MODERN
IRON FOUNDRY PRACTICE.

PART I.

FOUNDRY EQUIPMENT, MATERIALS USED, AND PROCESSES FOLLOWED.

BY

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WITH NUMEROUS ILLUSTRATIONS.

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PREFACE.

THE following work has been prepared to meet the existing want of a Manual of Modern Iron Foundry Practice. The data on which it is based have been collected from many sources, and the Author fully appreciates his indebtedness to others for much that is embodied.

The division of the work into two parts was not decided upon until after a considerable portion of it had gone to press. The scope of this the first part is fully detailed in the table of contents, and it will be noticed that machine moulding and kindred subjects have been left to be dealt with in the second part, which will also include chapters upon physical testing, shrinkage and distortion of castings, the various methods adopted for cleaning castings, foundry costs, etc., etc.

Chiswick, July, 1902.

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ERRATA.

Page 46, sixteenth line from bottom: For "above" read "about."

,, 57, seventh line from bottom: For "0·6 to 0·8 per cent" read "0·16 to 0·18 per cent."

,, 94, eighth line from bottom: For "McNiel" read "McNeil."

,, 195, second line from top: For "A and B" read "A and C."

MODERN IRON FOUNDRY PRACTICE.

CHAPTER I.

INTRODUCTION.

WITH the rapid advances made of late years in most departments of the iron and steel industry the foundry can scarcely be said to have kept pace, although the growing tendency towards specialisation, so noticeable in other departments, will undoubtedly affect the iron foundry in the near future, when not only will there be no foundries for general work, but every shop and every workman will be confined strictly to a particular class of work. Moulding machines will be employed in greater numbers and variety, adapted to the work; the purchase of pig iron by analysis will become universal; foundries will be better equipped with suitable appliances for transporting the cupola charges and the molten metal, a system of narrow-gauge tracks extending throughout the entire works, with a more general use of lifts and cranes, advances which have already been made in many of our modern foundries with improved economy, and which, in conjunction, amongst other things, with a more intelligent treatment of mixtures of different kinds of iron, has led to their seldom losing a casting, a habit which is a most important element in the financial success of a foundry. The small iron foundries run in connection with machine shops or steam-engine works are fast disappearing, as it has been found that they could seldom be run profitably and successfully except in the case of large establishments. In these small foundries it was the custom for each moulder to prepare his own sand, according to the class of work that he was engaged upon.

The mixing of the iron was very often only suited to one or two of the more important castings to be made, whilst being totally unsuitable for a large proportion of the work in hand, since only one cupola existed, and records of materials and methods were seldom kept, with the result that antiquated or absurd practices were often repeated. In this connection the author would suggest the use of the camera as a means of recording the successive stages during the progress of any unusually difficult piece of work, so that, in the event of its having to be repeated at some later date, the method previously employed may be inspected and followed, or possibly improved upon.

Of the many branches of the engineering trade, there are few which offer such scope for the exercise of mental power and perceptive faculty as the construction of a mould in which to cast an intricate portion of a machine or engine, and a careful study of the moulder's art by the pattern maker and draughtsman is essential if thoroughly satisfactory work, both technically and financially, is to be produced. And it is all-important that the management staff of the foundry should work harmoniously with the pattern makers, for it is from the pattern rather than from a drawing that the moulder obtains the best idea of what is required, and every facility should be given him to suggest any alterations that will simplify or expedite the moulding. In a consideration of modern iron-foundry practice and its possibilities, we realise at once that indifference is giving way to active research and investigation with regard to the questions of the supply of suitable material and the equipment of the foundries. The old rule-of-thumb method of charging the cupola has given place to the more rational and economical system of weighing all material in correct proportions decided by the chemist, whose advent in the foundry marked a new era in ironfounding, much of the doubt and indecision hitherto existing having ceased, and by aid the satisfactory and successful mixing of different of pig iron, as also the alloying of other metals with to obtain a higher degree of homogeneity, or other uality in the resultant casting, is more easily ed; and not only do we find this more intelligent treatment of mixtures of different kinds of iron making up the cupola charges, but also improvements in the cupolas themselves, more especially with the object of reducing the waste of heat by so arranging the tuyeres as to burn the ascending combustible gases without heating the fuel to incandescence, and thus unduly heating the iron and fuel before it reaches the melting zone. The melting of cast iron by electricity has been successfully accomplished, and it is claimed that by the Taussic system, in which the iron is melted in exhausted chambers by the aid of the electric current, that oxidation and creation of air bubbles are avoided, and further, that the cost of driving the dynamos is only about one-half that of melting the given quantity of iron in the ordinary way; but at the present time the cupola is almost universally employed in the foundry, although the reverberatory furnace finds a place in some foundries, as the metal melted in such a furnace is more pure, since it is not melted in direct contact with the fuel, and consequently does not so readily absorb its impurities, sulphur, &c., as in the case of cupola melting, and further, with the reverberatory furnace there is the possibility, in the event of the metal containing too high a percentage of carbon, of removing part of it by the oxidising action of the flame. On the other hand, it is found that the reverberatory furnace consumes more fuel and produces a higher percentage of waste than does the cupola. The "direct" casting process has not met with very marked success up to the present, yet, with the development of methods of treating the iron in the ladle, the process will probably receive greater attention in the near future. As regards equipment, we find the hand riddle and the upright screen superseded by the swinging and sliding machine riddles, and in many foundries by the revolving screen; machines in endless variety, which, without the aid of costly patterns, will make either spur, bevel, mitre, or worm wheels with great accuracy. The equipment found in the modern cast-iron pipe foundry is such as to render that branch of moulding all but independent of skilled labour; whilst the same may be said of many other classes of foundry work where there is a demand for large numbers of duplicate castings, which are now produced in the several moulding machines with a facility and despatch impossible by the old method of ramming by hand. And last, but not least, as an indication of the prevailing desire on the part of the foundry-man to emerge from the slipshod ways of the past, we have the extending use of the pyrometer in the core oven and drying stove, which will undoubtedly help toward regularity in the quality of production.

CHAPTER II.

MOULDING SAND.

THE sand employed is one of the most important factors in the production of good work in the foundry, and the utmost care should be exercised in its selection. The features which it should possess are—refractoriness, porosity, fineness, and binding power. Refractoriness is ensured by choosing a sand rich in silica, which is practically non-fusible, and as a general rule it will be found that the best results are obtained with a sand containing the largest percentage of silica that it is possible to work, only sufficient alumina or clay being present to give the necessary coherence, and these two elements—silica and alumina—are the only ones necessary in a moulding sand, all others usually found, such as lime, magnesia, and metallic oxides, being more or less detrimental. Theoretically the proportion should be 90 per cent of silica to 10 per cent of alumina. Lime, although present as fine and small particles in moulding sand, will cause rough and unseemly castings, and if present, as it usually is, should not exceed one-half of 1 per cent. An excessive proportion of clay with the sand, either for green or dry sand moulding, will also result in rough castings. The microscope, and a small washing pan, such as is used by gold diggers, are all that will generally be found necessary to determine the composition, the clay being very readily washed out, and the remaining sand weighed, although the expert mostly dispenses even with these simple aids, trusting solely to the feel of the damp sand as he squeezes it up into a ball in his hand, and so determines its quality. In some cases, owing possibly in a great measure to the locality in which the foundry is situated, sand of a strong clayey nature is employed, and this with no small measure of success. In such cases the green-sand moulds are well vented by a free use of the vent wire, and for the heavier castings the bottom of the mould with ashes, and the sides and top with the vent wire. Sand of this strong nature is more suitable for moulds which are to be dried, but the drying must be very thorough, and extend from 3 in. to 4 in. in from the surface, even though it may become slightly burnt on the surface, a condition which will be found to be better for the casting than if the mould is only dried an inch or so in, for in that case no sooner does the heat leave the mould than a reaction takes place, the damp immediately striking to the front, and if filled in this condition a faulty casting is the imperative result. If, however, the cast were made before the heat left the mould, it might be successful, but it will seldom be found possible with a mould of any consequence to close up and make ready for casting before the heat has entirely left it. With the more thorough drying a successful cast may be made when the mould has become dead cold, as the greater depth of sand that has been dried precludes the penetration of the damp in any ordinary or reasonable time that is required to prepare the mould for the process of casting.

Whilst clay is the most usual binding agent used in the preparation of moulding sand, other substances have been suggested and employed; for instance, "jelulose," which is said to consist of the gluten of wheat without the starch, has been successfully used; or again, in the system proposed by F. Patrick,* who endeavours to render any ordinary sand suitable for foundry moulds, tar or liquid asphalte forms the binder. In this process the sand is first reduced to grains of uniform size, and then mixed with coal tar or liquid asphalte. The tar is first heated and mixed with an equal quantity of hot water, this mixture being poured over the spread-out sand, which is afterwards

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* Dingler's *Polytechnisches Journal*, vol. cclxxxiii., page 200.

dried, and may be used for all purposes in the foundry. The proportions which have been found to answer best in actual practice are five parts of tar with five parts of water to 100 parts of sand.

The term "moulding sand," in its broad sense, applies to the floor sand in a foundry, and is generally a natural sand obtained from certain localities, of which Belfast, Erith, Falkirk, Devizes, Worcester, and Derbyshire are some of the principal, although almost any district will yield suitable material, possibly not in the form of a natural sand having the requisite composition, yet, by a careful mixture of the existing materials, a good moulding sand may be produced which will fulfil all the conditions required in practice in its chemical composition, size of grain, and coherence. Most of the natural sands from the localities mentioned above contain from 91 to 94 per cent of silica, with 6 to 8 per cent of alumina, ½ to 2½ per cent of oxide of iron, and about ½ per cent of lime.

In order to keep up the strength of the floor sand a portion requires to be renewed at intervals, more especially in foundries where heavy green-sand work is done, such as girders, columns, &c., when the general body of the sand very soon becomes weak, owing to the presence of burnt sand. This is either done by spreading new sand freely over the floor, or when ramming heavy top parts, using for the purpose one-third new sand, with two-thirds from the floor.

The three principal methods of casting iron in the foundry are—(1) in green-sand moulds; (2) in dry-sand moulds; (3) in loam moulds.

GREEN SAND.

The sand employed for the moulds in the first method is termed *green sand*, from the fact of its being used, in most instances, in a green or natural state. Erith sand is very uitable for this purpose, as it possesses the proper grain for ary castings, and is also found to do very well for light For heavy castings an admixture of ground fireclay roportion of one of fireclay to eighteen of Erith sand es employed for the top parts of the mould, to give additional strength. Belfast sand is largely employed in the Scotch foundries for green-sand moulds, and does very well for the lighter work, but is somewhat weak, so that for heavy castings a sand of a stronger nature is usually mixed with it, and for this purpose rotten rock is extensively used by reason of its great strength, yet openness. The mixtures adopted vary from one of rotten rock to three of Belfast sand for ordinary work, to about equal proportions in the case of exceptionally heavy castings. Strength in a green sand facilitates the work, as a strong sand goes readily into a compact mass, and in the event of a break in the mould its repair is more easily accomplished than with a sand of a weaker nature, but trouble is likely to arise, more particularly with the top parts of the castings, which are liable to become "blown," owing to the strong sand not being sufficiently porous to allow of the free escape of the air and gases generated by the heat of the metal. A free use of the vent wire to the top of the mould will to a certain extent prevent the unwelcome appearance of these small globular holes in the top parts of a casting when the skin is taken off in the planing or other machine. Still, in some instances, a great many of these air globules are undoubtedly contained in the metal itself, and do not become liberated from it until the casting is machined.

Formerly it was the custom to make all heavy castings in dry-sand or loam moulds, but at the present time it is generally recognised that the face need not be harder than in small moulds, and green sand is largely employed, with the practice in some foundries of drying the top of the mould slightly immediately before casting.

In green-sand moulds, the sand which is rammed close around the pattern for an inch or so in is termed *facing sand*, and is a mixture distinct from that used for filling the remaining portions of the flasks ; generally it consists of the green sand with the addition of coal dust, although in some foundries old sand, or sand which has been used several times in moulds from which casts have been made, and is slightly burnt, is added, the mixture being six parts by weight of old sand, four of new sand, and one of coal dust for ordinary work.

The coal dust is added to the sand in order to prevent its fusion, and to burn out so as to vent the mould. The best quality of coal to use is a soft bituminous or gas coal free from slate and phosphorus; the coal dust weakens the sand considerably, but it makes it porous and open, and causes the castings to be very smooth, but without fine impressions, tending rather to destroy the sharp angles.

The proportion of coal dust in the facing sand used for heavy castings requires to be larger than for smaller castings, since the action of the hot metal is continued longer. In the absence of coal dust the molten metal slightly fuses the surface of the sand with which it comes into contact, and the surface of the casting becomes roughened in consequence. The oxidation of the coal dust prevents this burning and consequent roughening of the surface of the casting, as at the high temperature of the mould the carbon of the coal combines with the oxygen of the air, yielding either carbon-dioxide or carbonic oxide, and the thin stratum of these gases in a great measure prevents the direct contact of the metal with the sand, and therefore its fusion.

As a general rule, for light castings, about one part of coal dust to every fifteen parts of sand is the proportion adopted for facing sand, whilst for heavy work one to eight or ten is usual. The mixing must be very thorough, the various proportions required being first coarsely riddled or sifted separately, and again after their admixture.

Where thin, smooth, and sharp castings, such as stove plates and hollow ware, are made in green-sand moulds, soapstone powder has been found a very efficacious means of preventing the burning of the sand, but it must be used with caution, for it is as weak as coal dust, and is liable to spoil the sand of the foundry by making it too weak, and that more quickly than where coal dust is employed, for to a large extent the coal will burn out of the sand, but the magnesia of the soapstone will not. Anthracite dust, if not too fine, is also employed with success in this class of work; if the dust is too fine, it will fill the pores of the sand and [illegible] its object.

DRY SAND.

For *dry-sand* moulds, mostly used for heavy work requiring special excellence and absolute soundness, as, for example, steam-engine cylinders, the sand may be much stronger and closer in the grain than ordinary green sand—which when dried in the stove after the mould is made, or in cases where the mould is larger than the stove will admit, the drying has been done on the foundry floor—is comparatively hard and firm. In fact, only such heavy sands of close clayey texture will bear drying; the green sand mixtures ordinarily used would not retain the necessary coherence, but would become friable and pulverise. Many foundries, more particularly those employing Belfast sand, make their dry sand by mixing rotten rock and dried loam in the proportion of one part of rotten rock to eight to ten parts of dried loam, in the pug mill. The red sand found in Lancashire is very suitable for dry-sand moulds, and is extensively employed. Coal dust is added to the sand forming the face of the mould, as in green-sand moulds, and in many instances horse dung, cow hair, or straw is mixed with dry sand, in order to ensure the moulds being sufficiently open for venting. When horse dung is employed, the undigested hay contained in it becomes partially carbonised, and at the same time the moisture evaporates during the process of drying the mould.

LOAM.

Unlike green sand or dry sand, which are rammed around the patterns, *loam* is wrought in a wet state, and is either struck or swept up with boards, or is daubed around the pattern, that forming the face of the mould being finer than the ordinary building loam, and no coal dust is employed in its composition, which in most English iron foundries is principally Erith sand, or Lancashire red rock sand, with the admixture of old dried loam obtained from moulds which have been used, and cow hair, the proportions adopted being about one part of the old dried loam to five parts of Erith sand, to which is added a good handful of cow hair to give cohesiveness to the loam, these ingredients being all ground up together with sufficient water to give the right consistency in a *loam mill*, care being taken when adding the cow hair to prevent its running into lumps. When the Lancashire sand is used the cow hair is not generally required. In many foundries in Scotland loam is made from sands which are very different in texture and grain to either Erith or Lancashire sand; for example, in the Clyde district a sharp iron sand of a very coarse grain, obtained from the iron districts of the river Clyde, is used, with the addition of clay to impart the necessary binding power. Such a coarse sharp sand loam is necessarily very difficult to work with, but at the same time the drying of the moulds is more easy than in the case of those made with the previously-mentioned loam sands, although great care must be taken that burning of the mould may be avoided, as should this occur a faulty casting is almost sure to follow. A mould which is slightly burnt on the face may often be set right by washing the affected parts with clay water. In more serious cases it may be necessary to pick the burnt portions away and apply fresh loam from the mill in its place, which is a very disagreeable and difficult job, since when dried the moulds are very easily broken. With loam made from these coarse-grained sands, which in some instances even require to be riddled before being put into the mill, there is more difficulty in obtaining a fine and smooth surface to the mould than with other loams; still it possesses some advantage as regards venting, as, being naturally very open, but little special provision need be made, and, further, the metal may be poured when the mould is quite cold, as it does not absorb damp readily, provided there is no trace of salt in the sand, which even in minute quantities becomes a source of great danger, as, after the mould has been dried and the heat has left it, the salt attracts moisture, which is absorbed by the mould after it has been closed and prepared for the cast. The practice adopted in some foundries, although discontinued of late, of passing hot air through the moulds immediately before pouring, would seem to tend towards safety in this respect, although adding considerably to the cost of production.

CORE SAND AND CORE LOAM.

Sand for purposes other than those described above are required by the moulder, and of these possibly that required for making cores is the most important, and needs even more care and skill to be exercised in its choice and preparation than does the sand which forms the outside of the mould For ordinary work, where the castings are of a fair thickness, say from $\frac{5}{8}$ in. to 1 in., common moulding sand is mostly used for making the cores ; but where the metal round about the cores is thin, and the cores themselves are small, they should be made of a weak porous sand, yet not so weak as to be deficient in the necessary cohesive power to enable the core to be properly made and handled. This openness and weakness is necessary where the metal is thin, say from $\frac{1}{4}$ in. to $\frac{1}{2}$ in., because it is important that the air shall pass from the core quickly, for if it does not the metal will not lie upon the core, and a waste casting would be the result. Another reason why the core sand employed for the lighter class of work should be comparatively weak and open is that the cores may readily come out of the casting without excessive hammering. To ensure these results the cores are made from common moulders' sand freely mixed with sharp sand, whilst for very light and thin castings it is the practice in some foundries to add peameal mixed with barm.* In the case of heavy cores and castings having a thickness of over $1\frac{1}{2}$ in., a sufficiently strong sand having the requisite porosity is obtained by mixing the ordinary moulding sand freely with loam which has been used in moulds from which casts have been made, with an addition in some instances of sawdust, and generally of horse dung. The mixture is put into the mill and ground for about a quarter of an hour, which improves its coherence without destroying its porous and open character. Core sand is always damped before use, care being taken not to make it too wet, more particularly for the smaller cores, lest the sand should adhere to the core boxes, and so hinder the preparation of the cores, which in the event of the sand being too moist will come away with

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* Residue obtained in the making of porter beer.

roughened surfaces. Too much dampness in the sand for large cores will prevent its being properly rammed, and also necessitate a needless amount of drying. In many foundries there is at the present time a marked inclination towards the replacement of dry sand by green sand cores, and with a little judicious care in the preparation of the patterns much may be done in this direction. In America, some foundry-men employ practically pure silica mixed with oil for making their cores, and find that smoother and cleaner castings can be made than with other core sands, and at the same time without the use of "core wash" of any kind, as the refractory powers of silica absolutely prevent any burning of the sand; so that it may be used over and over again, as it is not injured by contact with the molten metal, the only change being its discolouration by the burning of the oil, which does not alter its value for subsequent use.

Core loam differs from the fine or facing loam described above only in having sawdust and horse dung added in order to render it more open and porous, and in some instances where there is likely to be difficulty in extracting the cores from the castings, owing to their form and position, charcoal blacking is added with beneficial results, causing the cores to leave the casting very readily; but great care is required when handling cores made of such loam, as they are very easily broken.

PARTING SAND.

Parting sand, as its name implies, is used to prevent the partial amalgamation or sticking of joint surfaces in the moulds which are being rammed one against the other, and for this purpose a loose, friable, and open sand, which, unlike the rock sand, has not been naturally consolidated, is required. Burnt sand scraped from the surface of castings, or new green sand baked in the stove to reduce it to a non-adhesive powder, is, however, mostly employed, although in some foundries sand obtained from the sea beach is used, and prepared as required by pouring a few hand ladlesful of molten metal into a cavity formed in a mound of the sand; other foundries employ finely-powdered blast-furnace cinder, whilst some use brickdust as the parting material, which is always used in a perfectly dry state.

FACINGS, ETC.

Besides the coal dust mixed with the sand employed for the face of green-sand and dry-sand moulds—which, strictly speaking, should possibly not be classed as a *facing*—there are several facings employed in the mould to give a good surface to the casting, of which plumbago is one commonly used, and probably the best. Ceylon graphite is the most suitable quality for all descriptions of moulding in dry or green sand, and should be put on with a fine brush or a lint swab. The graphite is very effective in preventing the destruction of the sand; but, owing to its highly refractory nature, it must not be dusted on in such quantities as to close the pores, and so prevent free exit for the gases. Powdered French chalk, soapstone, and other substances are also employed for facing the mould, but, next to plumbago, oak charcoal is probably the most extensively used, notwithstanding its liability to float occasionally and give a rough casting. For specially light castings, such as stove plates, &c., a double facing is often employed, first a comparatively thick facing of graphite, and then one of a lighter carbonaceous material, such as soapstone.

Loam moulds are sometimes blackened, whilst hot, with a facing composed of equal parts of ground charcoal and plumbago, mixed with lant to the consistency of whitewash, a mixture which is largely used in all classes of moulding as core wash; and in some foundries the practice with green-sand moulds is to first sprinkle them with peameal, which absorbs the dampness of the sand and forms a pasty layer which helps the blacking—oak charcoal dust—to adhere.

Clay wash, made by mixing clay with water, often spoken of as moulders' glue, is used for a variety of purposes, such as cementing core sections one to another, &c.

As previously pointed out, the preparation of moulding sands depends largely upon locality as well as upon the class of work for which they are intended, as not only is it found necessary to prepare green sand, dry sand, and loam mixtures in various grades to suit different classes of work, but also differences of strength or body are often rendered necessary in individual portions of the same mould; so that it becomes difficult to give more than a general treatment of the subject such as the foregoing, for the writer is of the opinion that for some time to come the mixture of sands will continue to be largely a matter of individual opinion and experience, each foundry foreman following the practice which in his experience has yielded the most satisfactory results under the given set of conditions, and which he invariably guards jealously as a trade secret.

CHAPTER III.

THE CUPOLA AND ITS CHARGE.

AT the present time the cupola furnace is generally regarded as the most economical apparatus for the re-melting of cast iron in the foundry, although its management is still far from being under perfect control, and it is the exception rather than the rule that absolutely uniform meltings are obtained, a fact which is largely responsible for much of the uncertainty still existing in iron foundry practice in obtaining uniform results, and it should be the endeavour of all foundry-men to reduce errors resulting from the working of the cupolas themselves as far as possible; more especially where a great many different grades and qualities of iron are dealt with in the foundry, as this in itself is conducive to uncertainty—particularly in cases where chemical knowledge is not brought to bear on the daily working—owing to the great variation in the raw materials supplied to the melter.

Cupolas differ from one another mainly in the way the blast is introduced, the various modifications nearly all turning on an attempt to reduce the quantity of fuel consumed in the re-melting of the pig iron. Theoretically only about 60 lb. of coke should be required to melt a ton of cast iron in a cupola, whilst in practice an average of 200 lb. of coke per ton of iron melted is considered a very good performance. There is very little—at all events, far less than some writers would seem to suggest—in the form of a cupola. The height from the hearth to the charging door should bear some relation to the diameter, which for cupolas of small diameter may be five times the maximum inside diameter, and for those of comparatively large diameter, say 4 ft. and above, four times the maximum diameter is a sufficient height. Any further height above the charging door is of no importance, and is determined solely from the point of view of convenience.

Fig. 1. shows a very common form of cupola, the shell of which is built up of iron plates, riveted together, and lined with a single lining of firebrick, 9 in. thick, a space of $\frac{3}{4}$ in. being left between the iron casing and the lining, which is filled in with a mixture of dry, finely-ground cinder and fireclay, to act as a cushion for taking up expansion and contraction, and so prevent crushing of the lining when the shell contracts. The bricks, which should be shaped to fit the sweep of the circle, are laid dry, and only the thinnest mortar of a composition as nearly as possible the same as that of the bricks is used, and that in the least possible quantity. For ease in clearing the cupola of the residue at the termination of a heat, a "drop bottom," made of iron plates, hinged as shown in the illustration, is fitted, and protected from the action of the molten metal which collects over it by means of a bed of sand, mixed with moist loam, well trodden in, to give it consistency. The depth of the hearth, or the height from the sand bed to the underside of the tuyeres, is usually about 10 in. for all sizes of cupola, although it is found that a less depth gives better results, and allows the iron to be drawn off hotter, an arrangement, however, which is not universally applicable, as where long heats have to be run it is especially important, with some materials, to have a good space between the slag hole and the tuyeres, as when they come close together it brings the slag up to a level, where it is readily chilled by the incoming cold blast, and may eventually lead to the tuyeres becoming choked. The total combined tuyere area varies from about one-tenth of the cross-sectional area of the cupola, inside the

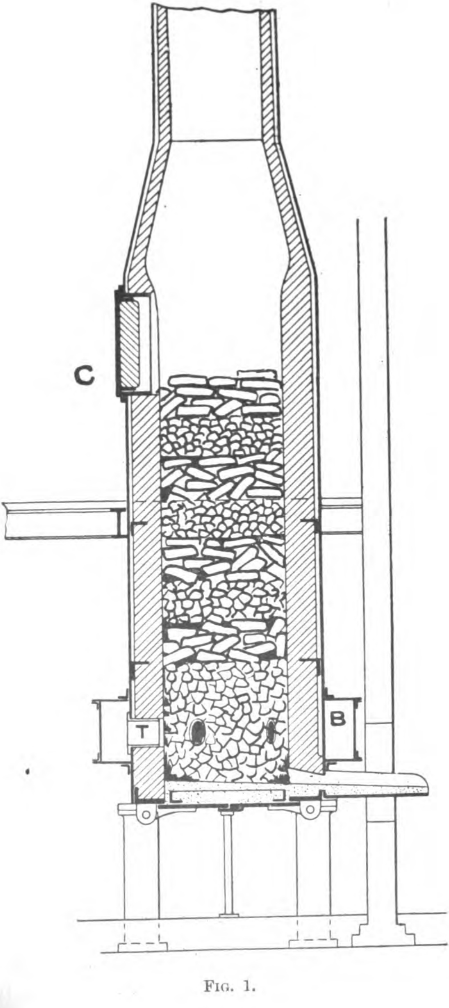

FIG. 1.

lining, in the case of small cupolas, to one-seventh, for those of large diameter; the presssure of the blast usually being from 6 to 8 ounces per square inch in the former, and 12 to 14 ounces in the larger sizes. In some cases the sides of the cupola, instead of being straight all through, as shown in fig. 1, are brought in so as to reduce the diameter about 15 per cent at the tuyere level, the reduction being gradual from the hearth, up; from the tuyere level the sides are carried up parallel nearly as high as the first charge of coke, from which height, upward, the diameter expands to its full value at the level of the charging door, a form of cupola which it is claimed usually produces hotter metal than when the sides are parallel throughout the whole depth of the cupola, from the charging door to the hearth, and, further, that there is less chance of "scaffolding." With the arrangement of wind-box and tuyeres, shown in fig. 1, a reduction in the diameter of the cupola at the tuyeres has been shown by experience to be absolutely necessary in the case of cupolas of 5 ft. diameter and above, because it is not possible to force the blast to the middle of the stock effectively at any greater diameter.

The cupola illustrated in fig. 1 is one of a pair employed in a foundry having an annual capacity of about 3,000 tons of castings. The diameter of the cupola inside the lining is 3 ft. 8 in., and the height from the sole plate to the underside of the charging door C is 10 ft. 10 in.; the charging door is of cast iron lined with firebrick, and is carried by a cast-iron frame bolted to the shell. The blast, which is supplied by two No. 8 Sturtevant fans, is delivered into the annular wind chest B, 20 in. by 10 in., from which it enters the cupola through the tuyeres T, seven in number and 5½ in. in diameter, arranged in one row, their centres being 16¾ in. above the sole plate. The blast, at a pressure of from 8½ oz. to 9 oz., is led to the two cupolas through a main 22in. in diameter, made of galvanised iron, the seams being riveted and soldered to ensure air-tightness. A relief pipe, with a valve opening outwards, and weighted so that it opens when the pressure reaches 14 oz., is fitted on this main. Branch pipes enter the wind chest at two points directly opposite each other, and placed between the tuyeres,

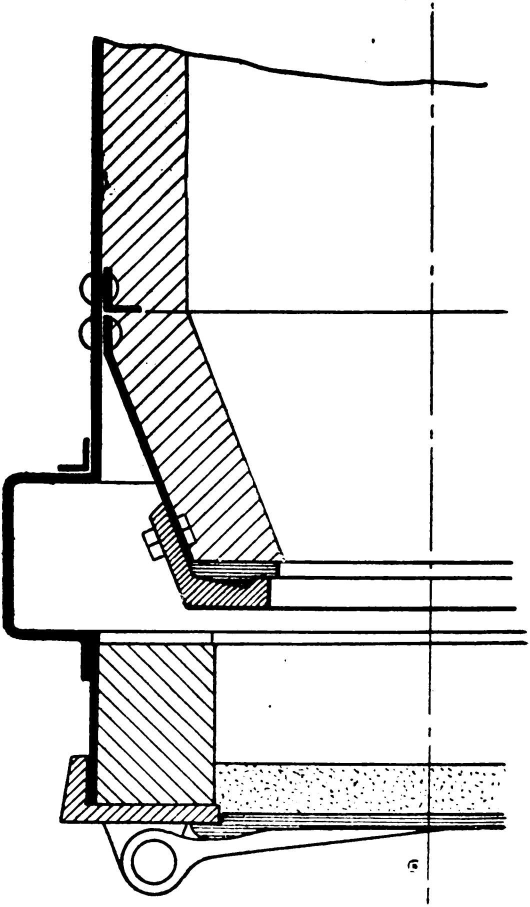

Fig. 12.

and not opposite to any one of them. With these cupolas in daily use, it is found that the linings will last about eleven months, when the first bricks to burn out are those in the zone of fusion, about 1 ft. 6 in. above the tuyeres, and in order to enable repairs to be carried out without disturbing the rest of the lining, angle-iron rings are riveted inside the shell to support the lining at several points.

That the uneven distribution of the blast is the greatest drawback to obtaining the best economy of fuel is now fully recognised, and there is a growing tendency towards the employment of greater volume of blast at reduced pressure, together with arrangements for its better distribution, as a means of economising fuel, and obtaining clean and fast melting. No cupola can ever yield economical and otherwise satisfactory results which does not ensure a fairly-even distribution of the blast, and it is undoubtedly for this reason that many of the earlier types of cupolas, with only one or two tuyeres, failed. With an equal distribution of the blast, we obtain an even descent of the materials, a condition of things which is necessary to consume all the fuel to the best advantage; and, further, the iron will melt at a uniform rate, and, in consequence, its composition is less likely to be modified, and there will be less waste of metal.

Cupolas with flat tuyeres, having a comparatively long narrow horizontal section, generally show better and more regular combustion than those with circular tuyeres, because the space between the tuyeres is largely reduced. In some cupolas, as, for instance, in the Mackenzie cupola, an advance on this has been made, and the dead space between two consecutive tuyeres has been done away with entirely, the air entering through an annular slit, as shown at fig. 2. This continuous tuyere was first introduced some forty years ago, in the Bocard cupola, which was arranged with a crucible carried on wheels, so that it could be run out from under the cupola stack, and used as a casting ladle. The air for combustion entered through a slit between the crucible and the cupola stack.

In a later cupola, the Herbertz, illustrated in fig. 3, the annular opening running entirely round the cupola just above the hearth, may be increased or diminished in width at will, by raising or lowering the hearth by means of screws placed in the columns, and in this way the air may be made to enter in as thin a sheet as may be desired. Unlike most other cupolas, the blast in the Herbertz is induced by means of a steam jet exhauster placed in a flue leading off from the upper part of the cupola. The working of the cupola may be watched at all times through the slot as well as at the sight holes placed above it. These sight holes are provided with covers glazed with thick glass and mica or talc, a ½ in. air space being left between the glass and mica, which is on the inside, preventing the glass from being cracked by the heat. In place of the more usual charging door, this cupola is fitted with a cast-iron counter-weighted bell, which fits into a seat at the bottom of an inverted cone placed over the mouth of the cupola. The feeding is accomplished in the same manner as with a blast furnace, the materials being placed in the cone, and then the bell is raised, whereupon the charge immediately slides down and the bell is replaced. This type of cupola has its advantages where small casts only are made, but in cases where the outrun is to exceed 2½ tons per hour, a much larger cupola will be found necessary for a given outrun than with one of the ordinary form in which blast under pressure is employed. The chief advantages claimed for the Herbertz cupola are small expenditure of fuel in relation to metal melted—some trials carried out at Birmingham showing the relation to be 145 lb. of coke per ton of iron, including that used for lighting up—and in foundries where the cupolas run for days without stoppage the possibility of substituting a newly-built hearth for a burnt one, and lighting the cupola up again for a fresh start with very little loss of time.

The chief difference in the process of melting in a cupola in which the air is introduced as a blast and one in which the air is induced, is that in the former the air enters in a [illegible]ghtly compressed state, whereas in the latter it is drawn [illegible] a a state of atmospheric density only. The consequence [illegible] is difference has been explained by Dr. A. Gurlt, of [illegible] who conducted a series of experiments with the [illegible] cupola erected by Mr. Herbertz, of Cologne, to be

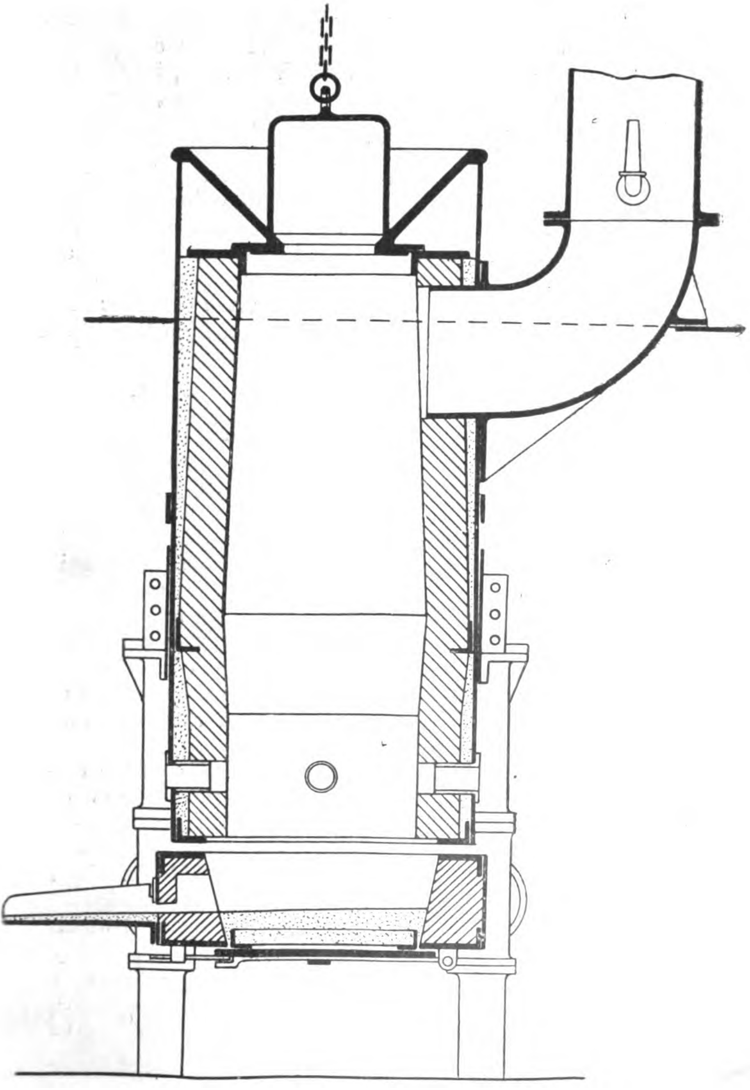

FIG. 3.

as follows: The compressed oxygen of the denser air assimilates itself more energetically and more completely with the carbon of the coke with which it meets, forming at once carbonic acid, which, on rising in the cupola, is partly reduced to carbonic oxide. The consequence of such a reduction is that a very considerable depression of temperature occurs in the upper part of the furnace and the cold materials are imperfectly heated up as they descend to the zone of fusion, whilst combustible gases escape through the stack unconsumed. Turning now to the case of the air entering under atmospheric pressure, the complete combustion to carbonic acid takes place necessarily slower; free oxygen reaches the upper portion of the cupola, causing an elevation of temperature, with the result that the descending materials are in a better condition when they reach the fusion zone. At the same time the carbonic acid which has been formed has no opportunity of being reduced to carbonic oxide before escaping, and thereby carrying off unused any of the elements of the fuel. The Herbertz cupola has been modified by Mr. J. B. Nau, who, finding that the consumption of steam required by his 10-ton cupolas was high, arranged a wind-box round the annular slit, as shown in fig. 4, and so transformed them into "blown" cupolas, still retaining the possibility of regulating the air by raising or lowering the hearth. This he accomplished by constructing the wind-box of thin sheets of steel, in the form shown at C, which, by reason of their elasticity, can be compressed or extended according to the requirements of the blast, and still form a perfectly air-tight joint.

Of the various methods which have been adopted to overcome the difficulty of reaching the middle of the furnace with a sufficient volume of blast to ensure a regular and perfect combustion all over the section of the melting zone, the central blast—the chief exponent of which is Mr. D. West, who arranges his cupola with central blast combined with outside tuyeres, as shown at fig. 5, an arrangement which he claims as being the most economical, although probably a continuous outer tuyere, as in the Mackenzie cupola, and illustrated in fig. 2, combined with a central one, would give ven better results—has received the greatest share of

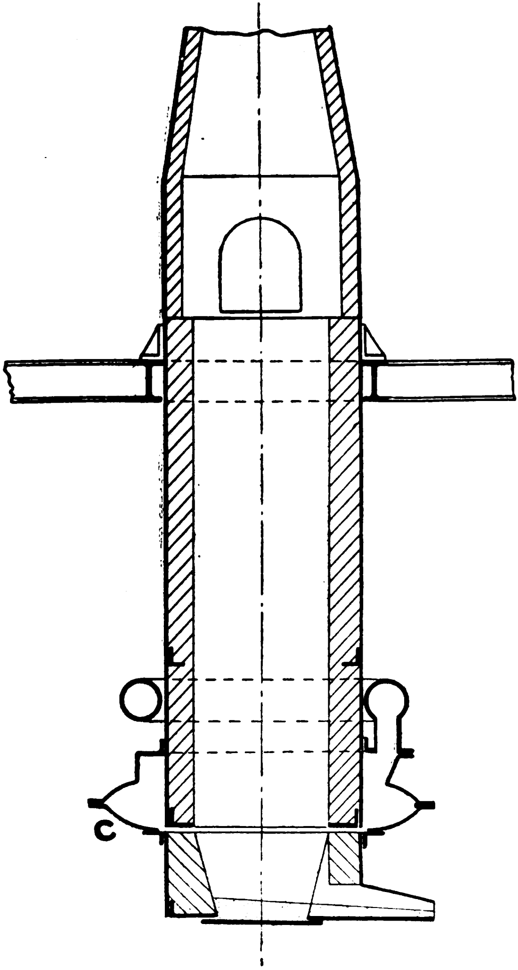

FIG. 4.

attention, more particularly in America. The central-blast cupola has in some instances not given satisfaction, owing to the attempt having been made to work with a central

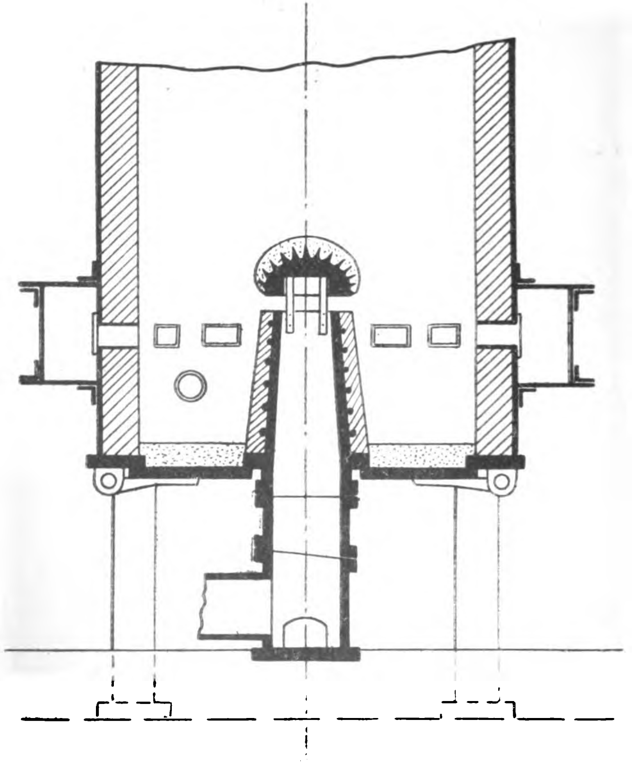

FIG. 5.

yere alone, a plan which should never be adopted where ts have to be longer than one and a half hour, or in olas of more than 4 ft. diameter inside the lining, her running short or long heats. Small cupolas, which do not run longer than about one hour, have been economically worked with central blast alone, but the best results have been obtained with cupolas of large diameter having a central blast combined with tuyeres at the side, the air supply to these and to the central tuyere being controlled by separate valves, and the central tuyere's blast opening arranged at about 3 in. to 4 in. above the level of the top edge of the outside tuyeres.

Mr. West has given the following as the results of working of a 66 in. central-blast cupola, and it may be remarked that the charges were mostly all pig, and that the mixture used was such that the phosphorus did not exceed 0·10 per cent, which calls for a larger expenditure of fuel than if the percentage of phosphorus had been higher, owing to the greater fluidity which an increase of phosphorus can impart to the metal, and, further, that no account has been taken of the coke saved from the "bottom drop," which amounted to 300 lb. to 400 lb. per heat, in calculating the ratio of fuel to iron. The charges were made up of 1,430 lb. of coke and 4 tons of iron on the bed, then 390 lb. of coke between each successive charge of 3 tons of iron. For a 40-ton heat, which was considered to be as small as should be run in this size of cupola, the amount of coke used per ton of iron melted was 171 lb., or in the ratio of 1 of fuel to 13·1 of iron; for a 50-ton charge, 169 lb., or 1 to 13·49; for a 60-ton charge, 161 lb., or 1 to 13·93; and for a 70-ton charge, 160 lb., being a ratio of 1 to 13·97.

Another cupola which has found favour, more especially in foundries where there is a large quantity of light work produced, owing to the extreme fluidity of the iron when melted, is Stewart's cupola, illustrated in fig. 6. It is arranged with a fore hearth between the furnace and the tap hole, as in the "Krigar" cupola, thus admitting of a large quantity of metal being collected and kept hot before being tapped; and has a further advantage in that the molten iron does not remain long in contact with the coke, which results in its taking up less sulphur. This cupola is known as the "Rapid," and has been made to yield some remarkable results in carefully conducted tests, the amount of coke used per ton of iron melted, including the bed, ranging from 137 lb. to 211 lb.

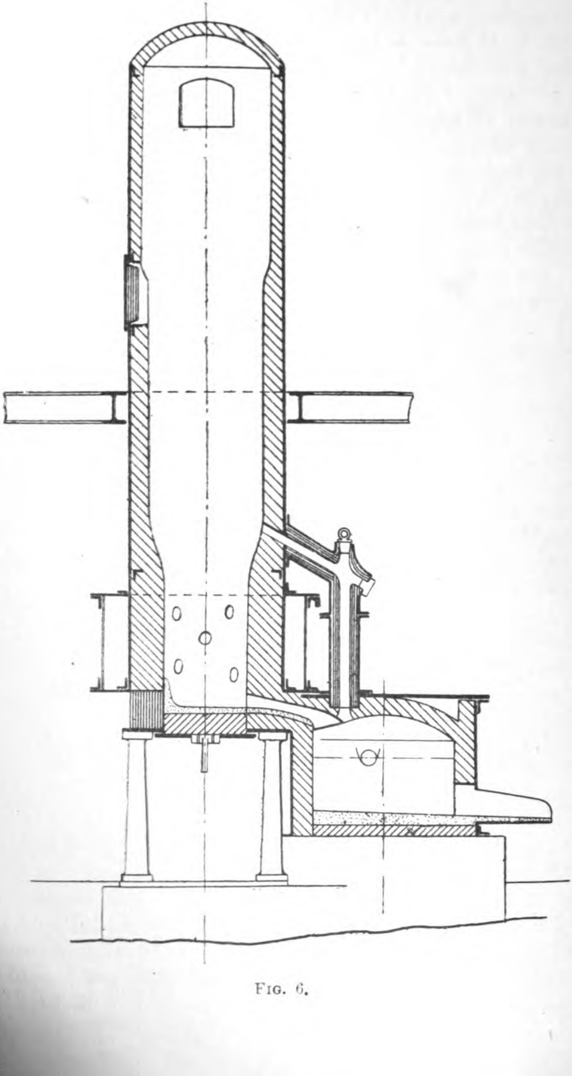

FIG. 6.

The lower figure was obtained as the result of a trial of a cupola having a shell 3 ft. 6 in. diameter, and intended to melt 4 tons per hour. The trial lasted for two hours and thirty-two minutes, from the time the blast was started until it was finally stopped; although, owing to it not being convenient to take away the metal as fast as it was melted, the blast was stopped three times during the trial, so that the actual time that the blast was on was only two hours and four minutes. The total amount of iron melted was 9 tons, and the total quantity of coke consumed was 1,232 lb., including the bed, or a ratio of 1 of coke to 16·36 of iron. The charge was made up of 336 lb. of coke on the bed, then 1 ton of iron, the succeeding charges being 1 cwt. of coke between 1 ton of iron, each 1 ton charge of iron being made up of ½ ton of machinery scrap and ½ ton of Stanton pig. The metal was running down five minutes after the blast was started, and 2 tons were taken off after twenty-six minutes from the time of starting the blast, 15 cwt. nine minutes later, 2 tons after a further twenty-nine minutes, 2¼ tons twenty-eight minutes later, and the remainder of the 9 tons, in hand ladles, before two hours and thirty-two minutes after first starting the blast. The blast was supplied by a No. 3 Roots blower. The pressure during the trial varied from 18 in. of water column (10½ oz.) to 34 in. (19½ oz.), the mean throughout the trial being 26 in. (15 oz.) per square inch, and the volume of air supplied per ton of iron melted was 40,738 cubic feet, and per hundredweight of coke consumed 33,331 cubic feet.

The results of some other trials of "Rapid" cupolas are given on page 28, and probably represent more nearly what may be expected in every-day use.

It will be seen from fig. 6 that the sides of the cupola are brought in so as to reduce the diameter at the tuyere level, and also that there are three rows of tuyeres, the wind box being so arranged that it is possible to shut off the top row at any time. The additional rows of tuyeres are introduced with the object of concentrating the fire at the melting zone into the smallest compass, when the metal in fusion will have to traverse as little space as possible while exposed to the oxidising influence of the blast.

With the cupola of the form shown at fig. 1, it is possible to penetrate the centre body of the fuel to a much greater extent by employing a higher blast pressure or smaller tuyere area at its entrance to the cupola than is usual, but such a practice, especially when coke is used, is very objectionable, and leads to choking of the blast passage at the front of the tuyere by the rapid chilling caused by the high-pressure cold blast. Excessive blast causes faster melting, but it burns out the softener and generally produces colder iron, whilst hot blast is in very few instances practicable, owing to the cupola being only intermittently at work, and so does not afford the same facilities for utilising the waste heat passing off from the top as does the blast furnace, although various attempts have been made in this direction, in one of which the air supply to the cupola was heated on its way from the fan or blower by causing it to pass through a coiled pipe placed in the stack, immediately above the charging door, whilst in another, with cupolas fitted with a fore hearth, the blast was heated during its passage through a

Rated capacity of cupola, per hour.	Total amount of iron melted during trial.	Actual rate of working on trial, per hour.	Mean pressure of blast.	Cubic feet of air per ton of iron melted.	Pounds of coke (including bed) per ton of iron melted.	Pounds of coke used for bed.	Time elapsing between starting blast and metal first running down.	Pounds of iron melted per pound of coke.
Tons.	Tons.	Tons.	Ozs.				Mins.	
5	10·0	5	12¾	36775	182	504	10	12·32
6	13·0	5·6	11	30526	163	588	5	13·70
3	4·0	2·35	6¾	44178	202	406	8	11·0
5	12·0	6·0	11	42793	199	672	5	11·23
8	13·25	5·45*	11	40486	211	672	10	10·6
5	9·62	3·05†	14	41275	170	340	8	13·11

* For about one-fifth of the time of trial only one-half blast power was available.

† Half blast power only during 55 per cent of trial.

coiled pipe P (see fig. 7), which was connected to the blast main at one end, and to the wind chamber W at the other. The pipe P was placed within the receiver for the molten metal H, the gases passing from the furnace into the receiver, escaping through the pipe N, and entering the furnace at K. The fact that the gases escaping from a properly-working cupola are at a much less temperature than those passing off from a blast furnace also minimises any advantage that may be sought by such means as the above. The intermittent working of the cupola also militates against economy

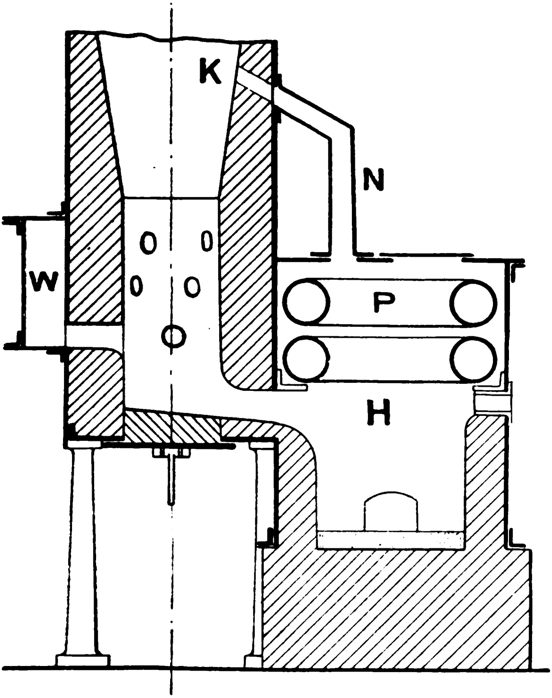

Fig. 7.

of fuel, as the cupola has to be lit up very frequently, an operation which consumes a fairly large proportion of the fuel used; yet it is not desirable to use too little fuel in starting up if we wish to ensure the casts being good from the commencement, nor is it wise to attempt too great economy in the fusion coke, as any excess fuel exerts a protective action in the chemical changes which take place in the cupola. The iron as it descends in the cupola is gradually heated up to the melting point, and in the molten state is exposed to the chemical influence of the ascending current of air and gases from the moment the iron begins to melt until it has fallen into the hearth. The free oxygen combines with some of the constituents of the metal; iron, silicon, and manganese are oxidised, whilst some of the carbon may also be eliminated, and in the event of too little limestone being present sulphur may pass from the fuel into the iron. The shorter the distance from the zone of fusion to the hearth, and the greater the quantity of fuel and its products of combustion present, the better will be the protection afforded to the iron from the action of the oxygen of the blast. To obtain satisfactory results with a low consumption of fuel invariably necessitates the employment of pig richer in silicon and manganese than would otherwise be necessary, so that it becomes a question as to whether the saving in fuel is not more than counterbalanced by the extra cost of the superior metal.

As regards the fuel employed, coke is most general, although some foundries use coal alone in the cupolas, whilst others use coal for the bed, and afterwards charge coke with the iron. The coke should be hard, and of good quality; in fact, it is generally held that the best obtainable is none too good for the purpose of melting iron, and will prove to be the cheapest in the end. It should not contain more than 0·75 per cent of sulphur. Coal, for use in the cupola, should be an anthracite, bright, hard, and entirely free from slate. It should be carefully sized before use, as on 's its successful employment largely depends. For small olas, the size known as "egg" should be used, whilst for cupolas "lump coal" may be employed.

hen melting iron with coke in a cupola, it is necessary to add some fluxing material in order to impart fluidity to the ash of the coke, and enable it to be run off the surface of the molten iron in the form of slag, care being taken, however, when the slag hole is used not to allow the whole of the slag to clear off the molten iron, and so expose it to the oxidising effect of the blast. For this purpose, limestone is most generally used, preferably chips from a white-marble yard, although some foundry-men use oyster shells, which, if used in sufficient quantity, form a thin fluid slag. When limestone is the flux adopted, the quantity fed in usually averages from 15 to 20 per cent of the weight of coke charged, and it is better to err on the side of too much rather than too little, as an excess of lime does no harm, except making the slag rather more pasty, whereas too little may cause sulphur to pass into the iron. The limestone must be added with every charge of coke, including the bed, as if this is not done the first metal tapped will have taken up sulphur, &c., from the coke, and be bad. The lime, besides imparting fluidity to the refuse matter in the cupola, has a tendency to absorb the sulphur from the iron as it drops down in a molten state through the slag. Everything that is possible should be done to keep the iron free from sulphur, for it is practically impossible to make castings free from blow holes when the metal contains 0·10 per cent, and since ordinary foundry pig rarely has more than 0·06 per cent of sulphur in its composition—the more usual figure being less than one-half this amount—it is to the fuel we must look as the principal source of danger, and for this reason the greatest care should be exercised in its selection.

Turning now to the raw material with which the foundryman has to deal, pig iron, which is a very impure form of iron, is obtained by smelting iron ores in the blast furnace, and seldom contains more than 93 per cent of iron, the remainder being foreign elements such as carbon, silicon, manganese, phosphorus, sulphur, &c., some of which are essential in order to render the material suitable for making castings, whilst others may cause it to be totally unsuitable for the purpose. For instance, carbon is absolutely essential in foundry pig, and usually exists in two forms—*i.e.*, as graphite and as combined carbon, the former being "free," whilst the latter is in chemical combination with the iron, &c. The graphite does not influence the quality of the iron to any very great extent; what little effect it does have is to weaken the iron. The existence of the carbon in the pig iron in these two forms may be explained briefly as follows: When the iron is tapped from the blast furnace, being in the liquid state, all the carbon is held in combination, but on solidifying the equilibrium is disturbed, and the iron is no longer able to retain the whole of the carbon present in combination, with the result that some of it is liberated, and not being able to escape from the solidifying mass, it remains entrapped, and can be distinctly seen at the fractured surface of a pig as black flakes. The greatest amount of carbon which iron can absorb under normal conditions in the blast furnace is a little over 4 per cent. The amount usually present in the pig is about 3½ per cent, and on how much or how little of this exists in one or other of the possible forms depends the quality of the iron.

If a large percentage of this total carbon exists as graphite, the metal will be soft and weak, whilst a low percentage of graphite, with a corresponding high percentage of combined carbon, renders the iron hard and brittle. This subdivision of the carbon is influenced in a remarkable degree by the presence of silicon, which lowers the saturation point for carbon, and causes graphite separation, and softens the iron. This effect is, however, inappreciable if the carbon present is only about 1 per cent, when several per cent of silicon may be present before the graphite can be observed, and even then softening of the iron may not result, as silicon when by itself or in excess has a hardening effect, although not nearly so great as has combined carbon. Graphite has no hardening power whatever, so that silicon when present in moderate and suitable quantities in foundry pig is an advantage when soft and grey metal is desired. How greatly the silicon influences the separation of graphite from pig iron is shown by the diagram, fig. 8, giving the results of experiments with iron having from 3¾ to 4 per cent of total carbon, from which it will be seen that with 1·76 per cent of silicon present 84·5 per cent of the total carbon existed as graphite, whilst when the silicon was increased to

2·41 per cent the percentage of carbon as graphite was nearly 93.

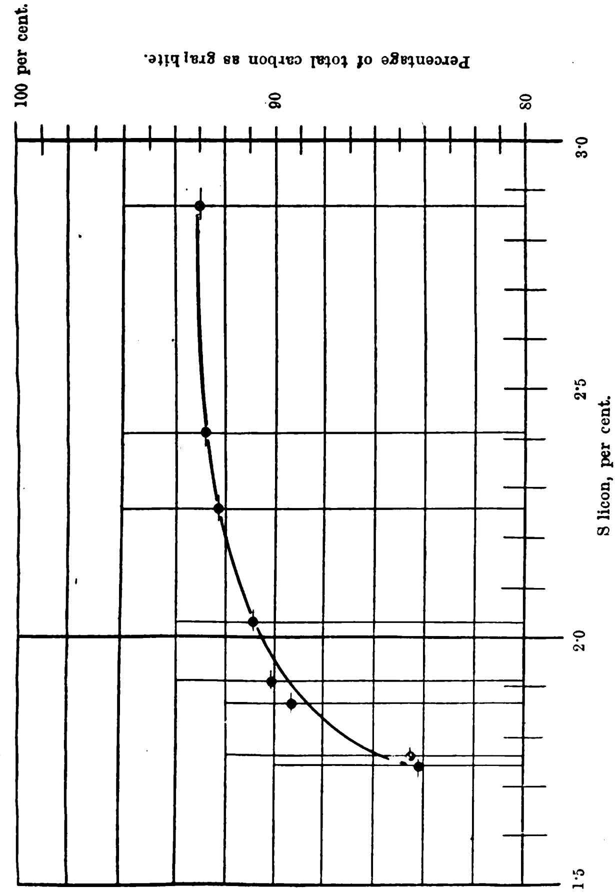

FIG. 8.—Diagram showing the influence of silicon in the separation of graphite from pig iron.

As has already been pointed out, silicon has both a direct and an indirect influence on the iron; the former being to harden it, if the indirect influence, causing the separation of the carbon as graphite and consequent softening of the iron, does not predominate, which will generally be the case for all percentages of silicon up to 3 per cent, above which the direct hardening action will predominate. This influence of silicon on the hardness, and also on the tensile strength of cast

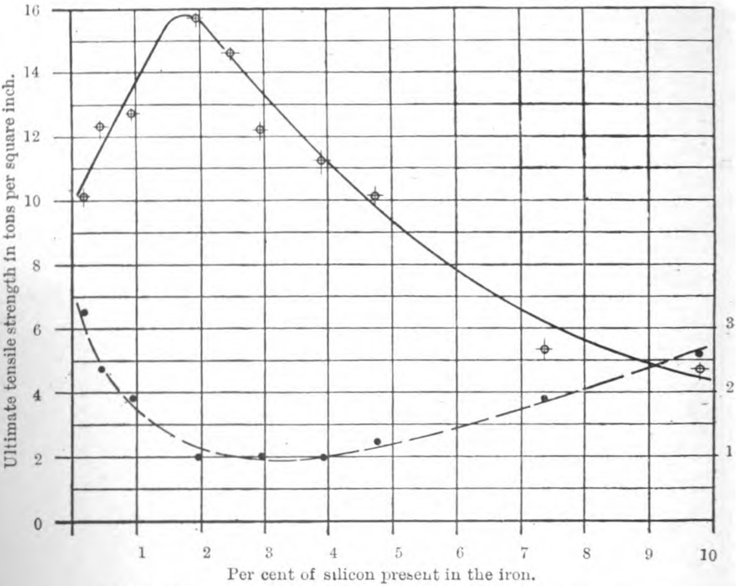

FIG. 9.—Diagram showing the influence of silicon on the tenacity and hardness of cast iron.

iron, is well shown by the diagram, fig. 9, giving the results of some experiments conducted by Mr. T. Turner, published in the *Journal of the Chemical Society.* Silicon also has a marked influence on the permeability of cast iron, as shown by the B—H curves, fig. 10, giving the results of xperiments with cast iron containing 3·5 per cent of silicon, d also when only 1·8 per cent of silicon was present. It found in these experiments that the addition of silicon between these limits always increased the permeability of the iron, the increase following the straight-line law for inductions up to 8,000. As regards the influence of silicon on the transverse strength of cast iron, the diagram, fig. 11, gives the results of a series of experiments carried out by Mr. W. J. Keep, the test specimens being ½ in. square bars, which were placed on supports, 1 ft. apart, and loaded at the centre with a weight gradually applied until they fractured. The values of these breaking loads are shown by the figures to the left of the diagram, whilst the corresponding value of the percentage of silicon present in the test bar is given at the base. The variation in the silicon contents was obtained by the addition of ferro-silicon containing 16·32 per cent of silicon and 0·62 per cent manganese, so that 0·04 per cent of manganese was added with every 1 per cent increase in silicon, which is probably too small a quantity to appreciably affect the results; the other constituents of the iron remained practically unaltered, as the ferro-silicon was so high in silicon that the amount used was not sufficient to vary to any extent the sulphur, manganese, or the phosphorus. Although the presence of other foreign elements may exert modifying influences, it will generally be found that grey

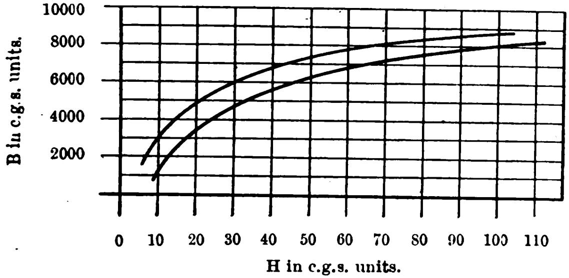

FIG. 10.—Diagram showing the influence of silicon on the permeability of cast iron.

NOTES.—The upper curve gives the result with cast iron containing about 3·5 per cent of silicon; the lower curve with about 1·8 per cent of silicon; B is the induction; H is the magnetising force; and $\frac{B}{H}$ = the permeability of the iron.

irons, in which the percentage of graphite is large, will be rich in silcion, and in white iron, containing but little graphite, the percentage of silicon will be low; facts which have led to the suggestion that pig iron should be graded according to the percentage of silicon it contains, as being the nearest approach practicable to the ideal method in which the combined carbon would form the basis of the grading. The influence of silicon on cast iron, having regard to the properties required, has been investigated by Mr. Turner, who found that for any given property an advantage was gained by increasing the percentage of silicon from 0 per cent up to a certain definite value, given below, and that beyond this amount any further increase was disadvantageous to the particular property desired, the detrimental effect of small excesses usually being large. Silicon reduces the melting point of the iron, but not so much as does carbon.

The following are the figures given by Mr. Turner as being the best percentage of silicon to ensure maximum value for different desired properties in the iron :—

	Per cent of silicon.
For maximum tensile strength	1·8
For maximum crushing strength	0·8
For maximum general strength	1·42
For maximum modulus of elasticity	1·0
For greatest softness and general working qualities	2·5

Of other elements usually found in foundry pig iron, manganese counteracts the effect of silicon, since it increases hardness and brittleness by preventing the separation of graphite, and when present in large quantities it raises the melting point of the iron. Manganese increases the saturation point for carbon. Sulphur reduces the saturation point for carbon, acting in a similar way to silicon, but has an opposite effect to silicon as regards the separation of graphite. Iron containing silicon or sulphur never contains as much carbon as the maximum for the particular kind of iron. These elements replace carbon nearly in the ratio of their atomic weights, thus one part of silicon replaces three-sevenths of carbon, and one part of sulphur three-eighths of carbon. Sulphur lowers the melting point, and tends to produce low carbon, white, metal when in large quantities, an influence which is quite perceptible when but a few tenths of one per cent of sulphur are present in the iron. Phos-

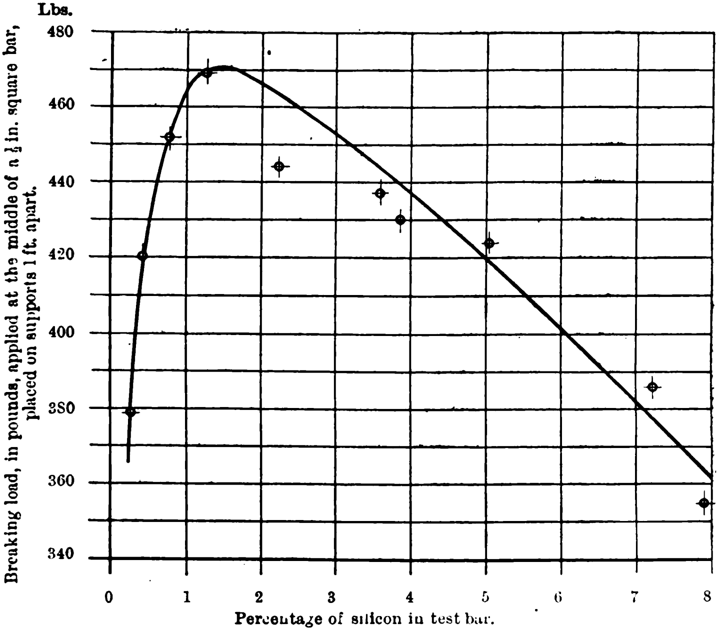

Fig. 11.—Diagram showing the influence of silicon on the transverse strength of cast iron.

Note.—The iron used as the base in these experiments was a charcoal iron made in a blast furnace, and having the composition:—

Total carbon per cent.	Graphite per cent.	Silicon per cent.	Phosphorus per cent.	Manganese per cent.	Sulphur per cent.	Iron by difference per cent.
2·98	0·95	0·186	0·26	0·09	0·03	96·454

The increase in the silicon was obtained by the addition of ferro-silicon containing 16·32 per cent silicon and 0·62 per cent manganese.

phorus increases the fluidity and hardness, but not to the extent that carbon does. The increased fluidity delays solidification, and allows more time for the separation of the graphite, and since silicon is the most active element in separating the graphite, an iron rich in silicon may contain a larger percentage of phosphorus than one low in silicon; also, owing to the manganese and sulphur preventing the separation of graphite, the more manganese or sulphur present the greater the amount of silicon required to produce graphite, and, further, it is generally found that pig iron when highly manganiferous has a tendency to readily absorb large quantities of gases which may cause blow holes if very special precautions are not taken when making the cast.

The only way to obtain reliable and useful information concerning the effect of the various metalloids on the carbon in giving characteristic qualities and in changing the grade of the iron, is to deal with actual practice, since physical conditions in founding may often affect the character of iron or the condition of its carbon quite as much as alterations in its chemical composition. Tests of crucible-melted iron are of very little practical use so far as advancing our knowledge of the effects of metalloids is concerned. A careful study of the working of blast furnaces shows us that silicon and sulphur are almost wholly responsible for the variation in the grade of the iron produced from similar mixtures of ore, fuel, and flux, since the total carbon, phosphorus, and manganese generally remain practically the same in successive casts, what little variations may occur in the percentage of manganese or phosphorus will at all events not be sufficient to change the grade or character of the iron, although, even when the greatest care is exercised to ensure all the conditions being alike, no two casts will be identical as regards the amount of silicon and sulphur contained in the iron produced. This being so, we may look to the furnace-man to supply either a high, medium, or low manganese, or phosphorus iron, since he is fully able to control the percentages of these elements in his iron by his mixtures of ores, fuel, and flux; and by a careful selection and sorting of the pigs, according to the percentage of silicon and sulphur they contain, he can supply various irons, to comply with particular analyses, as asked for by the foundry-man.

