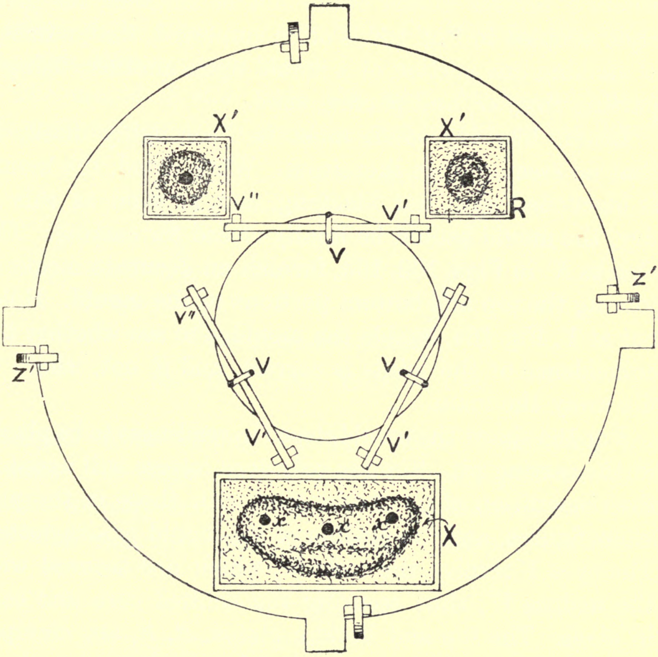


FIG. 163.—LOAM MOULDING.

being formed to correspond with the reverse check *K* in Fig. 162—and allowed to set firmly. While it is setting, the plate *H* is partly loamed up on separate blocking. The future position of this plate is seen in Fig. 163; the arms *S*, shown at *D*, in Fig. 158, are laid in due position, and stiff loam is daubed around them, so that when this sets the arms are kept pretty rigidly in place. While the loam is setting, the work on plate *R* is continued; courses of bricks, *U*, *U*, are built upon the bed which has been already struck with the board, the joints being vented with cinders, or with the wire. Coarse loam is daubed around the outside, and also on the top of the uppermost layer. Then the plate, *H*, is laid upon the top layer of loam, Fig. 163. The irons, *V*, are for the purpose of wedging up and securing the core and cope when finally in place. *H*, bedding firmly on the loam, the spaces between the ribs are filled in with loam bricks, U′, and these, with the deep prods cast on the plate, together with the stiff loam daubed between them all, form, when dried, a solid mass which can be turned over with perfect safety for closing the mould. The block *W*, which gives the metal around the termination of the bottom steam passage of the cylinder, *E*, in Fig. 158, is bedded in, and the whole surface is lastly swept up and finished with fine loam, *SS*, and the whole dried bodily in the stove.

The turning over of a body of bricks, etc., like that in Fig. 163, is only done in cases where the mass is not excessive. In the example which we have selected there is no difficulty or risk involved in turning over. But in some heavy work it would be necessary to make a reverse mould, and to daub the loam upon that, standing thus in the position in which it is to stand when finished. Also

PLAN.



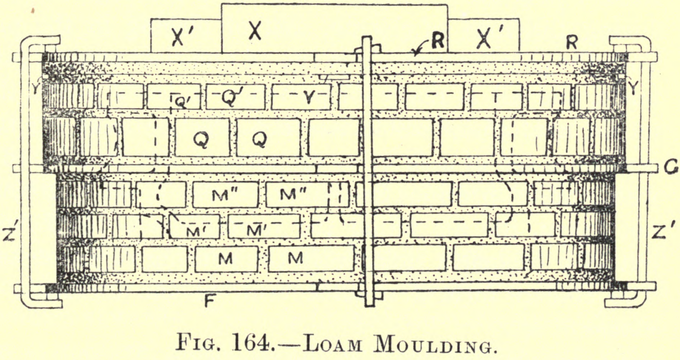


FIG. 164.—LOAM MOULDING.

where a reverse mould would not be suitable, the principle adopted in Fig. 162 is often employed, that, namely, of striking one portion of a mould upon another, using a parting ring, *G*, and parting sand.

Loam, like dry sand, must be thoroughly dried, so that no steam issues therefrom. When dried, the mould is blackened with wet blacking, and, as soon as this is dry, the mould should be finally closed for casting. The checks *K*, in Figs. 162, 163, furnish an accurate means of joining the top and bottom portions of the mould. Holes cut at *Y*, Fig. 164, enable the moulder to see whether the coincidence of the joints is correct, and if not, where to file away the loam.

Fig. 164 shows the mould closed in readiness to be placed in the casting pit. Similar reference letters will assist in the recognition of parts identical with those in the previous figures, and the outline of the mould is also dotted. The eyes *V* receive the rods *V′*, which are secured with the wedges *V″*, thus securing the central core and cope in place. The top and bottom plates, *R*, *F*, are clamped together with the clamps *Z′*, *Z′*, which are wedged. Runner pins are inserted at *x*, to keep the ingates clear during the time of closing, and of placing in the pit. Then the pouring basin, Fig. 164, *X*, and riser cups, *X′*, are made, and all is ready for pouring. In cases where the mould is of considerable size the practice is to fill the central space of a bricked up core, as *SS*, in Fig. 163, with cinders, previous to casting. If this precaution were not taken, the air filling the vacant space would rush out with explosive violence on the pouring of the metal. The cinders form a natural vent, to the exclusion of excess of air.

Feeding is performed at the riser cups *X′*, and at the pouring basin *X*. Vents are brought away all over the surface of the cope, and also from the bottom, the latter through diagonal vent pipes.

The mould is sunk into the floor, or pit, and sand rammed around it, in order to prevent risk of the liquid

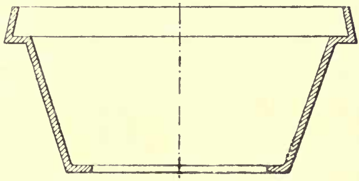


Fig. 165.—Soap Boiling Pan.

pressure from forcing out the bricks composing the mould. For large work, therefore, special pits are built in the foundry floor. These, when permanent, are built up with cast iron plates, or rings. They are made of

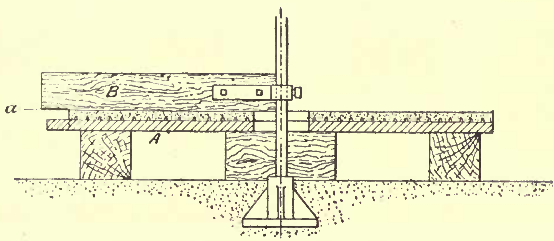


Fig. 166.—First Stage in making Mould.

depth and diameter most suitable for the special requirements of the foundry.

Fig. 165 illustrates a soap boiling pan, and Figs. 166 to 170 show how the loam mould was made. It was cast bottom upwards. The hole in the bottom receives a dished or cup-shaped vessel (not shown) surrounded by a flange which was bolted to the inner face of the flange on the casting, so forming the bottom of the pan.

First the outside was swept up, and then removed to allow of rigging up the board for sweeping the inner or cored portion. Fig. 166 shows the first stage in the work. Plate *A*, about 3 in. thick, is cast with prods and supported on wood blocking, and then a level loam joint face *a* is swept on it with the board *B* which is bolted to a strap set on the central striking bar in the usual way.

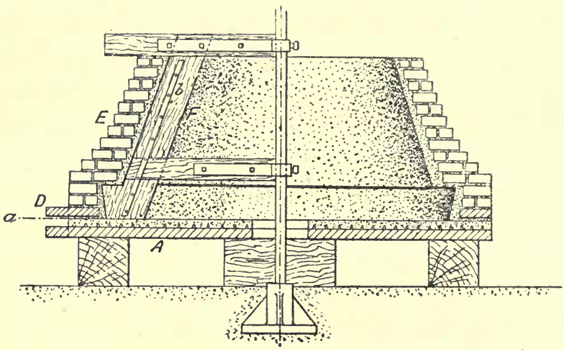


FIG. 167.—MOULD BODY SWEPT UP.

The loamed joint *a* is dried, and then an outer ring of cast-iron, *D*, Fig. 167, which is first loamed over on the under side, dried and turned over—is jointed to it, and on this ring the courses of bricks, *E*, Fig. 167, are built up and a coat of loam swept on the interior by the board *F*, which is made as shown, and attached to the central bar with two straps. The board has a strip *b* screwed on it to prevent the loam from falling from the overhanging body on to the level bed which has been previously swept over the bottom plate.

When this coat has set sufficiently, the ring *D* with its bricked mould is lifted away, hung by its lugs in the crane slings, and is put in the oven to dry while the inner portion or core is being swept up. Fig. 168 shows the bricking up on the plate *G*, and the sweeping board *H* rigged up. To allow the metal to shrink in cooling without risk of fracture, four tiers of loam bricks are built up between the common bricks, 90° apart. These are broken out with a bar soon after the casting has set,

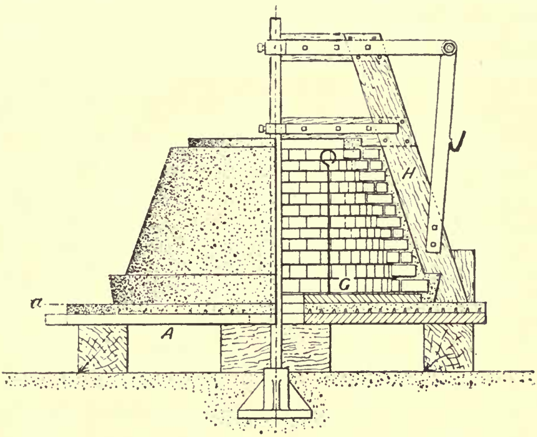


FIG. 168.—CORE SWEPT UP.

and so leave the hard bricks free to yield before the shrinking casting without risk of fracture of the latter. The overhang of the board is stiffened, and prevented from wobbling and dragging by means of an iron strap *J*, attached as seen in Fig. 168. When finished, the bottom plate with its core is put bodily into the stove and dried, and afterwards the outside mould is put in position finally.

Figs. 169 and 170 show the top of the mould, which is a plain cope only. It is formed of a plate *K* exactly like the bottom plate *A* in Fig. 166, with prods, loamed, and swept level with the board *B* in Fig. 166 to make the joint face *c* in Fig. 169. Six holes are cast in the plate through which the ingates *d* pass, the pan being poured thus. A pouring basin in sand is rammed on top, through which the runners are filled. This is conveniently formed in the manner shown in Figs. 169 and 170. Two cast iron pit rings *e*, *e*, are selected of any approximate diameters suitable, and laid concentrically on the top plate, and the annular pouring basin is made up between them as

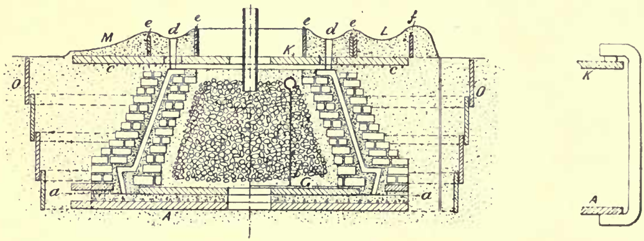


FIG. 169.—MOULD COMPLETED.

seen in section in Fig. 169, half-a-dozen runner sticks being set in, while the basin is being moulded by the rammer, and smoothed by the hands. This is preferable to allowing the metal to enter by one or by two ingates only at opposite sides, as it would have a tendency to chill in filling the mould. Entering hot at so many different places there is no risk of cold shuts or of imperfect edges.

It is better to conduct the metal through an exterior basin *L* than to pour it directly into the annular channel, which if attempted would probably result in the falling of driblets of metal into the mould, to become chilled before the ladle could be properly adjusted to pour the main volume. Pouring the metal into the basin *L*, exact adjustment of the ladle is effected, while the basin slowly fills, after which a steady volume being emptied into it, overflows into the annular basin, and through the in-gates *d*. The basin *L* is made within any moulding box part *f* of suitable size, prevented from shifting by an en-

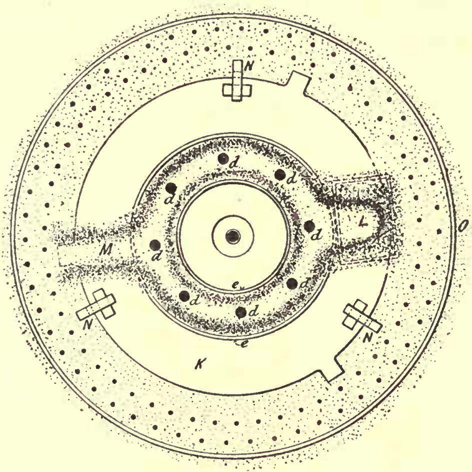


FIG. 170.—PLAN OF MOULD.

closing body of sand. Opposite it is the flow-off basin *M*. This is made of sand alone, supported by ramming in a few wetted bricks.

The top and bottom plates *K* and *A* are secured during pouring by means of iron clamps *N*, seen in Fig. 170 and to the right of Fig. 169, held fast with wedges. For casting, the mould is placed in a convenient pit *O*, Figs. 169 and 170. The interior of the core has been filled with cinders to receive the gases quietly, and prevent explosion.

These are conducted away through a central pipe. The outside is rammed around with sand to prevent displacement of the bricks by the liquid pressure. The outer air will come up through the sand which will be well vented vertically with the vent wire.

Loam patterns.—These constitute another type of this branch of work, having a single point only in common

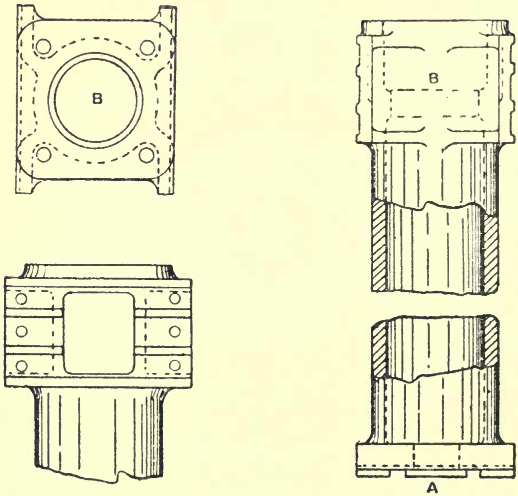


FIG. 171.—HYDRAULIC CYLINDER.

with loam moulds—the material in which they are made. They are employed when the work is of a medium size—too small to be struck upon bricks, yet so large as to involve costly outlay for patterns in wood. They are struck up pretty much like cores on core bars, except that no venting is required, and the surface is protected and rendered hard with a coating of tar. In many cases, however, as when one casting only is required, the core is struck first and vented in the usual way, and then a body of loam, representing the thickness of metal in the casting, is struck thereon, a coat of black wash intervening. The mould is then made and the thickness removed, the black wash acting as a parting, allowing of the ready peeling off of the thickness, and the core is placed in its mould. The boards used for striking are similar to those used for striking cores.

The figures illustrate the manner in which the pattern for one of the lifting cylinders of a hydraulic crane can be made. They afford a good example of the economy of patternmaking in loam when the cylinder is large in diameter and of considerable length. In this case it is 12 ft. long by 18 in. diameter.

Fig. 171 shows the casting. The bracket for the bottom chain pulleys is bolted to the flange *A*, while the end *B* forms the stuffing box for the ram; and by means of the facing strips shown at the sides three cylinders are bolted to each other on one side, and to the cheeks which form the side members of the crane post on the other.

This is not a loam pattern pure and simple, but one of a composite character, being partly of loam and partly of wood. It is clear that the more intricate and delicate portions of patterns cannot be formed so economically or strongly in loam as in wood, hence there are few patterns which are constructed entirely of loam, except those of the very simplest and most symmetrical types. Generally, as in this instance, the main body is of loam, and the small attachments are of wood.

The loam body is made as follows: A common core-bar (Fig. 172, *A*) is used, and hay bands are wrapped around it, sufficient in number to make up the size of the body required. There is no need to use plates in a case like this (such as are rigged up when sweeping cores), because a bar sufficiently rigid in itself can be selected without further aid from plates. A plate must be used at each end, in order to afford support to the loam there. Hay bands and loam alone form the pattern body. The bands, especially the first layer or two, must be left rather open, and the loam worked into the openings, going down to the corebar, and becoming interlocked and held fast among the bands, so that there will be no risk of its flaking off afterwards.

As in coremaking, the first application must be allowed

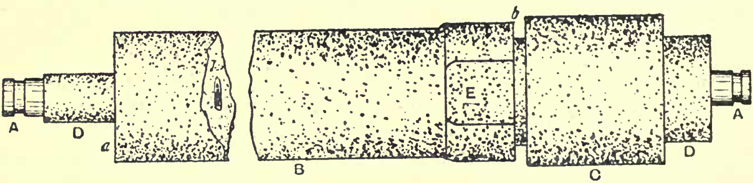


FIG. 172.—LOAM PATTERN OF CYLINDER.

to become partially set before the final coat is put on, and the last coat of all must be thinner and finer than that used for the main body. Fig. 172 shows the pattern at this stage, *A* being the bar, *B* the body, *C* the head metal, and *D*, *D* the prints.

The mode of attachment of the wood fittings to a loam pattern is governed by the facilities which are afforded by the shape of the pattern itself. Loose fittings are apt to become rammed out of truth, since the same means are not available for the attachment of wood to loam as for wood to wood. Screws cannot be inserted, and nails, though used, afford but a flimsy fastening in the loam, and their principal use is to steady rather than to secure. Square-shouldered portions (Fig. 172, *a*) afford ample means of security when wood is fitted to loam, because where such a deep shoulder exists it gives a good bedding for a wood fitting without any fastening, and the latter is readily held against the shoulder by pressure of the hand while the first portions of sand are being rammed around it. A recess like that at *b* is more secure still. Often, however, there need be no better fitting than thatwhich a butt joint affords. Then the wood portion may be either set and kept in place by careful measurement, with rule, straightedge, or square; or in

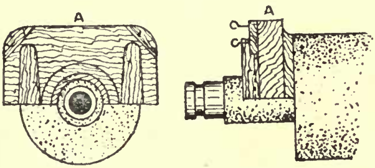


Fig. 173.

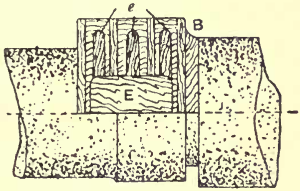


Fig. 174.

Wood Fittings.

some cases slight assistance can be derived from nails passing deeply into the loam, either through the wood or alongside of it.

Fig. 173 shows the mode of attachment of the bottom flange *A* in Fig. 171 against the shoulder *a* in Fig. 172 one-half the flange only being in place, a face view of the same half being given to the left. The flange is simply held against the square shoulder until sufficient sand has been tucked around to keep it in position. The facings and core prints are self-explanatory.

Figs. 174 to 176 illustrate the fittings which go at the head *B* in Fig. 171. The flange *B* forms—along with the flanges *C*, *C* by which the cylinders are bolted together and to the post, the ribs *d*, *d* stiffening these—together with sundry prints and planing strips—a single pattern piece which drops over the portion marked *b*, *E*, in Fig. 172; the flange *B* in Figs. 174 and 175 dropping into *b* in Fig. 172, and the flat *E* in Fig. 172 being filed to allow the width *D* in Fig. 176 to embrace it. In the absence of the flats, the facings *C*, *C* in Fig. 176 would have to be cut away to fit the circular body of loam, which would not be so conveniently done.

The prints *E*, *E* are merely for lightening recesses,

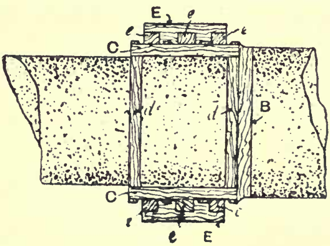


Fig. 175.

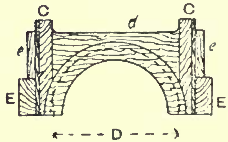


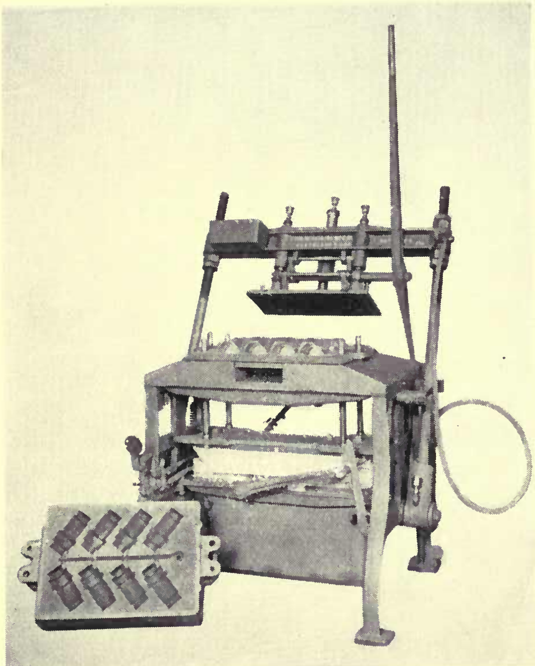
Fig. 176.

Wood Fittings.

and the pocket or drop prints *e*, *e* are for the bolt holes. This entire piece is retained in the groove *b* in Fig. 172, and therefore requires no assistance or support when ramming.

The appearance of the completed pattern is seen in Fig. 177, the view being taken looking down on it from above, so that the joints in the fittings do not show.

The economy of making large loam patterns is well illustrated in this example, both in regard to time and material saved. Hay bands and loam do not cost so much as wood, nor does the striking up occupy so much time as the turning of timber. But the latter is never-



See p. 301

FIG. 205.—THE BERKSHIRE MACHINE

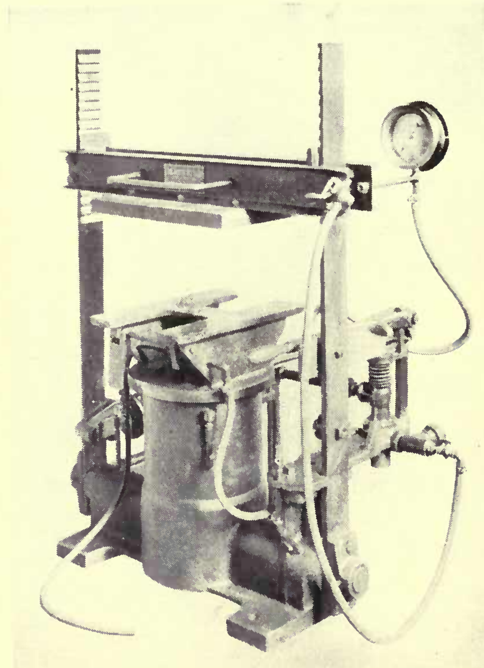


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FIG. 206.—THE TABOR 10-INCH POWER SQUEEZING MACHINE FOR LIGHT WORK

theless cheaper when there are many castings required, even though the pattern should be large. The question is merely one of relative cost. In this case the pattern was of large dimensions, and only three castings were required. The storage room necessary for large wood patterns also has to be considered when deciding between timber and loam.

Loam patterns which are swept up are necessarily unjointed, which is a slight disadvantage, because they cannot be laid upon a bottom board, neither have they a flat central face from which to square up and mark off the

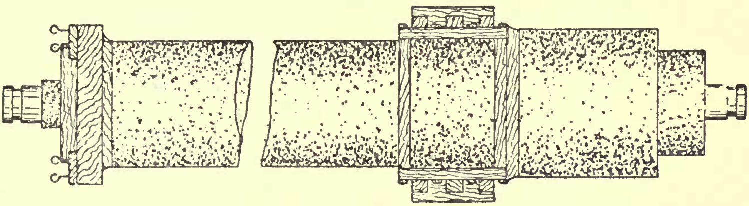

Fig. 177.—Pattern Completed.

positions of their attachments. Hence centre lines have to be obtained by rule, compasses, and straightedge, and most squaring up must be done from the outer surface of the body or by geometrical means.

When moulding a solid pattern of this kind it is bedded in the sand of the floor and covered with a top part; or in a complete flask. If in the latter, the box part which is to come in the bottom is rammed over it. Then it is turned over and the top rammed on. Or, if cast in the floor, it will be bedded-in like any other pattern, and the top part rammed. In either case a longitudinal centre line is marked deeply down each side as a guide to the moulder for marking his parting joint by, and the edges of the flanges must be tried with parallel or winding strips before the ramming is completed, and if out of truth with each other must be corrected.

Cylinders of this character are cast on end to ensure closeness of metal, since they have to stand very high pressures. The metal is poured at the top, and falls the entire depth; and though poured as "dead" as it is safe to run it, and the mould made of dry sand, the iron will cut up and burn into the bottom portion of the mould. The driving in of a number of flat-headed nails in close contiguity (Fig. 178), just level with the surface of the

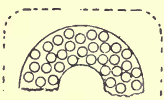

FIG. 178.—NAILS IN BOTTOM OF MOULD.

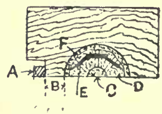

FIG. 179.—STRICKLING.

sand, and well oiling them, will prevent this cutting up and burning, by giving the metal a hard bed to fall on.

Loam patterns of irregular outline are worked up with strickles, guidance to which is afforded by means of guide irons, or by striking plates. The principle is simple. Fig. 179 shows a strickle of half a pipe, working by means of a check against a guide iron, *A*, which is curved longitudinally to correspond with the required outline of the pipe, Fig. 180. The guide iron remains in the same position for both core and pattern, the concentricity of core and pattern being assured by the method of cutting the checks upon each strickle, the distance, *B*, being less in the pattern strickle than in the core strickle by an amount equal to the thickness of metal in the pipe to be cast. In making the core, the vents have to be carried from the outside to the central portion, and away at the ends. Cores are differently made according to their diameters. A small core is stiffened only with a couple of irons. A large one has a grid with prods. In a small one, the central vent is simply cut with a trowel in the joint after each half has been dried and turned over, while in a large one the central vent is formed by daubing the loam over a central body of green sand, first made roughly semicircular with the hands.

Fig. 180 shows the various stages in making a common

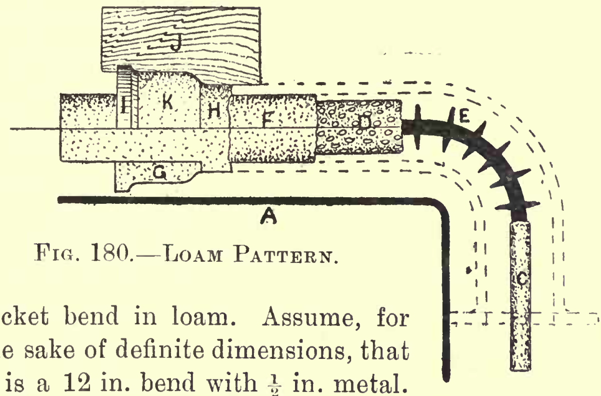

Fig. 180.—Loam Pattern.

socket bend in loam. Assume, for the sake of definite dimensions, that it is a 12 in. bend with $\frac{1}{2}$ in. metal. Then the first thing is to lay down a guide iron, *A*, which may be $\frac{1}{2}$ in. away from the outside, and of course 1 in. away from the core. Then the core strickle will have a 1 in. check, *B*, Fig. 179, and the pattern strickle a $\frac{1}{2}$ in. check. Weights will steady the guide iron. First a body of green sand, *C*, is made roughly semicircular with the hands. Then wet loam is daubed upon this and brought up to within about $\frac{1}{2}$ in. of the strickle as shown, Figs. 179, 180, *D*; a cast iron grid, *E*, being bedded in the loam at the same time. While the loam is yet plastic, a number of $\frac{3}{8}$ in. or $\frac{1}{4}$ in. holes are pierced through it, reaching to the interior. These are the main vents. When this coat of loam has partly set, the finishing fine coat is laid on and swept round with the strickle, as shown at *F*. It is evident that two such halves put together joint to joint and cemented, will form a properly stiffened and vented core.

The enlargement in diameter at the socketed end is usually made by striking up a ring of loam and threading it upon the core, its vents being brought into the main core vents.

The next stage, if one casting only is required, is the striking of the pattern thickness upon the core. Nothing is moved, but the core is coated with black wash, and the loam struck thereon with the pattern strickle, as at *H*. This also is dried.

The socket is variously made. Sometimes the thickness, forming the socket core, is not put on until after the pipe has been moulded. The socket body is struck and threaded directly on the plain core as at *G*, or a standard wooden or iron socket pattern is slipped over. Sometimes the socket is struck up on its own core, either by means of a guide ring, Fig. 180, *I*, which forms a portion of the pattern, and strickle, *J*, working thereon transversely, or the two separate diameters, *I*, *K*, are struck with two separate strickles working from the guide iron, and the curves by which they merge into one another are rubbed by hand with rasps and glass-paper.

When a pattern thickness is struck upon a core as in this case, it is usually necessary to secure the thickness firmly, during moulding and handling about, with flat-headed plasterers' or chaplet nails; without this precaution the thickness is apt to peel off at the black wash joint.

When a pattern is struck, the diameters of which vary at every position, no single templet will shape it. Then strickles are made to the extreme diameters, and if the pattern is of awkward shape, strickles also for certain intermediate positions, and the loam is rubbed between these positions with files or rasps, the eye being the arbiter, with or without the assistance of sectional templets. In a reducing bend three such positions might be taken, one at each end, and one at the centre, and two guide irons would properly be used. The three strickles resting against the guide irons would give the semicircular outline at each position, and the longitudinal outline of the guide irons would give the curves by which the joint edges of the cores would be imparted, the strickles for these being of a sectional form, giving the edges only.

When the core has been rubbed down to its proper curves, the thickness is variously put on. Thus, strickles may be used at the ends and middle just as in the core. But this leaves the eye to judge of thickness, which in thin castings is too risky. Hence thickness pieces are fitted to the core, being either wood strips, curved or straight, gauged to thickness, or flat-headed nails are driven in by templet. These afford a guide by which the loam is daubed on and strickled off. All these are easily removed after the pattern is moulded and the core is required.

The flanges on loam patterns are usually made in wood, and they rest against the shoulders of the loam which forms the pattern thickness. These shoulders are therefore filed quite square after the thickness has been dried in the stove.

In some loam patterns there is a great deal of this fitting of wooden parts, portions which cannot be made in loam being conveniently made in wood. A little knack and some rough geometry is often essential therefore in this class of work. Centre lines, and lines at right angles, which can only be struck with trammels or compasses, are often wanted, and their accurate laying down is rendered all the more difficult, because many loam patterns are unjointed.