Until quite recently little attention was given to the chemical composition of the pig iron supplied to a foundry, the quality of the iron being judged by the appearance of the fracture when broken cold, although many founders prided themselves on being able to judge of its quality from its appearance when in the fluid condition as tapped from the cupola. A further supposed guide to its quality was the difficulty or ease with which it was possible to break the pigs in halves with a sledge hammer. If the crystalline structure of the fracture appeared of a medium grey colour, with a close and compact grain, and a bright metallic lustre, the iron was generally judged to be strong; if, on the other hand, it presented a very dark colour, with the absence of lustre, it was usually considered to contain too much graphite, and to be weak; whilst if the grain were very large and spongy, the iron would be considered to be soft, with, in all probability, a large percentage of sulphur in its composition. Foundry pig iron, including the four or five grades of grey iron, and sometimes mottled iron which is used for chill castings, is usually cast in sand moulds, which has been the cause of a deal of confusion in the foundry, owing to the fact that it is possible to obtain a fracture of a particular kind, even with metals of very different nature, by adjusting the rate at which the pigs cool down after casting. In this way it is quite possible, even with a pig iron containing not more than 1 per cent of silicon, to obtain a fracture showing a very coarse grain with a deep grey colour, provided the carbon is high and the manganese low, by allowing the pigs to cool slowly, as, for instance, under a covering of slag. Taking the percentage of silicon present as being a fairly trustworthy indication of the quality of the iron, Mr. O. Simmersbach has shown by analytical results how greatly one may be deceived in judging by the size of the grain the quality of foundry pig iron. The results of his investigations were as follow:—

Pig iron.	Percentage of silicon contained.	Nature of grain.	Pig iron.	Percentage of silicon contained.	Nature of grain.
1	2·07	Very coarse.	6	1·70	Very coarse.
	2·01	Almost fine.		1·96	Somewhat coarse.
2	1·94	Somewhat coarse.	7	1·86	Fine.
	1·72	Coarse.		1·83	Coarse.
3	1·82	Both somewhat coarse	8	2·51	Fine.
	2·43			1·85	Somewhat coarse.
4	1·59	Coarse.	9	2·17	Fine.
	1·67	Fine.		1·85	Coarse.
5	1·40	Both coarse.	10	1·94	Both coarse.
	2·06			3·06	

By casting the pigs in iron moulds the iron would be cooled down to such an extent that a very coarse-grained iron would never result, while an edge of white iron would always be formed next the mould, the relative thickness of which would admit of a very fair judgment being formed as to the amount of manganese and silicon present, and generally, the tendency shown by the iron to harden. Some further advantages in favour of the employment of iron in place of sand moulds are, (1) that the pigs are free from adhering sand, in consequence of which less limestone will be necessary in the cupola; (2) the pigs are more brittle, and consequently more easily broken; and (3) they are more fusible, and so require less fuel in remelting in the cupola than do pigs which have been cast in sand. It is claimed by some that by using chilled pig a greater loss by oxidation would be incurred, as the sand scale adhering to the pigs affords protection to the iron against oxidation or its burning away while being brought to the liquid state, but further experiment is necessary before any objection on this score can be said to be well founded, as the determination of the actual amount of iron lost in a foundry presents so many difficulties as to be almost impossible. In buying pig iron, makers generally allow about 260 lb. per ton for scale and sand, but how much of this is actual refuse no one can determine accurately; then again, scrap very seldom comes to the foundry clean, shop tools cast almost daily, very seldom appear in the returned weights, so that any attempt to keep a close record of the losses generally proves unreliable. There can be little doubt that the only true guide in estimating the value of pig iron for use in the foundry is its chemical composition. It has been suggested that the appearance of the fracture combined with a knowledge of the silicon contents is all that should be required to enable the founder to produce satisfactory results. This is undoubtedly better than the old method, where even the amount of silicon was unknown, and the cupola charges were made up of a mixture of different brands of pig, in the hope that by so doing the risk of improper selection might be minimised, yet since the other metalloids usually present may exert an important influence on the quality of the iron, it is becoming customary to demand a complete analysis of all iron delivered to the foundry, but before even such a practice can be regarded as entirely satisfactory, some standard method of taking the sample, and also of making the analysis, must first be decided upon. The extreme importance of this latter condition is well shown by some data furnished by Mr. T. D. West, of the variations in the returns of different analyses made on the same sample of various descriptions of pig iron. The maximum variations in eighteen sets of analyses were as follows: Silicon, 0·27 per cent; sulphur, 0·0155 per cent; phosphorus, 0·114 per cent; manganese, 0·23 per cent; graphite, 0·77 per cent; combined carbon, 0·50; and in the total carbon, 1·09 per cent; and although much of the difference may be due to the method of taking, and in preparing the samples, still there is little doubt that it does not altogether arise from this cause, but is in some measure caused by variations in the method of making the analysis. Some further results cited by Mr. S. B. Marshall, of determination of the phosphorus and sulphur in similar samples of pig iron, made by twelve chemists employing several different methods are given below, and go to show how necessary it is to exercise care and caution in the matter, for if such differences as these occur in carefully conducted analyses, we at once realise that serious trouble may arise in the foundry by a careless chemist giving inaccurate results, or by accepting analyses which have been made by the aid of the many different rapid methods in the rush of every-day furnace practice.

Determinations of Sulphur.

Method employed.	Average per cent.	Highest per cent.	Lowest per cent.	Difference between highest and lowest per cent.
Evolution	0·049	0·053	0·044	0·009
Aqua regia	0·052	0·058	0·0454	0·0126

Determinations of Phosphorus.

Volumetric	0·355	0·400	0·350	0·050
Magnesia	0·352	0·356	0·350	0·006
Yellow precipitate....	0·347	0·400	0·325	0·075

As regards the question of taking the sample, the very commonly adopted method of drilling into the fractured end of a pig and collecting the drillings is unsatisfactory, as it is known that drillings from different pigs in the same cast, and even from different parts of the same pig, may differ considerably in composition, for the elements are so unevenly distributed on account of segregation, that it is possible that in two samples of drillings, even though they were taken from the same hole in a pig, may give widely different composition on analysis, and even with a test bar of 1 square inch section there is time for the chemical elements to concentrate in patches in this way, and for this reason: the practice followed in some foundries and ironworks, of casting four small test ingots by taking ladles full near the beginning and end of the tap, equal portions of fine drillings from each of which being mixed together and taken as the sample, is not altogether satisfactory. Probably the following method will give as near an approximation to the true composition of the metal as any, and is at the same time cheap and easy of accomplishment. The method referred to consists of granulating the sample by pouring from a shallow ladle, through coarse wire gauze, into water, segregation being prevented by the sudden cooling, and all the elements are more likely to be evenly diffused. Clean well formed shot under ¼ in. in diameter only should be selected in making up the sample, and should be pulverised in a steel mortar until the particles will pass through a 100-mesh sieve.

Another very important consideration governing the value of a pig iron for foundry purposes is the amount of scrap that may be admixed with it without the resulting castings being hard and brittle, and since some silicon and graphite is lost with every additional melting, the resulting scrap requires the addition of pig richer in silicon. The amount of scrap produced in a foundry will depend largely on the nature of the work produced; for instance, in a foundry turning out small castings only, the scrap may be as much as 50 per cent of the iron melted, whilst in others employed on heavy work, the yield of castings may be as high as 80 to 95 per cent. Commercially, it is important to use as much of the scrap as possible, and generally scrap is sought for outside, since it is very much cheaper than pig iron. Since foundrymen have come to regard silicon as a valuable softener, it has become a practice in some foundries to keep on hand a supply of ferro-silicon containing 10 per cent of silicon, for use in certain classes of work, in order to bring the silicon in the castings up to a certain desired percentage, and it is claimed that with this and a small supply of ferro-manganese, to ensure sound castings, and employing a coke containing less than 0·75 per cent of sulphur, any desired kind of casting can be successfully produced. If, however, a good brand of pig is used, there will generally be found little need for the employment of this ferro-silicon, unless a large proportion of inferior scrap is used, as the tendency of modern blast-furnace practice is to increase the percentage of silicon in the iron. This will be seen from the following typical analyses of Scotch foundry pig irons :—

	Carron.	Glengarnock.	Gartsherrie.
Total carbon	3·57	3·75	3·20
Combined carbon	0·10	0·25	0·20
Graphitic carbon	3·47	3·50	3·00
Silicon	2·42	3·50	2·70
Manganese	1·18	1·75	1·20
Phosphorus	0·73	0·90	0·70
Sulphur	0·05	0·03	0·02
Iron by difference	92·05	90·07	92·18

No very general system of grading pig iron by analysis has so far been adopted, some foundrymen classifying it more particularly by the percentage of silicon it contains, and others by a full analysis. With the former the grading is somewhat as follows :—

No. I., with a high percentage of silicon (2·5 to 3·25 per cent).

No. II., No. I. with less than 3·5 per cent of carbon, or No. III. with about 1 per cent of manganese.

No. III., with an average percentage of silicon (1·75 to 2·5 per cent).

No. IV., No. III. with less than 3·5 per cent of carbon, or No. V. with about 1 per cent of manganese.

No. V., with a low percentage of silicon (below 1·75 per cent).

Other foundries adopt a classification for pig irons containing 3·5 to 4 per cent of carbon, as follows :—

	I.	II.	III.
	Per cent.	Per cent.	Per cent.
Silicon	Not less than 2·5	Not less than 1·9	Not less than 1·5
Manganese..	0·20 to 0·50	0·40 to 1·00	0·50 to 1·20
Phosphorus.	0·50 to 0·80	0·50 to 0·80	0·50 to 0·90
Sulphur	Not exceeding 0·03	Not exceeding 0·035	Not exceeding 0·045

Those foundrymen who prefer to have complete analyses vary considerably in their method of grading, although in a general way, the following may be said to present the views of many :—

No.	Total carbon about, per cent.	Graphitic carbon about, per cent.	Combined carbon about, per cent.	Silicon about, per cent.	Manganese about, per cent.	Phosphorus about, per cent.	Sulphur about, per cent.	Typical purposes for which iron is employed.
I.	3·50	3·20	0·30	2·75	0·60	0·60	0·015	Pulleys and small machinery castings.
II.	3·50	3·30	0·20	3·00	0·50	0·80	0·010	For carrying harder pig iron or scrap, and for choice light hardware castings, &c.
III.	3·30	2·90	0·40	2·40	0·60	0·60	0·020	For heavy machinery castings, &c.
IV.	3·30	3·00	0·30	2·60	0·50	0·80	0·015	For carrying harder iron, and for light machinery castings, stove plates, &c.
V.	3·30	3·00	0·30	2·50	0·30	0·90	0·020	General use.*

* It is in this grade that the greatest variation in the specification occurs.

When making up the cupola charge to produce a metal best suited to a particular purpose, it is necessary—(1) to know the mechanical characters of the material most suited for the particular application ; (2) the chemical composition which, under suitable conditions of moulding and casting, will yield that material ; and (3) to so mix the pig iron, the approximate composition of which is known, as to give the required result. It is not possible to give here the composition which experience teaches to be best for all the multifarious uses to which cast iron is put, although in a general way it will be found that a soft iron casting, the transverse breaking load for a test bar from which 1 in.

square, loaded at the middle between supports 1 ft. apart, is 2,000 lb., the shrinkage on a length of 1 ft. is not less than 0·14 in., and the chill not over 0·05 in., would probably contain from 2·2 to 2·8 per cent of silicon, the sulphur would not exceed 0·085 per cent, the phosphorus would be not less than 0·70, and the manganese would not exceed 0·70, the percentage of silicon varying with the general thickness of the casting somewhat as follows: in castings less than ½ in. thick 2·5 to 2·8 per cent; ½ in. to ¾ in., 2·3 to 2·6 per cent; and in castings about 1 in. thick, 1·9 to 2·3 per cent. A medium iron, a test bar of which 1 in. square, placed and loaded as above, would support 2,200 lb., the shrinkage on a length of 1 ft. being not under 0·15 in., and the chill not over 0·15 in., would on analysis show silicon 1·40 to 2·0 per cent., sulphur not over 0·085 per cent, phosphorus not less than 0·70 per cent, and manganese not above 0·70 per cent; whilst a hard iron supporting a load of 2,400 lb. at the middle of a 1 in. square test bar placed on supports 1 ft. apart, and showing a shrinkage on a length of 1 ft. of not less than 0·16 in., and a chill not over ¼ in., would probably contain from 1·2 to 1·60 per cent of silicon, and not more than 0·095 per cent of sulphur, the phosphorus would be above 0·70 per cent., and the manganese below 0·70 per cent. For chill castings special iron has to be selected.

For the manufacture of chilled rolls, what is known as a close No. 5 cold-blast Staffordshire pig iron is largely used, and is perhaps the nearest approach to an ideal pig iron for the purpose. Other cold-blast brands of Wales and Yorkshire are probably almost as good, but their price is generally higher. The average analysis of a good No. 5 Staffordshire cold-blast pig is a follows: Silicon, 1·12 per cent; sulphur, 0·10 per cent; phosphorus, 0·48 per cent; manganese, 0·65 per cent; graphitic carbon, 2·4 per cent; and combined carbon, 0·55 per cent. For casting chilled car wheels, a leading American railroad foundry employ a mixture of one-fifth pig iron with four-fifths old chilled wheel scrap, the composition of the pig iron being :—

Total carbon	4·60 per cent.
Graphite	3·70 ,,
Combined carbon	0·90 ,,
Silicon	1·73 ,,
Phosphorus	0·24 ,,
Sulphur	0·08 ,,

The chilled wheels, on analysis, show the following composition :—

	Hard surface.	Unhardened interior.
	Per cent.	Per cent.
Graphite	0·16	2·55
Combined carbon	3·75	1·40
Silicon	0·54	0·60
Phosphorus	0·33	0·37
Sulphur	0·10	0·35

It is generally found that the metal charged into the cupola for producing chilled castings should be richer in graphite, silicon, and manganese, and have less combined carbon than is required in the finished product, although when present in quantities less than 1 per cent; phosphorus and silicon remain practically constant, whilst some of the manganese always disappears. The total carbon remains the same, but the proportions existing as graphitic and as combined may vary considerably.

Mr. Henderson, in a recent paper on "The Manufacture of Car Wheels," gives the following limiting values for the chemical constituents of wheels :—

	Graphite	Combined carbon.	Silicon.	Manganese.	Phosphorus.	Sulphur.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
From	2·75	0 50	0·50	0·30	0·35	0·05
To	3·00	0·75	0·70	0·50	0·45	0·07

[illegible]
[illegible] supports
[illegible] length of 1 ft.
[illegible] 0·05 in.,
[illegible] per cent of silicon,
[illegible] per cent, the
[illegible] manganese would
[illegible] varying with
[illegible] as follows:
[illegible] per cent; ½ in.
[illegible] 1 in. thick,
[illegible] bar of which
[illegible] would support
[illegible] not under
[illegible] would on analysis
[illegible] sulphur not over 0·085
[illegible] per cent, and
[illegible] iron supporting
[illegible] square test bar
[illegible] shrinkage on a
[illegible] and a chill not
[illegible] 1·60 per cent
[illegible] per cent of sulphur, the
[illegible] per cent., and the
[illegible] castings special iron

[illegible] of chilled rolls, what is
[illegible] cold-blast [illegible] pig iron is
[illegible] approach to an ideal pig
[illegible] Other cold-blast brands of
[illegible] almost as good, but their
[illegible] cold-blast [illegible] average analysis of a good
[illegible] pig is as follows: Silicon,
[illegible] per cent; phosphorus, 0·48 per
[illegible] graphitic carbon, 2·4 per
[illegible] per cent. For casting
[illegible] railroad foundry
[illegible] four-fifths old chilled
[illegible] ron being :—

Total carbon	[illegible]	per cent.
Graphite	[illegible]	..
Combined carbon	[illegible]	..
Silicon	[illegible]	..
Phosphorus	[illegible]	..
Sulphur	[illegible]	..

The chilled wheels, on analysis, show the following composition:—

	Hard surface.	[illegible]
	Per cent.	Per cent.
Graphite	[illegible]	[illegible]
Combined carbon	[illegible]	[illegible]
Silicon	[illegible]	[illegible]
Phosphorus	[illegible]	[illegible]
Sulphur	[illegible]	[illegible]

It is generally found that the metal charged into the cupola for producing chilled castings should be richer in graphite, silicon, and manganese, and have less combined carbon than is required in the finished product, although when present in quantities less than 1 per cent. phosphorus and silicon remain practically constant, while some of the manganese always disappears. The total carbon remains the same, but the proportions existing as graphite and as combined may vary considerably.

Mr. Henderson, in a recent paper on "The Manufacture of Car Wheels," gives the following limiting values for the chemical constituents of wheels:—

	Graphite	Combined carbon.	Silicon.	Manganese.	Phosphorus.	Sulphur.
	[illegible]	[illegible]	Per cent.	Per cent.	Per cent.	Per cent.
	[illegible]	[illegible]	0·50	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	0·70	[illegible]	[illegible]	[illegible]

The changes which take place in cupola melted iron due to the oxidising atmosphere are very difficult to pre-determine, for whilst all the constituents of pig iron—iron, silicon, carbon, phosphorus, manganese, and sulphur—are readily oxidised, but which of them will be attacked first, &c., depends largely upon the temperature and other conditions, so that it becomes all but impossible to say how much of the change in any particular instance is due to natural causes and how much to faulty working of the cupolas. Under normal conditions the silicon will oxidise first, and if the blast is excessive—more especially at the commencement of a run, and with cupolas of comparatively small capacity—it will oxidise very rapidly, as the openness of the fuel and clear tuyeres render the action of the blast far more effective than later in the heat, when the charge, in settling down and becoming obstructed by slag, offers a greater resistance. The heat required is no greater at the beginning of a run than later on, so that to prevent this abnormal burning out of the softener the blast pressure should be reduced to the lowest point possible without delaying the melting process. Carbon will not oxidise out, since the iron is in contact with excess of carbon in the fuel, and it is found that even when wrought-iron scrap or turnings are fed into the cupola, with a view to increasing the toughness and closing the grain of the casting, the percentage of total carbon is still unchanged. Manganese in the pig iron charged is of advantage when not above 1·2 per cent, and it will generally be found that a high percentage of manganese is accompanied by a low percentage of sulphur. The manganese prevents loss by oxidation of the silicon when the metal is re-melted in the cupola, but since it influences the state of existence of the carbon in the iron, by preventing the formation of graphite, leading to hard and brittle castings when the cast contains more than 0·70 per cent, many foundry-men prefer to ensure against such a possibility by not accepting pig iron of any grade with a percentage higher than 0·60 per cent, although some portion of the manganese is always lost on re-melting. Phosphorus will generally remain unchanged, owing to there being a considerable quantity of silica present; whilst sulphur is likely to be taken up from the fuel. The chief chemical change which takes place when iron is re-melted in a cupola is, therefore, the removal of some of the silicon, which, as has already been shown, may so change the character of the iron as to render it unsuited for the work in hand. The quantity of silicon present being lessened enables the iron to hold a larger proportion of the total carbon in the combined state, so that it is possible, by re-melting a number of times, to cause the iron to become white (containing less than 1 per cent of graphite), and totally unfit for foundry purposes. Just how much silicon disappears on re-melting depends on a number of circumstances, including the method of working the cupola, and no very definite information is available. Some authorities give the average loss as 20 per cent, or one-fifth of the quantity originally present; whilst others say that the loss is constant and equal to 0·25 per cent, irrespective of the total amount of silicon present, with a constantly running cupola, and rather more in the case of short heats. The diagram, fig. 12, gives the results of some experiments carried out with a view to determining the loss of silicon on re-melting cast iron, from which it will be seen that the average loss was about 12 per cent. The melting in these experiments was done in a crucible. The general practice in the iron foundry is to allow for a loss of 25 per cent. As regards the mechanical considerations which may lead to a change in the character of the iron produced from the same mixture in different heats, or at different times during the same heat, probably the faulty placing of the iron in the cupola is one of the most common, the iron being so placed as to cause uneven melting, allowing one brand to melt and mix ahead of others, or one brand may not be broken as small as others; whilst in other cases sufficient care is not exercised in weighing up the charges, and carefully levelling up each successive charge of coke or iron before throwing in the next. The first iron is often found to be harder than succeeding tappings, which may be due to several causes, but more often than not may be traced to improper drying of the cupola, or of the receiving ladle, and even if the latter be dry, but cold, the condition of the iron may be changed by chilling; while, on the other hand, if the lining of the cupola has been made too hot in drying out, the charge of fuel above the melting zone may be ignited, probably at one side only, with the result that the stock comes down unevenly, which may also occur by reason of the tuyeres being formed unevenly, with larger openings on one side than the other, or by the section of the wind-box being too small to ensure a fairly even distribution of pressure at the tuyeres, a fault which is sometimes aggravated by the inlets from the blast main being placed directly opposite tuyeres. Drawing off the iron at a greater rate than that at which it is melting will often cause variation in its quality by not allowing it to mix properly. Where extreme economy in fuel is attempted, not only will the loss [illegible] iron by oxidation, &c., probably be greater, and the iron [illegible] be not so hot with low as with high beds of fuel,

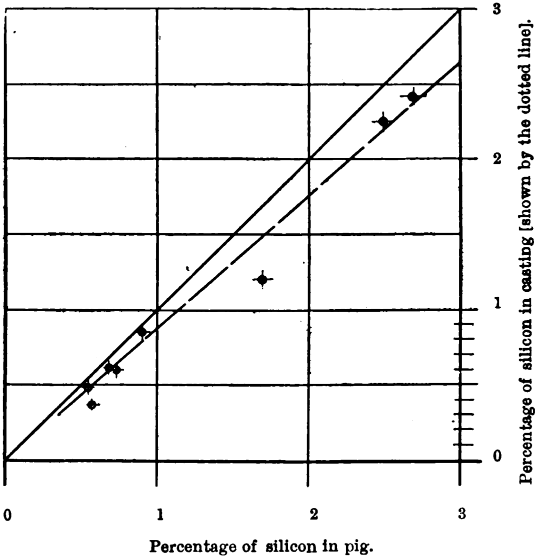

FIG. 12.—Showing the loss of silicon on re-melting cast iron in a crucible.

although with the latter the melting is somewhat slower, but there is also a danger of the iron melting too near the tuyeres, which is almost invariably a cause of hard iron. This result may also be brought about by the employment of too soft fuel; or even with suitable fuel, and a high bed, the excessive use of blast may so reduce the bed that the iron may melt too near the tuyeres before very long after the heat is started. A very commonly adopted rule for charging the cupola is to put 3 lb. of iron to 1 lb. of fuel on the bed, and then 10 lb. to 12 lb. of iron on each pound of fuel in the succeeding charges, and where different qualities of iron are to be melted during the same heat the better brands should be charged first, so that they are tapped while the furnace remains comparatively clean. With a view to ensuring homogeneous metal, it is usual, in melting mixtures of different grades of pig iron and scrap, for all important castings, such as steam-engine cylinders, &c., to re-melt the iron two or three times before the final casting is made, the first charges being run from the cupola into pigs, which are subsequently broken up and again charged into the cupola. The mixture for such castings generally includes some cold-blast iron,* which possesses great strength with closeness of grain. Proper allowance must be made for this re-melting when the first charge is being made up, or the resulting casting may prove to be of unsuitable composition, owing to the silicon having been reduced to too great an extent by the repeated meltings. A very good analysis for finished cylinder castings would be :—

Combined carbon	0·62	per cent
Graphite	2·45	,,
Silicon	1·52	,,
Phosphorus	0·65	,,
Manganese	0·34	,,
Sulphur	0·07	,,

It was formerly held that re-melting cast iron even up to twelve or fourteen times always improved its quality, but

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* Iron manufactured with air at the ordinary atmospheric temperature, and called *cold-blast* iron to distinguish it from the generality of irons, which are made with a blast heated to about 700 deg. Fah. "Blænavon" is probably the best known and most generally used brand of cold-blast iron.

whether this is so or not depends upon its original composition, and also upon what particular property we choose to base our estimate of its quality, for, as has already been shown, an iron containing, say, 3½ per cent of silicon would gain in tensile strength on re-melting until the silicon was reduced to about 1·8 per cent, after which any further re-melting would diminish its tensile strength, whereas much fewer re-meltings would be necessary to bring the silicon down to the 2·5 per cent, at which the property of softness reaches a maximum, and after which re-melting will have the effect of hardening the iron.

If the iron has become hard and white by re-melting, it is always possible to soften it by the addition of ferro-silicon, or by the use of aluminium, which acts in the same way as silicon in changing combined to graphitic carbon, and may be added after the metal is melted, the practice being to put from 1 to 2 lb. of aluminium per ton of iron in the ladle and pour the molten iron on to it. The addition of the aluminium lessens the tendency of the metal to chill, and for this reason alone many foundries employ it when difficult and intricate castings are to be made. When the quantity of aluminium in the iron is over 2 per cent the shrinkage is found to be materially less.

The prevailing practice in charging the cupola is to adopt greater sub-division than formerly. For cupolas of the n shown at fig. 1, having a depth of hearth of from 10 in. 12 in., the charges would be somewhat as follow :—

Diameter of cupola inside lining.	Weight of fuel on bed.	Weight of first charge of iron.	Weight of succeeding charges of fuel.	Weight of succeeding charges of iron.
ft. in.	cwts.	cwts.	cwts.	cwts.
2 0	2½	7½	½	5
2 6	5	15	1¼	12½
3 0	7½	22½	2	20
3 6	10	30	3½	36
4 0	12½	37½	5	52
6	15	45	6	65
0	17	51	7	80

In charging cupolas arranged with central blast, it is best to place the first charge of iron, in the form of a ring, round a central core of fuel connecting the bed charge with the charge of fuel immediately over the first charge of iron; the central core being of a diameter equal to about one-half that of the cupola inside the lining.

CHAPTER IV.

REVERBERATORY FURNACES.

AIR furnaces of the reverberatory type are, it is to be regretted, becoming almost obsolete in the United Kingdom for melting iron in the foundry, although in localities where good soft bituminous* coal can be obtained at a low price such furnaces are still to be found, whilst they are also employed in some foundries in conjunction with the cupolas as a reservoir for collecting and keeping hot a considerable quantity of metal till it may be wanted for a heavy casting. The chief reason why reverberatory furnaces are not now so commonly used as formerly for general foundry purposes is that they are less economical than the cupola, requiring as they do fully twice the quantity of fuel that is necessary to produce good hot iron in a cupola furnace, yet for chilled work, and for melting iron for making castings which are to be converted into malleable castings, the reverberatory furnace has some advantages over the cupola. Iron to be benefited by annealing must have the carbon combined with the iron, giving a clear white fracture free from little black specks, which is more easily attainable with the reverberatory furnace than with the cupola, as with the former a test bar can be cast, cooled, and broken, when, should there be any signs of graphite, all that is necessary is to allow the iron to remain longer in the furnace, when it will continue to lose oxygen, with the result that the graphite is converted

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* Hard coal, or coke, is not suitable, as with such fuel large quantities of fine ashes are carried over from the firebox to the hearth, covering the molten metal in the bath, and preventing its absorption of heat.

into combined carbon. The test bar should be cast as soon as the metal is tapped, for if the metal is allowed to stand long in the ladle before pouring, the silicon present will have time to separate the carbon. Iron melted in the reverberatory furnace will shrink less than that melted in the cupola, and, it is claimed, will anneal at a heat much lower than is required for iron melted in a cupola, whilst it is undoubtedly stronger and purer, owing to the fact that it is not melted in direct contact with the fuel, as it is in the cupola, and in consequence does not so readily absorb its impurities.

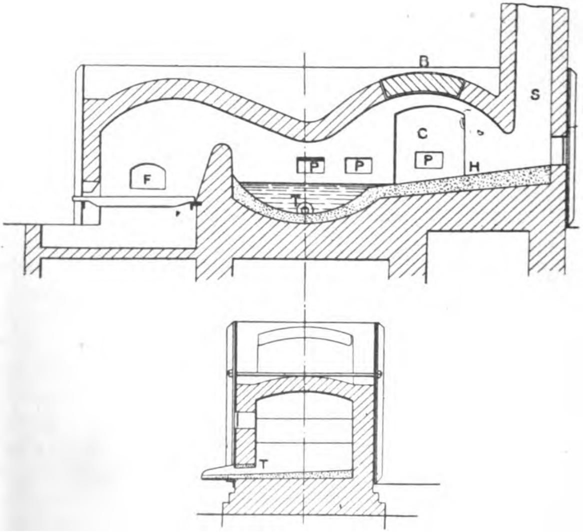


FIG. 13.

As a rule, the reverberatory furnace is driven with forced d ht, natural draught being too slow, and in some a further supply of air is introduced over the h a view to ensuring complete combustion; still, pressure employed should not be very high, t above 10 in. of water column, whilst with a well-designed furnace in which the area over the fire bridge, and also that at the neck of the furnace, have been suitably adjusted to the area of the firegrate, so as to enable the blast to fill these openings, a pressure equivalent to about 6½ in. of water column is all that is needed, with suitable fuel to generate a perfectly white flame when the metal has begun to oxidise.

Very little change has taken place in the form of the reverberatory furnace during the past ten years, although there are at the present time evidences of a tendency towards the adoption of increased grate area for a given furnace capacity. The two general forms of furnace are shown by figs. 13 and 14, of which probably that shown by fig. 14 is the more common. In this furnace the bath is situated at the end of the furnace, remote from the bridge, where the greatest heat is generally to be found; whilst in the form of furnace shown at fig. 13 the bath is placed immediately behind the bridge. In this furnace a charge of 5 tons is melted in 3½ to 4 hours, the firegrate being 4 ft. 3 in. square, or 18 square feet in area. The furnace shown at fig. 14 has a capacity of about 10 tons, and a grate area of 30 square feet. The charging in this furnace is all done from the side through the charging hole C, fitted with a cast-iron counterweighted door lined with firebrick; whilst

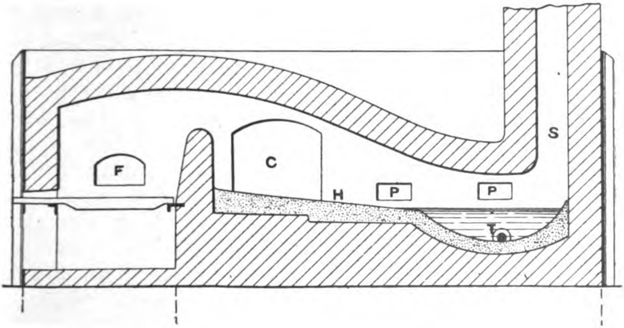


FIG. 14.

in the furnace illustrated at fig. 13, in addition to a charging door C at the side, the roof immediately over the hearth H consists of bungs or arches of firebrick in iron frames B, placed side by side, which can be lifted for charging. The walls and roof of the furnace are built with the most refractory kind of firebrick, and great care must be taken to ensure close joints in the brickwork, all crevices being carefully stopped up in order to prevent the inrush of cold air, which, besides chilling the furnace, may be the cause of changing the chemical nature of the iron, as under such conditions it is liable to lose graphitic carbon, with the result that the castings may prove hard and brittle. For the same reason the furnace should be fired regularly, and the formation of holes in the fire carefully guarded against when raking or cleaning the fire. The sand used for making the bed is similar to that used for cupola bottoms, although perhaps somewhat more open, a commonly used mixture being eight parts fire sand to one part each of clay and ground coke, with which a bed can be made that will last eight or ten heats, provided it receives from one and a half to two hours' good firing before the first charge is laid on.

When charging the furnace the first layer of pigs should be laid on the hearth with their ends pointing in the direction of the length of the furnace, and a little apart the following layers being placed in opposite directions successively, leaving spaces between each pig for the free passage of the flame, a condition which must always be observed in charging either with pig or with scrap. With the reverberatory furnace it is seldom possible to melt any additional metal immediately after the heat is down, owing to the considerable cooling off of the furnace by the admission of cold iron and cold air making it all but impossible to melt a second charge before the iron first melted becomes cold and useless, so that all iron required should be charged at the first. The sight holes P, P, P, fig, 13 enable the melter to watch the melting, and also to [illegible] bly hasten the process by separating pieces which [illegible] ndency to weld together, and breaking up the [illegible] tory ones, thus increasing the surface of metal [illegible] he flame. The molten metal is also skimmed through the holes P, P, situated immediately over the bath, a process which is usually carried out two or three times during a heat, for it is very important to keep the molten iron clean, as any accumulation of dirt or scum upon its surface shields the metal from the direct action of the flame, with the result that the furnace rapidly loses in efficiency. These holes also serve for the introduction of the puddling bar and for performing the operation of "boiling the metal," a process which is always necessary when the charge is made up of two or more different grades of iron, and usually consists of thrusting one or two green saplings into the molten iron, creating a violent ebullition throughout the mass, which has the effect of thoroughly mixing the various brands of iron and ensures a homogeneous product. When the iron is all melted and at a white heat the melter dips a sample out of the furnace, by means of a small hand ladle, for testing purposes, when, if satisfactory, he polls up the charge for five or six minutes, after which, provided the iron is still hot enough and the moulds are ready, the damper in the flue is closed and the furnace tapped. All these various operations are conducted with the utmost despatch, the doors over the sight holes not remaining open any longer than is absolutely necessary, or cold air may rush into the furnace in sufficient quantity to spoil the iron for its intended purpose. When the reverberatory furnace is employed for malleable work the pig iron charged has most of its carbon in the combined state, the graphitic carbon being generally less than 1 per cent, whilst the silicon and phosphorus are low, the former being usually not much above 1 per cent, and the latter from 0·6 to 0·8 per cent. The silicon is burnt out to a considerable extent, and the iron, though quite fluid when at an intense white heat, approaches the point of solidification with a rapidity that to one accustomed only to grey iron is astonishing, and for this reason everything must be done to enable the metal to be brought to the moulds with the least possible delay.

CHAPTER V.

THE BLAST AND ITS PRODUCTION.

IN order to support combustion in the melting furnace, oxygen must be introduced in sufficient quantity to combine with all the combustible elements of the fuel (carbon, hydrogen, and sulphur), the necessary supply being usually obtained by introducing atmospheric air, the oxygen content of which combines with the combustible matter, whilst the nitrogen remains neutral. Atmospheric air consists of a mechanical mixture of oxygen and nitrogen, with generally some impurities, the proportion being 1 lb. of oxygen to 3·35 lb. of nitrogen, or, by volume, 1 cubic foot of oxygen to 3·76 cubic feet of nitrogen, so that for every pound of oxygen required for combustion 4·35 lb. of air must be introduced, or for each cubic foot of oxygen employed in combustion 4·76 cubic feet of air must be supplied. The quantity of dry air, at about 62 deg. Fah., chemically required to effect the complete combustion of 1 lb. of good coke, containing about 98 per cent of carbon, and less than 0·75 per cent of sulphur, may be taken at 150 cubic feet, or 11·4 lb.; whilst for an average quality coke, containing, say, 95 per cent of carbon and about 0·75 per cent of sulphur, 148 cubic feet, or 11·27 lb. are required. When coal is the fuel employed, about the same quantity of air is needed, but the pressure of the blast necessary will generally be found to be greater than with coke, owing to the cupola charge being more dense. The actual quantity of air to be supplied will be greater than that chemically required for complete combustion of the fuel, as some portion will always pass off unconsumed with the products of combustion.

In practice it is found that from 30,000 to 36,000 cubic feet of air are required to melt a ton of iron, faulty iron [illegible]g more frequently due to a scarcity of air than to an [illegible], so that for every ton of iron to be melted per hour in [illegible]pola there must be delivered from 500 to 600 cubic [illegible]ir per minute. In modern ironfoundry practice the [illegible]variably produced either by a fan blower or by a rotary displacement blower, the older methods for obtaining a draught by means of a high stack, or by creating a partial vacuum in the cupola by the aid of a steam jet placed in a contracted outlet from the cupola, being generally considered insufficient to produce rapid melting. In the cupola furnace the free passage of air is restricted by the iron and fuel, so that in order to supply the large volume of air necessary forced draught must be employed.

The function of a blower is to create a pressure by compressing the air in a casing surrounding it, and from which the air escapes through an outlet, the velocity with which it will flow being dependent upon the excess of pressure maintained in the casing over that existing in the receiver into which the air escapes, and upon the density of the air. The pressure per unit of area, divided by the density per unit of volume, gives the "head due to the velocity," the velocity produced being that which would be attained by a body falling freely through a distance equal to this head; or if

V = the velocity in feet per second,
H = the head in feet,
g = the acceleration due to gravity,

then $V = \sqrt{2 g H}$;

and if P = the pressure per unit of area maintained by the blower, and D the corresponding density per unit of volume, whilst p = the pressure of the air per unit of area in the receiver into which the air from the blower is flowing, and d the corresponding density per unit of volume, the head due to the velocity will be

$$\frac{P}{D} - \frac{p}{d} = H.$$

The pressure in a cupola when in blast is always less than that in the wind box, the amount of difference depending on the closeness of the iron and fuel and the height to which the cupola is charged, and also on the tuyere area provided. The pressure to be maintained in the wind box surrounding the cupola must be so much higher than that existing inside the cupola as will create a velocity of flow high enough to admit of the passage of the requisite volume of air through the cupola to ensure complete combustion of all the fuel necessary to melt the iron at the required rate, and can only be determined by actual experiments.

In the case of common cupolas, as illustrated by fig. 1, well constructed and carefully operated, the average results of a large number of tests were as follow:—

Diameter of cupola inside lining in inches	24	26	30	36	40	45	54	60
Melting capacity of cupola in tons per hour	0·66	0·86	1·35	2·10	2·80	4·00	6 00	7·42
Blast pressure in wind box, ounces per square inch ..	6	6	7	8	10	12	14	14

The pressure in the wind box towards the end of a heat will generally be higher than at the beginning, owing to the tuyeres becoming clogged, although with ample tuyere area the difference will seldom be great. As speed in melting is chiefly augmented by the air supply, the cupola should be arranged to take all the volume it is possible for it to use profitably, for the more rapid the melting, the better and hotter will be the metal produced; and it cannot be too strongly emphasised that it is the volume of blast, and not the pressure, which does the work in a cupola; and further, that a high pressure of blast does not necessarily indicate a large volume, but may mean the reverse, for it is quite possible for a gauge to show 10 oz. or 12 oz., while there may be not one cubic foot of air per minute passing into the cupola. The readings of the air-pressure gauges can be made to show very accurately the pressure of blast on a cupola, and if the size and arrangement of the tuyeres and of the air connections generally are suitable they may indicate in a measure the resistance offered to the free [illegible] of the blast into the cupola, but they do not indicate [illegible] the right volume of blast is being delivered, which, [illegible] absence of a satisfactory instrument, can at the [illegible] ime be told but approximately—and that only by [illegible]nced melter—by noting the cupola's action.

The air pressure gauge devised by Professor F. E. Nipher, of the Academy of Science of St. Louis, is probably one of the best, and has the important property of being totally unaffected by air currents, and is thus capable of recording true statical pressures. The feature of this gauge is the collector, which is constructed by compressing between two thin circular discs, about 2½ in. diameter, several layers of wire gauze, the edges of which extend about ½ in. beyond those of the afore-mentioned discs. A tube leading from the centre of one of the discs serves to connect the apparatus with a manometer of any convenient type. At its outer circumference each disc is ground to a thin knife edge, so as to eliminate the eddies which might form were the edges left square. Such a collector is intended to be employed with the faces of the discs parallel to the wind, but is found to work equally well when placed in any other position.

With a displacement blower, delivering a definite quantity of air per revolution regardless of the condition of the cupola, there would perhaps be more certainty about the quantity of air supplied, although, owing to the construction of many of these blowers, a considerable and unknown quantity of air leaks back through the narrow spaces between and around the "revolvers," more especially after they have been in operation for some time and, as is often the case, not sufficiently well cared for. There are, however, still a large number of foundry-men who prefer this type of blower to the centrifugal fan, although the balance of advantages would seem to lie with the fan, being more economical in power and cost of repairs, less liable to get into inefficient condition, has a lower first cost, is not susceptible to leakage, and if for a while only some portion of the normal supply of air is required, and the speed of the blower cannot be altered, the outlet may be partly closed, when only a little more than a corresponding portion of the power required to drive the fan at its normal output will be expended, and the pressure will be increased somewhat with a decrease of outlet area up to the capacity area of the fan; whereas with a rotary displacement blower of the Green or the Root type, which are probably the most extensively adopted, any reduction in the air supply required would not result in any reduction of power expended, since the blower must deliver the full volume, and all the air not required be allowed to escape through a relief valve. When the blast is entirely shut off on a fan the power required will be only that necessary to overcome its friction and that of the air confined within the case, while a displacement blower will still require the same power as when doing maximum duty. When changes are likely to occur in the amount of air required displacement blowers

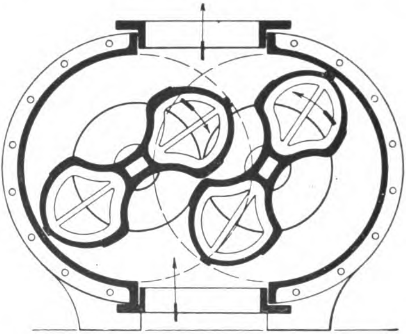


FIG. 15.—Section of the "Green" Rotary Displacement Blower.

should be driven by independent engines or motors, or some other provision be made to enable their speed of running to be readily accommodated to the requirements.

Fig. 15 is a sectional view of a Green patent rotary displacement blower, manufactured by the Wilbraham Baker Blower Company, in nine standard sizes, having capacities varying from 3 cubic feet to 200 cubic feet per revolution. The working parts of this blower consist of two perfectly-balanced impellers, each of which is a single casting, well ribbed inside, and mounted on a steel shaft, which extends the full length of the machine, and is flattened where it passes through the body of the impeller. he blower is geared at both ends, the gear wheels having hine-cut teeth, and are enclosed in an oil-tight case, excluding dust and dirt, and enabling the gears to run in an oil bath. The finished surfaces of the impellers are two circles, which roll together, forming an even and continuous practical contact, the point of contact being always on the pitch line of the gears, and travelling at the same speed at all points of the revolution. In order to give additional strength to the impellers, and at the same time form a protection in case the journals should become worn, the ends of the impellers are provided with circular heads turned to a diameter slightly larger than that of the contact circle of the impellers, so that, in the event of the journals becoming worn, the heads of the two impellers will roll together, and prevent their bodies from coming into actual contact. The maximum speeds recommended by the makers for the various size blowers, together with the delivery per revolution, are as follow :—

No. of blower.	1	2	3	4	5	6	7	8
Displacement, cubic feet per revolution	3	5½	9	13½	25	42	67	112
Maximum revolutions per minute	290	275	245	240	200	180	150	115

The general form of this blower is similar to the Root, the chief difference being in the construction of the impellers or pistons, the configuration of which has been the subject of quite a large number of patents since the first introduction of this form of blower by Root. In some modern Root blowers the impellers have the curves of the rolling surfaces formed with two radii from four centres, obtained as shown by fig. 16, in which the circle C has a diameter equal to three-fourths that of the pitch circle P. The recesses H are left in the rough, as they do not roll, and the tips are cleared away for the same reason.

Fig. 17 illustrates a Root's blower, as made by Messrs. Thwaites Bros., of Bradford, who have probably done more than any other firm in perfecting the machine. In these blowers the curved outline of the pistons or revolvers is formed of a series of circular arcs without breaks or angles at their junctions (see fig. 18), thus avoiding irregularity of flow and consequent vibration, and allowing of the delivery of a larger volume of air at a greater pressure, with a smaller expenditure of power, and also of running at a higher speed with less vibration than was the case with many of the earlier blowers of this type.

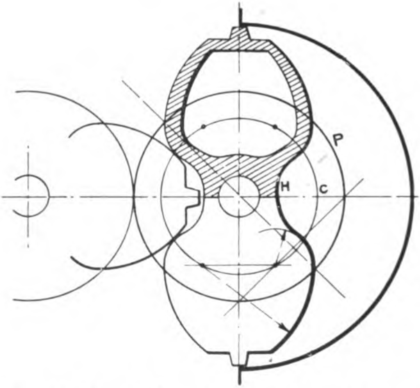


FIG. 16.—Form of Impellers for "Root" Blower.

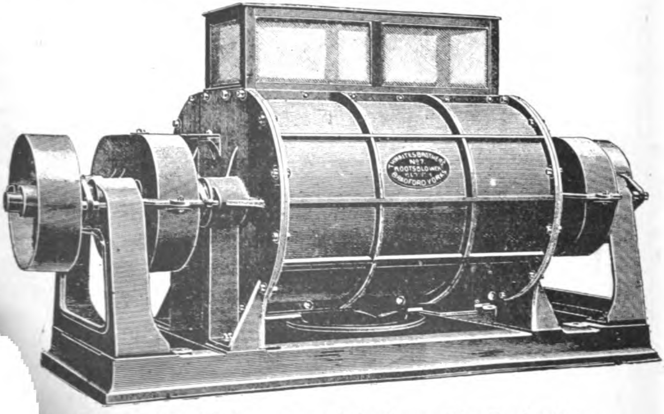


FIG. 17.—"Root" Blower, as made by Messrs. Thwaites Brothers.

These blowers are manufactured in fifteen sizes, capable of delivering from 230 to 19,000 cubic feet of air per minute. The maximum speed of running for some of the different sizes of blower, as recommended by the makers, together with the quantity of air delivered and the horse power required on the assumption that the air is delivered by the blower at a pressure of 12 oz. per square inch, &c., is given below :—

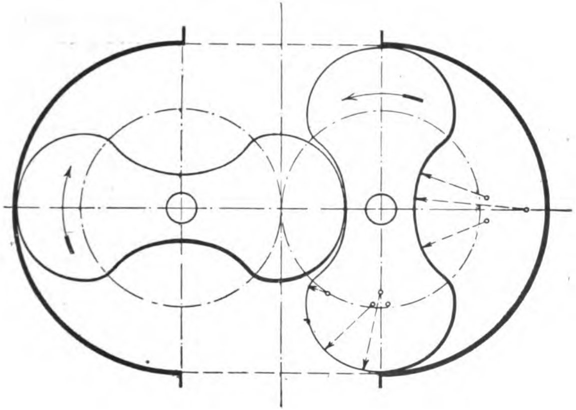


FIG. 18.—Form of Impellers of "Root" Blower, as made by Messrs. Thwaites Brothers.

No. of blower	*2a*	*1a*	1	2	3	4	5	6	7	8	9	10
Diameter of outlet in inches	5	6	7	8	10	12	13½	17	19	22	24	27
Maximum number of revolutions per minute	350	350	400	400	380	350	320	310	300	280	260	240
Cubic feet of air delivered per minute at the above speed.	600	800	1300	2000	3000	4550	6400	8680	11000	12500	15500	19000
Horse power required to deliver the above volume of air at a pressure of 12 oz. per sq. in.	2½	3¼	5¼	8	12	18¼	25½	35	44	50	62	76
Cubic feet of air delivered per revolution	1·715	2·285	3·25	5·0	7·9	13	20	28	36·67	44·6	59·7	79·3

TABLE I.

Pressure in ounces per square inch = P.	Corresponding pressure in inches of water-column per square inch.	Velocity due to pressure in feet per minute = V.	Volume of air in cubic feet which may be discharged in 1 min. through an orifice having an effective area of 1 square inch.
4	6·92	10,260	71·23
4½	7·79	10,870	75·50
5	8·65	11,440	79·50
5½	9·52	11,990	83·25
6	10·38	12,510	86·89
6½	11·26	13,010	90·35
7	12·11	13,480	93·65
7½	12·97	13,940	96·84
8	13·84	14,380	99·92
8½	14·71	14,820	102·88
9	15·57	15,230	105·76
9½	16·45	15,630	108·60
10	17·30	16,020	111·25
10½	18·17	16,400	113·88
11	19·03	16,770	116·45
11½	19·90	17,130	118·94
12	20·76	17,480	121·38
12½	21·64	17,820	123·75
13	22·49	18,150	126·10
13½	23·37	18,480	128·35
14	24·22	18,800	130·58
14½	25·08	19,110	132·75
15	25·95	19,420	134·89
15½	26·81	19·720	136·98
16	27·68	20,020	139·00

NOTE.—The above table is calculated on the assumption that the air is dry, and at a temperature of 50 deg. Fah., and that the barometric pressure is 14·7 lb. = 235 oz. per square inch. Then $V = 60 \sqrt{31{\cdot}6 \times (235 - P) \times P}$. The effect of increasing the temperature of the air is to decrease its density, with the result that the pressure required to produce a given velocity will be less.

These rotary displacement blowers are often termed *positive blowers*, a name which, if applicable at all, is only so in the case of an exceptionally well-designed and constructed machine, since the production of a pressure is entirely dependent upon the accuracy of its construction. Any leakage due to bad workmanship, improper adjustment, or wear renders its *positiveness* dependent upon the amount of such leakage; and when we consider the high velocity at which air will flow through an orifice under a pressure of but a few ounces per square inch (see Table I.), we can readily see that even small leakages may greatly reduce the pressure of the confined air, especially in the case of blowers of small cubic capacity.

The pressure of air created by a fan blower is due to centrifugal force, and is as certain as the law of gravitation, upon which it is based. The circumferential velocity of the fan wheel, which is necessary to produce a given velocity of flow through an outlet within the capacity of the fan, is substantially equal to the velocity of flow. If, therefore, the circumferential velocity of a given fan is known, the resulting pressure for the production of velocity through an outlet of proper size and shape may be readily calculated. Fig. 19 gives the results obtained with a small experimental fan, having a wheel 23 in. in diameter, enclosed in a casing, with a 12½ in. diameter inlet on each side; these inlets were, however, partially blocked by the driving pulleys, 5 in. in diameter. The fan wheel was 6⅝ in. wide at its periphery, and had eight blades, each having an area of 45½ square inches. In these experiments the speed of fan was maintained as nearly as possible constant, whilst the area of the discharge outlet was varied, and the pressure of the air in the fan casing was carefully noted, which, it will be seen from the results plotted on the diagram, fig. 19, remained unchanged for areas of discharge of from 6 to about 25 square inches, after which the pressure dropped as the area of the outlet was further increased. Other experiments, the results of which have been published, show this same effect, clearly demonstrating that a peripheral discharge fan, if enclosed in a case, will, if driven at a given speed, maintain the pressure corresponding to its circumferential velocity over areas up to a definite limit, which is often spoken of as the "square inches of blast," and is the greatest effective area over which the fan is able to maintain the given pressure. For any smaller area the pressure will remain the same, but for any area above this limit the pressure will no longer remain that due to the velocity of the fan tips.

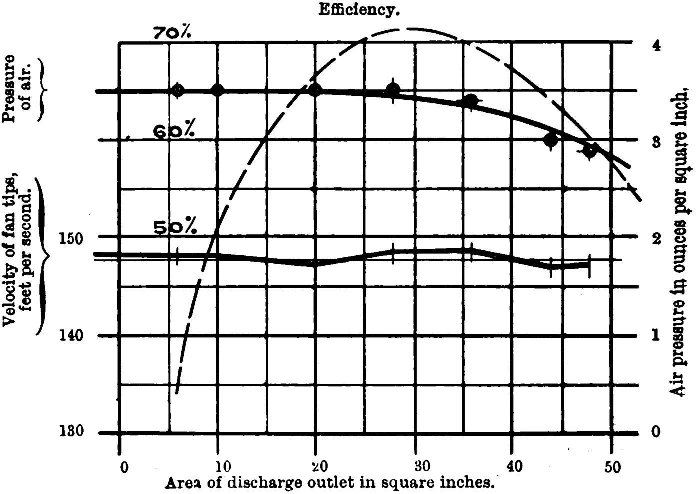


FIG. 19.—Diagram showing the influence of the area of discharge outlet from a fan on the air pressure.

Mr. W. B. Snow has given an empirical formula, by the aid of which the square inches of blast, or, as it may be termed, the capacity area of a cased fan, may be approximately determined, in which

D = the diameter of the fan wheel, in inches;

W = the width of the fan wheel at circumference, in inches;

x = a constant, depending for its value upon the type of fan and casing;

$$\text{capacity area, in square inches} = \frac{D\,W}{x}.$$

Mr. Snow gives 3 as an approximate value for x for general practice, but points out that it is to be used only to determine the capacity area over which the given pressure may be maintained, and must be used with great discretion, acquired through experience and a thorough knowledge of all the conditions liable to affect the fan in operation.

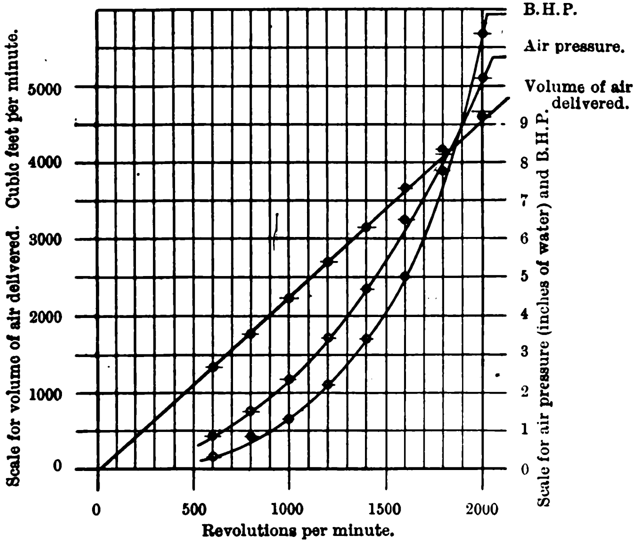


FIG. 20.—Results of trials of blast fan. (Area of discharge opening constant).

As fan casings are usually made, the area of outlet is always larger than the square inches of blast, and, in consequence, the pressure is lower and the volume discharged rather greater than would result through an outlet having the square inches of blast for its area. But the maximum pressure may be realised when the sum of the resistances is equivalent to a reduction of effective outlet area to that of the capacity area.

The results obtained by running a centrifugal fan at different speeds, but with all other conditions unchanged, are shown plotted on the diagram, fig. 20, for a series of experiments carried out with the 23 in. diameter experimental fan previously referred to; from which it will be seen that the volume of air delivered per revolution is constant, whilst the power expended and the pressure of the air in the fan casing increase at a greater rate than does the speed. It has already been shown that the pressure

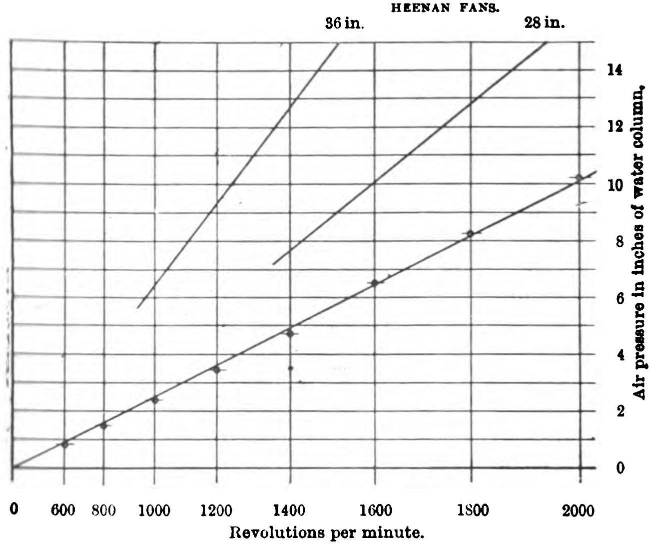


FIG. 21.

created by a given fan varies as the square of its speed, and as the work done by a fan in moving air is represented by the distance through which the total pressure is exerted, [illegible] power will vary as the pressure multiplied by the [illegible] moved in given time; and since the pressure varies [illegible] square of the velocity or revolutions per minute of [illegible] and the volume delivered varies directly as the [illegible], the power expended will vary as the cube of the [illegible] per minute. How nearly the results of these experiments conform to these laws is shown by the lines on the diagrams, figs. 21 and 22, passing through the dots representing the results of the trials, striking the base at 0 revolutions per minute, the successive values being set off along the base, not directly proportional to the revolutions, but proportional to the square of the number made per minute in the case of the diagram, fig. 21, on which the air pressures corresponding to the successive speeds are transferred from fig. 20; and proportional to the cube of the revolutions per minute in the case of fig. 22, dealing with the brake horse power.

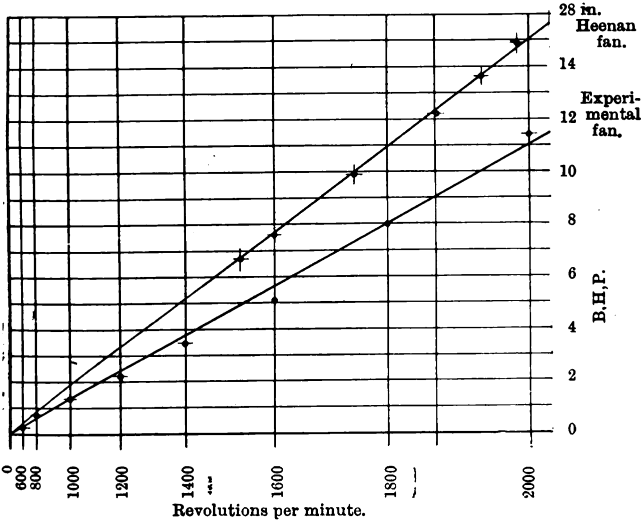


Fig. 22.

Fig. 23 shows the results obtained in a similar series of experiments carried out with a 28 in. "Heenan" fan; the air pressures and brake horse powers at the different speeds shown on this diagram have been repeated on the diagrams, figs. 21 and 22 respectively, and show an even closer agreement with the above-stated theoretical laws than do the results obtained with the 23 in. experimental fan. The selection of a fan most suited to the work to be done, and running it to the best advantage, is a problem but seldom solved. The fan chosen should have a capacity area practically equal to the effective area through the fuel and iron in the cupola, less the influence of the resistances of the piping, air valves, wind box, and tuyeres, which together are equivalent to so much reduction in area, and may be determined with a considerable degree of accuracy, although the effective area through the fuel and iron depends upon the quantity and character of the charge which introduce such variable conditions that it becomes impossible to design a blower of any type that shall at all times be just exactly proportioned to the work to be done. Experience is the only guide to the pressure required in the wind box of a given cupola to accomplish successful melting, when run-

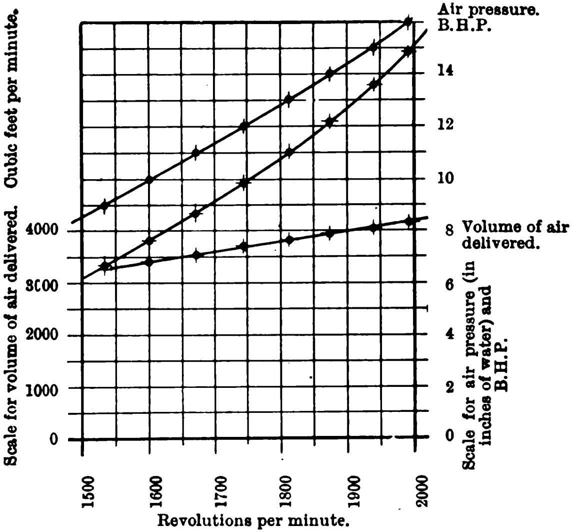


FIG. 23.—Results of trials of a 28 in. Heenan cupola fan.

ning under normal conditions. Using this known pressure as a basis, and adding to it the pressure necessary to overcome the losses due to transmission, we arrive at the pressure required to be created by the fan, which will determine its peripheral speed provided the effective area of outlet is within its capacity area. Now, this peripheral speed can either be obtained with a small wheel running at a high speed of revolution or with a large diameter wheel running at a low speed of revolution, and on whether we choose the one or the other will depend the width to be given to the wheel at its periphery in order to provide for the required volume of air. The third column of Table I. or Table II. gives the peripheral velocity required to create the corresponding pressures given in the preceding columns of the tables, so that—

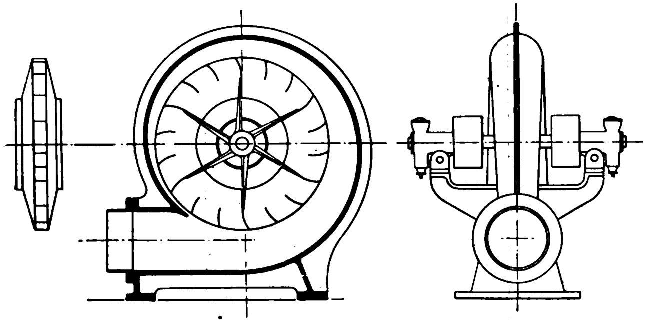


Fig. 24.—The Sturtevant patent blast fan.

$$\frac{\text{V}}{\text{circumference of wheel in feet}} = \text{revolutions per minute,}$$

V being the velocity in feet per minute due to the required pressure P. Fan makers usually fix the width of the wheel at the periphery at some convenient proportion of its diameter, and manufacture their fans in a number of standard sizes to meet the requirements of cupola furnaces of dimensions commonly met with.

TABLE II.—Calculated for the Same Conditions as Table I.

Pressure per square inch in inches of water column.	Corresponding pressure in ounces per square inch.	Velocity due to pressure in feet per minute.	Volume of air in cubic feet which may be discharged in 1 minute through an orifice having an effective area of one square inch.
6	3·47	9,5.0	66·21
6½	3·75	9,938	69·01
7	4·04	10,400	72·63
7½	4·33	10,590	73·80
8	4·62	10,980	75·98
8½	4·91	11,400	79·10
9	5·20	11,680	81·02
9½	5·48	11,960	83·10
10	5·78	12,270	85·31
10½	6·07	12,530	87·26
11	6·36	12,860	89·65
11½	6·65	13,130	91·53
12	6·94	13,420	93·21
12½	7·22	13,640	95·43
13	7·51	13,950	97·00
13½	7·79	14,180	98 48
14	8·08	14,390	99·97
14½	8·37	14,660	101·61
15	8·66	14,910	103·21
15½	8·95	15,220	105·68
16	9·24	15,440	107·18
16½	9·53	15,640	108·56
17	9·82	15,840	110·14
17½	10·11	16,050	111·73
18	10·40	16,280	112·98
18½	10·69	16,510	114·20
19	10·98	16,760	116·40
19½	11·26	16,940	117·73
20	11·56	17,140	119·06
20½	11·85	17,315	120·29
21	12·14	17,490	121·53
21½	12·43	17,800	123·70
22	12·72	17,980	124·92
22½	13·01	18,160	126·10
23	13·30	18,340	127·33
23½	13·59	18,510	128·65
24	13·88	18,690	129·98

There are quite a large number of different types of fans at present in the market adapted for blowing cupolas, but space will not allow of reference to more than the one or two following :—

The Sturtevant blast fan, illustrated at fig. 24, is a very popular blower manufactured by the Sturtevant Engineering Company, in ten standard sizes suitable for cupolas of from 22 in. to 84 in. in diameter inside the lining, and having melting capacities of from ½ ton to 15 tons per hour; the fan wheels of these blowers are built of Siemens-Martin steel plates, galvanised, and have a number of curved vanes, some of which extend only for a short distance in from the periphery and prevent the return of the air to the wheel centre, and thereby maintain the pressure due to their tip velocity. The wheel centre is of malleable cast iron, and great care is exercised in their manufacture to make the centre of gravity of the complete wheel coincide exactly with the centre of motion, a condition which is absolutely essential if the wheel is to run smoothly when driven at high speed.

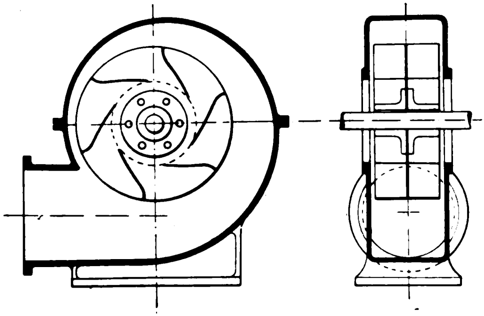


FIG. 25.—The Heenan patent blast fan.

Some useful data concerning these blowers are given on page 76.

The speed at which these blowers must be run in order to maintain any other given pressure over an area which is within the capacity of the blower may be determined thus:

Taking the No. 3 blower, which has a wheel 17 in. in diameter and a capacity area of 6·38 square inches, over which a pressure of 7 oz. per square inch can be maintained when the fan makes 3,030 revolutions per minute, corresponding to a peripheral velocity of 13,480 ft. per minute, which we find from Table I. corresponds to a pressure of 7 oz. per square inch, then to maintain a pressure of, say, 10 oz. per square inch over this same area we find from Table I. that the corresponding value of V, the peripheral speed, will need to be 16,020, and the revolutions per minute equal to

No. of blower	1	2	3	4	5	6	7	8	9	10
Outside diameter of spigot on outlet in inches	4⅞	5⅝	6¼	7⅜	8⅞	10¼	12	13⅞	16	18½
Suitable for common cupola of a diameter inside lining of, in inches	22	26	30	35	40	46	53	60	72	84
Iron melted per hour in tons[1]	0 5	0·85	1·30	1·88	2·76	4·0	5·6	7·4	11	15
Blast pressure in wind box in ounces per square inch	5	6	7	8	10	12	14	14	16	16
Revolutions per minute of blower necessary to produce the above pressure[2]	3569	3282	3030	2818	2690	2670	2316	2023	1845	1627

$$\frac{16020}{\text{circumference of wheel in feet}} = 3600;$$

or approximately, if we neglect the difference of density, we may obtain the revolutions per minute necessary to maintain any required pressure over the capacity area from the known revolutions per minute corresponding with some other air pressure. Thus we know that 3,030 revolutions per minute maintained a pressure of 7 oz. per square inch; then, to maintain a pressure of 10 oz. per square inch, the [illegible] must run at

$$3030\sqrt{\tfrac{10}{7}} = 3630 \text{ revolutions per minute.}$$

[illegible] as regards the volume delivered by the fan under [illegible] pressure maintained over its capacity area, and

---

[1] Based upon an average of numerous tests on some of the best cupolas, and is reliable when the cupola is well constructed and managed.

[2] These speeds do not allow for transmission losses; the actual speed at which the blower must be driven will be higher, depending on the existing conditions.

considering the No. 2 blower with a fan wheel $14\frac{9}{16}$ in. diameter and a capacity area of 4·6 square inches over which a pressure of 6 oz. per square inch can be maintained with a speed of 3,282 revolutions per minute, corresponding to a peripheral velocity of 12,510 ft. per minute. From Table I., we find, in the last column, that 86·89 cubic feet of air may be discharged per minute through an orifice having an effective area of one square inch if the pressure of the air is 6 oz. per square inch, so that the total volume which this blower is capable of discharging per minute, whilst still maintaining the pressure due to its tip velocity, is 86·89 × [its capacity area of 4·6 square inches] = 400 cubic feet. The horse power theoretically necessary to accomplish this would be 0·654. Now, suppose this fan were put on to deliver, say, 600 cubic feet per minute, corresponding to a discharge of 1½ times the volume per effective square inch previously required, or 130·35, which we find from Table I. will require a pressure of 14 oz. per square inch, corresponding to a tip velocity of 18,800 ft. per minute and a speed of revolution of 4,932 per minute, and the power expended theoretically would be 2·29 horse power, or 3½ times the power to supply only 1½ times the quantity of air. If, instead of using the above fan under the latter conditions, we increase the tuyere area, &c., so that the equivalent orifice becomes, say, 6 square inches, and we employ a No. 3 blower, then to supply 600 cubic feet per minute, or 100 cubic feet per square inch, will require a pressure of 8 oz. per square inch, the corresponding peripheral speed being 14,380 ft. per minute, and the revolutions of the blower 3,233 per minute. The horse power theoretically required with this fan would be 1·308 to deliver the 600 cubic feet per minute, or only twice what was required to deliver the 400 cubic feet. This all points to the folly of putting in a fan and tuyeres too small for the work, which necessitates running at a high speed in order to secure the required volume, with the consequent abnormal expenditure of power.

The Heenan patent fan, illustrated at fig. 25, is made by Messrs. Heenan and Froude in five standard sizes for cupola blowing, and also in a number of sizes arranged to deliver a relatively larger volume of air at lower pressures, suitable for supplying blast to air furnaces of the reverberatory type. Some particulars of the high-pressure fans adapted for cupola work, together with the results of an extensive and extremely interesting series of tests carried out by the makers, are given in the table on page 79.

The power theoretically required to discharge 1,000 cubic feet of air per minute at the various pressures at which these fans were tried, on the assumption that the air was dry and at a temperature of about 50 deg. Fah., would be as under:

Pressure in inches of water column ..	9	10	11	12	13	14	15	16
Horse power required	1·43,	1·59,	1·75,	1·91,	2·04,	2·19,	2·33,	2·48.