CHAPTER XIII

THE ELEMENTS OF MACHINE MOULDING

THE elements of machine moulding exist in the use of turn-over boards, and in plate moulding, devices which are employed to a greater or less extent in nearly all shops.

Turn over boards, joint boards, bottom boards, as they are variously named, are employed to facilitate the making of the joint faces of moulds. In ordinary work these faces are made by strickling and sleeking down, as noted on pp. 140-2 in connection with Figs. 64-70. But when similar work is often repeated the joint faces are rammed directly upon boards, the contour of the faces of which corresponds with that of the joint faces of the sand—flat, if required flat, irregular, sloping, curved, etc., if so required. In the simplest mould, the flask which is to become the bottom or drag is laid upon the bottom board over the pattern, rammed, lifted off with the pattern or portion of the pattern belonging thereto enclosed *in situ,* turned over, and the cope rammed upon it. This method is very advantageous in two cases: first, when the pattern is so flimsy that it would probably become rammed out of truth, or could only be kept with difficulty from winding during ramming; and second, when the parting joints are so uneven, unsymmetrical, curved, sloping, and irregular, that to cut and sleek them with the trowel at each time of moulding would entail much loss of time.

Plate moulding is an advance upon this practice. Using turn-over boards, the cope is rammed on the drag, joint to joint, in the positions which both are to occupy finally at the time of casting. But in plate moulding the joint faces are not brought together at all until the time of final closing. The pattern is divided into two portions, one portion being upon one side of a plate of wood or metal, the supplementary portion being upon the opposite side. Or in many cases distinct plates are employed, each carrying that portion of the pattern which is the supplement of the portion on the other plate. Cope and drag being rammed, each on its respective side of the plate, or on its separate plate, form when brought together a complete mould, corresponding at the joints. Thus, taking an example, the trolly wheel shown in Figs. 64-67, p. 141, would, if moulded on a plate, be made as in Fig. 181. It is clear that the portion of the wheel on the face *B* of the plate is supplementary to that on face *C*. The faces *B* and *C* form the joint faces of the drag and cope. Patterns like these are arranged singly or in series on plates, according to size and quantity required. A pattern of large size will occupy a plate to itself; several small patterns, alike or dissimilar in character, may be arranged on one plate, and poured from a central ingate and spray of runners.

The difference between the solid pattern used on a joint board and the divided pattern on a plate is due to the difference in the methods of moulding. In the first case, one-half the mould is rammed on the other half—the latter being the one which is rammed on the board. In the second case the mould parts are rammed independently of each other, and they do not come together at all until finished. In both cases there is much economy over the ramming of patterns by the ordinary method of turning over, in which the joint has to be prepared by the trowel of the moulder. Both in joint board and in plate moulding the joint is made at once by the face of the board or plate. But the latter also saves time in the lifting out of numerous patterns, besides which it is a more permanent arrangement, and one moreover that lends itself to still further economies, as arrangements of runners and the use of separate plates for top and bottom

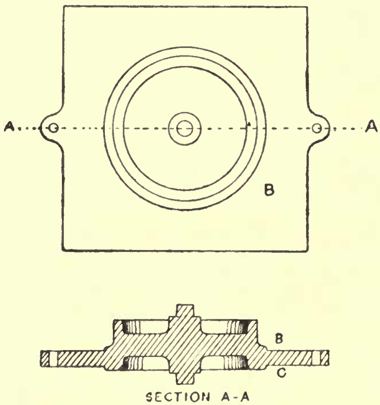

FIG. 181.—PLATE MOULDING—TROLLY WHEEL.

boxes. Also the system is more adaptable to the preparation of patterns and plates in which the joint faces instead of being flat are sloped, curving, or otherwise irregular in contour.

Patterns are dowelled on plates (Fig. 182) just as they are when moulded by bedding in or by turning over. Usually the dowels are made long enough to pass right through the plates into the holes of the other half pattern. The pattern halves are fitted up with their dowels and are tooled and finished before being attached to the plate *A*, which is usually done with screws, or rivets, Fig. 182, sometimes with solder. In a plate *A* fitted thus with pattern parts on opposite sides the boxes are cottered to the plate, and

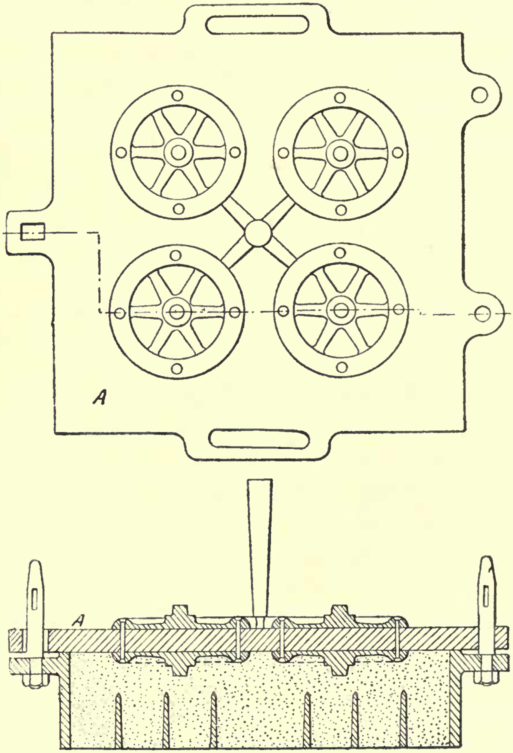

FIG. 182.—PATTERN PLATE ON BOX.

so rammed, Fig. 182. The cotters are then knocked out and the boxes removed and closed for pouring. But separate plates are often used so that two sets of men can be working on one class of castings. The positions of the pattern parts are then set on the separate plates by centre lines, and the box pins located properly so that when the half moulds are prepared they will come together without any overlapping joints. When patterns are

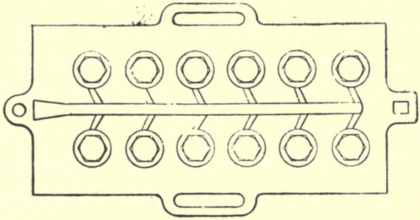

FIG. 183.—ARRANGEMENT OF SMALL PATTERNS AND RUNNERS.

moulded with irregular joint faces the original pattern is rammed within a suitable box and turned over and the

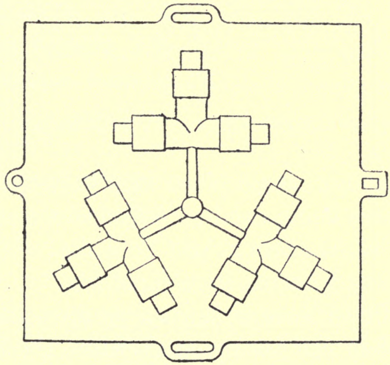

FIG. 184.—ARRANGEMENT OF PATTERNS AND RUNNERS.

other side rammed. Then a frame, prepared to the thickness of the intended plate, is laid on the joint face in the box and rammed round its edges to give the size and shape of the plate, and the mould poured, so producing a plate in one with its pattern. There is no essential difference in plate-moulding and in moulding done on a machine, in fact the plates will frequently interchange, and in the case of small patterns several are mounted on a plate as in Figs. 182 to 186, and the runners also are suitably disposed thereon. Figs. 182 to 184 are shown as though mounted for plate-moulding in ordinary boxes, having hand holes, and holes for the box pins. Fig. 185, having no holes, might be attached to a moulding machine in various ways, with clips or otherwise. Also Fig. 184

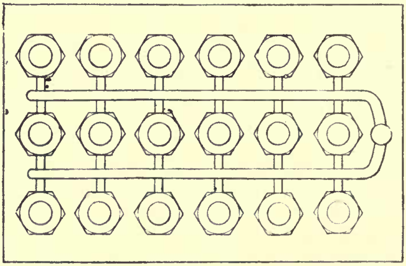

FIG. 185.—ARRANGEMENT OF PATTERNS AND RUNNERS.

might represent a single plate with patterns on one side only, two plates being used on different boxes, or the two sides of the same plate might be alike. Fig. 186 shows anvil jaws plated for use on a machine.

Fig. 187, Plate V, represents a pattern-plate of a locomotive wheel in the background, while the halves of the mould made from it are seen on the ground in front. Figs. 188 and 189, Plate V, also show pattern-plates; the first is that of a sprocket wheel, the halves of which are on one side of a plate. With two rammings two wheels are moulded. The lower figure is that of a boiler door, made on two separate plates.

The utility of a *moulding machine* consists largely in this, that in place of the clumsy and often inaccurate separation of the pattern plates from the flasks by hand, there is substituted the steady, equal, and perfect separation by mechanism. Some of the more useful machines include much more than this, as the ramming or pressing of the sand around the patterns, and the use of stripping plates, that is, plates through which the patterns are drawn, the plates sustaining the sand and preventing broken edges; but such elaboration is not essential to machine moulding, though often convenient and advantageous.

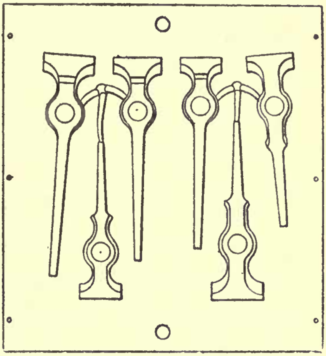

Fig. 186.—Anvil Jaws arranged on Plate.

The rapid growth of machine moulding is one of the most remarkable features of present foundry practice. The machines made now number several scores of distinct designs, though the broad types may be reduced to less than a dozen. To understand the essential differences between these types it is as well to consider the principal stages in making moulds, which include ramming, turning over, rapping, and withdrawal and closing, the dimensions of moulds, and the case of repetitive work. Each of these aspects of moulding has occasioned the evolution of broad and distinct types of machines, while many machines are built to combine more than one of these cardinal features.

Ramming.—This is the subject which naturally arises first in any question of machine moulding. Because it is the most difficult feature to embody in a machine, is the reason why, notwithstanding hundreds of patented devices, only a minority of machines to-day include provision for complete mechanical ramming, though the number is increasing. The majority are still built for hand ramming, though these usually include a presser head, so that the utilities of the moulding machines lie mainly in other features. The exceptions to this general rule lie chiefly in some special classes of work which are largely repetitive, in consequence of which considerable expense can be incurred for blocks having irregular contours, more or less approximating to the form of the pattern, and by means of which the force of ramming can be graduated. Something of this kind is essential, the cases of shallow patterns excepted, or those with fairly level faces over which the sand can be pressed and consolidated equally by a flat pressing plate. It seems hardly necessary to explain the reason of this. The moulder knows well how the force of ramming is varied continually, and almost unconsciously over different sections of the same mould, as well as in moulds made of different mixtures of sand, and that such ramming is done sideways in undercut portions under flanges, lugs, bosses and so on, work which no machine can imitate perfectly. Still it may be stated that almost any class of work, even though irregular or intricate, can be rammed by power if the number of castings required off is sufficiently numerous to warrant the cost of ramming appliances. The question then is one of relative cost, as in smiths' stamping dies, and in machine shop jigs.

The reasons for adopting machine ramming are most cogent when the joints of moulds are of irregular outlines, that is, when the faces of the joints have to slope upwards and downwards, with plane or curved outlines to follow pattern parts which stand above or below the general plane of the moulding-box joints. These irregular joints, when made with the trowel and the moulder's hands, often occupy a considerable time, and they have to be repeated for every mould unless a ramming board or block is prepared and used for moulding on. When a pattern plate, made in a similar way, is put on a moulding machine, the economy of power ramming is very great. And further, on the same joint plate, runners, or sprays of runners, are usually arranged once for all, so effecting a further economy in time.

Turning-over.—The turning-over of the parts of moulding boxes, when done by a machine, avoids the risk of the sudden shock and fracture of sand which sometimes follows from a clumsy turn-over done by hand. Sometimes it is the pattern plate alone that is turned over, sometimes the moulding box on the plate. But in any case it is always done steadily, and the plate, or the box, is locked in a truly horizontal position, and also at a height convenient for working at, instead of lying down on the ground. This last is one of the less appreciated features of machine moulding, but it nevertheless has considerable advantages.

The turn-over table is fitted to the greater number of machines designed for general use, because it affords the handiest method of ramming tops and bottoms. But as machines increase in dimensions, its weight becomes objectionable, and the largest machines therefore, as well as many of medium sizes, employ a non-turnover type of table. Then tops and bottoms can be rammed on separate machines, or on one machine at different times, or at the same time if the length of the table is sufficient to receive two boxes side by side, which is often arranged.

A large machine, with a non-turnover table, is often preferred to two or more smaller ones, because several patterns can be moulded at one time on one or on separate plates. This is an extension of the method adopted in hand work, of arranging several small patterns in one moulding box, or on one bottom board or plate.

Rapping and Withdrawal.—The delivery of patterns from moulds when done by hand is commonly a cause of enlargement, and variations in the sizes of moulds, and often of fracture of the sand, which when mended up tends to produce variations in the dimensions of moulds. The larger a mould is, the more risk is there of such accidents happening, because of the difficulty of getting a truly level lift when two or three men are lifting at once, or when the crane has to withdraw a pattern. The principal value of very many moulding machines, therefore, lies in the simple fact that patterns and moulds are separated by the coercion of rigid slides instead of by the unsteady action of the human hand, or of the crane. So valuable is this feature that many moulding machines embody no other provision besides this. Subject to the condition that patterns are made well, there is no fracture of sand, and a hundred moulds made from the same pattern will show no variations in size.

But there are aids to the withdrawal of some kinds of patterns which are essential. A deep pattern having little or no taper or draught cannot be withdrawn without tearing up the edges of the sand unless some rapping or vibration is imparted to it, or unless a stripping

PLATE XII

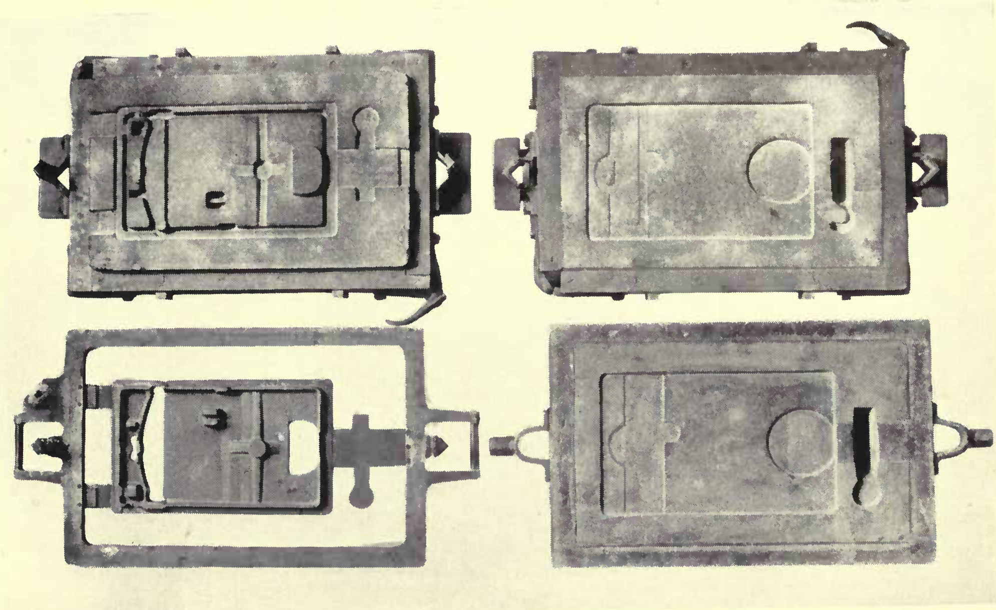

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FIG. 207.—TABOR PATTERN PLATES

plate is used to hold down the sand around its edges. Shallow patterns and those which are well tapered can be withdrawn readily if the machine plate on which the pattern is mounted is rapped with a wooden mallet during the act of withdrawal, and this is usually done. But that is a different thing from the lateral rapping with an iron bar inserted in the pattern, and which is imparted previous to the lifting by hand of the pattern from an ordinary mould. Rapping on the plate merely loosens the sand next the pattern and prevents its adherence. But slight enlargement of the mould, imitating the action of the rapping bar is provided for in the jarring or vibrating class of machines in which slight lateral rapid movements are imparted.

The majority of machines have no provision for vibrating the pattern, but when deep lifts have to be made of patterns provided with little or no taper, a stripping plate is made to encircle the pattern closely. It is laid on the face of the mould and the pattern is withdrawn through the plate. This is an extension of the method often adopted in making common moulds by hand work, when strips of wood are laid down along the edges of the mould beside the pattern, and retained by weights during the withdrawal of the pattern. The sand around the edges is thus prevented from being torn up by the lifting of the pattern. Frequently metal stripping plates are used for hand moulds, as in machine moulding,—in some gear wheels for example, both of spur, and special types. These are rather expensive, being filed out of sheet metal to embrace and fit the pattern outlines, hence they bear a high proportion to the cost of the castings unless a large number are required. But many are made now cheaply by casting white metal within an iron frame surrounding the pattern. And so when the inaccuracies which result from hand rapping and withdrawal are eliminated by machine moulding, castings are more uniform in size and shape. Hence the allowances for tooling can be lessened, with reduction of costs in the machine shop.

The idea of drawing the pattern through a plate has been familiar for the past forty years or more, even in hand work. The late Mr. James Howard, of the firm of James and Frederick Howard, of Bedford, took out a British patent for a moulding machine worked on this principle as far back as 1856, and that firm has used machines of this type ever since for the bulk of their repetition work.

Closing.—Moulds are usually closed by hand. But a few machines are made to fulfil this function after the removal of the box parts from the moulding machine. There are, however, apart from this, many adjuncts to machines for taking the finished moulds away for closing them, as trolly tracks, turn-tables, etc.

Dimensions.—The dimensions of moulds impose some limitations on the sizes of moulding machines, though a large increase in size has been noticeable in recent years, chiefly in some American and German machines. All the early machines were designed only for dealing with articles of small dimensions, not exceeding from about 2 ft. to 3 ft. across, and the greater number moulded were even smaller than that. The reason is obvious, since the first machines were operated by hand alone. After power was applied, dimensions increased, and the largest machines now, which will take lengths of 10 ft. to 15 ft., are operated by hydraulic pressure with the greatest ease. A large machine has the advantage over a small one that it is adaptable for dealing with single moulds of the largest size within its capacity, as well as with two or more separate moulds of smaller dimensions, thus combining in one the advantages of two machines.

Repetition.—The production of repetitive work on a large scale has been the cause of the development of the portable types of machines, of multiple moulding, and of numerous adjuncts to fixed machines of ordinary and of special types, such as tracks, conveying systems, cranes, etc. This aspect alone opens up a very wide field of interesting detail which illustrates the numerous and varied ways in which similar results are secured. For though the small light machines may be moved along the floor, leaving their work behind them, the large heavy ones must be fixtures, and the work must be brought to and conveyed from them. Conveying systems also deal with the sand and the moulding boxes. In some shops these systems have become very highly developed.

Adaptability.—The practice of machine moulding is adaptable to all classes of work that lie within the capacities of the machines. Like die-forging, it is suitable alike for a limited number of articles only, or for hundreds or thousands of similar parts. And the cost of the pattern work is mainly controlled by the numbers of castings required; ordinary cheap patterns of wood for a few moulds; high-class, well made patterns of metal when hundreds or thousands of moulds have to be taken therefrom. So that moulding machine practice ranges from that in which ordinary patterns are mounted on plates, as in the plate-moulding which is done by hand, and put on the machine, to those in which metal patterns on plates are got up in the best possible manner for use on the machine alone. And between these extremes every grade and method of pattern work is represented in machine moulding. Formerly, too, only simple patterns were attempted, but now many intricate forms are used. The simplification of the moulder's task also follows, with the result that men who have not had the moulder's training, or mastered any section of the moulder's craft, are able in a few weeks to operate machines.

Patterns.—As in ordinary hand moulding, patterns are either unjointed or jointed. In the first case a plain top only is wanted, and then the pattern is mounted on one side of a plate. In the second case the pattern parts or halves, as the case may be, are mounted on opposite sides of one plate, or each on one side of two distinct plates, which may be moulded on the same machine by one man, or on different machines by different men. The matching of the moulds depends on the degree of care and accuracy with which the pattern maker has done his work. Each of these methods is also adopted in much hand moulding when it is of a repetitive character. Another fact is that in moulding by machine it does not matter essentially whether the pattern is lifted from the mould, or whether the mould is withdrawn from the pattern, and whether upwards or downwards. Neither, as already stated, is turning over on the machine an essential. The details vary with types of machines.

A point to be emphasized is the futility of pinning one's faith and practice to one class of machine. No matter how excellently designed and economical a machine is, there is always another that will go a point better on certain classes of work, and operated under different conditions. That is the reason why a firm should feel its way in laying down plant of this character, and not order a lot of machines of one type, if the range of work done is of a varied kind. The case is paralleled by that of machine tools. No sane manager would fill a shop with machines of one build and type, unless, of course, the character of the work done was uniform, as in the case, say, of ranges of screw machines, or gear cutters, always operating on the same kinds and nearly the same sizes of work.

The question of type of machine then opened up is a very wide one. So is that of dimensions. So, too, is that of method of operation. Thus, if men work regularly on separate parts of the same moulds, on separate machines, there is no need, as a rule, to have turn-over table machines. Nor when tops are uniformly plain are turn-over machines necessary. Nor when the two parts of moulds are made side by side on one plate, or when a number of tops and then a number of bottoms are made on the same machine, is it necessary to have a turn-over table.

With regard, again, to dimensions, the size of a single pattern alone is not only the governing question, since it is often more economical to put several patterns on one large machine than to have single patterns on smaller machines. This holds good not only in relation to very small patterns that are commonly grouped thus, but to those of comparatively large dimensions, which can be moulded on oblong machines of several feet in length. Another advantage in using such machines is that top and bottom box parts may be, and often are, rammed on one side of one plate at once, not of the turn-over type.

The method of operation is an important governing condition when we get into machines of very large dimensions, for it is obvious that however well counterbalanced a table may be, and though human power may be multiplied and used to the best advantage, with levers and with worm gear, there is a limit to its employment beyond which hand operations cannot be conveniently and economically carried, and this is the opportunity for the power machine, and this raises the broad question of power operation.

Generally this should be settled by the character of the plant already existing in a shop, or of that which it may be contemplating to lay down. All progressive foundries are now equipped with power of some kind, as steam or water power for cranes, air or electricity for hoists, and other purposes. Of hydraulic moulding machines there is an immensely greater choice than there is as yet of steam or of pneumatic machines. But in view of the recent rapid growth of air-operated machinery which has been shared by the foundry in common with other departments, we may anticipate that pneumatic moulding machines will be in much greater demand in the future than they are yet. If the question is one of laying down power plant in a foundry as yet unsupplied with power, it may be pointed out that a pneumatic plant is less expensive and less bulky than a hydraulic one. Air-compressing plants are very suitable for small foundries, and they serve also for hose-piping for blowing out moulds, in place of bellows: and a few air hoists also are more handy than fixed hydraulic cranes. None of these questions can be settled offhand, but each separate shop must work out its own problems, independently of the governing conditions of others.

CHAPTER XIV

EXAMPLES OF MOULDING MACHINES

Fig. 190, Plate VI, illustrates one of the simplest machines that can be made, being a *mould press* simply. Ordinary boxes and snap flasks are moulded on it, the latter being shown in place. Preliminary ramming may or may not be done by hand, according to the outline of the pattern. The final pressure is imparted to the top and bottom of the moulds, to which presser-boards are fitted, by the downward pressure of the hinged head, actuated through toggle levers by hand. The levers on opposite sides of the machine are connected by a horizontal shaft. The height of the presser-head is adjusted to suit boxes of different depths by means of the nuts on the screwed rods. There is no mechanical delivery, patterns being rapped and withdrawn by hand in the ordinary way. But the saving in time is very considerable on repetitive work.

A hand machine of more advanced type, which has been in successful use during many years, is that manufactured by Messrs. Darling and Sellers, Limited, of Keighley. It is made in a large range of dimensions, both for general work, for specially deep work, and for stripping plates. The machine is designed for hand ramming, and no special pattern plates are necessary, since any patterns of suitable size, either in wood or metal, can be mounted on the table. The illustration, Fig. 191, Plate

VI, shows one of these machines, which is specially designed to take deep and heavy boxes, with which object it is made rather differently from those which are built for small and medium work of a general character, as in Fig. 192, Plate VII. It will be noted that though the general design is similar in both instances, the differences are that gearing is used in Fig. 191 for operating the turnover table, and that the elevation is done by racks and gears instead of by simple movements of a lever, as in Fig. 192. But with these exceptions the same general description will apply to each.

The two standards in these illustrations carry the mechanism between them; they are built at various distances apart, ranging from 30 in. upwards to about 16 ft., to suit boxes of different lengths, and are maintained apart by stretcher bolts and a bottom casting, while the larger machines are also bolted to a baseplate. The pattern is fixed to the upper face of the top table, which is of the turn-over type, and the box is placed over this and rammed by hand. It is retained in place by means of screws and sockets which are adjustable for different depths of boxes, or in the case of light work, by spring clips. The table is fitted with trunnions of large diameter, in capped bearings in the standards. Set screws, with large nuts, afford the means by which the table is adjusted for level without further check, and it is prevented from moving by the catch handles above. In the machines for general service the trunnions are placed in the centre of the table, as in Fig. 192. But in the example in Fig. 191 they are placed eccentrically in order to come more in line with the weight of the pattern and moulding box. But they are arranged in or out of centre, in either machine, to suit requirements.

When the pattern has been rammed, the catches above are removed, the table is turned through half a revolution and relocked, leaving the moulding box with its contained mould and pattern suspended from the underside of the table. At this stage another portion of the mechanism, the lifting table, the bottom one, in both figures, is brought into operation. This is a ribbed plate, underneath which two turned stems or pillars, seen in Fig. 191, are attached with bolts through flanged ends on the pillars. These are the means by which the lifting table is elevated and depressed through the action of slotted links hidden within the base, actuated by two levers on a horizontal shaft, which is turned by the long lever seen to the left in Fig. 192. The total mass of these parts is counterbalanced by the weight seen at the right. The effect of moving the lever is to bring the table up towards the back of the box that has just been rammed. In the deeper class of machines shown in Fig. 191, the table is lifted by cylindrical racks seen beneath. These slide in bored sockets, and are actuated by the hand wheel and gears to the left of that illustration. The raising and lowering of the table are performed with ease, because the weight of the latter, together with that of its load, is counterbalanced by adjustable weights, which descend into the foundations.

The table is lifted up until it presses the carriage against the back of the rammed box. The clamps are then released and the table lowered, the mould descending with it away from the pattern. During the period of this delivery the upper surface of the turn-over table is rapped with a mallet to assist the separation of the pattern from the sand.

The mould is now left lying on the carriage, immediately above the lower table, on which it is drawn away by means of rollers beneath the latter, not visible, to the receiving rails in front, which, being clear of the machine, permits the mould to be lifted off and taken away. The carriage is of wood, and its movement is controlled by flanges on the ends of the table. The receiving rails are similarly flanged, and form the top edges of cast-iron brackets, which are bolted to the front of the machine. The empty carriage is now pushed back on the lifting table, and the turn-over table revolved to bring the pattern on its upper face ready for the next box.

Front and back plates enclose the lower portion of the machine. These are fitted by planed joints to the standards, and serve the double purpose of bracing the machine and preventing sand from falling inside. Inner sloping top edges of these plates shoot off any sand that falls from above. A handy table is supported on brackets at one side, Fig. 192, to carry the moulders' tools, swab pot, blacking bag, etc.

A machine of this kind is of great value in any foundry, even where few specialities are handled. Any ordinary pattern within its range can be taken and put on the table and moulded with a perfectly vertical lift. It will pay to use the machine for two or three moulds only. When a plain top only is required, the latter can be rammed on the plain table. When patterns are jointed, their halves or parts must be fitted on opposite sides of the table, or be fixed on separate machines, which involves some fitting that would not be justified for two or three castings, though in this respect the machine is quite adaptable in firms that have not much specialization. But outside of these there are many cases in which the patterns are cast with the turn-over or swivel table, as in labour-saving repetition work. Patterns are specially mounted in three ways—on a *false-part* box, or on thin cast-iron plates exactly as used in many shops for plate moulding without the assistance of a machine, or mounted in plaster-of-paris.

In all these cases the piece carrying the pattern or patterns is capable of being attached simply and rapidly to the turn-over table by a couple of bolts, and the usual practice is to mount the bottom-part pattern on the table, make the required number of half-moulds, and then replace it by the top-part pattern; the change of patterns being only the work of a few minutes.

Messrs. Woolnough and Dehne's moulding machine, manufactured by Messrs. Samuelson and Co., Ltd., of Banbury, is illustrated in Fig. 193, Plate VII, and Figs. 194 and 195, p. 285. Fig. 193 is a perspective view of the machine, Fig. 194 a sectional elevation of one of the standards, Fig. 195 a horizontal section through the standard on the line *A-B*. A base plate, Fig. 193 carries a couple of pillars, one of which, that to the right, is permanently fixed, the other, to the left, is capable of horizontal movement, rendering the machine adjustable to the width of any pattern plates within its range. The pillars *A*, are hollow, enclosing spindles *B*, to which vertical movement can be imparted by means of the weighted lever handle seen in Fig. 193. The lever actuates the horizontal shaft *H*, Figs. 194 and 195, upon which are keyed two worm wheels *F*, enclosed in the semicircular casings *G*. The shaft and casings are seen at the front in Fig. 193. The worm wheels engage with screws cut on the vertical spindles *B*, and so raise and lower the pattern plate, which has its bearings, *c*, in the upper ends of the spindles, and which can be turned over in its bearings. Two triangular plates furnished with slots and bolts for vertical adjustment slide in faces upon the pillars, Fig. 193, and their upper edges form the tracks for the wheels of the plate, upon which the moulding box is supported. The provision for vertical adjustment permits of the employment of flasks at various depths.

The method of moulding is as follows: That face of the pattern plate from which the impression is to be immediately taken, whether for cope or drag, is turned uppermost, and the appropriate flask placed thereon and clamped or screwed. The sand is then rammed in by hand, and scraped level. The flask and plate are turned bodily over and lowered, until the back of the flask rests upon the table beneath. The pattern plate is then pinched in its bearings with the set screws seen at the tops of the pillars, and lifted clear of the flask by the lever handle. A very slight amount of rapping is imparted to the pattern plate in the act of withdrawal. When the mould has been blackened the pattern may be returned temporarily in order to press the blackening down, thus saving the trouble of sleeking.

The sleeve, *D*, Fig. 194, is simply for the purpose of protecting the vertical spindles from access of dust, and a screw gland, *E*, similarly protects the worm and worm wheel.

Fig. 196, Plate VIII, shows a machine of a similar type by the London Emery Works Company, carrying the pattern for tramway axle boxes, castings of which are seen in the foreground. The tubular standards each enclose a flat threaded spindle, the top of which is formed into bearings to receive the trunnions of the turn-over

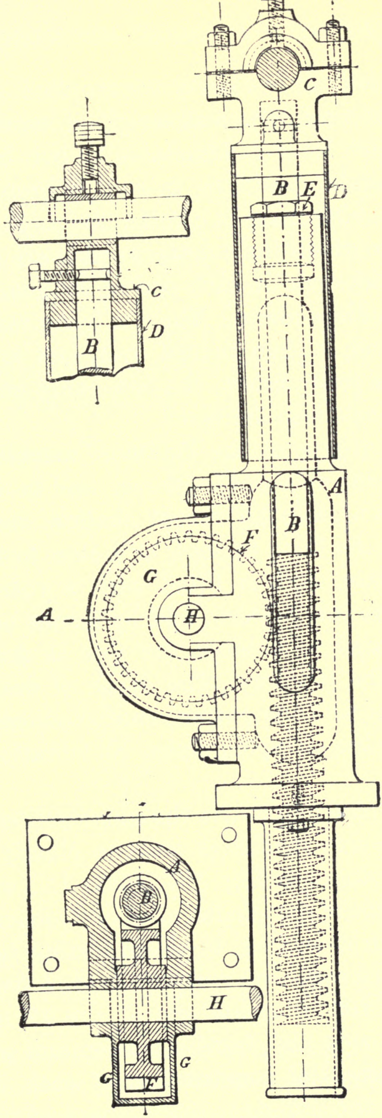


Fig. 195. Fig. 194.

Woolnough and Dehne's Moulding Machine.
Sectional Views.

table on which the box parts are rammed. The racks are moved in unison by the long weighted hand lever seen at the left, which lever is adjustable by bolt holes into five different angular positions to suit different amounts of lift. The moving mass is counter weighted at each end; the chains to which the counterweights are attached lead off from pulleys one on each end of the gear shaft below, leading to pulleys above. The box being rammed uppermost, by hand, is then turned over, and lowered by the lever on to a trolly below, the box being ran away after the pattern has been delivered.

The general type of the Pridmore machines is that in which the table does not turn over, and in which a stripping plate is used in all except shallow work. A frame standing on the floor by legs, or a claw foot, carries the stripping plate, and is fitted with a yoke or plunger which carries the pattern, and by means of a crank or cranks operated by a lever, the *yoke* is drawn down or raised with the patterns. The depth of draw is capable of adjustment, and the pattern can be adjusted for height in relation to the stripping plate. No vibration or rapping is required.

The broad plan followed in the construction of the small and medium-size machines may be clearly understood from the photograph Fig. 197, Plate IX, which shows, to the right, one of the smaller sizes of "square" machines with a pattern mounting, to which further reference will be made; and a rock-over machine to the left of the figure. Figs. 198 to 200 illustrate one of the 12 in. "round" machines, in side and front elevation and plan respectively. The essential construction of each is identical, unaffected by the square or round shape of the framings.

The design is that of a main frame, *A*, formed of a single casting, and a pattern-carrying yoke, *B*, consisting of a second single casting, which is lowered and

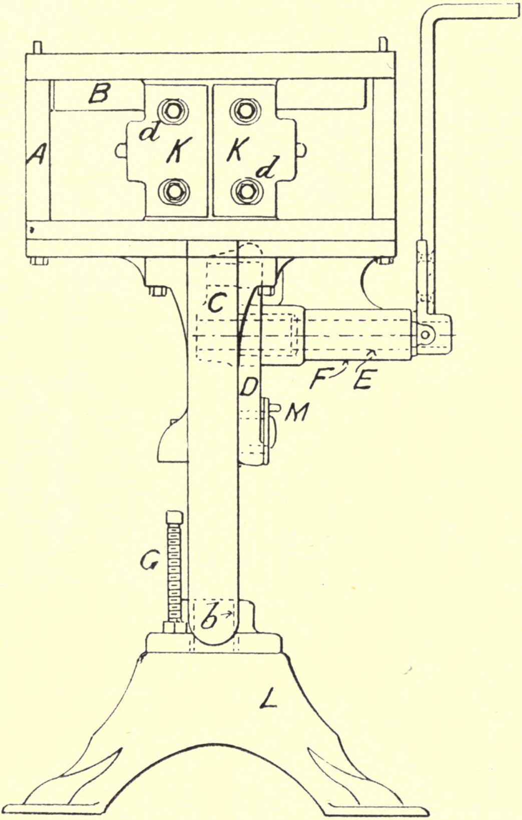


Fig. 198.—Pridmore Machine. Side Elevation.

raised within the main frame by a crank, *C*, and pitman, *D*. The yoke, *B*, is guided at the top in adjustable ways, *a*, *a*, and at the bottom of the frame in a round, brass-bushed guideway, *b*. The distance between the upper and the lower guides being great in proportion to the width of the frame, ensures a true draw. The crank-shaft, *E*, upon which depends the weight of the yoke and the patterns,

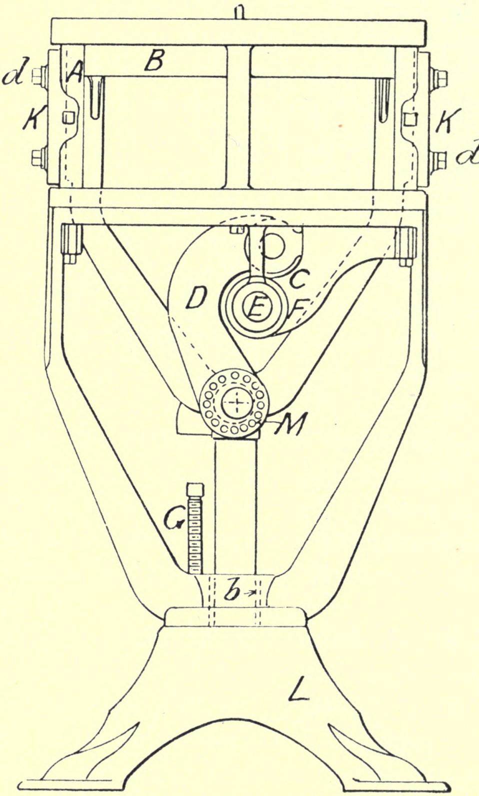
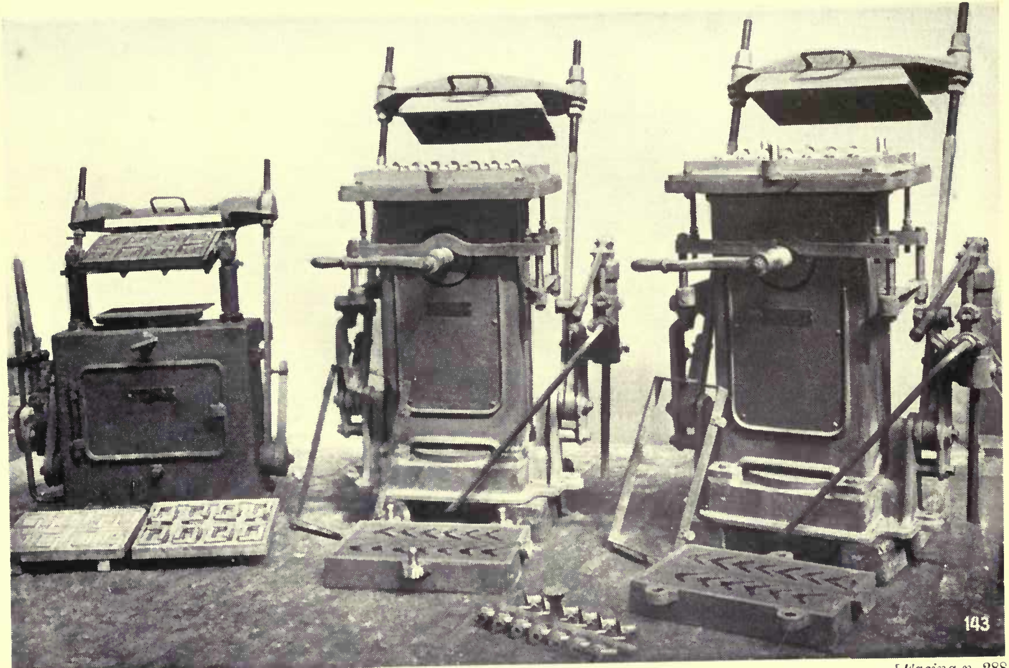


FIG. 199.—PRIDMORE MACHINE. END ELEVATION.

through the crank and pitman, is journalled in a long brass-bushed bearing, *F*, extending one-half of the width of the machine, and cast solid with the main frame. The yoke when raised is locked securely in position for ram-

PLATE XIII



See p. 312

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FIG. 211.—TWO HYDRAULIC MOULDING MACHINES TO THE RIGHT, AND CORE-MAKING MACHINE TO THE LEFT. THE LONDON EMERY WORKS CO.

ming the mould by the crank passing slightly beyond the centre and bearing on the edge. The amount of *draw* can be adjusted to the height of the patterns by a simple bolt, *G*, and set-nut. Any wear upon the crankshaft or pin, or yoke pin, can be taken up by an eccentric brass bushing on the yoke pin, with a series of holes registering with differential holes in the pitman, *M*, so that all wear can be adjusted to one-five-hundredth of an inch.

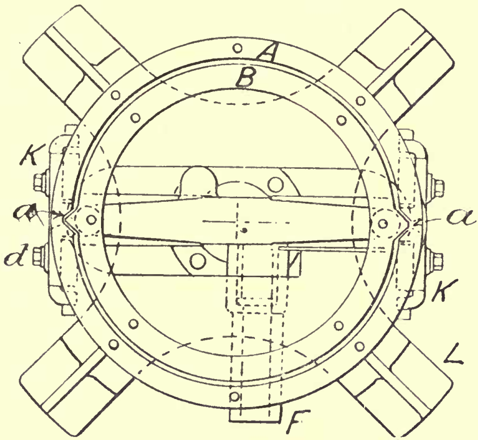

FIG. 200.—PRIDMORE MACHINE. PLAN.

Wear on the guideways, *a*, is taken up by adjustable plates, *K*, which are set along horizontally and pinched with the bolts, *d*. The machine is supported on a claw foot, *L*.

The various types in which these are made are as follows, classified broadly as "light" and "heavy" machines:

The light machines, supported centrally on a claw-like foot, are of either round or square outline. The round ones are made to take circular patterns, such as gear wheels, pulleys, and similar classes of work—in diameters ranging from 10 to 20 in., and with a depth of face not exceeding 10 in. The depth of draw is $4\frac{5}{8}$ in. The yoke is controlled by two guideways above and one in the centre, with a single crank. The square ones also take 10 in. in depth with a draw of $4\frac{5}{8}$ in., and range in capacity from 9 in. + 12 in. to 18 in. + 28 in., the general construction being similar.

Oblong machines are made of square type, but are supported on two legs or standards, one at each end, with the yoke duplicated over and within each standard, connected with a central shaft, and operated by a single crank at one end. They have the same draw—$4\frac{5}{8}$ in.—and they embrace patterns from 12 in. to 20 in. in width and from 24 in. to 48 in. in length, and larger to order.

The frames of all square or rectangular machines are left open at the ends, thereby permitting the use of patterns which are considerably longer than the frame of the machine. The stripping plate setting upon the top of the frame is not limited to any particular size, so that a wide range in sizes of boxes is permitted.

The foregoing form a class of machines which are comparatively light, have but one crankshaft, and with the exception just named have shallow draws and high tables, and are adapted to work of small and medium dimensions.

There is another large class having characteristics of an opposite character, being "heavy," and suitably designed for heavy work (Fig. 201, Plate IX). These illustrate a machine in which a wooden pattern is mounted with a wooden stripping plate, a method suitable for occasional work.

These machines consist of single heavy castings for the main frame, standing upon legs at each corner. The frame is rigidly designed, which is essential in all moulding machines. Want of rigidity, causing the pattern to swing, and the moulding box to register imperfectly, has been the cause of the inefficiency of some moulding machines. The "heavy" machines are square, oblong, or round, but the yoke which raises and lowers the pattern or patterns is operated by two parallel crankshafts and four guideways, or six in some of the longer machines. In these, too, the yoke upon which the patterns are mounted is a second single large casting. The yokes slide in guideways on the inside faces near the ends of the parallel sides of the main frames, on the top edges of which the stripping plate frame is mounted. Long bearings are cast in each corner of the main frame, close to the legs, and in these bearings are fitted two heavy parallel shafts. Upon each end of each of these shafts, setting close to the bearings, is keyed a double-ended crank; in the upper ends of these cranks are pins upon which are journalled heavy pitmans, the upper ends of the pitmans being journalled on pins riveted into the corners of the yoke. In each one of the lower ends of the four pitmans are the eccentric adjusting bushings described on p. 289 in connection with the small machines. The lower ends of the double-ended cranks carry cross connections to the lower ends of the cranks on the opposite shafts. The two sets of cranks at the opposite ends of the machines are at right angles with each other, thereby transmitting a perfect rotary motion from one shaft to the other. The end of one of the shafts is extended, and carries a lever by which the pattern is lowered and raised. A special feature is the coiled compression springs, two or more in number, by which the weight of the yoke and its burden is counterbalanced, so that patterns are drawn and raised easily. Springs of different strengths can be substituted in the sockets provided for them, to permit of exact adjustments for patterns of different weights.

Square machines of this class are built in dimensions ranging from 18 in. upwards to 60 in. wide and 120 in. long, with draws of from 6 in. to 8 in. They are built low to take deep flasks. Round machines are also made with double shafts, with deep draws, in capacities ranging from 24 in. up to large sizes; 60 in. is a large standard size, but larger ones are built when required.

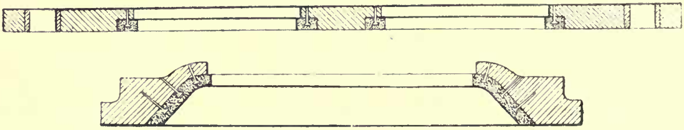

FIG. 202.—BABBITT-LINED STRIPPING PLATES.

The babbitt lining of the stripping plates in Fig. 202 will be observed. The practice of using stripping plates is generally open to the objection of being costly, when the openings are tooled or filed to make a close fit with the bounding edges of the patterns. The babbitt system dispenses with this labour in the following way (the only exception is circular openings which can be turned readily):

The stripping plate is cast with an opening about $\frac{1}{8}$ in. larger all round than the patterns. Its upper edge is recessed to a width of $\frac{1}{2}$ in. and depth of $\frac{3}{8}$ in., and small holes are drilled at distances of about $\frac{3}{4}$ in. apart, into which wire nails are driven, leaving the heads about $\frac{3}{16}$ in. below the intended surface of the babbitt. When the pattern plate is placed on the machine, with the stripping plate surrounding it, asbestos string is laid around the pattern, and between the opening in the stripping plate and the backing or filling-down thickness pieces on the pattern joint. A layer of putty is laid round to form a trough. All is then warmed, and babbitt is poured in around the pattern, filling up the space. Before this has quite cooled, the operating lever is pulled, and the pattern drawn down through the babbitt. The surplus is then cut away from the surface of the stripping plate. If the babbitt is found to make too tight a fit around the pattern, it is trimmed off until the pattern moves through freely. From 50,000 to 150,000 moulds can be made before a plate requires to be re-babbitted. By the adoption of this cheap and ready way the objection to stripping plates no longer holds good.

In fitting these up, a single plate is thus prepared before the second is taken in hand. The second stage is as follows:

Pattern plates and stripping plates are prepared for the complementary portion similarly to the first, and placed on a moulding machine adjacent, but without as yet having dowell holes drilled, or the babbitting done. But the pin holes are drilled in the lugs, and so the stripping plate first formed is taken from its machine and turned over and placed on the second stripping plate—located by the pins. The first stripping plate thus locates the position of the second part, which is now, therefore, dowelled in place, and the stripping plate No. 1 put back on its own machine. The plate No. 2 is now babbitted round its portion of the pattern. Two pattern plates are thus prepared with strippers, to mould on separate machines for cope and drag respectively, and which will match perfectly when the moulds are closed.

The question often arises about making provision for moulds with irregular joint faces. Generally the method adopted is to cast pattern and plates in one, in a mould rammed originally with cope and drag face to face, and then separated by the intended thickness of the plate, and poured, after a suitable frame has been rammed around the mould. In the Pridmore system this is avoided by fastening pieces on one plate to stand up and come to the raised pattern joint, and to cast pockets in the other plate which are approximately the reverse of the raising pieces, and deeper. Nails are driven into holes drilled about $\frac{3}{4}$ in. apart over the surface. The plates are then placed together and babbitt poured in, so forming an exact reverse.

Rockover Machines.—One of these is shown at the left-hand side of Fig. 197, Plate IX. These are used for patterns in which there is sufficient draught to permit of the lowering of the mould from the pattern, assisted frequently by a vibrator rapping action. Often they are used in conjunction with a stripper plate machine making one portion of the mould. The action of the machine is as follows: The pattern plate, being covered with its flask, is rammed by hand when carried on one side of the machine. The superfluous sand is strickled off and a bottom board laid on the surface and clamped. Then the plate with its flask and board is rocked over on its pivots to the other side of the centre of the machine, and the bottom board deposited on a stand by means of a lever, the labour being rendered easy by the counterbalancing action of coiled springs. The mould is dropped from the pattern and the latter is returned to its original position to be re-rammed. The varying depths of boxes are provided for by adjustments in the height of the stand. Some machines have provisions for self adjustments by means of four depressible pins to accommodate unevennesses in bottom boards and differences in thickness of sand.

Portable Machines.—The Farwell moulding machines, manufactured by the Adams Company, of Dubuque, Iowa, are built in two broad types to accommodate work lifted with or without stripping plates, and in both fixed and portable designs, and some have turret heads for multiple and other moulding. All the Farwell machines are of the presser type, and are all hand operated. That is, no hand ramming is done, but the moulds are pressed, and the patterns delivered by hand levers.

The general construction of the ordinary machine is as follows (Fig. 203, Plate X): Two standards support the superstructure. In the fixed machines these terminate in feet, to be bolted down upon timbers. In the portable shown, they are divided and spread out to receive the pins upon which plain wheels run. On the top of the standards a longitudinal is bolted, carrying a table consisting of crossbars, or an open frame upon which the cleats or battens of the bottom board rest. The table is a rigid fixture. Above is the presser head—a planed casting carried at the ends of pitmans which are screwed along for a considerable length from the ends to permit of a wide range of adjustment of the presser head for height. The head can be thrown back out of the way, or brought into a horizontal position over the table and mould by the left hand. Then the lever to the right is pulled over, the attendant pressing his weight on it, so compressing the mould. The lever is in the horizontal position when the man's greatest effort is being exercised upon it, which is more favourable for obtaining the maximum result than a vertical or nearly vertical one would be.

This is a simple machine—termed the *moulding press*—designed for work that requires no stripper plate. In this, as in others having no turn-over table, the cope and drag are pressed by the turning over method, or else rammed simultaneously or independent of each other on the same or on separate machines. The operation of moulding is briefly this:

Taking first a pattern requiring a plain top: A *match*, which may be either a *bottom board*, as we should call it, or an oddside, is placed with its pattern or patterns in position on the table. The drag or bottom box is laid over it. Facing, and then box-filling sand are riddled and shovelled in and struck off level. A bottom board used for pressing is laid on the sand. One movement of the lever brings the top forward and presses the mould. The drag is now turned over on the table, occupying approximately the same position centrally; the match is removed and put aside, leaving the pattern or patterns embedded. Parting sand is strewn and the cope laid in place, facing sand riddled in, followed by the box filling, and strickled off, a presser board laid on, which is identical with the bottom board in function and in shape, with a trifling difference in the cleats or battens, which are hollowed out at the sides so as to be easily grasped. This completes the moulding.

The sprue cutting, the rapping, and lifting out of the pattern are all done by hand, as in ordinary work, so that the saving of time by the machine is due to the consolidation of the sand by the presser instead of by hand. The precautions adopted to ensure the proper degree of pressure over all areas will be noted presently, and also the withdrawal of deep patterns used with a stripper plate.

In the plain moulding press to which these remarks have reference patterns are also used, the halves or portions of which go on opposite sides of one plate. In these cases the plan adopted is this: the operation proceeds as in the previous case until the drag part is laid upon the bottom board and filled with sand over the pattern. Instead, now, of pressing the board down, the drag part with the board is turned over and the cope laid on and filled, and the presser board laid in position. The presser head is now pulled down on the presser board, and the cope and drag sand are thus pressed at once between the top and the bottom boards.

The Farwell universal moulding machine, Fig. 204, Plate X, is more complete than the moulding press. It can be used either for shallow patterns, or for deep ones, with a stripping plate, and the lift is mechanical. In the choice of fixed or portable mounting it is similar to that just described. But the universal machine is fitted with mechanism for lifting the pattern or patterns from above the stationary table. The patterns are mounted on a movable table, which is supported by a long slide of hexagonal section, with provision for taking up wear. The machine combines a common moulding press, with a stripping plate, so that either can be used at will. The construction is this:

For moulding with stripping plates, the patterns are secured to one side of a board or plate, which is supported a little way above the stationary press table. Only one side of the plate is utilized, because the table is not of the turn-over type. Cope and drag are therefore rammed on different machines, or on a long machine capable of dealing with both boxes side by side at one operation. The pattern plate is fitted with tubes near the edges, through which loose studs pass and rest upon the movable table, termed the *lift table.* When a lever at the side of the machine—the *lift lever*—within reach of the operator's left hand, is raised, these studs engage with the edge of the flask and lift the mould off the pattern plate. The sand is loosened during the lift by the right hand of the attendant, who strikes a rapping bar horizontally between two projections. The box is then taken off and laid where required for coring or pouring. This is an arrangement suitable for a large volume of work which is either shallow, or, if deep, well tapered, or of circular section. The lift is truly vertical, while the rapping given is as efficient as that imparted in a common mould, but less in amount—less being necessary because the machine lifts perfectly vertical.

When deep work with little or no taper, which requires a stripping plate, is to be moulded, the pattern plate or frame rests upon the stationary press table. The stripping plate lies on the pattern plate. Three or four studs attached to the stripping plate come down and rest upon the lift table. They engage with guides on the pattern plate, and control the vertical movement of the stripping plate. By raising the lift lever both the stripping plate and mould are lifted off the pattern, after which they are taken away.

This is a concise account of these machines, without dwelling much on minute details. Some of these must now be noted, and the first matter which a moulder would like to be informed about is the pressing operation, by which hand ramming is wholly dispensed with.

In shallow work the Farwell press simply utilizes the presser head coming down on the plain presser board for the consolidation of the sand. But in deeper patterns two further devices are utilized. One is *peining*, the equivalent of our *pegging* of sand down the deeper sides of patterns before ramming over the upper surfaces; the other is the device of cutting out the presser board to the approximate outlines of the patterns to be rammed.

Peining is done by tacking a strip of wood of about $\frac{3}{4}$ in. square on the faces of both bottom and presser boards, close alongside the edges. These, of course, being thrust into the mould before the flat portion of the board comes into operation, consolidate the sand firmly round the edges of the pattern and against the box sides adjacent, just as would be done by the moulder's pegging rammer.

The presser head, which is cut to conform to the shape of the patterns, is attached to the presser top of the machine. The expense of cutting it out is not so objectionable as might appear. It is a question of number of moulds wanted. One would hardly cut it for a few moulds, but it would generally pay for a score or two, while when the cost is distributed over hundreds it is a mere trifle on each. The expense is not so great as that of cutting out half a core box, which it resembles, because the accuracy necessary in a core box is not required for pressing the sand.

When the Adams Company plate patterns they use saw-blade steel plates $\frac{3}{16}$ in. thick, which are straightened, ground, and polished on one side. As the patterns are only mounted on one side, the plates are stiffened by riveting three bars $\frac{1}{2}$ in. by $1\frac{1}{2}$ in. on the underside, and running in the longitudinal direction. The patterns are of metal, secured to the polished face. Sockets of gas-pipe, previously mentioned, are fitted near the edges of the plates to receive the loose pins, which have been described as coming down and resting on the lift table of the machine. When patterns of wood are used, they are secured to one side of a board.

As the pattern plate stands up on its pins away from the lift table, curved patterns and curved stripping plates are easily fitted.

For more rapid production, pattern plates are duplicated on the same machine, so that one man will ram cope and drag simultaneously. The pattern or patterns are set by centre lines to right and left of the common centre dividing the cope from the drag portion; or two machines are employed. In plain cored work a boy may then set the cores.

Moulding boxes are not necessarily made to fit these machines, as they simply lie upon the table, and the stripping plates, when such are used, can be adapted to the boxes. But there are certain relations between boxes and bottom or presser boards which should be regarded if the best economy is studied. The boards and boxes and the depths of patterns should be mutually related. As the bottom and presser boards enter the drag and cope to press the sand, $\frac{3}{4}$ in. is the allowance in depth made for this, so that whatever the depth of flasks required for hand moulding, $\frac{3}{4}$ in. must be added for machine moulding. The differences in depth of flasks for different jobs are recommended to be made in these boards and in the match. Thus, taking $9\frac{1}{2}$ in. as a convenient distance between the table and top, when the pressing lever is about horizontal the machine should be adjusted to that, and shallower flasks fitted by increasing the thickness of the cleats of the boards and the match. The bottom and presser boards are made smaller by $\frac{1}{4}$ in. than the inside of the flasks, so that they enter easily when pressed. They are of white pine $1\frac{1}{2}$ in. and $1\frac{1}{4}$ in. thick respectively, with battens 4 in. by $1\frac{1}{4}$ in. The battens of the top or presser board are hollowed out for the hands.

Ordinary flasks of wood, or iron, or snap flasks are employed. A cherry snap flask is made by the Adams Company, protected with iron on the top edges, grooved inside to hold the sand, with pins of triangular section.

A special Farwell machine is fitted with a turret head for the production of multiple moulds. It is an ordinary moulding press fitted with a head having two portions. On one portion a pattern plate containing a part of a mould is attached. On the other a peining or pegging frame is secured, the object of which, as previously explained, is to consolidate the sand around the edges preparatory to the surface pressing. A flask filled with loose sand is laid on the table over the second portion of the pattern, and the peining frame brought down upon it. The surplus sand is strickled off and a thin layer of facing sand riddled over. Into this the pattern or the patterns on the turret are pressed, so forming a portion of a mould on each face of the sand mould. The first section is placed on the floor, and the others are piled on as made until completed.

Fig. 205, Plate XI, shows a hand machine with non-turn-over table, and hinged presser-head, by the Berkshire Manufacturing Company, of Cleveland, Ohio. The pressure is intensified by toggle levers. The pattern-plate is lifted from the drag, and the cope from the plate simultaneously by the movement of the lever seen below, the guidance taking place through four posts, a pneumatic vibrator put into action by the knee assisting the delivery. The posts are attached to a frame which permits of adjusting their position to suit different pattern plates and boxes. The frame is operated by gears running inside racks ensuring a straight lift, and the frame is also coerced in guides. Canvas guards enclose the vital parts. Copes and drags are rammed on the two sides of a plate, or on different machines.

Tabor Machines.—The Tabor Manufacturing Company, of Philadelphia, make moulding machines to suit the varied classes of work required in foundries, some for stripping plates, some without, some for hand, and others for power ramming. Improvements are effected from time to time in the standard types, besides which special adaptations are constantly being made to suit special classes of work and existing moulding boxes. For these reasons it is not possible to take any one machine and describe it as being a Tabor. It would only be correct to say so respecting certain main elements in the design and some fundamental details. For this reason the firm is unwilling to have these machines described in any other than a general way, lest an idea should be conveyed that the illustration which might be given would represent a hard-and-fast design. We shall therefore only attempt to deal with the broad features which characterize these machines, illustrating one only, the 10-inch power squeezer for light work (Fig. 206, Plate XI).

An observer would notice the vibrating action through which the pattern is loosened from the sand previous to its withdrawal, as being one of the cardinal features of many of the Tabor machines. It does not dispense with other devices, but it renders possible a good deal of work which could not be accomplished by any other means, short of an expensive rig-up of stripping plates. The vibrator is a plunger from $\frac{5}{8}$ in. to 2 in. diameter, according to requirements, which plays to and fro under the action of compressed air at a pressure of about 75 lb. per square inch, brought through a hose and actuated by the attendant pushing a valve. The vibrator moves to and fro several thousand times in a minute, and strikes against hardened anvils at each end of its cylinder. The result is that the pattern is shaken at an extremely rapid rate with a much slighter degree of movement than that which is imparted in ordinary rapping. It is so slight that when a deep pattern is returned into the sand, it has to be rapped again before it can be withdrawn. The result is therefore the same as though an expensive stripping plate were used. In the vibrator frame machines, one vibrator frame is fitted to any single machine, but to that any patterns, large or small, are readily fitted. The frame is an open one, slotted around its inner edges to receive extensions from the pattern placed within the frame. The extensions, being thin, are sometimes attached to gates, and frequently to core prints. In the latter case they are utilized also as vents going to the outside of the mould. Pins or screws connect the extension pieces to the vibrator frame. Some firms keep a standard or jig frame in the pattern shop to facilitate the fitting of any patterns to the vibrator within the capacity of the machine.

The vibrator frame is guided in flasks by three-cornered pins, one at each end. These fit within the pins of the drag, which are also, of course, of triangular form, while triangular guides on the cope fit outside these pins.

We will now observe the operation of the Tabor machine (Fig. 206, Plate XI), and the first thing to note is the absence of the turn-over table which is embodied in numerous machines. This is an advantage in one respect, that unjointed patterns may be employed, which is impracticable on turn-over tables. No special fitting of boxes to plates or tables is required, but the boxes fit to the vibrator frames and to each other. Being able to take any unjointed pattern of wood or metal and fit it within the vibrator frame, Fig. 207, Plate XII, and mould it by turning or rolling it over, is a great point in favour of a machine. It would, of course, weigh more in the case of moulds of which a small number only were wanted than in the case of those where hundreds or thousands were required, because the latter will pay for the jointing of patterns and their careful fitting. Another point in favour of the moulding of unjointed patterns is that it is easier to ensure absence of overlap and fin than when they are jointed, especially when put on separate plates. Even though they match originally, the wear and tear of machines, of pattern, and of stripping plates, when such are used, tends to increasing departure from perfect jointing of moulds.