Comparing these values with the actual brake horse power required per 1,000 cubic feet of air delivered per minute, shows the efficiency of the fans to be about 70 per cent.

By choosing a fan of such a size that its capacity area is approximately equal to the equivalent orifice through which it is to discharge when working under normal conditions, we ensure its working at about maximum efficiency. This is shown on the diagram, fig. 19, by the dotted line, giving the efficiency as measured by the ratio—

$$\frac{\text{horse power in air delivered}}{\text{horse power required to drive fan}},$$

rising to its highest when the area of discharge was the largest over which the fan was able to maintain the pressure due to its tip velocity.

On the other hand, if the fan is speeded to give the required normal pressure in the wind box of the cupola, when the equivalent orifice is somewhat in excess of its capacity area, then, should the free area through the cupola from any cause be restricted, the pressure produced by the fan will immediately rise, thus tending at once to overcome increased resistance.

pressure to be created by the fan will always be han that required to be maintained in the wind box pola by an amount sufficient to overcome the

Diameter of fan in inches.	Size of outlet in inches.	Volume of air delivered in cubic feet per minute. Revolutions per minute. Brake horse power, and B.H.P. per 1,000 cubic feet delivered per min.	Pressure of air at fan outlet.							
			Inches of water column per square inch.							
			9	10	11	12	13	14	15	16
			Corresponding pressure in ounces per square inch.							
			5·20	5·78	6·36	6·94	7·51	8·08	8·66	9·24
18½	9 Diameter.	Volumes.	1,820	1,890	1,960	2.040	2,100	2,160	2,230	2,280
		Revolutions.	2,320	2,425	2,528	2,640	2,745	2,835	2,940,	3,020
		B.H.P.	3·70	4·20	4·78	5·45	6·07	6·70	7·50	8·16
		B.H.P. per 1,000 cubic feet.	2·03	2·22	2·44	2·67	2·89	3·10	3·37	3·58
23½	11½ Diameter.	Volumes.	2,340	2,440	2,530	2,640	2,720	2,780	2,880	2,950
		Revolutions.	1,828	1,910	1,990	2,080	2,160	2,230	2,310	2,372
		B.H.P.	4·75	5·42	6·17	7·02	7·85	8·62	9·68	10·60
		B.H.P. per 1,000 cubic feet.	2·03	2·22	2·44	2·66	2·88	3·10	3·36	3·59
28*	14 Diameter.	Volumes.	3,300	3,440	3,570	3,720	3,840	3,920	4,060	4,160
		Revolutions.	1,532	1,600	1,670	1,745	1,812	1,874	1,940	1,992
		B.H.P.	6·72	7·62	8·70	9·90	11·10	12·20	13·65	14·90
		B.H.P. per 1,000 cubic feet.	2·04	2·22	2·44	2·66	2·89	3·11	3·36	3·59
36	23 × 11	Volumes.	5,880	6,130	6,370	6,620	6,800	7,000	7,250	7,400
		Revolutions.	1,192	1,246	1,300	1,358	1,410	1,456	1,510	1,550
		B.H.P.	11·95	13·60	15·50	17·65	19·60	21·70	24·30	26·50
		B.H.P. per 1,000 cubic feet.	2·04	2·22	2·44	2·66	2·88	3·10	3·35	3·59
42	28 × 12½	Volumes.	8,000	8,310	8,650	9,000	9,260	9,500	9,850	10 100
		Revolutions.	1,023	1,068	1,115	1,162	1,210	1,250	1,292	1,330
		B.H.P.	17·30	18·50	21·10	24·00	26·70	27·50	33·00	36·20
		B.H.P. per 1,000 cubic feet.	2·15	2·23	2·44	2·66	2·88	2·90	3·35	3·58

---

* The results of the trials of this fan as here given are shown plotted in fig. 23.

resistance of the connecting pipes. The resistance offered to the flow of a column of air will depend upon the extent of surface which bounds it, so that the airways should be made as short as possible by placing the fan as near to the cupolas as is consistent with the general arrangement of the plant; and since the surface exposed to the air current also depends upon the sectional perimeter for a given sectional area, this perimeter should be made as small as possible, which is ensured by making the pipes circular. Not only is the resistance to the flow of air dependent on surface, but it is also greatly dependent upon the velocity of flow. As the result of experiment, it has been demonstrated that for low velocities the frictional resistance is proportional to the velocity; for greater velocities it is proportional to the square, cube, and higher powers of the velocity. For velocities usual in the air pipes to cupolas, we may assume that the friction is proportional to the square of the velocity; and also that

$$V = \frac{Q}{A},$$

Q being the cubic feet of air passing any section per minute, A the area of that section in square feet, and V the velocity of flow of the air in feet per minute.

These assumptions have been made in plotting the diagram, fig. 26, giving the loss of pressure by friction of air in straight pipes in ounces per square inch for every 100 ft. of length, when the pipes are clean and fairly smooth. For other lengths the loss will be directly proportional, thus: Suppose in a particular case the length of pipe from the fan outlet is 62 ft., and that its diameter is 16 in., and we wish to determine what excess of pressure must be created by the fan over that required in the wind box of the cupola in order to overcome the resistance offered to the flow of 6,000 cubic feet of air per minute. The velocity of flow under these conditions, V, will be—

$$\frac{Q}{A} = \frac{6000}{1 \cdot 395} = 4300 \text{ ft. per minute}$$

hich we find from the diagram fig. 26 the loss per length of 16 in. diameter pipe would be 1·3 ounces per square inch, so that for a length of 62 ft. the fan will require to be speeded to give a pressure of

$$1{\cdot}3 \times \frac{62}{100} = 0{\cdot}806 \text{ ounces per square inch}$$

above that required in the wind box of the cupola, in order to allow for loss by friction.

In order to minimise the expenditure of power in supplying the air it is customary, when the length of piping is in excess of a few feet, to increase the diameter of the delivery pipe after it leaves the fan outlet, thus reducing the velocity of flow, and in this way diminish the loss of pressure due to friction. For example, in the case cited above, suppose that 16 in. was the diameter of the fan outlet, then if by means of a coned pipe we connect the fan to an air main, say 22 in. in diameter, thereby reducing the velocity of flow to

$$\frac{6000}{2{\cdot}64} = 2275 \text{ ft. per minute,}$$

which, on reference to the diagram, fig. 26, will be found to entail a loss of pressure per 100 ft. of pipe of the increased diameter—*i.e.*, 22 in. of but 0·25 ounces per square inch; then, for a length of 62 ft., the loss will be only

$$0{\cdot}25 \times \frac{62}{100} = 0{\cdot}155 \text{ ounces per square inch.}$$

One of the greatest difficulties with which the fan blower has to contend in its application for cupola blowing lies in the resistances presented by improper piping and inadequate tuyere and wind box area, the great amount of power often used to run the fan being seldom due to the fan itself, but to the method of selecting, erecting, and piping it.

For a blower to work satisfactorily, it must be placed on a firm foundation, and kept free from dirt and dust, which can best be done by boxing it in, an inlet being provided from the open air. The lead of pipes should be as straight as possible, and where bends are absolutely necessary they should be made of as large a radius as possible, the radius of the centre line of the bend being never less than one and one-half times the diameter of the pipe, when the loss of pressure due to change of direction of the flow (for an angle of 90 deg). will not exceed that due to the friction of a straight pipe of a length equal to five times the particular diameter, whereas with a sharp right-angled elbow the loss of pressure would be equal to that due to the friction of a straight pipe about forty times the diameter in length.

All branches should lead-off at as small an angle with the line of the main as possible, and where a branch main terminates in two branches at a cupola the three pipes at the junction should form a Y, the diameter of each of the two smaller pipes being not less than 0·71 that of the larger one. When the pipes are laid underground, they are usually of cast iron, but when above, the material generally employed is sheet iron or steel, galvanised, the joints being riveted and soldered to ensure tightness; the thickness of the plates used for pipes up to 10 in. diameter being about

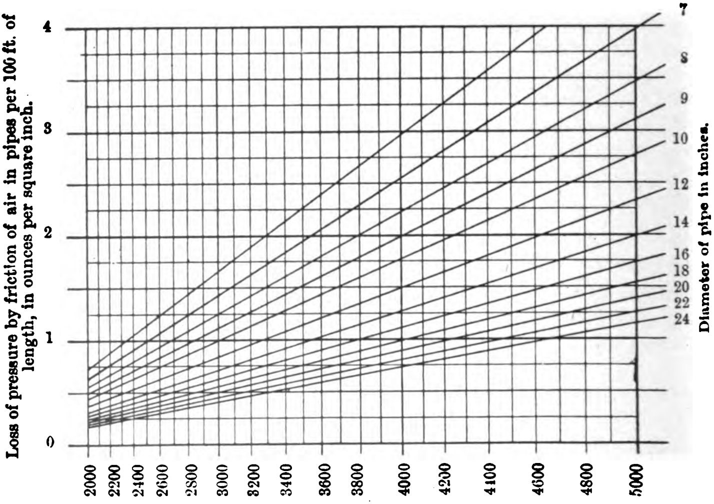


FIG. 26.—Velocity of flow in feet per minute.

24 L.S.G., for pipes from 10 in. to 20 in. in diameter 22 L.S.G., for pipes from 20 in. to 30 in. diameter 20 L.S.G., for pipes 30 in. in diameter and up to 40 in. 18 L.S.G., and for those of larger diameters up to and including those of 5 ft. diameter 16 L.S.G. When the blower is of the displacement type, the air pipe should always be fitted with a relief valve, so arranged and loaded that it will allow the air to escape if by reason of the cupola becoming clogged, or from any other cause, the pressure rises much above that required under normal conditions of working, and so prevent bursting of the pipe.

With fan blowers driven by belts, countershafts are invariably necessary in order to obtain the speed requisite for the production of the desired pressure. The practice of avoiding their use by fitting ridiculously small pulleys on the fan spindle should be avoided, as much power may be consumed in so rapidly changing the direction of running of the belt. When determining the maximum speed at which a given belt may be run, regard should be taken not only of the tension on the driving span due to the force transmitted, but also of the additional stress imposed by centrifugal force, to the neglecting of which may be traced many breakages of belts. When the belt is running round with the pulley it is subjected to a tension imposed by centrifugal force, just in the same manner as is the rim of the pulley itself, and some portion of the strength of the belt must be regarded as resisting such pull, the remaining portion only being available for the transmission of force.

From the elementary laws of dynamics it can be proved that if an endless belt of any cross-section whatever runs at a given speed, the centrifugal force produces a uniform tension at each cross-section of the band equal to the weight of a piece of the belt the length of which is twice the height from which a body must fall in order to acquire the velocity of the belt; or if

W = the weight of a foot length of the belt in pounds,
V = the speed at which it runs in linear feet per second,
g = the acceleration produced by gravity in feet per second, say 32·2,

then the centrifugal tension, as it may be called, will be

$$\frac{W V^2}{g} \text{ lb.}$$

To demonstrate this proposition, let us consider any two cross-sections, calling them A and B respectively, such that the particles at A move parallel with, but in the contrary direction, to those at B.

Now, the weight of the belt passing any cross-section is W V in one second; and since the particles at A are moving with the velocity + V, and those at B with equal but contrary velocity − V, the mass of matter of the weight W V undergoes a change of velocity represented by 2 V, and the force in pounds necessary to produce such change

$$= \frac{2 W V^2}{g},$$

one-half of which force is the tension at cross-section A, and the other half is supplied by the corresponding tension at B, so that the tension at either cross-section is represented by

$$\frac{W V^2}{g} \text{ as before,}$$

and is the force employed in compelling the particles of the band to circulate in a closed path, and the tension-producing pressures and friction on the pulley, or the "available tension," is less by the amount of this centrifugal tension. Therefore, as it is to the total tension the strength of a belt has to be suited, it follows that the dimensions of the cross-section to transmit a given force must be greater for a high than would be necessary for a low speed.

This being so, we can determine for any given belt of known strength and weight per foot run the limiting velocity beyond which any further increase of speed will not only be without advantage as regards transmission of power, but is actually injurious.

The tension necessary for the transmission of a given r varies inversely as the speed of the belt; or let P be wer to be transmitted, then the tension on the belt

$$T = \frac{P}{V}.$$

When a band is strained over pulleys it has a certain initial tension, which is replaced when running by an increased tension T^1 on the driving span, and a diminished tension T^2 on the following span; then

$$T = T^1 - T^2;$$

and if

μ = coefficient of friction between band and pulley = say 0·30 to 0·40 for leather belting on iron pulleys under ordinary conditions of working,

a = length of arc on smaller pulley embraced by belt,

and R = the radius of smaller pulley,

$$T = T^1 \left\{ 1 - \left(\frac{1}{2{\cdot}718^{\frac{\mu a}{R}}} \right) \right\}$$

For any given gear, the value of the fraction

$$1 - \left(\frac{1}{2{\cdot}718^{\frac{\mu a}{R}}} \right)$$

is constant, and independent of the velocity.

Call this x, and we have

$$T^1 x = T = \frac{P}{V}, \text{ and } T^1 = \frac{P}{x V}.$$

The centrifugal tension t, as given above,

$$= \frac{W V_1}{g}.$$

If we call the working strength of the belt S,

$$S = T^1 + t = \frac{P}{x V} + \frac{W V^2}{g}.$$

Then the value of V, at which P is a maximum, is given by the formula

$$V = \sqrt{10{\cdot}7 \frac{S}{W}};$$

or, calling the velocity of the belt in feet per minute V^1, we have, as a sufficiently near approximation,

$$V = 200 \sqrt{\frac{S}{W}}.$$

For leather belts the working strength of which, allowing for joints, may be taken at 320 lb. per square inch of cross-section, and weigh 0·43 lb. per foot run per square inch of section,

$$V^1 = 200\sqrt{\frac{320}{0\cdot43}} = 5455 \text{ ft. per minute.}$$

Taking the case of a leather belt having a cross-sectional area of one square inch and running at different velocities, we may calculate the corresponding centrifugal tensions, which, subtracted from the working strength of the belt, or 320 lb., gives the successive values of T^1; and since x remains constant, $T^1 \times$ the corresponding velocity will be proportional to the maximum power that could be transmitted at the given velocity without subjecting the belt to a greater working stress than the chosen 320 lb. per square inch. The results obtained in this way are tabulated below, and clearly show the effect of running a belt at too high a velocity on the power which it is capable of transmitting:—

Velocity of the belt in feet per minute. V^1	Value of $\frac{W V^2}{g} =$ the centrifugal tension t.	Value of $S - t = T^1$.	Value of $T^1 \times V^1$, which is proportional to the power which may be transmitted without exceeding the working strength S of the belt.	Relative value of the power transmitted, calling the maximum unity.
	Lbs.	Lbs.		
3,600	48·0	272	979,200	0·855
4,200	65·4	254·6	1,069,320	0 935
4,800	85·5	234·5	1,125,600	0·983
5,400	108·1	211·9	1,144,260	0·991
5,455	110·0	210·0	1,145,550	1·000
6,000	133·6	186·4	1,118,400	0·977
6,600	161·7	158·3	1,044,780	0·913
7,200	192·5	127·5	918,000	0·801

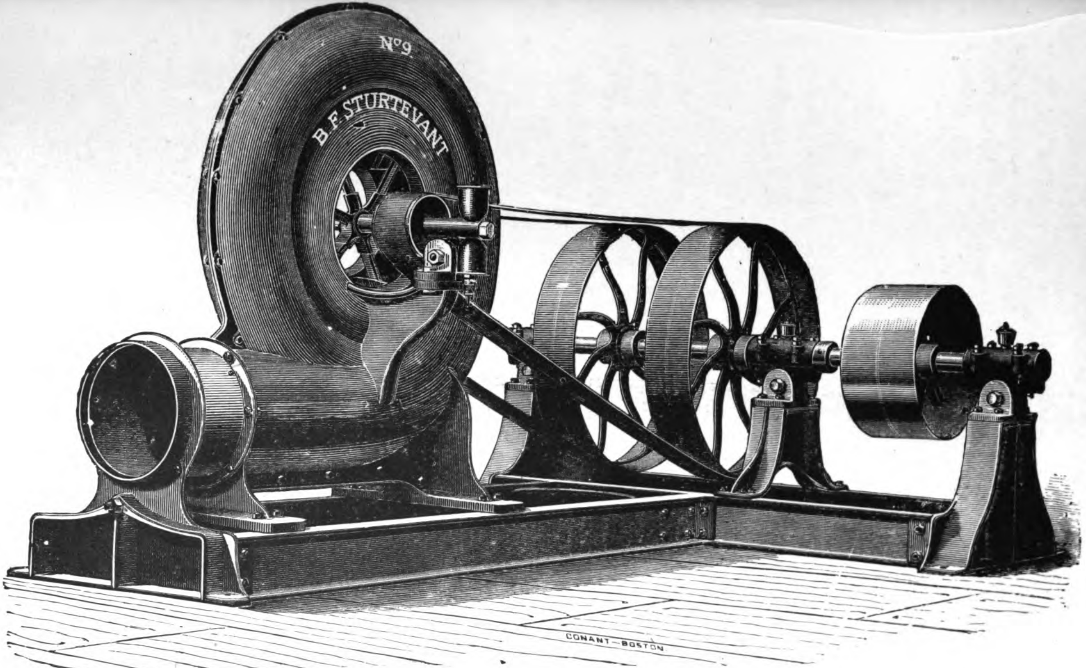


FIG. 27.

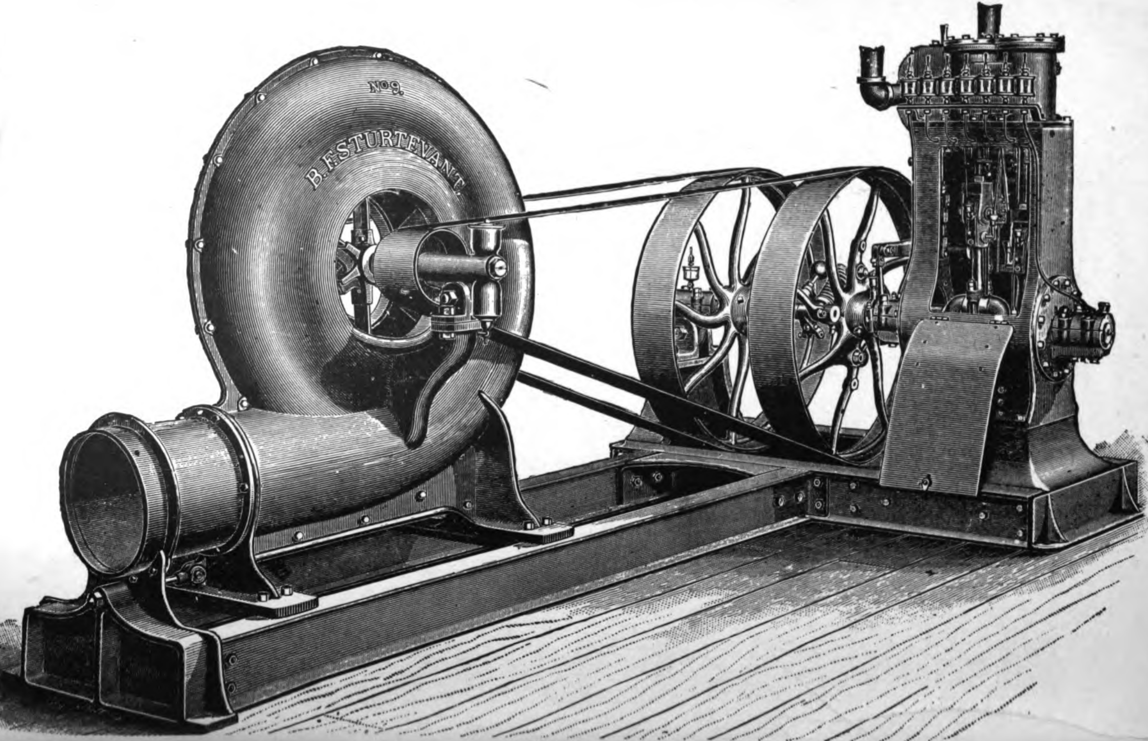
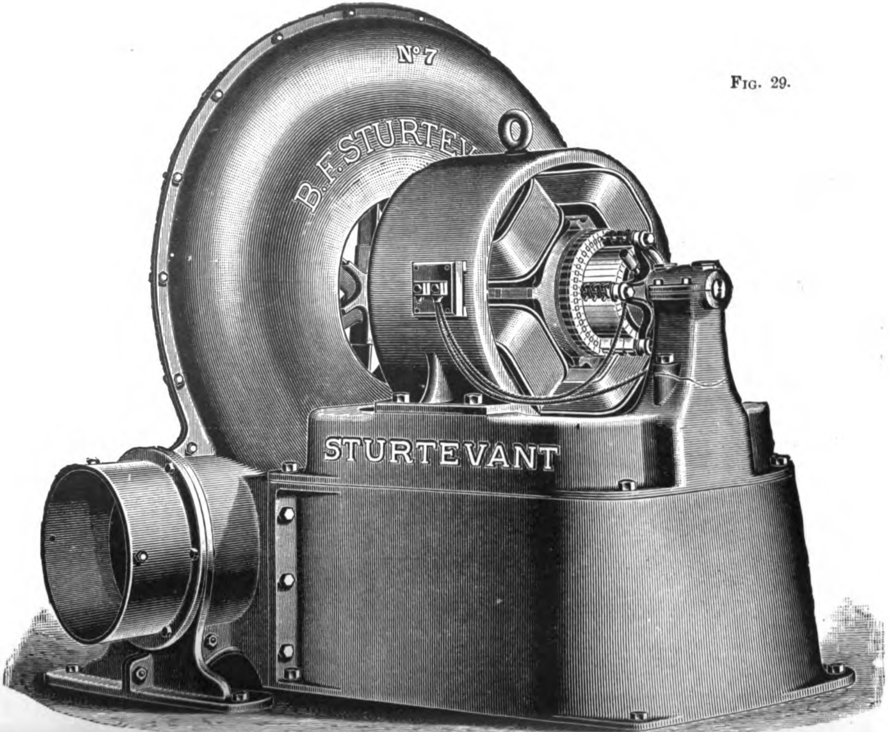


Fig. 28.

From these results it will be seen that the best speed at which to run a leather belt is about 5,400 ft. per minute. For other belts the most suitable speed of running may be readily calculated by the aid of the formula when the maximum working strength per square inch of cross-section and the weight per foot run per square inch of section are known.

When a countershaft is employed, the most satisfactory arrangement is that shown at fig. 27, in which the blower and countershaft are both mounted on a common foundation constructed of steel beams, and to which the blower may be readily bolted when in the correct position, the adjustment being made by means of the shackle bolt. The blower spindle is thus kept in perfect alignment with the countershaft, so that the belts track evenly and run smoothly, reducing their wear to a minimum. By the aid of the adjusting bolt, any required tension may be brought upon the belts while running, thus preventing inconvenience and loss incident to a stoppage of the blower while work is in progress. In order to allow of this adjustment being made without disarranging the blast pipes, the fan outlet is made telescopic, as shown. In many instances it is found desirable to drive the blowers by means of independent engines, thus rendering it possible to alter the pressure of the air delivered by changing the speed of the blower, without affecting any other portion of the plant. Fig. 28 shows a No. 9 Sturtevant blower, driven by a pair of vertical engines of the enclosed type, a type which is peculiarly fitted for such work, as the moving parts are thus protected from dust, which forms an inherent part of the atmosphere in or about all foundries. Some modern ironfounders employ electrical power, amongst other things, for driving the blowers, by the aid of which it is possible to do away with the loss of power in overcoming the centrifugal force of the belt, and in so rapidly changing its direction, as the electric motor can be connected directly to the shaft of the fan itself, as in fig. 29, showing a motor of the multipolar type driving a fan direct; whilst in other cases, where the pressure required is such that the speed of a direct-connected motor would of necessity be excessive, the belted arrangement shown at fig. 30 is adopted.

FIG. 29.



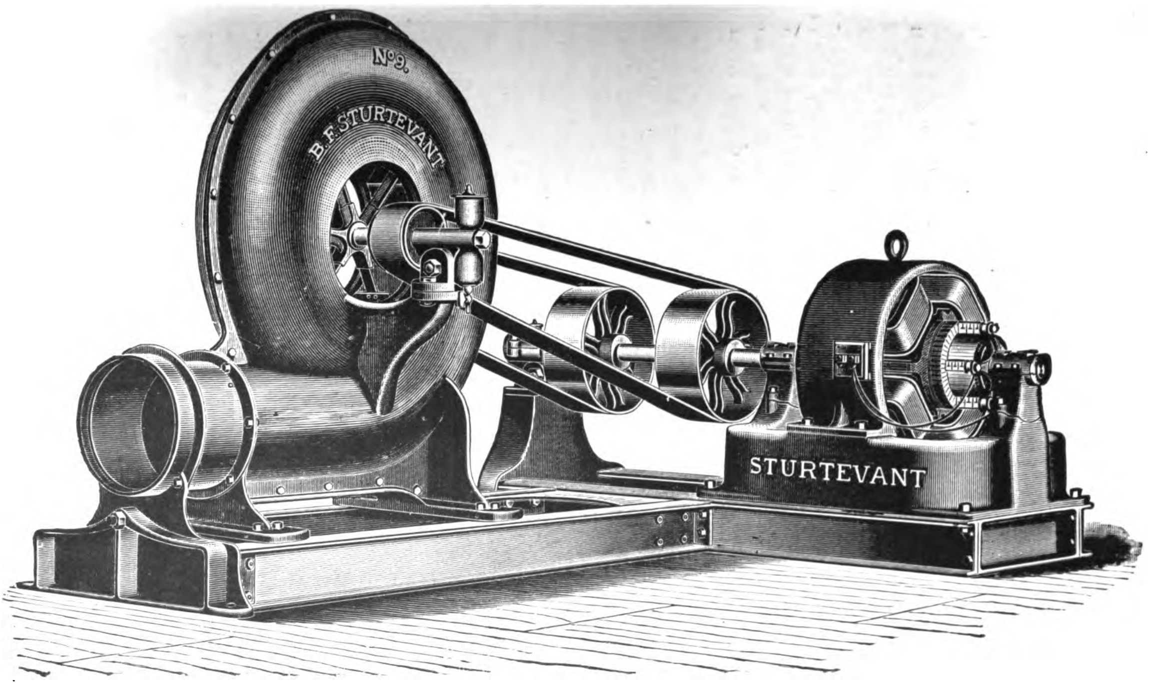


FIG. 30.

CHAPTER VI.

LADLES.

THE foundry ladle of to-day is very much what it was ten or twelve years ago, although the practice of fitting tilting gear—usually in the form of a worm and wheel—to all ladles, with the exception of those of but a few hundredweights capacity, is becoming more general. With such gear it is possible for one man to manipulate the ladle with ease and certainty, whereas, in former times, it was no uncommon sight to see as many as half a dozen men struggling to pour a casting from a 3 or 4 ton ladle, provided with no other means for carrying out the operation than a pair of crutch bars. The arrangement of the gearing most generally adopted is shown by fig. 31, the bevel wheels being introduced to enable the operator to stand on the side [illegible] he tips the ladle. The manufacture of foundry ladles [illegible] that of most other articles, virtually developed into [illegible], and is now carried on as a specialty by a few [illegible] the result that their design and construction

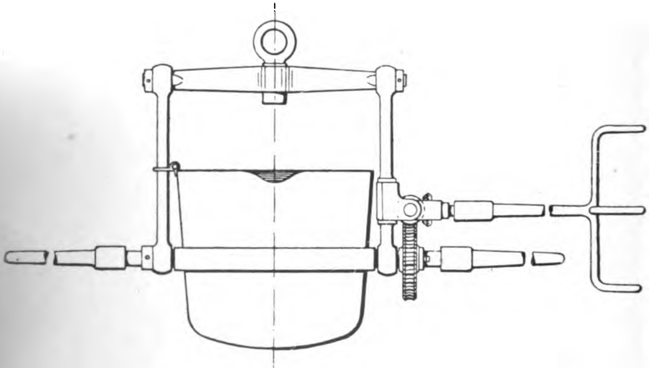


FIG. 31.

receive that careful consideration which experience has shown to be necessary, although we still find ladles in use fitted with ridiculously small and badly-fitted worms and wheels, which are a constant source of trouble and expense. The careful balancing of the ladle is another feature which has of late years received its due share of attention. The requisite cubic capacity of a ladle for containing a given quantity of iron will depend upon the thickness of lining adopted, which for large ladles—say 6 tons and above—usually consists of firebricks covered with a thin daubing of loam; whilst for those of smaller capacities the lining of the bottom is formed by a layer of fine cinders about 1 in. to 1½ in. thick, over which is evenly laid 2 in. of soft silica sand well rammed down, the sides being evenly daubed with loam to a thickness of about 2 in. at the bottom, tapering off to 1 in. at the top. The sand for the bottom should be thoroughly dried before use, as should also the ladle when completely lined, as a damp ladle not only chills the iron, but may cause it to boil, or, if the daubing is unusually thick, may even cause an explosion. Water in a ladle, or a wet lining, will explode the iron immediately it touches it. There is also great danger of an explosion if any scrap iron placed in the ladle is either wet or rusty. To guard against an explosion from such a cause it is the practice in some foundries to heat the scrap to a red heat just before placing it in the ladle to chill the iron. A precautionary measure often adopted is to drill a few small holes—say ¼ in. in diameter—through the bottom of the shell of the ladle to allow of the escape of steam, and so save the sand bottom from rising should the sand be at all moist. The proportions usually adopted for foundry ladles are those shown by fig. 31, the depth being about equal to the mean diameter. The sides taper slightly. The dimensions and approximate capacities (allowing about one-fourth for lining and for a margin at top) of a number of ladles of this form as actually made are given on the following page.

Approximate capacity.	Diameter of ladle.		Maximum depth of ladle.
	At top.	At bottom.	
Cwts.	Ins.	Ins.	Ins.
50	36¾	32	31
35	31¾	27½	29½
30	31½	27½	25¾
25	28½	23	28
20	27⅝	23	24
15	23½	20	23½
12	22	19	20¾
10	21½	19	17¾
8	19	16½	18½
6	18	14½	16¾
5	17	14	15½
4	16½	14	15
3	15	12½	14
2	13	10	11½
1½	12½	10	9¾
1	10½	8¾	10
¾	9½	8	8½
½	8½	7	7½

Some foundry-men prefer a deeper ladle, more after the proportions shown by fig. 32, which shows one of the well-known McNiel stamped steel ladles. These ladles are manufactured by a patented process from a single steel plate without weld or rivet, in all sizes up to 2½ tons capacity, and are much appreciated on account of their extreme lightness, strength, and durability. They are made not only of the form shown by fig. 32, but also of the form shown at fig. [illegible]—in fact, many of the ladles tabulated above were [illegible]actured at the Kinning Park Ironworks. The

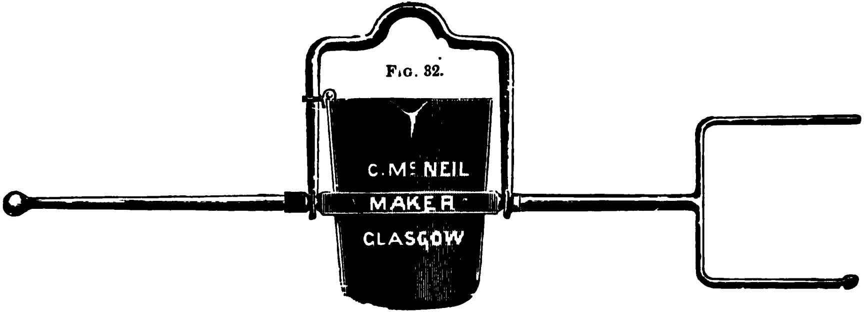


FIG. 82.

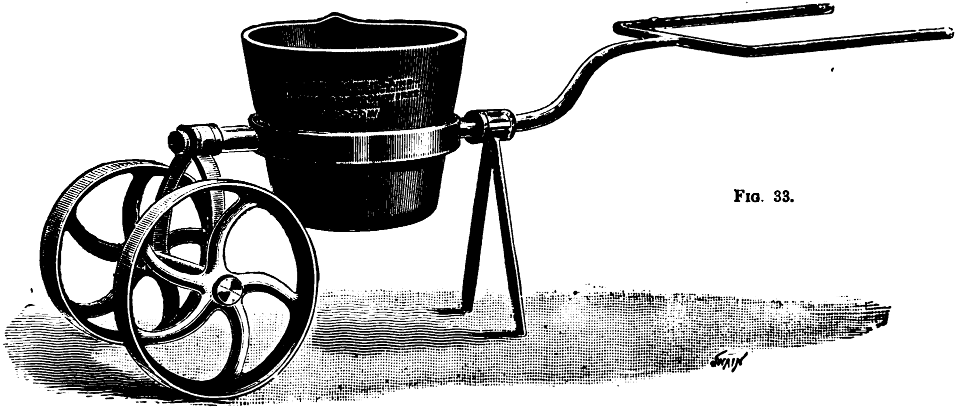


FIG. 33.

dimensions adopted for ladles of the form illustrated by fig. 32 are as follow :—

Approximate capacity of ladle.	Diameter of ladle.		Maximam depth of ladle.
	At top.	At bottom.	
Cwts.	Ins.	Ins.	Ins.
30	29	23	32¼
20	24½	20	29¾
15	22½	19	25
12	20⅛	16½	26
10	19½	16½	22⅜
8	18½	14	22¾
7	18	13⅞	20½

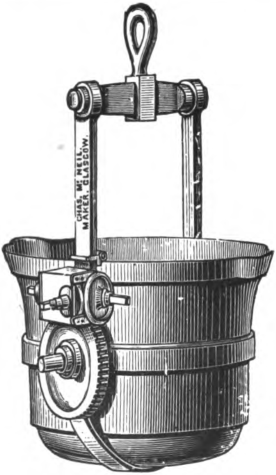


FIG. 34.

the rapid transport of small quantities of metal about dry, the trolley ladle, illustrated at fig. 33, is a very convenient article often met with. The McNiel ladle, for capacities of from 3 to 15 tons, takes the form shown by

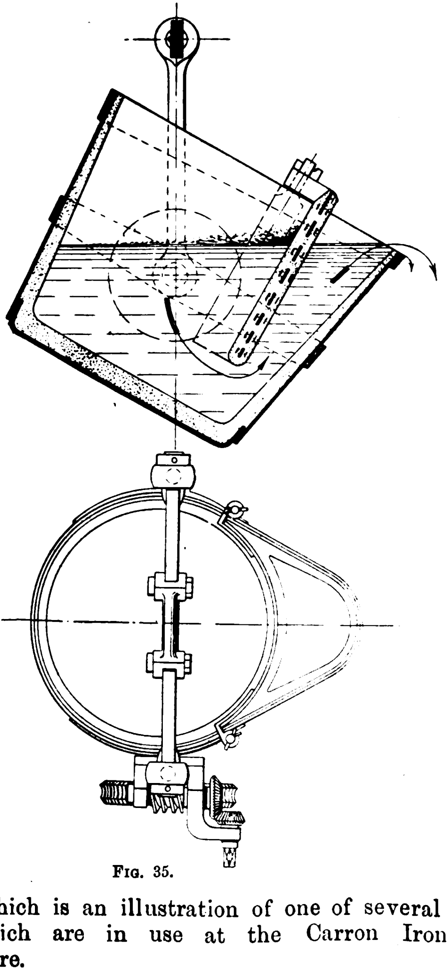


FIG. 35.

fig. 34, which is an illustration of one of several of these ladles which are in use at the Carron Ironfoundry, Stirlingshire.

With heavy masses of metal it is often difficult to satisfactorily clear the metal when pouring from an ordinary ladle. To overcome this difficulty Messrs. Goodwin and How introduced the self-skimming ladle, illustrated by fig. 35, with which a clear pour of metal, free from slag, is ensured. It will be seen from fig. 35 that the main body of the ladle is cylindrical, but it is extended one side to form a spout, by which the metal is poured. The communication between the ladle and the spout is made near the bottom, so that the metal which flows over the lip is drawn from the bottom of the general mass, and any scoriæ and sand floating on the top of the metal is prevented from escaping into the moulds by the division or skimmer plate between the ladle and the spout. This division plate is readily removable, and is provided with means for holding the refractory facing.

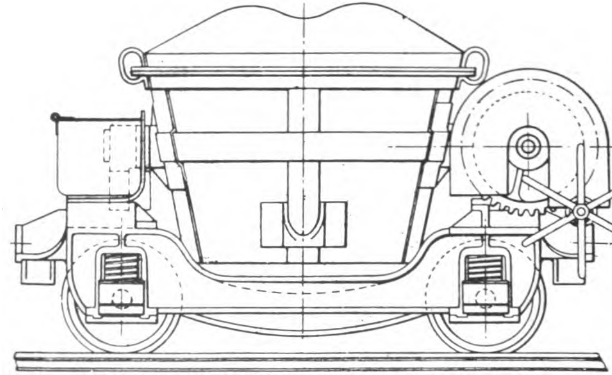


Fig. 36.

With the exception of the small trolley ladle, illustrated by fig. 33, all the ladles previously described are arranged [illegible] use with cranes. In many foundries the metal is [illegible]ught to the moulds in ladles mounted on trolleys, which [illegible] on rails, and are in some instances propelled by electro-[illegible] Figs. 36 and 37 illustrate a modern example of these "hot metal cars," in use at the Ohio Iron and Steel Works. As will be seen from the end view, fig. 37, the ladle is tilted or rolled by the trunnions to and fro, through the intervention of racks, the extreme position of the ladle when tipped being shown by the dotted lines. By rotating the spindle, the yoke is moved in one or the other direction.

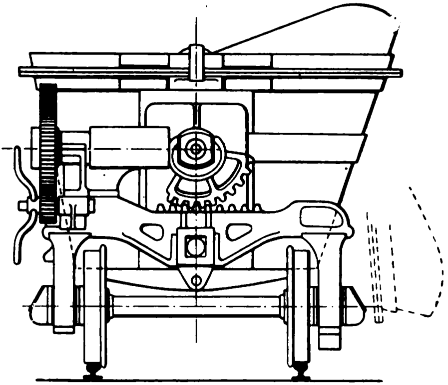


FIG. 37.

The chief advantages of this arrangement are that the ladle may be lifted off the car for re-lining without dismantling the tilting gear, and that the thrust is directly applied to the trunnions, thus making the operation of tilting easy and regular. The tilting may be effected by hand gear, as in the present example, or by the aid of an electro-motor.

CHAPTER VII.

Cranes and Hoists.

The advances which have taken place during recent years in iron-foundry equipment are very apparent as regards means for the handling of materials, the castings, &c., the swinging jib cranes and sheer poles, which existed in the earlier foundries, being mostly displaced by overhead travellers—first by those driven by shafts, or, in a few cases, by ropes; and yet more recently by those driven by electricity. Overhead travelling cranes possess many points of superiority over all other forms of cranes, including a great increase of ground covered, the facility for extension, when desired, the saving of valuable floor space, and the possibility of placing additional cranes on the same runway, or hoists on the bridge, thus increasing the hoisting equipment at a minimum expense. Those driven by shafts do fairly well when the motive power is not too far away; but the frictional losses with this type of crane are very great, the speed of the shaft is limited, and the tumbler bearings are often a source of trouble. Driving by means of a light quick-running cotton rope is decidedly a neater and quieter method, although not generally suitable for foundry cranes. Both these methods of driving involve the loss of a large amount of power, as, whether the crane is working or not, the revolving shaft, or running rope, requires a large proportion of the total power merely to keep it in motion. As the result of experiments it has been found that nearly 6 I.H.P. were required to drive each 100 ft. of rope at a speed of 2,200 ft. per minute in one case; while in another instance $6\frac{1}{3}$ I.H.P. were absorbed in maintaining every 100 ft. of rope at a speed of 1,570 ft. per minute; while tests [illegible]ried out by Mr. Adamson with his rope-driven travellers [illegible]ed that from 5 to 6 I.H.P. were required per 100 ft. [illegible] of shop. Besides this loss there are others, often of [illegible] magnitude, due to the mechanical means by which [illegible] is transmitted. Whether the driving be by square shaft or by rope there will be wear and tear—in the one case of the shafts and bearings and of the belts and pulleys from the engine, and in the other of the ropes, pulleys, and bearings; and further, there is the cost of oil used in lubrication. The problem of conveying energy to a machine that is continuously changing its position, even though its movement is confined within the limits of a defined track, is most satisfactorily solved by the aid of electricity, on account of the facility and efficiency with which a moving body can be maintained electrically in contact with a generator. Electric leads are easily erected, are noiseless, motionless, and cheap, and can be made to convey power along routes otherwise impracticable. They do not suffer from wear and tear, and absorb only a very small proportion of the power to be transmitted. These advantages, together with the ease of control, have led to the electric motor gradually taking the foremost place as a motive power in modern foundries, not only for travelling and other cranes, but also for driving the cupola blowers, revolving rumbling barrels for cleaning castings, actuating "skull crackers" for breaking pig and scrap iron, &c. With regard to travelling cranes in particular, it has long since been realised that electricity is peculiarly adaptable for their driving; but until comparatively recent times foundry-men did not regard the employment of electrical machinery with much confidence, as high-speed frail motors of the "open" type were used on most of the early electrically-driven travellers installed for this purpose. This feeling of distrust is, however, gradually dying out, as cranes have been improved so much from time to time, that now, when electrical systems of this kind are well worked out, it makes one of the most substantial systems, whilst at the same time effecting great economy in operation. Even in the busiest foundries cranes are seldom actually engaged more than about 10 to 20 per cent of the working hours. The rest of the time is occupied in adjusting slings, preparing loads, &c.; and during this interregnum there need be absolutely no power of any sort taken by the electric traveller, which we have already seen is not the case with either the rope or the shaft-driven travellers.

Whether the motors of an electrically-driven traveller remain running when the crane is standing idle or not will depend upon the type of motor adopted. If they are shunt-wound, they cannot be made to start with the full load, and so in cases where this type of motor has been employed they have been arranged to run continuously, clutches or belts and pulleys being used to control the various movements of the crane. On the other hand, by the employment of motors of the series-wound type, the motor remains stationary so long as its power is not required, for such a motor gives a maximum torque at the moment of starting, thus enabling it to start with the full load.

The earlier electrically-driven overhead travelling cranes were fitted with a single shunt-wound motor carried on the wheel boxes, and running at a constant speed in one direction only. Although this was undoubtedly an advance, seeing that the high-speed rope or specially arranged length of shafting was dispensed with, these cranes, practically speaking, offered no improvements in actual working beyond what had already been attained by rope or shaft driven travellers, for they still retained the most troublesome features of the mechanically-driven cranes, such as the cross shafts with their tumbler bearings, the complicated head-stock, with its open and crossed belts or elaborate system of clutches and gearing, the necessary worms and worm wheels, with their concomitant evils, were all retained in this one-motor crane.

The objection to the use of the series-wound motor for most purposes, due to the variation in speed in proportion to the load, renders it a perfect machine for crane work, for the ideal crane in lifting or traversing its load should start into motion slowly, accelerate rapidly, and deal with the major portion of the hoisting or travelling at full speed, then slow quickly and stop. This is rendered possible only by the use of a separate motor to each motion, and when these are made reversible, allowing each motor to lie in continuous [illegible]ar with its work, and fitted with carbon brushes, we have [illegible]stem which represents the most advanced practice in [illegible]ad travellers.

[illegible]f the earliest three-motor travellers in this country was designed by Messrs. Vaughan and Son Limited for the Woolwich Arsenal. It was capable of lifting a maximum load of 7 tons, and, like many of the early cranes of this type, the crab generally was designed to suit the motors, whereas in the more modern type of the "Vaughan" crane, as illustrated by fig. 38, the motors are designed and constructed to suit the crab, the magnets and armatures being situated on the inner cheek of the crab side, whilst the commutators, with their brush gears, are brought to the outside, so as to permit of ready inspection and adjustment from the platform.

With many of the early electric cranes installed in foundries a deal of trouble was experienced owing to the destructive effect of dust, &c., on their machinery, especially on bearings, motors, toothed wheels, and controllers. On the more recent cranes, however, most of the trouble is overcome. Cast-steel wheels with chilled treads are used on the tracks of runways and bridges; the journals are similar to those on railway cars, the shafts run in half boxes which are removable, and the lower part of the bearing is stuffed with oily waste, or the spindles on which the wheels are keyed run in gun-metal bushes, the undersides of which are cut away to allow a light wooden roller, floating in a bath of oil, to run in contact with the spindle and automatically keep it constantly flooded with oil, as shown at fig. 39, and adopted by Messrs. Adamson and Co. These bearings are found to give excellent results, and are very easily attended to and kept in good order. Cut-steel gears are used in all cases where the speed is at all high, and in some cranes the gear wheels are enclosed in oil-tight casings, thus effectually excluding dust and dirt, and prolonging the life of the gears.

The comparatively high rate of revolution of electro-motors renders some form of reducing gear between the motor and the final motions necessary, and the slower the crane has to work the greater this reduction will require to be, and for this reason the later cranes are arranged so that as little intermediate gearing as possible may be required, first by adopting slow-speed motors, preferably of the closed-in type, as used on street cars, and, secondly, by employing working speeds of hoisting and traversing as high as are consistent

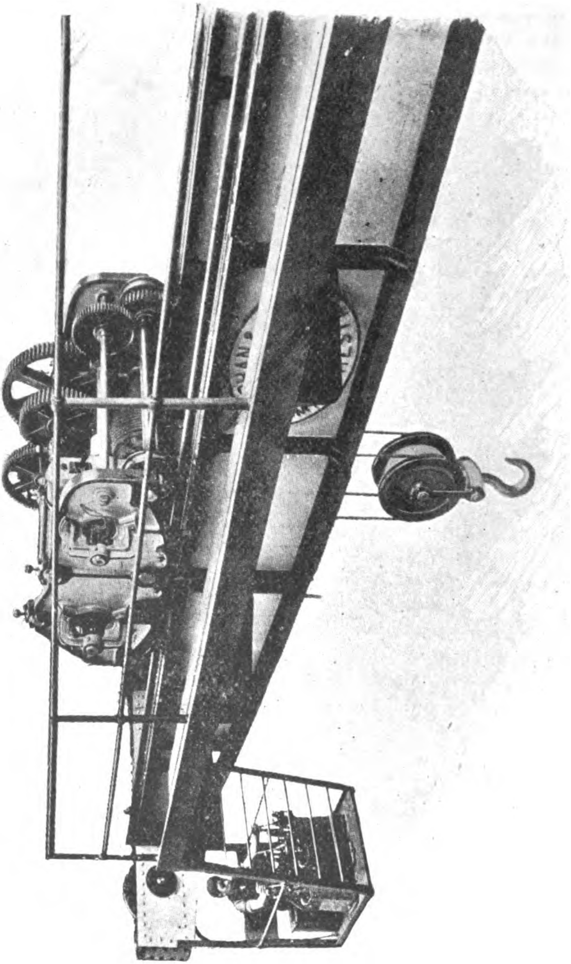


FIG. 38.—20-TON THREE-MOTOR "VAUGHAN" OVERHEAD ELECTRIC TRAVELLER

with safety. The reducing gear in many cranes consists of a worm and wheel, the worm in some instances being single-threaded, although the modern practice when this form of gear is used is to employ double or even treble threaded worms, with a view to securing a higher efficiency, the worms and wheels running in an oil bath, and ball bearings fitted for taking the end thrust.

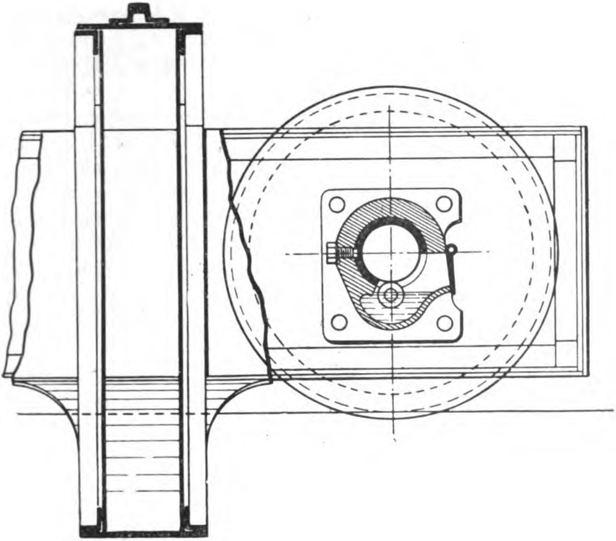


FIG. 39.

This latter practice entails the necessity of fitting some form of brake to prevent the load "taking charge," as with a multi-threaded worm gear it is possible for the worm to be revolved by the wheel when under load; whereas with a single-threaded worm the gear is self-sustaining in any position when the load is on, thus rendering a brake unnecessary. The tendency with the leading crane builders at the present time is to discard worm gears altogether for traveller drives, and to effect the speed reduction between the motor and the hoisting barrel by means of one or two sets of spur gear, enabling the crab or trolley to be made very compact and snug, as in the "Vaughan" traveller, illustrated by fig. 38. This simplification of gearing reduces the length as well as the weight of the crab, and allows of a longer travel on the bridge, with the result that a load may be lifted from a position more nearly under the runways; while, at the same time, the reduced weight of gearing—more especially when low-speed motors, which respond quickly to variations of load, are employed—reduces inertia, and so conduces to ease in starting and stopping rapidly.

In the three-motor type of traveller one motor is usually mounted alongside the bridge girders, and geared by means of a spur pinion and wheel to the travelling shaft which extends along the bridge, the rotation of which is communicated to the travelling wheels through spur gears; and as each motor is fitted with an independent controller, the operator is able to start very gradually, which is a great advantage when it is required to travel the bridge only a short distance. With other kinds of power-driven cranes it is much more difficult to travel a small distance and stop again with precision, owing to the inability on the part of the operator to vary the speed of the motive power.

Although the most usual method of arresting the longitudinal travel of the bridge is by the gradual stoppage of e motive power and its reversal, some travellers are fitted th a foot brake on the travelling motion, by the aid of which the bridge may be stopped at any point without reversing the motor. The motor for hoisting is mounted on the crab; and here, again, the three-motor type of crane shows to advantage in being able to run slowly for a short time, as when drawing patterns, a process which is certainly more difficult to carry out successfully with a clutch or strap-driven crane. The series-wound motor, with its characteristic feature of running faster under lighter loads, o renders it possible to dispense with the change of gear iving a higher speed with lighter loads, although where e proportion of the work to be done is the manipulation s much below the maximum power of the crane, it is more economical in working to equip the crab with an auxiliary hoist with a fourth motor for dealing with these lighter loads, while in some other cases it is found desirable to have two trolleys on the bridge.

With regard to the efficiency of the electrically-driven traveller, some carefully-conducted tests, carried out by Messrs. Joseph Adamson and Co., of Hyde, with their three-motor travellers, gave the following results, which far surpass anything in the way of efficiency or in point of convenience of manipulation that can be attained with rope or shaft-driven travellers, or even with single-motor electric travellers :—

Lifting capacity...........................	5 tons	10 tons	30 tons
Speed of lifting in feet per minute........	13·10	6·30	2·40
Horse power absorbed by motor with full load	10·40	9·60	9·00
Efficiency or ratio— $\left.\frac{\text{Work done in raising load}}{\text{Power absorbed by motor}}\right\}$	0·469	0·563	0·543
Longitudinal speed of bridge along gantry in feet per minute......................	160	100	80
Horse power absorbed in travelling bridge along gantry at the above speed	2·80	3·30	5·00
Speed of trolley across bridge in feet per minute	59·30	40·60	20·00
Horse power absorbed in traversing trolley across bridge at the above speed........	0·85	1·35	3·10

More recent tests of a 50-ton three-motor traveller, constructed by Messrs. Adamson for Messrs. Sir Wm. Armstrong, Whitworth, and Co., showed a maximum efficiency as measured by the relation of the work done in raising the load to the power absorbed by the motor, of 63 per cent with a load of 30 tons, which was assumed to be the average load with which the crane would have to deal. The efficiencies of this traveller at progressive loads were found to be as follow :—

Load in tons	3	5	10	15	20	30	40	50	55
Efficiency per cent...	19	26	44	54	60	63	61	56	51

This traveller is fitted with an auxiliary hoist and motor, for dealing with loads up to 5 tons, at a speed of 15 ft. per minute, which on trial showed an efficiency of 53 per cent when dealing with its maximum working load of 5 tons; whilst for loads of from 3 to 4 tons the efficiency was 54 to 55 per cent. A comparison of these results, with those obtained with the main hoisting gear when dealing with similar loads, clearly indicates the desirability of incorporating such an auxiliary hoist in all travellers which are likely to be employed to any extent on loads which are small compared with the maximum for which the crane is designed; whilst another point worthy of note in connection with the hoisting gears fitted on this traveller is that they work at their highest efficiencies, not when dealing with their maximum loads, but with loads that approximate to the average values likely to be met with in daily working.

The framing of overhead travellers employed in foundries, where much of the work is of an uncertain and jerky nature, such as that of lifting and turning over flasks, dragging castings out of moulds, &c., should be stiffer and with a greater depth of girders than is necessary when the work is more regular. These girders are usually built up of solid plate, single or double webbed, of the fish-bellied form, with the cambered edge downward, a practice which is followed both for electric travellers and for those of other types by English manufacturers. This arrangement leaves the trolley exposed and free of access, thus facilitating rapid inspection, adjustment, renewal, or repair from the platform, which is a point of considerable importance, for when it becomes necessary for a shop traveller to undergo repair serious interruption of the work below invariably takes place, and may be unduly prolonged if the design of the crane prevents ready access to all the working parts, as, for instance, when the trolley runs between the bridge girders instead of along their top. Jib cranes are still retained in many foundries, and when electrically driven are now generally fitted with two motors, one for lifting and one for slewing.

Hydraulic and pneumatic cranes are also to be found in comparatively modern iron foundries, and will probably continue to be employed for some years to come, despite the serious rivalry of electric cranes, which, though more expensive themselves, are less costly in generation and transmission of power, and are not affected by frost. The hydraulic crane is convenient where the work to be done is fairly constant, and the load always approximate to the maximum with which it is capable of dealing. In such a case the power may be used to its full advantage, whereas, with variable work, it becomes necessary to introduce some form of gear in order to adjust the water expended to the work it has to perform. The nature of this gear, as usually fitted, only enables the crane to adjust itself to variation of load by steps, and does not permit of the perfect graduation which is attainable with the electro-motor. With a view to retaining the direct application of the power, which is the leading feature of the hydraulic crane, and yet allow of some adjustment of the water expended to the work done, Mr. J. Stannah introduced his differential hydraulic crane in which two concentric rams work in one cylinder. The inner ram is solid, while the outer ram is annular, and is open-ended at the bottom, so that it can slide upwards while the inner ram remains stationary, or both can rise together. The bottom end of the central ram carries a pair of lugs, capable of engaging with corresponding lugs at the bottom of the cylinder. At its upper end there is a worm gearing by which the ram can be rotated, so as to cause its lugs to engage with, or to disengage from, the lugs on the bottom of the cylinder. The outer ram can also be secured by means of movable hooks, which catch over its shoulder just above the stuffing box.

Now, if a light lift has to be made, the outer ram is held, and the inner ram cast loose. The latter then does the work, and the water used is equal to a volume represented by the cross-section of the ram multiplied by its travel. For a lift of medium weight the central ram is secured and the outer ram cast loose, when the expenditure of water is equal to the annular cross-section of the outer ram multiplied by its travel.

For a heavy lift both rams are released and they move up together, acting as the equivalent of one solid ram. For overhead travelling cranes hydraulic power is but seldom employed, owing to the difficulty in satisfactorily taking the high-pressure water to the moving crane. Although shaft-driven travellers, actuated by hydraulic engines from a pressure main, are to be met with, still experience undoubtedly shows that at anyrate for travelling cranes electric driving is more satisfactory than any other and is generally cheaper.

The following brief descriptions of two 50-ton electric travellers, one constructed by Messrs. Vaughan and Son, of Manchester, and the other by Messrs. Joseph Adamson and Co., of Hyde, Cheshire, afford a very good idea of what may be regarded as the most advanced practice in electrically-driven overhead travellers.

The "Vaughan" crane has a span of 50 ft., and occupies a headroom—that is, a distance from the top of gantry rail to nearest roof tie—of 9 ft. 6 in. The girders are double-web section, built up of mild steel plates and angles, well strengthened with T bar stiffeners. The web plates are $\frac{5}{16}$ in. thick, and the depth of the girders at their centres is 5 ft. The bridge can travel along the gantry at a speed of 200 ft. per minute, while the crab traverses the bridge at a speed of 100 ft. per minute. The crab sides are each of double steel plates firmly stayed together. All shafts and axles are of steel, and revolve in gun-metal bearings. Two barrels are mounted on the crab suitably geared for the following loads and speeds—

Larger barrel { For lifting 50 tons at a maximum speed of 1¾ ft. per minute.
„ 25 „ „ „ 3½ ft. „

Smaller barrel { For lifting 7 tons at a maximum speed of 12 ft. per minute.
„ 3½ „ „ „ 24 ft. „

The barrels have right and left hand grooves to ensure a true vertical lift of the load and its equal distribution on each girder. Steel wire ropes are used for the lift, which is 25 ft. high. The hooks are provided with hardened cast-steel balls and plates under the head to permit of the maximum loads being freely revolved. All gear wheels running at high speeds are machine cut, and the large spur wheel on the main barrel is of cast steel. The total weight of the crane with its full load is 95 tons.

The electrical equipment consists of three series-wound motors, each controlled by its own independent resistance and reversing switch (Vaughan and Foster's patent). The normal speeds of the motors are as follow: Hoisting motor, 300 revolutions per minute; motor for travelling bridge along gantry, 600 revolutions per minute; motor for travelling crab across bridge, 300 revolutions per minute.

Though these comparatively slow speeds involve larger and more expensive machines, the advantages derivable—such as the longer life to the crane, the elimination of high-speed gear wheels, and consequently smoother running, the quicker stopping and reversing powers—more than compensate for the increased cost. The controlling switches are of a type specially designed and constructed by Messrs. Vaughan and Son for crane work, and are arranged with liquid resistances, in preference to the more usual metallic coils. The disadvantage due to the presence of the liquid is slight compared to the destructive action consequent upon the unavoidable sparking in the latter type, which involves the necessity for frequently renewing the contacts. By simple movements of the switch levers the speeds of the motors may be varied independently and almost instantly from zero to their maximum, or the direction of rotation of the armatures reversed. These switches are so arranged in the operator's cage that the three motions of the crane may be operated simultaneously or individually as required. The reduction of speed of the motors to that of the hoisting barrels, trolley wheels, and runway wheels is effected entirely by spur gearing. The hoisting gear is provided with a magnetic brake, so arranged that, when the current is switched on to the hoisting motor, it puts into circuit an electro-magnet possessing sufficient power to raise the brake lever and render the brake inoperative at the moment that hoisting or lowering commences, and also during their continuance. Immediately the current is switched off from the motor the brake applies itself automatically, and without any attention whatever on the part of the operator. The advantage of this is obvious, as if from any cause during working operations the current should fail, the brake magnet would instantly release the brake and allow it to take charge of and sustain the load. Besides the three controlling switches, an emergency switch is also fitted in the cage, by the aid of which the operator can, if necessary, instantly cut the crane completely out of the electric circuit. The electric current is conveyed to the crane by two bare insulated copper wires stretched along the gantry girders, and collected therefrom by means of sliding collectors carried on a bracket at the rear of the operator's cage.

The 50-ton electric overhead traveller, by Messrs. Adamson and Co., is of the same general design as the "Vaughan" crane. The girders, built up of steel plates and angles, are box girders of the fish-bellied type, with the cambered edge downward, and have the trolley rails bolted along their top flanges, as in fig. 39, which also shows the type of axle bearing adopted. The runway wheels are of cast iron, with rolled steel tyres, and have cast upon them rings, in which the teeth for transmitting the motion are machine cut, these teeth gearing into pinions on the train driven by the electro-motor. The crane bridge can be travelled along the gantries at a speed of 80 ft. per minute, and the maximum speed at which the trolley can traverse the bridge is 40 ft. per minute, the reduction of the speeds of the motors to these travelling speeds being made in two stages in both instances. Two barrels are provided, suitable for the following loads and speeds :—

Large barrel	For lifting loads up to 50 tons, at a maximum speed of 4 ft. per minute.
Small barrel	For lifting loads up to 5 tons, at a maximum speed of 15 ft. per minute.

Both lifting drums are controlled by electric brakes. These are mounted on the motor shafts, and work automatically. The brake wheel is pressed on by shoes applied by springs, and released by an electro-magnet, which is energised when the current is switched on to the corresponding otor, so that immediately the operator sets the crane to [illegible] or lower, the brake is taken off. Should the load, in [illegible]g, drive the motor too rapidly, the counter electro- [illegible] force would reduce the current, and the brake would [illegible]elf, and so check the speed. The main hoist carries its load by a steel-wire rope 5 in. in circumference, passing in two bights round two sheaves on the hook block. The two ends of the rope are fixed to the drum, and the centre bight is led round an equalising pulley to ensure a true vertical lift. The maximum height of lift is 22 ft. The reduction of speed from motor to main hoisting barrel is effected by spur gearing, and there are three intermediate shafts between the motor and the barrel. All these spur gears are steel, with the teeth machine-cut out of the solid, except the last two, which are of the double-helical type. The auxiliary hoist, for dealing with loads up to 5 tons, has a barrel 16 in. in diameter, with right and left hand grooves to receive the steel-wire rope 2¼ in. in circumference. The speed is reduced in two steps—first, by a worm and wheel; and secondly, by a pair of spur wheels. The worm is of steel, four-threaded, and gears into a bronze wheel having machine-cut teeth, both the worm and wheel being cut on the principles recommended by Mr. J. H. Gibson,* which render it possible to obtain almost as high an efficiency for power transmission with a worm gear as with a spur gear. This crane has four series-wound motors—one for giving longitudinal motion to the crane, one for the transverse motion, and one each for the main and auxiliary hoists respectively. These motors run at the following speeds under normal conditions: Main hoisting motor, 400 revolutions per minute; auxiliary hoisting motor, 300 revolutions per minute; motor for travelling bridge along gantry, 300 revolutions per minute; motor for travelling crab across bridge, 500 revolutions. The power absorbed by each of the four motors is as follows, when the crane is fully loaded: Main hoist, 25 brake horse power; auxiliary hoist, 12 brake horse power; traversing, 7 brake horse power; and for longitudinal travelling, 5 brake horse power. Taking these figures for the power required by the hoisting motors, and the speeds of lifting given above, it will be seen that the mechanical efficiency of the main hoist is 54 per cent, and that of the auxiliary hoist 43 per cent.

It will be noticed that on both these travellers steel-wire ropes are used, a practice which has become very general of

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* See *Engineering*, vol. lxiii., pages 403, 438, and 619; or *The Practical Engineer*, vol. xv., pages 275 and 291.

late years, more especially for high-speed cranes and those dealing with heavy loads. Chains are noisy when rapidly worked, and are more liable to sudden fracture than a steel rope; whilst for heavy loads chains are cumbersome and weighty, unless a number of sheaves are used. A wire rope entails a somewhat larger barrel and pulleys than does a chain. Thus, in the Adamson crane the main barrel is 30 in. in diameter, or six times the circumference of the rope; while the auxiliary barrel is 16 in. in diameter, which is also about six times the circumference of the rope. When ropes are used, it is usual to form the surface of the barrel as a spiral groove or grooves, in which the rope coils, thus not only preventing riding and chafing of contiguous coils, but also giving support to half the circumference of the rope, and so counteracting the tendency of the rope to flatten under the crushing action of coiling.

A useful rule for determining the safe working load for steel-wire ropes when in good condition is—

$$L = \frac{C^2}{3},$$

L being the safe working load in tons, and C the circumference of the rope in inches.

For chains, a simple and easily remembered rule is—

$$L = \frac{(\text{diameter in eighths})^2}{10},$$

by which we see that a chain, the links of which are forged from $\frac{5}{8}$ in. diameter rods, would be suitable for a working load of

$$\frac{25}{10} = 2 \cdot 5 \text{ tons.}$$

So far very little mention has been made of the use of compressed air, although its application to cranes may be made in an almost endless variety of ways. The most common method met with in the foundry is the employment of direct-acting air hoists of the simple cylinder type, as illustrated at fig. 40, which was constructed by the Whiting Foundry Equipment Company, of Harvey, Ill., U.S.A.* These hoists are often suspended from trolleys which run on overhead tracks constructed of "I" beams,

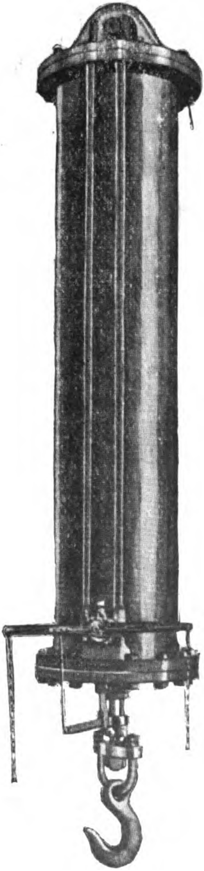

FIG. 40.

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[*] Messrs. J. W. Jackman and Co., 39, Victoria Street, London, are the sole agents in this country for the Whiting Foundry Equipment Company.

and arranged with switches, curves, &c., so that a load may be lifted from any point over the floor. Fig. 41 is a sketch of such a trolley supplied by the Whiting Company. The frame of the trolley is cast steel, and the wheels have chilled treads, and are mounted on steel axles running in roller bearings. In many instances direct-acting air hoists have been applied to existing hand-power cranes without in the least interfering with the gearing, and have proved very satisfactory for loads up to 10 or 12 tons. The hoist, illustrated at fig. 40, is fitted with a safety check, which prevents the load falling suddenly in case of a break in the supply hose. The height of lift is regulated automatically by a collar clamped on the piston rod engaging with a lever connected by means of a link to the rocking arm attached to the valve stem, and closes the valve at any desired height or lift without attention from the operator; whilst an adjustable speed regulator enables the valve to be set for all speeds, the adjustment for raising and lowering being independent. When the head room available is limited the hoist is arranged with a telescopic cylinder, by which means nearly double the lift of the ordinary type can be obtained [illegible] given distance between hooks.

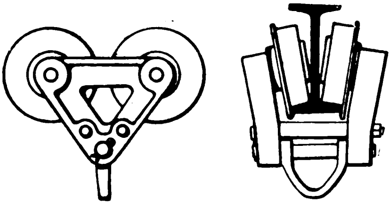

FIG. 41.

[illegible]ct-acting air hoists are also employed on overhead [illegible]g cranes, when the cylinder is suspended in the [illegible] Fig. 42 is a sketch of a 5-ton crane with an air [illegible]nted in this way, the trolley running on a double-[illegible]ge. The operation of travel gear is by means of [illegible]d chains, and the hoist by the usual chains and [illegible]m the ground. The cylinder is 12½ in. in diameter, and the hoist will lift a load of 5 tons with a pressure of about 100 lb. per square inch, and uses approximately 25 cubic feet of free air per lift of 4 ft. The capacity will, of course, vary in proportion to the pressure; while the quantity of free air consumed for a given height of lift will vary in inverse proportion to the load.