Having the pattern mounted within the vibrator frame, the sequence of operations is as follows: The joint board is laid upon the table, and the pattern or patterns contained within the vibrator frame are placed on it. The drag or bottom box is laid on, fitting it by its hollow vee-shaped pins over the pins at the ends of the vibrator frame. Sand is shovelled into the box and struck off level, and a bottom board with thick cleats or battens laid on the sand. Above this there is a presser head, hitherto thrown back clear of the work by hinged rods at the sides, but now pulled forward until the presser board

PLATE XIV

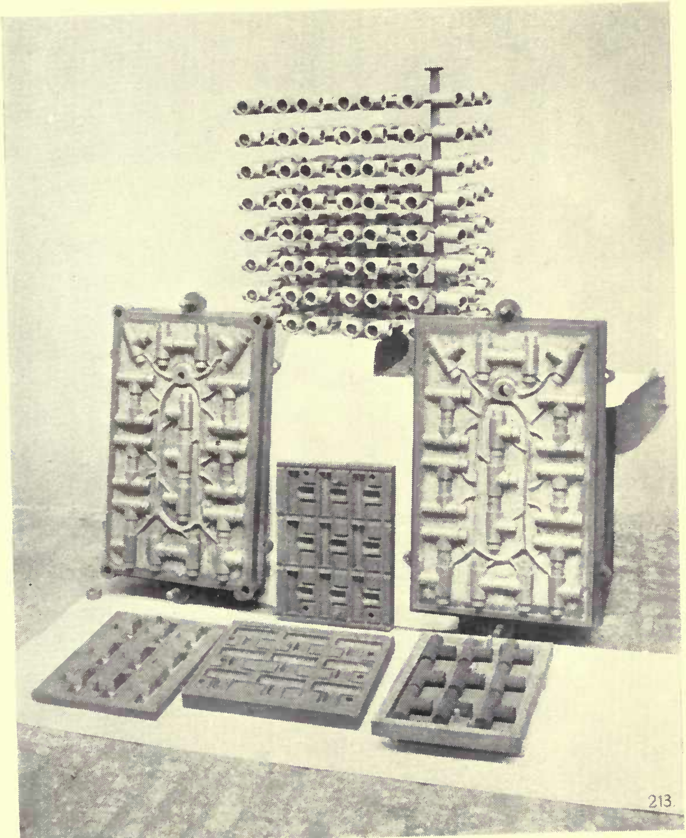

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FIG. 213.—PATTERNS, CORE BOXES, AND MULTIPLE CASTINGS. THE LONDON EMERY WORKS CO.

stands horizontally, in which position it is arrested by stops. There is a three-way cock at the side of the machine by which the attendant admits compressed air at from 60 lb. to 80 lb. pressure, into the inverted cylinder in the base of the machine, forcing the match board, drag, and bottom board up against the presser head once, twice, or thrice, as happens to be most suitable for the work in hand. This completes the first stage.

The ramming head is next thrown backwards, and the drag, with its joint board, turned over, with the vibrator frame between them. The match is then lifted off, leaving the joint face open to receive the top box, which is fitted over the pins of the bottom box. Parting sand is dusted over the face, moulding sand thrown on, a board placed over, the presser head pulled forward, the cock turned, and the mould pressed up against the head. This completes the second stage.

Delivery of the pattern is effected as follows: The cope is first lifted by hand. As it is about to be lifted the attendant pushes a hinged pad in front of the machine with his left knee, which admits air to the vibrator, and during its action he lifts the cope off. To withdraw the patterns from the bottom box the vibrator is started, and the frame is lifted by the handles at the ends.

On first thought we might be disposed to think that one of the chief advantages of a moulding machine, that of a perfectly vertical lift, is sacrificed. The importance of this is greater in the top than in the bottom. But the drag pin is sufficiently long to ensure perfect control of the lift in moulds of medium depth at least, so that unless in work which is obviously suitable for stripper plates the supposed objection does not apply, and in some deep stripper-plate work the vibrator is included with advantage.

Tabor machines are fitted with stripping plates of sheet metal when required, and with the devices termed *stools*. The sheet metal covers the entire surface of the machine, except, of course, where it is cut out round the patterns. The sheet is supported by the pattern plate during ramming, and the stools carry its edges during the withdrawal of the pattern. The stools in this case are loose cylinders of metal which fit in round holes bored through the pattern plate. The surfaces of their upper ends come flush with the surface of the plate, and their lower ends rest on a *stool plate*. This last is supported rigidly by means of brackets from the frame which carries the moulding boxes, so that it has the same upward motion as the boxes, and the upper ends of the stools therefore remain in contact with the sand of the mould until it is lifted from the machine.

Machines made by the Baden Engineering Works of Durlach embrace nearly every type. Some are of small size; others are of very large dimensions; they include numerous designs and systems, embracing hand, hydraulic, and pneumatic operation, turn-over plates, and fixed plates, pulley moulding, and other special machines for pipes, firebars, toothed wheels, etc.

The simplest type of hand machine made is of very plain design. It consists of a table supported on four stiff legs, which bring it to a height suitable for ramming by a man standing upright. The pattern plate is fastened on the table, and the moulding box placed over it, fitting by its pins thereto. The sand is rammed and strickled level, and the box lifted off the pattern truly by a pedal lever arrangement, which lifts a crosshead underneath, when four rods at each corner that pass through the pattern plate push up the box clear of the pins. These machines are made for boxes that range from 12 in. to 24 in. square, and are intended to be used in pairs for top and bottom boxes respectively.

Another single-lift machine without a turn-over plate is designed for boxes of larger dimensions. Instead of the box being lifted off, which could not be readily done because of its weight and size, the pattern is drawn downwards by means of a lever actuated by a screw of quick pitch, the weight of the pattern table being counterbalanced. The box is left supported on four projections on the frame. This machine is suitable for patterns of no great depth. In deep work it is better to lift the pattern upwards out of the sand than to draw it downwards.

Other hand moulding machines by this firm have a turn-over plate fitted, the pattern parts being fastened on opposite sides of it; patterns of plaster, white metal, or other materials being used equally well with those of wood or metal. When preparing these pattern plates for foundries which deal less in repetitive work than in small numbers of castings, the plates are made with a large number of holes which are fitted with corks when not in use. Holes can be selected from these to suit various patterns, and the remainder left with the corks in. The method of fastening is by means of tubes, screws from one half the pattern entering into holes in the tubes in the other half, ensuring the correct placing of the two portions through the intervening plate. The halves of the moulding boxes are placed on opposite sides of the plate, their positions being fixed by two pins which pass through the plate, and stand out on opposite sides, and to which the box lugs are secured by wedges. Or, the pins form a part of the box and pass through the plate. These machines are made for work of medium dimensions, taking boxes ranging from 16 in. by 12 in. to 40 in. by 32 in. The

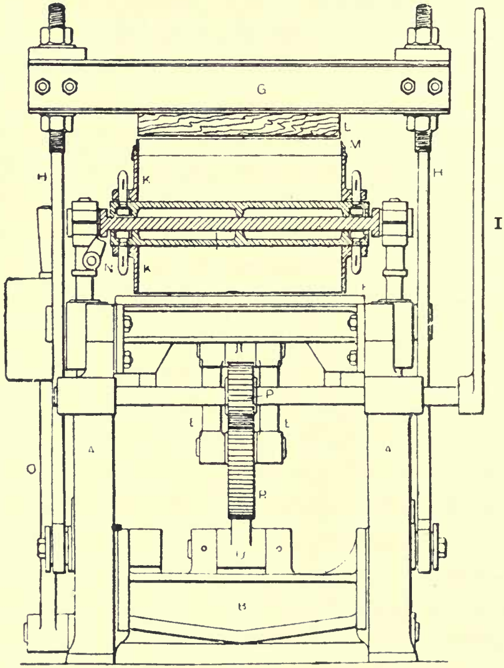


Fig. 208.—Turn-over Table Machine. Front Elevation.

depth of each half-box varies from 10 in. to 12 in., a good depth for machine moulding; but in this case, of course, the pattern plate is lifted from each box part.

In another hand machine of larger dimensions, in which the design of a turn-over table is retained, the moulding box is supported on a carriage running on wheels, and is lifted up to the pattern plate and lowered therefrom by hydraulic power. A piston underneath does the lifting and lowering, and as no great power is required, a hand pump can be used in the absence of a regular hydraulic plant. Boxes of larger dimensions are used on this machine, ranging up to 172 in. by 16 in., with a depth of 12 in.

In other turn-over types of machines, instead of hand-ramming, provision is made for compressing the sand. In one of these toggle levers are employed to permit of the exercise of increased force as the depth of sand increases. This machine is illustrated by the drawings Figs. 208 and 209 in part elevations and sections. Two **A**-shaped frames *A*, *A*, sustain the mechanism. Two cross stretchers *B*, *C* connect the frames. *D*, *E* are the levers which form the toggle—straightening out as the pressure on the mould is increased. They are pivoted in bosses in *C* above, and in *B* below, and are actuated by the hand lever *I* which turns the pinion *P* engaging in the quadrant rack *R* on the lever *D*. The table *F* is thus pressed

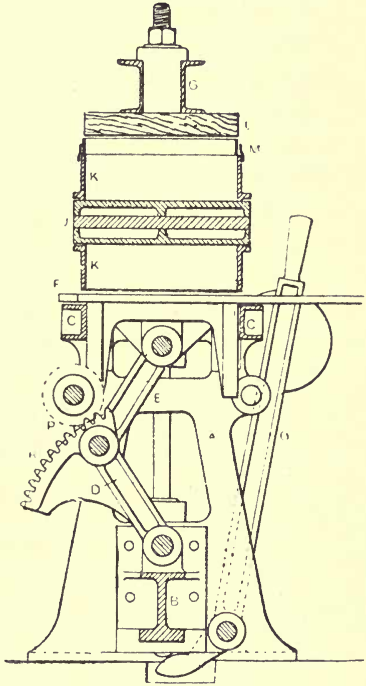


Fig. 209.—Turn-over Table Machine. Vertical Section.

upwards against the moulding boxes *K*, *K*, in opposition to the crosshead *G*, which is connected by rods *H*, *H* to the bottom of the standards. *G* is pivoted by the rods, and can be swung back out of the way to permit of the insertion and removal of boxes.

The turn-over table is seen at *J*, with boxes at *K*, *K*. *J* carries intermediate blocks, the function of which is to receive the pins for the boxes. *L* is the presser board, and *M* a loose frame into which the surplus sand is shovelled, of a thickness about equal to the reduction effected by the compression. The box parts are secured to the table while being turned over by clamps, one of which is seen broken off at *N*. Each half is fitted and compressed separately, turned over, the cottars knocked back, the box part received by the table *F*, and the pattern plate lifted from off it by the counterweighted lever *O*, the crosshead *G* being of course thrown back out of the way. The top and bottom parts of the mould are thus prepared alternately on one machine. The sequence is as follows:

A box part is first fastened on each side of the turn-over plate on which the patterns are set, and the bottom box being first turned upwards, is filled with facing and coarse sands up to the top of the clamping frame *M*, the pressing board *L* is put on, the head *G* brought over it, and the toggle lever *I* pulled. The turn-over plate is next reversed, bringing the box just pressed down on the table, and the other or top box is treated similarly. Then the wedges of the bottom box are knocked back, and the plate lifted and the box drawn forward on the table. The plate is then turned over for another box part.

Besides these there are large numbers of machines that are operated hydraulically, ranging from some of very

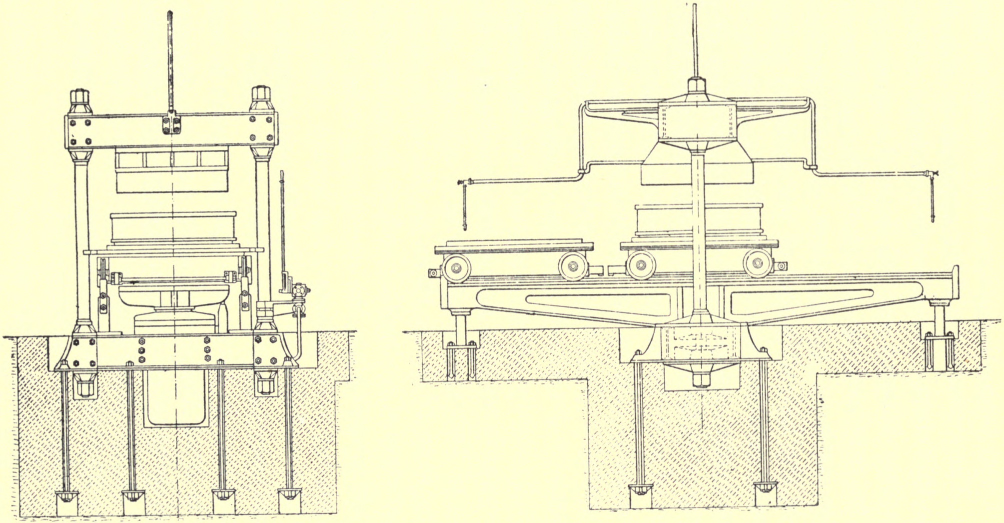


Fig. 210.—Double Hydraulic Machine.

simple type for small castings, and attended by boys, to others of very large dimensions and of more or less complexity. The advantages of the application of hydraulic power to this class of work are indisputable. The standard pressures adopted are 750 lb. to the square inch for moulds for iron castings, and 1,500 lb. for those of steel and other castings. As the sizes of boxes increase, the weight of the box, with that of the enclosed sand, taxes the muscles severely in hand machines, in spite of long levers and counterweighting. The application of power does away with this exertion, and permits of the use of machines of any dimensions adapted to heavy classes of work that could not be economically put on hand-operated machines. The hand machines, with turn-over plates just now described, are also made after the same model for hydraulic power, a piston beneath pressing the moulds upwards between it and the crosshead at the top. Machines of this type range from a capacity for boxes measuring from 16 in. by 12 in. to 172 in. by 16 in.

Another class of hydraulic machine is double, Fig. 210, without a turn-over plate, the object being to have two men working on top and bottom of a mould with a central presser. The moulding tables travel to and from the press. The moulds are prepared on these tables, and brought under the press in turn. The pattern plate is removed downwards from the mould after pressing, leaving the moulding box on two side bars. The largest machines are fitted with a light hydraulic crane, to place the boxes on the closing-up table. In the largest of these types, boxes up to 150 in. by 16 in. are handled.

The Figs. 211, Plate XIII, show a group of machines by the London Emery Works Company, for moulding flat and shallow castings, such as gas, water, or electric light fittings, stove and grate parts. The two machines, seen at the right hand, each comprise a pattern plate, mounted on a hydraulic ram enclosed in a cast iron case to prevent the intrusion of sand and dirt. The rammer head is supported on pivoted links, and is swung back during the filling of the moulding-box with sand, and it can be adjusted to regulate the length of stroke, thus economizing power. The moulding-box is lifted off the pattern by four rods actuated by the lever seen in front. These rods must be flush with the pattern plate in their lowest position, and they can be adjusted to suit the various heights of pattern plates.

It is advantageous to have two machines working together as shown, one making the bottom and the other the top boxes, as the work can then be carried on continuously, otherwise the patterns must be changed, or arranged on the reversible pattern-plate system. If required, the machine can be constructed for extracting deep patterns through a stripping plate. Snap flasks can be used. Should an hydraulic plant be unavailable for any reason, the machine can be worked by hand without any alteration. At the left a hydraulic core machine is shown, completing the installation.

Messrs. Bopp and Reuther, of Mannheim, make a speciality of hydraulic moulding machines of several types, comprising very advanced examples.

A hydraulic machine with turn-over table is shown in vertical section in Fig. 212. The table A swings in trunnions, which are clamped by the handles a, a when the table is set in its horizontal position. The trunnion bearings are in one with the sleeves B, B that slide in the uprights, and the height of which is set by the collars b, b clamped to the pillars. At the commencement of working, an empty half-moulding box is set on the turn-over plate, and the other half on a wagon *C* that runs on rails. The upper box is first filled with sand, and the regulating valve *D* operated, causing the ram to move upwards, pressing the sand in the box up against the presser head *F*. The latter is hinged, to be flung aside during ramming. A pressing frame *G*, to confine the loose sand, is laid over the box, as is usual in such cases. Before taking off the pressure, the two half-boxes are clamped together against the intervening plate, the clamps being shown at *c*, *c*. The regulating valve *D* is now released, allowing the ram to sink gently, and with it the plate *A* with the box parts, until their movement is arrested by the collars *b*, *b*. The plate is now turned over, bringing the rammed box underneath and the unrammed one upwards. The latter is then filled with sand, and pressed as the other was. The clamps are next released and the ram lowered; the descent is arrested by the collars *b*, *b*, and the second box sinks away from the pattern. The process is thus repeated, successive half boxes being rammed on opposite sides of the plate.

It is customary in using these machines to press the pattern into the mould after blackening, as brass-founders do. Various presser heads can be made interchangeable on the arms to suit moulds of different depths. These machines are made in a large range of dimensions. With the hydraulic arrangement very heavy moulds can be handled with great facility.

The question of floor space often arises when the adoption of moulding machines is being considered. Even if the machines themselves do not occupy much room, much space is required for the finished moulds, the sand, and empty moulding boxes. The problem becomes acute in proportion to the rapidity of action of the machine. One solution is the portable machine, p. 295. Another solution is that of multiple moulding. Machines are constructed by which a single half moulding box, after being pressed on both sides carries a mould. The half

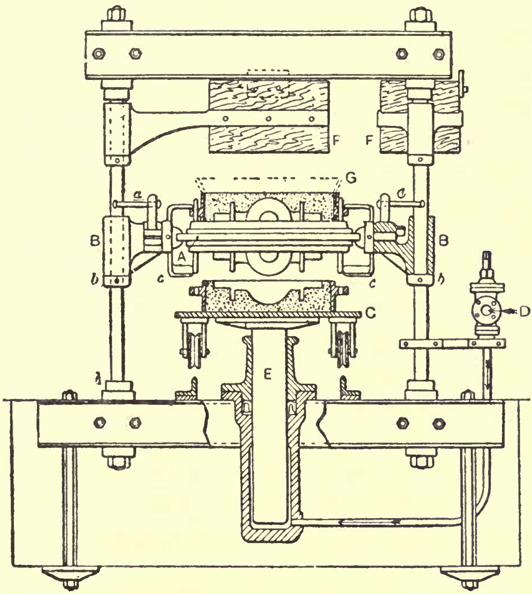


Fig. 212.—Hydraulic Machine with Turn-over Table.

boxes are then stacked on top of each other, a complete mould being formed at each joint, and the entire stack is poured through one gate. By stacking the boxes in this manner the difficulty of floor space is solved, but other important advantages result. Thus, as each half moulding box contains two half moulds, one half box suffices for each complete mould; and on reference to the illustration, Fig. 213, Plate XIV, it is shown that by using nine half boxes eight piles of castings are obtained. As only the upper half box in each stack contains an ingate, a considerable saving of metal is effected. Also, only half the quantity of sand is necessary for each mould. As, using ordinary machines, two half boxes are required for each complete mould, the capacity of the multiple machine is therefore nearly doubled. The illustration shows pattern plates, *core plates*, or boxes, some cores, and a pile of castings as poured. The machines used are practically identical with those shown in Fig. 211, Plate XIII. The moulding box is lifted off the pattern on four pins by the lever in front of the machine. The presser-head, however, which carries underneath one-half the pattern, does not swing back, but is arranged to push back on rollers.

The method of working is as follows: a moulding box is placed on the pattern plate, a sand frame placed on it and filled with sand. The presser-head with pattern plate is then drawn over and the box rammed in the usual manner. A half-mould is thus made on each side of the half box. After pushing the presser-head back, the moulding box is raised off the pattern plate on four pins by a lever in front of the machine. Continuing in this way one box after the other is made and stacked in lots of ten to twelve, the top one being weighted as usual.

A machine designed for multiple moulding, by Messrs. Bopp and Reuther, is shown in Figs. 214, 215, in which two half-moulds are made at one pressing. One half is done in the usual way by a half-pattern *A*, on a plate; the other half is by a frame *B*, which is pressed into the upper half of the moulding box *C*. The relations of the moulds and patterns plate before pressing are shown in

Fig. 214, and after pressing in Fig. 215. The method of operation is as follows:

The box part *C* is carried upon a frame *D*, which is slid by means of sockets upon vertical guides. When set

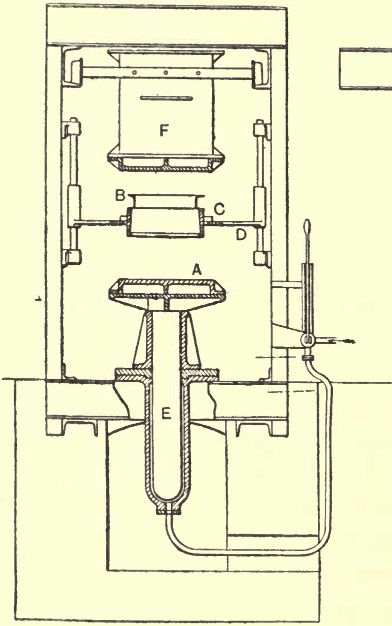


Fig. 214.

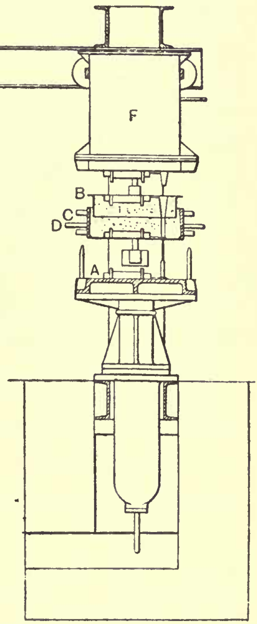


Fig. 215.

Machine for Multiple Moulding.

thus in place, sufficient pressure is put on the ram *E* to bring the pattern and plate *A* into contact with the lower face of the box *C*. The latter is now filled with sand and the frame *B* laid upon it, the latter also being filled with sand. The water is turned on again, pressing the lower half-pattern into the box *C*, and the upper half into the frame *B*, after which the ram is lowered, leaving the mould complete with its ingate. It will be observed that the top half of the pattern is carried on a travelling wagon, which can be run aside when the sand is being shovelled into the boxes. A series of superimposed mould is shown in Fig. 216.

The larger the number of moulding machines of a single type and size used in a foundry, the better chance is there to make economical arrangements in the department. In some English shops, a circus is used for loading and conveying away the boxes. It is an annular table suspended by rods from a central pillar, around which it is turned. In other cases a conveying table runs on rollers. In others, parallel rails are used, down which the boxes are slid away from the machines, and from which they are taken and laid to right and left on the floor. These are adjuncts of the fixed machines. The use of portable machines is growing in the case of light machines. If a large number of power machines can be utilised, then the most elaborately designed plant results in the highest economies, and probably a hydraulic plant is the best on the whole to adopt. When many machines are fixed in a large system, the question of handling the sand and moulds offers far less difficulty than in the case of a few machines only. Not only does it pay to make mechanical provision for taking away the finished moulds, but adequate arrangements can be made for conveying the sand and empty boxes to the machines. In a perfect

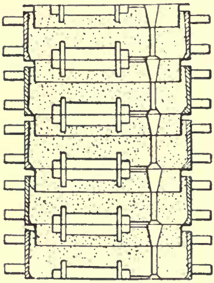


FIG. 216.—MULTIPLE MOULDS.

system such as this, the men never leave the machines, but the making of a mould is the work of several, beginning with the sand room, and ending at the metal pourer. Each machine operator receives his sand ready mixed, and boxes, rams the whole, or probably only half a mould, which is conveyed away to be cored by others, closed by others, and poured by another set of men.

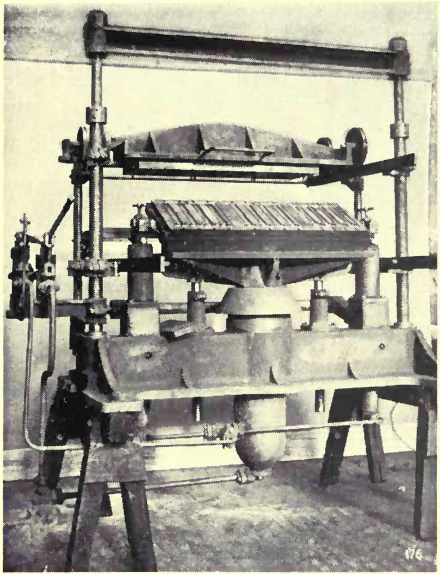
And further, in this entirely mechanical system, which is carried on with nearly military precision, other machines besides those used directly in moulding attain an importance beyond that which they possess in the general jobbing shop where a heterogeneous class of work is done. Coremaking machines are moulding machines of a special class, and the use of these is extending. The fettling department is affected, for machine-moulded castings are, or should be, cleaner, more free from lumps and fins than hand-made ones, and the tumbling barrel and emery wheels are able to deal with these in quantity.

Core Making.—The making of cores by machines inevitably follows the preparation of the moulds, or otherwise the coremakers could not keep pace with the output of the machines. For many years cores of circular and polygonal sections have been made by machines provided with pistons which push the cores out of the boxes endwise, but these now constitute only a small section of the work done in coremaking machines. The largest of these, of which Fig. 217, Plate XV, is a typical example, resemble the hydraulic moulding machines, the difference consisting chiefly in the substitution of core-plates for the pattern-plates. In these cases the edges of the *core-plates*, or core-boxes strictly, are chamfered to cut away the sand and prevent it getting in the joints.

This is shown very well in Figs. 218, 219, Plate XV, in which the plates are seen above and the cores moulded from them below. The output of Fig. 218, in which the core-plates measure 16 in. by 12 in., is 48 cores per hour when made on a hand machine. The output of Fig. 219 with core-plates of the same size and using a hydraulic machine is 72 cores per hour with one man. Fig. 220 is an example of a coremaking machine of another kind, in which the halves are withdrawn laterally by means of a right- and left-hand screw.

Withdrawal of Patterns.—Not the least interesting section of machine moulding, from the operative moulder's point of view, are the mechanical details of pattern moulding. In ordinary work we may say broadly that the pattern is either lifted from the mould, or the mould is lifted off those portions of the pattern which come in the top; and the pattern is self-contained—that is, it is not attached to or cast with any kind of plate. In machine moulding both lifts are common, either the pattern or the mould being lifted. But besides these, the pattern is just as often drawn downwards, leaving the mould above it; or the mould is drawn downwards, leaving the pattern above. Neither of these two last would be practicable in hand moulding, as they are in a machine where vertical movements are rigidly controlled; and their practicability widens the range of usefulness of the moulding machine. Either device has advantages over the other in certain classes of work. In the case of shallow patterns it makes no difference whether the box or pattern is lifted off the pattern, or the pattern drawn down from the box. In deep work it is better to lift the pattern and plate off the mould, or to lower the box away from the pattern. In either of the

PLATE XV



See p. 319

Fig. 217.—Core-making Machine. The London Emery Works Co.

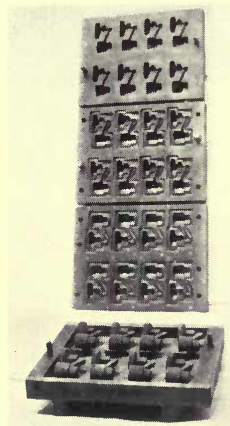


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Fig. 218.—A Pair of Core Plates. The London Emery Works Co.

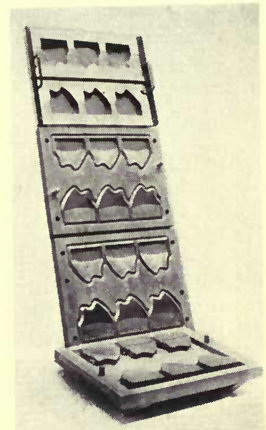

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Fig. 219.—A Pair of Core Plates. The London Emery Works Co.

latter plans stripping plates must often be used to prevent the sand from breaking down.

Machine moulding has developed into a highly-organized system where machines and methods are correlated and interdependent. It has effected a revolution in some shops in costs, in labour, in many of the details of pattern work, and what it has accomplished in the few will be

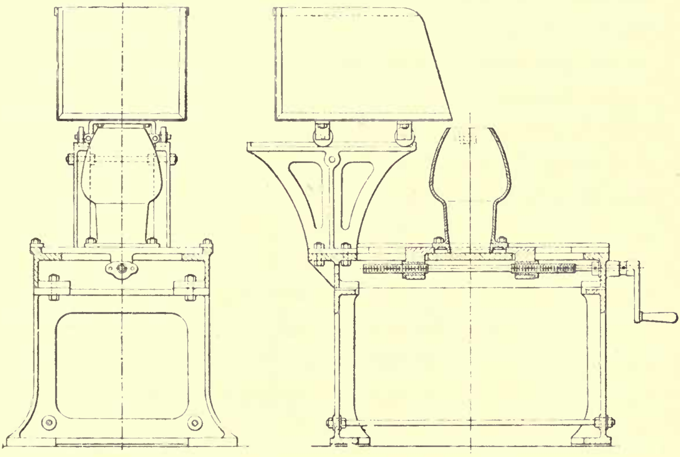


Fig. 220.—Core-making Machine, with Sand Bin.

done in many ere long. It must be so as competition becomes more severe. Already work is done by machines that would have been deemed impossible half-a-score of years since, and it would be unwise in the light of that advance and the promise of the future to attempt to set any limits to the capabilities of moulding machines, and the systems of which they form a part.

Boxes.—It may be taken as a fact that many moulding boxes in the near future will be designed specially for one class of work only. To some extent this holds good now, just as it does in the case of large numbers of machine tools which are only seen in the shops in which they have been designed, if not built. Pulley moulding machines are a familiar example of special machines; so are car or railway-wagon wheel moulding machines, and machines for moulding firebars, others for radiator pipes, and for the vertical parts of radiators. In these, stripping plates are used, and power pressing, notwithstanding that the bars and ribs are deep, and the spaces both between bars and ribs are very narrow. The numbers required off pay for the cost of fitting up stripper plates and presser heads, and though the work is massive, the application of hydraulic power robs it of all excessive labour. Pipes are moulded by these up to 6 ft. in length, and firebars up to 60 in., and several firebars are moulded at once.