Cupola hoists, for raising the materials to the platform from which the cupolas are charged, are sometimes worked by electric power, although more generally by either steam, compressed air, or hydraulic power; and as the loads to be dealt with in this case are practically constant, the work may be done with fair economy by these latter sources of power, and with machinery of very simple nature. In its simplest form the hydraulic hoist consists of a table or a cage mounted on a ram, the ram working in a cylinder fitted with a valve for controlling the water supply, and constitutes a most perfect type of lift from the mechanical point of view, apart from economy. With this type of lift the ram has to lift the moving parts before it lifts the load, a condition which has led to the fitting of wire ropes from the

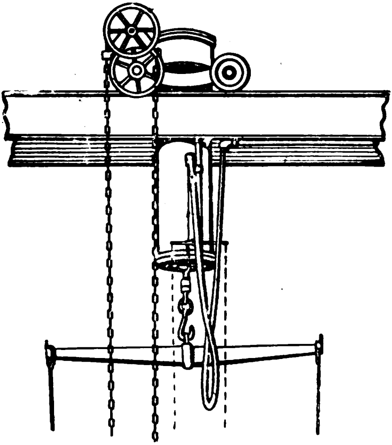

FIG. 42.

top of the cage, or from the corners of the platform, connected with balance weights, and to the adoption of the suspended type of lift. The weight balanced should include not only the moving parts of the hoist, but also the major portion of the trucks, so that the hydraulic or other power employed only has to lift the actual materials.

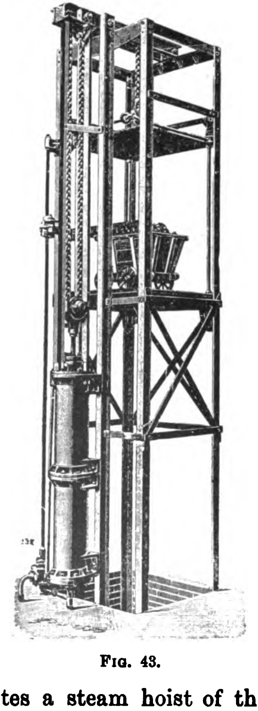

FIG. 43.

Fig. 43 illustrates a steam hoist of the suspended type, made by Messrs. Thwaites Bros., of Bradford, and designed to lift 1 ton. The frame is built up of angle bars well braced together, and held in cast-iron frames at the top and bottom. The cage is of wrought iron, and has a platform 4 ft. by 4 ft. 10 in. The lever for controlling the steam-admission valve is carried with the cage, and slides along the upright shaft shown on the left-hand side of the illustration. The cage can thus be set in motion either at the top or bottom, or checked whilst in motion if desired, by the workman who travels with it. The hoist is fitted with lifting barriers and check stops.

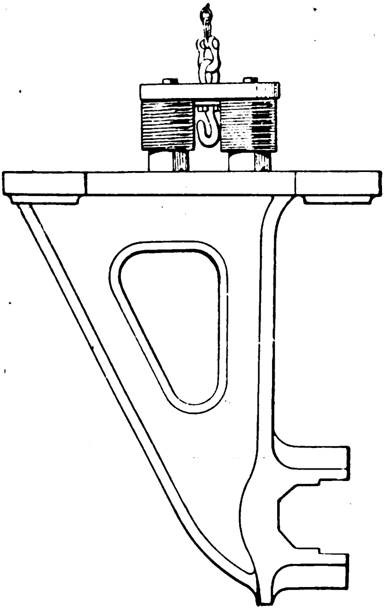

FIG. 44.

The employment of electro-magnets in conjunction with cranes for lifting castings, &c., has been introduced in a number of foundries; and when we consider the possibilities of such a system as regards saving of labour, it is remarkable that electro-magnetism has not been more often used for lifting purposes than it has. In the comparatively few instances where electro-magnets are used in conjunction with cranes they have proved a success. At the Sandycroft Foundry and Engine Works Company Limited, near Chester, electro-magnets have been employed for lifting purposes for some years past, and the value of the method so conclusively proved, that this firm has taken up the manufacture of magnets as a branch of their business.

The current may be controlled by means of a switch placed at the top of the magnet; or if the magnet is employed in conjunction with an electric crane, the switch may be placed in a convenient position in the operator's cage.

In foundries where electrical machinery is already in operation the use of magnets entails but a very small expense, as the amount of current required is trifling compared with the enormous gain in convenience and saving of time following their adoption.

Fig. 44 shows a "Sandycroft" magnet lifting a casting. The pole ends of these magnets are made of a peculiar shape, and longer than necessary for the actual requirements for lifting, for convenience in handling the castings. The hook between the limbs of the magnet is added for the purpose of engaging slings, &c., on non-magnetic articles.

The approximate weights of "Sandycroft" magnets for lifting loads of from 10 to 60 cwt., together with the watts required, are given below:—

Load to be lifted. Cwts.	Approximate weight of magnet. Cwts.	Watts required.
10	1	150
20	3	250
30	5	350
40	7	450
50	9	550
60	12	650

CHAPTER VIII.

THE PREPARATION OF MOULDING SANDS.

THE manner in which the sand is prepared for the use of the moulders is an important item in the commercial success of a foundry, and has come in for a considerable share of attention, most foundries at the present time including in their equipment not only loam mills, but also a number of other power-driven machines for grinding, mixing, and riddling the sand, which, whilst saving labour, tend also to a greater uniformity in the materials, the whole of the operations being under the charge of a "sandman," and not left to the individual moulders, as was formerly the case.

It will seldom be found that the "clay binder" and the grains of the sand are uniformly distributed so as to make a homogeneous material, for, owing to various local causes, such as a contiguity to grass roots or other vegetation, the depositing of an excessive proportion of clay by infiltration and settlement from muddy water, &c., different portions of the same sandbank may have quite dissimilar compositions, some of which may yield a sand containing too much clay, or, as it would be technically termed, "too fat"; whilst other sections may be composed too largely of sharp sand, in which case it would be described as "too lean." If such heterogeneous sand were used there would be every chance of the moulds being hard in some parts and spongy in others, conditions which are apt to cause various defects in the mould and casting, such as a breakage of the former due to a local deficiency of binder in the sand; or scabs on the casting, due, on the other hand, to the hard spots in the mould caused by local excesses of clay.

It is far more difficult to thoroughly mix different grades of sand, or other substances with sand, than it is to ascertain the composition; and when certain measures of flour, coal dust, or other materials are added to a given number of barrow loads of sand in the preparation of "core sand," for example, it is necessary to turn over the heap many times, and also to pass the materials through sieves to obtain even an approach to a homogeneous mixture; and even when the sand is to be used as it is delivered to the foundry, without the admixture of other sands or materials, it is always riddled before use, necessitating both time and labour, to save which the power-driven sand sifter, illustrated at fig. 45, was introduced, and is a great improvement upon the older method of sliding hand riddles to and fro over a light horse formed of wrought-iron bars. The sifter, illustrated

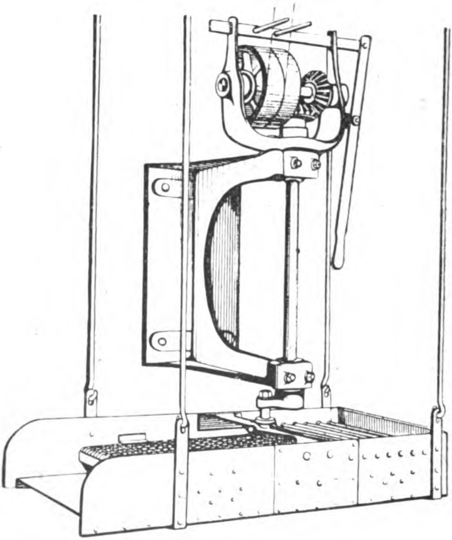

FIG. 45.

t fig. 45, has a frame 5 ft. long by about 2 ft. 3 in. wide, lt up of $\frac{5}{16}$ in. plate. A series of $\frac{1}{2}$ in. diameter bars are nged across the frame, and serve to break up the larger s of sand. The sieves, whose mesh may vary from o 1 in., are interchangeable. The motion is made to h as nearly as possible that of hand riddling by a succession of impulsive movements, the riddle being suspended by four rods, and has motion imparted to it by a crank making about 120 to 140 revolutions per minute driven from the belt pulley by means of mitre gearing. The fine sand falls through the sieve, while the unbroken lumps are thrown out in a pile at the end.

Fig. 46 illustrates in longitudinal and transverse section Hosgood's patent machine for grinding, mixing, and riddling coal and sand for facing mixtures, &c., manufactured by D. J. Morgan and Co., of Barry. This machine consists of a pair of rollers A, A for grinding the coal and sand, under which is a horizontal spindle carrying the spiral and inclined blades B, C, and D for mixing and delivering the ground material to the sieves S, S, which are situated under the end of the barrel of the machine. The sieves slide in grooves, and are reciprocated by means of a crank attached to the lower end of a vertical spindle, which is revolved by means of bevel gear driven from the horizontal spindle. The rollers A, A are pressed together by spiral springs, which admit of their separating to allow small pieces of ungrindable material passing between them without breaking the machine.

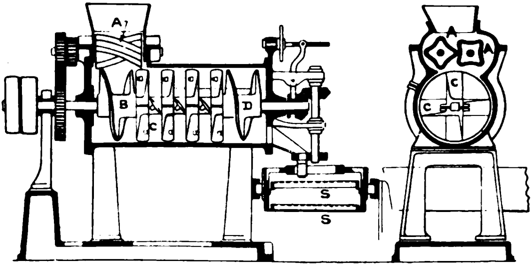

FIG. 46.

The Griffin mill, manufactured by the Bradley Pulveriser Co., of Boston, whose London offices are at 37, Wallbrook, and illustrated at fig. 47, is employed in some foundries for the preparation of facing sand. The chief feature of this mill is the adoption of a mechanical movement, which the makers assert has not hitherto been employed in pulverising, viz., the running of a roll against a ring or die. It will be seen from the sectional illustration of this mill, fig. 48, that there are no journals in the pulverising chamber, an important point when we consider efficiency and wear and tear. The material is reduced to a very fine uniform product, every particle of which is perfectly fractured and granulated, the reduction being effected entirely by the crushing force of the roll, which by centrifugal action can be made to bring a pressure of as much as 6,000 lb. to bear

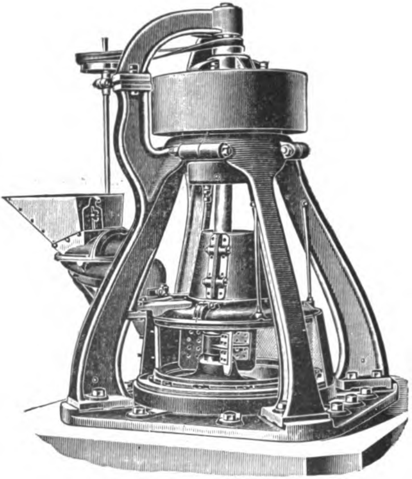

FIG. 47.

on the material being pulverised between the roll and die; and since the roll is revolved within the die in the same direction as the shaft is driven, when it comes in contact
th the die it travels around the die in the opposite
ction from that in which the roll is revolving with the
and so gives the mill two direct actions on the
al to be ground. It will be seen that the mill
power by the pulley P, running horizontally upon
d and adjustable bearing B, which is supported by

the frame. From this pulley is suspended the shaft by means of a universal joint, and to the lower extremity of this shaft is rigidly secured the crushing roll, which is thus free to swing in any direction within the case. The ring or die is mounted in a pan forming the base of the machine. A number of openings *p* in the base, outside the ring or die, are provided for the discharge of the material to the pit below, after having been driven through the circular screen S by the action of the fan F mounted on the shaft, which draws air in at the top of the cone C and discharges it through the screen, together with the fine material, thus effectually keeping all dust within the mill.

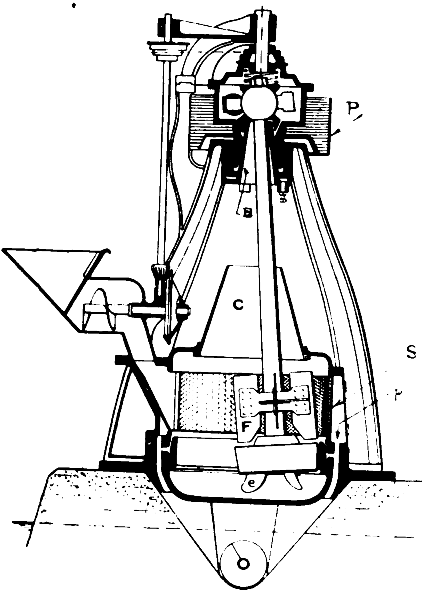

Fig. 48.

In fig. 48 a conveyer is shown for withdrawing the pulverised material from the pit. On the underside of the roll the ploughs *e* are fitted, and work in the material to be reduced; stir it up, and throw it against the ring, so that it is acted upon by the roll, and when fairly in operation the whole body of loose material whirls around rapidly within the pan, and, being brought between the roll and die, is crushed, and all that is sufficiently fine passes at once through the screen above the die, while the coarser portion falls down to be acted upon again. The universal joint, by which the shaft is connected with the pulley, allows perfect freedom of movement to the roll, so that it can easily pass over obstructions, such as iron nails, &c., without damaging the mill. The circular screen S surrounding the pulverising chamber is of much coarser mesh than the delivered product; for instance, a 16 mesh screen delivers a product over 90 per cent of which will pass a 60 mesh screen, so that there is no danger of clogging even when producing the finest products.

The Griffin mill is made in two standard sizes, having rings or dies of 30 in. and 36 in. inside diameters respectively, the former being arranged for a speed of pulley of from 190 to 200 revolutions per minute, and fitted with a roll about 18 in. in diameter and 6 in. deep; whilst the 36 in. mill runs at from 135 to 150 revolutions per minute, and has a roll about 22 in. diameter, with a depth of contact surface of 6 in.

In Germany, some few years back, a method of preparing moulding and core sand by the aid of centrifugal force was proposed by a Mr. Schütze, and has subsequently been largely adopted not only there, but also in this and other countries, a typical machine employing this force being that illustrated at fig. 49, and manufactured by the Sellers Co., of Philadelphia. With this machine it is possible to accomplish as much work by the help of two labourers working [illegible] hours a day in preparing facing sand as five men [illegible] do in ten hours by the older methods; whilst, at the [illegible] me, it is found that, as the sand is much more [illegible] mixed and tempered, its quality of toughness [illegible] pairment of porosity) is greatly improved. The [illegible] very simple construction, consisting essentially [illegible] revolving plate P, having upon its upper surface a number of prongs *p* grouped about a central axis.* The sand is fed through the hopper H, and thrown with great force from prong to prong, emerging from beneath the cover C in a fine shower, free from lumps and thoroughly mixed. Even agglomerated sand in large lumps too big to pass through any ordinary riddle comes out of the centrifugal mixer in a fine powdery condition along with

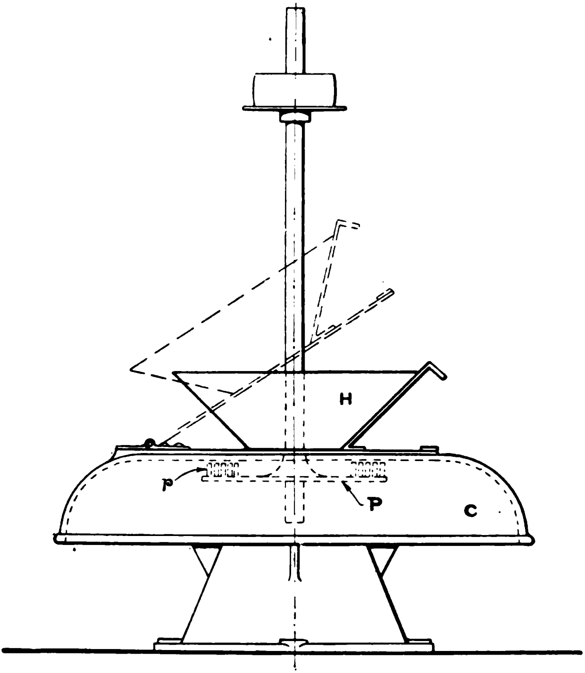

FIG 49.

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* A machine having a revolving plate of 22 in. in diameter is run at a speed of about 1,200 revolutions per minute, and has prongs ⅝ in. diameter standing 2½ in. above the face of the plate.

the other materials, consequently no previous sifting is required. In everyday work the materials are placed in layers, sandwich fashion, on the floor, in a convenient position for being shovelled into the hopper of the machine through which they are passed as fast as it is possible for two men to shovel them. The hopper H is hinged for convenience in cleaning the revolving plate and prongs, and for removing stones, nails, or other obstructions. The machine is often made portable, and sometimes furnished with an electro-motor, so that it can be shifted to any part f the foundry that may be at the time convenient for its eration. The original Schütze centrifugal mixer, some ndreds of which are in use in Germany, had the revolving

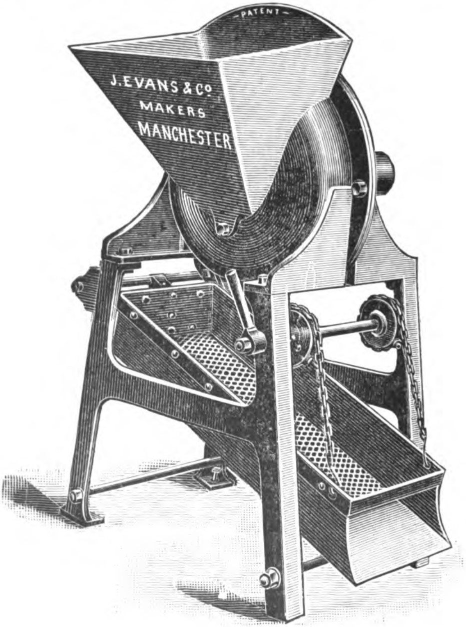

FIG. 50.

plate driven from below, and an indiarubber shield was placed round the outside of the table a few inches from the edge of the plate which guided the sand into a circular heap after it had been whirled from the table. In a paper before the Institution of Mechanical Engineers, Mr. W. Bagshaw gives a carefully made comparison of the cost of preparing sand with one of these machines, and by hand labour, showing that with the machine preparing 30 tons of sand per day of nine hours, the cost per ton, allowing for depreciation, repairs, and interest on capital outlay, was a little over 2d., whereas with hand labour, the average output in riddling and treading sand is 4 cwts. per hour per man, which, with wages at 5d. per hour, gives 2s. 1d. per ton, or twelve times the cost by the machine.

The power absorbed by the machine was taken at three horse power for the purpose of the comparison for an output of 3⅓ tons per hour, which is an ample allowance, as a similar machine in Devonport dockyard takes only one horse power when mixing 2 tons per hour. These rates do not at all represent the maximum capacity of the machines, for it is possible to mix as much as 12 tons per hour. A test of one of these machines was carried out at the Woodside Ironworks, Dudley, when there was weighed a mixture consisting of 21¾ cwts. of sand, and 2⅜ cwts. of coal dust, making a total of 24⅛ cwts. or 1·206 tons. In six minutes the whole of this mixture passed through the machine and was turned out in perfect condition. Before this machine was employed a staff of four men was needed at a total cost of 11s. 6d. per day for preparing by hand sufficient sand to supply about fifty moulders; nor could four men always meet the demand, and it sometimes happened that moulders had to leave their work and help to prepare their own sand. After the introduction of the machine, at a cost of 6s. per day for labour, the whole of the fifty moulders were supplied, and not only the moulders, but the core makers and loam workers were supplied with pulverised loam, the newly ground loam fresh and wet from the loam mill being superficially dried in a stove, mixed with a proportion of old and passed through the machine with saving of time and improvement in the character of the work.

Another machine of this type, which has found a place in a large number of foundries, is the Evans patent centrifugal sand-tempering machine, illustrated at fig. 50. This remarkable little machine, both as a labour saver and as an improver of moulding and core sands, has supplied a long-felt want in foundries generally for an efficient and rapid temperer.

For grinding coal, or coke dust and charcoal, for use in the preparation of facing sand, &c., Messrs. Evans and Co. supply a very simple mill, as shown in section at fig. 51, in which the pulverising is effected by heavy cast-iron balls being rolled over the material contained in the pan. These mills are made in two sizes, the smaller of which has a pan 25 in. in diameter, with a depth of 13 in., and is fitted with 8 in. diameter balls, weighing about 68 lb. each; while the larger size has a pan 32 in. in diameter, $19\frac{1}{2}$ in. deep, and has balls of about 10 in. diameter, weighing approximately 0 lb. each.

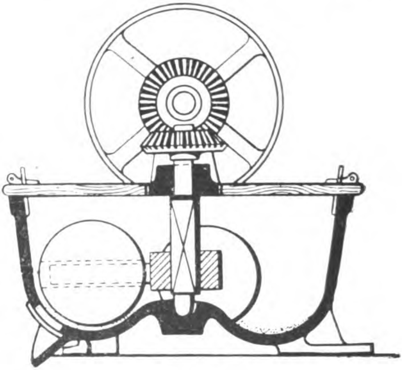

FIG. 51.

52 shows a facing sand mill, with a form of runner
has been found to be a great improvement on the
mills, which left the sand in a caky condition,
ing its being lifted out of the pan and riddled;
with these improved runners the sand is turned

out in a more perfectly granulated condition, free from lumps and cakes, and ready for the moulders.

Messrs. Smedley Bros. also fit a special form of webbed runners in their modern mills for mixing sand and loam, except for very light and fine work, as they are found to mix the sand thoroughly, but not grind it too dead. The form of runner adopted is clearly shown in the illustration of one of their 5 ft. 6 in. revolving pan mills, at fig. 53. Many foundrymen prefer a mill with a revolving pan to one having the pan stationary, and the runners rotated by the upright shaft, although the latter are supposed to have an advantage in being "self-delivering"; yet it is doubtful whether, in actual practice, it is not possible for a man to empty a revolving pan mill in considerably less time than a self-delivering mill, with a pan of similar diameter, would

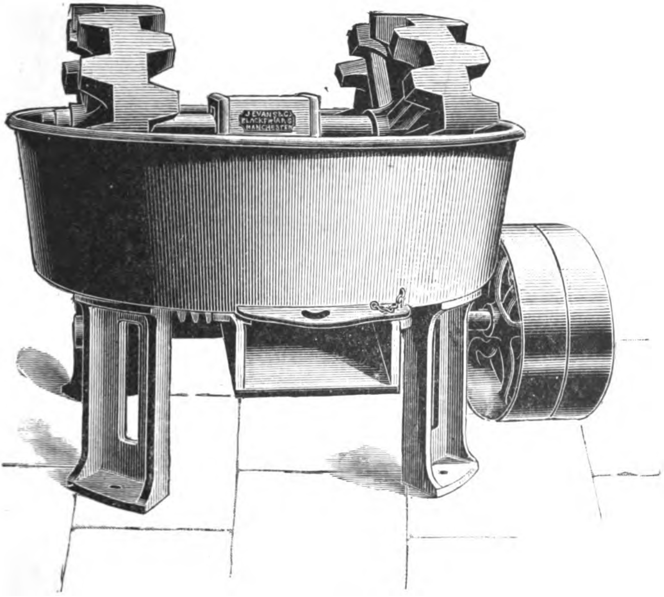

FIG. 52.

require to empty itself, whilst, at the same time, the loam can be taken out of a revolving pan mill in a less sloppy condition than is generally found necessary for it to leave a livering mill. Messrs. Smedley Bros. supply these ing pan mills in ten different sizes, having pans of ft. to 9 ft. in diameter, the diameter of the runners ch vary from 24 in. in the case of the mill with 4 ft.

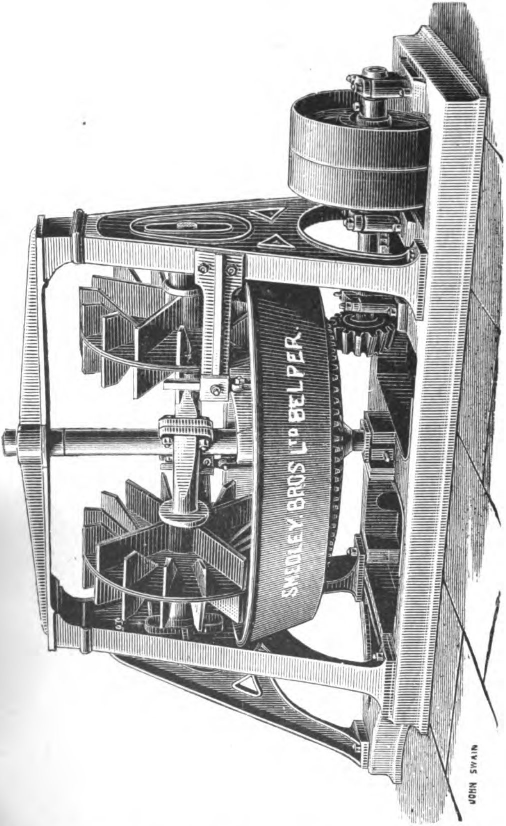

Fig. 53

diameter pan, to 42 in. in the mill having a pan 9 ft. in diameter, the width on face of the runners varying from 9 in. in the former to 18 in. in the latter, whilst the speeds of the pans recommended are as follow :—

Diameter of pan at top.	Revolutions of pan per minute.	Diameter of pan at top.	Revolutions of pan per minute.
Ft. In.		Ft. In.	
4 0	30	6 6	24
4 6	30	7 0	20
5 0	26	7 6	20
5 6	26	8 0	18
6 0	24	9 0	18

Adjustable scrapers are fitted and arranged to scrape the material from the outside and the centre of the pan, and throw it under the runners.

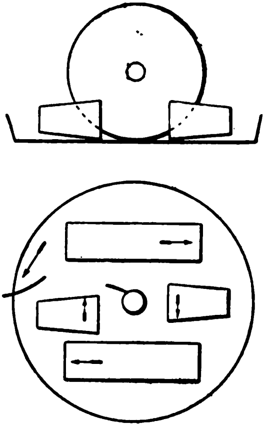

FIG. 54.

In the edge-runner mills made by O. Erfurth, Teuchern, Germany, conical transporting rollers are added for the purpose of more effectually bringing the materials under the runners. Fig. 54 shows diagrammatically the arrangement adopted. The material to be ground is charged on to the middle of the pan, and by the rotary motion of same and a vertical feed scraper is carried under slightly conical transporting rollers, whereupon the material is pushed under the edge runners which disintegrate it, the following transporting roller pushes it somewhat further towards the circumference of the rotating pan, and the process is repeated until the material is pushed far enough outward to be removed by a fixed curved scraper. It is possible by giving the transporting rollers a greater or less inclination to the bottom of the pan to bring the material quickly or slowly to the point of discharge, whereby coarser or finer grinding is effected.

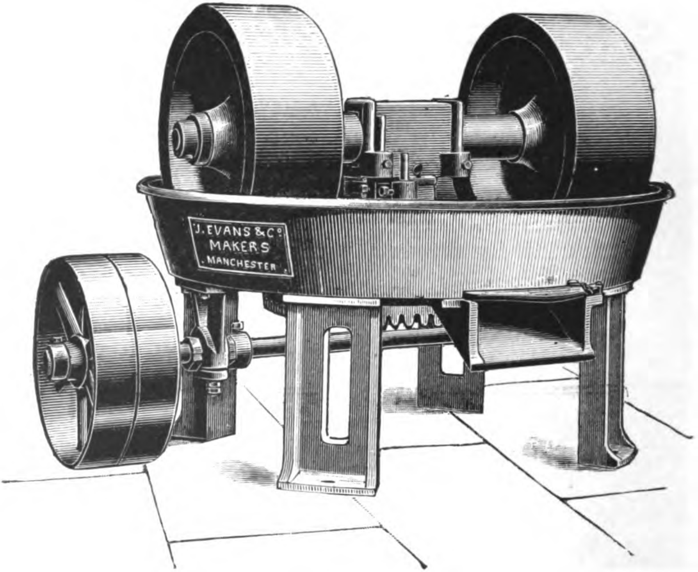

FIG. 55.

Fig. 55 shows a stationary pan self-emptying mill, specially designed for grinding loam, and so constructed that the runners exert a continued and even pressure across the whole width of their face upon any depth of material in the pan. Mills of this type are usually fitted with runners of the following dimensions:—

Diameter of pan ....ft. and ins.	3 0	3 6	4 0	4 6	5 0	6 0
Diameter of runner ....ins.	18	21	24	27	27	33
Width of face of runner ....ins.	6	7	8	9	10	12
Weight of each runner about ......cwts.	3	4	5½	7½	9	14

Besides the usual water-supply pipe led into the pan, it is a very good plan to also conduct a branch pipe from an exhaust steam pipe for use in cold weather, when the loam can be delivered to the moulders warm, thus enabling them to handle it with much more comfort than if it were cold.

CHAPTER IX.

MOULDING.

An iron foundry which is laid out for producing all descriptions of castings that may be offered for execution will require to carry on at least three kinds of moulding, viz., "green sand," "dry sand," and "loam" moulding, and before entering into the detail of these several methods as practised to-day, it will be well to consider briefly what are their distinguishing features, and how each system has been developed.

Green sand moulding is the most generally used for every pattern that is of moderate dimensions and of simple form, and is a ready means of producing an almost endless variety of castings. The simplicity of impressing an object or pattern in the yielding sand could hardly fail to suggest this simple mode of preparing moulds, even from the earliest times, since when it has gradually developed into its present advanced state. It is generally considered to be the cheapest process, and in consequence most engineers and millwrights aim at having their castings made in green sand as far as practicable, although the product is not usually the best obtainable. This branch of moulding is, however, confined within certain limits, and it is reasonable to suppose that it was when these limits where first reached that dry-sand moulding had its origin, in order that moulds might be made to effectively sustain extreme pressures and successfully resist the abraiding influence of a violent flow of molten metal. The fluid metal puts a pressure upon the mould directly proportional to the depth of the mould, and it can easily be seen that a pattern may be of such deep dimensions that the soft, damp mould of green sand would not bear the pressure of the molten metal at the lowest part of the mould without yielding more or less. Ramming the sand sufficiently hard to resist the pressure would prevent the gases formed in the casting process from escaping through the hard mould as they do when the sand is in a lightly rammed state, and the metal would boil and bubble, with the gases working up through it, the commotion continuing until the metal had set, and resulting in the casting being filled with air holes. The facilities for the escape of air from the mould must be ample in all cases. Air or gas must ascend, and as the metal fills the mould much of the former must rise higher and higher until at last it reaches the top of the mould, where it can escape through the apertures provided, which are termed flow gates or risers for the flow or rising of air, and afterwards the metal. What air or gas is too slow to escape through the gates will naturally be spread all over the top part, and the vent-wire holes and the porosity of the sand ought to be ample for the escape of the remainder. The amount of venting required will depend on the grade of sand employed, and also on the size and shape of the casting, and only in very special cases can venting be dispensed with, the exception being for the most part open sand and loam moulds. Green and dry-sand moulds invariably require venting, more especially [illegible] former, when the sand is close, over damped, or hard [illegible] in order to supply in an artificial manner that [illegible] exit for the gas generated by the decomposition [illegible] which the sand itself, owing to its density.

fails to provide. When a mould is poured, hydrogen issues from every vent hole and box joint, and when fired burns in long blue flames, and may continue to burn for a quarter of an hour or longer, according to the size of the mould. In cases where large masses of sand have to be vented, it is customary to ram up a central portion of ashes, thus forming a reservoir for the air and gases, from which they can be led off in large volumes, and in many dry-sand cores the presence of the ashes not only affords a good vent, but also allows the cores to yield when the metal shrinks on cooling. Care must be taken, however, that the ashes are not too close to the faces of the mould, more particularly where there will be much liquid pressure, since the sand would be apt to yield there, with the result that the casting would be lumpy and distorted.

The methods adopted in venting are largely a matter of experience, the moulder following practices which he has previously found satisfactory with moulds of similar character. The manner of using the vent wire varies with individual moulders; some cover the patterns with pricker holes, while others who are more careful will scarcely mark them. There is no need that the vent wire should touch the pattern at all, except perhaps in very thin light work, all that is necessary being to push the vent wire in to a distance about a quarter of an inch off the face of the embedded pattern, the gas easily striking through the intervening porous sand. In the case of bedded-in moulds, when the vents are driven downwards from the lower face of the mould it is necessary to rub the surface over with sand in order to close the openings of the vents, as if this is not done the metal gets in and chokes them up, and the casting is liable to be scabbed. The dry-sand mould being dry and hard, bears the pressure easily, and if thoroughly dried there will be no steam, and but little gas, formed in the filling of the mould with molten iron, what little there is, easily escaping through the porous though hard sand of which the mould is composed. This quality of hardness eminently fits it for every description of mould that has loose parts to be fitted together, and is also conducive to the production of cleaner castings, for the simple reason that the mould itself is necessarily more compact and rigid than one in green sand could possibly be made, and further, if the mould is made in a flask it may be placed at any angle for pouring, and in this way the greatest pressure may be brought to bear upon any particular part of the mould, ensuring in the casting soundness and density at such part.

In discussing the relative merits of these different systems of moulding, the personal element must not be forgotten, for there is no doubt that relatively less skill is required to mould a similar casting in dry than in green sand, as with the former much less care is required in their ramming, unskilled help being often employed, which would invariably be out of the question with green-sand moulds, the ramming up of which needs to be conducted with considerable delicacy and skill in order to graduate the degree of ramming to the depth of the article moulded, and to the pressure the mould has to sustain; and if the material used is of the correct nature and the drying is thorough, little or no venting will be required ordinarily unless it be to carry off steam in the process of drying; further, dry-sand moulds can be closed with greater facility and more safely than green-sand moulds, and where large numbers of castings which are to be machined in some parts whilst at others they are required to present a more than ordinary finished and clean appearance, it is found to be true economy to proceed at once in making ample oven provision, rigging up the requisite number of flasks, and by establishing a rigid and systematic rule of order, ensure a constant output of creditable castings.

Another distinctive difference in these two systems of moulding is the readiness of the one over the other. A pattern that is mouldable in green sand can be embedded [illegible] once into the prepared sand of the foundry floor, the only [illegible]ding box required to take the impression of the upper [illegible] the pattern being a "plain top part," so that with [illegible]n of moderate dimensions a man can mould it and [illegible]e cast on the same day on which he takes the job [illegible] whereas a dry-sand mould requires some time to [illegible] may vary from a few hours to, in some instances, as long as four days, depending on the size of the mould. The moulds require to be portable to admit of their being moved on iron carriages into the drying stoves, which generally necessitates their being "flasked" or completely enclosed in moulding boxes, a large number of which, capable of taking in patterns of different sizes, must be kept on hand, and is a cause of expense which is largely avoided in green-sand work. In some cases a pattern may be received of extra large dimensions, and from which only one casting is required, when it would probably not pay to make a moulding box sufficiently large to accommodate it, when, if it must be made in dry sand and the expense of a box be avoided, the pattern is moulded in the floor and rammed up hard with the special sand used for dry-sand moulds. The top part is made removable and is dried in a stove, while the "drag," as the lower part is called, must be dried where it is formed, by means of fires kindled around it and suspended over it. This method of "drying on the floor" is only resorted to under very special circumstances, as it is attended with great inconvenience, the dirt and smoke caused often seriously interfering with other work that is going on in the moulding shop. With dry-sand moulds the castings are usually truer to the patterns, and have a better surface than those made in green-sand moulds, as with the latter, if more than one foot in depth, the castings are almost sure to be swollen more or less, being invariably thicker in the lower parts than the pattern, due to a very natural preference on the part of the moulder to err on the side of having his mould too free rather than that it should be so hard as to prevent the gases escaping freely, yet with good siliceous sand and the many excellent carbon facings now so common, the possibilities in green-sand moulding have been enhanced to a remarkable degree, and very elegant castings are now obtained; still, where accuracy of outline and strict adherence to dimensions are to be observed, loam or dry-sand moulds are usually preferred.

The keen competition which now exists renders it a matter of the greatest importance to turn out castings with as little chance of loss as possible, and a very careful consideration often becomes necessary in deciding the system to be adopted in particular instances having regard to economy, as the problem may involve so many others of paramount importance as to make it difficult of solution without giving due attention to the issues so raised, and considerable skill and judgment are demanded on the part of the foreman or manager of a foundry when patterns of unusual form or dimensions are presented for moulding. It is sometimes an open question whether it would be more economical to make a box and dry in a stove or mould without a box and dry on the floor, when the probability of the box being useful or not for other purposes has to be considered, and also the greater facility of constructing and subsequently drying the mould when flasked, the process of ramming being more easily and speedily accomplished, as the box can be turned over as required. The saving of time in moulding and of coals in drying, together with the avoidance of smoke and other inconveniences involved by moulding on the floor, and the greater certainty of producing a satisfactory casting, are often a sufficient set-off against the cost of a box.

The founder can generally claim a higher price for dry-sand castings, although in many instances, even when this is not obtainable, the form of the pattern and body of metal in the casting may be such as to warrant a dry-sand mould as being more profitable and certainly more satisfactory to the engineer when speedy delivery is not important. This will depend largely upon the class of men available, the skill required in preparing, finishing, and handling a green-sand mould, owing to its tender nature, rendering it liable to deformation and little accidents, being far greater than is necessary with a dry-sand mould, which will bear much freer handling, so that even though a little more expense may be incurred by providing an extra box and on account of the fuel required for drying, yet the labour, being less skilful, need not be so costly, whilst at the same time the ances of producing faulty castings in dry sand are not rly so great, that it often happens, on the whole, the sand process is really the cheaper.

m moulding is another method which is sometimes when the article to be moulded is of unusual dimensions, and when the cost of a box would outweigh its advantages. This mode of moulding is justly recognised as the leading branch, since it embodies in the highest sense the art, the loam moulder's methods being closely akin to those followed by a sculptor, whilst, in addition, he has to display great mechanical and constructive ability in order that the objects which he fashions, with or without the aid of the pattern-maker, may be securely contained within a suitably devised mould. Loam moulding is, however, the most expensive process, and is seldom resorted to when a complete pattern is supplied; in fact, the chief advantage of this system is that in many cases a pattern is not necessary at all, or at most only a few parts of patterns, or a mere skeleton form of the article wanted, the loam moulder working with sweeps and strickles which constitute ample means for producing an infinite variety of shapes in the plastic substances he employs, and not unfrequently his hand and eye must be the only guide for the achievement of many tasks that are imposed upon him. Innumerable are the forms of castings which come into the experience of the general loam moulder, for there is nothing, however intricate in form or massive in weight, that cannot be moulded and cast in the department of loam moulding. In some instances it may be that cost of production could be greatly reduced in the pattern shop by making a certain casting in a loam mould, a contingency that can be met only by the moulder and pattern-maker whose ability is equal to the occasion. Too often the requisite ability is not available, and recourse is had to the green-sand floor with its extra risks, provided a skilful green-sand moulder is available, as, if not, a prudent ironfounder will unhesitatingly consign the pattern to the dry-sand department.

A moulder's tools, or those necessarily his own, are never very numerous, and generally consist of a few "sleekers" (used for smoothing the faces of moulds), two or three trowels of various shapes and sizes, one or two cleaners, gate knives, a two-foot rule, and a pair of calipers. The foundry usually provides, in addition, a square-mouthed shovel, rammers of various forms and sizes, two or three small hand sieves varying in mesh from $\frac{1}{8}$ in. to $\frac{7}{16}$ in., a brush, straight edges, spirit level, swab pot, hammer, rapping bar, two or three prickers for venting the moulds, which are merely long pieces of pointed steel wire, gate pins, and, for dry-sand moulding, a pair of bellows, some blacking brushes, and a loam saw.

Fig. 56 illustrates an assortment of moulder's tools, a list of which, with corresponding numbers as marked against the individual tools in the illustration, is given below:—

1. Broad heart trowel } for going easily into corners.
2. Long heart trowel
3. Scotch trowel (iron handle).
4. Taper trowel.
5. English square trowel.

6 and 13 Gate knives combined with trowels.

7. Combined heart and square trowel.
8. Spoon tool.
9. Slicker or dog tail tool.
10. Circular beader.
11. Pipe sleeker
12. Square corner sleeker } These are sometimes made in cast iron, although usually in wrought steel.
14. Safe-end pipe sleeker
15. Scotch cleaner.
16. Boss tool.

Foundries that are run for the production of specialties, such as railway chairs, pipes, standard machine parts, or "hollow-ware," usually have a special system with labour-saving machinery, including moulding machines, which will be dealt with *in extenso* in a later chapter. With regard to the use and manufacture of cast-iron pipes in this country, a great saving in plant might be effected if some standard patterns could be adopted by general consent, especially in pipes up to about 18 in. diameter, by which means prices might be reduced. The American cast-iron pipemakers will not conform to any and every specification and drawing submitted, but supply pipes made to standard patterns which are in general use for all sizes of ordinary straight pipes of from 2 in. to 60 in. diameter, and also for a large number of special castings, such as bends, branches, tees, &c. On visiting the English pipe foundries, one is surprised to see the very large number of patterns in the shops for the same size pipe, and manufacturers say that one of the chief difficulties with which they have to contend is the great

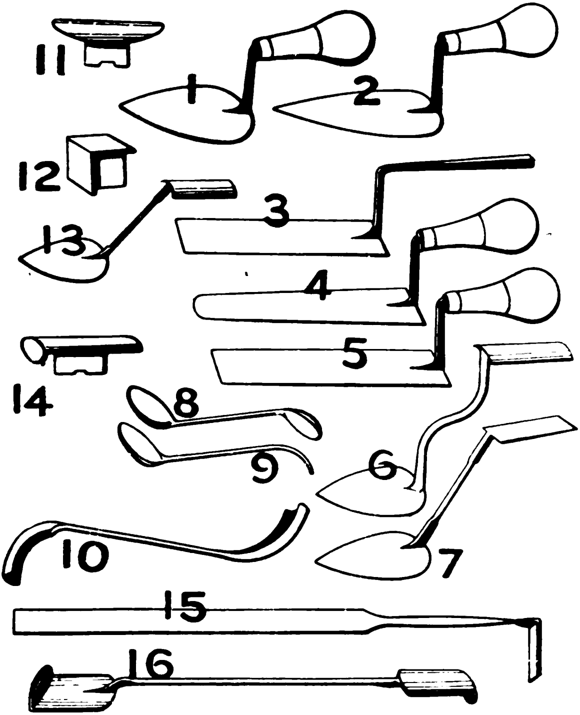

FIG. 56.

diversity of patterns in use by waterworks engineers and managers throughout the country, thus practically precluding them from keeping any considerable stock of pipes.

CHAPTER X.

GREEN-SAND MOULDING.

THE simplest method of moulding in green sand is in open moulds, and is only adopted for the roughest work, including, however, many foundry requisites, such as moulding boxes or "flasks," foundation plates for loam moulds, core rings, plates and grids, &c., in which rough surfaces are an advantage. An open mould has its upper face exposed so that the molten metal finds its own level, and is not restrained by a top covering or "cope," as in a closed mould, and for this reason it must be carefully levelled—a condition which is of no importance in the case of a closed mould, provided the runners and risers are suitably arranged. Closed moulds are employed in all the ordinary and general run of green-sand work, and may be described under two heads—(1) Those in which the pattern is "bedded in," and (2) those in which the pattern is "turned over." Generally speaking, the second method is the one ordinarily adopted for the best work, and where there is much repetition from patterns of moderate dimensions, although the choice of a system is often a matter of shop usage, the moulders giving preference to the particular system with which they may be most accustomed. Shops in which much bedding in is carried on are, as a rule, more dirty and disorderly than those in which most of the work is done in turned-over moulds, and for this reason many foremen advocate the latter method in preference to having their shop floors all dug up, even though the work may be well suited for bedding in. Turning over presents such undoubted antages over bedding in, that, were it not for the large ber of flasks required,* it would be even more generally d than it already is. The greater convenience in ramming lessens the risk of its being unequal in er than in bedding in, while the construction of

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over," a two parted flask is required in any case, one part nd the other the cope, whilst often there are three or more ddition to the cope and drag, one or more middles.

the mould usually requires less skill, and with good flasks the process is safer, and there is less risk of the castings becoming strained and distorted by the pressure of the metal when turning over is adopted than when the patterns are bedded in. An important development of the system of turning over is the employment of "turnover boards," variously called also "bottom boards" and "joint boards," upon the face of which the joint of a half pattern, or the face of a flat pattern, is placed, and a flask laid over it and rammed up, when, on being turned over and the board removed, there is left a true joint face of sand ready for receiving the other half of the pattern. This principle is capable of being modified and extended almost indefinitely, since the board need not be a plain flat one, but may have its face cut to the irregular outlines of patterns, or may be either blocked up or cut down in some portions, so as to form sand partings in other planes than that of the board, some of which may have sloping faces. By this method of moulding much time and trouble may be saved, more especially when moulds necessitating sloping sand joints have to be often repeated, as the moulder has not to cut and sleek the joints at every repetition of moulding. In machine and plate moulding further modifications are introduced, but these will be fully considered later.

The practice of "bedding in" is largely adopted in many foundries for the rougher class of work, or when the patterns are bulky, much flask-making being thereby saved. In this method, the lower portion of the pattern is moulded in the sand of the foundry floor, instead of in a flask, the upper part alone being enclosed or covered in by a cope. In some instances there may be one or more middles, but in no case is a bottom box or "drag" required. With unusually long patterns the cope may consist of two boxes, laid on with their adjacent ends set a little apart, say 1 in., this space being partially filled up by putting a covering of sand about ⅜ in. thick on the end of each box after the pattern has been withdrawn, which will allow a space of ¼ in. between the two after the mould is closed. This space will cause a fin to be formed on the casting, which cannot, however, be avoided in this case, as it would be dangerous to entirely fill up the space between the boxes with sand, and the moulder chooses the most favourable position for the joining, so as to leave as little mark as possible on the casting after it has been dressed. In bedding in, some moulders pound the pattern down, whilst others tuck it up. The former practice is very severe on the patterns, and although the risk may be slight with heavy, stiff patterns, yet much damage is often done to those of lighter construction by the injudicious use of the sledge, and, if only for this reason, the practice of tucking up should be encouraged; but there are others, for when a pattern is forced down into the sand by the aid of a sledge hammer, there is every chance of the mould being too hard and close, with the result that the casting comes out rough and scabbed, whereas, by adopting the more scientific method

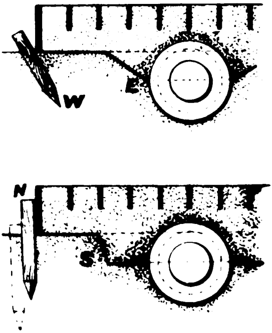

FIG. 57.

of tucking up the pattern, the moulder is better able to judge of the condition of his mould and to regulate it to the requirements, so that the casting will be as smooth as those produced in turned-over moulds.

In bedding in, the top part is securely staked at the four [illegible], to ensure that when lifted off it will be replaced, when [illegible] in exactly the same position. These stakes should [illegible]le length, so that even with top parts having [illegible] sand the box is guided and made to rise perfectly plumb from the parting until it is clear of the pattern. When driven, at least two-thirds of the length of the stake should be in the floor, and the projecting end should not stand away from the side of the flask at an angle, as shown at W, fig. 57, although it is still a very common thing to see them driven in this way. A correctly driven stake is shown in the lower view of fig. 57, at N, the second one indicated by dotted lines showing the practice sometimes adopted for greater surety of driving two stakes, one behind the other, at each corner of the flask. A badly-driven stake, like a badly-fitting flask pin, will often be the cause of an overshot casting, the ugly joint of which may ruin the appearance of what might otherwise be a faultless casting. Irregular-shaped joints in a mould are avoided as much as possible, but when they become a necessity, care should be taken to avoid the difficulties of lifting fine bodies or points of sand; for example, in making a parting, such as is illustrated by fig. 57, the joint should not be made as shown in the upper view, but in the manner indicated in the lower view, thereby avoiding the fine edge of sand, which would be formed at E, by following the plan suggested in the upper view. The slope at S should be as little out of the vertical as will effect a clean parting, about 1 in. of slant for each 3 in. height being usually all that is required. The lifting of these bodies of sand, in moulds having irregular-shaped joints, is generally effected by the aid of "lifters," variously termed also "gaggers" and "hangers," fig. 58, the detached parts being further strengthened, in some cases, by the insertion of a quantity of roughly split sticks of wood, about 1 in. square, called

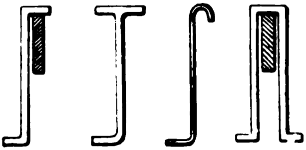

FIG. 58.

"sodgers," having their ends dipped in clay wash. These should be of such a length as to be within ½ in. of the pattern, and yet come up nearly to the upper surface of the box. When rammed up against the bars, they hold the sand firmly together in deep parts and prevent a "drop-out." It will be seen that the form of joint illustrated in the lower view of fig. 57 presents a better bottom on which to set the lifters than does that shown in the upper view, and greatly increases the probabilities of a good lift, for, as a general rule, the larger the body of sand to be lifted the better the chances of successfully lifting it. These "lifters" are made of cast or wrought iron in various shapes, and are invariably employed in green-sand work, their function being to bind and retain the body of sand lying between the flask bars, the spacing of which alone is generally insufficient for security. They are dipped in clay wash, and hung from any convenient point of support, such as the top edges of the vertical bars in the cope.

In order to give stability to the surfaces of green-sand moulds, it is the practice in some foundries to skin-dry the moulds immediately before casting. In this case a loamy facing sand is employed, and as the face of the mould, when dried in this way, is but a crust having little union with the body of the mould, surface nailing is extensively employed, more particularly in the region of the gates and sections where the metal first enters, for if the rush of metal should break away the crust, the sand immediately under it offers but little further resistance, and soon washes away. To prevent this cutting at the gates, when any considerable quantity of iron is to be run through them, a more reliable plan than the mere nailing of the surfaces is now commonly adopted by moulders, dry-sand cores being made to the shape [illegible] mould in way of the gates, and rammed up with the [illegible]. Skin-dried green-sand moulds are probably the [illegible]icate of any, and require the utmost care in handling, [illegible]is account, any projecting parts are usually made [illegible] They may be blackened in a manner similar [illegible]ed in the case of dry-sand moulds, but the [illegible]thod is to rub the blacking on dry, and then, [illegible] over the surface with beer or molasses water. This latter plan has the advantage of not moistening the face of the mould so much as does blacking with the wet material used for dry-sand moulds.

As an example of an open mould in green sand, we may consider the moulding of an ordinary foundry flask; but before doing so, the following remarks on the construction of flasks or moulding boxes generally may form an interesting digression. In the first place, stiffness is the most essential feature to be regarded in their construction, in order to ensure that the castings are true to the patterns; for, in the event of a box not being sufficiently rigid to withstand the twisting and wrenching it receives on being turned over, the mould may be so seriously distorted as to become useless, or the sides of the box may spring to such an extent as to cause trouble by allowing the sand to drop out. The prevailing practice now is to make the flasks somewhat heavier than in former days, so that their strength is almost always in excess of their stiffness, and as the only objection to weight in a flask is the extra labour involved in handling and carrying, and this has to a large extent been counteracted by the more general use of cranes and hoists, there can be no real economy in stinting the metal in moulding boxes, since the iron is always of value. For the general work of most jobbing foundries the flasks employed are mostly

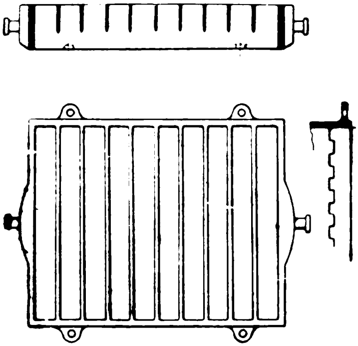

FIG. 59.

square or oblong, and range in size from about 1 ft. square up to 10 ft. or 12 ft. square, or with lengths up to 20 ft. in the case of oblong flasks, the shape and sizes adopted in any particular foundry being governed by the general character of the work undertaken. Fig. 59 shows a plain top part or cope, consisting of a mere grating of bars on edge about $\frac{7}{8}$ in. thick, the inner bars being sometimes notched on their lower edge—as shown to the right in the figure—to assist in holding the sand, although the more general plan is to chamfer the whole length of the bottom edges of the bars to a thickness of about $\frac{1}{8}$ in., in order to allow of the sand

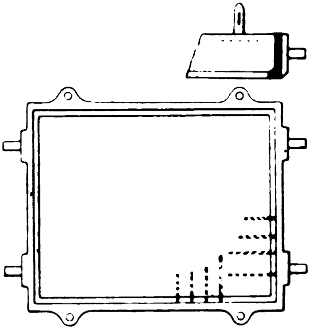

Fig. 60.

being rammed close around the pattern without leaving soft unrammed portions under the bars. The depth of these top parts is usually made about 4 in. to 5 in. in the smaller sizes, and from 6 in. to 7 in. in the larger sizes, although many foundries engaged in jobbing work now include amongst their stock of regular flasks a number having somewhat deeper sides, say 10 in., fitted with shallow bars of about 4 in., and having frames from 8 ft. to 14 ft. long, with widths of from 3 ft. to 5 ft. Moulding boxes of this latter description will often save deep lifts and dispense with elaborate partings, which occupy much time and are a source of anxiety to the moulders, besides which they may be turned upside down and used for a mould having a plain surface and a plain parting, provided the bars are not brought quite up to the level of the top edge of the frame, as if the bars are too near the face of the mould, leaving only a thin stratum of sand under them, which in all probability will not get properly rammed, swelling takes place in the mould at each bar, leaving marks of them on the casting. In green-sand work there should never be less than $\frac{3}{4}$ in. of sand intervening between the face of the mould and the bars, and for heavy work the spacing of the bars should not exceed 6 in., if local swelling of the mould is to be avoided. With the bars at a greater distance apart, and any considerable liquid pressure, the castings are very liable to be slightly swelled between each pair of bars, a fault noticeable in many columns, etc., which have been cast in green sand, more especially after they have received a coat of paint. With a view to making their moulding boxes more generally useful, many foundry-men adopt the plan of making the bars loose and bolting them to the outside frame, the bars being cast in pairs, so that one bolt in each end secures two bars. Fig. 60 shows a middle part of ordinary construction which has no bars, but is made with a lip round the inner bottom edge. These middle parts are usually of about the same depth as the corresponding top parts, and when deep moulds are required, two or more are placed one

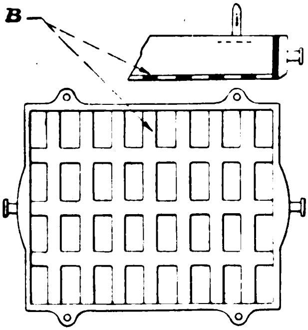

FIG. 61.

above the other over the drag and bolted together. When the pattern admits of their use loose bars should be bolted in the middle boxes, whilst in other instances radiating rods of iron are driven through holes in the sides of the flask to within $\frac{1}{4}$ in. of the pattern, to give support to the lifters and bind the sand together. Some such bars are indicated by dotted lines in fig. 60. Another plan sometimes adopted is to lay in a light frame of iron to serve the same purpose as

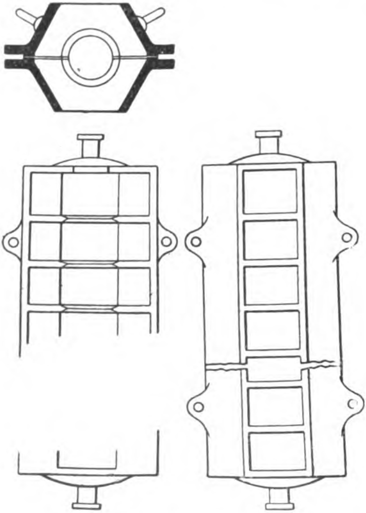

FIG. 62.

the bars or rods. Fig. 61 illustrates a bottom box or drag, hich is cast with flat bars B to prevent the sand dropping A middle part may be readily converted into a drag ing a flat latticed plate to it.

of large size are often made in parts and bolted by which means their utility is greatly increased, the substitution of new sides, or ends, their ns can be modified to suit patterns of different This practice is very common with pipe and column boxes, and greatly reduces the stock required. The boxes, being built up of a number of comparatively short lengths, may be readily extended or shortened to suit the requirements by the addition or removal of one or more sections, or a flask-section having a pocket on its side to receive a branch piece or other lateral extension may be inserted. Fig. 62 illustrates a moulding box specially adapted for pipes or columns, the sides being made to follow more or less the configuration of the pattern, in order to economise sand and labour in ramming. These boxes are often provided with back plates, which are bolted on, flanges being cast on the boxes for receiving them, and serve to prevent the pressure of the liquid metal from forcing out the sand when the moulds are placed on end for pouring. They are also, in many instances, fitted with loose bars, so that they may be used for columns of different diameters, and having caps and bases of various forms and sizes, by the substitution of one set of bars for another. In making flanged pipes, it is a good plan to make the pattern

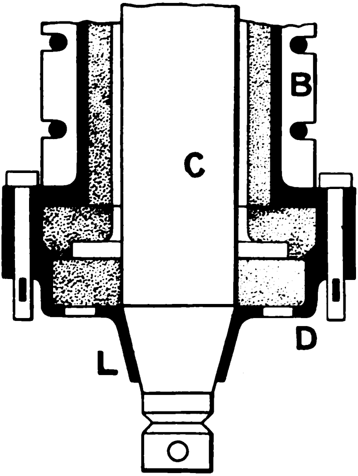

FIG. 63.

without flanges, and mould in a plain circular box, such as B, fig. 63, made in halves, and having an internal diameter less than the external diameter of the flange. The part of the mould in which the flange is cast is made in a separate box, attached by bolts and cottars to the lower part of the box B. The lower end of the mould is then closed by the dish D, with the conical nozzle L, which receives the end of the core. The upper flange is made with a template fitted to a ring which revolves on a pivot on the pattern, leaving a space for the cover. The core C is inserted, and centred by the cover at the top and the nozzle L at the bottom. After casting, the cover and plate D are removed, and the

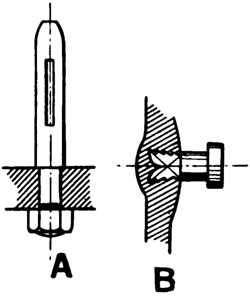

FIG. 64.

core spindle drawn out, so as to allow for the contraction of the pipe without fear of cracking. The portion of the mould which forms the pipe, being thin, can be dried more easily than if the box B were wider than the flanges. In most foundries the joints of the flasks are not planed, but re left rough, just as they leave the sand, except when they [illegible] to be used for plate and machine moulding, in which [illegible] the joint edges are machined to ensure a close fit. d edges are also an advantage when the patterns are [illegible] as the sand can be strickled off level, thus leaving a rue plane on which to lay the joint face of the [illegible] ramming up. The most common method of [illegible] is by means of lugs and pins. The pins ned to fit closely yet freely into drilled holes in the lugs, and should be renewed when they become worn, as badly fitting pins give the moulders a deal of unnecessary trouble, and may be the cause of many overshot castings. The pins should be of ample length to prevent damage being done to the mould on lowering the upper box, the flasks being guided by the pins alone for a distance of an inch or so before any sand faces come into contact. They should be turned parallel, with the points rounded off as shown at A, fig. 64, which also shows the method of attaching them to their lugs. Screwed bolts and nuts are sometimes used for uniting flasks, but pins and cottars are most general. Clamps are also employed for this purpose, but the wedging of clamps is not so secure as the fastening of cottars and bolts, although in many instances it supplies a ready method of holding the sections of a flask together, and is therefore often resorted to. A very simple, convenient, and cheap clamp may be formed with two exactly similar cast-iron pieces, one of which is shown in two views at fig. 65. These two symmetrical and reversible pieces are made with inter-penetrating locking arms, those on one piece being

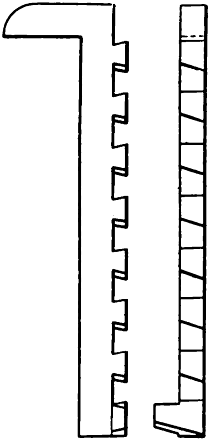

FIG. 65.

adapted to engage in corresponding recesses on the opposite piece. By having a number of such recesses into which the arms can engage, it is possible to set the clamp at the approximate position desired, and the final adjustment be effected by the aid of lining strips and wedges. Fig. 66 shows the clamp in position.

For handling the flasks various attachments are provided, flasks of small size being usually cast with flat lips or handles standing out from opposite sides, while those of larger size are fitted with handles made of wrought-iron rods, which are cast in circular bosses, the method being to ram up the handle in a core with the jagged portion to be cast in standing out, this core being set in position in the mould after the pattern of the flask has been withdrawn. Flasks of large size are also provided with trunnions for the purpose of turning them over in the crane slings. These are made of wrought iron, and are cast in, the sides of the boxes being locally thickened to receive them, and give good hold, as shown at B, fig. 64, and in figs. 59, 61, and 62. In this case the jagged end around which the metal is to be poured should be made square to prevent its turning.

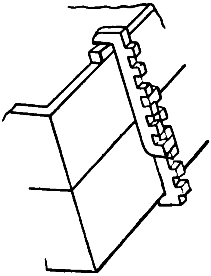

FIG. 66.

Returning now to the example of an open mould in green sand—which may be, say, for casting a plain top part box, such as is illustrated at fig. 59—we will assume that a complete pattern of the body of the flask has been provided, although in many instances all that is actually required is the frame, and one or two pattern bars. This pattern should be made with plenty of taper, say $\frac{3}{16}$in. per foot of depth in the frame, and about $\frac{1}{4}$ in. per foot on the bars, and of about $\frac{1}{2}$ in. greater depth than is actually required in the casting.* In preparing the mould, the moulder first digs out a hole in the floor somewhat larger and deeper than the pattern, and into this he shovels, in this particular instance, ordinary floor sand, to form a loose bed, into which the pattern is bedded by beating it down lightly with a wooden mallet until it stands perfectly level in both directions, when, provided the pattern has not been distorted, which may be tested by placing a straight edge at cross corners, the ramming up is proceeded with, the sand on the outside being levelled up simultaneously with that on the inside, and the whole strickled off level with the upper edge of the pattern. During the process of ramming up, the various attachments, such as lugs for pins, handles, trunnions, &c., are placed in position in the mould. Of the several methods adopted for putting in lugs, that of making them in a core box is probably the simplest when the lugs are not on the patterns. Fig. 67 shows at L the lug core in place, the sand in its vicinity being dug away to allow it to be bedded in, a centre line scribed on the core being made to correspond with the lug centres marked on the edge of the frame pattern, when the sand may be rammed around and over the core up to the top face of the mould. Another method, sometimes followed, is to lay in and mould a loose pattern lug in the position assigned for it before ramming up the outside, and while the body pattern is still in the mould. After drawing the lug pattern the moulder covers its impression with a dry sand core or cake,† as shown at C, fig. 67, and can then proceed to ram up the side of the box without fear of injuring this mould under the cake. When a number of flasks are to be made from the same pattern, it will generally be found cheaper to put the lugs on the pattern sides with prints over them, and make plain cores

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* All patterns used for open moulds should be made about $\frac{1}{2}$ in. deeper than the required depth of the castings, as in such moulds the metal is not allowed to run over the top, but through overflow channels cut at the sides at about $\frac{1}{2}$ in. below the top edge.

† A piece of slate is sometimes employed in place of this dried cake.

simply to fill the prints. • In putting on handles the moulder takes the cores containing the wrought-iron handles, which have been previously made, dried, and blackened, and places them in position in cavities in the mould formed by corresponding prints placed on the pattern. Pocket prints, shown in dotted lines at TT, fig. 67, are also attached to the pattern for the trunnions, and after the

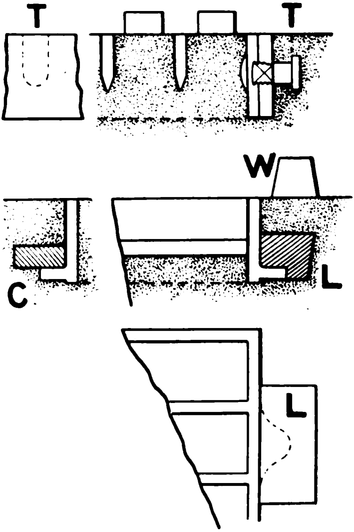

FIG. 67.

pattern has been withdrawn the sand is dug away beyond the print thickness in order to allow the neck of the trunnion [illegible] be bedded down into the cavity left by the print, when the [illegible] is stopped over it, leaving the square jagged portion [illegible]ing into the mould, as shown in fig. 67. The inner [illegible] the box and the bars are the better for being rough, [illegible]d adheres more readily, and for this reason it is [illegible] in some foundries to roughen the surfaces by [illegible] vent wire diagonally in both directions between the pattern faces while still in the mould and the abutting sand; so that these surfaces on the casting present a chequered, ridged, and rough appearance. A mould of this class would be arranged to be fed from the bottom at or near one or more corners, all four of which would be provided with runners in the case of a large flask, and overflow channels would be cut at the sides at about ½ in. below the top edge, as explained above. Weights W must be placed over all projecting parts to prevent their being lifted out of place by the inflowing metal, and it is a good plan to lay a light weight on each block of sand forming the interspaces of the bars, to prevent its swelling.

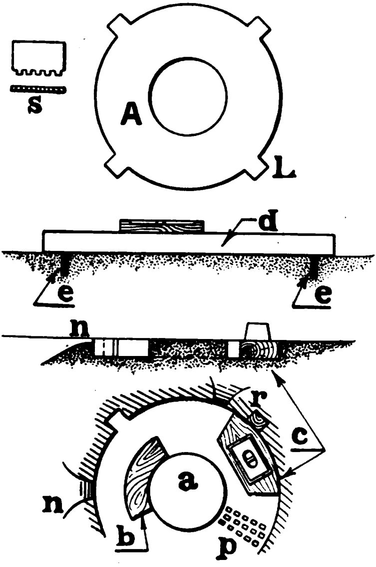

Fig. 68.

As a further example of open moulds, the moulding of a foundation plate on which to build a loam mould may be taken. Such a plate is shown at A, fig. 68, and would have a thickness varying from an inch up to 2 in. or 3 in., according to its diameter, and one face would be studded all over with "dabbers," which are simply projecting pins about ½ in. long, which serve to make the loam hold to the surface. To mould a shallow plate of this description no pattern is required, but merely a couple of segments of wood, marked *b* and *c*, fig. 68, of a thickness exceeding that of the casting by ½ in., and cut to the radius of the hole and outside radius of the plate respectively. In preparing the mould, the moulder first makes a level hard rammed bed by bedding in a couple of straight-edges *e*, *e* into the floor, setting them level one with the other by the aid of a spirit level, which is placed along each straight-edge *e*, *e* in turn, and also on a third parallel straight-edge *d* set at right angles to, and resting upon, the top of the two which are sunk into the sand. These straight-edges, or winding strips, are sometimes wood, but preferably consist of flat wrought-iron bars planed along the edges. Having adjusted the winding strips *e*, *e*, the space between is well rammed and made up to a height a little above their top edges, and finally strickled off with a straight-edge worked along the top of the embedded strips *e*, *e*. On this level bed circles are struck with a pair of trammels having one leg on a wooden peg driven into the bed, one of a diameter equal to that of the hole in the plate, and a second corresponding to the outside diameter of the plate; with these as guides, the moulder next rams up the inner edge in detail, using the segmental wood block *b*, which he shifts into successive positions until the whole of the central circular block of sand *a* is rammed up, when he proceeds to ram up the outer edge of the plate similarly with the block *c*, the lugs L being measured in at their correct positions, and formed in the mould by the aid of a block of wood *r* laid against the segment *c*. Some parting sand is sprinkled over the mould, and then with a wooden "dabber" pattern shown at S, fig. 68, he presses these projecting knobs into the sand at intervals, as at *p*, over the entire surface of the mould. Overflow gates *n*, *n* are cut, and a basin formed at one side of the mould by means of three bricks, and the mould is ready for pouring. Should the plate be required for the top cake of a mould, gate holes would be made in it by laying pieces of loam cake on the bed where needed, weighting them down before casting to prevent them being washed out of place by the inflowing metal. Further holes would also be put in anywhere over the surface of the plate to serve not only for retaining the loam, but to act as vents for the escape of gas from the mould while casting. To form these holes, pieces of coke or coal are pushed into the sand, and knocked out of the casting when cold.

To *bed in* a simple pattern such, for instance, as the small cylinder cover shown at A, fig. 69, the moulder first digs out a hole in the floor a few inches larger and rather deeper than the pattern; into this hole he sifts fine sand and rams moderately hard, then vents the bed well, downwards, with a vent wire of about ¼ in. diameter. On this bed, more fine sand is riddled, into which the pattern is pressed down firmly, and the sand tucked in all round under the flange. The pattern is next withdrawn, and a layer of facing sand about ½ in. thick is sifted over the whole surface of the mould. On this the pattern is laid and hammered down, using a block of hard wood between the hammer and the pattern. The limit to its impression into the bed—in order to impart to the mould the proper degree of firmness just to bear the pressure of metal—whilst being fairly definite, for this, as for every pattern that is bedded in, can only be decided by experience, and a careful moulder will use judgment as to what that limit is, and not follow the all too common practice of pounding the pattern down until it will go no farther. Before the pattern is first drawn, the three guiding stakes, S, S, S, fig. 69, are driven into the bed until their tops are level with the upper face of the cover flange. These stakes serve as a guide in showing how much the pattern is to be knocked down when it is returned after the facing sand has been sifted over the surface. In this particular instance, a distance of about ¼ in. is all that the pattern need be pounded down, after which, the moulder places a weight on the pattern to steady it while he packs and rams the sand all round the edge, drawing the stakes and filling in with sand as he proceeds, always taking care to have facing sand next the pattern, and when he has heaped up the sand well above the top face of the flange, he rams it fairly hard with a "dog" rammer and strickles it off with a straightedge to the level of the pattern, and with his trowel, sleeks the surface all round over an area

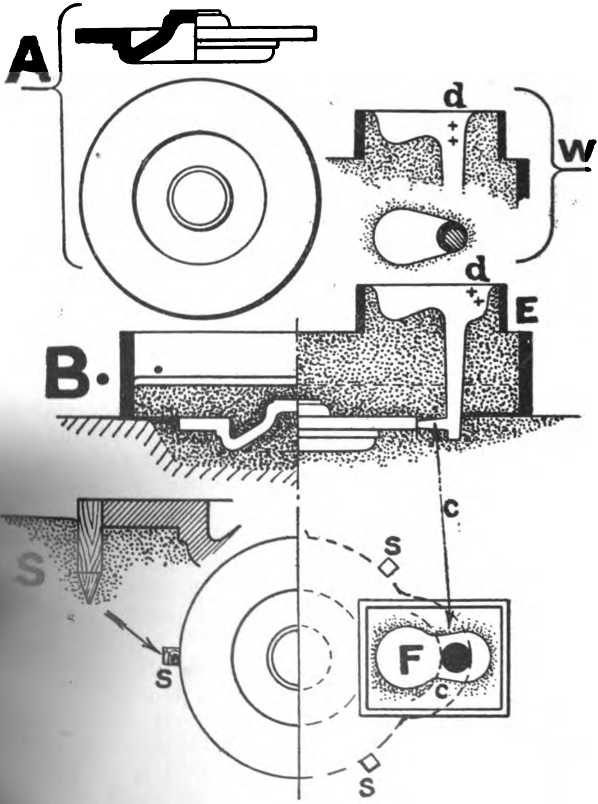

FIG 69.

mewhat larger than will be covered by the cope, carefully ing any soft spots that he may find close to the pattern. this prepared surface, the moulder now sprinkles a thin layer of parting sand, and places a suitable moulding box B, fig. 69—a plain rectangular top part 2 in. or 3 in. wider than the pattern—in position over the pattern, carefully staking it near the four corners.

A gate pin about 1 in. in diameter, and having a taper of say ½ in. on the diameter per foot length, is next placed in a convenient position for running the casting, and a layer about ½ in. thick of facing sand laid over the pattern, when ordinary floor sand is thrown in and rammed to fill the box, a few giggers being introduced to give support to the sand below the joint level, after which the vent wire is thrust down to within ¼ in. of the pattern at frequent intervals over the whole area under which the pattern lies. The cope is now lifted off, and turned over, any broken parts are mended, and the surfaces examined as to their firmness, soft spots that may be found being filled up with facing sand, and weak ones fortified with long spike nails specially made for the purpose. The loose parting sand is next brushed off the joint surface of the mould in the floor, and a little water swabbed round the edge of the pattern to bind the sand well together there and prevent it from breaking away when the pattern is being drawn. Before the pattern

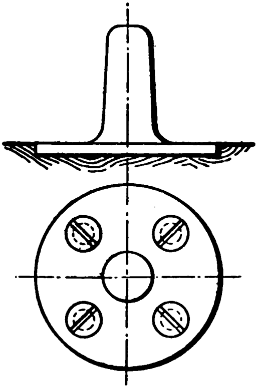

FIG. 70.

is drawn, it is loosened a little in its place by the aid of a rapping bar, which is inserted in a hole in a small iron plate let into the pattern. Holding the bar with his left hand, the moulder gives it a few blows with a hand hammer, striking it as low down as possible. By this means the pattern is shaken a little sideways, which enables it to be more easily withdrawn. These rapping plates are usually provided with a second hole tapped to receive a screwed bolt for drawing the pattern, and generally consist of a strip of wrought iron which is sunk into and secured to the pattern by two or more wood screws. For small patterns it is a good plan to substitute for the rapping and draw plates a plate having a pin cast on it, as illustrated at fig. 70, which serves both for rapping against and also for drawing the pattern.

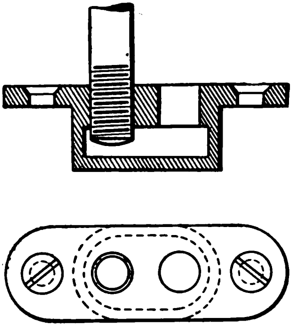

Fig. 71.

The draw and rapping plate, shown at fig. 71, and described by Mr. E. T. Wires,* is an improvement upon [illegible]se commonly employed in which the holes go clear [illegible]gh the plate, allowing the sand to be forced under the [illegible]y the pressure of the rapping bar and draw iron, [illegible]y when the threaded draw iron is screwed down, [illegible]n loosens the securing screws and wrenches the [illegible]he pattern. It will be noticed that the plate

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[illegible] *The Foundry*, June, 1900, Vol. xvi., No. 94.

illustrated at fig. 71* has a solid bottom, and a chambered passage between the holes to allow the sand when crowded from one hole to escape to the other. The pattern is now gently and slowly withdrawn, care being taken to keep it as level as possible, and as it rises it is rapped lightly with a hammer to shake down any of the sand that might otherwise be drawn up with the pattern. The mould is carefully examined for defects, and the runners C C, fig. 69, are cut from the impression of the gate-pin to the side of the mould.

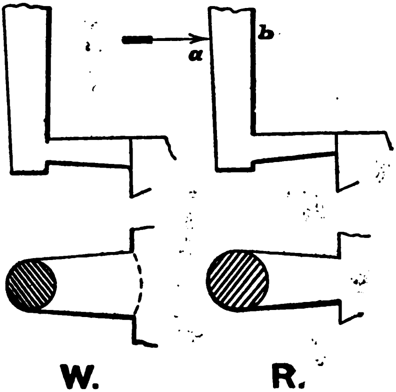

FIG. 72.

The form of the runners is of considerable importance, as a badly-shaped runner may cause a serious blemish on a casting owing to a "break-in," or, on the other hand, may involve much time and labour in chipping away an unnecessarily long stump of the runner left on the casting. The most important feature about these runners is that they should have the proper weakness where they are to be broken off, and it should be remembered that the course of the fracture is determined by the size, and the rigidity or

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* In plan view, the outline of the plate and of the chamber would preferably be in the form of a number of intersecting circular discs, in order that the recess in the pattern for the reception of the plate may be made with a boring tool and without the use of a chisel.

elasticity at other points than that at which they break, or, in other words, by the angle at which the runner leads away from the breaking point. A runner formed as shown at W, fig 72, would be sure to cause a break-in, tearing out a cavity as shown by the dotted line. Runners to be satisfactory should be made as illustrated at R, fig 72, and when breaking them, the hammer blow should be struck at the point indicated by the arrow at *a* which puts the tensile stress on the material at the bottom of the sprue where the breaking point is as distinctly fixed by the shape as by the "notch in a stick." At the top side, which is flat, as in all ordinary runners, the breaking point is not so fixed, and the sprue would not break as true, nor yet so easily, if the blow were given at *b*, on the opposite side.

Having cut the runners, the moulder next proceeds to blacken the two halves of the mould by shaking over them a canvas bag filled with finely-powdered graphite, thus depositing a film of blacking on the surfaces, which, when gone over lightly with a sleeker, gives the mould a fine polish. The mould being now ready for closing, the top part is carefully turned over and laid on, the stakes driven into the bed, guiding it into its correct position. Generally speaking, no avoidable head to produce a pressure in a green-sand mould is added, as is often done in the case of dry sand and loam moulds, the head being usually no greater than the depth of the box forming the top part; all that is attempted being to get the mould just filled up without risking any pressure upon it. In the case of the cylinder cover under discussion, however, the casting being comparatively shallow and intended to be machined all over, some little additional head may be of advantage, and is allowed for by forming the pouring basin in a small flask laced on the top of the cope, as shown at E, fig. 69. On rm of this basin will depend largely the cleanliness of ting; if made as shown at W, fig. 69, there is every of the iron upon running into the mould drawing y dirt that may be directly over or near the gate; if the basin extends beyond the gate as at E, and F, fig. 69, the iron poured into it flows beyond the arries with it, to a large extent, any dirt that may be present, thus preventing the bulk of the latter from passing into the mould, provided, of course, that the basin is filled quickly and kept full during the whole time occupied in filling the mould. The larger the space around the gate in a basin, the more chance is there of all the dirt remaining upon the top of the iron. The importance of the form of basin to ensure clean casting should not be lost sight of, seeing that the great bulk of the moulds in many foundries are arranged with top-pouring gates, not so much, perhaps, on account of a knowledge of their merits as valuable skimmers in pouring moulds, as for their convenience; yet when properly formed, and kept full, top-pouring gates are positive in their action as skimmers, since there is nothing to prevent the rise of the dirt to the top of the basin and thus ensure the iron that passes into the mould being clean.

Whilst on the subject of gates, a few remarks on the general principles underlying the practice adopted in gating moulds may not be out of place. The method adopted for running the metal into the mould depends largely on the individual character of the job in hand, although, generally speaking, moulds having great depth are run at the sides or bottom, shallow ones are run at the edges, either through a single runner or, if of considerable area, by means of a spray, while the most general practice is to run from the top, single ingates being used for heavy castings and sprays for light ones. The most general practice in ordinary work is to pour the metal directly through the ingate, but where the castings are required to be particularly free from dirt, a special skimming chamber is employed. It is not possible to make a casting which shall be entirely free from dirt, as a certain amount will always be generated from the mould's surface, depending upon the size and shape of the mould; but in the majority of cases the bulk of the dirt that the castings contain is carried into the mould with the metal, and can be prevented from entering by the adoption of a suitably contrived "skimming-gate," such as is illustrated by fig 73. The action of this gate is as follows: The molten iron is poured into the basin B, which is filled as quickly as possible so as to prevent dirt from passing into the gates at the start. From this basin the metal flows to the gate D, down which it runs to the passage E. Through this passage it passes to F, and is carried downwards, as indicated by the arrows, and enters the mould at G. In this way the iron that runs into the mould is drawn off from the bottom of the molten metal in the passage E, and is free from the dirt which, rising to the top, is carried along and passing up the

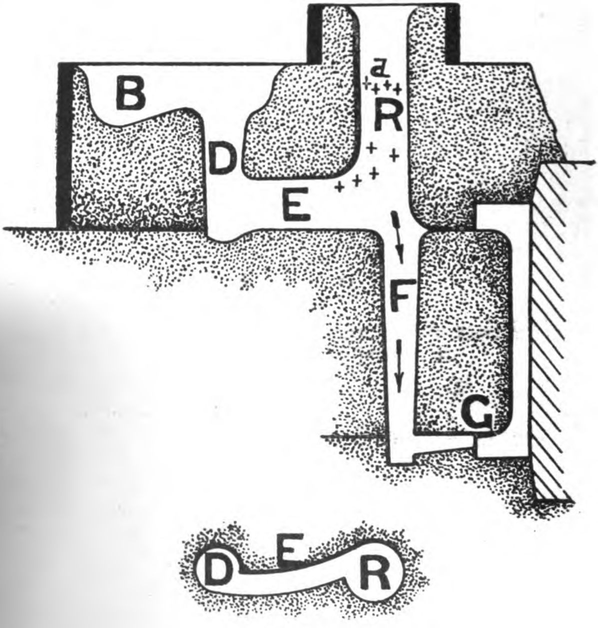

Fig. 73.

riser R accumulates at *d*. The essential feature of the g-gate consists in making the runners D and F and of correct relative cross-sectional area; thus, R ys be larger than either D or F, in order to afford for the dirt to rise, and D should be larger ere F the larger it would take the metal faster the result that the riser R and the passage E could not be kept full, as it must be if the dirt is to be collected outside of the mould. The flow of metal should be retarded as much as is practicable in order to give the dirt every chance of rising. The relative cross-sectional areas of F, D, and R should be about as 1 : 1¾ : 3, and if the passage E, connecting D to R, is cut in the manner shown

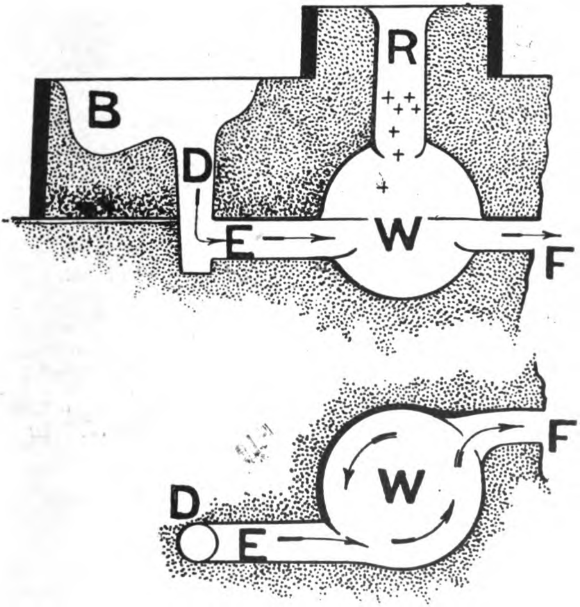

FIG. 74.

in the plan view, fig. 73, the metal will be made to whirl in R, which materially assists the dirt to rise.

Skimming gates are sometimes arranged as shown at fig. 74, the skimming chamber W being formed by ramming up a ball* in the mould, the ingate D in the basin B is put into communication with the spherical chamber W by a

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* A flat circular disc is sometimes employed in place of the ball, but the latter forms the best chamber.

runner E, and the metal is led off to the mould through the runner F. By arranging these runners, as shown in the illustration, a rotary motion is imparted to the metal on entering the chamber W. The molten iron, impelled by the pressure from behind, passes through F, but the lighter particles remain in the centre of the chamber W. In small moulds this chamber will contain all the dirt, but it is usual to place over the centre of the chamber a riser R, fig. 74, to carry off the dirt.

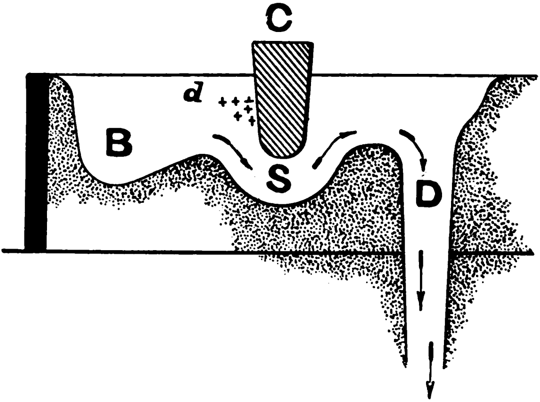

FIG. 75.

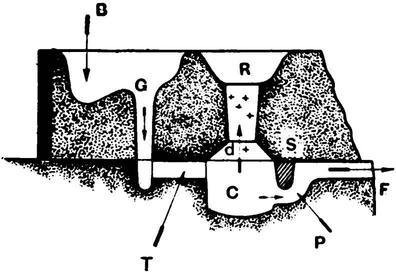

FIG. 76.

Another plan often adopted to trap off the ladle's dirt and prevent its entering the mould is to set a skimming core C, fig. 75, in the main basin with a passage S under it. When the basin B is filled with metal, the dirt is held at *d* and the clean iron flows through the passage S to the ingate D.

The skimming core is sometimes set under the cope as shown at S, fig. 76, when the metal flowing from the basin B down the git G enters a chamber C, where the impurities are caught by the skimming core S, and collected in the riser R, whilst the clean metal flows through the passage P under the core S, to the mould at F. In some foundries skimming basins, made of refractory material, are employed. These are divided into compartments A, B, C, D, fig. 77, which are in communication at their bases through apertures. The area of the first of these, between A and B, is made greater than the sum of the areas of the rest, the area of the last being the least. The last compartment is placed over the git G. The molten iron is poured into the first compartment A, its contact with the partitions *d* tending to free the slag and gases, and permit them to rise. An iron bar passing through the second compartment causes a commotion in the metal for the same purpose. To prevent

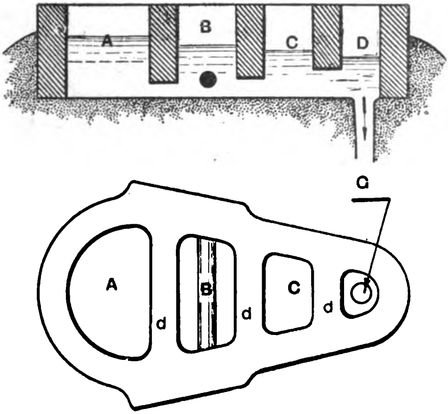

Fig. 77.

the sand from being cut up and washed into the mould, all corners in the runners and basins must be well rounded, and, as has already been mentioned, in cases where large quantities of metal have to pass through the ingate a block of loam cake should be built in the mould to receive the impact of the metal. The runners and gates should be treated as carefully as any other part of the mould, their proper ramming and venting being just as important, for if badly done, cutting or scabbing takes place, making dirt which will be washed into the mould. Some moulders use the swab much too freely around the gate pins, the idea being to prevent any loose particles from falling into the mould, but often the result is quite the opposite, as the wet sand causes cutting.

The size of the gates and runner is made such as will enable the mould to be filled at a moderate speed, small gates being best if the metal is to be poured very hot; and when the moulds are large, it is better to pour them through several ingates rather than through a single one of large area, as the latter would be likely to cause local shrinkage in the vicinity, by the chilling of the metal at the top and sides of the runner, drawing the casting underneath, and this shrinkage, taking place at the hottest portions, causes the metal to become porous in the neighbourhood of the runner. When, however, the runner may be placed directly over the mould without fear of the entering metal damaging any fragile parts, it can be made to serve as a feeding head, in which case the objection to the employment of a single runner of large area no longer holds, except as regards the labour entailed in its removal from the casting. Natural feeding is possible only so long as the iron in the neck of the runner or riser remains fluid, but in all ordinary cases, [illegible]he time the metal in the neck has set, there will still [illegible] a considerable volume of iron in a molten condition [illegible] mould. By the use of feeding rods* a communication

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[illegible]ds consist usually of lengths of nail rod ¼ in. to ⅜ in. square, which [illegible]wn into one or more of the gates immediately after the mould is [illegible]hould enter the casting for a depth of a few inches when possible, [illegible]p and down with a rapid motion, as in churning, the movement [illegible] long as the metal in the gate remains fluid and appears to go [illegible]tal begins to congeal, the rods are allowed to penetrate the [illegible]ed distance each successive stroke, and are thus gradually is kept open, and the supply of hot iron to the mould prolonged to compensate for the loss from shrinkage, which might otherwise cause the casting to be spongy. The action of the feeding rod is not of the nature of a force pump forcing the metal into the mould, as is sometimes erroneously supposed, but its motion merely preserves a free channel through which the iron can pass into the shrinking mass below. The feeding should always be effected at the heaviest parts of the casting, such as bosses, thick flanges, &c., and care must be taken to avoid risks of damaging the mould by breaking away sand or shifting the cores, or of the blowing of metal near the rods, to prevent which the rods, immediately before pouring, should be dipped into the molten metal in the ladle, and allowed to remain until they are almost white hot and quite free from rust, which would cause blowing. Some foundries make very little use of feeding rods, their practice being to cast good heads of large diameter, and thus ensure against the risks of bad feeding.

The feeding head is usually a riser, and to be satisfactory must be made of sufficient size to prevent the metal in it becoming solidified while that in the mould at any part remains liquid or in a semi-fluid condition, which often entails heads of unwieldy dimensions. This practice will generally be found unsuitable in green-sand work, where pressure on the mould is avoided as much as possible, and the risers are not carried up any higher than the top of the casting, "flow-off gates" being used, if necessary, for the purpose of carrying off dirty metal. These flow-off gates are kept closed by plugs of clay while pouring until the rising metal lifts them. If these gates were left open from the start, the flow of metal would be liable to create such a strong rush of air outwards through the openings as to cut the sand and otherwise damage the more fragile portions of the mould. In moulds of moderate dimensions the risers

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withdrawn. It is the general practice to apply this process of feeding to all castings of any magnitude, whether in green sand, dry sand, or loam. In some heavy loam work, such, for instance, as mill rollers, the feeding has to be continued for upwards of half an hour, when, should the metal in the feeding head be inclined to set before the demands of the casting are satisfied, fresh metal has to be brought from the cupola in hand ladles and poured into the feeding head, in order that the process of feeding may be maintained until all "drawing" has ceased.

are allowed to simply fill up, but in large moulds the metal flows over the tops of the risers and is led down a slope running into pigs in the foundry floor. Risers serve as an indicator showing when a mould is full, and also as suitable openings for feeding, but primarily, as a means of relieving the cope of the mould from pressure, and for this reason should always be of at least the same area as the runners, when the molten metal will exert no upward pressure on the cope, for the pressure due to the height of the runners will be kept in equilibrium by that in the risers. In the absence of risers, considerable strain may be put upon the cope by the enclosed air being compressed and heated by the inflowing metal, and in the case of green-sand moulds by the generation of gas and of steam from the moisture in the sand, which have no adequate means of egress, and consequently exert a considerable upward pressure on the cope. The position of the gates should be carefully chosen so that the stream of metal does not beat against a core which would be liable to be dislodged, nor directly against a wall of sand, but rather into a rib, and, further, it is bad practice to lead the metal in at a level with the bottom of the mould, the better plan being to allow the metal to fall through a short distance into the mould, thus avoiding the chance of cutting up the sand forming the bottom. When the metal enters near the bottom of a mould it rises quietly, but there is always a risk of the impurities lodging under cores and any projecting parts. In deep green-sand work, running from the bottom is customary, being less liable to cause damage to the mould by cutting, and also in many instances because it is considered unsafe to pour from the top, as when there are fragile parts projecting into the moulds.

For top pouring, the runners may be of less area than when [illegible] metal flows into the mould near its bottom, as in the [illegible] case the inflowing stream has to overcome the inert [illegible] metal accumulating above. Thin castings are run [illegible] of sprays such as is illustrated at fig. 78, those of [illegible] often being run at two or more ingates, from each [illegible]wo or more runners are led off to the mould. As [illegible] the immediate vicinity of the runners is liable [illegible]se and contain more dirt than elsewhere, the position chosen for the runners should be as remote as is possible from those portions of the casting which are intended to be machined, and as almost every structural casting may contain a reasonable amount of dirt in certain parts without materially impairing its strength for the purpose for which it is intended, these parts should be indicated to the moulder, so that he may gate his mould accordingly. When the castings are to be machined all over, either a skimming gate must be employed, or an extra thickness of metal allowed on the top of the casting to contain the dirt, this additional metal being subsequently turned or planed off during the process of machining. A third method commonly practised is to place a large number of risers over the top face into which the dirt can collect.

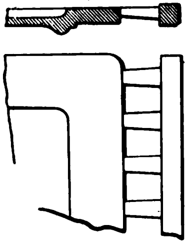

FIG. 78.

In the case of the cylinder cover, the mould for which is illustrated at fig. 69, an extra thickness of metal of $\frac{1}{4}$ in. over the whole of the top faces was allowed for in making the pattern, so that the dirt, which would be distributed over the whole top area of the casting, may be turned off with the metal by a rough cut or two, and leave the surface clean and free from blemish when finished in the lathe. Before a bedded-in mould is poured, the cope must be weighted in order to prevent its rising from the floor sand joint upon which it lies, owing to the upward load imposed upon it by the liquid pressure, and the compression of the contained air as the mould is filled. It would be difficult to give even an approximate rule which would apply generally as regards the amount of weight required to hold a cope down, as the problem resolves itself into something more than a simple hydrostatic one, entailing merely a calculation of area and height, being complicated by other considerations such as the heat of the iron, whether "dull" or "hot," the speed at which it passes into the mould, whether it is poured direct into the mould or through a pouring basin, and by the existence or otherwise of risers, having regard to their height as compared with that of the pouring basin; all of which are modifying conditions which must be taken into account if we wish to arrive at anything like an approximate estimate of the weight necessary for any particular job, so that in most instances the moulder relies on his experience gained in the execution of previous work of similar character, and usually follows the safe course of putting plenty on. To determine the load tending to lift a cope due simply to the head of metal, it is only necessary to multiply the area of the cope surface exposed to the pressure by its depth from the top of the pouring basin, and to multiply this product by the weight of the iron. For example, suppose the cope area equals 300 square inches, and is 10 in. below the top of the pouring basin, then, taking the weight of a cubic inch of cast iron at 0·26 lb., the load ending to raise the cope will be

$$300 \times 10 \times 0{\cdot}26 \doteq 780 \text{ lb., or, say, 7 cwt.,}$$

and 7 cwt., minus the weight of the cope, will be the amount of weight to be placed on the cope in order to prevent its lifting. Such a calculation may form a useful basis, but as it is unwise to run any risks in the weighting of copes, all modifying influences must be allowed for, and it is here that the moulder's experience serves to enable him to an adequate and safe margin of load beyond that which be necessary to resist the pressure due to the head alone.

here be pointed out that not only are the copes of moulds weighted, but also in many instances with r work the copes require to be kept from rising sition of weights, as when the area of the cope is tral portion is often not sufficiently restrained from lifting by the cottered pins at the sides alone, with the result that the cope bulges under the fluid pressure and causes the casting to have increased thickness of metal in the corresponding parts. In pouring the mould of the cylinder cover, fig. 69, the metal should be run "hot" in order to ensure the casting being solid in its internal structure, for when the metal is poured "dull," or when it has assumed a yellowish colour, it is too sluggish to expel its gases, which consequently remain in the casting and cause the "blow holes," which are the cause of so many uncomplimentary remarks bestowed upon the foundry by the engineers. Hot iron, on the other hand, readily throws out any gases generated in the mould during the process of pouring, and closes up solidly before it sets, and for this reason castings which are to be machined should always be run with "hot" iron. Castings poured with "dull" metal generally present a smoother appearance than when the iron is "hot," as with the latter the surface of the mould is more liable to be burnt. and for this reason moulders have a preference for casting their iron dull, except when the work is thin; but appearances are often deceptive, and it is scarcely necessary to point out the folly of sacrificing solidity for the sake of external appearance in a casting, more particularly when it is to be machined, in which case it matters little whether the skin that is removed be rough or smooth.

The construction of the pattern will sometimes determine the process to be followed in the moulding; thus in the case of a grooved pulley, the pattern for which may be made in halves with the groove formed in it, as shown at C, fig. 79, or the groove may be arranged to be cored out, when the pattern would not require to be in halves, and in place of the groove the rim would have a print P attached, as shown on the solid pattern marked B, fig. 79. A pattern constructed on this latter plan could be bedded in, as shown at fig. 80, the parting being made at the upper edge of the print and a plain top part employed for the cope. A dry-sand core C laid in the mould forms the groove. Such a mould would be run at the boss. When, however, the groove is formed in the pattern, the latter being in halves, the moulding is done in a three-part box when the pulleys are more than, say, 15 in. in diameter, whilst those of smaller size are often moulded in an ordinary flask without

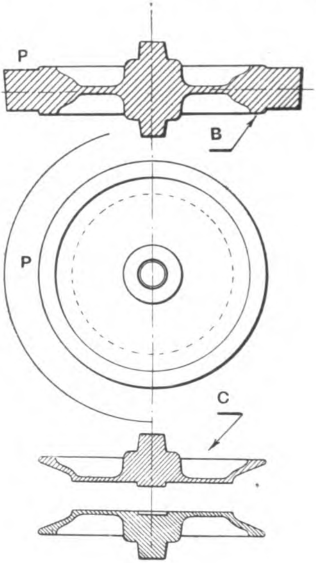

Fig. 79.

a "middle" by a very ingenious method, which will be described later.

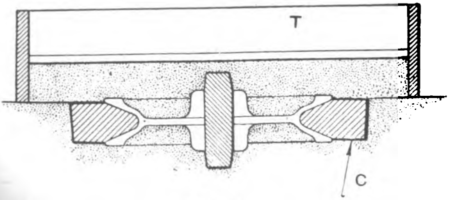

Fig. 80.

e case of a grooved pulley of large diameter, the for which is in halves and has the groove formed in the rim, the moulding is proceeded with as follows: On a level bed of sand A B, fig. 81, the lower half of the pattern P is laid, and sand tucked in all round under the lip and rammed up all round beyond the pattern up to the top edge E F. After being levelled, the surface E F is sprinkled with

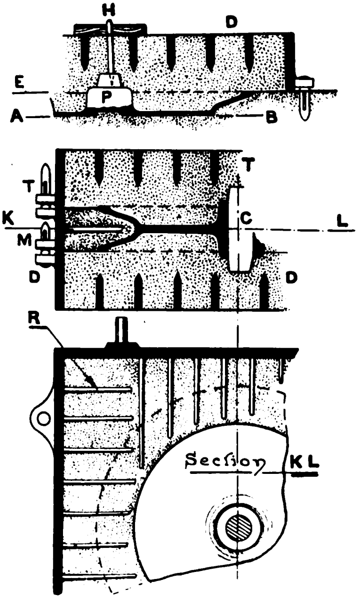

FIG 81.

parting sand, when the drag part D is laid over it and rammed up, and well vented with a vent wire, facing sand being used against the pattern. A screw bolt H is inserted for holding the pattern in position when the drag is lifted and turned over. This being done, the middle section of the flask M is put in place over the drag, a parting prepared, and a little facing sand laid around the groove, when the other half of the pattern is laid on and ordinary sand thrown in, and the box rammed up to the upper edge of the pattern, from which a second joint surface is made to the top edge of the mid part M. This joint face having been sprinkled with parting sand, the top part T is put in position, a layer of facing sand laid over the pattern, and the box filled and rammed up to its top, vented, and the necessary gate pins put in. The mould is now taken apart and the pattern withdrawn, after which the surfaces are examined and blackened, the central core C inserted, and the mould closed ready for pouring. It will be noticed that the part of the mould forming the groove will tend to lift, owing to the slight upward pressure put upon it by the molten metal.

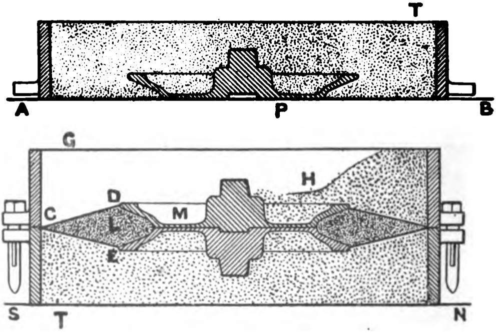

FIG. 82.

To resist this upward pressure the iron rods R, radiating from the sides of the mid part M to within ½ in. of the pattern all round, are fitted. This method of moulding will generally ensure the castings being more satisfactory than when the groove is formed by laying in segmental cores round the rim, as in this latter method fins will always be formed between the segments, and there is a risk of the junctions of the successive core sections being out of line. With pulleys of small diameters it is possible to dispense with a mid part, the method of moulding being illustrated by fig. 82. Following this method, the moulder selects a square top part T of suitable size, and places it over the half pattern P lying on a flat plate A B; then, using facing sand next the pattern and floor sand above, he rams up the box in the usual way, placing a gate pin in position, which he afterwards withdraws, and forms a pouring basin round the hole.

After venting well down to within $\frac{1}{4}$ in. of the pattern with a vent wire, he next lifts the box, turns it over, and lays it on a level bed of sand S N, which has been previously sprinkled with parting sand. He now cuts and sleeks a parting, sloping down from the edge of the box at C to the edge of the groove at E. Over this joint surface he strews some parting sand, and then places the other half of the pattern on, and makes up the sand all round to a fresh parting, sloping upward from the edge of the box at C to the edge of the groove at D. In ramming up this ring of sand L, it is customary to lay in one or two wire rings and some nails* placed radially in order to hold the overhanging sand well together when the pattern is withdrawn, although such a precaution may be neglected without serious risk when the wheels are very small, the dampness of the sand giving it sufficient cohesion to retain the form. Having prepared this second joint face, the moulder lays on the drag part G, which he rams up and vents. This being done, the drag part G is lifted off, and the upper half of the pattern L removed, when, provided the impression is good and the surfaces unbroken, the drag is replaced, the two halves of the flask securely held together by the pins and cotters, and the whole turned over so that the top part T is now uppermost. This is now lifted off, and the remaining half pattern removed. It will be seen that the ring of sand L has been supported the whole time by the sand in the half box which happened to be at the bottom. The mould is now blackened, and the spindle core set in position, when the mould is finally closed in readiness for receiving the metal.

When a large number of castings are required it is advisable to supply the moulders with a metal pattern, which if made smooth is far more pleasant to work with than one constructed of wood, and is durable enough for any number

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* Any iron put in to strengthen parts of moulds is first dipped in clay wash to cause the sand to adhere.

of castings. Cast iron is mostly employed for such metal patterns, although in some up-to-date foundries aluminium—to which about 5 per cent of copper and an equal proportion of zinc have been added—is used for the purpose. The lighter weight of these aluminium patterns greatly facilitates the moulding, and, as the actual value of the metal is probably small as compared with the cost of preparing the patterns, the general substitution of aluminium should be worthy of consideration.

In bedding-in some classes of work portions of level beds can be used with advantage, the plain surfaces of the patterns resting upon the beds and the irregular parts being tucked up. These beds can be hard-rammed and rendered capable of withstanding the pressure of the metal—which is always greatest on the bottom of a mould—without danger of the sand breaking away in patches and causing scabbing, as they can be thoroughly well vented to allow the air and gases to escape freely. The usual method of preparing the bed is to ram a hard bottom stratum, and over this a thin stratum of softer and more open facing sand. In this way bubbling at the surface is prevented, as the gas easily strikes through the more open sand into the denser but well vented body of sand below. In the case of castings having large under surfaces, the amount of gas generated will often be greater than would be carried off by a bed vented as described above, and special provision in the form of a "coke bed" has to be provided to prevent its accumulation in the mould. In preparing such a bed, a pit is first dug out of the floor of about the same area as the casting to be made, and about 18 in. deeper than the lower face of the pattern when bedded in. Over the bottom of this pit a layer of coke or furnace clinker is spread and beaten down with a flat rammer to a depth of from 9 in. to 12 in., and over this a covering of hay [illegible]bout 1 in. thick, when floor sand is shovelled in and flat [illegible]mmed up to the height at which the level bed is required, [illegible]ing strips being bedded in while the sand is yet loose, so [illegible]heir level may be adjusted with as little use of the [illegible] possible, the necessary blows being struck either at [illegible]e ends of the winding strips, or on an intervening [illegible]d, in order that their working edges may not be bruised. When levelled, the sand is hard-rammed, first against the faces of the winding strips to prevent their shifting, and finally over the whole of the area between them; facing sand being used for a depth of an inch or so at the top, which is strickled level by means of a straight-edge worked along the upper edges of the embedded strips two or three times. Before the final scraping, the bed is well vented with a $\frac{3}{8}$ in. vent wire down to the coke bed, over the whole area to be covered by the pattern. The final strickling then closes the mouths of the vent holes, so that the iron does not run in and choke them when the mould is poured, but not sufficiently to interfere with the striking of the gases through to the vertical vents, by means of which they are conducted down into the porous coke bed below, which they traverse and are brought away through one or more vent pipes laid in at the edges. These pipes should be of ample size, say about 3 in. in diameter, and sufficient in number to ensure a perfectly free egress of the gases, as otherwise there is danger of an explosion occurring in the bed, accompanied by loosening of sand and shifting of cores in the mould above.

The moulding of a face plate for a lathe furnishes a good example of the employment of a level bed in bedding-in, and is illustrated at fig. 83. The pattern N is, with the exception of the core prints C P, of the same form as the casting F, and, in order to ensure a clean surface for machining, would be moulded face down on a level bed A B, vented to a coke bed beneath, not shown in the figure. The pattern N would be first laid on the bed, and pressed down gently to produce slight impressions of the core prints, when it would be lifted off and the sand dug out under these impressions, the cavities formed being somewhat larger and deeper than the prints. Into these fine sand is thrown, when, after brushing away any loose sand from off the surface A B, the pattern is again laid on and pressed firmly down on to the bed and weighted, whilst sand is rammed up all round its outer edge, and a parting prepared at the level of the top of the rim. Having sprinkled this joint surface with parting sand, a plain top part T is laid on and rammed up in the usual way, provision being made for pouring at two points about 90 deg. apart at the rim. The cope is now lifted off, and the pattern withdrawn, when the dry-sand cores C, to form the slot holes S and the hole through boss, are set in position, the mould carefully examined and blackened, closed, and weighted ready for receiving the metal.

Fig. 84 is an example of bedding-in, with a mid part, although, as will be shown later, in this particular instance the mid-part box could be dispensed with. The casting to be made is a cylinder cover, and to facilitate the moulding the pattern is made with the stuffing-box flange F loose, so that on lifiing off the top box T this flange F may be withdrawn, while on replacing the top box T, and lifting it and the mid-part box M together, the remainder of the pattern can be withdrawn. In this figure the coke bed is shown at K, with one of the vent pipes P to carry off the gases, inserted. The stuffing-box is formed by means of a dry-sand core C set in the impressions of the prints *p p* formed on the pattern. The bed joint is made level with the upper edge of the cover flange H, and the casting would be run through horizontal runners into this flange. The

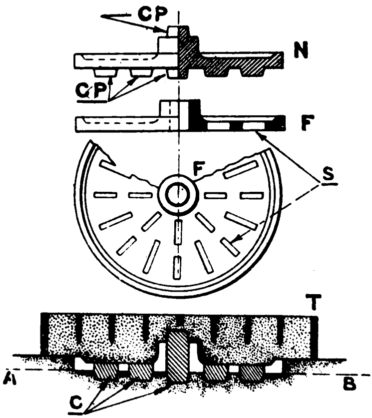

FIG. 83.

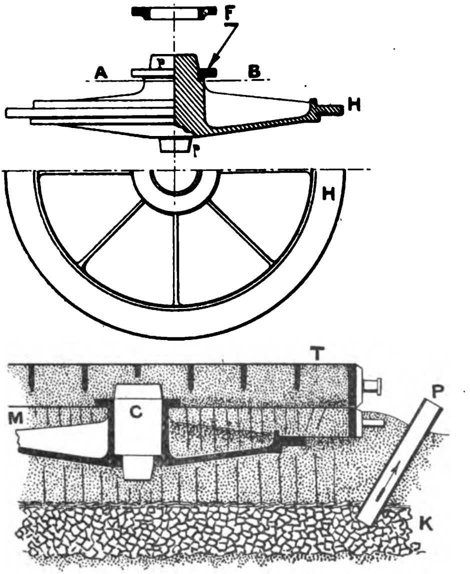

Fig. 84.

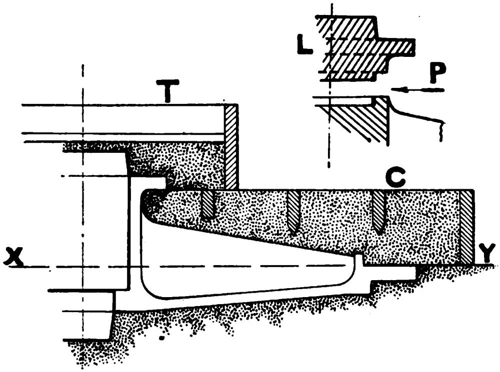

Fig. 85.

top box T does not necessarily require to be of the same size as the mid-part box M, but may be only so large as will cover the flange F and leave a few inches for a joint all round, as shown at fig. 85, when the lower box C, resting on the joint surface X Y, becomes the cope proper.

The pattern is sometimes parted, as shown at P, fig. 85, the core print coming away with the stuffing-box flange, a method of construction which simplifies the moulding, a single box being all that is required.

The cover moulded in this way is shown at fig. 86. The main body of the pattern being bedded into the floor, and a parting prepared on the level A B, the top box T is laid on and rammed up, a cake of loam C, into which the loose portion L, fig. 85, of the pattern is bedded, being set in position, and the sand rammed in all round up to its top edge. The loam cake C is now lifted out, and the loose portion L of the pattern withdrawn, when the cake C is

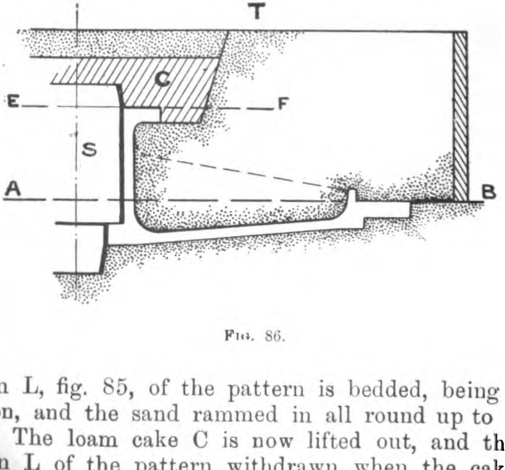

FIG. 86.

ed in the mould and sand rammed in over it, filling
T up to its upper edge. After being well vented,
is lifted off and the remaining portion of the
ithdrawn. The surfaces of the mould are now
d blackened, the necessary gates are cut, the
core S is placed in position, and the mould
d, the cope being weighted down as a whole, and

some additional weights placed immediately over the loam cake C to prevent lifting when the mould is filled.

A large amount of dried core work accompanies the green-sand moulding in many foundries, much of which might often be avoided by the introduction of loose pieces, which are left in the sand after the body of the pattern has been withdrawn, and are subsequently drawn into the mould cavity and lifted out. In other instances troublesome parts of a pattern may be withdrawn from the mould by first removing portions of the sand in their vicinity, such portions of sand being lifted out of place on plates or "drawbacks." These drawbacks are also largely employed in situations where they may not be necessary for the withdrawal of the pattern, yet their introduction is a great convenience when cleaning up the mould, as, for instance, when there are deep narrow ribs which could not otherwise be cleaned up and blackened without great difficulty. In order to ensure that these portable sections may be readily put back into their correct positions in the mould, it is customary to cast two or more prongs on the underside of the plates, which, bedding into the sand below, leave holes which form a guide when returning the plates to their respective positions. For the same purpose, it is usual to bevel the edges of the plates. Bosses and facing strips are largely moulded as loose pieces. These are wired to the patterns, as shown at P, fig. 87, the wires being withdrawn when the sand has been rammed up sufficiently to retain the piece in its intended position in the mould. When the

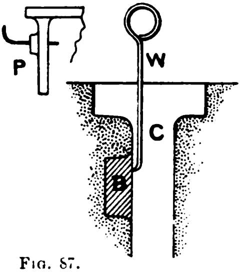

FIG. 87.

body of the pattern has been withdrawn, the loose part—such, for instance, as the boss B, fig. 87—is simply picked back by means of the pointed wire W into the mould cavity C, and drawn out. As an example of the use of drawbacks, the moulding of a lathe bed may be described. The pattern in this case is of the same form as the casting, and is made up of a main portion U and a couple of loose strips S, shown in cross-section in fig. 88. These strips are provided with dowel pins, which enter corresponding holes in the body of the pattern. The bed is moulded in a reversed position, so that the surfaces of the casting which are to be planed shall be free from dirt. A bed A B, fig. 88, having been rammed over and vented down to a coke bed beneath, the pattern is laid on and bedded down,* so that it bears

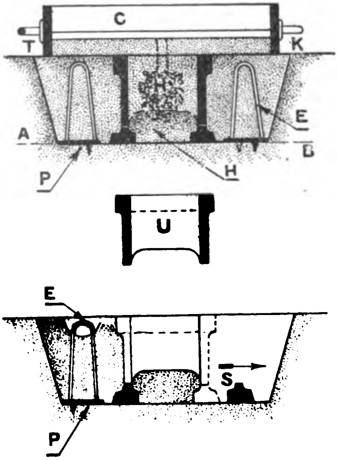

Fig. 88.

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* Lathe bed castings generally show an inclination to bend in an opposite direction from that usual with long castings, in which the ends come up in cooling, whereas the central portion of a lathe bed casting invariably comes out high. For this reason the bed of the mould on which the pattern is laid is commonly made rather higher at the ends than at its middle, in order to counteract the tendency of the casting to be high at the centre. This is usually allowed for in the pattern by giving it an upward camber of about ⅛ in. for every 5 ft. of its length.

evenly all over, facing sand being tucked under, or scraped away, as may be found necessary. Sloping sandbanks T A and K B are next prepared to form a backing for the sand which will subsequently be rammed over the plates P. These plates P, provided with lifters E cast in, are now laid on the bed, and sheets of brown paper, or a thick layer of parting sand, is laid on the sloping banks to permit of the separation of the sand on the frames from the outer sand of the floor, when the ramming up is proceeded with, the central portion H being filled in and rammed up simultaneously with that over the plates P on the outside of the pattern, facing sand being used next the pattern. In the middle of the central body of sand H, between each rib, cinders or clinkers are rammed to form a reservoir for the vent gases, and a runner stick, sufficiently long to reach through the cope, is rammed up in the centre of each mass of cinders to form a passage for carrying off the gases through the top of the mould. The sand should be rammed only as hard as is necessary to sustain the pressure of the metal, and before the cinders are thrown in, the sand, which is already rammed up, should be well vented. Those portions of the mould where the sand has to hang over flanges and beyond the edges of the plates are strengthened by means of rods bedded rather thickly in the sand one above another, or where the overhang is slight long nails will suffice to sustain the sand. When the sand has been rammed up to the level T K, runners for pouring being inserted at each end of the mould, feeding in through core gates set against the pattern near the bottom, a long vent wire is thrust down at frequent intervals, both diagonally and vertically, to bring the gases off from the vertical faces into the joint of the mould on the outside, and into the cinder spaces in the middle portion, and the joint face T K is strickled off and strewn with parting sand. The cope C is now laid on and rammed up, one or two riser pins being inserted, after which it is well vented over the pattern, then lifted off and swung aside.

At this stage the body of the pattern U is withdrawn, leaving the strips S—which are partly covered by the sand on the plates P, and the central body of sand H—in the mould.

The plates P and the sand upon them are now removed by means of the lifting rods E, when the strips S are withdrawn in the direction indicated by the arrow. The whole of the surface of the mould is now quite accessible for mending-up, cleaning, and blackening. This being done, the blocks of sand carried on the plates P are carefully returned into their respective positions in the mould, which is now ready for closing. The joint of a mould of this character is always more or less liable to be scratched up, so that before closing it is a good plan to cut a scarf at the edge, and also to scatter a little flour within a couple of inches of the edge of the mould all round, to ensure that the cope not only bears where it should, but also as it should. Before finally closing the mould, it is usual to lay the cope on and drop a little parting sand through the gates and vent holes to prove that these openings are all clear and where they are intended to be. In preparing the mould for pouring, the cope is weighted down at regular intervals throughout its whole length, and after the casting has been poured the cope should be allowed to remain in position until the following day, when it is removed and the casting dragged out, any adhering sand being knocked off as quickly as possible in order that it may cool evenly.

The introduction of loose pieces in a pattern may often facilitate the process of moulding, quite apart from the question of withdrawing the pattern, for, in many instances, the ramming up can be performed more easily and in a more satisfactory manner when such loose portions exist than would otherwise be the case. As a simple example, take the bedding-in of a webbed frame, when, if the plated portion of the pattern is of considerable area, much difficulty would be experienced in ramming or tucking the sand beneath it if left solid, whereas, by cutting a few holes through the web, the moulder is able to get his rammer and hands under the pattern, and so make good the sand beneath it. Loose pieces corresponding in form to that of the holes, and of a thickness equal to that of the web, are inserted in these holes when ramming up the cope. In casting baths, troughs, and similar objects it is a very common plan to make the pattern, as shown at P, fig. 89, with a hole L in the bottom, through which the sand on the inside may be rammed; this hole being filled up by means of a plate during the formation of the outer part of the mould. A special form of moulding box suitable for this class of work is shown in fig 89, and consists of a shallow drag part D, a deep mid part M, and an ordinary top part T. To permit of the free shrinkage of the metal during cooling, the central portion C of the drag part D is allowed to drop, by turning the eccentrics E, E, on which it rests, after the metal has set. The part C of the moulding box is well perforated for the purpose of bringing off the vents.

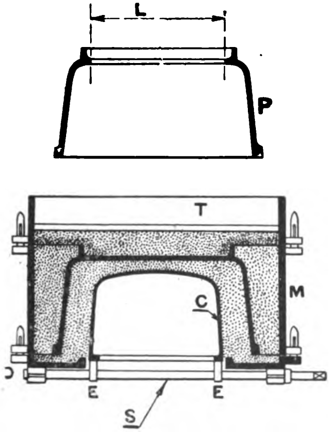

Fig. 89.

Many circular objects such as gear wheels, flywheels, etc., are moulded in green sand with but little expense as regards pattern making, a segmental block or a striking board, and a core box or two often being all that is required. The capstan base shown at fig 90 may be taken as an example of this method of moulding in green sand. All that is required of the pattern makers in this case is the segmental block B, fig 91, a pattern for the lugs L, and core boxes in which to ram up the cores S, and the central core U, fig 92. A level bed D E, fig 91, having been prepared and well vented down to a coke bed beneath, the segmental block B is laid on and sand rammed against it in successive positions, two weights W, W being placed one upon the block B, and one behind it on the bed, to hold it steady. A block of wood F, and a third weight W_1 are used to keep the sand from falling away while being rammed up in the space S. The lugs L are provided for in the mould by measuring off and laying in the pattern lug which bears against the segmental block B,

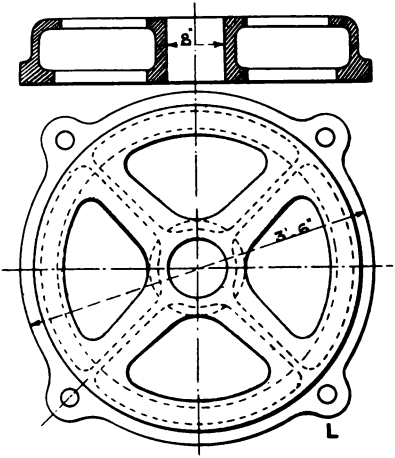

FIG. 90.

as shown by the dotted lines in the figure, and is rammed up with it at each quarter of the circle. Having completed the ring mould, fig 91, the dry-sand cores S, fig 92, which form the radial arms, after being dried and blackened, are carefully set by measurement in their correct relative positions on the bed.

When making these cores, a cast-iron grid G, fig. 93, having the lifters E, E cast in, is dipped in clay wash and bedded on a thin stratum of core sand spread over the bottom of the box. Over this grid more sand is rammed to a depth of

1 in. or so, rods and nails being bedded in with the sand in order to give support to those portions which overhang the

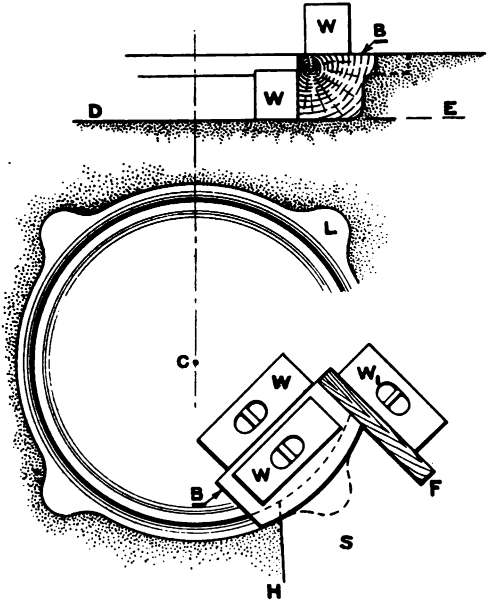

Fig. 91.

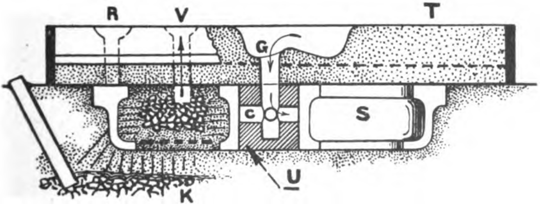

Fig. 92.

grid. Sand is next rammed along the sides of the box all round, leaving a central space, which is packed with cinders to form a reservoir into which the vents from the edges and faces of the core may be brought, and from which they are led off by means of a passage V, fig. 92, through the cope. The hole V in the core is kept open while the sand is being rammed over the central mass of cinders by the insertion of a short length of gas pipe P about 2 in. in diameter. In this particular instance the cores rest on the bed, but there are many similar castings made which are plated over at both top and bottom, which may necessitate the cores being supported on *chaplets* laid on the bed, and prevented from rising with the upward pressure by other chaplets inserted between the cores and the cope.* Various forms of chaplets

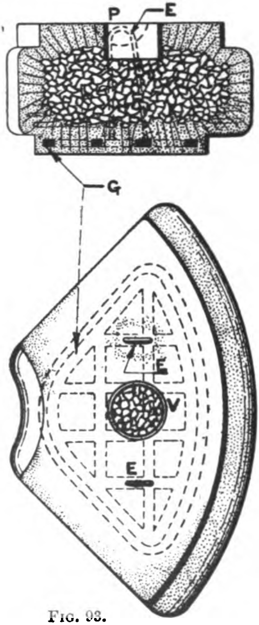

FIG. 93.

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[*] In some cases when there are a number of large cores to keep down it becomes necessary to have a dried top part in order to successfully bear the pressure of the chaplets.

are illustrated in figs. 94 and 95. Those shown at fig. 94 are wrought iron, A and B having heads forged on, and special shanks, rendering them particularly suitable for castings which are to be subjected to fluid pressure, as they greatly reduce the chances of leaks around the chaplets. D, fig. 95, is the form commonly adopted when the chaplet is of cast iron. E shows a form employed in some foundries for heavy work, which is adjustable, and enables the moulder to adjust it to give the exact thickness of metal wanted without resorting to the use of several small pieces of cast or sheet iron to make up a deficiency, as is so often the case when cast-iron chaplets are used, as with the latter it generally happens that one of the exact length required cannot be found. Briefly described, this chaplet consists of two cast-iron washers, and a central stem threaded throughout. F is a simple form readily made from a strip of plate; G consists of a plate base with two or may be more supporting studs attached; H is a chaplet with a split shank, and has the points bevelled outwards as shown, so that when driven the two parts of the shank spread outwards as shown by the dotted lines. K is constructed from one piece of sheet metal by shearing and bending; *a* shows the form to which the plate is cut before bending, and *b* an elevation and *c* a plan of the finished chaplet. Other forms, such as where several distance pieces are carried by the same base plate, and where supporting plates are carried by spikes of V and other channelled sections, may be similarly formed. L and M

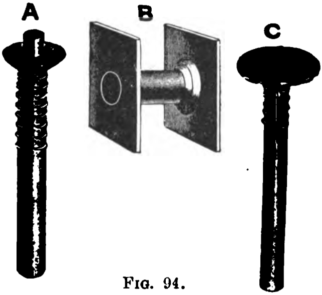

FIG. 94.

are two common forms of spiked chaplets, sometimes described as "stangies." Blocks of wood are usually sunk under the surface of the mould, end up, to receive these stangies. All chaplets must be well coated with tin to prevent rust forming on their surfaces, which would cause blowing. In estimating the amount of pressure that is exerted upwards on cores by the molten metal beneath them, a rough-and-ready method is to assume it to be equal to the difference between the actual weight of the sand core and the weight of an equal volume of cast iron.[*] When

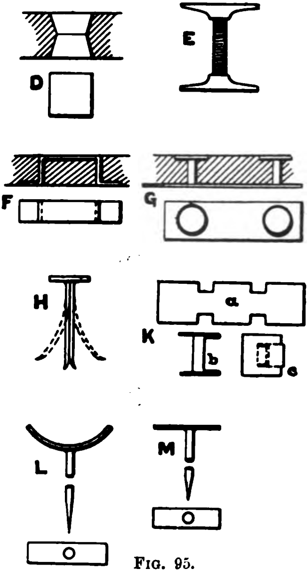

FIG. 95.

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[*] A block of cold or unmelted cast iron will float at the surface of molten iron, displacing almost its entire bulk, so that were the cores of solid cast iron, they would float when the molten iron rose to their upper surface, the upward pressure being then equal to the weight of the core. Sand cores, being much lighter than an equal volume of cast iron, consequently tend to lift long before the metal rises above them, the upward pressure increasing as they become more and more immersed, reaching a maximum when the cores are fully immersed, when its value may be taken as equal to the weight of the core reckoned as solid cast iron, minus the actual weight of the sand core.

some portion of the core is resting on a print, or lies over a cavity to which the metal has not access, the upward pressure will be less, provided the core is prevented from rising at all, for should even a thin web of metal find its way under the core at these parts, the upward pressure becomes greater, proportionately to the increased area thus exposed to the fluid pressure.

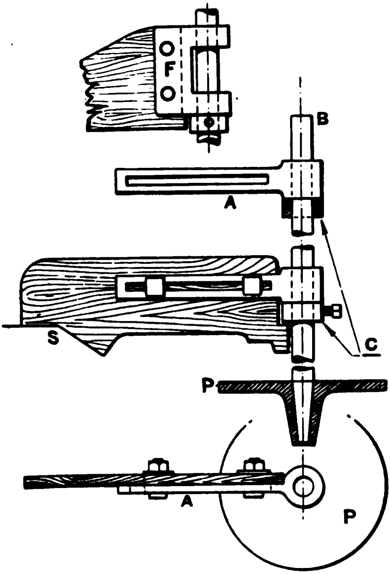

FIG. 96.

To return to our mould of the capstan base, the cores S, fig. 92, being set in position, the central core U is laid in. Provision is made in this core for running the casting from the centre, a method which is now largely adopted for circular castings. The central ingate G, fig. 92, and the runners C are formed in the core U by ramming up pins, and when the core is laid in the mould it would be set so that the metal flowing down the git G passes through the runners C directly into each of the four radial arms. For the cope, a plain top part T is rammed up on a level bed, holes being cut through it as required for the risers R, and the vents V, fig. 92, and when laying it on care must be taken that it bears well on the cores; the distribution of the weights being also regulated with this end in view, in order that there may be no risk of their shifting when the mould is poured.

The practice of sweeping green-sand moulds is becoming more common, especially in jobbing foundries, where so often but one casting of the particular form and dimensions is required. The type of rigging usually employed for the purpose is illustrated at fig. 96, and consists of a cast-iron plate P, carrying vertically a central wrought-iron spindle B with a tapered end. On this spindle, the arms A, to which the strickle-boards S are bolted, revolve, being held at the required height by the collars C, which are firmly secured in position by set screws. Another form of arm is shown at F. The plate P is generally cast in an open mould, when the tapered end turned on the spindle B is set in the mould and used as a chill, the metal being poured around it, and the spindle drawn out while the casting is still hot. In this way we ensure having a steady spindle, and if the tapered end is always well oiled before it is put in place for sweeping a mould, the dampness of the sand is not liable to rust it, and it will always remain a good fit in the plate.

Fig. 97 illustrates two modifications of the gear which have been introduced to obviate the inconvenience of moving the spindle S, which carries the strickle-board M, when moulding the two halves of a split pulley or wheel in one box. In the method shown at A the arm M carrying the strickle-board, or a pattern block, works on an eccentric pin C, [illegible]med on the spindle S. When one half of the wheel is [illegible]ded the spindle S is turned through 180 deg., and the [illegible] half struck from the new centre. Another method [illegible] at B is to mount the revolving arm M on an [illegible] E on the vertical shaft S. After the one mould [illegible] made, the eccentric E is turned half round, and [illegible] to the shaft by means of the key K, and from [illegible]tre the second mould is struck.

As a preliminary example of the employment of the gear illustrated at fig. 96, we may consider the sweeping up of a mould for a dished cover such as fig. 98. A suitable position having been found, a hole is dug in the floor and the spindle seat P, fig. 99, bedded in with a good coke bed all round, as shown at fig. 101, after which the spindle is inserted and the hole filled up with floor sand to the level O U, fig. 99, and hard rammed with a flat rammer. For this class of work many foundries now employ portable pneumatic rammers in place of hand labour, the time required with them being much less, while the sand can be rammed more uniformly than when done by hand with an ordinary flat rammer. Small sizes are made for hand use,

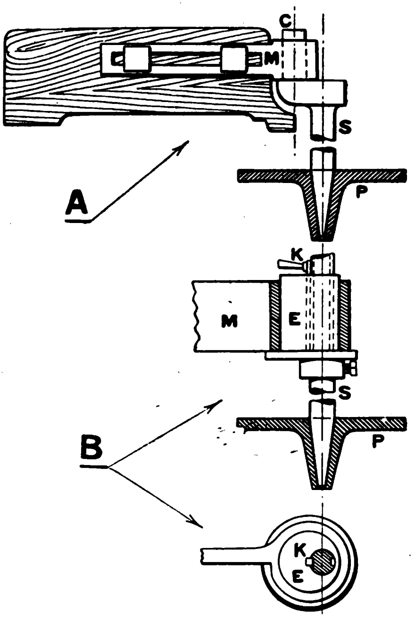

Fig. 97.

and larger sizes for suspension from the crane; either compressed air or steam may be used, and upwards of 200 blows per minute be given, the stroke being varied at will. By replacing the rammer-head by prongs, the apparatus becomes useful for digging purposes. Fig. 100 illustrates a very successful type of pneumatic rammer manufactured by the Maywood Foundry and Machine Co., of Maywood, Ill. This rammer comprises both the butt and pein ramming ends, and may be reversed at pleasure during operation, so that it is possible to ram the corners and around the bars in a flask, the rammer working with equal facility at any angle. After the bed O U has been well rammed and vented with a $\frac{3}{8}$ in. vent wire down to the coke
bed beneath, facing sand is thrown in and rammed up some-
above the floor level, a mound being formed approxi-
to the curve A B of the top of the cover. The
board S, having its lower edge shaped to correspond
with the curved upper face of the cover, and
off as shown at H, is next mounted on the spindle
the surface A B, fig. 99, swept, the board being
in the direction indicated by the arrow below H, or

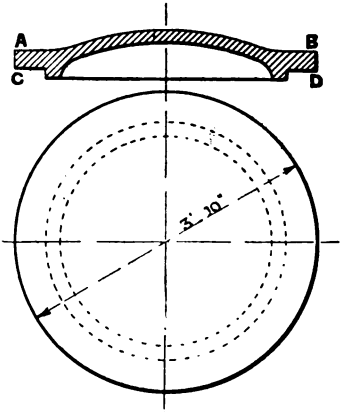

FIG. 98.

in the opposite direction to that in which the strickles are rotated when sweeping loam moulds. The strickle S is now removed, together with the collar *c*, when the surface A B is sleeked and strewn with parting sand and a plain top part box, T, is laid on, carefully staked near its four corners, and rammed up as usual, with a piece of tubing, E, slipped over the spindle to allow the cope to be lifted off without disturbing the sand, and runner and riser pins, R, inserted as required. The cope being lifted off, is turned over and laid with its edges resting on four bricks, the tube E is driven back about half an inch and plugged, when facing sand is rammed in and made up to the surface of the mould, which is then carefully vented, sleeked, and blackened. A second

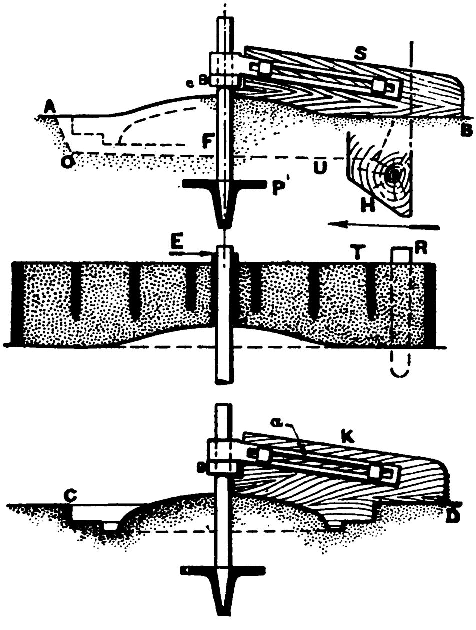

FIG. 99.

sweep K, fig. 99,* having its lower edge shaped to the outline of the underside of the cover, is bolted to the arm *a*, and the bottom of the mould, C D, fig. 99, swept out, being well vented downwards before the final strickling. The sweep being removed and the spindle withdrawn—the cavity left by the latter being filled up to within an inch of the top with cinders, and over these facing sand rammed in and made up fair with the face of the mould—the surface is sleeked and blackened, and the gate channels C, shown in plan in dotted lines at N, are cut to the right and left of the impression G of the runner-pin to the edge of the mould. A casting of this size would be run through two ingates, situated at about right angles one with the other. The cope is now lifted and turned over into its normal position,

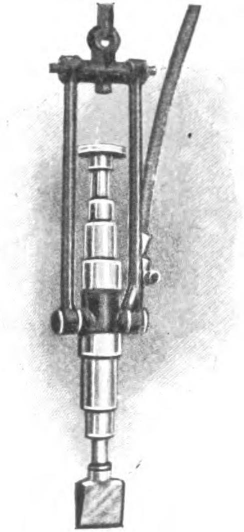

FIG. 100.

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* In many instances, instead of the second sweep, the top and bottom edges of the same board would be shaped, the one for sweeping the drag and the other the cope.

when the pouring basins and riser cups are formed, the pins withdrawn, and the cope lowered into position as shown at fig. 101.

Gear wheels of moderate dimensions are now commonly cast with blank rims, and the tooth spaces are cut out by a milling tool in a wheel-cutting machine. Greater accuracy of pitch may be secured in this way than when the teeth are moulded, and, if care is exercised, a better tooth form also. With the increase in speeds of gear drives accompanying the extending employment of electro-motors, there is no doubt that the use of cut gears will become even more common, and in the near future the choice will probably lie between machine moulded and cut gears for all high-speed machines, whilst for moderate speeds machine-moulded wheels will doubtless entirely displace those moulded from full patterns, or by means of segmental blocks, or with cores, although at the present time a goodly number of large spur and other gear wheels are still made by the latter method, in which the teeth are formed in cores, and in point of accuracy leave little to be desired when carefully made.

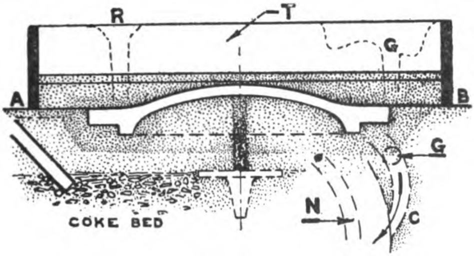

FIG. 101.

Moulding from full patterns is still carried on to a large extent, as wheels which are often repeated can be moulded far more cheaply in this way than by machine, as by the latter method one or, say, two teeth only are rammed at one time, and the tooth block has to be withdrawn and removed after each act of ramming; while with a full pattern the whole of the teeth are rammed before withdrawal, and, further, the arms of machine wheels are usually formed by cores which are rammed separately and set in place by measurement, whereas in moulding from a full pattern the arms are rammed at the same time as the teeth.