Mechanical Pressing.—It has been made clear that mechanical pressing cannot in all cases properly supersede the necessity for hand ramming. It is claimed for presser heads that the moulds are all pressed uniformly, and that therefore castings will all come out alike. But uniform pressing is just what is not desirable in many moulds, because uniformity of pressure over the area of the head does not mean the same thing at different depths of irregular moulds. Besides which, it is well known that some portions of many moulds must be rammed harder than others. In proof of these facts, which are obvious to moulders, many of the most successful machines in use now are made for hand ramming. Power ramming has its place in foundries, but its utilities are limited to certain classes of work, or to work for which suitable dummy presses are cut. Many devices have been patented to facilitate the ramming by power of deep patterns and irregularly shaped contours. They emphasise the fact that power ramming, except in plain, rather flat work, is not successful, apart from the assistance derived from suitable devices.

Jar-Ramming Machines.—The chief utilities of these machines (the latest type) lie in the ramming of deep moulds. They are not suitable for shallow ones unless an excess of sand is used. Depth is necessary to ensure consolidation of the sand, which is increased by the jarring from twenty-five to thirty per cent. The sand is denser at the bottom than at the top. The upper stratum is usually lightly rammed by hand after the jarring. A sand frame has to be used to confine the extra sand required for consolidation. No venting is required. The economies are enormous. The actual jarring does not occupy more than half a minute. A flask can be placed on the machine, jar-rammed, and removed in two minutes. A similar mould of moderate size if hand rammed would occupy from twenty minutes to half an hour. There is a vast future for these machines though they are little known at present.

Figs. 221 and 222, Plate XVI, illustrate the Hermann jar-ramming machine constructed by the Pneumatic Engineering Appliances Company, Limited, of Westminster, S.W. This is built both for stripping-plate work and for turn-over moulding, the latter being an arrangement which is removable, and not shown in the photograph. The parts of the jarring mechanism are enclosed in the cylinder seen at the base of the machine, to which air is admitted through a valve to effect the jarring. The mould is raised off the pattern by the pneumatic cylinders at the end, and the separation of pattern and mould can be effected either upwards or downwards as desired. A special feature of the machine is the oil-governing arrangement in which the cylinders for raising and lowering the pattern table and moulding box are governed perfectly, so preventing injurious shock. The oil tank is seen at the front in Fig. 222. The machine is set to strike about 120 blows a minute, and twenty-five to fifty jars are sufficient to set the sand in an ordinary mould.

The action of the jarring machine may be understood by regarding it as composed of two essential elements, the jarring table which carries the pattern and mould, and the anvil. The table is lifted and dropped repeatedly and rapidly on the anvil. But in order to lessen the resulting shock the latter is cushioned, and is often also made to lift to meet the falling table. In the delicate relative adjustments of these two movements the efficiency of the machine lies. Hence, though the action of the jarring machine is simple, the details have to be worked out with care, because the jar or shock which is the efficient agent in the consolidation of the sand is also, if too severe, destructive to the machine, the flasks, the sand of the mould, and even to structures in the immediate vicinity.

The weight of the table, the flask, pattern, and sand, is lifted to a height which varies from say 2 in. to 3 in. on an average, and is then dropped on the anvil, the action being repeated perhaps thirty or forty times within the space of half a minute. The early blows are more efficient than the later, and longer drops also are more so than shallow ones. But the deeper the drop and the more prolonged the action, the more severe are the effects on the mechanism of the mould. Destructive effects can only be avoided by a very solid construction, and by the recognition of certain facts which are concerned with the impact of falling bodies. Fracture of the sand will also occur in any case if there is imperfect fitting of patterns, flasks, or mechanism, which would cause slight relative movements to take place.

By the laws of impact the heavier the anvil the better, so that an anvil bedded on rock would be the ideal one. But a rock bottom would be bad from another point of view. It would transmit the ground waves set up by the machine to a long distance, with disagreeable if not destructive effects to neighbouring walls, floors, and buildings. And a very heavy cast iron anvil would increase the cost of the machine unduly. The practice therefore is to make the anvil of about the same weight as the jarring table when loaded with its pattern, flask, and sand, and to bed it on a timber cribbing. An anvil cushioned in this way will, when struck by a table of its own weight suddenly acquire one half the velocity of the table at the instant of impact, after which both table and anvil will be brought to rest by the yielding resistance of the timber foundation. The loaded table thus loses only one half the velocity it would lose by falling on an anvil of infinite weight, as a rock foundation, and the ramming effect is one quarter as much, being measured by the square of the change in velocity.

Compressed air is used for the operation of these machines, its supply being controlled by a valve which is put into and out of action by a lever, but the action of which is continuous and automatic as long as the lever is retained in a certain position. There are two general methods of operation in use. In one the air which lifts the jarring table is exhausted into the atmosphere during the falling stroke. In the other it passes into the anvil cylinder and assists in raising the latter to meet the falling table, the rest of the work being affected by compressed springs under the anvil. When the air is not exhausted thus, the springs do all the work of lifting. The idea is to cause the momentum of the rising anvil to be approximately equal to that of the falling table at the instant of impact, and so produce a maximum of jarring effect on the sand without injurious shock on the foundations, on the sand, or the mould fittings. By this action the tendency of the table to spring away from the anvil after impact is met and neutralized, since the rising anvil remains in contact with it, and one of the causes which would tend to produce damaged moulds is eliminated.

Specialization in the foundry.—We are coming into a time in which the work of the foundry is likely to undergo radical changes, not only with respect to the employment of moulding machines, but of the system of which they form an important section—though but a section after all. For, though the installation of a machine or machines in a shop is, in the first place, usually done with the idea of helping the jobbing work, or that which is but slightly repetitive, dissatisfaction with all the methods in vogue usually results, as the latent possibilities of the innovation in moulding becomes apparent.

The introduction of any moulding machines, therefore, however simple in design, and few in numbers only, is often the beginning of a wider system, of which this particular machine forms but a single detail. Though the advantages which it confers over the unassisted work of the floor or bench are great, its ultimate tendency is to lead to economies in all the work that leads up to the machine, and in that which follows. The desire to specialize grows as the economies of one particular section of specialization becomes apparent. It tends to introduce, and must with some machines introduce, new types of moulding boxes, new methods of mixing and conveying sand, of grading iron, of making cores. The labour problem has to be wholly readjusted, while questions come up for solution that never troubled old-time moulders—such as the installation of power (steam, hydraulic, or pneumatic) in the foundry.

Perhaps the keynote in the problems which are raised is to be sought in the word "specialization." Firms who are able to specialize sufficiently, can choose almost any system and moulding plant, and make a success of it. Those who have grown accustomed to one system are naturally prejudiced in its favour, and it is hard for outsiders to say whether it is worse or better than any other for particular shops. Generally, one would like to believe that firms can be trusted to know their own business requirements better than any others can know them. Yet this is not always true, because outsiders in walking through shops see, almost as if by intuition, things which might be improved; though long habit in the case of those who have grown with the system has developed a kind of permanent set, or, to use another simile, a colour blindness, which is prejudicial to clear insight and reform.

An instance of what we mean by extreme specialization is this:

In the machine-made moulds in the ordinary work of the foundry, the box parts are put together either by hand or by the crane, in both cases the controlling power being exercised by the hands of the men. There is not very much involved in this, it is true, but it does sometimes happen that a cope will be damaged by not being lowered quite horizontally, or hitching of the pins in the holes occurs, or because the movement is jerky. And when intricate cores are being inserted, these may become pushed aside, or crushed in the act of closing the mould. Now a machine is made by which the top is lowered on the bottom box, perfectly plumb, and it thus fulfils the same function in the accurate closing of the mould that the moulding machine does in a square lift of the pattern. It stands on a circular base, carrying the table on which the bottom box is laid. Two uprights stand up from the table, and carry centring pins that pass from bottom to top. The top box being supported by hydraulic pressure, the removal of the latter allows the box to descend, along with a supporting crosspiece moving in guides underneath the table. Or, worm gear is substituted for hydraulic power. The capacity of these machines ranges from boxes of 24, 36, and 48 in. in length. These are limited by the distances between the uprights, but there is no limit to any width, within reason.

CHAPTER XV

MACHINE MOULDED GEARS

Gear wheel moulding machines, though extensively used, are not found in all shops, so that there are still many moulders and pattern makers who have had no experience whatever of them. There are six or seven different types. The machine of Messrs. Buckley and Taylor, of Oldham, is selected for illustration in this volume. Before discussing the actual moulding of wheels, the construction of the main framework of the machine may be described.

The illustrations, Figs. 223 and 224, represent a *table machine*, that is, one in which the moulding flasks are set and rammed on a table. In the *floor machines* the lower portion of the work is rammed in the foundry floor, and a top box is employed to form the cope mould only. The first machines are used for wheels of small and of moderate dimensions, the second for those of large diameter. The table machines are entirely self-contained, but all the upper portions of the floor machines are portable, that is, the essential dividing apparatus and carrier arms are, when required for use, set down over a central pillar or base sunk permanently and levelled in the foundry floor. The machine of Messrs. Buckley and Taylor is made capable of employment in each capacity, the upper portion being removable, and the base, with the dividing apparatus, being adapted to fit into a massive bed in the floor, while a radial arm, made to slide in vee'd guides screwed upon the bed, is substituted

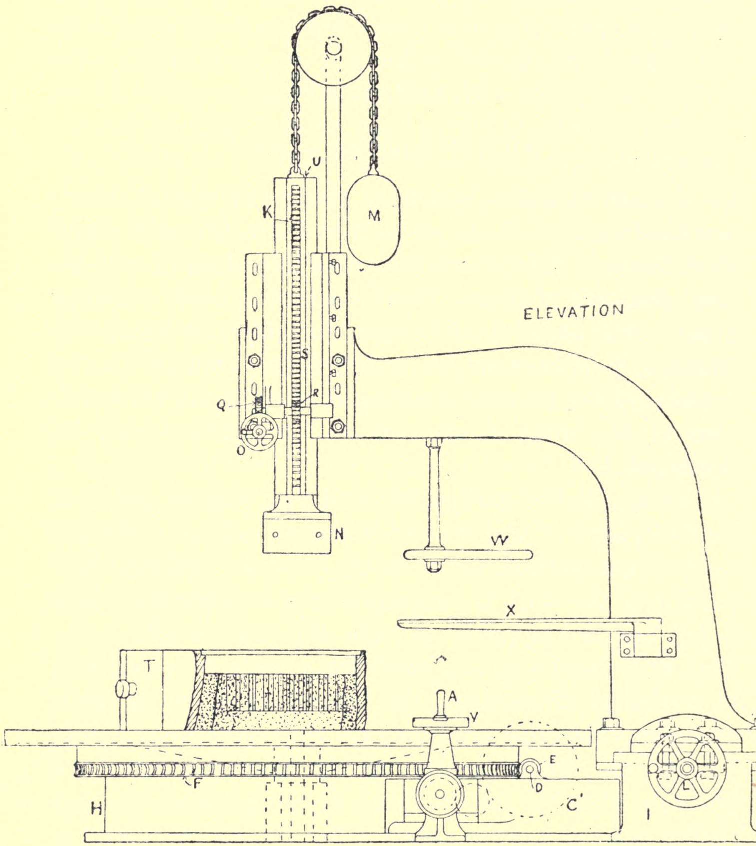


FIG. 223.—WHEEL MOULDING MACHINE.

for the arched arm. This radial arm carries at one end the vertical slides for the tooth block, and the radius of the wheel to be moulded is only limited by the length of the arm. Wheels up to 25 ft. are moulded in the floor machine.

Figs. 223, 224, are an elevation and plan respectively of

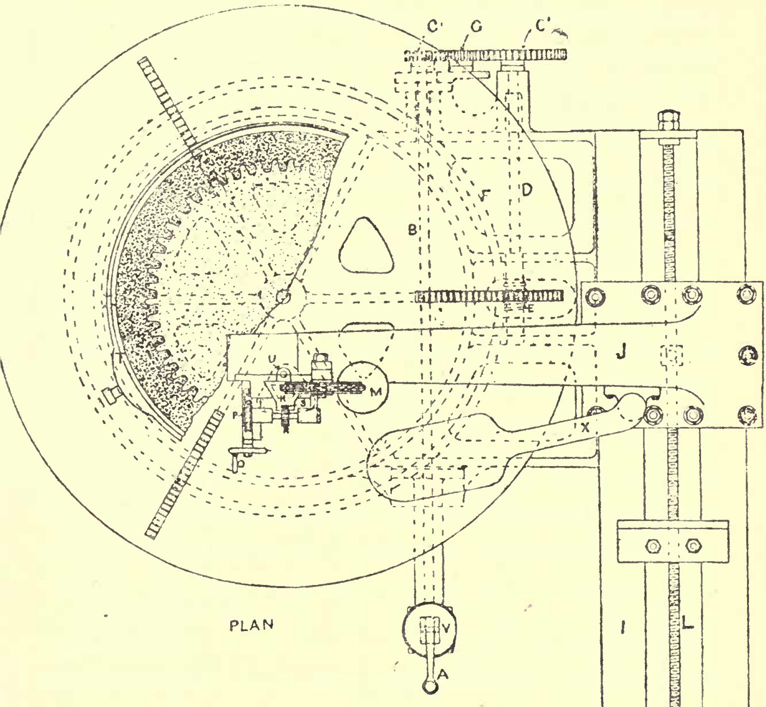


Fig. 224.—Wheel Moulding Machine.

the machine. In these, *H* is a strong foundation against which the bed *I* is bolted. The table fits by means of a turned pin into the boss of the foundation plate *H*. This table carries the moulding flask *T*, on which is shown a sectional portion of a spur wheel mould, and is revolved by means of the dividing wheel *F*, and tangent screw *E*. The bed *I* carries the arched arm *J*, at the extremity of which moves the vertical slide *K*, to which the tooth block is bolted.

The essential mechanism by which the dividing out of the wheel teeth is effected is as follows. The dividing wheel *F* is attached to the under side of the table. Into this gears the tangent screw *E*. This is actuated by the handle *A* turning around on a notched division plate *V*. The short hollow pillar beneath encloses a pair of small mitre wheels, through which the motion of the handle *A* is communicated to the shaft *B*, at the opposite end of which the first change wheel *C* is placed. This gears through the idle wheel *G* with the change wheel *C′* upon the tangent screw shaft *D*. Any gears of the set usually supplied with these machines are interchangeable at *C*, *C′* and *G*, a slotted quadrant plate, together with the idle gear *G* furnishing the means of adjustment for centres. Of course the idle wheel counts for nothing in the calculation of the train.

Suppose the tooth block to have been set at the correct radius for any given wheel to be moulded, by the sliding along and clamping of the arm *J*, on the bed *I*. It is evident that a single turn of the single threaded worm *E* will pass the dividing wheel *F* a distance equal to one tooth. Hence, having wheels of equal diameter at *C* and *C′*, and giving one turn to the handle *A*, a wheel would be moulded on the table having precisely the same number of teeth as the dividing wheel. But by employing unequal change gears to connect the handle shaft *B*, and the worm shaft *D*, and by doubling or trebling or quadrupling the number of turns of the handle, or by giving to the handle some definite fractional portion of a turn only, we have, as in the screw-cutting lathe, a means for establishing almost any number of proportional relationships between the number of teeth in the dividing wheel *F* and the wheel to be moulded. Hence the rule, "As the number of teeth in the dividing wheel is to the number of teeth in the wheel required to be moulded, so is the number of teeth in the wheel on the handle shaft to the number of teeth in the wheel required on the worm shaft."

Thus: suppose a wheel of 100 teeth has to be moulded. The dividing wheel *F* has usually 180 teeth. Put, say, a 90 toothed wheel on the handle shaft. Then:—180 : 100 : 90 :: 50. A wheel of 50 teeth would therefore be placed on the worm shaft *D*, and *one* turn given to the handle shaft *B*. But supposing we have not got a wheel of 50 teeth, we can multiply 50 by 2 = 100, and put a wheel of 100 teeth on the worm shaft. But then we must give *two* turns to the handle. For in any case, if we multiply the quotient which gives the number of teeth on a change wheel on the worm shaft, we must also multiply the number of turns of handle, or if we halve the number of teeth, we must halve the number of turns given to the handle.

If we are doubtful of the wheels, they may be *proved* thus. Divide the number of teeth in the wheel on the handle shaft by the number of teeth in the wheel on the worm shaft, multiply the quotient by the number of turns given to the handle. The product will be equal to the quotient of the number of teeth in the dividing wheel divided by the number of teeth in the wheel to be moulded. Thus in our first example:—

$$\frac{\text{Handle shaft} \quad . \quad . \quad . \quad 90}{\text{Worm shaft} \quad . \quad . \quad . \quad . \quad 50} = 1{\cdot}8 \times 1 \text{ turn} = 1{\cdot}8$$

$$\frac{\text{Dividing wheel} \quad . \quad . \quad . \quad 180}{\text{Wheel to be moulded} \quad 100} = 1{\cdot}8$$

The mechanism for actuating the *tooth block* is as follows:—The *radius* of the block is adjusted by means of the arched arm *J*, which travels upon the bed *I*, to or from the centre of the table. This is adjusted with the screw *L*, and clamped by the pinching screws in its foot in its required position, remaining immovable during the whole period of the ramming of the wheel teeth. The vertical slide *K* is carried in vee'd guides, which have provision for taking up wear. It is actuated by the small hand wheel *O* turning the worm *P*, which revolves the worm wheel *Q*, upon the spindle of which is the spur pinion *R*, gearing with the rack *S* attached to the vertical slide *K*. The slide is counterbalanced by the weight *M*. The vertical movement of the slide is checked at the proper position by means of the adjustable stop *U*, so that there is no risk of the tooth block being thrust down too hard upon the sand bed. The lower portion of the slide receives the carrier *N* to which the tooth block is attached.

The essential portions of the machine are therefore the firm base *H*, the revolving table carrying the flask, *T*, with the dividing apparatus, the arm *J* moving radially in reference to the table, and the provisions for the vertical movement of the tooth block. The tables *W*, *X*, are simply convenient attachments for the reception of the moulder's small tools. We are now in a position to take up the details of the actual moulding of toothed wheels.

Spur gears.—These are moulded very simply. The teeth are formed with a block, and the arms by means of cores. The block, Fig. 225, in this case, has two teeth only, and the inter-tooth space alone is used in the formation of the mould. Three teeth, Fig. 226, or four are often used on the block. A bed is first struck, Fig. 227, with a board attached to the striking bar *A*, the depth *B* being equal to the depth of the face of the wheel, the bottom edge *C* striking the bed, the top edge *D* the top or joint face.

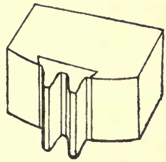


Fig. 225.—Tooth Block.

The striking bar *A* in Fig. 227 is turned to fit into the bored hole in the centre boss of the table in Figs. 223,

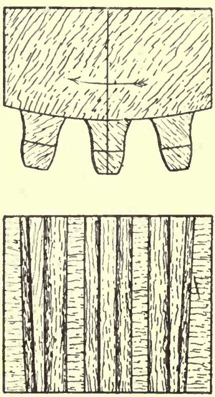


Fig. 226.—Tooth Block.

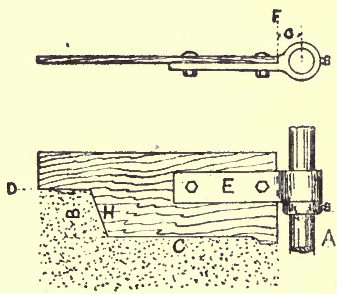


Fig. 227.—Striking Board.

224. The *strap E* is bored to fit over this bar, and its shoulder *F* is cut to a definite distance from the centre of the bar, so that the radius of any striking board is less than the radius of the wheel by the distance *G*.

The central bar or post *A* is removable at pleasure. Its purpose is, first, the carrying of the strap or bracket *E*, and second, it is the part from which the radius of the tooth block is measured.

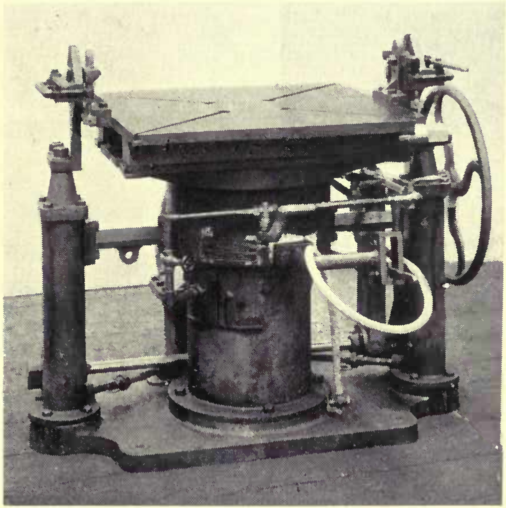
The vents from the bed are carried down to a coke bed if the wheel is moulded in the floor, to the bottom of a flask, if in a flask. The tooth block is screwed to the carrier, set to the correct radius, either by means of a strip or gauge cut to reach the precise distance from the post of the machine to some portion of the block,—either root or point, and the machine is clamped to preserve that distance constant. The length of the gauge will be equal to the radius of the root or point, as the

FIG. 228.—RADIUS GAUGE.

case may be, minus the radius of the post. Or a gauge, Fig. 228, may be cut to fit partly round the post *A* in Fig. 227, and the radius be marked upon that to root or point. The radius once obtained, and the arm clamped, the gauge strip is no longer required. The block is lowered until its lower face bears upon the sand bed, and then the stop *U*, Fig. 224, is clamped, and all is in readiness for the ramming of the teeth.

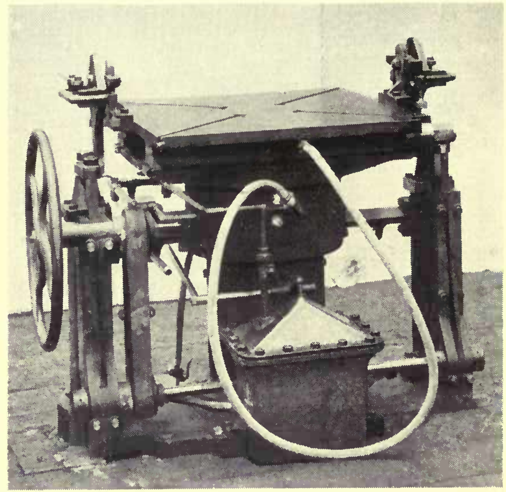
It will be noticed that the end *H* of the board in Fig. 227 is bevelled. This is not always done, but it is a good plan, as is apparent by the sectional view in Fig. 229, where the tooth block is seen in its exact relationship to the circular wall of sand *A*, within which it is rammed up. Space is left between the points of the teeth, and the outer roughly-struck wall of sand, in order

PLATE XVI



See p. 323

FIG. 221.—THE HERMANN JAR RAMMING MACHINE. THE PNEUMATIC ENGINEERING APPLIANCES CO., LTD.



[*Facing p.* 336

FIG. 222.—THE HERMANN JAR RAMMING MACHINE (REAR VIEW)

to give a narrow zone for ramming facing and strong sands into, and the wall is made sloping, because it is easier to sweep up than a perpendicular wall, from which the sand would tumble down.

Facing sand is thrown into the space between the wall *A* and the teeth, and strengthened with nails (dotted). The sand is rammed between the teeth with a small pegging rammer, being, for these small teeth, only a rod of round iron flattened and narrowed at one end. When the inter-tooth space is filled, the sand is levelled over with a flat rammer, scraped and sleeked with the trowel, and vented diagonally, the vents *B* passing into a main vent *C*, either going down to a coke bed, or coming out in the joint of the flask. Only the inter-tooth space gives the tooth shape, and one tooth space or more may be rammed at a time (see Figs. 225, 226). The hinder part and the ends of the block are slightly rapped with the hammer previous to the withdrawal of the teeth; but there is no rapping in the sense in which it is employed with ordinary patterns. The pattern is simply started, and the block lifted without any sensible lateral play. There is, or should be, no taper in the tooth space, and the sand would therefore become torn up on the withdrawal of the block but for the fact that it is held down by a stripper bit cut to the shape of the inter-tooth space, upon which the moulder presses the two forefingers of his left hand, while elevating the slide with his right.

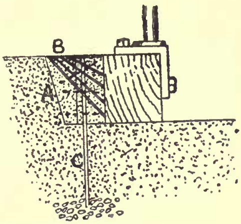


Fig. 229.—Ramming of Tooth Block.

Having lifted the block clear of the mould, the requisite number of turns is given to the handle shaft, and the block thereby carried round a distance equal to the pitch. The slide is then lowered, bringing the block into a suitable position for ramming the succeeding tooth or teeth, the process for each tooth being simply a repetition of the first. In order that the outside faces of the teeth on being lowered shall not scrape or push aside the sand already rammed, taper is given to those faces, as shown in Fig. 226, so that the outer edges of the block do not come into actual contact with the sand at all, or at least, only when finally in place, the top edge may just coincide. Also, to prevent the sand from tumbling down on the side

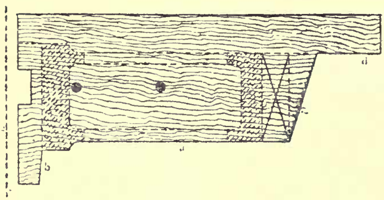


Fig. 230.

Section of Wheel Marked on Board.

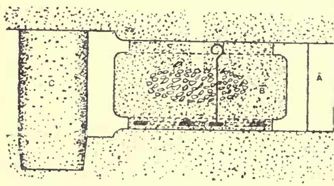


Fig. 231.

Section through Mould.

opposite to that which is already rammed, a block of wood is laid against the tooth block to sustain the sand in that direction during ramming.

Striking boards also are desirable, though not always necessary in the case of perfectly plain wheels. But it is better to use them even for these. A plain wheel can be made by ramming the teeth round on a level bed, inserting the arm cores, and covering with a plain top. But if a board like Fig. 227 is used, it forms a wall of sand within which the facing sand used for surrounding the wheel teeth is rammed, and it gives the exact depth also of the wheel, and the face upon which the top is to be laid. Such a board is made parallel, so that a spirit level is tried upon the top edge, without which precaution the board may become tilted a little, and strike a bed that is slightly dished. The edges are chamfered like those of a loam board. A careful man will mark the section of wheel rim and boss upon the board, Fig. 230, and cross hatch it as a guide to the moulder. Sometimes a narrow strip is tacked on the board at the exact radius of the points of the wheel teeth, instead of indicating the teeth

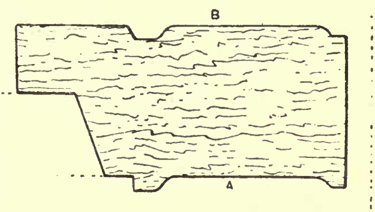


Fig. 232.

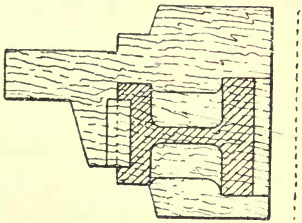


Fig. 233.

Boards for Striking Half Shroudings.

with crossing lines, as in Fig. 230. Fig. 231 shows the mould in section.

Half shroudings furnish the commonest cases in which the use of a plain top is not possible. Made in the manner first mentioned, by ramming the top on a reverse mould, Fig. 232 shows the striking board used, the edge *A* being for the bottom and the edge *B* for the top, both edges also including the bosses, the position of the board being of course reversed for the separate operations. Usually one piece of board serves thus for both the opposite edges, being cut to the shapes required; but sometimes separate boards are made. The edge *B* is used first, striking a reverse top on which the actual top mould is rammed. Afterwards the sand is dug out and the edge *A* is used, striking the wheel face to the proper depth below the top face. The advantage of this method is that the top and bottom are bound to be concentric, the former having been rammed in the actual place which it will again occupy after the ramming of the teeth and the coring up are done. In the other method the edge which strikes the top is like that one which strikes the bottom, and the fitting of the boxes ensures the top

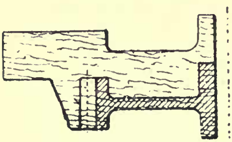


FIG. 234.—BOARD FOR PLATED WHEEL.

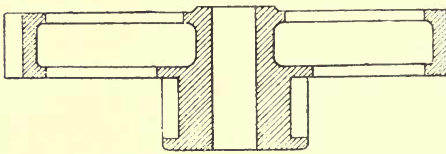


FIG. 235.—WHEELS CAST TOGETHER.

and bottom being concentric. Or a check is used, as in loam work.

Fig. 233 shows a board used for striking a top mould directly, the shape of the half-shrouded wheel being marked upon it. The correspondencies are clear. The interior is formed with cores, for which prints are provided. Fig. 234 is a board for a plated wheel in which the recessing is swept in the mould. Generally, when a wheel is plated, the plate and interior of the rim are formed by annular cores made in an annular box.

When wheels have to be cast together, as in Fig. 235, or in other combinations, they can be bedded in the floor, making suitable joints for shroudings, and moulding the pinion first. Or they can be prepared in two separate boxes, which will have to be centred properly.

When facings are cast on the rim, or on the arms of wheels moulded from tooth blocks, they are set in place singly by measurement—work that can be done by centre

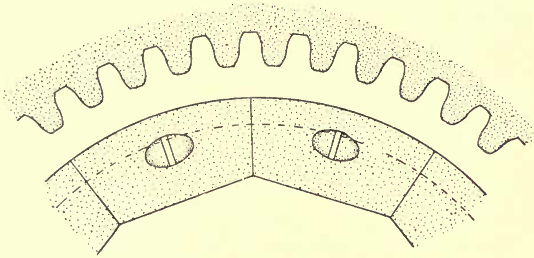


FIG. 236.—LARGE BORE FORMED WITH SEGMENTAL CORES.

and circular lines set out on the plain bed. The pattern-maker is usually called upon to do this. When such pieces come in the top, there is an advantage in laying

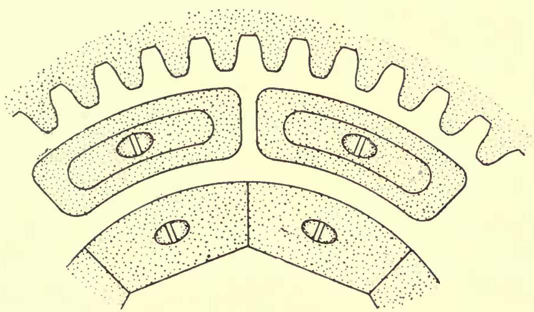


FIG. 237.—LARGE BORE AND ARMS FORMED WITH SEGMENTAL CORES.

them on a reverse mould and ramming the top over them.

The tooth block moulds a ring of teeth only, and the interiors of the wheels have to be formed with cores.