For some time past it has been the custom with some engineers to specify that all wheels, whether small or large, if not machine cut, shall be moulded by machine, as it is generally recognised that more accurate wheels are produced by machine than from patterns, although this depends largely upon the amount of personal care bestowed upon their manufacture, for there are many causes from which inaccuracies may result, such as back-lash in the working parts of the machine, incorrect diameter due to carelessness in setting to radius, badly cut tooth blocks causing inaccurate pitching of teeth, faulty setting of the blocks on the machine, etc., defects which are always liable to occur if constant watchfulness and care are not exercised, so that the accuracy of machine-moulded wheels is probably as much a question of handicraft as is that of pattern-moulded wheels. Much of the inaccuracy of gear wheels moulded from patterns is due to faulty pattern making, which often becomes magnified by wear and tear, and carelessness on the part of the moulders when withdrawing the pattern from the sand. Teeth are sometimes set "out of square" on the wheel rim, and as this often only applies to some of the teeth, it is usual to compensate for the want of uniformity in the setting and other clumsiness by allowing an excessive amount of taper on the teeth.

Pattern wheels are now generally made with metal rims carrying the teeth, which are either cast in machine-made moulds or have the teeth cut by machine, and can be made to mould well with no more taper than is indicated by
and slack fitting of the calipers.* The only risk is
teeth may tear up the sand, and necessitate mend-
In machine-moulded wheels this is prevented by
piece, which is pressed on the sand while the

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amount of taper should exist on the tooth block, or be given in
d not be left to the fitter to impart with a file; the only filing
a metal pattern should receive being just what is necessary to
roughening, when the pattern should be heated slightly and
beeswax.

tooth block is being withdrawn, and with complete metal patterns by means of a stripping plate, through which the pattern is drawn.

The chief advantages of making the arms and bosses of pattern wheels in wood is the facility it allows for making alterations to suit particular jobs, or entirely different arms and bosses can be readily substituted, while the accuracy of the teeth is maintained.

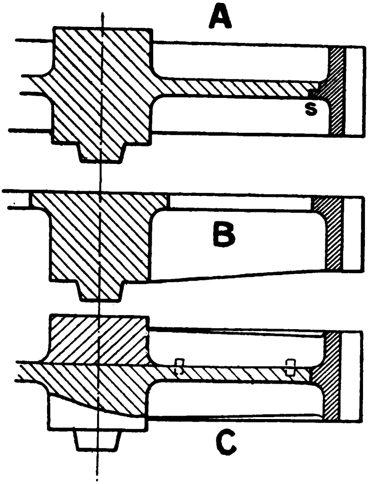

FIG. 102.

Fig. 102 shows three types of spur wheel patterns made with rims and teeth of metal, and central portions of wood. A is for a wheel having a plated centre, and is made with a shoulder at S for holding the central wooden portion in place. In B the inside of the rim is turned, and the arms are constructed in the same way as if the whole pattern were of wood; they are, however, not sunk into the rim, but simply fit closely within it, without any fastening. In moulding, the rim is withdrawn first, and the arms and boss follow. C has arms of cruciform section, the upper portions of which are loosely dowelled on the lower portions, as shown, in order to allow of their removal. Fig. 103 shows the usual section adopted for the arms when they are formed by cores set in the mould.

The methods employed in the manufacture of machine-moulded wheels will be discussed later, under "Machine Moulding," so that for the present we may confine our attention to (1) those moulded in green sand from full patterns, and (2) by the use of cores in which the teeth are formed, the earlier method of ramming up in successive positions a segmental block carrying a number of teeth—of which the modern wheel moulding machine is the outcome—need not be described here, as it is now but rarely employed, having been superseded, in shops destitute of machines, by the core method.

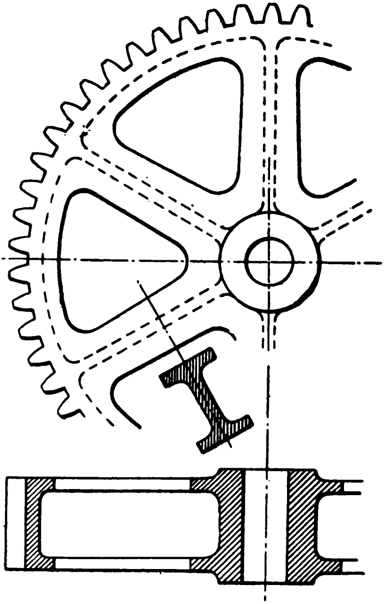

FIG. 103.

Spur wheels moulded from full patterns should always be placed in gear with the draught of the teeth in opposite directions, as otherwise the teeth bear chiefly on one side.

The moulding of gear wheels from complete patterns need not be described in detail, as the process does not differ from that followed in the usual run of pattern-moulded green-sand work, except perhaps as regards the ramming of the tooth spaces, which requires to be done more evenly and with greater care than any other class of work. Swelling at the sides of many castings will not attract attention, whereas, if the face or sides of teeth are swelled, the fault soon becomes apparent. The draught given to the pattern will, however, allow of some swelling without causing trouble, provided the sand between the teeth is rammed evenly, when the straining of the lower part of the casting, particularly when the face of the gear is wide, may compensate for the taper of the teeth on the pattern. For this reason light ramming generally produces the best castings. In ramming up spur wheels with closely-pitched teeth, say from 2 in. down, the sand is pressed in with the hands only; for larger teeth it is usual to throw in 2 in. or 3 in of sand, and then, after the outside is rammed, use the end of a round iron rod or a small pegging rammer to ram in between the teeth. The larger the teeth the more solidly should the spaces be rammed, and in no case should there be more than 3 in. for a ramming. All loose sand should be scraped away, and any soft portions pressed down with the fingers before throwing in sand for another course of ramming. This will lessen the chances of soft spots between the courses of ramming, which would result in lumpy teeth. Facing sand only is used for ramming up the tooth spaces, except when the teeth are large, and nails are bedded in to give support to the sand. If the teeth are small a single nail will suffice, whilst for large teeth four or five may be inserted, the uppermost ones being laid in at an angle to strengthen the weak top corner of sand. When the ramming is finished a few diagonal vents are driven down to within $\frac{1}{4}$ in. or so of the pattern, between each tooth, and in the case of bedded-in moulds, these are connected to a single large vent, which is driven down to the coke bed.

This plan is preferable to bringing the gases away at the joint, as there is less risk of the vents choking, and the sand can be rammed hard around the box edges, to prevent the metal from running out. In "turned-over" moulds the vents would, of course, be brought off at the bottom face of the drag, and through the top of the cope. The teeth of bevel-gear wheels are generally more difficult to mould by bedding-in than are those of any other class of wheels, owing to the trouble experienced in properly ramming them. In the case of large wheels, having closely-pitched teeth, it is sometimes possible after a bed is made to lift out the pattern and turn it over so as to bring the face up, then fill and press the spaces between the teeth full of sand, and gently roll the pattern over on to its bed again, and proceed to bed it in the usual way.

The withdrawal of the patterns is another operation which requires to be very carefully done if the wheels are to be satisfactory, a true vertical lift—except in the case of angle or screw wheels—being essential, for if the pattern is lifted more on one side than the other the diagonal pressure on the sand breaks it away, and any subsequent mending up is troublesome and seldom satisfactory. Angle or screw wheels are withdrawn from the sand by being twisted out in a helical curve; and since the weak wedge-shaped sections of sand near the top of the mould if unassisted are liable to break away, it is customary to use a stripping plate, through which the pattern is drawn. This plate is a piece of sheet metal about $\frac{1}{8}$ in. thick, with its central portion cut out so that it exactly embraces the pattern wheel, fitting accurately around each and every tooth. It is laid upon the face of the mould, and weighted down immediately before withdrawing the pattern. A bridge piece is securely attached to the pattern wheel or tooth rim, and through the centre of this bridge piece is screwed an eye bolt, and to this is attached a cord, which is led up and over pulleys, and carries a counterweight. This arrangement enables the moulder to slowly and easily draw the pattern up through the stripping plate, imparting the necessary twist as he does so by the aid of the cross-arm of the bridge piece.

The question of the use of a full pattern, or of moulding by means of tooth blocks with a machine, is often mainly one of dimensions, as the teeth of small gear wheels, particularly when they have a broad face, are difficult to ram from blocks, and are costly, while equally good results are obtainable by moulding from patterns having machine-cut teeth, with the aid of a stripping plate, and at a much reduced cost. On the other hand, in the case of large wheels, there can be no question of the superiority of machine moulding, both as regards the accuracy of the wheels and their cost.

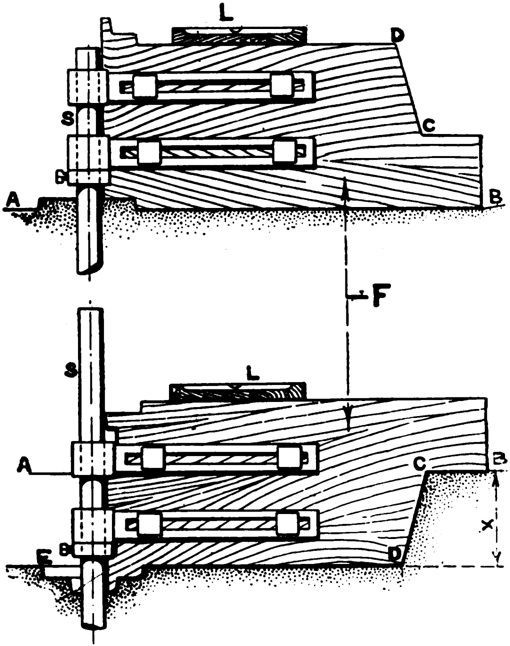

FIG. 104.

In moulding a spur wheel, such as is illustrated at fig. 103, by the core method, the process is as follows: First a coke bed is made and the spindle seat bedded in, so that the spindle S, fig. 104, stands truly vertical. The cope is next rammed up on a dummy mould,* A B in the upper view of fig. 104, which is swept up by means of a strickle board F, a piece of tube being slipped over the spindle in order to allow the cope to be lifted off without disturbing the sand, as in the last example, and two runner pins inserted for pouring at the boss, and a riser pin or two set at a radius to bring them over the wheel rim inside the teeth. The surface of this dummy mould is well rammed, and the top and bottom edges of the sweep F being planed truly parallel, the surface may be swept perfectly level by setting the sweep horizontally by the aid of the spirit level L. The cope, being rammed up, is lifted off, and the sand dug out of the floor to enable a level bed to be swept at a depth X (equal to the breadth of the wheel face) below the level A B. This bed is swept by the second edge of the strickle F, which is cut to form a radial section of the form required, or with a separate strickle, but the former is the plan generally followed, being preferable to making a distinct board for each edge, because it not only economises timber and storage room, but also avoids the risk of separation and loss of boards in the stores. The strickle board F, when securely bolted to the arms and carefully levelled, is swept round, the sand being rammed and smoothed over with the hands, consolidated in the softer rammed parts, and finally finished with the board and sleeked with the trowel. The bed so formed would be of a larger diameter than the wheel to be made, in order to allow of the laying on of the cores K, fig. 107, and would be well vented down to the coke bed in the spaces over which the metal will run to form the arms and rim, it being unnecessary to vent the areas that ill be covered by the cores, as the vents from these latter carried out through the cope. The cores K having the spaces formed in them are rammed up in a core box as is shown either at fig. 105 or fig. 106. In fig. 105

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is the one usually adopted when the cope is to cover a mould made nd ensures absolute concentricity between the top and bottom mould. It is also advantageous in the setting of facings, brackets, cope, these being laid upon the dummy mould in the positions to occupy in the casting.

the teeth are attached to the block B, whilst in fig. 106 they are separate from it, and are arranged to be drawn out of the box endwise. This latter method of construction is rendered necessary when the flanks of the teeth are undercut, as shown at T, which would prevent their delivery were they fixed in the box. Apart from this, boxes made as at fig. 106 are the more satisfactory, as the teeth can be withdrawn before the sides C C of the box are removed, whereas in the case of fig. 105 the teeth attached to the block B need to be lifted from the core after the sides C and the ends E of the box have been removed, and there is the risk of fracture of sand occurring.

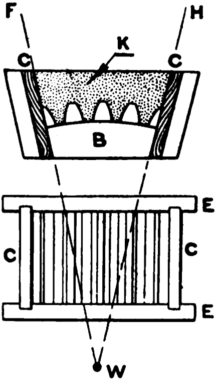

FIG. 105.

Both types of box are turned upside down after the core is rammed, and the sides, ends, and block B removed in detail, leaving the core standing on a soft bed of sand. These boxes require to be very carefully made, the sides C being set absolutely radial, in order that the cores shall match correctly when laid around on the bed. In boxes made as at fig. 105 no taper at all need be given to the teeth, since the curved form of the tooth flanks and faces usually provides more than is necessary for free delivery, while in those constructed with loose teeth little or none is required if the teeth are cut and fitted accurately. The angle between the sides of the box should, whenever possible, embrace an aliquot number of teeth, and the joints of the cores are preferably made through the centre of a tooth, as shown, and not through a tooth space.

In pitching off the teeth the length O P, fig. 106, or the sum of the pitches of the total number of teeth to be included in the box, should be taken, and the position of the intermediate teeth fixed by dividing up the arc O P equally. The length of this arc is best determined by setting off the angle F W H, fig. 105, which embraces the number of teeth to be inserted in the box. After being dried and blackened, the cores K are laid round to a circle

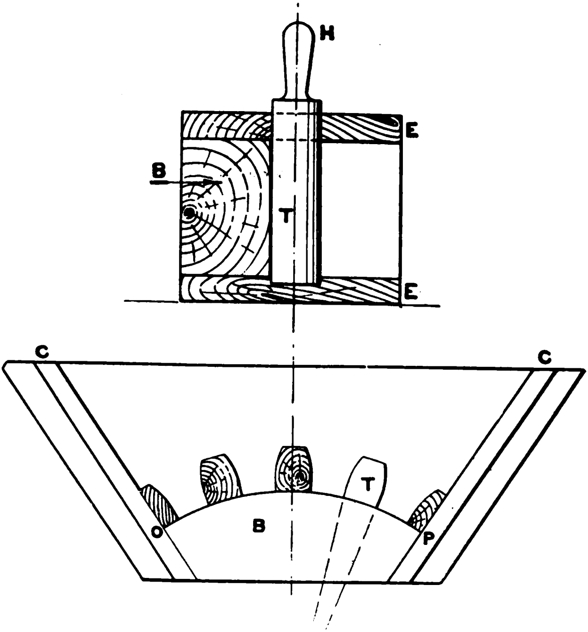

Fig. 106.

scribed on the bed corresponding to the diameter of the wheel at the bottom of the teeth, and are held in position by a backing of floor sand, which is rammed up level with the upper face of the cores.

The cores marked C in fig. 107, which form the arms, are rammed up in a core box, the construction of which is shown by fig. 108. The inner faces of the sides S S correspond to the exact centre of the vertical arms, the strips V, of a thickness equal to one-half that of these arms, being inserted. This method of construction enables the thickness of the arms to be readily altered as may be required, and at the same time simplifies the pattern-maker's work, for by inserting one-half the thickness of each arm in the box he has to strike out an exact segment of the wheel, in this particular case one-sixth, instead of one-sixth minus an allowance for the arms. The box is made up of a number of loose parts jointed together in such a way as to facilitate

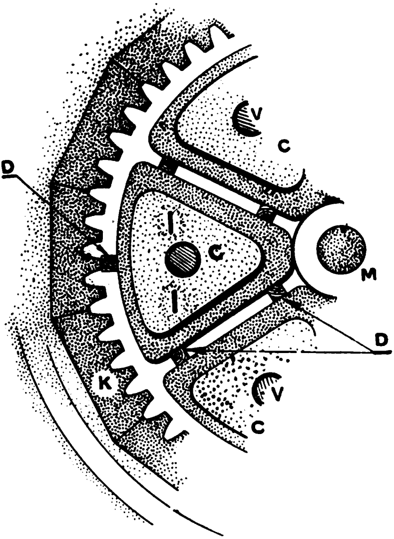

FIG. 107

their removal from the core with the least difficulty and risk of fracture.

In fig. 108 one of the upper portions T is shown removed, and in fig. 109 the sides S, S, the strips V, the curved sweep E, and the upper portions T, T, and F are shown removed from the core C, whilst the lower portions T, T, and F are shown still in position, and would be drawn away sideways. The curved sweep E is attached by screws between the sides S, S, and the remaining parts of the box are simply dropped loosely into position. The core C would be rammed up on a grid in a manner similar to that previously described for the cores forming the radial ribs in the capstan base, and illustrated by fig. 93. This grid fig. 109, would be made small enough to pass between arms, so that it need not be broken up for extraction, may be used over and over again.

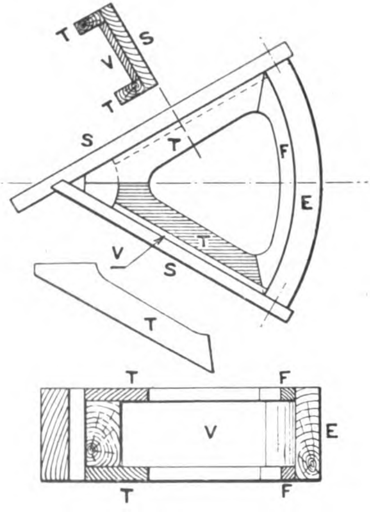

FIG. 108.

[illegible]r ramming up small cores core sand is used through[illegible]ut for large ones core sand against the faces and floor sand in the central portion and over the ashes. The core leaves the box with sharp edges, as shown by fig. 109, but these are always rubbed off to the required radii before the cores are laid in position on the bed. After being dried and blackened the moulder proceeds to set these cores in the mould, and here will be seen the necessity of having the striking edges of the strickle used in preparing the bed set quite level, for if this is not attended to the bed will be dished and out of truth, with the result that the cores will not set level nor take a proper bearing under the cope. In setting these cores gauge sticks D, D, D, fig. 107, are employed to adjust their relative positions on the bed. The central core M, fig. 107, is set with its lower end in a print impression struck by the board F, fig. 104.

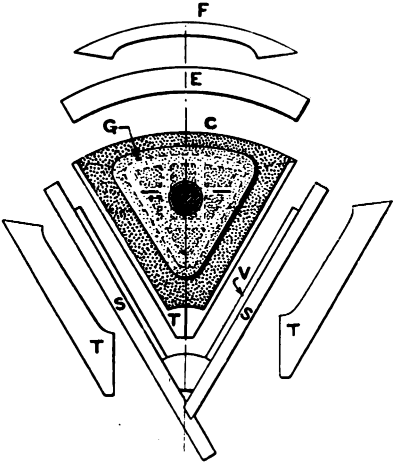

FIG. 109.

In many instances the cutting away of the board to suit the radius of the striking spindle S absorbs the print, when a pattern of the latter must be set and bedded in the mould by measurement, or the core itself may be set on the bed by measurement, and held in position by the cope, as was shown in a previous example, see fig. 92. Yet another plan is to make the core with an axial hole through it of such a diameter as will just allow of its being slipped over the spindle S, which is left in position until after pouring, and maintains the central core M in its correct position.

Simple ring moulds for the rims of wheels, which are to have their teeth cut by machine from a solid blank, are

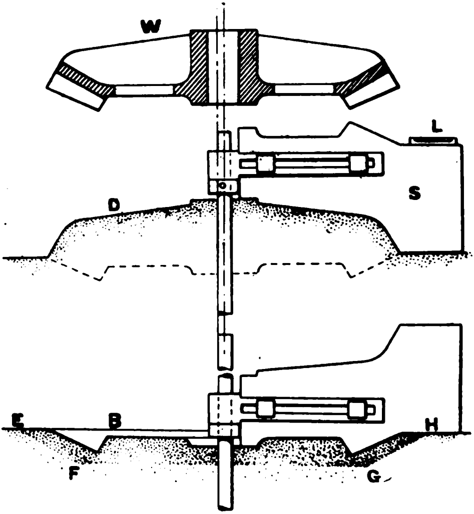

FIG. 110.

made by ramming up in successive positions a segmental block attached to the end of a radial arm mounted on the striking spindle.

The following simple method of moulding gear wheels from tooth blocks without the aid of a wheel moulding machine is practised in some foundries. To describe the method, the moulding of the bevel wheel shown in section at W, fig. 110, may be taken as an example. Having set the spindle, the dummy mould D is struck up with the sweep S, and on this a cope is rammed up in the usual way and lifted off, when the dummy mould, having served its purpose, is cleared away and a shallow pit E, F, G, H dug out, into which fine sand is riddled and well rammed and the bed B swept, care being taken that the strickle board is set horizontally. After venting the bed over the areas which are to be covered by the arms, teeth, and boss, the ramming of the teeth is proceeded with. The tooth block T, fig. 111, is rigidly bolted to the arm A, after being carefully set to the correct diameter, and here it may be well to mention that although the points and small ends of the teeth are struck by the strickle board, the impressions thus made should not be trusted as a true guide for setting the tooth block by, as small errors in diameter so easily occur in sweeping up beds. The radius at which the block T is to be set is preferably adjusted by the aid of a strip Y supplied by the pattern-makers, and the most convenient edge for the purpose is the

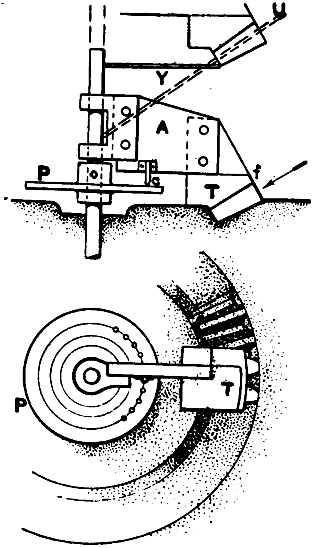

FIG. 111.

point of the tooth on the small diameter as shown. Besides being correctly set to radius, the block must also be carefully levelled to ensure the teeth being at the required bevel, for if they depart from this in but a slight degree the result will be that they bear at one end only instead of along their whole length. To enable the block to be set for bevel by means of a spirit level, its top face requires to be planed with the utmost care, as the moulder practically depends upon the pattern-maker's work for the accuracy of the bevel. To test the true radial position of the teeth, a tapered strip U, fig. 111, fitting the tooth space exactly and reaching to the central spindle, is employed. Before the arm A carrying the tooth block is mounted on the spindle, the plate P, fig. 111, is slipped over the latter and fixed in position by set screws. The faces of this index plate are smoothly turned and have a number of concentric circles scribed on them, and divided off in a gear cutter to suit any number of teeth that may be required. The plate P being in position, the arm A with the tooth block T attached, is slipped over the spindle, and the pointer *c*, adjusted so as to drop into the centre punch marks on the index plate, and allow the flat portion of the underside of the tooth block to come down upon the bed. It is a good plan to strike that portion of the bed coming immediately under the teeth somewhat full, so that the pattern teeth on the block are pressed into the face of the sand to a small extent when the block takes a bearing on the bed inside the tooth ring. This not only makes the surface firm, but also steadies the block while the tooth spaces are being rammed. The block is weighted and the tooth space rammed from the direction indicated by the arrow in fig. 111., the process differing in some details from that already described for spur wheels. Nails are not necessary nor any provision for preventing tearing up of the sand on the block being withdrawn. To assist the adhesion of the facing sand which is rammed between the teeth, the sand previously swept up by the strickle board is first hatched over with the point of a trowel. As each tooth space is rammed up, the sand is sleeked level with the face *f*, and vents are driven in to bring the gases off at the joint of the mould or down to the coke bed beneath, after which the pattern block is withdrawn, and the arm shifted to the next hole in the the index plate.

When the teeth are all formed and blackened, the cores C, fig. 113, which form the arms, are set in the mould by measurement, and the central shaft core is bedded in. These cores are made in dry sand, those for the arms being built up upon a grid, shown at G, fig. 113. This grid is provided with a number of radiating prongs R of wrought-iron rod, which are cast in and bent over to carry the mass of sand which overhangs the wheel rim. A number of loose rods are also rammed into the core with their ends projecting beyond the grid, for the purpose of giving support to the sand overhanging the flat arms. The box for these cores is shown at fig. 112, together with the strickle S, used for sweeping the top face of the core. A vertical section through the mould completely cored, and with runners, and pouring basin formed, is shown at fig. 113. The holes for the ingates, and for the vents V, from the cores C, are either cut through the cope, or are formed by the insertion of pins when the cope is being rammed up.

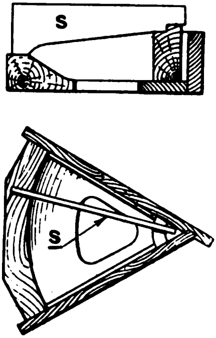

FIG. 112.

When wheels are required in halves, the splitting is effected by two general methods, illustrated at fig. 114, of which that shown at A is generally considered the more satisfactory, as by this method the wheel is cast entire, and the halves separated on removal from the mould, the splitting plates being set in the mould in such a way that a narrow strip of metal unites the two halves of the casting at the rim and boss. The effect of this is that the casting remains circular while cooling, whereas by the second method, shown at B, fig. 114, in which the lugs placed within the rim and at the boss, as at A, are replaced by a continuous web connecting the boss and rim, there is always a risk of the separate halves not shrinking exactly alike, or of not being moulded alike. Although wheels divided as at B are nearly always cast in separate halves, it would, of course, be possible to cast them entire, but the area of

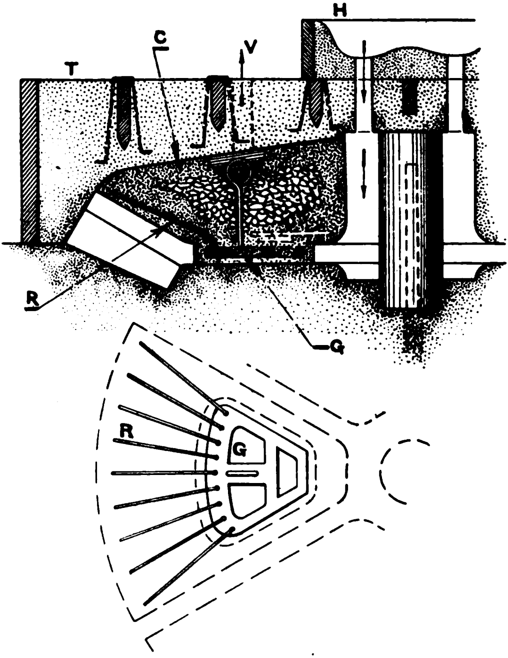

FIG. 113.

splitting plate would generally be so great as to make it almost impossible to produce a casting free from blow holes.

Following the method shown at A, fig. 114, pattern lugs L, L with prints P, P for the splitting plates are put in place in the core box, as shown by fig. 115, and rammed up with two of the arm cores, which are subsequently set diametrically opposite each other in the mould, and the splitting plates inserted in the print impressions. The remaining four cores for a six-armed wheel would be rammed up in pairs in the same box with the pattern lugs L, L taken out and a block B inserted, at the one side for the first pair of cores rammed, and on the opposite side of the box for the second pair. Cores to form bolt holes are inserted in holes drilled through the splitting plates, and adjusted so that

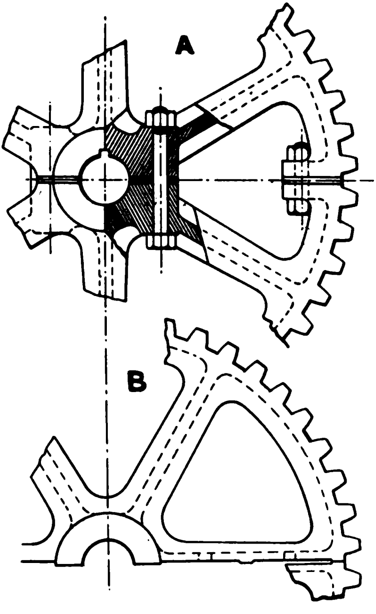

FIG. 114.

their ends abut against the lug faces as at F, F, fig. 116, which is a part plan and sectional elevation of the drag of a mould for the split spur wheel, a portion of which is shown at A in fig. 114. The splitting plates are shown in position at S, S, fig. 116. They are steadied by the prongs formed on their bottom edges being driven into the sand. These

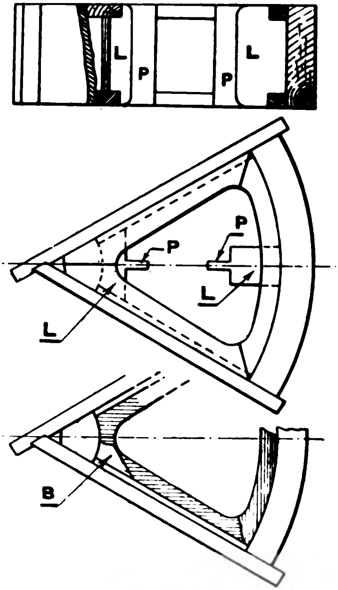

Fig. 115.

lates, if of wrought iron, are protected with a loam facing,* l blackened, and are thoroughly warmed immediately e being placed in position. When cast-iron plates are they are coated with black wash and warmed. Well-ened loam-cake cores are sometimes employed for the ose, and have the advantage that there is not the risk blowing" that accompanies the use of metal plates, but

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* Tar is sometimes employed in place of the loam facing.

they need to be thicker. In gating moulds for split wheels care must be taken that the inflowing metal does not beat against the splitting plates, but rises quietly round them, and for this reason they are seldom run at the boss. The usual plan is to place the ingates over the rim or arms, and risers—which serve for feeding—over the boss.

In the case of a spur wheel divided as at B, fig. 114, a half-ring of teeth is rammed up, the finger piece T, fig. 117, being laid on and weighted over each tooth space to prevent the sand tearing up when the pattern block is being withdrawn. The board B, fig. 117, having facings F, F, and

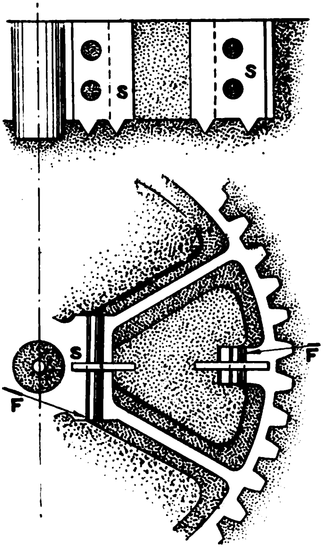

FIG. 116.

a part print for shaft core S attached, is next set carefully in the diameter with an allowance for machining the facings. This board is provided with right-angled brackets K, K, which ensure its face standing truly vertical over the bed. Weights W are placed at the back of the board to hold it firmly in position while the sand is rammed against its outer face. The arms would be formed by cores in the usual way, those adjacent to the joint face being modified on one side to suit the increased half thickness of the divided arms by the insertion of a thicker side rib in the box.

The boss alone of a wheel is sometimes split in three places, for the purpose of relieving stresses due to shrinkage. For the same purpose, the arms of light pulleys are invariably made of curved form, thus giving them sufficient elasticity to take the strain of the rim. Cast-iron flywheels which are cast all in one piece are now commonly made with the arms staggered, starting from the centre of the rim, and diversing alternately to either end of the boss. Fig. 118* illustrates a wheel constructed especially to meet the requirements of band-saw mills, and other high-speed drives. The method adopted to enable the wheel to relieve itself of shrinkage strains in cooling, and thus permit it to run with safety at speeds beyond the traditional 100 ft. per second, which has come to be regarded as the limit for cast-iron

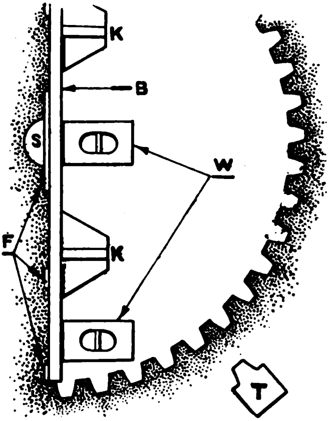

FIG. 117.

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* This form of construction was patented by Mr. G. M. Hinkley, and is used by the E. P. Allis Company of Milwaukee, Wis.

wheels, is simple and ingenious. As will be seen, the arms are staggered, and pass from one side of the rim to the opposite end of the boss alternately. When first cast the boss is in two pieces, separated by a core $\frac{5}{8}$ in. thick. As the wheel cools down the space C between the two portions of the boss increases in width to about $1\frac{1}{2}$ in. After the wheel has become quite cold this space is filled by pouring in molten iron, and the ends are fastend together with bolts, the ends of which are riveted over.

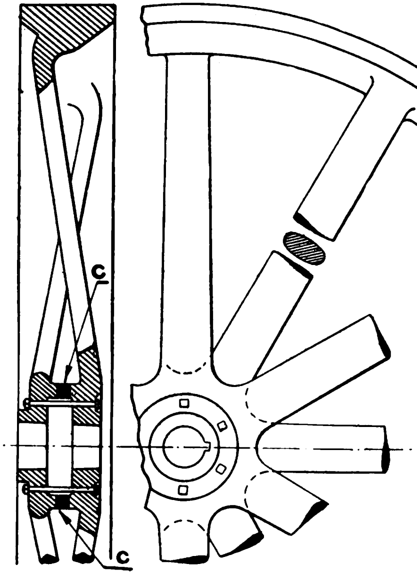

FIG. 118.

A large number of these wheels of diameters up to 10 ft. are now in use, having weights of from $2\frac{1}{4}$ tons to $3\frac{1}{2}$ tons for wheels of 8 ft. diameter; from $2\frac{3}{4}$ tons to $4\frac{1}{2}$ tons for wheels of 9 ft. diameter; and of from $4\frac{1}{2}$ tons to $5\frac{1}{2}$ tons for 10 ft. diameter wheels, and are being regularly driven at a speed of 10,000 ft. per minute without mishap.

A large number of flywheels are still made of the simple form shown at W, fig. 119, and when of moderate dimensions, and the speed at which they are to run is comparatively low, they prove satisfactory. This type of wheel is simple to mould, a segmental block being used to ram up the rim, after a suitable bed has been swept, whilst the arms and boss are formed by cores. The box for the arm cores is shown at C, fig. 119, and being for a six-armed wheel, the angle formed between its sides is 60 deg., so that when all six cores K are set in the mould they just complete a circle. The box is made with the curved end sweep, the sides, and the boss piece B removable, and when a core has been rammed up on a grid in the usual manner they are removed in detail, leaving the arm A, which, being tapered, may be driven out with a mallet. Dowels D, fig. 119, hold the arm A in position while the core is being made. As already mentioned, this type of wheel does very well for moderate speeds, but when high rim velocities become necessary or desirable it is customary to adopt some form of construction which ensures freedom from shrinkage

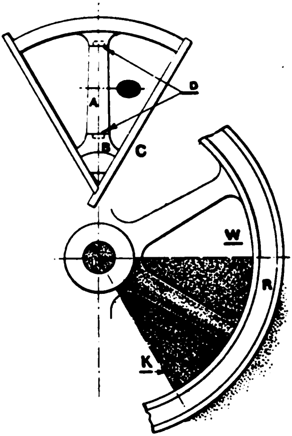

FIG. 119.

strains. Fig. 120 illustrates a form of wheel suitable and safe for high speeds, which has the rim R or L, and the hub H, of cast iron, and the arms of wrought iron or steel of square section. The arms are upset at each end, and carefully tinned as far as they enter the cast iron. In casting a wheel of this description, the rim is poured one day and the hub the next.

Many castings which in former times would have been made in loam are at the present day made in green sand with the aid of dry sand cores. Thus wheels such as that illustrated at fig. 121 are now invariably moulded in green sand in preference to loam, the process of the work being somewhat as follows: First, a level bed A B, fig. 122, is swept, and the strickle S removed, when the core forming the portion of the boss of the wheel below the arm cores is slipped over the spindle and bedded in position as shown at K, fig. 122. The strickle S is now replaced with the guide F attached, and having its inner edge at the radius of the inside of the wheel rim from the centre. The cores C, fig. 122, which are to form the lower flange inside the wheel rim are next laid in position on the bed, the guide F serving for their adjustment, and stakes T are driven at their back. When setting these cores, spaces diametrically opposite are left for the insertion of the lug cores carrying the rim splitting plates. A pattern P, fig. 122, of a segment of the

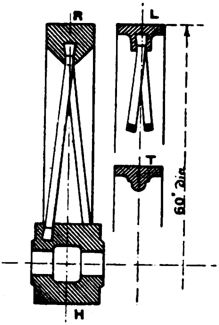

FIG. 120.

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wn on the out-

rim minus the lower flange and back web, but with the addition of a shrink head or dirt catcher H, is now set up. Weights W are laid against the segment pattern to prevent it from ramming out while sand is being rammed in behind the cores C back to the boss core K. When the whole space within the cores C has been rammed up with sand to the level of their top edges, or somewhat higher, a gutter G

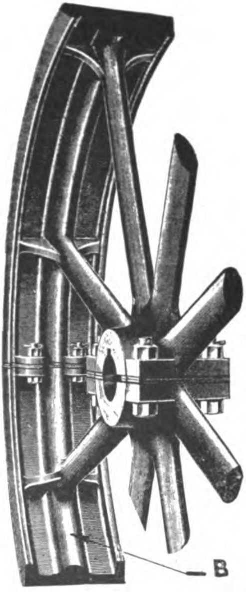

FIG. 121.

is cut, and the sand is levelled off by means of the strickle to receive the arm cores. The outer end of each arm core A, fig. 123, has a portion of the back web B, fig. 121, formed in it. This web is continued to the next arm by setting the web cores F in the mould, as shown at fig. 123. At their inner ends the arm cores are attached to extensions on the boss core N, plates and bolts being employed to hold them securely together, and waste or clay is used to stop any cracks.

When the arm cores have all been carefully spaced and set in position with their inner ends connected up to the intermediate portion N of the boss core, the segment pattern P is again placed in position and bolted at its top edge to an arm mounted on the central spindle. The flask ring R, fig. 123, made in four sections bolted together, is now lowered on to the bed and set around the mould, a number of stakes S, fig. 123, being driven against angle brackets bolted to the ring, to ensure its return to the same position after subsequent removal. Sand is next rammed evenly on both sides of the segment, the lug cores and web cores F being carefully set in position as the ramming proceeds. The gutter G, fig. 122, is filled in with cinders, and gate sticks are inserted between the arm cores to form vents V, fig. 123, for bringing off the gases from this ring of cinders. Vents are driven through from the gutter G to the face of the mould under the web cores F, and before the segment pattern is shifted a row of vents is driven down on the out-

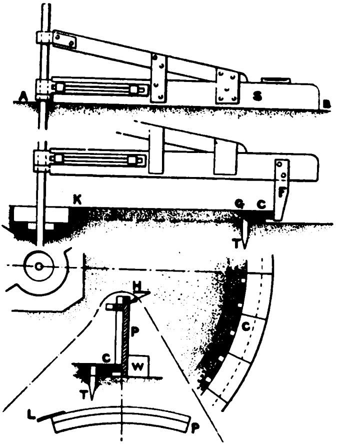

FIG. 122.

side next to the face of the wheel. When the sand has been rammed up to the top of the segment it is struck off level with the top of the shrink head on the outside, and level with the upper edge of the flange on the inside. A channel way X, fig. 123, is cut on the inside 2 in. or 3 in. from the inner edge of the flange, and after vents have been driven from this channel way to the face of the mould, over the web cores F, and under the flange, it is filled in with cinders. When the segment pattern has been rammed up in one position, a short chain is passed through the eye plate L, fig. 122, at one end of the segment, and the ends joined up to form a loop through which a bar is dropped, the lower end being inserted in one of a number of holes in the inner bottom flange of the ring R, fig. 123, and the segment is drawn along and rammed up in successive positions all round the circle, finally sliding into its initial position.

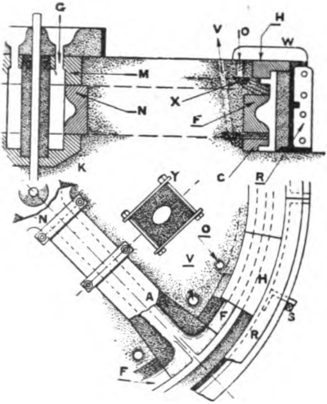

Fig. 123.

The central shaft core, and the core forming the portion of the boss above the arms, are now set in position together with the boss splitting plates. The latter core has holes through it for the pouring gates G, fig. 123. Sand is rammed around this core M, fig. 123, and a shallow cope T is rammed up over it, gate sticks being inserted in the holes through the core M, and a pouring basin formed around them. The segment pattern is now withdrawn, and the flask ring R, fig. 123, hoisted off, when the centre of the wheel is finished and blackened, and the plates for splitting the rim lugs are set in position. The inside of the ring is sleeked and blackened, and is then hoisted and returned to its position on the bed. Covering cores H formed to suit the dirt head, and extending to the flask ring, are now laid over the rim as shown in fig. 123, and sand is rammed in behind them, gate sticks being rammed up at frequent intervals over the cinders in the channel way X to form vents as at O, fig. 123. Finally, these covering cores are weighted down by pigs W, and weights are placed on the cope T, when all gate pins are withdrawn and the mould is ready for receiving the metal.

Large pipes are sometimes cast in green sand by the aid of a draw-pattern, and when somewhat rough surfaces are not a serious objection the plan has the merit of cheapness. The moulding of one of a number of short lengths of pipe used for a tunnel on a colliery tramway will serve as an example for the description of this method of moulding. These pipes had a diameter of 7 ft., with a length of 4 ft. 6 in., and were cast with a flange at each end for the purpose of bolting them together. Referring to fig. 124—the right-hand portion of which shows a vertical section through one-half of the finished mould, and to the left of the centre line a half section of the mould at an early stage in its construction—L is a sheet iron lining, 10 ft. in diameter, which was sunk into the floor to prevent straining, and to facilitate the ramming and digging out of successive moulds. The ring R was bedded in, and also remained in place during the whole time occupied in making all the castings required, and being carefully set with its upper edge level, served as a guide for striking a level bed by working a straight-edge over its upper edge as the making of each mould was commenced. Having prepared a bed, the draw-pattern P, which in this instance consisted of a ring of boiler plate welded at the joint, and having a depth of 16 in., is laid on the bed, and cores C, having the bottom flange formed in them, are set around the pattern, as shown at fig. 125. Two of these cores are specially formed with runners, as shown at K, fig. 124, and are set at about 90 deg. apart. When these cores are all set and the joints luted, sand is rammed in and around the pattern up to the level of its upper edge, the facing sand used next the pattern being rich in coal dust, as the sides of a mould of this description cannot be blackened in the ordinary way after ramming. A ring of vent sticks V, within the pattern P, and a second outside, are rammed up, also runner pins over the cores K, as shown in fig. 124. A stake S is driven into the bed with its upper end standing 4 ft. 6 in. (the required length of the pipe) above the bed, to serve as a guide for the height to which the pattern is to be drawn. When different lengths of pipes are to be made, their respective lengths are marked on the stake, and the moulds rammed up to the level of the marks. Having rammed the sand solidly up to the top of the pattern and vented it thoroughly, the pattern is drawn up 4 in. or 5 in. by means of four screws U, connected to eye plates N, bolted to the

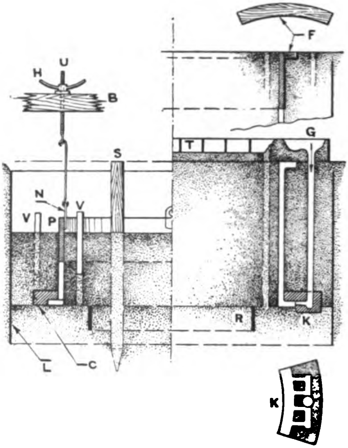

FIG. 124.

pattern ring P, fig. 124. These screws are supported by crossbar nuts H, bearing on washers carried by a suitable bridging of timber B, placed over the mould. When the pattern is to be drawn up, a man stationed at each screw, at a given signal, turns his handle through one complete revolution, repeating the operation at each repetition of the signal. In this way the pattern is drawn up square, but as a precaution it is also levelled after each drawing. The vent sticks V and the runner pins are pulled up in steps

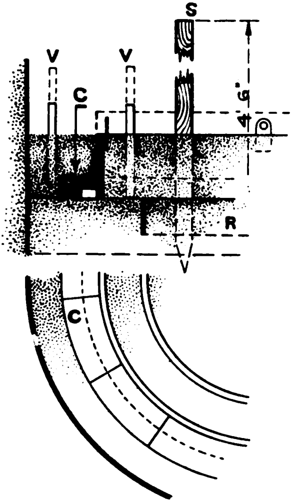

FIG. 125.

with the pattern, the latter being drawn up, and the mould rammed and vented 4 in. or 5 in. at a time until the upper edge of the pattern stands level with the top of the stake S. The top of the mould is then trued off and strewn with parting sand, and a shallow cope T rammed up over it, the vent sticks V and the runner pins being left standing sufficiently high above the joint face as to reach through the cope, and so provide a free communication for the gases from the vents to the atmosphere, and for the flow of metal from the pouring basins G to the mould. The cope T is now lifted off, and the segment F, fig. 124, is bedded-in in successive positions all round the pattern to form the top flange, when the ring pattern P is withdrawn, and the cope replaced and weighted down, and the mould made ready for pouring.

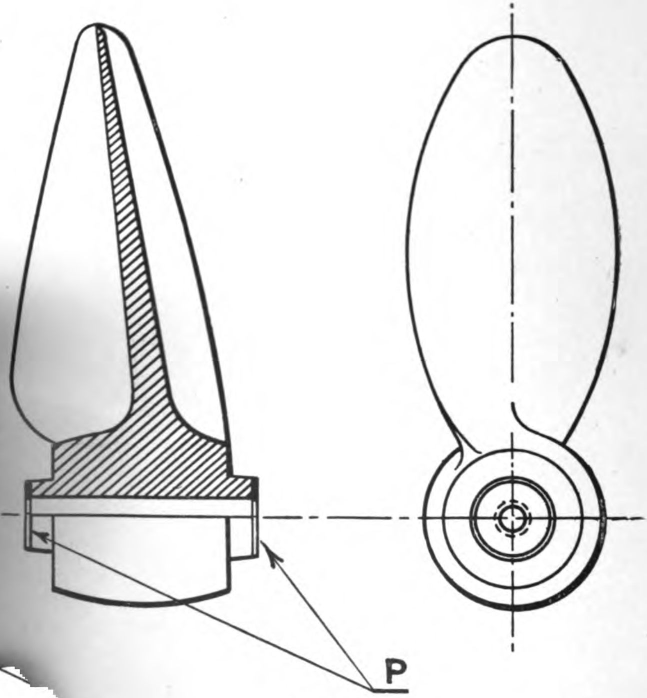

FIG. 126.

propellers are now often cast in green sand, two, four-bladed propellers being moulded from a single lade such as is illustrated at fig. 126. A suitable been dug and a good coke bed put down with a level bed of sand rammed over it, the spindle is set plumb, and the pattern, which has metal plates with holes through their centre of a diameter slightly larger than that of the spindle, attached to the core prints, as shown at P, fig. 126, is slipped over the spindle with the face of the blade down.

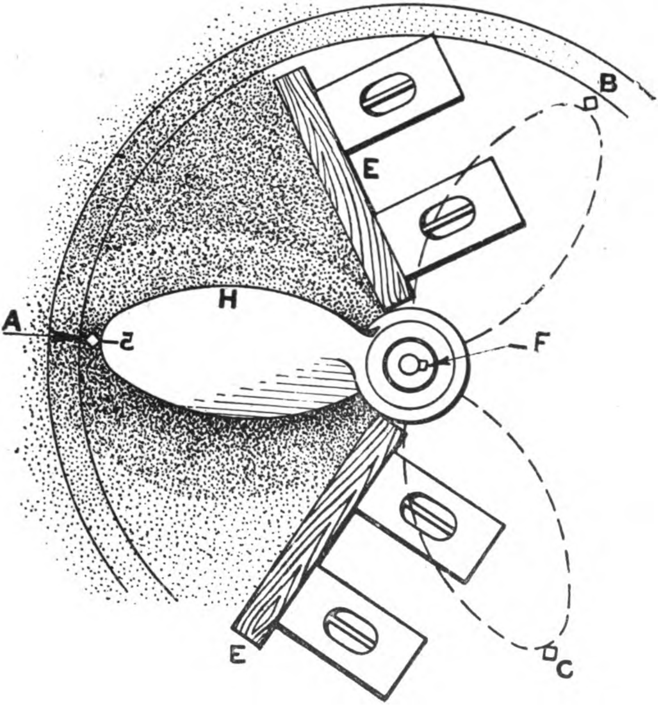

FIG. 127.

If a three-bladed propeller is to be made, three stakes A, B, and C, fig. 127, are now driven with one angle toward the blade as shown, each stake being carefully set so as to be just outside the circle swept by the tip of the blade, and equidistant from the two others. The pattern blade, with its lower core print resting on the bed, is next placed with the mark *d* opposite the stake A, fig. 127, and is held in this position by means of a wedge driven into a notch F, fig. 127, cut in the upper plate on the pattern. The pattern blade is also weighted down, and boards E E, with weights behind them, are placed as shown in fig. 127, to prevent the sand from falling away while the blade is being tucked under and rammed up. When the ramming is finished, a joint is made starting from the edge of the blade all round, slanting from the top of the blade at H down to the bed, and rising from the blade on the opposite side to the level of the upper face of the boss. The wedge at F is now loosened, the pattern rapped, lifted, swung around, and

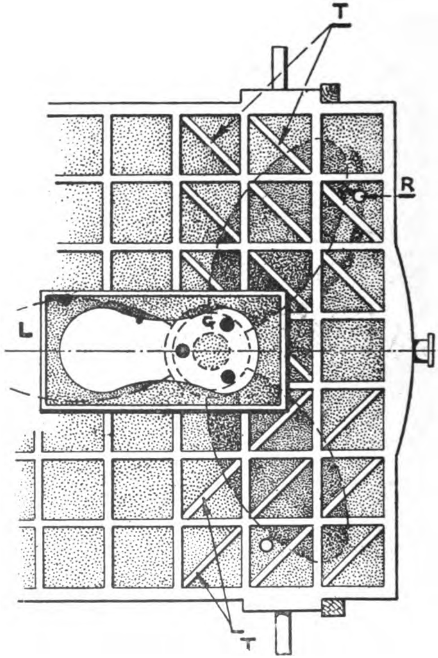

FIG. 128.

dropped on to the bed again with the mark *d* on its back coinciding with the corner of the stake B, when the second blade is rammed up, and so for the third, the parting being made and the stakes drawn as each blade is rammed up. After ramming the third blade, the pattern is left in the mould and a top-part box is laid on, rapped down to a solid bearing, and staked near its four corners. In order to carry the deep pockets of sand over and between each blade, temporary wooden bars are fitted in

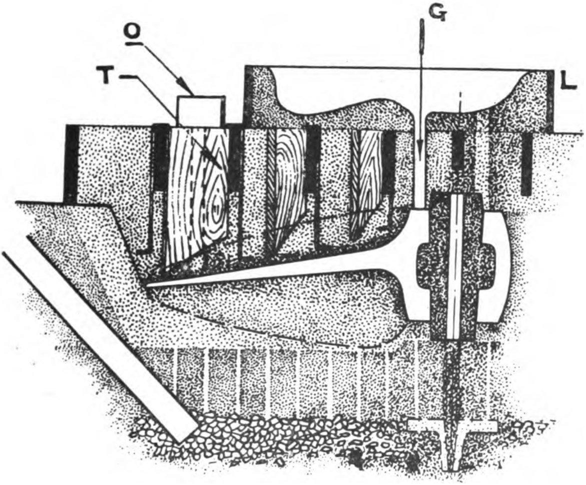

FIG. 129.

the flask as shown at figs. 128 and 129. These additional bars have their bottom edges shaped to come within an inch of the pattern, and "lifters" and "sodgers" are freely employed to guard against a "drop-out." The third of the flask immediately over the pattern is now rammed up, gate sticks being set for the ingate G and for the riser R, fig. 128, and also one or two others at the high side of the blade for bringing off some of the vents. Weights are now placed on the cope opposite the rammed portion to balance it, and after venting down to within a quarter of an inch of the pattern over the whole area under which the pattern lies, the cope is hoisted off. A channel way is cut along near the upper side of the blade under the gate sticks which were set to assist in bringing off the vent, and from this channel vents are driven in under the blade. The pattern is now lifted and set in the next drag impression when the cope is lowered into position again and another third is rammed up, gate sticks being set as before. The process having been repeated for the third blade, the cope is hoisted

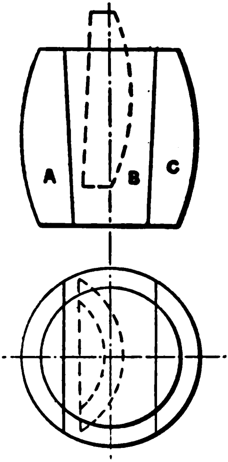

FIG. 130.

off and the mould is finished and blackened. It will be noticed that the form of the boss makes it impossible to withdraw the pattern without breaking away some of the sand around the boss. To facilitate the mending up of the mould, a duplicate boss built up in three pieces as shown at fig. 130, is sometimes provided. By withdrawing the portion B first, the remaining portions A and C may be drawn back and lifted out without causing breakage of the surrounding sand. After the mould is finished and blackened, and the drag well vented down to the coke bed, the boss core is set and the cope tried on, when, if all is right, the mould is finally closed and the runner box L, figs. 128 and 129, is placed in position and a pouring basin formed in it. The cope is well weighted down, flow-offs O, fig. 129, are built to lead the metal away from the risers, and one or two pigs are laid across the runner box. Balls of clay are placed over the mouths of the risers and lightly weighted, so that they will not lift before the metal reaches them, and all is ready for the cast.

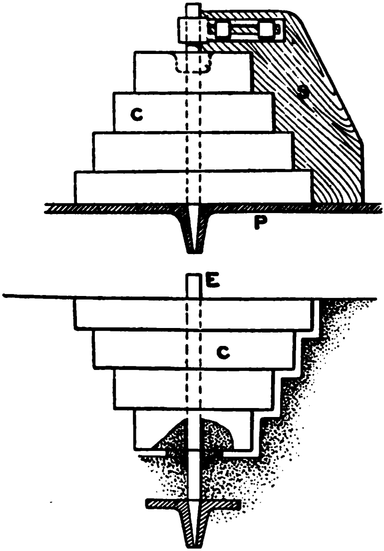

FIG. 131.

An interesting example of the aid afforded by the striking spindle in setting cores is the moulding of cone pulleys, the patterns of which are often provided with central plates as in the case of the propeller pattern. The pattern, being slipped over the spindle, is rammed up and removed, when the core C, fig. 131, which has been swept up on the plate P by means of a strickle S, and has a piece of tubing at its centre which slides over the spindle with the least possible clearance, is slipped over the spindle E by which it is guided into a truly concentric position relative to the outer mould face. The difficulty in producing well-balanced cone pulleys is mostly a question of getting the core central. By the earlier method, even when a good stiff flask was employed and the core bolted to the cope as solid as possible, some slight movement often occurred in turning the cope over. By the method described above all this difficulty is avoided, as the core is not attached to the cope but is lowered into the mould independently. Fig. 132 shows another method

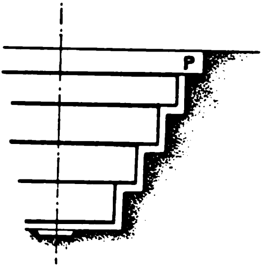

FIG. 132.

sometimes adopted in which the core is also independent and is set in the mould and centred by means of a core print P.

The foregoing examples will suffice to give an idea of ordinary green sand moulding as at present carried on in general iron foundries. Castings weighing many tons are now cast in green sand, provided their depth does not exceed about 3 ft., as beyond this there is considerable risk of the pest parts becoming swollen and out of shape. Projecting rts are sometimes moulded separately in dry sand, s dried part inserted in a green sand mould tely before closing; but the result is seldom ry as the junction between the green sand and dry tions of the mould is generally very apparent.

CHAPTER XI.

CORE OVENS AND DRYING STOVES.

Before dealing with the details of dry-sand moulding it will be well to consider briefly the ovens employed for drying the moulds and cores. These generally consist of brick-built chambers, the shape and size of which are governed by the character of the work undertaken by the particular foundry. A very common form of oven is illustrated at fig. 133. The walls are built of ordinary brick, with, in some instances, a firebrick inner lining, and when exposed to the outside air it is customary to build them double with an air space between, as shown at A B. The roof is composed of rough cast-iron ⊥ beams laid crosswise at intervals of 4 or 5 ft., which carry flat arches from one to the other of 9 in. brickwork. The oven is closed at one end, and has a steel plate door C at the other. This door is arranged to slide up and down in guides, and is connected at its uper edge to a chain passing over a pulley and carrying a counterweight. The furnaces F, F are placed at the closed end of the oven, and are fired from the outside. Generally only one furnace is fitted, but in the case of a rush job it is an advantage to have two; although for ordinary working each should be separately able to create all the heat required to properly dry a mould. The grate area provided is usually about 1 square foot for every 500 cubic feet capacity of drying chamber. The outlet for the products of combustion, etc., is placed about 6 in. above the floor level, and at an opposite corner from the furnaces, as shown at O, fig. 133, to ensure that the heated air does not pass off without doing duty. This outlet communicates with a stack P, having a cross-sectional area about one-fifth the area of grate, and a height of from 40 to 50 ft. In addition to the outlet O, there should either be another large flue in the roof, which may be kept opened or closed by a damper, or the flue P, if made wide enough, can have close to the roof a shutter that can be opened from the outside, when it is desired to enter the stove or open the doors for the purpose of withdrawing or admitting moulds or cores while the fire is on. By this means the oven may

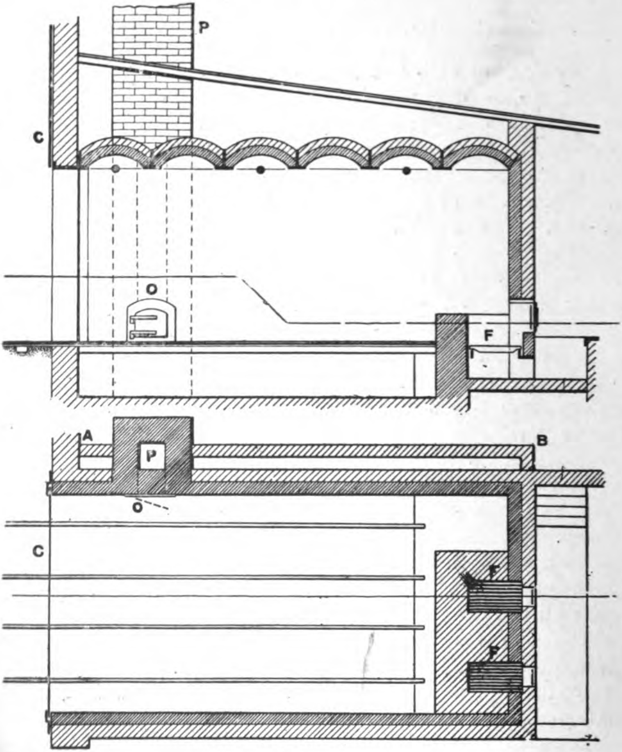

FIG. 133.

cleared of smoke without polluting the atmosphere of the ndry.

For stoves of moderate dimensions the best floor is formed cast-iron plates laid smoothly all over the surface; the on wagons carrying the moulds can then be run into any part of the chamber; but large stoves are usually laid with one or more lines of rails, as shown at fig. 133. These rail tracks are continued outside into convenient positions

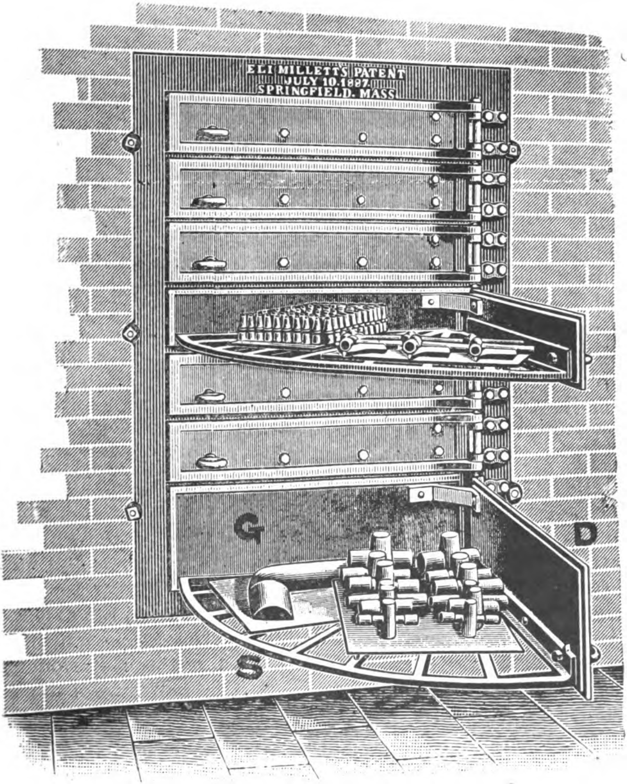

FIG. 134.

under the cranes. A number of ovens is better than one large one, and even in small foundries there should always be at least two, one for large work, and one for small work and emergencies. For drying small cores, the Millett core oven,* illustrated at fig. 134, is now largely used. This oven is arranged to be continuously in operation, and the work on any one of the seven shelves may be examined without interfering with the drying of the cores on the others. As the door D is opened and the shelf S brought forward to its full extent, the front opening is closed by the guard G, thus preventing the escape of smoke and hot gases. This oven may either be let into the side of one of the main drying stoves, as shown at fig. 134, or it can be set up independently and made portable, similarly to the Evan's improved independent core oven,† illustrated at fig. 135. The firing of this oven is provided for by a small furnace arranged at one side, and a chimney C is fitted for taking off the moisture, with a regulating damper T to ensure a proper temperature.

This principle of continuous operation has been applied to ovens working with cars, as shown at fig. 136. In this case the oven has a number of openings or doorways through each of which a car track is laid running into the oven and extending outside. The cars are constructed entirely of steel and brass, and are fitted with shelves on which the cores are laid. The front of the car is made of sheet steel, and it extends a little beyond the top, bottom, and side edges of the opening, thus serving as a door to the oven when the car is inside. The back is formed the same way and it serves also as a door to the oven when the car is run out. In some instances the cars are operated by compressed air. Directly under the body of the car and above the axles, a brass tube T is fitted, extending along the whole length of the car. This is the air cylinder. The piston is stationary, and the apparatus double acting. The movements of the car are controlled from the front of the oven by the manipulation of a four-way valve. With the car in the oven, [illegible] as has been previously stated, the front serving as a [illegible]ing door, the valve is opened, and the car comes out full [illegible]h. The back serves as another closing door, and cores [illegible]ken from the car or placed upon it, when another turn

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[illegible] J. W. Jackman and Company, 89, Victoria Street, London, W., are the [illegible]ts for Millett core ovens.

[illegible]mes Evans and Company, Manchester.

of the valve sends the car back and simultaneously closes the oven again. The flue F, fig. 136, runs underneath all the cars.

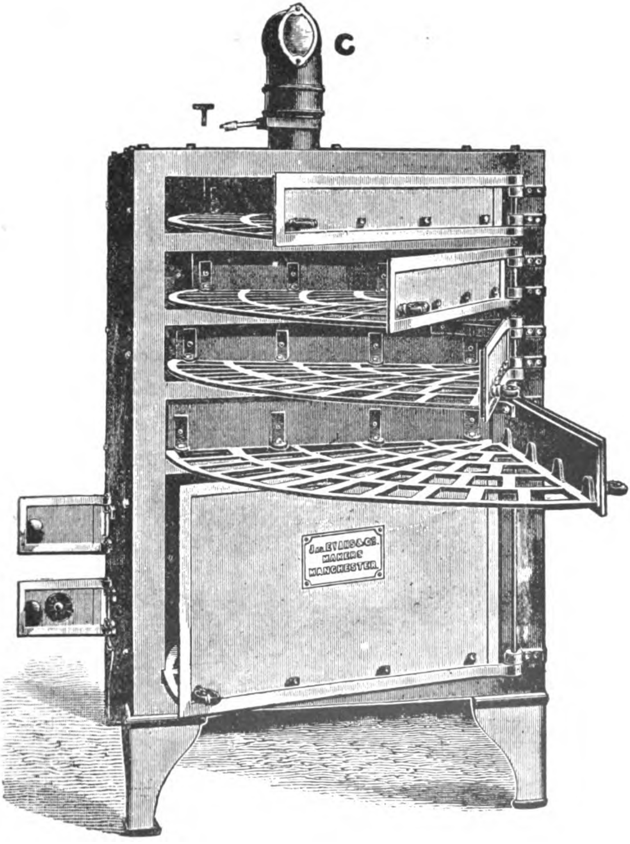

Fig. 135.

Fig. 137 shows a type of core oven which is in use in a number of foundries in the United States. This oven was designed by M. F. S. Taggart, superintendent of the Missouri Malleable Iron Company, at East St. Louis, Ill., and is arranged for continuous operation. From fig. 137

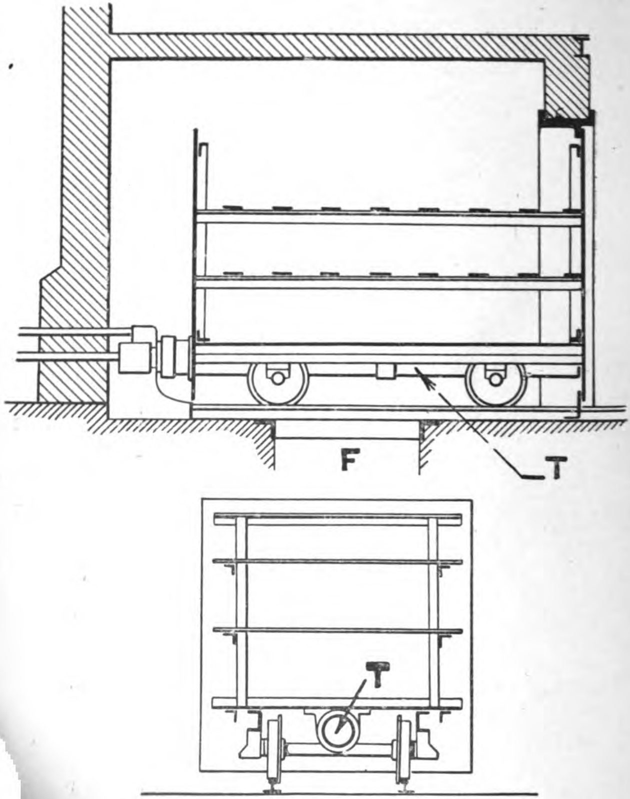

Fig. 136.

will be seen that the oven consists of a number of partments, there being four tiers of shelves to the height. h shelf is arranged to be withdrawn independently by means of the gear shown in detail at fig. 138. Suspended from a trolley T, running along a rail beam L, is the vertical bar B. When it is desired to withdraw any particular shelf, the fork F is adjusted for height on the bar B, and is hooked into the eyes E provided on the front plate P; when the shelf is drawn forward, the front part being supported by the trolley T, while the rear end is carried by the wheels W.

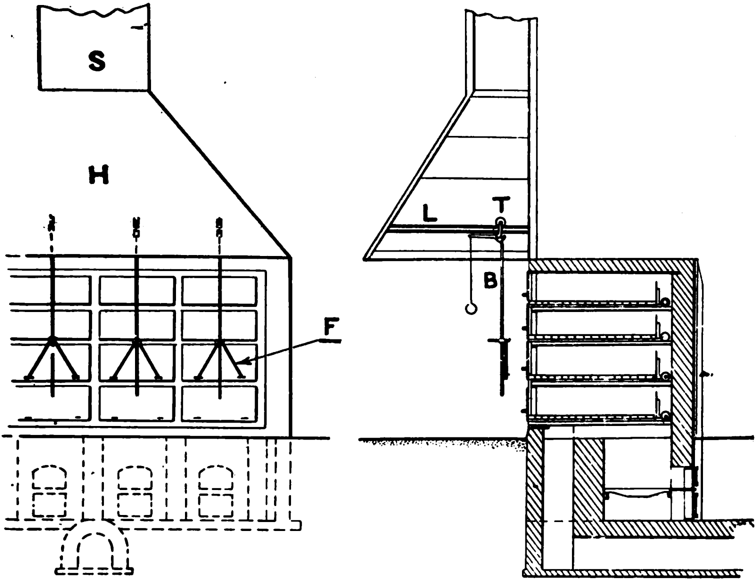

FIG. 137.

The shelf being drawn out to its full extent, the front opening is closed by the guard G, thus keeping the oven in practically continuous operation, and interfering in but the smallest degree with its working. From fig. 137 it will be seen that the firing pit is below the floor level, and at the back of the oven; and a corrugated iron hood H and stack S are provided at the front, for catching and carrying off any smoke and fumes that may escape when the shelves are being brought forward. The trolley wheels and the wheels W, fig. 138, are arranged with roller bearings, as shown in detail at fig. 139.

An oven of this type erected at the Missouri Malleable Iron Company's foundry consists of sixteen compartments, arranged in groups of four to the height placed side by side. The depth of the oven from front to back is 7 ft., the width inside 16 ft. 10 in., and the height above the sill 8 ft. 1 in. There are four fire-boxes, each with a grate of 5 square feet area, and the stack has a cross-sectional area of $2\frac{1}{2}$ square feet, or one-eighth of the total grate area.

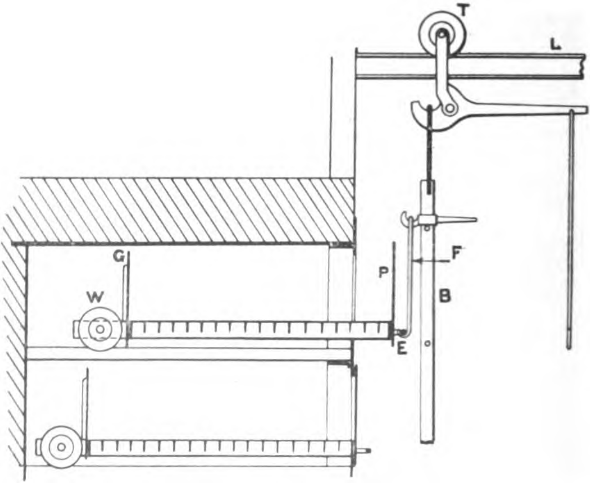

FIG. 138.

The cars on which the moulds and cores are run into the [illegible]ng stoves are constructed of iron or steel, and are [illegible]mes made with two or more platforms, arranged one [illegible]he other as in fig. 136, but for heavy work they [illegible]onsist of a single platform mounted on wheels. Of [illegible]r type, fig. 140 illustrates, in side elevation, one [illegible]vantages over many others both as regards [illegible]a construction and the ease with which it can be moved. This car was devised by Mr. Paul R. Ramp,* and is employed by him in connection with ovens used for drying locomotive cylinder moulds. It will be noticed that there are no axle boxes, but, instead, a recess C D is cut in the frame of the car at each side over both axles. The ends of the axles protrude through the wheel bosses about 4 in., and support the body of the car. When the car is being pushed into the oven the axle A acts as a roller till it reaches D, making it possible for one man to push a very heavy load, as there is but little friction before the axle reaches D, and by that time he will have acquired enough headway to get the car where wanted. Should it run too hard it can be

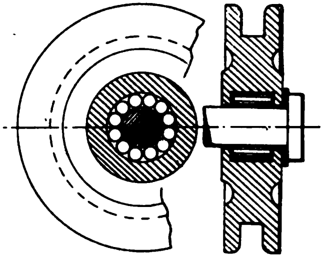

FIG. 139.

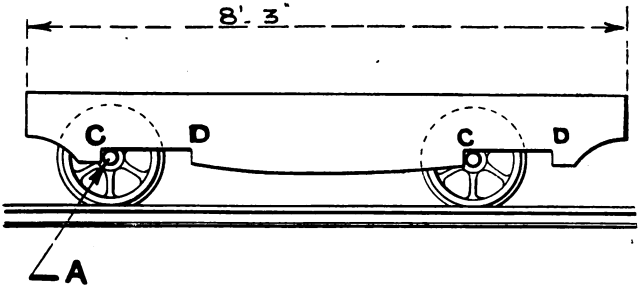

FIG 140.

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* See the *Foundry*, February 1900, page 216.

pulled back a short distance, as the axles would then be in a location, as to act as rollers. When the car is in the oven

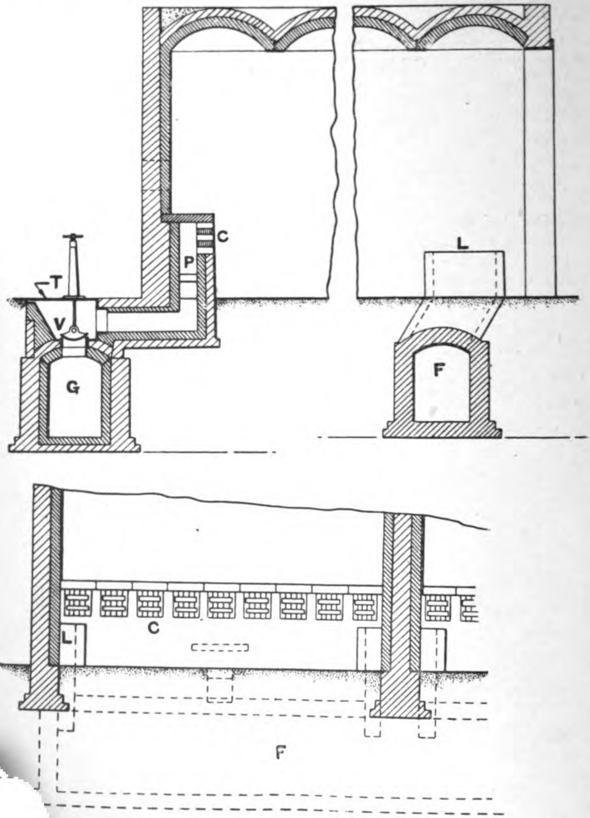

FIG. 141.

s will be at the ends of the recesses marked D, gives the same advantage in starting to pull the car the oven as when commencing to wheel it in.

Gas-fired core ovens and drying stoves are now in use in many foundries, and in point of view of cleanliness, along with the steady regulation of a moderate temperature, such a system has much to recommend it. In some instances the waste gases from blast furnaces are utilised for the purpose, whilst in others producer gas is employed. When gaseous fuel is applied to existing drying stoves in which coal or coke has hitherto been used, it is customary to introduce the gas immediately above the furnace bars, on which a small coal fire is maintained, but when the stoves are built expressly for gas firing their general arrangement is as shown at fig. 141. The gas main G runs along at the back of the stoves, and valves V for controlling the supply of gas to each stove are provided. The air necessary to support combustion is drawn in through gratings in the floor plate T at each side of the gas inlet, and the gas and air passes up the passage P, and through the red-hot chequered brickwork C into the stove. On passing through this chequered brickwork the gas and air are thoroughly mixed, and their temperature is raised sufficiently to cause ignition and maintain combustion, the products of which, mingling with a further supply of heated air, pass through the dryng chamber, and after becoming saturated with moisture escape through the outlets L to the main flue F. Another method of introducing the air supply is shown at fig. 142; here the inlets A are placed above the floor and the air enters a passage N, extending the whole width of the stove, and meeting the gas coming up through the passage P—which also extends from side to side of the stove—mingles more uniformly with it than when the air is admitted in the manner shown by fig. 141. The arrangement shown at fig. 143 is sometimes adopted, a supply of air sufficient for combustion being admitted at the lower inlet A, while the additional quantity necessary for drying is drawn in through the upper inlet F and mixes with the products of combustion, the high temperature of the latter causing that of the whole to be sufficient for the satisfactory drying of the work in the stove. With this arrangement the temperature and flow of heated air and products of combustion can be very accurately adjusted to give the maximum drying effect. The method of introducing the heated air and products of combustion into the drying chamber, shown in fig 143, differs from that of the previous examples. After leaving the mixing chamber C, fig. 143, they divide up and enter a number of separate channels P, from which they pass upwards through perforated brick arches R, which form the floor of the drying chamber E.

Liquid fuel is also applied for the purpose of drying moulds and cores, and, as with gas, the combustion can be rendered practically perfect owing to the ease with which the air supply can be adjusted to the requirements, the result being an entire absence of the soot and dirt associated with the direct combustion of coal burned on an open grate. The temperature in the drying chamber can also be instantly raised, kept steady, or allowed to drop by a simple adjustment of the burners, so that altogether there is much less waste of heat, and the cores and moulds after drying are perfectly clean.

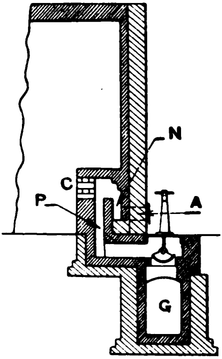

Fig. 142.

Fig. 144 illustrates the application of Kermode's liquid fuel system to a core drying oven at Messrs Bayliff and Sons' foundry at Birkenhead. The dimensions of the oven are: length, 25 ft. 5 in.; breadth, 10 ft.; and height, 10 ft. 8 in. The oil flows by gravity to the burner from a tank placed at a height of 11 ft. 6 in. above. Figs. 145 and 146 show the arrangement of the burner and its connections

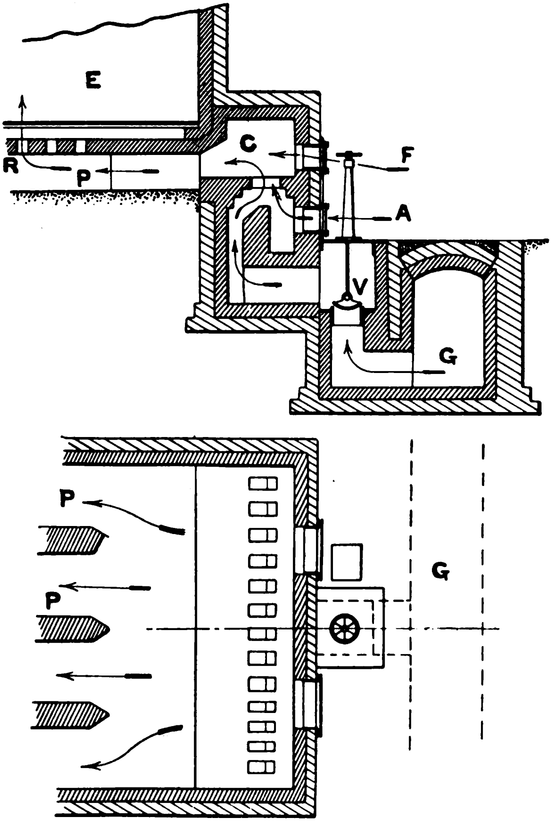

FIG. 143.

to a larger scale. In these figures, O is the oil supply pipe, and A the air supply pipe, this latter being carried round inside the furnace, as shown in fig. 144, thus heating the air before it enters the burner. The pressure of the air does not require to be more than 2 lb. per square inch to operate the burner satisfactorily.

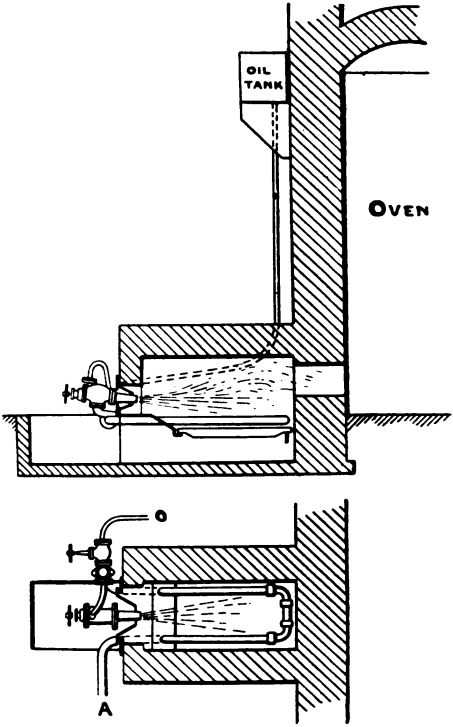

FIG. 144.

In operation, 44 gallons of crude Borneo oil were used in the drying of the cores for a 12-ton marine engine cylinder casting, comprising two truck loads, and including two cores 4 ft. 6 in. × 4 ft. 2 in. × 1 ft. 6 in.; one core 2 ft. 4 in. diameter × 1 ft. 6 in., one core 4 ft. × 5 ft. × 8 in., one 2 ft.

diameter × 1 ft. 8 in., one 6 ft. × 4 ft. × 8 in., one 4 ft. × 2 ft. 2 in. × 1 ft. 2 in., and one 4 ft. × 3 ft. 2 in. × 1 ft. 10 in. The time occupied in drying these cores was 5¾ hours, and the temperature of the drying chamber at a point a few feet in from the door was about 340 deg. Fah. There was practically no smoke produced, so that the cores were free from deposition of soot and required no subsequent cleaning.

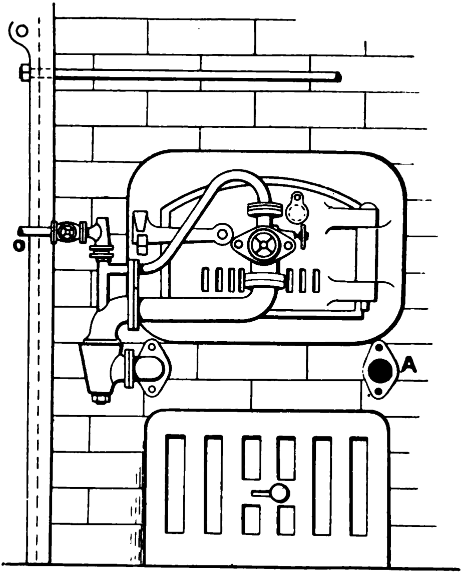

Fig. 145.

To accomplish this work with coal, the fire is started at 5 p.m. and kept going until noon the following day, using about 1 ton of coal, the combustion being at the rate of about 14 lb. of coal per square foot of grate per hour. Crude Borneo oil costs about £3 10s. per ton at Birkenhead, but the work may be done with creosote oil, which is obtainable in some districts at a much lower price than crude Borneo. Taking the latter, however, which has a specific gravity of 0·965, the cost per gallon works out at $3\frac{5}{8}$d., and for the 44 gallons used a little over 13s.; but even if the oil costs as much as coal, there are great advantages with the former, in the absence of dirt, smoke, and soot, the saving of time, and the labour of stoking, etc.

In order to dry the cores and moulds a current of air is necessary, for if the air in the drying chamber is not changed before it becomes saturated with moisture the work cannot be dried, but will simply be steamed. The object of heating the air is that it may absorb or hold in suspension a greater amount of vapour. A current of air, if saturated with moisture or vapour, has no power whatever to dry out moisture from bodies with which it comes in contact. To act as a medium for the evaporating and carrying off of moisture it must be either perfectly dry, or, at the least, sub- rated; and, inasmuch as its capacity for absorbing sture (in the state of vapour) increases with its perature, it is obvious that the higher the temperature of air the greater is its efficiency. This surcharging of the current with heat stimulates evaporation in two forms—

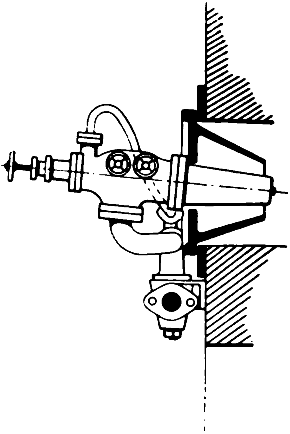

FIG. 146.

(i.) by imparting a portion of its heat to the moist surfaces of the cores and moulds, which is utilised in the evaporation of the moisture; and (ii.) by tolerating the presence of a greater quantity of moisture in mixture with it, which is carried away as it rises from the surface by the current. The diagram, fig. 147, illustrates the rapid increase in the quantity of moisture that can be held in suspension by still air with increase of temperature. From this diagram it will be seen that at a temperature of 100 deg. Fah. one cubic foot of air is saturated with 19 grains of water; whereas at 200 deg. Fah. saturation is not reached until 204 grains are absorbed. The effect of the motion of the air on the rate of evaporation has been made the subject of experiment by

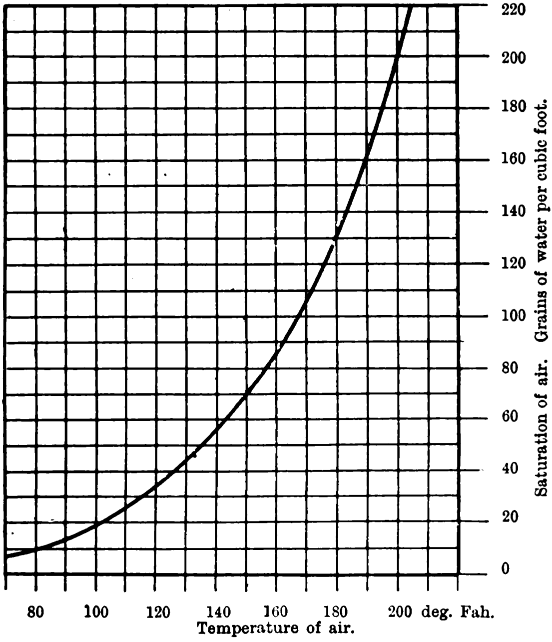

FIG. 147.—Diagram showing saturation of air at different temperatures.

Dr. Dalton,* who found the rapidity of evaporation to be greater with a current of air than when the air is still—owing to the air in motion sweeping away the vapour as it rises, and a continuous supply of comparatively dry air being thus secured—in the ratio of 1·28 to 1 for a gentle wind, and 1·57 to 1 for a brisk wind.

The most favourable conditions for drying, then, are a high temperature and a brisk current, but, as regards cores and moulds, too high a temperature introduces a risk of fracture, while too strong a current may cause cutting. A committee recently appointed by the Western Foundry-men's Association to inquire into the question of the most suitable temperature for drying cores determined, from a series of tests made in a number of ovens, that 350 to 400 deg. Fah. was the best temperature at which to bake cores thoroughly. This temperature, the report states, applies to all sizes of cores; the only difference necessary between large and small being the length of time they are left in the oven.

CHAPTER XII.

DRY-SAND MOULDING.

WHEN full patterns are provided, dry-sand moulding affords the best and cheapest way of making sound castings that are poured under any considerable head of pressure. As has already been pointed out, the skill required on the part of the moulder in this branch of sand moulding is not necessarily so high as that required in either green-sand or loam moulding. In the ramming of dry sand there is no danger of ramming too hard, nor has the degree of ramming to be graduated to the depth of the particular part of the mould in hand, as is the case in green-sand moulding. With he latter, too, the "temper" of the sand needs careful nsideration. If too damp, the gases will not escape adily, and "scabbing" will occur, as when the sand is

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*Memoirs of the Literary and Philosophical Society of Manchester, vol. V., ge 579.

over rammed, whilst on the other hand, with the sand too dry, the mould will not hold well together; some parts will, in all probability, be washed away by the inflowing metal, and the mould will be dirty, with loose sand, and the resulting casting a "waster." No such delicacy is required in the temper or manipulation of the dry-sand mixture, all that is necessary being that it shall be sufficiently damp to ram well, and have enough sharp sand and dried loam in its composition to render it porous. The loam used should have a small quantity of horse dung mixed along with its other ingredients, as this is found to be unequalled for making it open and porous when well burnt out in the drying process. Cow hair, such as is used by plasterers in their mortar, is sometimes added in small quantities, and serves not only for giving cohesiveness to the loam in its moist condition, but also, when burnt out in the drying, leaves fine winding tracts throughout the mass, thus contributing to its porosity.

As a simple illustration of this branch of sand moulding we may consider the moulding of the circular base shown at fig. 148. A full pattern being provided—which in form corresponds to the exterior of the casting, with the addition of the prints P, fig. 149, and has the flange R loose—a suitable flask, with drag, cope, and mid part to match, is found, and its inside washed over with strong clay water to cause the sand to adhere well. The drag part is now filled with sand and hard rammed, the pattern, meanwhile, being bedded in up to the level of the upper edge of the flange R, fig. 149, when a joint surface is scraped off and sleeked level with the top edge of the · box. The mid-part box is now laid on over the pins N, which should be a good fit in the holes when right home, as any slackness due to frequent use and exposure to rusting introduces a risk of the mould being "closed aside." As a precautionary measure the moulders, in putting on a box, invariably twist it as far round as the pins will allow, always in one and the same direction, or in the direction of the sun's movement. By this means the clearance, if any, is always kept to one side, and so ensures the two parts of the mould coming accurately together.

The joint surface having been strewn with parting sand, and the mid-part box securely cottered to the drag, the mid part is filled and rammed up to a second parting at the upper edge of the flange L, fig. 149. The top box is now laid on, and rammed up in the usual way, pins being inserted as required for runners, risers, and vents. The face F, fig. 148, is to serve as a roller path, and will be machined, so that it is desirable to cast this face down, the mould being poured when in the position shown by fig. 149. After being rammed up the cope is lifted off, and the pattern rapped and withdrawn, leaving the flange R in the mould. To remove this the mid-part box is lifted. The three parts of the mould are now examined, and mended if necessary, spike nails being put into any weak parts, and the surface sleeked, when they are ready for the drying stove. The core G, fig. 149, is rammed up in a core box, on a grid, with a central mass of cinders, in the manner previously described for similar cores. The grid, in this instance, would be made in six pieces, tie bars of wrought iron—shaped to clear the ribs D, fig. 148, which are inserted in the core box—being cast in to connect the parts as shown

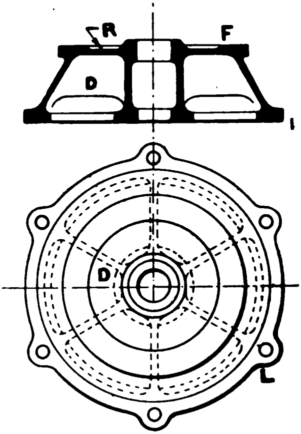

Fig. 148.

at fig. 150. When dried this core is inserted in the print impression, and securely held in position in the dried cope by means of three bolts B, fig. 149, having their lower ends either screwed or cast in the grid. The central core C, fig.

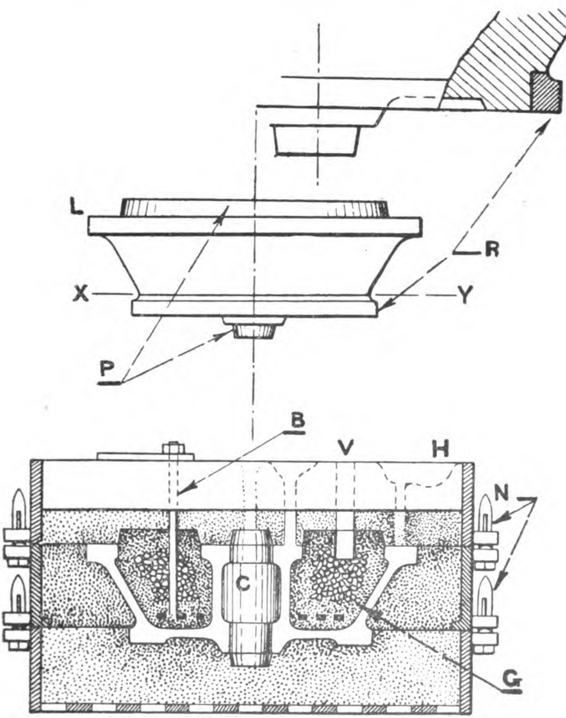

FIG. 149.

149, would be "strickled" on a core bar consisting of a tube of wrought or cast iron, perforated over its periphery. Excepting those of small diameter, these core bars are cast or fitted with cross bars and centre pins, as shown at P P, fig. 151. One of the pins is formed with a square end, to take a handle by which the core is revolved when being strickled; the other pin is shown with an eye at its end for slinging it when necessary. T, fig. 151, shows a very common form of trestle for carrying core bars while the core is being strickled.

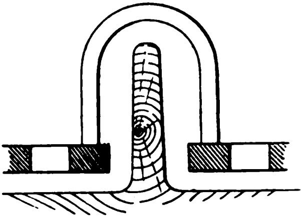

FIG. 150.

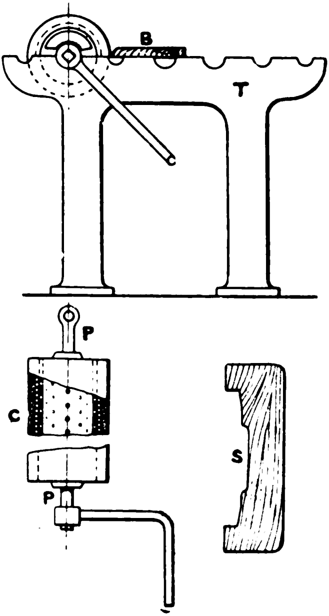

FIG. 151.

In the case of the core shown at C, fig. 151, the strickle board B has a straight edge bevelled as shown, but for the core C, fig. 149, the edge of the board would be shaped to the required outline of the core, as shown at S, fig. 151. In making such a core, a course of hay or straw rope about ¾ in. in diameter is first wound tightly upon the bar, when soft loam is spread over and rubbed in between the ropes, and a second course of ropes is wound on at the middle portion to make up the diameter to within about an inch of the required size all round, along the whole length of the core. More loam is now put on and the core strickled, but not to its full diameter, irons being put in and the core bound with iron wire while it is being strickled, to give it strength when taken off the bar. The core is now partially dried in the stove, and when sufficiently hard is again placed on the trestles to receive a finishing coat of sifted loam made thin with water, after which it is returned to the stove to dry thoroughly, when it comes easily off the bar. In many instances—such as, for example, the cores for the pipe moulds illustrated at figs. 153, 154, and 155—the core bars are left in to give support to the cores, in which case the hay ropes are wound on with a little loam here and there to give adhesion. These hay or straw ropes are now usually machine spun, and are found to be a great improvement on the hand made ropes formerly used; being spun on a machine, they are of a uniform thickness throughout, free from knots, are strong, and do not unwind on being cut. Many foundries include machines for spinning these hay and straw ropes in their equipment, although it is a very common practice to obtain the ropes ready for use, as they take up much less space than loose straw, and the trouble of having every now and then to make up small quantities is avoided.

Fig. 152 illustrates a hay-rope spinning machine made by Messrs. Jas. Evans and Co., of Manchester, with which a labourer can, without assistance, spin upwards of 400 yards an hour, the machine making about 140 revolutions per minute. By suitably proportioning the speed of the feed rollers and the revolutions of the frame, ropes of any degree of hardness may be produced.

Continuing the description of the process of moulding the circular base, fig. 148, we now come to the finishing of the mould. The blacking of wood charcoal cannot be laid on as dry powder in dry-sand moulds, but must be painted on in a liquid condition. The appearance of the castings depends to a large extent upon the quality of this blacking, and the care with which it is applied. If the clay water with which the pulverised charcoal is mixed is too strong, the mould will not peel readily from the casting, and there is a risk of excrescences of iron being formed where the sand has lifted because of the closeness of the surface. On the other hand, a blacking mixed too weak may cause scales to form by the peeling of flakes of blacking, and so give the casting a rough and disagreeable appearance. Quite a large number of substances have been tried from time to time for making blacking, but so far, having regard to both cost and fficiency, nothing has been found to answer better than oak arcoal reduced to impalpable powder, and mixed with ple clay water of proper strength. Care has to be taken t the moulds are not too warm when the blackwash is

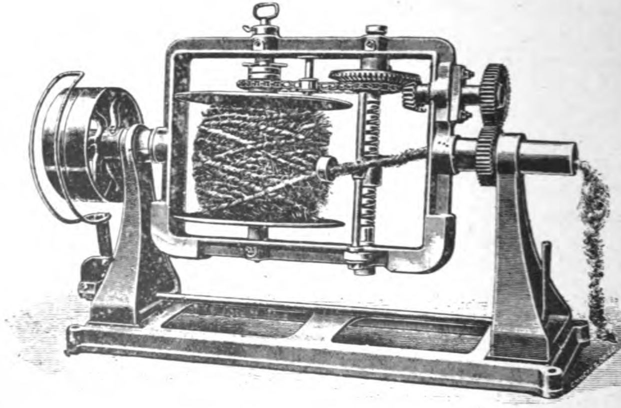

FIG. 152.

applied, as in this event it will dry too quickly to permit of its surface being properly sleeked. The thickness of the coating of blackwash should be increased when the body of metal in the casting will be heavy, and to do this smoothly and efficiently it should be applied as a succession of coats while the blacking remains moist, as if laid on a previous coat that has become quite dry, it will undoubtedly peel off in the form of scales. In some foundries these risks are avoided by blackwashing the moulds before they enter the stove, the dampness of the sand rendering the application of sufficient blacking an easy matter, and allowing ample time for sleeking it properly. When this practice is followed the moulds need. to be more carefully and slowly dried, as otherwise the blacking is liable to be cracked, or even burnt off completely, in the stove. The three parts of the mould and the cores C and G, fig. 149, being thoroughly dried and blackened, the moulder brushes off any smoke and soot, and lays the drag part in a convenient position. He then puts on the mid part, giving it the "sun-about" twist previously referred to, just as it is near touching the drag. These two parts are now securely cottared together, and the central core C is set in position, when the cope, with the core G bolted in place, is laid on, a number of pieces of soft clay having previously been laid on the bottom of the mould, for the purpose of ascertaining whether the core G leaves sufficient thickness of metal under it. These pellets of clay are formed in the hands, of cylindrical shape, and are put on rather deeper than the intended thickness of metal, so that, when the cope is lowered down to its postion and raised again, each piece of clay is crushed to the exact thickness the metal would be. Such a trial should always be made, more particularly when new patterns or core boxes are being used for the first time. If all is right, the mould is finally closed, the three parts being clamped together to prevent separation, and the joints of the boxes all luted with loam to prevent the escape of metal. The casting should be allowed to remain in its mould as long as convenient, so that it may cool slowly. If of moderate size, it should lie overnight, and be knocked out of the boxes in the morning, and turned over to the dressers to have the cores taken out, and its gates and fins cut away. A casting removed from its mould while red hot is liable to crack and become hard and brittle

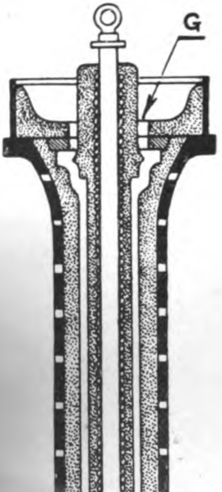

FIG. 153.

surface, and will not present the fine blue colour so dmired.

The manufacture of cast-iron pipes for water mains, &c., is an important branch of dry-sand moulding which has been developed to such an extent as to be, at the present time, all but independent of skilled labour. In some of the most recently built foundries carrying on this trade the casting pits serve both as pits and ovens, When in use as ovens the pits are covered over, and hot air is admitted through flues, only a small fire being necessary, as the pits are naturally hot as a result of casting the pipes in them. The moulds are set over openings in the floor, which connect with an exhaust flue. The heated air entering the pit passes up around the outside of the flasks and down through the moulds to the exhaust flue. Under this, the Bast system, the handling of the flasks is reduced to a minimum. They are first set on stools in the pit and rammed, then on the plugs of the exhaust flue, and after drying they are set in place to be poured.

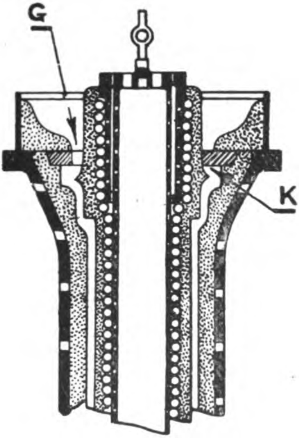

FIG. 154.

The pipes are cast vertically, and usually with the socket down, as shown at fig. 155, in order to ensure solid metal in this part, although small pipes are frequently cast with the socket up, or as in figs. 153 and 154, the core for the socket of pipes of the smallest diameter being formed by an enlargement of the main core, as at fig. 153, while larger ones have an iron sleeve slipped over the upper end of the bar to reduce the thickness of the covering, as shown at fig. 154. In the case of large pipes, cast socket down, the core for the socket is formed independently on an iron ring, fitting a recess in the base casting, as illustrated at fig. 155. The ring has an internal cone at its upper end, into which the lower end of the main core enters, and is thereby centred. Referring to fig. 155, it will be seen that the mould consists of five parts, each of which is made by a special gang of men, in separate parts of the foundry, the work being carried on systematically, so that the cores and rings will all be ready as soon as the moulds are dry. These five separate parts are: The base B, the flask F, the main core C, the socket core S, and the bead ring R, which forms the mould for the bead on the spigot end of the pipe. The flask F is made in halves, and bolted together with a longitudinal hinge joint, and is perforated to allow of the escape of steam and gas when the moulds are being dried, and also when they are being poured. Small pipes are sometimes cast two or three in one flask.

In making a mould such as fig. 155, a cast-iron pattern of the socket would first be clamped in place, on the base casting B, being centred by a spigot on its under side dropping into the recess in the base casting. The flask F, having an inside diameter sufficiently large to allow of a thickness of sand of about two inches between the pattern and the wall of the flask all round, would next be lowered into position, and bolted to the base casting B, and an iron
ttern for the barrel of the pipe set in position, the
meter of which would be slightly larger than the outside
pipe, in order to allow for shrinkage. Sand is now
in around the pattern, and well rammed with long
ntil the flask is filled, when the pattern is withdrawn,
e interior of the mould inspected by means of a lamp.
ould is now blackened, the method of doing this in
oundries being to pour a bucketful of black-wash
mould, a disc suspended inside the top of the

mould serving to distribute the blacking over the entire circumference. The mould is now ready for drying. The core C is strickled on a bar, as previously described, the bar

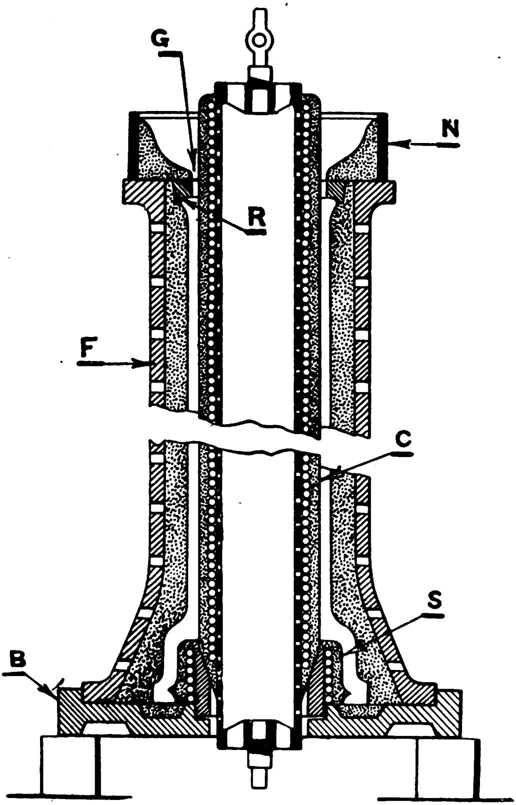

FIG. 155

being usually revolved by power. In this case the core is not removed from the bar, but is inserted in the mould with the bar in place. The contraction of the metal on cooling grips the core, which necessitates the latter being made collapsible, in order to allow of its withdrawal when the metal has set. The loam mixture forming the core should not be too dense, as the gases have to escape through it. The heat of the molten metal causes the hay to burn, the products of combustion escaping through the holes into the interior of the core bar, which communicates with the atmosphere, all core bars having their upper ends open. This partial burning of the hay ropes wrapped round the bar provides for contraction of the core. The core bar, after being wrapped with the ropes, has loam plastered on to a thickness of about $\frac{3}{4}$ in., which is strickled off by means of a metal-edged board extending the full length of the core, and held against it while the core revolves. This strickle board also forms the taper on the lower end of the core to fit the coned recess in the socket ring S, fig. 155. The core is now partially dried, and then returned to the machine, and given a finishing coat about $\frac{1}{2}$ in. thick. In many foundries this consists of a mixture of sand, sawdust, and old cores, and is strickled off to give the core its required diameter, which the coremaker tries by a pair of calipers or a gauge. The diameter of the core, as put in the mould, is always slightly larger than the interior diameter of the pipe, in order to allow for the contraction, the core for a 12 in. diameter pipe being made about $12\frac{1}{8}$ in. diameter.

The standard length of pipe is generally 12 ft., exclusive of the socket or bell, so that a further gradual increase in diameter toward the lower end of the core has to be made, to allow for the compression due to the weight of the column of metal. The lower end of the core is made about $\frac{1}{16}$ in. to $\frac{1}{8}$ in. larger in diameter than the top, the latter [illegible]gure being the allowance usually made for pipes of 4 ft. [illegible]meter. The hay rope is generally regarded as the most [illegible]ensive item in the manufacture of these cores, and many [illegible]mpts have been made to dispense with its use by [illegible]g the core bar itself collapsible. These various [illegible] have, however, so far met with but little practical [illegible] owing chiefly to the expense of maintaining the bars [illegible]cient working condition. The general character of these collapsible bars may be gathered from fig. 156, which shows a section on a plane at right angles to the axis of the core bar patented by Mr. J. Chambers* a few years back. This bar consists of two segments A, A, capable of movement about projections on the piece B, and held together and limited in their movement by bolts C. To distend the segments a wedge D, attached to links E, working round the bolts C, is drawn longitudinally in the direction to make it rise, and is fixed, when the limit of its motion is reached, by a cottar passing through a stud in its end.

Various attempts have also been made to obtain an efficient substitute for the hay ropes. In 1896 Mr. Fletcher,† of Cincinatti, introduced one consisting of a paste composed of sawdust, ground straw, or other comminuted combustible material, mixed to a paste with a 3 per cent solution of hydrated starch and 10 per cent of loam. In a patent taken out in 1900 Mr. Fletcher describes a combustible core coating, in which the starch solution is not used. The almost universal practice, however, is still to employ the hay ropes.

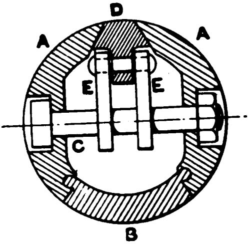

FIG. 156.

The cores are blackwashed, and inserted in the mould, the main core C, fig. 155, being centred by the cone at its lower end entering the ring on which the socket core is formed, and by the bead ring R at the top. In preparing the socket core the ring is wrapped with hay rope, over which the loam is plastered, and strickled off in a species of

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* No. 13628. October 15, 1884.

† Journal of the American Foundry-men's Association, 1897.

lathe, in the same manner as described above for the barrel core. To prevent it from being broken by the impact of the inflowing metal, a ring of chain is sometimes embedded in the upper part of the loam coating. The bead ring, or "cake ring" R, is made on an iron ring, and has a number of semi-circular notches, marked G in figs. 153 to 155, formed in its inner edge. These serve as gates, through which the metal poured into the runner N, fig. 155, flows into the mould. Other similar notches, protected from the molten metal, act as risers. The general practice is to pour pipe moulds from the top, although large pipe moulds are sometimes poured from the bottom by a gate leading down through the mould to an opening into the socket until the socket core has been covered, after which the rest of the metal is poured direct through the top. This plan reduces the risk of damaging the socket core, but introduces the danger of a "cold shut" between the "bottom poured" metal and that entering the mould at its top.

The cores are withdrawn from the mould as soon as the iron has set, the crane stripping the bar from its covering, the hay bursting into flame as soon as the air gets to it. The flask remains in the pit until the contained pipe is black, when it is hoisted out and swung over a pair of skids, the clamps knocked back, allowing the flask to open and the pipe to drop upon the skids.

Flanged pipes are cast in practically the same way as the socket pipes, as already described in detail, dry-sand moulds and loam cores being used. In order that the flanges may be sound there is usually a shrink head cast upon the upper flange. A brief description of the moulds for flanged pipes has already been given, together with an illustration of the flasks used (see fig. 63).

Drying cylinders of paper-making machines, &c., are [illegible]riably moulded in dry sand. The cylinder is moulded [illegible]e piece with its axis vertical, as shown in fig. 157, [illegible]eing three hand holes at one end for the removal of [illegible] and hollow journals at each end for the passage [illegible] The mould is made in three parts—A, B, and [illegible]7—and the core is made on a barrel built up of [illegible] and secured by bolts T, passed through lugs in the end sections. The sections are perforated, and are studded with pins for supporting the sand. The gases escape through an axial pipe P, forming the bar of the

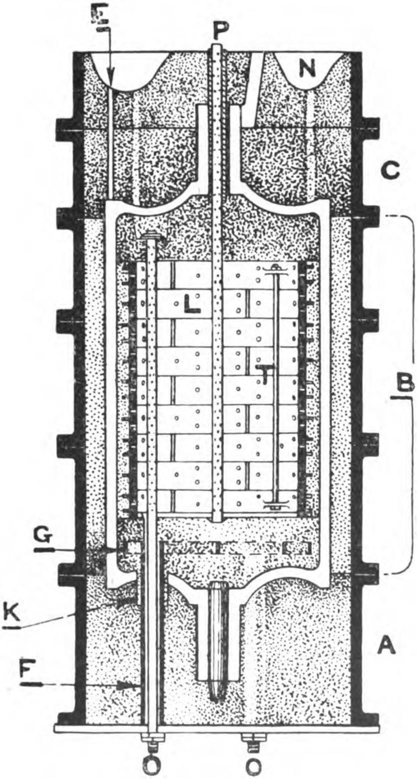

FIG. 157.

top journal core, and other pipes O, which pass through bosses on the grid G, on which the cores K for the hand holes are formed. The core is supported on metal ferrules F, slipped over the pipes O, under the grid G, and is secured in place on the base of the drag part A by these pipes O, as shown. The metal is poured into an annular basin N, and enters the mould through a number of ingates, E.

Steam engine cylinders are either cast in dry sand or loam moulds. When they are at all complicated the work on the cylinder proper forms so small a proportion of the total required on the mould that relatively little can be swept up, and it will generally be found to be cheaper and quicker to make a complete pattern and mould in dry sand, more especially when there are two or more to be made of the same size.

A description of the construction of a mould for the marine engine cylinder casting, illustrated at fig. 158, will furnish a further interesting example of dry-sand moulding. Fig. 158 shows a sectional elevation of the cylinder, a half-plan of bottom, and a half-section horizontally through C D. To facilitate the moulding, the pattern would be made with the top and bottom flanges detached and fitted over the core prints shown by dotted lines in the sectional elevation, fig. 158. The exhaust branches E, E and the drain branch M, the stuffing-box flange T, and the brackets K with the webs R, R attached, would also be loose. To mould the cylinder, a pit of suitable depth and area is first dug in the foundry floor and the resting bars H, fig. 159, laid in on which the drag flask is set. This is rammed up with floor sand and scraped off level at the depth of the core prints O and N, plus the thickness of the flange F, fig. 159, below the top edge of the flask. On this bed the pattern is laid, resting on the core prints O and N of the cylinder and steam chest respectively. The lower flange F is held in place, and the whole carefully adjusted by means of wooden wedges placed under the flange F. Before proceeding further, it is a good plan to give the pattern a coat of light machinery oil to prevent the sand from adhering to it, and also to prevent absorption of moisture from the damp sand. The remainder of the drag flask is now rammed up with dry sand, the sand being carefully tucked and rammed in under the flange F and the exhaust branch L, fig. 159, the wedges being removed as the ramming proceeds. A joint surface is prepared at the level of the upper edge of the flange F, except in way of the exhaust branch L, where, in order to allow of the flask immediately above the drag being lifted off without breaking the mould, the joint face is brought up to the level of the centre of this branch, the line of the joint being shown by the heavy dotted line W X Z U J G, fig. 159. The joint surface is now strewn with parting sand,

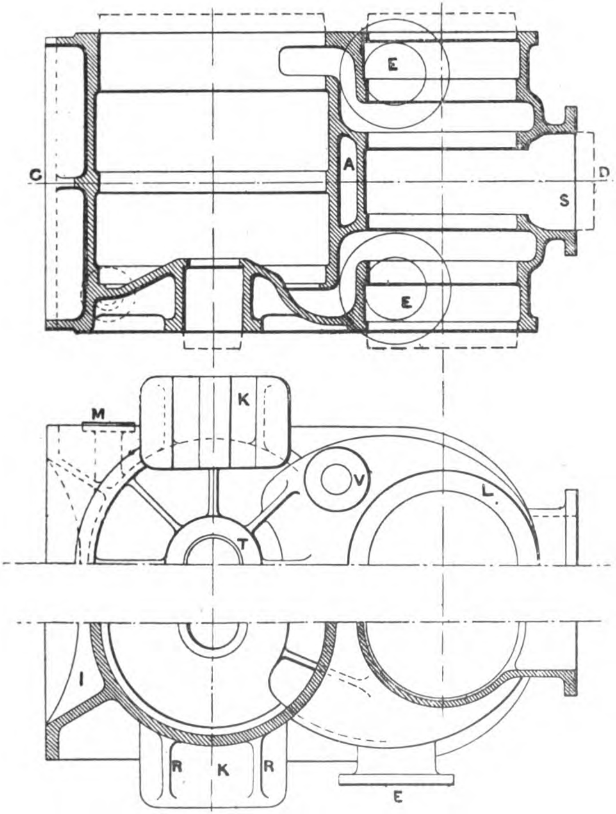

Fig. 158.

and the second section of the flask lowered into position and bolted to the drag. In this section thin cast-iron brackets marked C, fig. 160, are bolted to the sides to give support to the sand. These brackets are cast in open moulds, and have nails cast in along their lower edges. They are set at about 6 in. apart, and their width is an inch or so less than the depth of the flask section. Their lengths vary according to their position, being made such as to bring their inner ends to within an inch of the pattern, and they are cast with a number of 2 in. diameter holes through them for the purpose of locking them in the sand. The sand is now shovelled into the flask and rammed, gaggers being freely bedded in alongside the brackets, these and the brackets receiving the usual wash of clay before insertion in the flask. Other gaggers about 9 in. long are bedded horizontally, and with those hanging from the brackets give strength to the sand and prevent a "drop-out." They are worked in as the flask is rammed up, facing sand being used for a depth of an inch all over the bottom of the flask and for a thickness of about 2 in. around the pattern, and floor sand* for filling in the intervening space to the walls of the flask. As the top of the flask is reached all facing sand is used, say for a depth of an inch, and a second joint surface is prepared on the plane A B, fig. 159, which after being sleeked is sprinkled with parting sand, and the third flask section set in position and rammed up similarly, the pins securing the branches, brackets, etc, being removed as these parts become securely bedded.

To allow of the proper tucking up of the sand under the brackets K, figs. 158 and 159, rectangular pieces Y, fig. 159, are cut out of the pattern, and, after the ramming beneath is completed, are replaced while the cope is being rammed up over the brackets. The space A, fig. 158, between the cylinder barrel and the steam chest is preferably cored out, although it is sometimes arranged for by the sand rammed up in the flasks. For carrying this core H, fig. 160, prints P, figs. 159 and 160, are built on the pattern, and in ramming

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* The sand used for filling is sometimes rendered more open than the ordinary floor sand by the addition of fine gravel, its strength being maintained by damping it with clay water.

up the core the body of sand between the steam chest and the cylinder is supported on three $\frac{5}{8}$ in. diameter rods, to which gaggers are wired, as shown in fig. 160. By adopting the core method, the cavity left in the mould for receiving the core H greatly facilities the insertion of the steam chest

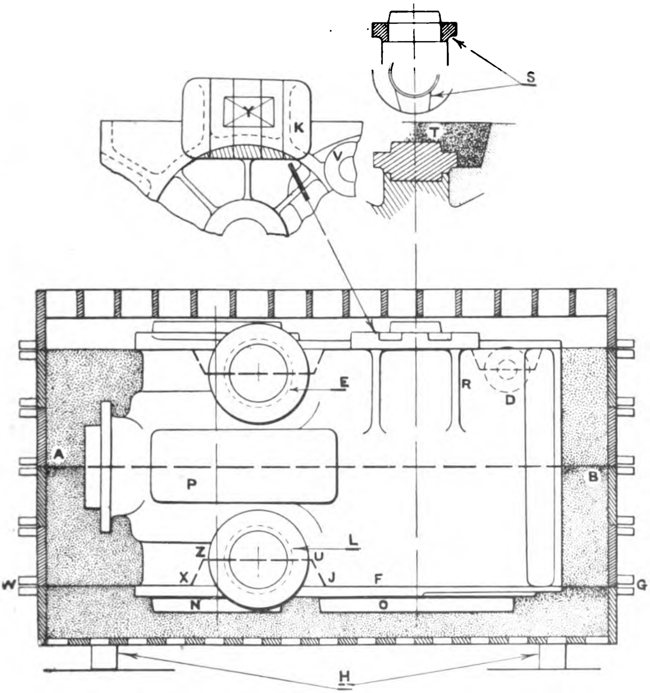

FIG. 159.

and steam port cores. The third section of the flask being rammed up, and a joint surface prepared at the level of the under side of the upper flange, the cope is laid on and rammed up, a number of gate sticks $1\frac{1}{2}$ in. by $\frac{1}{2}$ in. marked G, fig. 160, and vent and riser pins, as required, being set in position. The hanging sand between the webs surrounding the stuffing box is well supported by lifters, and numerous gaggers, nails, and rods are embedded all through the cope. The cope is well top-vented with a light vent wire, and lifted off, the stuffing-box flange T, figs. 158 and 159, and the loose (hatched) portion of the brackets K, fig. 159, being raised with it. If the stuffing-box flange is fitted to the main body of the pattern as shown at T, fig. 159, it will be necessary to provide for its withdrawal through the top of the cope, a removable loam cake being inserted as previously described (see fig. 86, page 186).

Another plan, more suitable in the present case, is to make the flange loose as at S, fig. 159, and to cut it obliquely, so that it may be drawn back in pieces into the stuffing-box cavity, and so removed. The cope, having been raised and swung aside, is turned bottom up, sleeked, and finished ready for the stove. The upper flange, with the brackets K, to which are attached the webs R, fig. 159, is now lifted off the pattern, and the upper exhaust branch E and the drain branch D, fig. 159, removed from the mould, when the section of the flask immediately under the cope is lifted off. The main body of the pattern is next withdrawn, leaving the lower flange F and the exhaust branch L, fig. 159, in the mould. To remove these, the section of the flask attached to the drag is lifted off. As each section of the mould is removed it is gone over carefully with a sleeker, any broken edges, cracks, or other defects repaired, and the face of the mould is given a coat of black wash. The various sections are then placed on the cars and wheeled into the drying oven. The main core K, fig. 160, is swept up in loam, and as the making of a similar core will be described later, under "Loam Moulding," a description of its construction need not be given here. The steam chest and steam port cores would be rammed up on grids in the usual manner in boxes provided. The steam passage cores are strengthened by nests of bent wires $\frac{1}{4}$ in. diameter, having one end cast in the grid, and the latter has also a number of nails cast in all over its area for the purpose of supporting the sand. The cores are rammed up with central masses of cinders, and vent plugs are inserted as previously described. When the mould sections and cores are all thoroughly dried, the mould is again put together

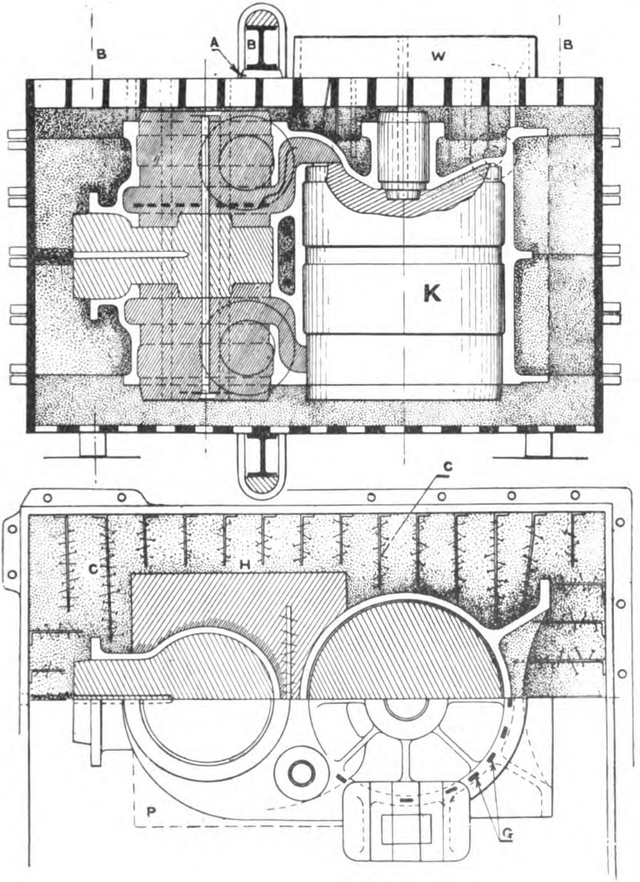

Fig. 160.

with the cores set in place. The foundation bars are first levelled carefully, and the drag part lowered in place by aid of the crane. The main barrel core K, the lower section of the steam chest core, the lower steam port core, and the lower exhaust branch core are set in position, and the second section of the flask is lifted by the crane, and while suspended previous to being lowered into position a moulder removes any loose sand from the under side by brushing the surfaces over. He then scrapes away a little of the sand around the edges of the mould in the drag with a trowel, which leaves a thin fin on the casting. This is done as a safeguard against the edges bearing on each other, which would result in corners being crushed and broken all around the mould at each flask joint. The moulder also looks out for any cracks which may have occurred during the drying, which he fills in with sand and plumbago mixed with molasses water. He next paints all round the edges of the mould and over any cracks with oil* to preserve their coherence. The upper face of the drag part is also brushed off, and a trail of dry flour is laid around the mould about two inches in from its edges, for the purpose of forming a joint with the following flask section, which is now lowered in position. The central portion of the steam chest core with the steam branch core attached is now put in place, rings of flour paste being first put on the lower section of the steam chest core around the vertical vents, to prevent any chance of the molten iron finding its way into the vent in case of any unevenness of the joint. The joints of all the cores are smoothed off and made fair with the plumbago and sand mixture mentioned above. For the purpose of bringing off the vent from the steam and exhaust branch cores, a hole about 1 in. in diameter is drilled up their centre before they are set in position, and channel ways are cut in the mould leading from these holes to the outside of the flask, which are filled in with cinders. The core H, fig. 160, and also the upper section of the steam chest core, are placed in position and the third section of the flask lowered on. The cylinder ends of the steam port cores are carefully rubbed to fit accurately against the main core K, fig. 160, to which

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* Oil is used on dry-sand moulds for most of the purposes that the water swab is employed in green-sand moulding.

they are joined with a paste joint and short dowel pins. During the process of building up the mould the spaces left for the metal are carefully tested for thickness, and corrected if necessary by rubbing the cores. Before lowering the cope in position the stuffing-box core is set in place and a number of clay balls are laid upon the top of the cylinder core K at different points, also on the upper exhaust branch core, to show the thickness of the space left for the metal as previously described, any variation from the required thickness being corrected by shaving or patching the cores. A ring of flour having been spread around the mould, the cope is lowered in position and the mould is complete. The method adopted for binding the whole flask securely

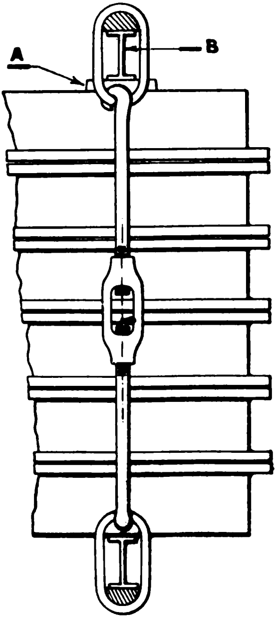

Fig. 161.

together is shown in figs. 160 and 161. Three heavy channel bars B are placed upon the cast-iron blocks A, resting on the top of the flask, while similar bars are placed under the flask. The ends of these bars all project beyond the flask, and the upper ones are tied to the lower ones by means of stirrups and tightening screws, as shown at fig. 161.

The practice in different foundries as regards the shrink-head to be added to a cylinder casting varies considerably, some foundry-men carrying it up as high as a foot or more above the face of the upper flange, whilst others advocate a depth of 3 in. or 4 in. Trouble is often caused by such a large mass of metal, owing to its "drawing" the metal of the flange beneath it, on cooling. The author has found in practice that adding a thickness of about $\frac{3}{4}$ in. above those upper surfaces which are to be machined, combined with a few risers of moderate section, is all that is required to ensure satisfactory castings, provided the iron is reasonably clean and is poured hot. In the present example the pattern was made with an additional thickness of $\frac{3}{4}$ in. on the facing strips on the brackets K, fig. 158, and also on the stuffing-box flange T, the facing V, for cylinder relief valve, and the steam chest flange L, fig. 158.

A rectangular mid-part box W, fig. 160, about 8 in. deep and of sufficient area to embrace all the ingates G, is laid around them, on the top of the cope, into which sand is shovelled and rammed up after gate sticks have been put in place, to form a green-sand basin, with a circular runner to supply all the feeding gates, a loam cake core being inserted to take the direct impact of the molten iron. At a point as remote as possible from these gates, and outside the box W, a hole about 2 in. in diameter leads through the cope to the top of the flange of the upper exhaust branch E, fig. 159, to serve as a riser. A flow-off gate is formed by building up sand around this riser about 6 in. high, and a wooden trough lined with moulding sand is set in place to lead the overflowing metal into pig moulds formed in the foundry floor. Other risers are brought through the cope and carried up above the level of the flow-off gate over such parts of the casting where they may be useful for the introduction of feeding rods. Pipes are led through the cope from the cylinder and steam chest core vents.

The mould being ready to receive the metal, the ladle of of molten iron is skimmed and brought into position by the travelling crane. Immediately before pouring, fine sand is strewn over the surface of the iron, to form a thin crust and gather any remaining slag and scoriæ. A small bunch of greasy waste having been placed over each vent pipe and lighted, the metal is poured into the basin until it runs off freely at the flow gate, when the pouring is continued, but at a much reduced rate, until the discharge at the flow-off gate begins to clog, any "feeding" of the casting that may be thought necessary being done at the same time. Shortly after pouring, the sand forming the basin in the box W, fig. 160, is dug out and the gates G broken before they cool. The casting should be allowed to remain in the sand for at least 48 hours before the mould is broken, the cores dug out, and the casting handed over to the trimmers. A good casting should require but little dressing, and certainly no filling up with "boman-tague," or any compound known by some other fancy name, to hide defects. It is far preferable that any flaws in a casting should be brought to the engineer's notice before any doctoring is resorted to, in order that he may judge whether or no the casting should be rejected or some remedy applied. In the event of the filling being put in with his sanction in a part where it is of little consequence, all may be well, whereas if done surreptitiously in some part which is subsequently machined, the discovery causes much irritation to all concerned. Castings are sometimes required from patterns which are too large to be conveniently flasked, and too deep for successful green-sand work, in which case recourse may be had to a loam mould, or the article may be moulded in dry sand by bedding-in in exactly the same manner as if it were being moulded in green sand, only that the mould would be subsequently dried where it has been formed. Moulding in loam would not only be very expensive, but is also so severe on the pattern that it would seldom be sanctioned.

Following the dry-sand method, the job would be cast in the pit usually reserved for the casting of loam moulds.

The bottom is first carefully rammed and several transverse grooves, a few inches deep, are cut in it, and into these coarsely spun hay bands are laid. These are covered over with sand and rammed up level with the rest of the bottom surface, when facing sand* is laid on to a depth of about 2 in. over those portions of the bed to be covered by the pattern, which is now "bedded down" on the facing sand. The pattern should be staked temporarily, as it may need to be lifted once or twice before the bottom bears satisfactorily all over. When properly bedded the moulders proceed to ram up the sides, using facing sand against the pattern and ordinary floor sand for the backing. The cope is rammed up in a top-part box in the usual way. If to cover the entire mould too large a box would be required, two may be used, which simply cause a fin on the casting at the junction, which is easily dressed off. The cope having been lifted off, the pattern is withdrawn, which is often a difficult operation with dry-sand moulds, for the rapping bar has but little effect in loosening the pattern in a hard-rammed mould. For this reason the pattern should be provided with strong draw straps and screw lifting bolts for the attachment of the crane tackle, so that it may be slowly hoisted, due care being taken to keep it level the while, and also to beat it with mallets as it comes up, to prevent its dragging the sand up with it. After the mould has been mended up, if necessary, and finished, it is dried by means of coke fires kindled in iron baskets and suspended inside the mould, but kept far enough back to prevent the surface of the mould being burnt. It is also customary to dig a trench all round the outside, leaving a wall encircling the mould as thin as can be made with safety. Fires are also kindled in this trench and the whole mould covered in with [illegible]n bars and plates, to retain the heat as much as possible, [illegible] thus expedite the process of drying. Where the mould [illegible]s are narrow the drying is accomplished by suspending [illegible] plates in them, which are renewed as they cool down. [illegible]ying of the mould in the floor is the chief objection

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[illegible] sand is a mixture of finely-pounded dried loam, rock sand, and [illegible]t sand finely sifted and made sufficiently damp with water, or, if [illegible]gth is needed, clay-water.

of such moulding, being very inconvenient and disagreeable when carried on during working hours, interfering seriously, or maybe rendering impossible, the carrying on of other work in its neighbourhood, and for this reason is seldom resorted to unless adequate arrangements can be made that the fires, if kindled when the day's work is over, will have dried the mould sufficiently before the work of the foundry is resumed.

CHAPTER XIII.

LOAM MOULDING.

MOULDING in loam is generally regarded as the most expensive method of producing castings, and is therefore seldom had recourse to except when the article required is of circular form, permitting it to be shaped in the loam without any pattern. Loam moulds are mainly constructed of brickwork, the bricks employed being usually made specially for foundry use, and are not burnt so much as are the bricks used for house building. They are thus comparatively soft, which renders them more easy to chip or cut to any required shape. Besides these ordinary bricks others known as "loam bricks" are employed, and are built in in parts where holes are to be bored, or where subsequent carving of the mould may be necessary. These loam bricks are usually made of sifted pit sand, to which some cut straw is added, mixed with clay water. The bricks moulded from this stiff loam are dried in the stoves, and besides being used in those parts of a mould where boring or carving has to be done, or into which nails have to be driven, they are extensively used in the building up of large cores as their soft nature allows of their being more easily crushed or compressed by the contraction of the casting. Were such cores built up of ordinary bricks the chances would be that the casting, unless very thick, would crack before the unyielding core could be withdrawn or slackened.

A loam mould can sometimes be made to serve for several castings, a good example being that of a propeller blade. After the first casting the bed is set in exactly the same position as that in which it was built and swept, when the skin of the mould is broken, and a thickness of facing loam swept over. On this the pattern is formed as usual, with guide strips. A thickness of facing loam is spread over this, and the cope, which has previously had the old skin scratched away, and has been given a coating of clay-water, is bedded on. A similar plan is adopted with many loam castings of a simple character, and moulds for pans, kettles, &c., are often used over and over again.

Flasks are seldom used to enclose loam moulds, although in some instances, as, for example, pipes of unusual form which are to be cast without a pattern, they are a convenience, and often save the necessity for the mould being cast in a pit. In these cases imitation patterns are struck up on bars, with hay ropes covered with loam to the required shape, with their branches, if any. These dummy patterns are laid together on loam in a box, and rammed up with their wooden flanges if necessary, and the cores are formed on core-bars in a similar manner.

Much pit digging may be saved by the use of cribs for enclosing the upper part of the moulds, as shown at fig. 162. These cribs are either cast in one piece, or are built up of a number of segments bolted together, by which means they can be made larger or smaller as required. They should have sufficient taper to enable them to be easily lifted off after the cast, and should be well perforated to allow the gases to escape freely. A shallow pit, D E F G, fig. 162, having been dug and the mould M set in position, sand is rammed in around it up to the floor level D G, when the crib C is laid over the mould, and the rest of the ramming is inside the crib until it is filled. In the absence of a crib the mould must be wholly below the floor level, the pit being made at least as deep as the mould, and larger in diameter to allow of sand being rammed up all round its outside, since a loam mould is not strong enough in itself to bear, unsupported, the pressure of the metal in casting. The advantage of a crib is most fully realised when the casing is being dismantled, for after the crib has been lifted off the removal of the sand from the upper part of the mould becomes a very easy matter, and but little digging is needed to get to the bottom.

For the purpose of describing the process of moulding in loam we will first take a simple cylindrical article such as the cylinder liner L, fig. 163. No pattern will be required for this. The foundry pattern-maker being supplied with a drawing cuts the necessary loam boards and gauges from the dimensions given thereon, making due allowance for contraction (one-tenth of an inch per foot) not only on the length of the boards, but also on the gauges for diameter. The striking edges of the boards are bevelled off as shown at fig. 164, and on the reverse side the edge is strengthened and rendered durable by the attachment of a strip of iron marked H, filed quite smooth, and square with the edge of the board. The angle of bevel should be about 25 deg. as shown if it is to impart a well-defined figure and smooth surface to the mould. With the loam board D, fig. 165—for sweeping up a "bearing"—as a guide, the moulder first selects a circular foundation plate P, of suitable size, which he lays upon a stove carriage provided with a centre socket for carrying the spindle S, about which he centres

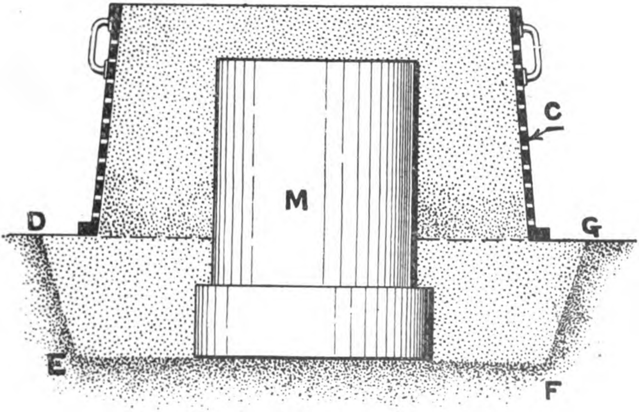

FIG. 162.