These are made from boxes, and are covered with a top, plain or otherwise, with boss facings bedded in top and bottom. Usually the **H**-section arm is employed for wheels made by machine, because it is easier of formation in cores than any other shape; but any shape can

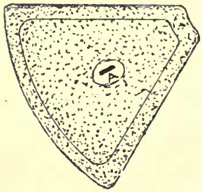


FIG. 238.—ARM CORE.

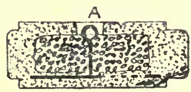


FIG. 239.—SECTION OF CORE.

be made if required. In patterns the ⊥ type of arm is easiest to make.

Arms.—The cores for *arms* are made in dried sand, and set in place without prints, by measurement alone.

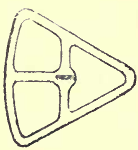


FIG. 240.—GRID FOR ARM CORE.

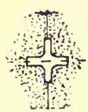


FIG. 241. ABUTTING CORES.

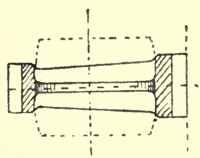


FIG. 242. DISHED ARM.

The arms of spur wheels are usually **H** shaped in section, partly because of their superior strength, but chiefly, as stated, because they are rather easier to make than arms of **+** section or ⊥ section. If a ring of teeth only is required the interior is formed with segmental cores, as in Fig. 236. Or if the bore is large and the arms short, with two sets of cores as in Fig. 237.

A core for **H** section arms is seen in plan, Fig. 238, a section in Fig. 239, and its grid in Fig. 240, and the core also in Fig. 231. The core is rammed upon the grid, the central part being composed of cinders, the main vent

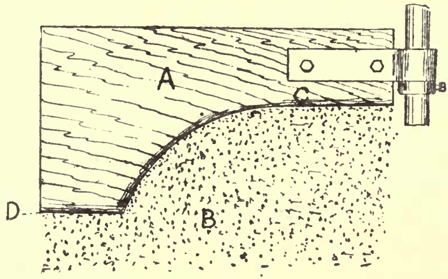


Fig. 243.—Board for Reverse Mould.

being brought off at the top, *A*, into which all the smaller diagonal vents are carried, as well as the vents from the cinders.

Wheels having arms of **+** or **⊥** shape can be also

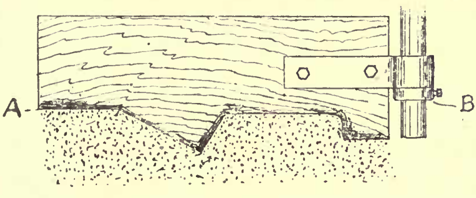


Fig. 244.—Board for Striking Bed.

made in cores, but the difficulty is that these cores have to abut and joint against each other, while with the **H** form they are kept asunder by an amount equal to the thickness of the vertical arm. The joints must abut when the edges of the arm are convex, Fig. 241; also, while the top and bottom faces of the cores for H arms always lie in the same plane as the faces of the wheel teeth, those of the other sections usually do not. A special bed and cope then have to be struck, and cores shaped to correspond, Fig. 242.

Bevel gears.—Fig. 243 shows the method of making a reverse mould for a *bevel wheel*, where *A* is the board, swept round over a hard-rammed bed of sand, *B*. The edge *C* coincides with the top edges of the arms, and therefore with the top face of the cores of the bevel wheel, and *D* is the joint face dividing the cope from

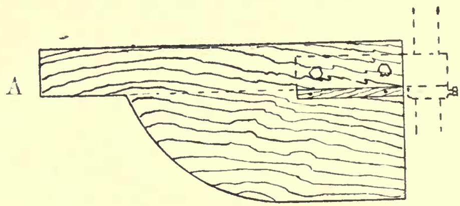


FIG. 245.—BOARD FOR STRIKING COPE DIRECT.

the drag. Upon this bed, the board being removed, the top or cope is rammed, parting sand intervening—being liftered and vented precisely as though it were being rammed upon a pattern. This is then taken away, and after the wheel is moulded and cored up, is returned finally into position.

On the removal of the cope, the sand which formed the reverse mould is dug out, and the board for striking the lower face, and corresponding with the tooth points, is attached to the strap and slipped over the bar, Fig. 244, the edge, *A*, coinciding with the joint face, *D*, already struck by the previous board, and the bottom sand swept out. The tooth block is then attached to the carrier and set in position, and the ramming, nailing, and venting proceed generally on the same methods as those pursued in the case of spur wheels, modified only by the bevel form. The alternative method of making the cope by a *direct* process is as follows: The centre pillar always has a movable collar fitting over it, seen in Fig. 244; this collar is set and pinched in such a position that its top face coincides exactly with the top or joint edge of the flask on the table, as checked with a straight edge. The boards, both for striking the cope and the drag, have strips nailed

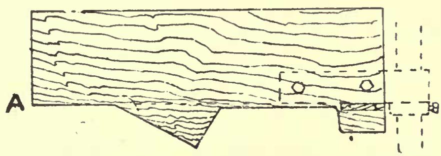


FIG. 246.—BOARD FOR STRIKING BED.

upon them, sometimes one strip only, sometimes two, the distance between the strips in the latter case being equal to the width of the strap, and the inner face of one strip coinciding with the joint edge of the mould. Figs. 245, 246, show the two boards, Fig. 245 striking the cope direct. It is clear that the collar remaining in the same position on the post, the joint faces, *A*, *A*, of cope and drag will coincide, if the fittings of the flasks and post are perfect. In work of this kind the flasks have properly to be turned and checked on their joint faces, specially for wheel moulding, but in the method first described any flasks can be used, and the wheel can be moulded in the floor just as well as on a table. When wheels are moulded in the floor the first method is the only one which can be adopted without risk of a crush or of finning occurring. The cope being rammed in place must, when the mould is closed for casting, make a perfect joint with the mould in the floor.

CHAPTER XVI

MISCELLANEOUS ECONOMIES—WEIGHTS OF CASTINGS

One of the duties of foremen lies in scheming other ways of working than those which are regular and commonplace. Occasions arise when, for economical reasons, it is desirable to get away from these and adopt other methods.

The question of numbers of castings required all alike, or nearly alike, generally determines in the main the methods of the pattern-maker. But dimensions also, whether large, small, or medium, have to be considered as well. So also have shapes, whether irregular or regular; as circular, which is admirably suited for sweeping up; or rectangular, for skeleton or sectional framings; or irregular, which cannot be so well treated. These things explain why the ideas of different men vary so much as to the most suitable methods of moulding, and of the amount of assistance which should be given to the moulder by the pattern shop, having regard to the relative expenses of each department. Broad views and due balancing of costs are therefore requisite in the conduct of these departments, which should never be regarded as having isolated interests.

As there are several alternative methods of working to achieve the same results in the ultimate forms of castings, we will consider the broad divisions of work just now instanced, those of numbers off, along with those of dimensions and of shapes, since neither stands in a state of isolation from the others.

The usual method when numbers are required all alike is to mould from complete patterns, made exactly like their castings, save for core prints and cored portions. And as the numbers off increase, more care is bestowed upon pattern construction, either in regard to the character of the wood work, or in the abandonment of wood for metal, and also by pressing into service the aids to be derived from mechanical methods of moulding.

In the pattern shop the difference lies in whatever is included in the terms *rough patterns*, and *standard patterns*. This means a great deal in extreme cases. A rough pattern may be broken up immediately that it is done with; and when that is the case, not a penny more is spent on it than is absolutely necessary. More work, of course, is thrown on the moulder, who will have to rub his fillets and the print portions of the cores, and will often have to work with sweeping boards or skeleton coreboxes, or with no boxes at all. Some parts will be made fast, instead of being dowelled, and the work will go into the foundry unvarnished, and without rapping or lifting plates.

On the other hand, a standard pattern in its best form will be perfect in dimensions and in finish. All fillets and radii will be put in, cores will fit their prints without rubbing, every core will be made in its own box ready for use, loose pieces will be fitted where there is the slightest risk of the mould breaking down if they were fast; and they will be so fitted, and the cores also, that it will be quite impossible for a careless moulder to set them in any but their correct positions. There will will be no excuse for a moulder to drive his bar or spike into such a pattern for rapping and lifting, for plates or straps will be provided where required. Care will be exercised in the selection of timber, which will be protected with three or four coats of varnish or paint, well rubbed down.

Between these extreme cases most patterns are made. Besides these, metal patterns are substituted generally for wood in small standardized articles, and in machine-moulded work.

But as there are many classes of jobs which are never repeated in large numbers, here the debatable ground lies. These include all engine cylinders of large dimensions, large fly-wheels, unusual sizes and shapes of columns, pipes, and bends, large drums for winding and hauling, big pulleys and sheave wheels and toothed gears, either of which may be made in one of two or three methods—namely, from full patterns, or in combination methods by the aid of sweeps in green sand or loam by the aid of fractional pattern parts, or of moulds in conjunction with such portions or sections of patterns and coreboxes that do not lend themselves to methods of sweeping up. The mere mention of these items will call up to the mind of a founder numerous alternatives possible in the production of a mould.

Dimensions, we said, determine methods of working to a large extent. Thus, methods which are practicable with castings measuring from a few inches to 3 ft. or 4 ft. across are often unsuitable for those of larger sizes, either for economical or other reasons. But in conjunction with dimensions, shapes also exercise much controlling influence in the choice of methods. Any symmetrical article, no matter how large, suggests at once the employment of sweeping up, for which either green sand, or dry sand, or loam, are often equally well adapted. And if an object is not wholly adaptable to this method—as, in fact, few are—then it is always practicable to utilize pattern parts or cores to complete

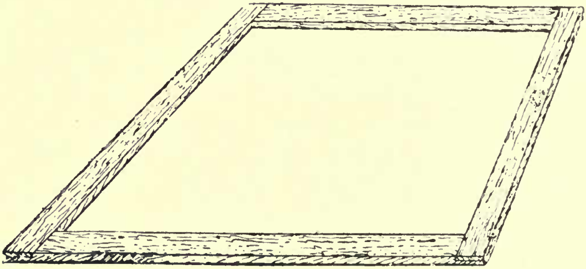


Fig. 247.—Skeleton Frame.

the work, whether done in green sand, loam moulds, or loam patterns.

Alternative methods.—The alternative methods, therefore, of the foundry may be very broadly classified thus: Complete patterns made in the ordinary way for hand moulding. Complete patterns in which mechanical aids

Fig. 248.—Strickle.

are utilized. Work which is moulded without complete patterns, which includes skeleton patterns and moulds taken from broken castings, as well as swept work. Also a large class of moulding made from segmental patterns, and sectional patterns in which a combination of several methods is utilized, such as pattern parts, sweeps, and coreboxes together. Lastly, there are devices for making moulds differing in some respects from their patterns, which includes alterations of certain details only; as of patterns in some degree standard, to which supple-

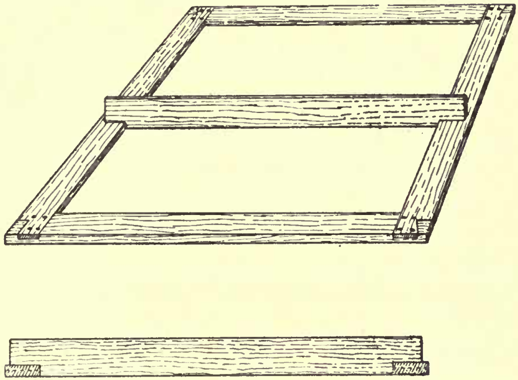


Fig. 249.—Strickle and Frame.

mentary parts may be fitted, or in the moulds, in which stopping-off is done; or both devices may be effected in the same mould in conjunction.

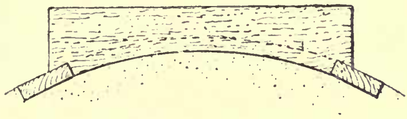


Fig. 250.—Strickling a Curved Plate.

In any of the methods of moulding, in which a complete pattern is dispensed with, there is a larger element of risk present, that of inaccuracy, than there is when a full pattern is employed. This arises in all work that is either swept up, or marked out on sand beds, or where pattern parts are bedded in green sand or in loam, or attached to loam patterns. These risks the pattern-maker is expected to foresee and guard against, and to accept responsibility for, even though the carrying through of the work lies in the moulder's hands. As a

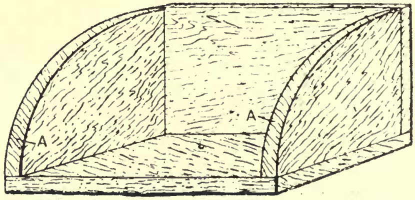


Fig. 251.—Edges of a Corebox cut for Strickling.

general rule the pattern-maker has to spend some time in the foundry, more or less, during the progress of such jobs, either marking out centre lines, or measuring-in parts, or checking the mould at certain crucial stages.

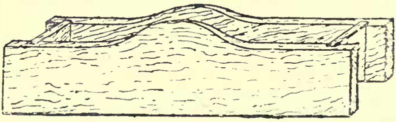


Fig. 252.—Edges of Box cut for Strickling.

Skeleton Frames.—Take a large plated casting, with or without flanges, say for a floorplate, a backplate, a tankplate, or a buckleplate, to be moulded from direct, or for making a metal pattern from for moulding in quantity. Instead of battening up narrow boards to make a continuous large area of, say, 4 ft. to 6 ft. square, a frame only is made, Fig. 247, of narrow strips

5 in. or 6 in. wide, the outside dimensions and the thickness only corresponding with those of the casting.

The interior of such a frame cannot be rammed on, as a solid-plated pattern can. So it is filled with hard-rammed sand, strickled off level with the top face, and the top box

FIG. 253.—STRICKLING A SAND BED FOR PATTERN OR CORE.

is then rammed on that. But if such a frame is used for an open sand mould, as many foundry plates are made, it is not filled up. A strickle like Fig. 248, having the depth *A* of its notch equal to the thickness of the plate, strickles out the sand level and true with the bottom face

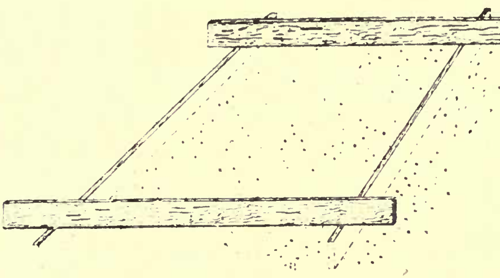


FIG. 254.—LEVELLING A BED.

of the plate, Fig. 249. On the delivery of the frame the mould remains just as though a solid-plated pattern had been used.

And if the plate should be curved (Fig. 250), as, say, for lighthouse, or tubbing plates, the frame can be made as shown, and the strickle curved to correspond. Or a straight strickle can be used, sweeping in the other direction. The illustration is given to show that a strickle is sometimes curved; it is sometimes also of an irregular shape, as straight and curved in combination.

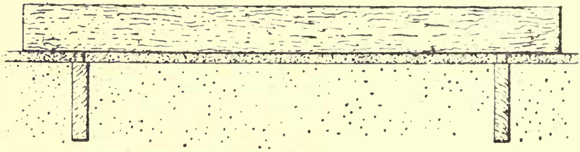


FIG. 255.—THICKNESSING FACING SAND.

Strickles are used thus in corebox work as well as in stopping down moulds or portions of the same. The curved face of a core can be obtained by strickling round

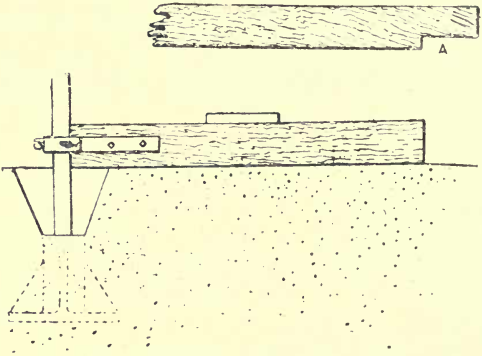


FIG. 256.—SWEEPING A LEVEL BED.

the edges *A*, *A* of the box in Fig. 251, just as well as by cutting a concave block of wood expensively, and fitting it in the box. So can the edge of the box in Fig. 252, while a bed for the pattern and core can be strickled as in Fig. 253.

Levelling Beds.—Level beds are in constant request, either for laying flat patterns or portions of patterns on, the edges of which are then rammed around, also for bedded-in work, or in some cases for ramming plain tops on, or tops on which otherwise plain facings, lugs, brackets, or prints have to be measured on and set to

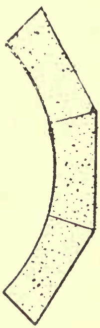


Fig. 257.—The Use of Segmental Cores.

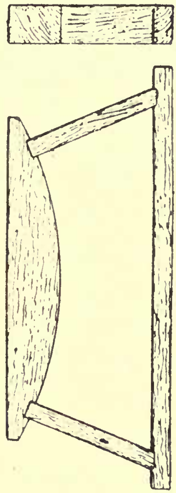


Fig. 258.—Box for Segmental Cores.

be rammed over. Such plain level beds are variously made.

A frequent method is to lay two parallel strips or straightedges in the sand, bedding them down with the mallet, and testing with spirit level along and across, and with parallel strips, Fig. 254. Then the top edges of the strips embedded in the sand become guides for a straightedge or a plain strickle by which the sand is levelled. At the same time venting and ramming will be done to form a firm, suitable bed for moulding on. The black floor sand is treated first, being rammed, vented, and strickled level with the tops of the strips, and then, if required for a mould, a layer of facing sand of about an inch in depth is rammed on this thickness, pieces being put on the straightedges as guides, Fig. 255. If the bed is only for ramming a top on, the facing sand is not wanted.

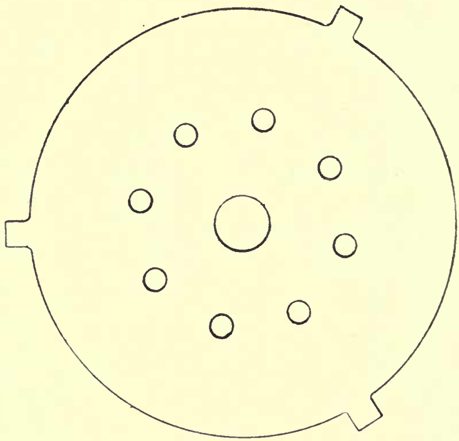


Fig. 259.—Loam or Core Plates with Lugs.

Another way to make a bed is to utilize the centre which is employed for striking bars, and bolt a plain strickle to it, taking care to level it properly, Fig. 256. Foundry appliances are made thus with little or no assistance from the pattern-maker by the aid of strickles, straightedges, sweeps, and plain thickness pieces. Thus, a circular loam or core plate can be swept up as in Fig. 256, with a board notched, as shown at *A*, fastened to the striking bar. An alternative method is to strike a plain bed by the method of Fig. 254, and form the edge by means of segmental cores, Fig. 257, made from a box like Fig. 258. If lugs are wanted for lifting slings, Fig. 259, they are cut out of the cores, or blocks of wood are bedded in if the plate is swept up by the board in Fig. 256, *A*.

When smaller plates are wanted, as for core plates, Fig. 260, the moulder borrows a flange from the pattern stores and beds it in in open sand, cuts off some round

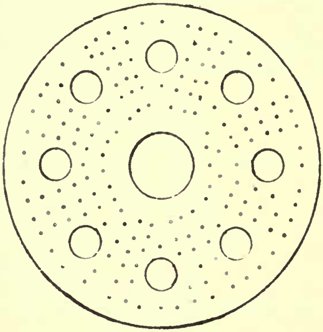


Fig. 260.—Core Plate.

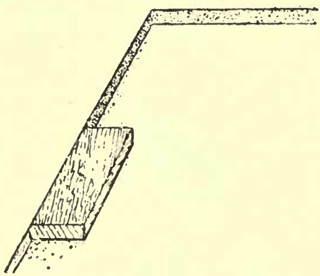


Fig. 261.—Ramming Edges against a Strip.

cores, and weights them down, and so makes his mould. If many plates are wanted, he has a few iron patterns of various sizes made and hung up in the foundry for stock service.

Rectangular frames for foundry use, as for back plates of boxes, core plates, etc., are made without even the wood framing of Fig. 247, by levelling a bed by the method of Fig. 254, and then marking out the size and shape of the frame, and ramming the edges against a strip of wood, Fig. 261, of the same thickness that the plate has to be. The edge of a circular plate can be rammed with a piece having a curved edge, Fig. 262.

Plates for loam work, and core plates like Fig. 260, are gaggered over without aid from the pattern-maker by sticking some stout nails into a handle, Fig. 263, and pushing these into the sand all over the surface required.

Sweeping in Greensand.—In the simple strickle or sweeping board the moulder has the most valuable economical aid. There are, however, limitations to the use of striking boards in greensand work. It is impossible to strike up vertical faces, whether deep or shallow, in greensand, though this can be done in loam.

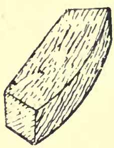


Fig. 262.—Curved Strip.

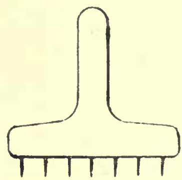


Fig. 263.—Gagger Pattern.

A vertical face of any depth can be swept truly in loam, provided the rough coat is allowed to set before the finishing coat is laid on, and the latter is kept thin. But greensand is too loose to hold together, and it will fall down from a perpendicular face; and this must be borne in mind when scheming methods. It limits such work to surfaces that are horizontal, or of moderate slope or curvature, beyond which ramming blocks must be used in conjunction with the striking boards. And the alternative of loam must not be rashly resorted to in all cases, because loam is more costly than greensand, due to the detailed labour of bricking, and to the cost of drying.

Another useful function often fulfilled by sweeping boards is the preparation of faces, either to lay patterns on, or to ram top parts on. If we have a flimsy pattern to mould by bedding-in, it will be next to impossible to ram up such a pattern truly by beating it down and tucking the sand under. The general level must be swept

Fig. 264.—Condenser Cover.

up and the pattern laid on this, and any projections or recesses be then attended to in detail.

The device of sweeping up a bed on which to ram a top has two advantages, besides the saving of cost in patternwork. One is that the top is bound to go back into exactly the same position relatively to the bottom

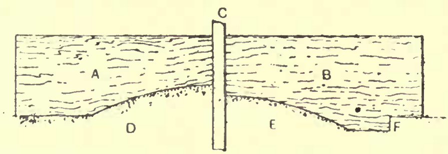


Fig. 265.—Sweeping the Mould.

for pouring. Another is, that small pattern parts, as facings, lugs, bosses, etc., can be measured in position exactly on the swept-up dummy mould better than they can be measured into the actual top. We will take examples illustrating the preceding remarks.

The condenser cover, Fig. 264, is swept in greensand, Fig. 265, in preference to making a large solid pattern. If the outside of the condenser were turned bright, it would be made the opposite way down from that shown in the drawings.

Two boards are necessary, one, *A* for the outer, the other, *B* for the inner face, both being attached to turn on any convenient centre *C*, such as that used for loam work, or for wheel moulding. The board *A* for the top is used first, and having formed a dummy mould *D* with it, the top box is rammed upon this.

The question may be asked, Why not strike the top part direct with a board shaped like a loam board—that is, cut the opposite way to *A*? The answer is that when greensand is being rammed it is easier to ram it wholly without combination and interference with the work of sweeping up. Another good reason is that the top being rammed in place, goes back exactly right, guided by the stakes by which it is set on the lower mould in the floor, or by the pins in a box.

After the top has been rammed and removed, the bottom *E* is swept out with its board *B*. The shoulder *F*, though shallow, will have to be made good with a sweep.

The moulding of fly-wheels with wrought-iron arms, in the absence of a full pattern, requires two boards and a sweep. The latter is of the same section as the rim of the casting, besides which it carries arm bosses and boss prints (see p. 170).

Moulds modified from Patterns.—In nearly all shops a good deal of makeshift work is done. It includes alterations in the depth of teeth of gear wheels, in rims, in thicknesses, in hubs, in the casting of wheels of different kinds and dimensions together, and many other matters. Some alterations can be effected in the foundry without alterations in the pattern.

Changing Depth of Patterns.—Suppose it often happens that a gear wheel has to be cast either shallower or deeper than the pattern wheel. In the first case it will be *stopped off*; in the second, *drawn.* The pattern, therefore, would not be cut in the first place, nor increased in thickness in the second. But drawing and stopping off affect other parts besides the teeth. Obviously, if a pattern is drawn in the sand, the depth or thickness of arms, ribs, and boss will be increased by as much as the teeth. If it is stopped off, the depth or thickness of these will be reduced by as much as the teeth. This in some

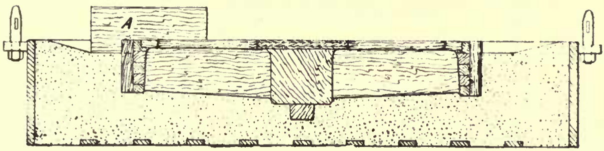


FIG. 266.—STOPPING OFF A WHEEL.

cases involves a good deal of work to be done all over the mould—so much, in fact, that if several castings altered thus were wanted, it would generally be cheaper to make a new pattern, or to have the wheels moulded by machine. We will take the two methods, and show in detail what has to be done in each case.

Stopping Off.—Take a wheel of the commonest type moulded from a complete pattern, one with arms of T-section. Say the wheel is 3 in. deep and it has to be stopped off to $2\frac{1}{4}$ in. The first thing is to make a small strickle, Fig. 266, *A*, and in perspective in Fig. 267, which after the wheel has been rammed up will, on being worked round from its upper face all around the teeth, form a new joint face $\frac{3}{4}$ in. below that made by the pattern. So far so good: but then it follows that the arm mould is still $\frac{3}{4}$ in. higher than the new joint face. Either the arms must, therefore, be cut out entirely, and a new pattern arm moulded by bedding-in, or the interior must be wholly formed anew by means of cores; or alternatively the wheel must not be strickled on the top face, but on the bottom, before it is turned over, and the vertical arms must be stopped off.

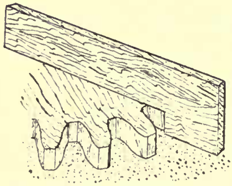


Fig. 267.—Using a Strickle.

This last is always the better plan to adopt in the case of a wheel of the type shown. Fig. 268, therefore, shows the stage of moulding at which the strickle is used—that is, after the ramming up of the wheel in the bottom box, previous to turning the latter over to take the cope. It necessitates, however, a three-part flask, because now there will be two joints at *a* and at *b* respectively,

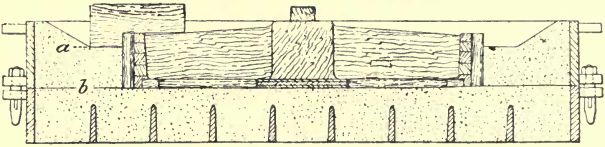


Fig. 268.—Stopping off a Wheel.

instead of one at *b* only, as in the ordinary way of moulding such a pattern. The sloping joint at *a* is now strewn with parting sand, and the second portion of the box, a bottom part, is put on and rammed over it. Then the mould is turned over, the cope put on the joint face *b*, and rammed, and removed (it has been only temporarily rammed in Fig. 268); the pattern drawn, and the boxes parted at *a*.

Fig. 269 shows the bottom part of the mould as it appears at this stage. Now all the tooth spaces *c*, which of course are $\frac{3}{4}$ in. deep, are filled up with sand level with the joint face. Also the supplementary portions of the ribs are filled up with sand to the dotted lines and made

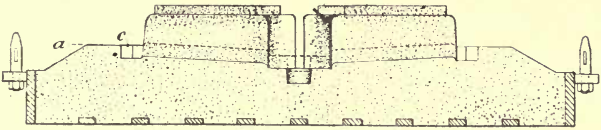


Fig. 269.—Stopping off a Wheel.

good with a pattern rib. The hub also is filled up with a pattern boss. This completes the stopping off, which is done neatly and with comparatively little trouble.

Pattern of Plated Type.—If the pattern is a disk or plated type of wheel, Fig. 270, then it is unnecessary to interfere with the disk at all. But the disk will be out of centre in the shallower wheel. In the event of this being considered objectionable, it is practicable to strickle down a new joint from each tooth face, the depth of each being equal to half the total reduction required. Then in the bottom the supplementary portions of the teeth would be filled up with sand in the way just noted, and on the top the cope would be lowered on the new joint formed directly by the strickle.

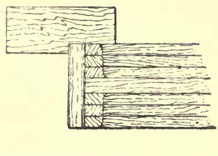


Fig. 270.—Stopping off a Plated Wheel.

Drawing.—Coming next to the work of *drawing* a wheel, and making use of the same examples as before, the ramming is done in the usual way. The wheel is then rapped and withdrawn. The distance to which it is withdrawn at this stage is equal only to the increased depth required. The exact depth is best gauged by means of three or four thickness strips *A*, Fig. 271, laid on the joint face of the mould close to the pattern. The ramming is now continued up to the top face *a* of the wheel. At this stage the cope is put on and rammed, and lifted off. Then the pattern is withdrawn wholly from the mould, leaving the teeth deeper than the pattern. It often happens that some slight fracture of the sand will occur in doing this work, and then three mending-up teeth are made and used of the total depth of the drawn teeth.

Objectionable Results.—The flat arms obviously become

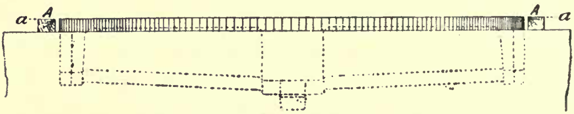


Fig. 271.—Drawing a Wheel.

increased in depth by this operation, and a single stopping-off arm, Fig. 272, is made and used to reduce the moulded arms to the right thickness. The surfaces of the mould are hatched over with the trowel, and the pattern arm being put in place, sand is tucked underneath and made up good to the under-face of the pattern arm. The hub is similarly treated. All this is troublesome and tedious, and makes much mess in the mould, especially at the junctions of the separate arms with the boss and with the rim.

In the case of a plated wheel drawn, the surface of the moulded plate is made good with sand to its proper thickness.

Broken Castings.—These are frequently utilized for moulding from, instead of making expensive patterns.

Customers sometimes expect a moulder to do marvels with a broken casting. They sublimely ignore such matters as delivery, roughness of surface, recessed portions, holes, shrinkages, and the rest. All they can say is that they want a new casting without going to the expense of a pattern, and the moulder is expected to furnish it.

Almost any casting can be moulded from, just as almost any pattern can be; but the question always arises whether it pays, having regard to the amount of work required to make it mouldable, and to the extra time occupied in the moulding. These, together with the numbers required, determine the alternative of moulding from old castings, or of making new patterns. The question is a very wide one, especially in jobbing shops, and it can only be settled after a consideration of the pros and cons in every individual case. These include the nature of the surfaces, the presence of broken parts, shapes suitable or otherwise for delivery, including coring, how to joint, shrinkages, the amount of wear which a casting has sustained, facility for getting it out of the sand, and allowances for tooling.

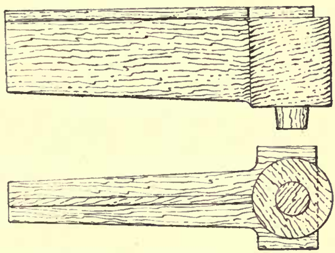


FIG. 272.—ARM FOR STOPPING OFF.

The first thing to do with a casting to be moulded from, is to clean it thoroughly, which is generally done by making it red hot in a clean coke fire in order to burn off all grease, oil, and dirt. When cold it is brushed with card wire or rubbed with emery cloth, and is then taken in hand by the patternmaker to prepare it for moulding. We will note the points to be attended to in various castings by some selected examples.

Fig. 273 shows a double bracket fractured at *K*. This can be moulded from very well without making a new wooden pattern by having a corebox to take out the interior space *A*, using a print for the purpose as shown. The thickness of the core will be the same as the width *B*, but the length *C* and width *D* of the print are unim-

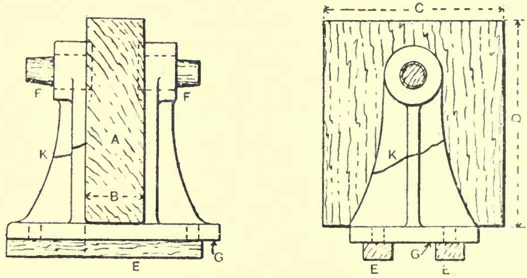


Fig. 273.—Broken Bracket prepared for Moulding from.

portant so long as there is sufficient bearing to carry the core without crushing the edges of the bracket mould.

Frequently the bolt holes are wanted cored. Pocket or drop prints have to be put on at *E*, *E* to core these. The prints may be secured sometimes by plugging up the old holes with wood and nailing the pocket prints to these plugs. If this is not sufficient, small holes may be drilled in the casting and plugged with wood to receive the nails from the prints. Round prints *F*, *F* will be driven into the holes in the bosses, giving $\frac{1}{4}$ in. allowance for boring. The moulding will be done with the bosses in bottom and top—that is, as the right-hand figure lies—and the parting in the mould will be along the top face of the print *A*. A corebox (Fig. 274) will be made to fill up the impression of the main print for coring out the space *A*, and the small facing bosses will be put in the core. The thickness *B* of the box corresponds with the thickness *B* of the print in Fig. 273, the length *C* with *C* in that figure, and the width *D* with the width *D*. The time saved is that of making the whole of the pattern proper, omitting the print and corebox, which would have to be done if a new wood pattern was made.

With regard to shrinkage, if the height of the casting from foot to centre is important, then it is usual to attach a thickness piece to the face *G* of the foot, to allow for shrinkage, $\frac{1}{8}$, $\frac{3}{16}$, or $\frac{1}{4}$ in., as may be required. In small patterns sufficient allowance may often be given by extra rapping.

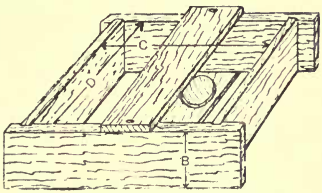


Fig. 274.—Core Box for Bracket.

Broken castings are generally varnished before being moulded. Vertical faces, if rough, must be smoothed with a file; the flat faces need not be. If the vertical faces are very rough, some beeswax may be worked in and smoothed over, or finely-powdered chalk mixed with varnish, and when hardened, glass-papered and varnished. These applications fill up the hollow parts of the rough surfaces.

Fig. 275 shows how a broken pipe bend is prepared for moulding from. The ends are plugged with round prints, and the broken parts are laid together in the mould without any fastening, the moulder seeing that they do not shift during ramming.

Fig. 276 shows how a common rope or sheave pulley is prepared for moulding from. A block of wood is fitted roughly to the interior of the groove, simply to assist in steadying the print *A*, which is fitted against the edges of the pulley rim, its thickness coming flush with the outside of the rim on top and bottom. This sweep is worked round the rim, being kept level by the small battens, and rammed in successive stages, so forming a print for segmental cores, by which the interior shape of the rim is produced. Before any of this is done, the arms are rammed up in the bottom and top, a joint face being formed flush with the top edge *B* of the rim. Then after that the sweeped print *A* is worked round, and when the cores are laid in they come flush with the joint face, which lies outside them. The corebox is of the same section as the interior of the rim, plus the added space required to fill up the print impression.

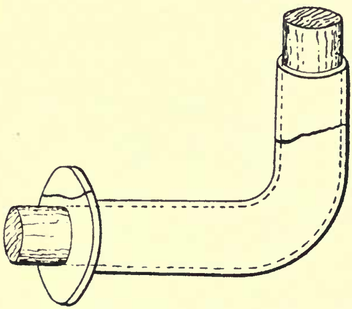


Fig. 275.—Broken Pipe prepared for Moulding.

A point that is very essential when taking moulds from broken castings is that the parts must be laid accurately in their relative positions for ramming. Straightedges, winding strips, and the rule must be used to test this. It is easy when ramming a fragmentary casting in the floor to get the parts out of truth, and so make crooked and winding castings. In many cases a levelled bed of sand will afford accuracy to the pieces in one plane. If the work is not absolutely level, but is so in the main, then the level bed of sand is necessary, and holes are dug in it to take those parts that project beyond the general plane.

Among the simplest castings that can be moulded from are bearings of ordinary kinds. The only difficulty is in adding the due allowance for machining, as boring and facing. In very small work a slight increase in the size can always be made by excessive rapping. Or a careful moulder can scrape out the mould a little larger with his trowel or cleaner, with or without the aid of thickness strips laid in the portion to be machined. The safer way, however, is to line up the portions which have to

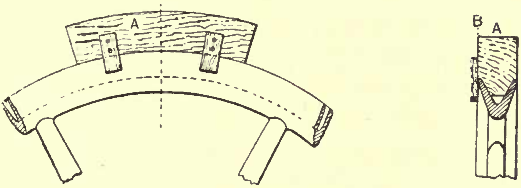


FIG. 276.—SHEAVE PREPARED FOR MOULDING.

be faced with sheet lead, or with thin leather or wood, and this must be done in many jobs. The linings need not necessarily be fastened to the castings. If laid against them in the mould that is sufficient.

A common belt pulley, with single arms, can be easily moulded from. The allowance for turning is given by laying thin strips of wood around the rim, and the moulder, guided by the thickness of these, scrapes out the mould so much larger than the broken casting. But a wide pulley, with double arms, cannot be moulded without making a corebox to take out the space between the arms, though all the rest will deliver freely. It would, however, cost less to make a corebox than to make an entire pulley pattern. But many shops keep pulley pattern rings and sets of arms of all sizes, and then it is cheaper to mould from one of these than to make a corebox for the broken casting.

Using broken castings as patterns frequently gives more trouble in making sand joints than if wooden patterns were made. Speaking very generally, the joints in pattern and mould coincide, with some slight variations. But all broken castings are destitute of any joints, and then there must be the alternative in some cases of using cores, in others of making sand joints, and lifts against faces frequently vertical, with consequent tearing up of the sand; or drawbacks may be used. Thus in Fig. 273 the sand must be lifted away from the vertical faces above the main core print *A*. In a pattern these portions would be left loose. The wood pattern for the pipe in Fig. 275 would be jointed along the centre. Moulded from the undivided casting, portions of the top sand are bound to fracture, so that more work is thrown on the moulder in mending up than when moulding is done from properly jointed patterns.

When allowances for shrinkage are excessive, due to the large dimensions of a casting, it results in undue thickening up of the parts—the plates or flanges—to which the thickening pieces are attached. Sometimes this does not matter, but often it is very objectionable, as in the rim of a light pulley or the flanges of light plates. The due proportioning of metal is interfered with, and in some cases fracture is liable to occur. If such is the case, then the broken work must not be moulded from. Sand can be scraped away without much difficulty, but it is very troublesome and unsafe to put it on in quantity in parts of a mould. It can only be done by hatching up the surface, moistening with the swab, and if the substance is sufficient, nailing also. Then, after all, there is risk of scabbing or washing away of portions of the added sand. So that, unusual cases apart, the work of the moulder is restricted to scraping moulds, mending-up only being done where the sand has broken down.

Often broken castings are also worn or corroded badly in places. Sometimes the moulder can make these parts good by scraping the mould; but as a rule the patternmaker takes charge of this, making good the worn portions with wood, nailed or screwed to plugs in drilled holes, or cemented on, or simply laid in place next the casting in the mould. Small parts also broken off are lost, and then the patternmaker has to supply them.

There is therefore more in this question of utilizing broken castings than appears at first sight. A foreman must be able in any given case to determine when old castings should be utilized, or the alternative of new patterns followed. The device is often highly economical; in other cases it is expensive and unsatisfactory.

Burning on.—This signifies the mending of fractured castings, or imperfect castings due to incomplete running, by a process of autogenous soldering of metal to metal. It is simply this, that sufficient molten metal is poured over the surface against which the union has to be effected until local fusion has taken place. Then the pouring is stopped, and the casting is afterwards as strong there as elsewhere. The danger is lest the local increase in temperature should cause fracture of the casting to occur in the vicinity.

Before commencing to burn on, the casting is heated in the drying stove, brought out, imbedded in the floor, and the particular locality where the fusion is to take place is heated with red-hot weights placed in proximity thereto. This is done to diminish risk of fracture. Sand or loam cake is built up around the spot where the new portion has to be burned on, and is shaped into the particular outline required. A gutter or channel is cut leading away from this. The molten metal is now poured gently and slowly over the fractured surface, and allowed to run away through the gutter. The heat of the metal soon produces fusion of the surface, and when the moulder learns by trial with the end of a rod that fusion has taken place, he ceases pouring. To burn on only a few pounds of metal several hundredweights have to be run over the surface into the gutter. This is broken up afterwards.

Weights of Castings.—The only correct way of calculating the weight of metal in a casting is to compute the number of cubic inches which it will contain, and multiply these by a number expressive of the weight of a unit volume of the kind of metal used. The latter is the cubic inch—only in very heavy work is the cubic foot employed. The following table gives the weight of a cubic inch of the common metals and alloys.

Metal or Alloy.	Weight of cub. in. in lb. avoir.
Cast iron	0.263
Wrought iron	0.281
Steel	0.283
Copper	0.3225
Brass	0.3037
Zinc	0.26
Lead	0.4103
Tin	0.2636
Mercury	0.4908

The simplest forms for calculation are those of rectangular outlines. After these come circular sections and

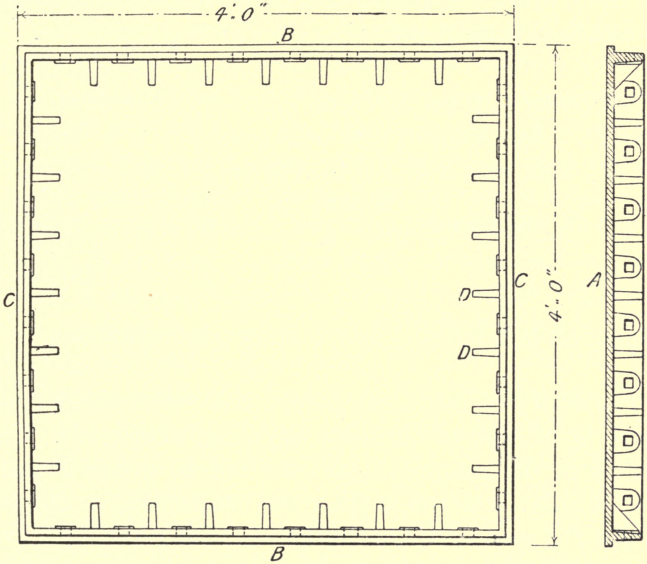


FIG. 277.—TANK PLATE.

regular curves, and then the numerous irregular outlines which occur in castings.

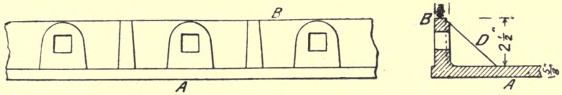


FIG. 278.—FLANGE AND BRACKETS OF PLATE.

As an example of the first, take a common tank plate (Figs. 277, 278). The details of this are wholly rectangular, and it is only necessary to multiply length by breadth by thickness of the various details, as follows.

In estimating weights it is well to set down all the details in a weight book, in ink, for future reference, if required, thus; the quotients in cubic inches being added as reckoned subsequently:

	Cub. in.
A 1 plate, 4 ft. $\times$ 4 ft. $\times \frac{5}{8}$ in.	$=1440$
B, B, 2 flanges, 4 ft. $\times 2\frac{1}{2}$ in. $\times \frac{3}{4}$ in. . . .	$=180$
C, C, 2 flanges, 3 ft. $10\frac{1}{2}$ in. $\times 2\frac{1}{2}$ in. $\times \frac{3}{4}$ in.	$=174$
D, 28 brackets, $\dfrac{2\frac{1}{2} \times 2\frac{1}{2} \text{ in.}}{2} \times \frac{3}{4}$ in. . .	$=65.5$
	1859.5

Deduct 32 bolt-holes, $\frac{3}{4}$ in. $\times \frac{3}{4}$ in. $\times \frac{3}{4}$ in. $=13.5$ cub. in.

The whole of the items being thus set down at first, there is no risk of omitting anything afterwards. The details of the computations need not be given, but the results only. The use of the reference letters, *A*, *B*, and *C*, enables one to see at a glance whether any item has been calculated or not.

Adding these figures we get 1859.5 total cubic inches. Deducting the 32 bolt-holes therefrom, we obtain $1859.5 - 13.5 = 1846$ cubic inches as the solid contents of the tank plate.

Angles or fillets are usually cast round the flanges and brackets and they will hardly be less than $\frac{1}{2}$ or $\frac{5}{8}$ in. on the sides. But instead of reckoning these up, simply knock out the 13.5 lb. weight of metal taken out by the holes, allowing that much for the added weight of angles. So that we say that there are 1859.5 cubic inches in the tank plate, and the decimal can be omitted.

To bring 1859 cubic inches into pounds multiply by the number representing the weight of a cubic inch of cast iron given in the table, p. 372 = 0.263 = 489.9 lb., say 490 lb.

In connection with the plate the frequent and considerable divergence between the estimated and actual weights may be mentioned. A plate of this or of kindred type is certain to exceed the calculated weight unless precautions are taken to prevent it. The reason is mainly because of the broad superficial area over which enormous liquid pressure takes place at the time of casting, causing the top flask to rise, with a consequent thickening of the casting. If the flask is rather light, and the weighting or loading down insufficient, the evil will be magnified; and if the moulder rams too lightly, or indulges too much in scraping, rubbing, and sleeking, the thickening will be still further increased. I have seen plates come out fully $\frac{3}{16}$ in. thicker in the central parts than the pattern, with the addition of something like $\frac{1}{2}$ cwt. to the calculated weight. So it by no means follows that when castings are found to vary considerably from the calculated weights, the calculations themselves are incorrect. It is specially in castings of this general type that we have to be on our guard. All broad *flat* areas tend to increase of thickness, while in the case of *vertical* webs, however deep, there is little or no difference in the thicknesses of pattern and casting observable.

Actually, some allowance is made in the pattern shop in cases where experience shows that a casting will come out thicker than the pattern. If a casting is liable to *gather* by $\frac{1}{16}$ in., the pattern is made $\frac{1}{16}$ in. thinner; if $\frac{1}{8}$ in. thicker, then $\frac{1}{8}$ in. less. A 4 ft. tank plate pattern should be made fully $\frac{1}{16}$ in. less in thickness than the thickness given on the drawing; and if the plate were larger than 4 ft., thinner still.

The fly-wheel shown in half plan in Fig. 279, and in section in Fig. 280, is an example of a circular casting. *A*, the section to the left is shaded regularly, that to the right being shaded to illustrate how it is divided into separate sections for convenience of calculation. Taking the rim *A*, first. Obtain the *mean circumference*, and then reckon the rim as a straight *strip* of metal. The outside

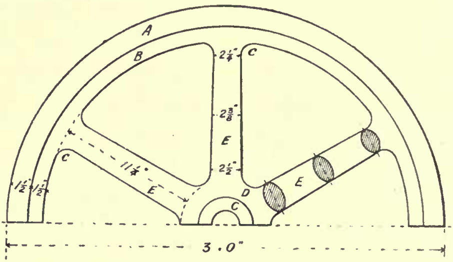


FIG. 279.

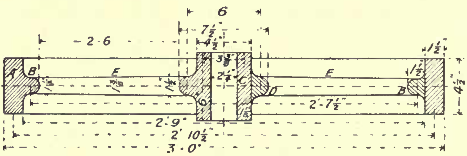


FIG. 280.

FLY-WHEEL.

diameter is 3 ft., the thickness $1\frac{1}{2}$ in. The inner diameter is, therefore, 2 ft. 9 in., and the *mean* diameter will be 2 ft. $10\frac{1}{2}$ in. Set down the first item of measurement of the wheel in tabular form as given on p. 377.

The inner ring, *B*, has its section concave and convex, and by reducing this to a plain rectangle the concave portion, will about compensate for the convex edges. This is sufficiently approximate; and time will only permit of practical approximations in all work of this character. So we reduce the ring, B, to a rectangular section. Its outer diameter is 2 ft. 9 in., and it is $1\frac{1}{2}$ in. wide; therefore its mean diameter is 2 ft. $7\frac{1}{2}$ in., and its section $1\frac{1}{2} \times 1\frac{1}{4}$ in. We set down B accordingly in the table. The central boss, C, in like manner has a mean diameter of $3\frac{3}{8}$ in., and a section of $6 \times 1\frac{1}{8}$ in. The ring, D, around the boss has a mean diameter of 6 in., and a section of $1\frac{1}{2} \times 1\frac{1}{2}$ in.

There are now six arms, E, of elliptical section. By making the necessary deductions at circumference and centre, we get six plain straight arms, each $11\frac{1}{4}$ in. long. The *mean* section of the ellipse at the centre is $2\frac{3}{8} \times 1\frac{3}{8}$ in. To obtain the area of an ellipse, the product of the two dimensions is multiplied by 0.7854. So we set down the arms, E, as shown in the table. Every item now is tabulated except the radii, c, by which the arms merge into the rim and boss, and these can be neglected, or a small allowance lumped on for them. Now:

		Cub. in.
A, 1 ring 2 ft. $10\frac{1}{2}$ in. dia. $\times 4\frac{1}{2}$ in. $\times 1\frac{1}{2}$ in. .	=	761
B, 1 ring 2 ft. $7\frac{1}{2}$ in. dia. $\times 1\frac{1}{2}$ in. $\times 1\frac{1}{4}$ in. . .	=	185.2
C, 1 ring $3\frac{3}{8}$ in. dia. $\times 6$ in. $\times 1\frac{1}{8}$ in.	=	69.9
D, 1 ring 6 in. dia. $\times 1\frac{1}{2}$ in. $\times 1\frac{1}{2}$ in.	=	42.1
E, 6 arms $11\frac{1}{4}$ in. long $\times 2\frac{3}{8}$ in. $\times 1\frac{3}{8}$ in. $\times 0.7854$	=	221
		1279.2

The circumference of A in the table, of 2 ft. $10\frac{1}{2}$ in. $= 34.5$ in. $\times 3.14159 = 108.3$ in. But it is not usual or necessary to take the trouble of calculating circumferences or areas, because tables of these are given in engineers' books of reference. Multiplying 108.3 in. by

4.5 by 1.5 in. we obtain 761 cubic inches in the rim, and set that down opposite *A* in the table, p. 377.

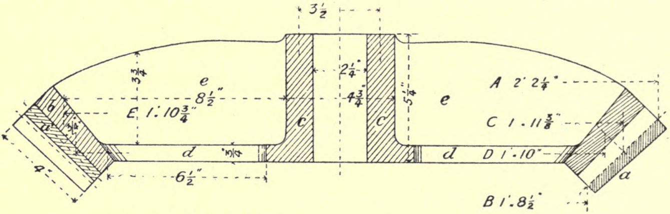


FIG. 281.—SECTION OF BEVEL WHEEL.

In a similar way we compute the number of cubic inches in each item, and record the results thus found in the table, as indicated.

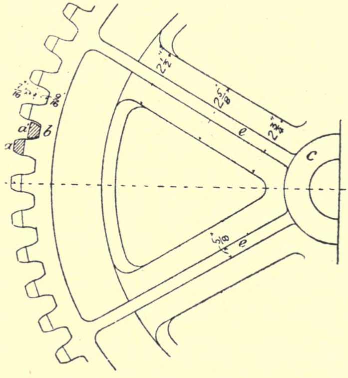


FIG. 282.—PLAN OF WHEEL ARMS.

The total is 1279.2 cubic inches. Multiplying by 0.263 we get 336 lb. weight of wheel, or 3 cwt.

The next illustration is a bevel wheel, Figs. 281, 282. There is a major pitch diameter, *A*, and a minor pitch diameter, *B*. In estimating the sectional areas of the rings formed by teeth and rim we take as our basis the *mean* diameters, C, and D, thus:

Instead of reckoning the sectional contents of a single tooth and multiplying by the number of teeth in the wheel, we make a ring of the teeth. Take the "face" portion—beyond the pitch line (shaded at a, right-hand and in plan)—and turn this over between the "flank" portions—below the pitch line (a', left-hand in figure and in plan). Say the tooth is 1 in. long (mean dimensions are taken to average the taper in the rim), and the flank portion $\frac{9}{16}$ in. long, as figured in section. Turning over a to a', we have a ring of metal $\frac{7}{16}$ in. thick, instead of $\frac{1}{2}$ in., which would be one-half the total length of tooth. But the "flank clearance" between tooth face and tooth flank will be set off against this, so that $\frac{7}{16}$ in. thickness of ring will be very approximately correct. So, instead of taking the mean *pitch* diameter, C, of the wheel for the diameter of the ring of teeth, we take the *mean* diameter, E, of the ring of metal $\frac{7}{16}$ in. in thickness. This is 1 ft. $10\frac{3}{4}$ in. diameter. We set down, then, the first item as a ring, a', 1 ft. $10\frac{3}{4}$ in. diameter by $\frac{7}{16}$ in. *mean* thickness by 4 in. width of face of tooth.

			Cub. in.
a'	1 ring 1 ft. $10\frac{3}{4}$ in. dia. $\times \frac{7}{16}$ in. $\times$ 4 in.	=	125
b	1 ring 1 ft. 10 in. dia. $\times \frac{3}{4}$ in. $\times$ 4 in. .	=	207
c	1 boss $3\frac{1}{2}$ in. dia. $\times 5\frac{1}{4}$ in. $\times 1\frac{1}{4}$ in. . .	=	72
d	6 arms $6\frac{1}{2}$ in. long $\times 2\frac{5}{8}$ in. $\times \frac{3}{4}$ in. . .	=	76
e	6 arms $8\frac{1}{2}$ in. long $\times 3\frac{3}{4}$ in. $\times \frac{5}{8}$ in. . .	=	119
			599

The rim, b, of the wheel has a mean diameter of 1 ft. 10 in., and its mean thickness is $\frac{3}{4}$ in., and width

4 in.; we set it down accordingly. The remainder of the wheel only embodies modes of dividing out, previously explained, so we just jot them down as above from the drawing without comment—namely, the boss, *c*, the flat arms, *d*, and the vertical arms, *e*.

The total number of cubic inches is 599. Multiplying by 0.263, we have 157 lb. weight of metal, or 1 cwt. 45 lb. in the wheel.

The next illustration is a bend pipe (Fig. 283). This is wholly circular. In thin castings of this type it is not usual to take the mean diameter of the ring or rings of metal into which we conveniently divide the castings, but to subtract the area of the internal diameter or bore from the area of the external diameter, as follows:

In the pipe shown in the figure the lengths are given, as is usual, from the centres of the straight lengths, *A* and *B*, to the faces of the flanges, *D* and *E*. We shall find it convenient to deduct the bend portion from the straight portion, to facilitate calculation. This gives two straight portions, *A* equalling 3 ft. 6 in. − 9 in. in length, and *B* equalling 1 ft. 1 in. − 9 in. in length, and we set these down accordingly:

	Cub. in.
A = 1 tube 2 ft. 9 in. long × 4 in. and 5 in. dia. . =	234
B = 1 tube 4 in. long × 4 in. and 5 in. dia. . . . =	28.4
C = quarter bend 56.5 in. circ. × 4 in. and 5 in. dia. =	99
D and E = 2 flanges $9\frac{1}{2}$ in. dia. × 1 ft. thick − 5 in. hole . . . . =	100.8
	462.2

The bend, *C*, happens to be a quarter of a circle, with *mean* radius, *r*, of 9 in. So we say 9 in. × 2 = 1 ft. 6 in.

mean diameter $= 56\frac{1}{2}$ in. circumference, and we want one-fourth of that circumference, and we set down C accordingly in list. Last, we have two flanges, D and E, each $9\frac{1}{2}$ in. diameter $\times$ 1 in. thick. From these we have to deduct holes 5 in. diameter, equal to the outside diameter of the pipe, because we took the total lengths of A and B over the faces of the flanges. We put down the flanges in the list and begin our calculations.

Taking A first, we obtain the area of 5 in.; subtract the area of 4 in. from it, and multiply by 2 ft. 9 in. $=$ 33 in. We do not go through the process each time of

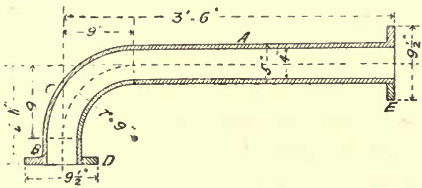


FIG. 283.—BEND PIPE.

squaring the diameter and multiplying by 0.7854, but go to a table of diameters and areas. The result is, area of 5 in. $=$ 19.6 in.; area of 4 in. $=$ 12.5 in.; then 19.6 in. $-$ 12.5 in. $=$ 7.1 in. area of cross-section of pipe, which $\times$ 33 in. $=$ 234 in., which we set down accordingly in the list of items. Then ring B, will also equal 7.1 in. area $\times$ 4 in. $=$ 28.4 in. The cross-section of the bend, C, is also 7.1 in. The mean length of the bend is 56.5 in. $\div$ 4 $=$ 14 in., and 7.1 in. $\times$ 14 in. $=$ 99 in. The area of a single flange is the area of 9.5 in. $-$ the area of 5 in. $=$ 70 in. $-$ 19.6 in. $=$ 50.4 in. There are two flanges $=$ 100.8 in.

The total sectional contents of the pipe is 462 in. Multiplying by 263 $=$ 121 lb., or 1 cwt. 9 lb. in the pipe.

Another way to run through the weight of plain pipes, and any plain cylindrical work, is to make use of a table of weights of pipes or columns per foot run. In most engineers' books of reference these tables are given for cast-iron cylinders 1 ft. long, of diameters ranging from 2 in. or 3 in. to 24 in., and in thicknesses ranging from about $\frac{1}{4}$ in. to 1 in. These tables cover the range of all ordinary pipe and column dimensions, and therefore save some little time in subtracting areas. Again, it is often the practice not to reckon out the flanges on a pipe as flanges, but to estimate two flanges as equal to 1 ft. in length of the pipe, which in standard pipes is not far out.

When getting out approximate estimates by direct calculation there is a good deal of mental work done which is not put down in figures. Thus in running through an intricate piece of work certain allowances or set-offs are made. Certain holes will be set off against certain lugs, brackets, corners, angles, and so forth, when one appears to about counterbalance the other, so that one would not be set down at all in the calculations, but allowances would be mentally made for it.

Measurements of areas and of volumes have to be taken with great expedition, because the element of time presses. Generally all rules of mensuration which involve much calculation are passed by, and figures are averaged into rectangles, triangles, and circles, or parts of circles. For the areas in the first case two dimensions only have to be multiplied together. In the second the base and height, and half the product taken. In the third, a table would be consulted. Flat and angular surfaces are either brought into square feet, or into feet square, and of a definite thickness. Curved surfaces, of whatever curve, are either brought into flat surfaces of square feet, or feet square, or into annular rings. In either of these forms the weights are easily obtainable direct from tables.

Not only are tables designed for use with a given metal employed, but tables are also utilized for metals other than those for which they are designed. Thus it is very easy and convenient to use tables of weights of wrought iron for cast iron and brass. Tables are given for the weight of a superficial foot of various thicknesses, and of the weight of a foot run of bar iron of various thicknesses and widths, and these can be utilized for any other metal by the employment of a suitable multiplier, often saving the trouble of some considerable calculation when a table of similar sections is not available for the metal or alloy required. Thus the multiplier 0.9538 converts the weight of bar iron into that of cast iron, 0.929 steel into cast iron, 1.15 bar iron into gun metal or copper. Not that any single calculation in itself amounts to much; but when hundreds of separate calculations are in question, a trifle of time saved on each makes a lot of difference in the sum total. These tables are given in the Appendix.

Even in calculations for bringing cubic inches into pounds, many do not use the multiplier 0.263 given for cast iron. It is more accurate than any other. But for very rough estimating some simply divide cubic inches by 4. This, however, would make a good deal of difference in a big casting. But a very fair approximation is obtained by dividing inches by 4, and the quotient by 20, and adding the two.

APPENDIX

TABLE I

Sand Mixtures

These mixtures, as stated in Chapter II, p. 12, are given as typical and illustrative only of the manner in which moulding materials are prepared to suit the ever-varying requirements of the foundry. Only from this point of view are they to be regarded as of value.

Two mixtures of strong sand from the Manchester district are:—

(1) 2 barrows of red sand.
    2 ,, road ,,
    2 riddles of horse-manure.
    5 buckets of coal-dust.

(2) 2 barrows of red sand.
    4 ,, ground road sand.
    5 sieves of coal-dust.
    1 ,, black sand.
    1 ,, loam.

Jobbing or common sand:—
    4 barrows of red sand.
    2 ,, ground road sand.
    2 ,, black sand.
    6 sieves of coal-dust.

For small work:—

3 riddles of red sand.
3 ,, road ,,
3 ,, fine yellow sand.
3 buckets of fine coal-dust.

For fine wheels:—

3 riddles of red sand.
3 ,, fine yellow sand.
2 buckets of fine coal-dust.

In the West of England. Strong sand:—

2 barrows of Seend sand.
1 ,, Devizes sand.
2 ,, loam.
5 buckets of coal-dust.
2 sieves of horse-manure.

Sand for light work:—

5 barrows of black sand.
5 ,, Seend ,,
3 buckets of coal-dust.

Loam:—

1 barrow of black sand.
1½ ,, Seend ,,
½ ,, Devizes sand.
18 shovels of manure.

The above mixture with *half* the amount of dung makes a good *core* sand.

The core sand used at Banbury is composed of equal parts of burnt sand and a porous red sand obtained in the vicinity of Birmingham. The dry sand is composed of the core sand ground in a mill and thickened with clay-wash. The red sand is largely used in Birmingham and Manchester, and, like the Worcester sand, which it resembles, is very free and open, being largely self-venting.

In the Bradford district (Yorkshire) a red sand from the Doncaster district is employed for general jobbing work; it is fairly open.

"Winmore," a very open gritty sand, is used for strong green sand moulds.

A yellow sand from Kippax is used for cores and for dry sand work.

For loam: Doncaster or Kippax sand is ground with clay-wash, and horse-dung or cow-hair added.

Mansfield sand (Nottinghamshire) is used for fine work; it is a close sand. This is also used in the Eastern Counties. A little old sand is mixed with the above, according to the class of work.

The following are from foundries in Bradford:—

(1) Ordinary green sand is composed either of Pontefract, Doncaster, or Snaith sand, mixed with 50 per cent. of old sand, and 1 part of coal-dust to 8 or 10 of sand, according to weight of casting.

(2) Fine green sand for small moulds and teeth of wheels is composed of Mansfield sand, with from 25 to 50 per cent. of old sand, and 1 part of coal-dust to 15 of sand.

(3) For cores: Pontefract, Doncaster, and Snaith sands are used, provided they are free from clay.

(4) For large cores: dried loam pounded, and horse-dung dried and sieved, are mixed with the above sands in various proportions.

(5) Dry sand: for facing—dried loam pounded, and brought to consistence of green sand; for box filling—old and new sand mixed, and weak clay-wash added.

From another firm I have:—

(1) For common green sand: yellow sand from Kippax, and red sand from Snaith and Doncaster, each mixed with old sand in different proportions, according to the quality of the work.

(2) For fine wheels: Mansfield sand.

(3) Strong sand is prepared from Buttershaw sand mixed with old sand, and coal-dust in varying proportions.

(4) Cores: red sand, or yellow sand, mixed with a little clay and old sand.

From a Leeds firm:—

(1) Common green sand: two-thirds of old sand to one-third of new yellow sand; coal-dust to suit work.

(2) Strong sand: one-half old sand, one-quarter yellow, and a quarter red; coal-dust in varying proportions.

(3) Core sand: two-thirds yellow sand, and one-third manure.

In the London district Erith sand is largely used; in Scotland, Belfast and Falkirk sands; each district and each shop having its own special mixtures; but the foregoing will suffice to illustrate the method of mixing.

TABLE II

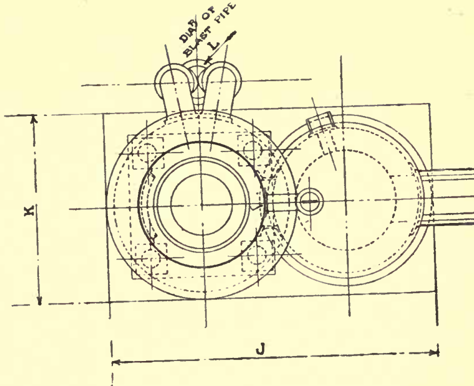
LIST OF SIZES, WEIGHTS AND DIMENSIONS OF "RAPID" CUPOLAS
(STEWART'S PATENT)

Plant to melt per hour between the following weights of iron . tons	½-1	1-2	2-3	3-4	4-5	5-6	6-8	8-10	10-12	12-15
Number of Cupola	1	2	3	4	5	6	8	10	12	15
Outside diameter of Casing . feet	2′ 4″	2′ 6″	3′ 0″	3′ 6″	4′ 0″	4′ 6″	5′ 0″	6′ 0″	7′ 0″	8′ 0′
Total Height from ground . "	20′ 8″	22′ 4″	24′ 0″	24′ 8″	25′ 10″	26′ 8″	28′ 7″	33′ 0″	40′ 0″	40′ 0″
Height of Charging Door above ground . . . . . . "	15′ 6″	16′ 6″	17′ 6″	18′ 6″	19′ 6″	20′ 6″	22′ 6″	24′ 0″	26′ 6″	26′ 6″
Thickness of shell plates . . inch	$\frac{1}{4}$″	$\frac{1}{4}$″	$\frac{1}{4}$″	$\frac{5}{16}$″	$\frac{5}{16}$″	$\frac{5}{16}$″	$\frac{3}{8}$″	$\frac{7}{16}$″ & $\frac{3}{8}$″	$\frac{7}{16}$″ & $\frac{3}{8}$″	$\frac{7}{16}$″ & $\frac{3}{8}$″
Thickness of air belt plates . "	$\frac{3}{16}$″	$\frac{3}{16}$″	$\frac{3}{16}$″	$\frac{3}{16}$″	$\frac{3}{16}$″	$\frac{3}{16}$″	$\frac{3}{16}$″	$\frac{1}{4}$″	$\frac{1}{4}$″	$\frac{1}{4}$″
Diameter of air belt . . . feet	3′ 3″	3′ 5″	4′ 1″	4′ 10″	5′ 8″	6′ 2″	6′ 8″	8′ 0″	8′ 8″	10′ 0″
Diameter of Receiver . . . "	2′ 9″	3′ 0″	3′ 6″	4′ 0″	4′ 6″	5′ 0″	5′ 6″	5′ 9″	5′ 10″	6′ 0″
Total Weight of Ironwork . cwts.	45	50	70	95	120	140	195	300	340	500

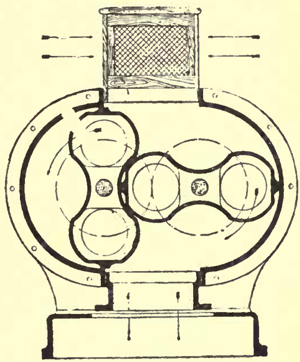
TABLE III

TABLE, WITH ILLUSTRATIONS ON P. 391, SHOWING THE PRINCIPAL DIMENSIONS OF "RAPID" CUPOLAS, WITH RECEIVERS AND DROP BOTTOMS

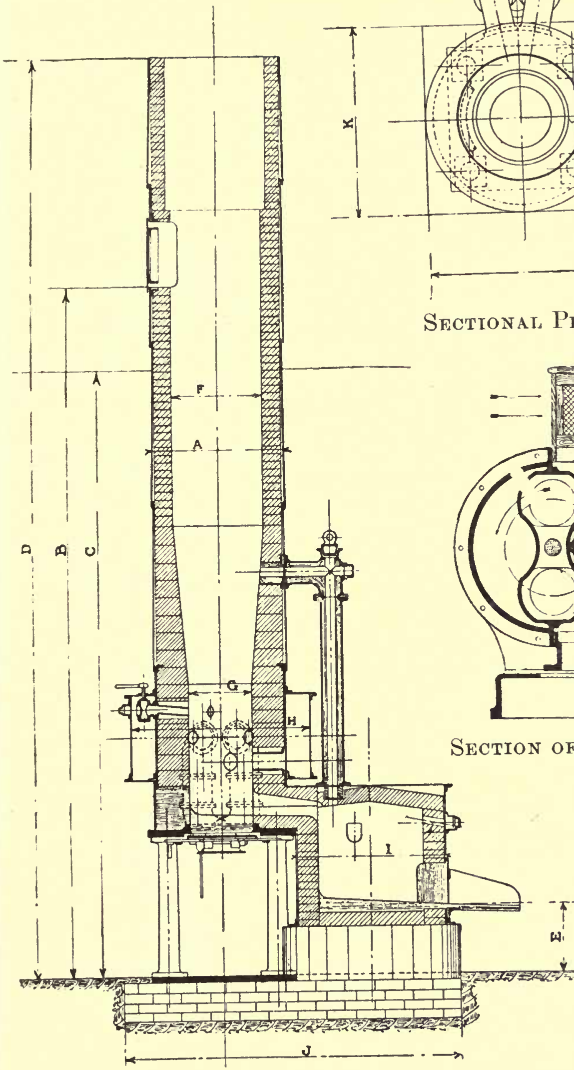
Letter	Number of Cupola									
	1	2	3	4	5	6	8	10	12	15
A	2′ 4″	2′ 6″	3′ 0″	3′ 6″	4′ 0″	4′ 6″	5′ 0″	6′ 0″	7′ 0″	8′ 0″
B	15′ 6″	16′ 6″	17′ 6″	18′ 6″	19′ 6″	20′ 6″	22′ 6″	24′ 0″	26′ 6″	26′ 6″
C	13′ 3″	14′ 3″	15′ 3″	16′ 3″	17′ 6″	18′ 6″	20′ 6″	22′ 0″	24′ 6″	24′ 6″
D	20′ 8″	22′ 4″	24′ 0″	24′ 8″	25′ 10″	26′ 8″	28′ 7″	33′ 0″	40′ 0″	40′ 0″
E	1′ 9″	1′ 6½″	2′ 0″	1′ 10″	1′ 10″	1′ 8″	2′ 3″	3′ 5″	3′ 8½″	3′ 8½″
F	1′ 6″	1′ 8″	2′ 2″	2′ 5″	2′ 11″	3′ 4″	3′ 8″	4′ 4″	5′ 3″	6′ 3″
G	1′ 2″	1′ 4″	1′ 6″	1′ 8″	1′ 10″	2′ 4″	2′ 8″	3′ 0″	3′ 2″	3′ 9″
H	3′ 3″	3′ 5″	4′ 1″	4′ 10″	5′ 8″	6′ 2″	6′ 8″	8′ 0″	8′ 8″	10′ 0″
I	2′ 9″	3′ 0″	3′ 6″	4′ 0″	4′ 6″	5′ 0″	5′ 6″	5′ 9″	5′ 10″	6′ 0″
J	6′ 0″	6′ 9″	7′ 6″	9′ 0″	10′ 1½″	10′ 10½″	12′ 9″	15′ 0″	15′ 9″	16′ 6″
K	3′ 9″	3′ 9″	4′ 6″	5′ 3″	6′ 0″	6′ 0″	7′ 6″	8′ 3″	9′ 0″	10′ 6″
L	7″	7″	10″	10″	12″	12″	14″	16″	17″	19″



SECTIONAL PLAN OF CUPOLA.



SECTION OF ROOTS' BLOWER.



VERTICAL SECTION.

Dimension lettering of Cupola to correspond with Table on p. 390.

TABLE IV

THWAITES' IMPROVED ROOTS' BLOWERS, ON P. 391, DRIVEN BY BELTS

Mounted on Cast Iron Bedplate, fitted with machined Revolvers and Gearing running in Oil-bath.
List of Sizes of Blowers for volumes of air, capable of delivering from 1,300 to 25,000 cubic feet per minute.

Size of Blower	1	2	3	4	5	6	7	8	9	10	11	12
Maximum Number of Revolutions per minute	400	400	380	350	320	310	300	280	260	240	240	240
Quantity of air delivered per min. cub. ft.	1300	2000	3000	4550	6400	8680	11000	12500	15500	19000	22500	25000
Approximate maximum melting capacity at this delivery, tons of iron per hour	2	3	4	7	10	14	20	25	30	40	42	50
Diameter of Delivery Orifice in.	7	8	10	12	13½	17	19	22	24	27	29	30
Diameter of Driving Pulleys in.	10	12	14	16	18	20	22	24	27	27	36	42
Breadth of Driving Pulleys in.	3	3½	4	4¾	5½	6½	7	9	10	10	11	11
Approximate B.H.P. at full speed and at 21 in. W.G.	6½	10½	15	22½	31½	42	54	60	75	95	112	123
Approx. Weight, unpacked cwt.	10½	19	27	45	50	72	83	97	150	170		

TABLE V

STURTEVANT "HIGH PRESSURE" FANS FOR FOUNDRY WORK

Size No. of Fan.	Melting Capacity.	Diameter of Cupola *inside* lining.	Speed of Fan.	Air Pressure.	Power required.
	Tons/hour	*in.*	*Revs./min.*	*In. of Water.*	*B.H.P.*
1	0.7	16	3,900—4,800	8—12	1.6— 3.0
2	1.0	18	3,250—4,000	8—12	2.2— 4.0
3	1.5	20	3,150—3,750	10—14	4.0— 6.5
4	2.5	26	2,750—3,250	10—14	5.0— 8.5
5	3.5	29	2,550—2,950	12—16	9.0—13.0
6	5.0	35	2,350—2,700	12—16	11—16
7	6.0	41	1,900—2,200	12—16	16—24
7	8.0	47	2,200—2,400	16—20	24—33
8	11.0	53	1,900—2,150	16—20	31—42
8	12.5	59	2,150—2,350	20—24	42—55
9	18.0	70	1,850—2,000	20—24	56—74
10	22.0	80	1,600—1,750	20—24	73—95

Melting capacity.—The above table gives the average melting capacity of the different sizes, determined from numerous examples of actual working. They represent the results ordinarily attained in good modern Cupolas, with a melting bed of average composition, good foundry coke and blast pipes of sufficient size, air-tight and constructed with easy bends.

Under favourable conditions, for instance, when using very hard coke and melting rapidly in tall, economical Cupolas, it is possible to bring down from 10 to 20 per cent. more iron than given in the above table. The power required to drive the fan will, other conditions remaining the same, be approximatety proportional to the weight of iron brought down in a given time.

TABLE VI.

SIZES, WEIGHTS, PROOF STRAINS, AND WORKING LOADS OF SHORT LINK CRANE CHAIN.

Size of Chain.	Approximate Weight per Foot in lbs.	Proof Strain in Cwts.	Working Load in Cwts.
$\frac{3}{8}$	1·33	36·75	20·0
$\frac{7}{16}$	1·91	45·0	24·0
$\frac{1}{2}$	2·33	65·5	27·0
$\frac{9}{16}$	3·25	75·0	44·0
$\frac{5}{8}$	3·66	102·0	53·0
$\frac{3}{4}$	5·33	147·0	80·0
$\frac{7}{8}$	6·71	200·0	110·0
1	9·33	268·0	140·0
$1\frac{1}{8}$	11·9	334·0	180·0
$1\frac{1}{4}$	14·5	408·0	220·0

TABLE VII.

SIZES, WEIGHTS, WORKING LOADS, AND BREAKING STRENGTHS OF HEMP ROPES.

Circumference in inches.	Weight per Fathom in lbs.	Safe Working Loads in Cwts.	Breaking Strain in Cwts.
$2\frac{3}{4}$	2·0	6	40
$3\frac{3}{4}$	4·0	12	80
$4\frac{1}{2}$	5·0	18	120
$5\frac{1}{2}$	7·0	24	160
6	9·0	30	200
$6\frac{1}{2}$	10·0	36	240
7	12·0	42	280
$7\frac{1}{2}$	14·0	48	320
8	16·0	54	360
$9\frac{1}{2}$	22·0	78	520
10	25·0	84	560

TABLE VII—*continued.*

SIZES, WEIGHTS, WORKING LOADS, AND BREAKING STRENGTHS OF ROUND STEEL WIRE ROPES.

Circumference in inches.	Weight per Fathom in lbs.	Safe Working Loads in cwts.	Breaking Strain in cwts.
1	1·0	9	60
1¼	1·50	15	100
1½	2·0	21	140
1¾	2·50	27	180
2	3·50	33	220
2⅛	4·0	39	260
2¼	4·50	45	300
2⅜	5·0	51	340
2½	5·50	60	400
2¾	6·50	72	480
3¼	8·50	84	560
3⅜	5·0	90	600
3⅝	10·50	100	720
3¾	12·0	115	840
4	14·0	126	960

TABLE VIII.

AVERAGE COMPOSITION OF PIG IRON.

	Grey.	Mottled.	White.
Graphitic carbon	3·10	1·99	2·42
Combined carbon	0·04	2·78	
Silicon	2·16	0·71	0·36
Sulphur	0·11	trace	0·87
Phosphorus	0·63	1·23	1·08
Manganese	0·50	—	—
Iron	94·56	93·29	95·27

TABLE IX

MENSURATION

1.—Areas

1. *Rectangle* or *Parallelogram.* Multiply the length by the breadth.

2. *Triangle.* Multiply the base by the perpendicular height, and take half the product.

Or: From half the sum of the three sides subtract each side separately. multiply the half sum and the three remainders together; the square root of the product will be the area.

3. *Trapezoid.* Multiply half the sum of the parallel sides into the perpendicular distance between them.

4. *Quadrilateral.* Divide the quadrilateral into two triangles; the sum of the areas of the triangles is the area.

5. *Irregular Polygon.* Divide the Polygon into triangles, and trapezoids by drawing diagonals; find the areas of these as above shown for the area.

6. *Regular Polygon.* Multiply the length of a side by the perpendicular height to the centre and by the number of sides, and half the product will be the area.

7. *Circle.* Multiply the square of the radius by 3·14159.

Or: Multiply the square of the diameter by ·7854.

8. *Circular Ring.* Find the area of each circle, and subtract the area of the inner circle from the area of the outer circle.

Or: Multiply the sum of the radii by their difference, and the product by 3·14159.

9. *Sector of a Circle.* As 360 is to the number of degrees in the angle of the sector, so is the area of the circle to the area of the sector.

Or: Multiply half the length of the arc of the sector by the radius.

10. *Segment of a Circle.* Find the area of the sector which has the same arc, and subtract the area of the triangle formed by the radial sides of the sector and the chord of the arc; the difference, or the sum of these areas, will be the area of the segment, according as it is less, or greater than a semicircle.

11. *Cycloid.* Multiply the area of the generating circle by three.

12. *Parabola.* Multiply the base by the height; two-thirds of the product is the area.

13. *Ellipse.* Multiply the product of the two axes by ·7854.

Note.—The area of an ellipse is equal to the area of a circle, of which the diameter is a mean proportional between the two axes.

II.—Volumes

14. *Parallelopiped, Prism,* or *Cylinder.* Multiply together the length, the breadth, and the height, and the product will be the volume.

Or: Multiply the area of the base by the height, and the product will be the volume.

15. *Pyramid* or *Cone.* Multiply the area of the base by the height, and one-third of the product will be the volume.

16. *Wedge.* To twice the length of the base add the length of the edge; multiply the sum by the breadth of the base, and by the height. One-sixth of the result will be the volume.

17. *Sphere.* Multiply the cube of the diameter by ·5236.

18. *Spherical Shell.* Subtract the cube of the inner diameter from the cube of the outer diameter, and multiply the result by ·5236.

19. *Zone of Sphere.* To three times the sum of the squares of the radii of the ends add the square of the height; multiply the sum by the height and by ·5236.

20. *Segment of Sphere.* To three times the square of the radius of the base add the square of the height; multiply the sum by the height, and the product by ·5236.

TABLE X.

WEIGHT OF TWELVE INCHES SQUARE OF VARIOUS METALS.

Thickness.	Wrought Iron.	Cast Iron.	Steel.	Gun Metal.	Brass.	Copper.	Tin.	Zinc.	Lead.
inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
$\frac{1}{16}$	2·50	2·34	2·56	2·75	2·69	2·87	2·37	2·25	3·68
$\frac{1}{8}$	5·	4·69	5·12	5·5	5·38	5·75	4·75	4·5	7·37
$\frac{3}{16}$	7·50	7·03	7·68	8·25	8·07	8·62	7·12	6·75	11·05
$\frac{1}{4}$	10·	9·38	10·25	11·	10·75	11·5	9·5	9·	14·75
$\frac{5}{16}$	12·5	11·72	12·81	13·75	13·45	14·37	11·87	11·25	18·42
$\frac{3}{8}$	15·	14·06	15·36	16·50	16·14	17·24	14·24	13·50	22·10
$\frac{7}{16}$	17·5	16·41	17·93	19·25	18·82	20·12	16·17	15·75	25·80
$\frac{1}{2}$	20·	18·75	20·5	22·	21·5	23·	19·	18·	29·5
$\frac{9}{16}$	22·5	21·10	23·06	24·75	24·20	25·87	21·37	20·25	33·17
$\frac{5}{8}$	25·	23·44	25·62	27·50	26·90	28·74	23·74	22·50	36·84
$\frac{11}{16}$	27·5	25·79	28·18	30·25	29·58	31·62	26·12	24·75	40·54
$\frac{3}{4}$	30·	28·12	30·72	33·00	32·28	34·48	28·48	27·	44·20
$\frac{13}{16}$	32·5	30·48	33·28	35·75	34·95	37·37	30·87	29·25	47·92
$\frac{7}{8}$	35·	32·82	35·86	38·50	37·64	40·24	32·34	31·5	51·6
$\frac{15}{16}$	37·5	35·16	38·43	41·25	40·32	43·12	35·61	33·75	55·36
1	40·	37·5	41·	44·	43·	46·	38·	36·	59·

TABLE XI.

WEIGHT OF CAST IRON CYLINDERS ONE FOOT LONG.

External Diameter.	Thickness in Inches.						
	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
inches.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
3	6·75	9·65	12·3	14·6	16·6	18·3	19·6
$3\frac{1}{2}$	7·98	11·5	14·7	17·6	20·3	22·6	24·5
4	9·20	13·3	17·2	20·7	24·0	26·9	29·5
$4\frac{1}{2}$	10·4	15·2	19·6	23·8	27·7	31·1	34·4
5	11·7	17·0	22·1	26·9	31·5	35·4	39·3
$5\frac{1}{2}$	12·9	18·9	24·5	29·9	35·2	39·7	44·2
6	14·1	20·7	27·0	33·0	38·9	44·0	49·1
$6\frac{1}{2}$	15·3	22·5	29·5	36·1	42·6	48·3	54·0
7	16·6	24·4	31·9	39·1	46·4	52·6	58·9
$7\frac{1}{2}$	17·8	26·2	34·4	42·2	50·1	56·9	63·8
8	19·0	28·1	36·8	45·3	53·8	61·2	68·7
$8\frac{1}{2}$	20·3	29·9	39·3	48·3	57·5	65·5	73·6
9	21·5	31·8	41·7	51·4	61·3	69·8	78·5
$9\frac{1}{2}$	22·7	33·6	44·2	54·5	65·0	74·1	83·5
10	23·9	35·4	46·6	57·5	68·7	78·4	88·4
11	26·4	39·1	51·5	63·7	76·0	87·0	98·2
12	28·8	42·8	56·5	69·8	83·4	95·6	108·0
13	31·3	46·5	61·4	75·9	90·7	104·2	117·8
14	33·8	50·2	66·3	82·1	98·0	112·8	127·6
15	36·2	53·8	71·2	88·2	105·4	121·3	137·4
16	38·7	57·5	76·1	94·3	112·7	129·9	147·3
17	41·1	61·2	81·0	100·5	120·0	138·5	157·1
18	43·6	64·9	85·9	106·6	127·4	147·1	166·9
19	46·0	68·6	90·8	112·8	134·7	155·7	176·7
20	48·5	72·3	95·7	118·9	142·0	164·3	186·5
21	50·9	75·9	100·6	125·0	149·4	172·9	196·4
22	53·4	79·6	105·5	131·2	156·7	181·5	206·2
23	55·8	83·3	110·5	137·3	164·0	190·1	215·0
24	58·3	87·0	115·4	143·4	171·4	198·7	225·8

TABLE XI—*continued.*

External Diameter.	Thickness in Inches.						
	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
inches.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs	lbs.
25	60·8	90·7	120·3	149·6	178·7	207·2	235·6
26	63·2	94·3	125·2	155·7	186·1	215·8	245·4
27	65·7	98·0	130·1	161·8	193·4	224·4	255·3
28	68·1	101·7	135·0	168·0	200·7	233·0	265·1
29	70·6	105·4	139·9	174·1	208·1	241·6	274·9
30	73·0	109·1	144·8	180·2	215·4	250·2	284·7
31	75·5	112·8	149·7	186·4	222·7	258·8	294·5
32	77·9	116·4	154·6	192·5	230·1	267·4	304·3
33	80·4	120·1	159·5	198·7	237·5	276·0	314·2
34	82·8	123·8	164·5	204·8	244·8	284·6	324·0
35	85·3	127·5	169·4	210·9	252·2	293·1	333·8
36	87·8	131·2	174·3	217·1	259·5	301·7	343·6
38	92·7	138·5	184·1	229·3	274·3	318·9	363·2
40	97·6	145·9	193·9	241·6	289·0	336·1	382·9
42	102·5	153·3	203·7	253·9	303·7	353·3	402·5
45	109·8	164·3	218·5	272·3	325·8	379·1	432·0
48	117·2	175·4	233·2	290·7	347·9	404·8	461·4
51	124·6	186·4	247·9	309·1	370·0	430·6	490·9
54	131·9	197·5	262·6	327·5	392·1	456·4	520·3
57	139·3	208·5	277·4	345·9	414·2	482·1	549·8
60	146·6	219·6	292·1	364·3	436·3	507·9	579·3

TABLE XII.

COMPARATIVE WEIGHTS OF DIFFERENT BODIES.

Cast Iron = 1		Bar Iron = 1		Steel = 1	
Bar Iron	= 1·0484	Cast iron	= ·9538	Cast iron	= ·929
Steel	= 1·0766	Steel	= 1·0269	Bar iron	= ·97378
Brass	= 1·153	Brass	= 1·1	Brass	= 1·07
Copper	= 1·2137	Copper	= 1·15163	Copper	= 1·1236
Gun metal	= 1·208	Gun metal	= 1·15094	Gun metal	= 1·12132
Lead	= 1·5645	Lead	= 1·5	Lead	= 1·4532

Brass = 1		Copper = 1		Gun Metal = 1	
Cast iron	= ·867	Cast iron	= ·83	Cast iron	= ·82888
Bar iron	= ·909	Bar iron	= ·8666	Bar iron	= ·86874
Steel	= ·9336	Steel	= ·89	Steel	= ·891735
Copper	= 1·05	Brass	= ·95	Brass	= ·95583
Gun metal	= 1·046	Gun metal	= ·9994	Copper	= 1·00045
Lead	= 1·3572	Lead	= 1·293	Lead	= 1·29246

Lead = 1		Yellow Pine = 1	
Cast iron	= ·64	Cast iron	= 16·0
Bar iron	= ·67	Steel	= 17·0
Steel	= ·688	Brass	= 18·8
Brass	= ·737	Gun metal	= 19·0
Copper	= ·774	Copper	= 19·3
Gun metal	= ·7736	Lead	= 24·0

TABLE XIII.

WEIGHT OF CAST IRON BALLS.

Diameter in inches	Weight in lbs.	Diameter in inches.	Weight in lbs.	Diameter in inches.	Weight in lbs.
2	1·10	6	29·72	10	137·71
2¼	1·57	6¼	33·62	10¼	148·28
2½	2·15	6½	37·80	10½	159·40
2¾	2·86	6¾	42·35	10¾	171·05
3	3·72	7	47·21	11	183·29
3¼	4·71	7¼	52·47	11¼	196·10
3½	5·80	7½	58·06	11½	209·43
3¾	7·26	7¾	64·09	11¾	223·40
4	8·81	8	70·49	12	237·94
4¼	10·57	8¼	77·32	12¼	253·13
4½	12·55	8½	84·56	12½	268·97
4¾	14·76	8¾	92·24	12¾	285·37
5	17·12	9	100·39	13	302·41
5¼	19·93	9¼	108·98	13¼	320·80
5½	22·91	9½	118·06	13½	338·81
5¾	26·18	9¾	127·63	13¾	357·93

TABLE XIV.

DECIMAL EQUIVALENTS TO FRACTIONAL PARTS OF LINEAL MEASURES.

One inch the integer or whole number.

·96875		$\frac{7}{8}$ & $\frac{3}{32}$	·625		$\frac{5}{8}$	·28125		$\frac{1}{4}$ & $\frac{3}{32}$
·9375		$\frac{7}{8}$ & $\frac{1}{16}$	·59375		$\frac{1}{2}$ & $\frac{3}{32}$	·25		$\frac{1}{4}$
·90625		$\frac{7}{8}$ & $\frac{1}{32}$	·5625		$\frac{1}{2}$ & $\frac{1}{16}$	·21875		$\frac{1}{8}$ & $\frac{3}{32}$
·875		$\frac{7}{8}$	·53125		$\frac{1}{2}$ & $\frac{1}{32}$	·1875		$\frac{1}{8}$ & $\frac{1}{16}$
·84375	are equal to	$\frac{3}{4}$ & $\frac{3}{32}$	·5	are equal to	$\frac{1}{2}$	·15625	are equal to	$\frac{1}{3}$ & $\frac{1}{32}$
·8125		$\frac{3}{4}$ & $\frac{1}{16}$	·46875		$\frac{3}{8}$ & $\frac{3}{32}$	·125		$\frac{1}{8}$
·78125		$\frac{3}{4}$ & $\frac{1}{32}$	·4375		$\frac{3}{8}$ & $\frac{1}{16}$	·09375		$\frac{3}{32}$
·75		$\frac{3}{4}$	·40625		$\frac{3}{8}$ & $\frac{1}{32}$	·0625		$\frac{1}{16}$
·71875		$\frac{5}{8}$ & $\frac{3}{32}$	·375		$\frac{3}{8}$	·03125		$\frac{1}{32}$
·6875		$\frac{5}{8}$ & $\frac{1}{16}$	·34375		$\frac{1}{4}$ & $\frac{3}{32}$			
·65625		$\frac{5}{8}$ & $\frac{1}{32}$	·3125		$\frac{1}{4}$ & $\frac{1}{16}$			

TABLE XV.

DECIMAL APPROXIMATIONS FOR FACILITATING CALCULATIONS IN MENSURATION.

Square inches multiplied by	·007	=	Square feet.	
Cubic inches „ „	·00058	=	Cubic feet.	
„ „ „ „	·263	=	Lbs. Avs. of	Cast iron.
„ „ „ „	·281	=	„ „ „	Wrought iron.
„ „ „ „	·283	=	„ „ „	Steel.
„ „ „ „	·3225	=	„ „ „	Copper.
„ „ „ „	·3037	=	„ „ „	Brass.
„ „ „ „	·26	=	„ „ „	Zinc.
„ „ „ „	·4103	=	„ „ „	Lead.
„ „ „ „	·2636	=	„ „ „	Tin.
„ „ „ „	·4908	=	„ „ „	Mercury.
Avoirdupois lbs. „ „	·009	=	Cwts.	
„ „ „ „	·00045	=	Tons.	

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