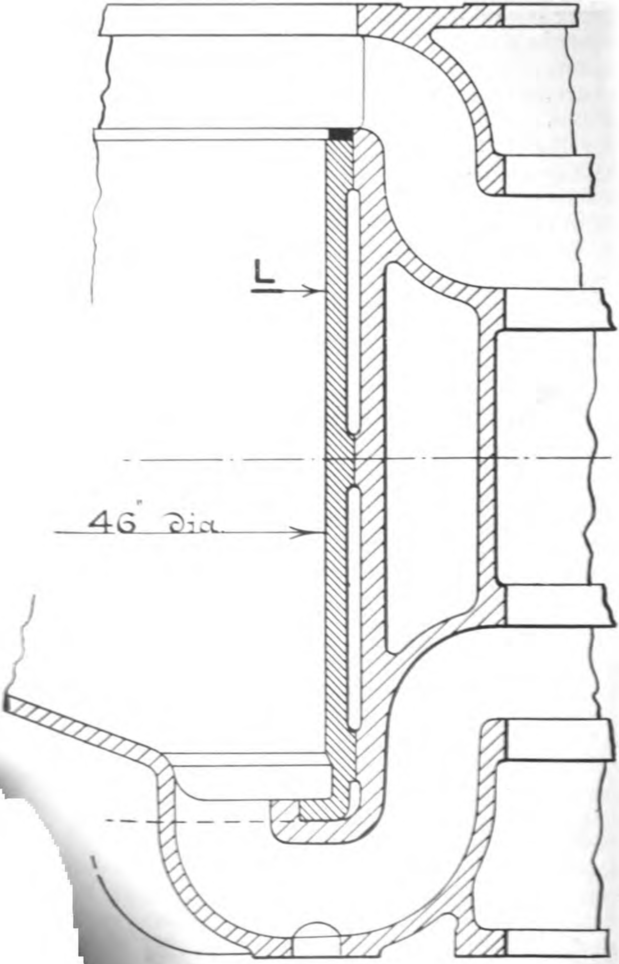

FIG. 163.

the plate and secures it in position. After oiling the foot of the spindle to ensure its revolving freely in the socket the board D is bolted to the arm A, which, in turn, is secured at a suitable height on the spindle by means of the pinching screw T, and the building up of the bearing B, fig. 165, is proceeded with. The position of the bricks is adjusted so as to be about ½ in. clear of the sweep of the Board D, the moulder trying the board opposite each brick he lays. The brickwork, when completed, is wetted and given a coating of soft brown loam, which the moulder rubs well over the bricks and strickles off to the required form with the loam board D, drawing the latter round with the sharp unbevelled edge in advance in order to leave the surface in a somewhat rough condition for receiving the finishing coat of finely sifted and softened loam, which is applied after a few hours, when the surface has become firm enough. This finishing coat is strickled off by drawing the board round, with its bevelled edge leading. The spindle and board are

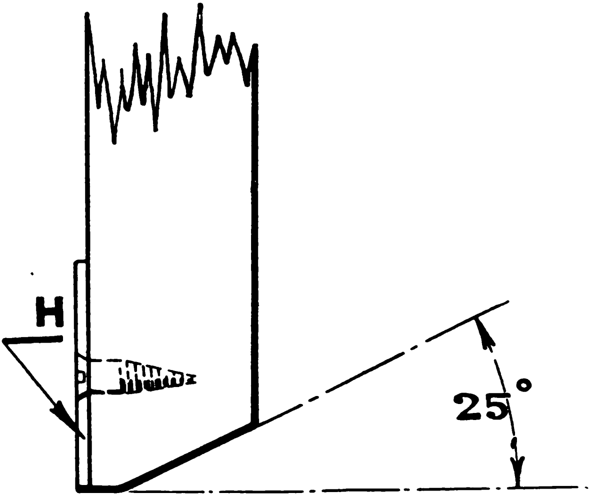

FIG. 164.

now removed, and the car is run into the stove for drying, but it need only remain for a short time as the bearing does

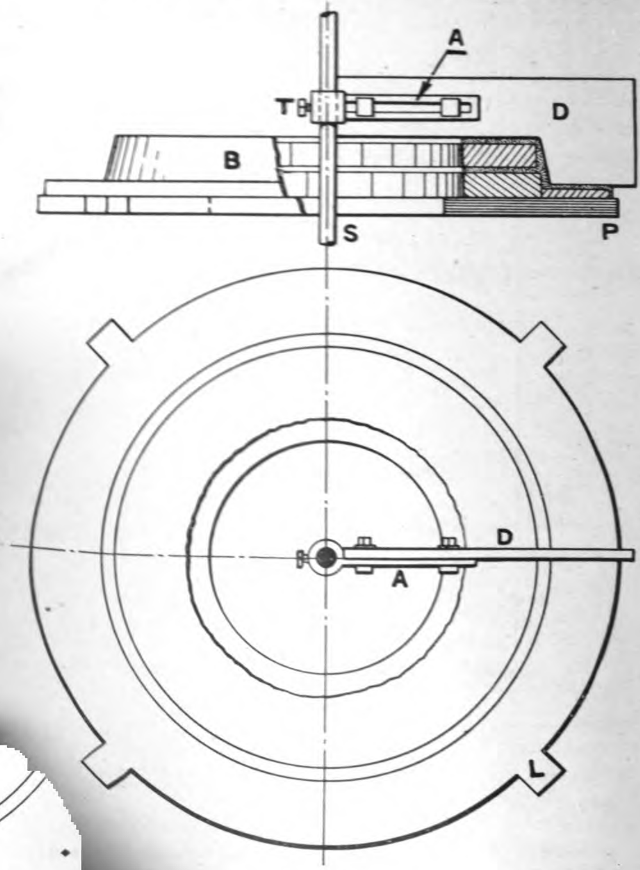

FIG. 165.

to be thoroughly dried at this stage of the work. drawn from the stove it is blackened all over with "parting" blackwash,* consisting of finely powdered charcoal mixed with water to the consistency of cream. This blackwash serves the same purpose in loam-moulding that parting sand does in sand-moulding.

The cope ring O, fig. 166, with snugs similar to those on the foundation ring P, fig. 165, and having an inside diameter sufficiently large to clear the tapered sides of the bearing, has its inner edge clay-washed to cause the loam to adhere, and is laid on. Upon this ring the cope† is built, the spindle S being again set in position, and the cope board F attached as shown at fig. 166. The correct radial position of the board is set by means of a gauge G having a semi-circular notch cut out at its centre to fit the spindle; a final adjustment being made when giving the finishing coat to the mould, for its true position is more correctly ascertained when the full diameter is swept than by a radius, as the spindle may not revolve quite truly owing to its being slightly bent. Comparing the upper striking edge of the board F, fig. 166, with the flange of the liner L, fig. 163, it will be noticed that an allowance has been made for a shrink-head on the casting, a provision which also allows of the mould being closed by a flat surface without there being a feather edge at the junction. In building up the cope, the moulder first lays about 1 in. thickness of stiff loam all over the bearing B, fig. 166, up to the circle swept by the loam board, when he covers the cope ring with building loam, and proceeds to lay course after course of brickwork, regulating the diameter of the successive circles built by means of the cope board F, keeping the inner end of each brick about ½ in. back from the sweep of the board to allow of the coating of loam. In laying the brickwork the moulder takes care that the vertical joints in each course "break joint" with those of the courses immediately above and below, for this condition is quite as essential in the buiding of a loam mould as it is in building a house, and

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* It is the practice in many foundries to supplement the blackwash with a little fine parting sand, which is dusted over the surfaces while they are still wet with the blackwash.

† In loam moulding, the word cope is applied to all built moulds which form the outside of the casting, while the word core is applied to the inside parts, or those almost wholly covered by the metal.

if neglected there is great danger of the mould cracking open when being handled by the crane. The building, being completed, is bound together by one or more hoop-iron bands

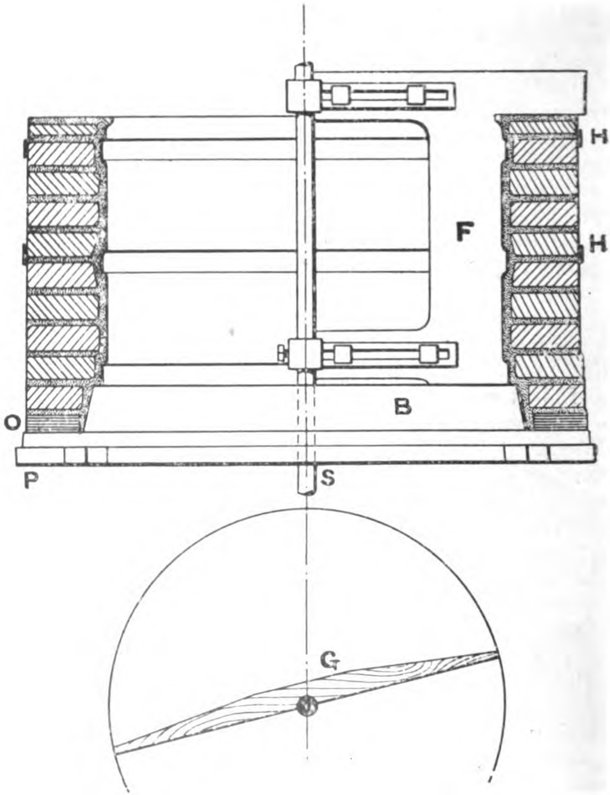

Fig. 166.

H, H, fig. 166, encircling it. By turning back the ends of the hoop iron to form hooks, the bands may be made to grip tightly by winding wire over the two hooks, and afterwards racking up the wire. The inside of the brickwork is now "roughed up" with loam, the moulder first scraping away any loose building loam with his trowel, and wetting the bricks. When this roughing up is done the gauge is applied, and if the diameter is correct the coating is allowed to become hard before proceeding to lay on the finishing coat. After this latter has been applied, the spindle and the board

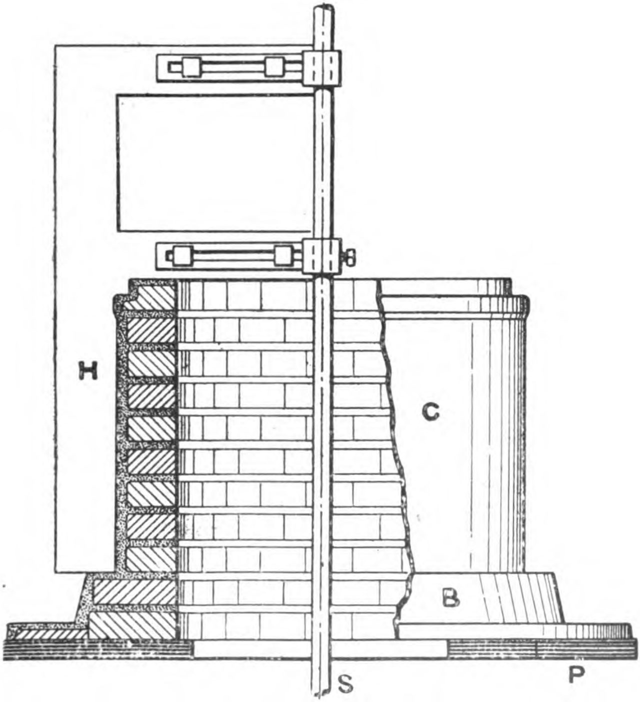

FIG. 167.

F are removed, when the crane tackle is attached to the four snugs on the cope ring, and the cope is lifted off, placed on a second car, and run into the stove to dry. The spindle is again put in place, and the board H, fig. 167, for striking up the core C, is set up, care being taken that it hangs plumb. The core is now built upon the bearing B, as shown at fig. 167, either entirely of loam bricks, or certainly with two or three loam bricks in each course, so that the core may be compressed by the contracting casting. The core having been roughed up and given its second or smoothing coat of loam, is placed in the stove, and after a night's drying both cope and core are ready for finishing, which simply consists of washing the surfaces over with plain water and applying the blacking. If this is laid on smoothly and equally, leaving no brush marks, the moulds may be considered to be finished, as there is no need for sleeking or polishing the surfaces of a mould for such a casting, and after another night in the stove to ensure their being thoroughly dry, the core and cope are ready. Fig. 168 shows the complete mould with the "top-cake" T in position. A plain top part box would serve in place of this top-cake, as a perfectly plain surface is all that is required to close the mould, and a box rammed up with damp pit sand with a thin facing of loam swept over its surface and dried would often be employed. When a top-cake is used, an iron plate is cast in an open sand mould as previously explained under the heading of Green-sand Moulding, and illustrated at fig. 68, page 159. After this plate has been clay washed, loam is bedded between the dabbers and laid over them and faced off with a straight-edge, as shown in section at fig. 168. It is then placed in the stove to dry, and after being smoothed and dried again, gate holes are bored through it, and that portion of its surface with which the metal will come in contact is blackened. The three parts of the mould, the cope, the core, and the top-cake, being now completed and dried, are ready for putting together in the pit. The foundation plate carrying the core is first laid on the bottom of the pit, and the cope carefully lowered over it. The top-ake T, fig. 168, is now laid on, and the bottom joint, and so that of the-top cake luted with soft loam to prevent kage of metal, when wrought-iron binders B are put on o opposite snugs of the foundation plate P, and made to ar upward under the snugs by the insertion of some king K, and a wedge W, in the lower eye, as shown at fig. 168. Sand is now thrown in round the mould, and rammed up in courses until the upper edge of the mould is reached, the ramming being usually left to labourers, although a careful moulder will ram up each course close around the mould himself, after the labourers have rammed

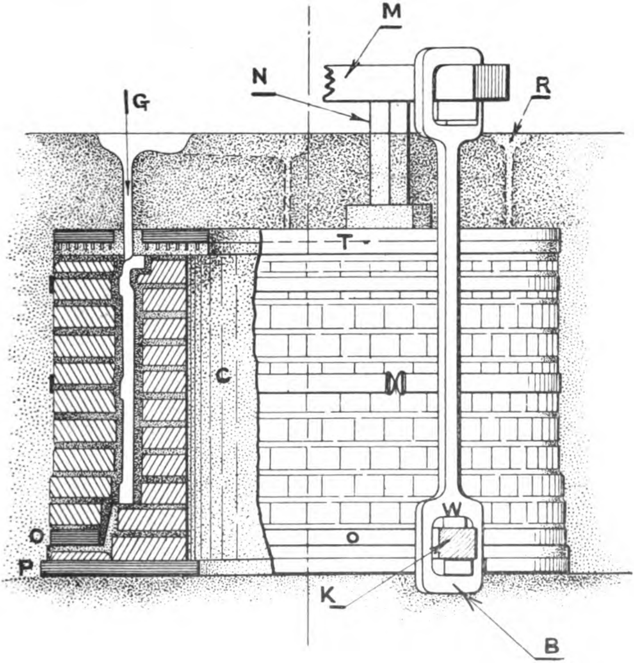

Fig. 168.

the remainder of the course to within a few inches of the mould. The parts of the mould are now securely bound together, a stiff crossbar M being passed through the upper eyes of the binders B, and cast-iron blocks N wedged tightly between this cross bar and the top-cake T. Gate sticks being inserted in the holes bored through the top-cake, and luted to prevent sand getting into the mould, the inside of the core C is filled up with sand, and more sand is rammed for a depth of a foot or so over the mould, in which a semi-circular runner terminating in a pouring basin is formed around the three or four ingates G, fig. 168. Two other pins would be inserted to form the risers R.

The venting of the mould has so far not been referred to, although a loam mould of this description would need little or no special provision for bringing off the gases from its surfaces, as the spaces between the joints and courses of bricks will generally be sufficient. When ramming up the mould in the pit vent rods would be laid against the brickwork about every 2 ft. apart, and cinders or straw should be introduced around the mould at the height of every foot or so, which, being connected with the upright vent passages left by the rods, ensures the gases passing off readily. In some instances it becomes necessary to have the brickwork built very solidly, to prevent distortion of the mould by the pressure of the iron when poured, and yet allow of the surface gases escaping backwards freely. This is accomplished in several ways, some moulders using straw between the bricks, while others build their brickwork very open, and fill in between the bricks with cinders rammed up solidly with an old flat file. Another plan is to lay the brickwork with a good thickness of building loam between the courses, and then vent between the courses of bricks with as large a vent wire as will pass through. Brickwork should always be built more open for thin castings than for thick ones, in order to allow the gases to escape as quickly as possible. Recesses under brackets or flanges, and other awkward parts of loam moulds, are vented by means of small hay ropes bedded in and led into the interior of the main core.

Bent pipes of large diameter are often cast in loam moulds, prepared without the aid of patterns, in the following manner: Taking the case of a pipe having a simple bend, such as is illustrated at fig. 169, a drawing or a full-size template cut from thin board, and having the positions of the flanges marked on, together with two pattern flanges made in halves, are supplied to the foundry. With these to guide him, the moulder casts two plates P, fig. 170, about ¾ in. thick, in open sand, about 1 in. wider each side and a few inches longer each end for the bearing of the core. The loam-board cutter supplies two strickles, one with the half circle as shown at L, fig. 170, the size of the core, and the other the size of the outside of the pipe, as at N. Core irons H, with a number of dabbers D cast on, having been clay washed, are placed on a bed of stiff loam on the plates P, and a half core is swept up in loam on each, one as shown at C, fig. 170, and one to the opposite hand, the edge E of the strickle L being held against one side of the plate while sweeping. After drying a little in the rough condition, they are smoothed and dried again, when they are ready for the second strickling, which forms the thickness of metal over the core, loam being spread over each black-washed half core, smoothed by the sweep N, and dried. A pair of half flanges—for which wood patterns are supplied—being screwed in their correct position, as

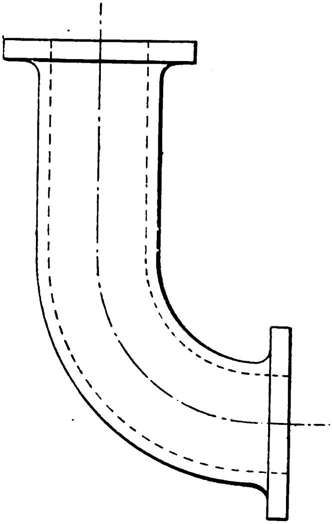

FIG. 169.

shown at fig. 171, and any surplus length of "thicknessing" removed from off the projecting ends of the core, this is then blackened with parting blackwash and bedded in the floor, the screws withdrawn from the flanges, and the plate P lifted off. The joint is then finished off, which leaves the flanges and loam block ready for the top half to go on, the top half flanges fitting on the pins of the bottom ones, setting the top half exactly. A cope would be rammed up in the usual way, lifted off, and the core with its thickness, which has done duty as a pattern, would be withdrawn

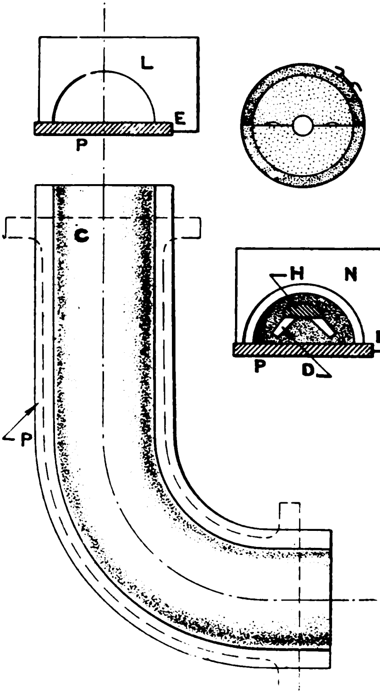

FIG. 170.

from the mould, and after having this thickness stripped off, the two halves of the core are stuck together, a groove

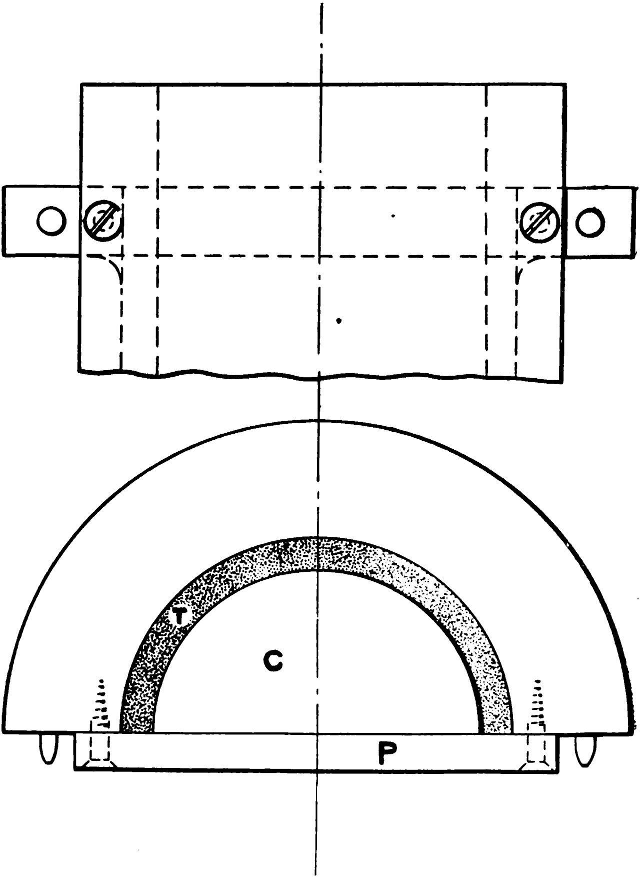

Fig. 171.

being scraped out along their centre to serve as a vent, and two smaller grooves near the edges to receive the glueing material. The core is now bound with wires sunk under the surface, and having their ends twisted tightly together. The surface of the core is made fair by filling up these wire tracks, and is then finished and blackened, and the core is ready for laying in the mould, where it would be prevented from rising at the bend by two or three chaplets.

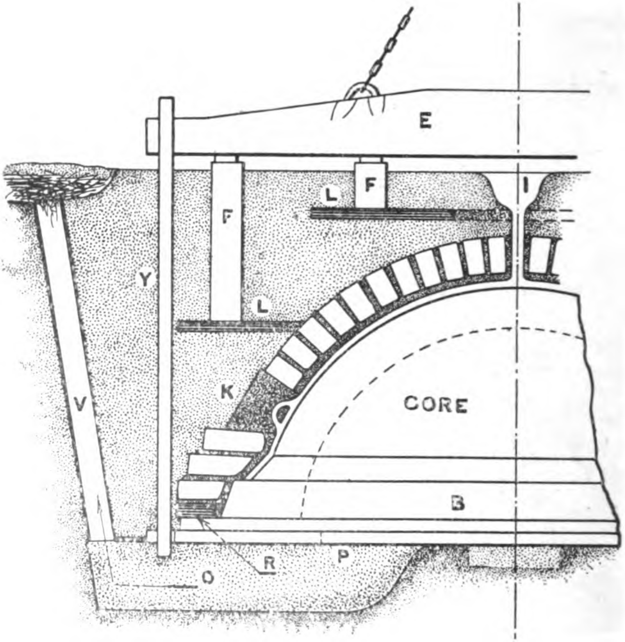

Fig. 172.

The circular cast-iron pans so largely employed in the chemical and other industries are another class of castings which, with the exception of those of small diameter, are invariably cast in loam moulds. The most common plan is to cast them "bottom up," owing to the facility of moulding and casting, although, when we consider that it is the bottom of the pan that is usually exposed to the most intense heat when in use, casting them "bottom down" is preferable, as this ensures soundness where it is most needed.

Fig. 172 illustrates a half section of a mould prepared for casting a pan "bottom up." It is customary to build such a mould in the pit in which it is poured, so as to avoid all risk of cracking the core in handling, as, after the foundation plate P is once set in position, it remains undisturbed, the core when built upon it being dried in the pit. The nature of the core renders this a very simple matter, which, with proper care, need cause but little smoke or inconvenience. In preparing the mould, the ring plate P is laid on the bottom of a pit of suitable size, and an iron centre is rammed up in a small flask sunk into the floor at the centre of the ring plate, as shown at fig. 173. This centre receives the lower end of the spindle S, the upper end of which is guided and maintained plumb by being held in a notch cut in the edge of a plank laid across the mouth of the pit, as shown at H,

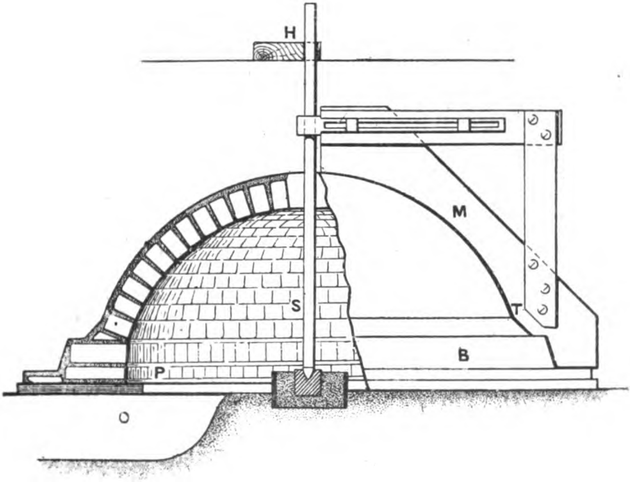

FIG. 173.

fig. 173. The loam board M is mounted on the spindle and set to the correct radius by means of a gauge from the spindle to the point T. This board sweeps up the core and also a bearing B for the cope. A detailed description of the building of the core need not be given. Half bricks would be used, as these lend themselves more readily to the formation of the curved surface required than would whole bricks. They would be built radially towards the lower centre with a little more loam under their outer edge in every course, to adapt them to the curve. The usual allowance of ½ in. for the coating of loam would be made, except when the crown of the dome is being reached, when less clearance would be allowed between the face of the bricks and the edge of the sweep, to allow for the slight sinking of the crown, which always takes place. A small space is left open around the spindle for the emission of smoke from the fire which is subsequently kindled in the interior of the core to dry it after the finishing coat of finely-sifted loam has been applied. A passage O, fig. 173, allows of access to the interior of the core, and also serves for bringing off the vent, which, in the case of a pan cast bottom up, is a matter of great importance. Supposing the pan is cast without previously filling up the dome space under the core with loose sand, there would be great danger of explosion, as this large space would be quickly impregnated with gases from the mould as soon as the metal began to flow into the mould cavity, and these, intermingling with the air already in the chamber, render its contents highly explosive. To avoid the risk of an explosion should a spark reach the gases escaping from the passage O through the vent pipe V, fig. 172, the mouth of the latter is covered with straw, over which loose sand is laid. With such a precaution there need be no fear of blowing up the mould, yet it is still the practice in some foundries to fill the dome space under the core with sand before casting, hay bands being bedded in freely and led to the base of the vent pipe V.

When the core and bearing have been dried sufficiently, the moulder proceeds to lay on the "thickness," which is swept by a second board N, fig. 174, having its striking edge cut to the shape of the outside of the pan. The position of this board is adjusted to give the required thickness of metal by setting it against two blocks of wood W, laid on the core, as shown. The core, having been washed with "parting" blackwash, is covered with a "thickness" of coarse loam, which is strickled off by the board N, and over

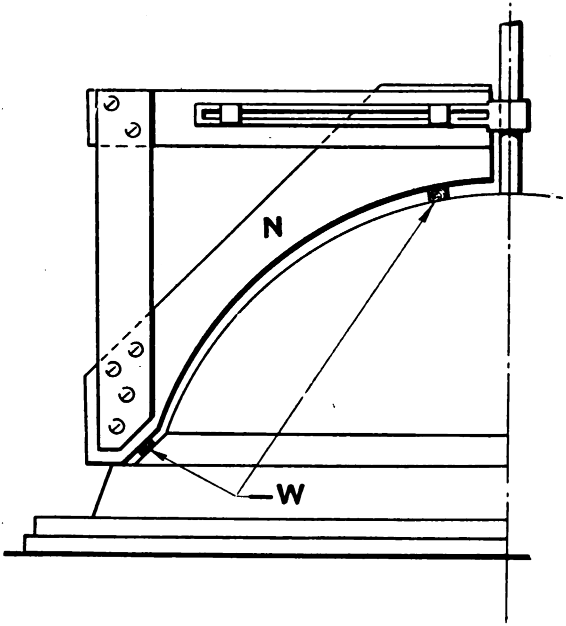

Fig. 174.

this a second coat of fine loam, thus forming a pattern on which the cope is built. The "thickness" having been dried, and any cracks which may have formed in the process being filled up and smoothed over, the whole surface, including that of the bearing B, is washed with "parting" blackwash.

The spindle S is now removed, and the building of the cope proceeded with. The cope ring R, fig. 172, is claywashed inside and laid on, when the whole surface of the mould is covered with a coating of soft brown loam about ½ in. thick, and over this the brickwork is built, cores K forming handles, and any bosses that may be required being built in at their respective positions. The mould is now given a night's firing, after which the cope is lifted off and set on supports high enough above the ground to enable the moulders to get at the inside for finishing and dressing. The "thickness" is now removed from the core, which is then dressed and blackened above the bearing. After the cope has been dressed by washing its surface with water, and then with a block of wood having its face curved to suit the surface, and a thin wash of fine loam, rubbing the whole surface over until it is made smooth, it is dried inside by means of a strong fire, the hole in the top being first reduced in size to that required as an ingate. The cope is then blackened, and, together with the core, is given a little more firing to dry the blacking. The hole in the crown of the core is plugged, and the surface made fair, a hot plate being laid on for a while to dry it. The cope is now carefully lowered on to its bearing around the core, and the binders Y, fig. 172, are slipped on the snugs of the foundation plate P, and wedged to take a bearing against the underside of the snugs. The joint under the cope ring is luted all round with stiff loam, to prevent escape of metal, and the pit is filled and rammed up in courses each about 1 ft. deep, the ring plates L, L, fig. 172, being bedded in together with sconces F, F for the purpose of binding. This method of binding is necessitated by the fact that in a mould of this nature there is no iron frame or surface on the structure that will enable it to be bound "iron on iron" in the more usual manner. The ramming must be done evenly, and not too hard over the crown of the cope. When the upper ring L is reached, the cross bar E is passed through the loops of the binders Y, and strained upwards by the crane, and all four sconces F are tightly wedged while the strain is on. More sand is now rammed over the plate, to form a pouring basin I. When such a mould is poured, it will be noticed that after the mould appears to be full the metal sinks a little, owing to the crown yielding under the pressure, and the extent to which this takes place is a measure of the imperfection in ramming and binding.

In moulding a pan "bottom down," a pit is first sunk, and a foundation plate P, fig. 175, laid on the bottom, with a couple of stiff crossbars C bedded in under it. The spindle is set up as before, and a loam board, having its striking edge cut to the form of the outside of the pan to be made, with an addition at the top to sweep up a bearing B, is mounted on the spindle, and the brickwork for the cope built up as shown in the half section of the mould, fig. 175. The four binders T having been placed in position, with their lower ends under the crossbars C, the pit is firmly rammed up to the surface all round the completed building, and the cope is faced with brown loam in the usual way, and when this facing has become sufficiently hard a finishing coat of fine loam is applied and strickled off smooth. The spindle and loam board are now removed, and the cope dried by means of a fire kindled in an iron basket and suspended in the mould, iron plates being placed over the mouth of the latter to retain the heat as much as possible. After drying, the cope is washed with "parting" blackwash, and the "thickness" laid on and swept with a second board cut to the form of the inside of the pan. This is dried in the same manner as was the cope, and is then given a coat of the "parting" wash. The core is now taken in hand, and as it will need to be lifted out after being built in place, special provision has to be made to enable it to be raised and handled conveniently.

Fig. 175 shows the commonly adopted method of building up such a core. A cellular grid G, having its underside curved approximately to the spherical form of the pan, is cast in open sand with four "lifters" H cast in. This is clay-washed and bedded down on a layer of loam spread over the "thickness," and broken bricks are wedged tightly in between the intersecting bars and the interstices filled in with loam, and then a course of bricks is laid over the whole upper surface of the grid, as shown in fig. 175. On this as a base further courses of bricks or half bricks are built up in rings, their outer ends being bedded into the layer of loam spread over the entire surface of the "thickness."

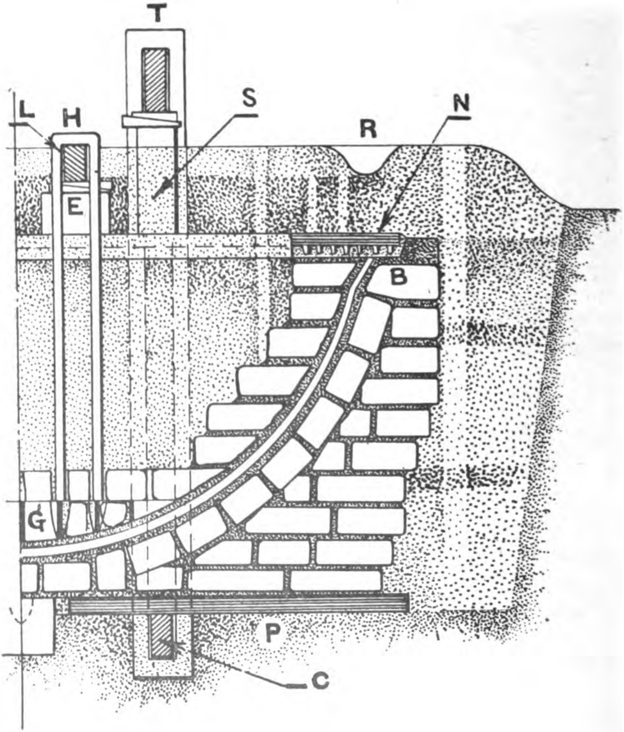

Fig. 175.

The upper ring plate N is cast with its underside studded with dabbers, and a number of holes in it to serve as gates. Its outer diameter fits into the bearing B, and after being ated with loam on the underside, and dried a little in the ve, the dried surface is washed with clay-water, and the plate bedded down into a thin layer of soft loam spread over the top of the core and the bearing B, fig. 175. This being done, crossbars L are slipped under the lifters H and wedged at both ends against the plate N, as shown at E, fig. 175.

The core is now dried by means of a fire kindled inside it, just sufficiently to ensure a good lift; the crane slings are attached to four snugs on the ring plate N, and the core lifted out, and while still suspended its surface is gone over, any cracks that may have occurred being mended, and the gate holes bored, when it is set upon suitable supports on a stove carriage and run into the stove, where it remains until thoroughly dry. The "thickness" is next removed from the cope, and the surface of the latter dressed and dried again as before. When both core and cope are thoroughly dried their surfaces are finished and blackwashed, and after a little further drying the mould is prepared for the cast. After brushing off any dust and dirt that may have collected on the face of the cope, the core is brushed over and carefully lowered into the mould, the bearing B, fig. 175, guiding it into its correct position. Two stiff crossbars are put through the binders T, and sconces S placed on the ring plate N under each end of these crossbars, and wedged up, as shown at fig. 175.

The interior of the core is now filled up with sand, trodden in, and more sand is heaped up about 1 ft. high over the mould, pins being inserted in the five or six gate holes bored through the top plate. An annular runner R, about 5 in. deep, is formed around the ingates, and is connected up to the pouring basin. To facilitate the escape of the gases from the core a number of vertical vents would be driven down through the sand inside, or vent sticks would be set in position when the sand was being trodden in, and subsequently withdrawn. Soon after casting, the core is "slacked" by attaching the crane slings and raising it 1 in. or so, thus allowing the casting to contract freely. A mould made in this way is often used for more than one casting, as the cope is rarely injured to any great extent, a good thick coating of blacking over the burnt loam being generally all that is required to fit it for further service, any

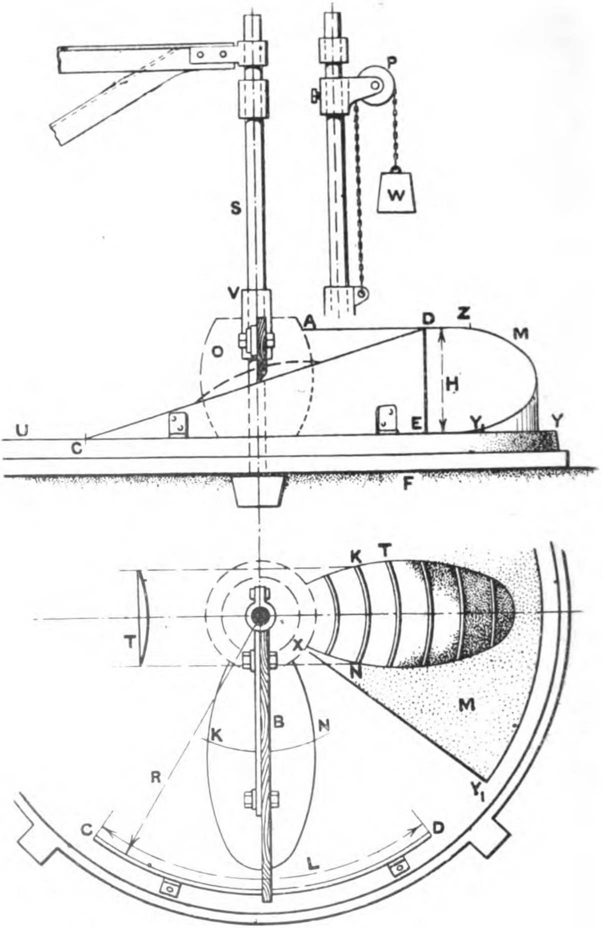

FIG. 176.

cores for handles, &c., that may have been built in being, of course, replaced by new ones. Another advantage lies in being able to cast pans of smaller diameters in the same cope, the building of which, when once made, will serve for any number of pans of different diameters that may be required, provided it is built in the first place to accommodate the largest pan likely to be called for. In cases of relatively small pans, floor sand may be thrown in and firmly rammed, its face freely clay-watered, coated with loam, and swept up to the required outline.

Sweeping up screw propeller blades is an interesting branch of loam moulding, and when carefully done the blades invariably come out truer as regards pitch than when moulded from a wooden pattern. Fig. 176 shows the type of rigging usually employed. The foundation, plate F, about 3 in. thick and 1 ft. or so larger in diameter than the largest propeller likely to be required, is laid level on the bottom of the pit in which the propeller is to be cast, and a stout spindle S set into a socket in the centre of the plate and held plumb by means of a stay at its upper end. This spindle is fixed, and should be turned parallel to suit a special loam-board carrier having a deep boss V bored to slide easily on the spindle. The carrier, with the attached loam board B, is balanced by means of the counterweight W suspended from the pulley P, so that it may be travelled up and down easily as required. A level bearing U Y, fig. 176, is first swept, and on this is placed the angle template C D E, curved when on edge to a radius of 3 in. or so greater than the radius of the blade, so that when in position it may be clear of the latter when sweeping up. This template is often cut from a thin steel plate, and when a true screw is to be moulded is of triangular form, and if L, fig. 176, is one-sixth of the circumference of a circle having a radius R, then H should be equal to one-sixth of the required pitch. This template when curved to a radius R is fixed in successive positions opposite each blade at a distance from the centre equivalent to the radius of its curvature. A rough form of each blade is built up of brick, leaving a space round the spindle sufficiently large to accommodate the boss. This brickwork is next faced with loam, which is swept up to a true screw surface by sliding the loam board B along the angled edge of the template. This surface of loam represents the face of the blade, which is invariably cast downwards. The striking edge of the board would be set horizontally if the blades are to be as shown at A, fig. 177, whereas, if the blades are to be set back as at B, fig. 177, which is now commonly done, more

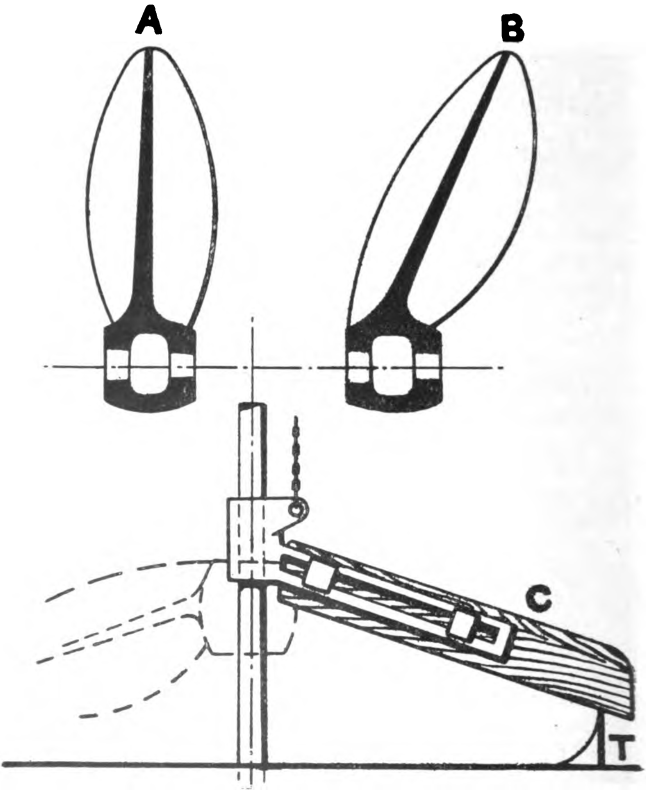

FIG. 177.

particularly in the case of high-speed screws, with a view to counteracting the influence of centrifugal force, the board would be set at the required angle as shown at C, fig. 177. When these surfaces are all swept up, finished smooth, and dried, they are given a coat of the parting black-wash, and the outline of a blade is drawn upon each, when thickness pieces T, fig. 176, formed as cross-sections of the blade at various radii, are nailed to the surface along lines such as K, N scribed on the face of the loam. These serve as guides, and the spaces between are filled up with loam, thus forming pattern blades, on which the top part of the mould is formed. Whenever possible, the author recommends the use of a box for the top part, rigged up as previously described in connection with the moulding of a propeller in green sand, bricks being wedged in tightly between the bars to carry the loam.

The boss O, fig. 176, may either be moulded from a wooden pattern, from a loam pattern struck up on a core bar bound with hay ropes, or it may be swept up in loam by means of a board mounted on the spindle S. Of these three methods the loam pattern is probably the most commonly adopted as being the most convenient. In this case the roots of the blades can be built close up against the boss, which is generally barrel shaped, and the loam pattern of the latter broken up in place and removed in pieces. Should the propeller be too large to allow of all its blades being covered conveniently by a single top-part box, separate boxes for each blade may be built up in the following manner: A stout bar of L section is laid on the bed U Y, fig. 176, along the line X Y_1, and a similar bar along the upper bearing A Z. A number of crossbars of increasing lengths are securely bolted at their ends to these radiating bars, thus forming a strong top-part box for each blade, which can be easily lifted and turned over for finishing, handles being attached to the radial bars for the purpose. The radiating bars should be made long enough to suit the largest diameter propeller that is likely to be required, and when smaller propellers are being made only so many cross-bars would be bolted between them as may be necessary to embrace the length of the particular blades.

To sweep up a propeller blade having an increasing pitch axially, all that is necessary is to shape the template accordingly. Referring to fig. 178, suppose the distance C E = L equals one-sixth of the circumference of a circle of radius R to which the template is to be curved, then for a screw of uniform pitch the upper edge of the template would be shaped to the line C D, the height E D or H being made equal to one-sixth of the required pitch, as before; but if the pitch of the leading edge of the blade is to be, say, 50

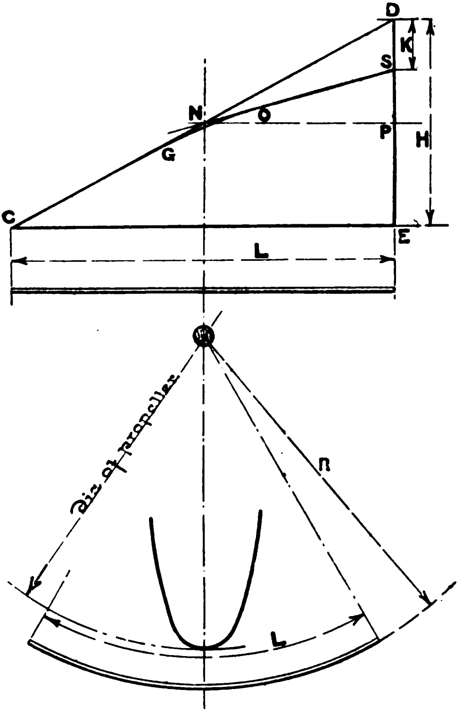

Fig. 178.

per cent less than that of the following edge, which is still to be 6 H; from the point N, the upper edge of the template would be shaped to the line N S, the point S being a distance K = 50 per cent of the distance D P below the point D. The abrupt change of direction at N would be avoided by shaping the template with a curved portion G O, joining up the slope C N with N S, as shown in fig. 178. The effect of this is that in a blade having a fairly fine tip the pitch does not attain its maximum value for a few inches in, which is perhaps a good feature, since if it is attempted to accelerate the water too much at the tip it is liable to escape round it to the back of the blade.

Should the propeller be required to have an increasing pitch radially, two angle templates are used for sweeping up the blades. This is shown at fig. 179, the outer template being formed with an angle corresponding to the spiral line described at the pitch of the screw required at the end of the blades, the height D E being the same proportion of the required pitch as the length U is of a circumference, and the inner template angled to suit the smaller pitch to be given to the blades at their root. In the case of a screw of uniform pitch, a point T on the lower edge of the sweep, starting from the point marked M in the plan view, fig. 179, would travel along the dotted line N O while the sweep was being revolved from the position M C to the position L D, as indicated on the plan view. If now the sweep is attached to a carrier connected to the sliding sleeve V by a hinged joint H, and the point T made to travel along some other path, such, for instance, as M L, the upper edge of the inner template, the screw surface swept up would have a radially increasing pitch, the relation of which at the radius of the inner template to that at the radius of the outer template would be as the height K L is to the height E D. Except for the purposes of maintaining the loam board truly radial whilst sweeping, and carrying the counterbalancing gear, the vertical spindle shown in fig. 179 would not be required. To ensure the board being kept radial the plan shown at S, fig. 179, is sometimes adopted, the hinged joint H and balancing gear being dispensed with, and only a small spindle set up in the centre of the mould for the loam board to turn about. It will be seen that by the method illustrated at fig. 179, in combination with templates shaped

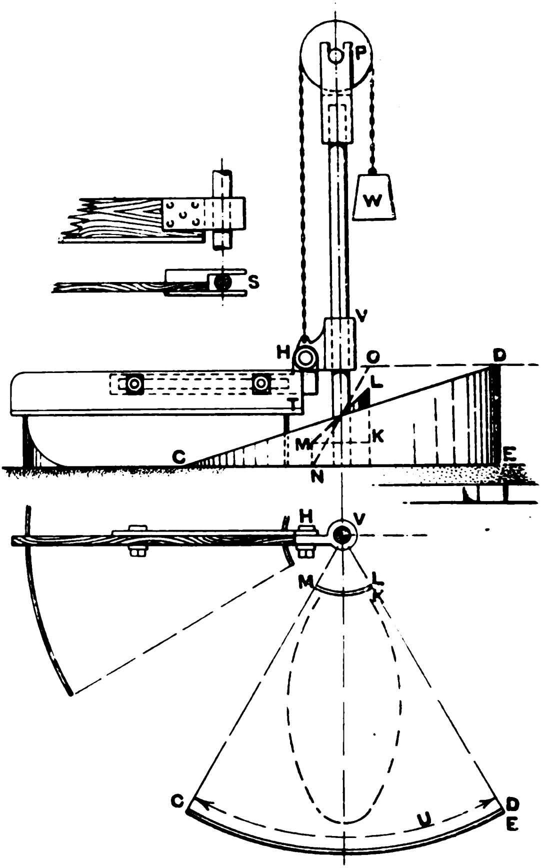

Fig. 179.

after the manner shown at fig. 178, it becomes possible to veep up propeller blades having an increasing pitch both lially and axially.

Fig. 180 illustrates two methods of sweeping up grooved barrels, such as are used for carrying the wire ropes or chains of cranes, etc. In the first method the sweep, faced with sheet iron at C, is attached to the arm A, and revolves about a fixed spindle. On this spindle is mounted a circular plate P having on its upper face a spiral roller path, the pitch of which corresponds to that of the grooves to be formed on

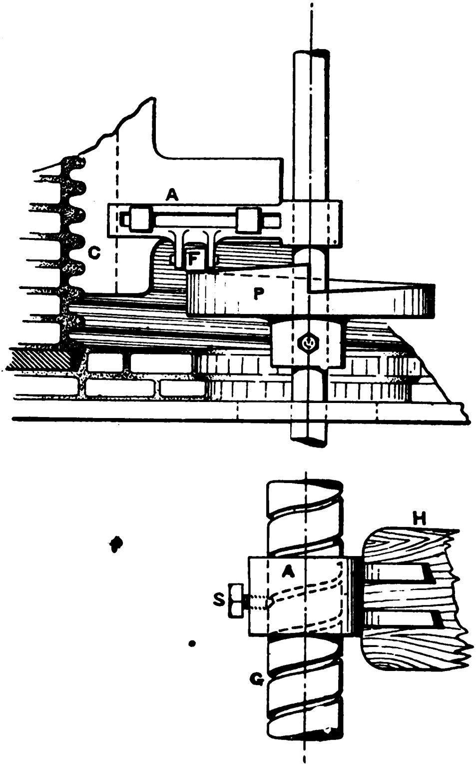

Fig. 180.

the barrel. The roller F mounted on the arm A runs on this path, and permits the sweep to be easily revolved. When the sweep reaches the step it is allowed to drop on to the lowest point of the incline, and is again revolved. This leaves a vertical strip the entire length of the sweep without grooves, but this can be filled up and grooved after the remainder of the circumference has been finished, by setting the plate P twenty or thirty degrees in advance of its first position, and re-adjusting its height so that the projections on the sweep enter the grooves formed in the mould a few inches behind the strip to be completed. The second method is to have a spiral groove G, fig. 180, cut on the spindle, which the end of a set screw S, screwed through the sleeve A of the loam board carrier, enters. Here again the spindle is a fixture, so that when the sweep H is revolved it also rises, the pitch of the groove on the spindle being made equal to the required pitch of the grooves on the drum.

It might be deemed an omission to close this chapter without a description of the moulding of a steam-engine cylinder in loam. Fig. 181, representing the low-pressure cylinder of a triple-expansion marine engine, will furnish a suitable example. This cylinder has a finished diameter of 54 in., and is suited to a piston stroke of 2 ft. 9 in. The casting as it came from the mould weighed nearly 5 tons, and after being machined its weight was 4·35 tons. A pattern of the valve face and that portion of the cylinder which embraces the steam and exhaust passages was provided, together with a few loose pieces, such as the guide lug L, column seatings F, facings for cylinder drains and relief valves E, ribs, etc. Having cast a foundation plate about 3 in. thick in open sand, with the usual snugs, central hole, etc., and of a size sufficient to cover the projected area of the cylinder with its valve face and allow for the brickwork of the cope beyond, the moulder puts it in place and sets it level. A 3 in. diameter spindle is next placed in position, with its lower end fitting into a socket bolted to the plate, and its upper end secured by an arm and diagonal stays from the foundry wall, as shown at fig. 182. The true vertical adjustment of the spindle having been tested [illegible] the aid of a plumb line, the foundation plate F, figs. 182

and 183, is covered where required with a layer of bricks, on top of which is spread about ½ in. of loam, and on this again the brickwork for the bearing B, fig. 182, which is built up and swept with loam to form a guide for the cope, the seating for the cope ring C being swept at the same time. Centre lines L, M, and H, K, fig. 183, at right angles one with the other, are scribed on this seating and the ends transferred to the plate at L, M, H, and K by means of a straight-edge and plumb line, and there marked with a chisel for use in the event of the lines on the seating becoming obliterated. The "dummy" D, fig. 182, is next built and swept up with loam to correspond to the circular part of the outer surface of the cylinder. This dummy is built hollow with a grating G,

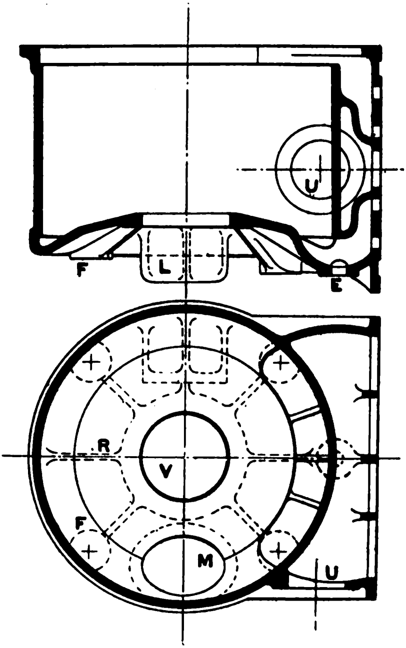

Fig. 181.

fig. 182—slotted radially, as shown in plan view at S, fig. 183, to allow it to pass the spindle—placed near the top to carry the bricks and loam, which is swept up to correspond with the outer surface of the cylinder bottom. This grating, if made about 3 in. less in diameter than the main core, will serve a similar purpose when the latter is being built, and for this reason it needs to be fairly strong, the bars being, say, 1¾ in. square in section, in order that it may withstand the pressure without yielding. The dummy, having been completed, has the centre lines transferred to it by means of straight-edges and plumb line. The pattern P, figs. 182 and 183, after being well oiled, is set in position against the dummy, the centre lines on the latter serving to ensure its true location.

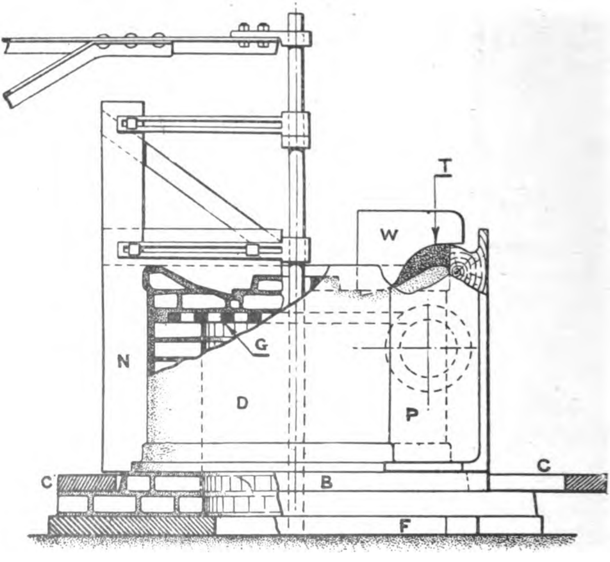

FIG. 182.

The space under the pattern is now built up so as to form a continuation of the bearing B, fig. 182, all round the pattern, which is scraped off flush with the pattern below the valve face, as shown. At the same time the outline of the cylinder bottom under the steam passage is completed by clay-washing the surface of the dummy at that part, and building up with loam and broken brick, and sweeping off with fine loam the portion marked T, figs. 182 and 183, the strickle board W being attached to the spindle for the purpose. These additions to the bearing and dummy being made, and their surfaces sleeked smooth, the bearing with the dummy built upon it is dried and afterwards given a coating of parting blackwash, when the cope ring C, figs. 182 and 183, is put on, the pattern P again laid against the dummy, and the work of building up the cope begun. A facing of about ½ in. of loam is laid on the dummy and sides

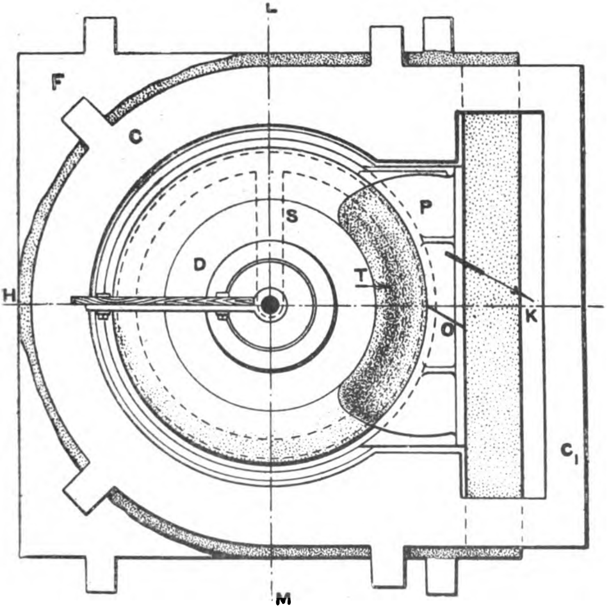

FIG. 183.

of the pattern, and the bricks, which are first well rubbed over with loam, are laid up to it. The brickwork, generally, would be 9 in. thick, and is carried up to the level H, fig. 185, a building ring W, fig. 185, being laid in at about 7 in. below the top face H. This adds greatly to the strength of the building, and by shaping the ring the same as the cope ring C, fig. 183, the extension beyond the valve face, similar to C_1 serves for wedging up the face plate K,

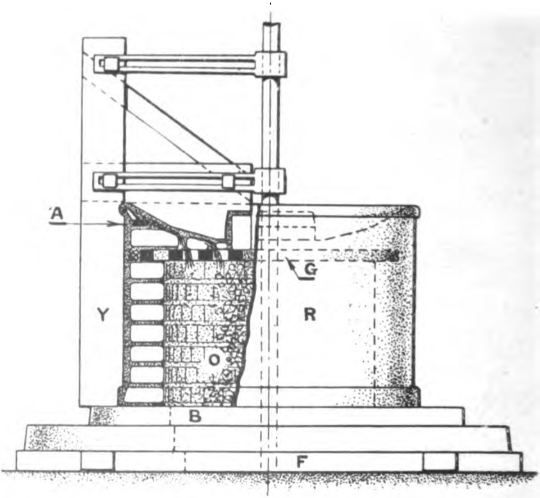

FIG. 184.

figs. 185 and 186, when the mould is being closed. The joints and interstices in the brickwork are filled with fine cinders, as previously explained. The cope is finished off and faced with loam flush with the outer face of the pattern, as shown in plan at fig. 186, and an opening left where the exhaust outlet core cuts through, in order to allow for securing it in place, and for bringing off the vent. The top-cake to cover the mould is formed on a plate T, fig. 185, st in open sand, and having openings in it for all parts of mould that may project above it, as, for instance, the guide lug L, fig. 181, and other holes for venting the main core, and the core for the manhole M, fig. 181, and also for the ingates in line with the thickness of the body of the cylinder. The holes for those parts of the mould which project above the plate T are covered by smaller plates secured by hook bolts to staples cast in the top plate. Dabbers are cast on the under side of the top plate, and the plate is first laid on to see that these dabbers are of the right length, the ends conforming closely to the top surface of the dummy cylinder on which had previously been set the loose pattern pieces, including the column seatings F, fig. 181, the facing E, the ribs R, and the facing ring round the manhole M. These loose pieces are nailed in their correct positions, which are verified by the pattern-makers, who constantly check the sizes and locations of all parts of the mould during the progress of the work. If the plate is found to be satisfactory, it is inverted, and broken bricks are wedged tightly between the dabbers, so that they will not fall out when the plate is again reversed. The surface of these brickbats is covered with a thin layer of loam well rubbed on, and the plate dried in the stove. When it is removed from the drying stove it is again laid over the dummy and fitted by carving, rubbing, and scraping till it takes a good bearing. This being done, the pattern pieces are oiled, and, together with the top surface of the dummy, are covered with an inch or so of fine loam.

The dried surface of the top-cake is now clay-washed in order to make the wet loam adhere to it, and the cake is inverted and lowered on the moist loam, and gently rubbed to and fro to make the loam take a good impression of the cylinder and to squeeze out any excess loam; the closer it is rubbed down the better, as there will be the less moisture left to be driven off. The joint between the cope sides and the top-cake is sleeked smooth and marked, so as to serve as a guide when finally closing the mould. The top-cake is now lifted off, inverted—to facilitate which it should be provided with trunnions—and its surface dressed and finished. The dummy is next removed by picking out the bricks and removing the dried loam, and, should the loam surface of the cope show any irregularities, the spindle is set in place and a sweep used to put it right. The pattern P, figs. 182 and 183, is then drawn out, being made in halves with an oblique joint between them, as shown at O, fig. 183, so that the portion marked P may be drawn out first, in the direction indicated by the arrow, and the remaining portion at a similar angle in the opposite direction. This is necessitated by the curved form of the sides of the pattern. The cope is now lifted squarely off the bearing by the crane, slings from the crossbeam attached to the latter being connected to the four lugs on the cope ring. It is placed on a car and there finished, the whole surface being washed over with fine loam, sleeked smooth, and given a coating of liquid blacking applied with a brush. For an extra finish, and to prevent the blacking from rubbing off after the mould has been dried it is again sleeked over and a soft brush used to wash the surface over with a mixture of molasses water and graphite. The top-cake is treated in like manner.

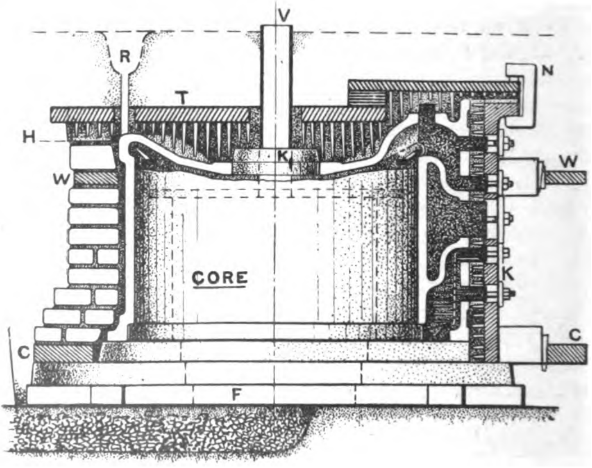

Fig. 185.

When the cope is removed its seating on the foundation plate is covered with loose sand to serve as a protection while the main core R, fig. 184, is being built. The spindle is again put in place and the sweep Y, fig. 184, bolted to the carriers at a radius to allow for shrinkage and for boring out the cylinder. The vertical striking edge of the sweep should not be set quite plumb, but should be adjusted so as to make the core about $\frac{1}{8}$ in. larger in diameter at the bottom than at the top, to compensate for the pressure of the molten iron.* The central portion of the core is filled with loose bricks and cinders, to allow of the gases passing freely to the vent pipes V, fig. 185, carried up through the openings for the piston rod and manhole.

In building up the core a "relieving bar" is built in, reaching from the upper face of the bearing B, fig. 184, to the top of the core, and placed immediately under the manhole opening. This is an iron bar about 8 in. wide and tapering along its length about $\frac{1}{4}$ in. per foot, its thickness at the lower end being about 1 in. It is placed with its outer edge flush with the face of the brickwork, and has a hole near its upper end for the purpose of attachment to the crane slings for dragging it up through the manhole after the cylinder is cast, thus allowing a clear space for the contraction of the metal as it cools. The crown of the core is supported on the grid G, fig. 184, placed so that the slot embraces the spindle, and also the relieving bar. A strengthening ring A, fig. 184, with dabbers cast on it, is introduced to give support to the narrow prominent ridge of the extreme top of the core. This ring has an opening to allow it to pass the spindle and relieving bar. The outside diameter of the grid G is about 3 in. less than that of the core, to allow of the contraction of the casting, and when in place has a couple of courses of hay ropes wound round its periphery. The crown of the core should be amply vented by small hay ropes bedded in the loam, with their ends carried down between the bricks and through the grating into the interior of the core, as shown at fig. 184. A part of the core for the steam passage to the lower end of the cylinder is swept up on the main core, as shown at fig. 185, and made

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* This increase in diameter towards the base, also helps to prevent the core from floating.

to correspond exactly with the core formed in a box for the remaining portion. The main core is now blackened and finished. The faceplate K, figs. 185 and 186, cast with one face studded with dabbers, is clay-washed, coated with loam, and bedded on a "boss" B, fig. 186, made to resemble the valve face of the cylinder, with prints P over each port. These prints are made an inch or so shorter each side than the full width of the ports, so that the passage cores may take a bearing against the faceplate as shown at S, fig. 186. This faceplate is sleeked smooth, blackened and finished similarly to the other parts of the mould, when all parts are transferred to the oven and thoroughly dried. Wooden core boxes would be provided for the passage cores, which are formed on light grids with cast dabbers to go through the ports in the valve face, and nail-rod dabbers cast in the opposite face, and made of varying lengths to suit the outlines of the cores. In building the cores some stiff brown loam is put in the box, and the core iron, which has been previously clay-washed, is bedded in. A couple of bolts are now thrust down through holes in the grid, of sufficient length to enable the core to be firmly bolted to the faceplate, as shown at fig. 185. Vent pins about ½ in. diameter are also inserted in other holes in the grid, with their larger ends passing through the ports and extending beyond the core. Well-spun hay ropes are next wound around and amongst the dabbers, and the box filled up with stiff loam and scraped off with a sweep. The cores, while still in the boxes, are put into the oven for a little slow drying, the boxes being daubed over with loam to prevent them being damaged by the heat. After this they are turned out of the boxes and roughly dressed, their corners are filleted, and they are returned to the oven to dry thoroughly before being blackened.

The mould would be closed in the pit in which it is to be cast, dug in the foundry floor where it can be readily reached by the crane, and of sufficient size to allow of a curb of sheet iron to encircle the mould. The bottom of the pit [illegible]ould be levelled to give a fair seating for the foundation [illegible]e, and as a precautionary measure it is a good plan [illegible] a deep channel in it, leading from the centre of the pit to a point beyond the outside of the mould, which, when filled with cinders, will help to conduct the gases from the main core in case the openings at the top may be too small for the purpose, and thus

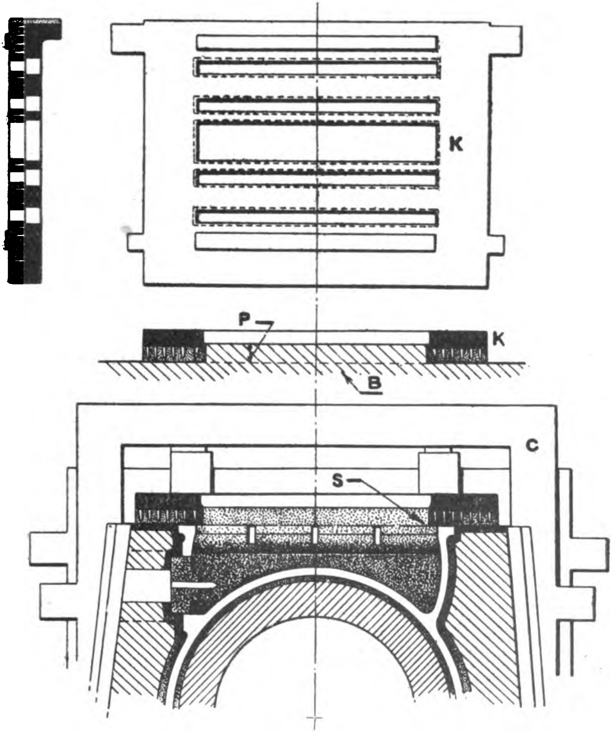

FIG. 186.

effectually guard against the possibility of an explosion. The foundation plate carrying the main core is first lowered into the pit, and all dust and dirt brushed off. The cope is next lowered over the core and the space for the thickness of metal gauged to see that it is correct and equal all round.

This space is then filled up with tow to prevent dirt falling into the mould. The faceplate K, fig. 185, with the passage cores securely bolted to it, is now carefully lowered into position, care being taken that the top and bottom steam passage cores come quite close up to the main core, but do not bear hard against it, as, in that case, there would be danger of their being partly crushed when the faceplate is wedged tight up and the sand rammed up in the pit against . Cast-iron chaplets are placed in the thickness spaces between the passage cores, to serve as supports and to enable them to resist the pressure while the metal is being poured. Soft clay balls are placed at numerous points all over the top surface of the main core to test the thickness, and the top-cake lowered into position and then removed, when, provided the thickness spaces for the metal are found correct, cast-iron chaplets are placed where required, all clay balls and tow removed and the top-cake replaced in position. The cake should touch and bear upon the outside bearing first, the part over the central core K_1 fig. 185, being preferably a little clear, and a thin layer of soft loam interposed when the top-cake is laid on for the last time. The mould is now prepared for binding and clamping, all joints being luted with loam, and iron distance pieces set at intervals between the foundation and top plates to prevent the mould being crushed while being clamped and bolted together. A stiff iron cross-beam is then swung over the mould, and its four arms secured to the foundation plate by iron links, leaving about 3 ft. between the underside of the beam and the top plate T, fig. 185. Some strain is put on by lifting with the crane, and iron sconces placed, one near the centre and one under each of the four arms of the cross-beam, on the top plate, and iron wedges driven tightly between their upper ends and the beam. Iron clamps N, fig. 185, would be added to secure the top plate to the face plate K. A cylindrical "curbing" of sheet iron is next placed around the mould, leaving a space of about 1 ft. between it and the mould. Vent sticks are placed upright against the brickwork at frequent intervals around the mould, and straw laid in for the purpose of leading the gases to the top, as previously explained, and floor sand is thrown in and rammed up in courses about 10 in. deep inside the curb, and also outside between the curbing and the sides of the pit. The lower courses need to be packed and rammed very hard, as the pressure towards the bottom of the mould will be heavy. The upper edge of the curbing should be 18 in. to 20 in. above the highest part of the casting, as the bottom of the runner R, fig. 185, should not be less than 1 ft. above the top surface of the casting, to ensure a fairly uniform pressure sufficient to drive the gas through the mould and cores. Gate sticks are inserted in the gate holes bored through the top plate, and pipes are placed in position over the vent holes, when sand is rammed over the mould as high as the top of the curbing, and in this sand a pouring basin about 2 ft. in diameter is formed with a flat dry-sand cake at its bottom, to prevent cutting.

Leading from this basin a channel R, fig. 185, is formed about 5 in. wide and 8 in. or 9 in. deep, connecting up all the ingates. The surfaces of the basin and channel are carefully sleeked and blackened, any loose sand or dirt being cleaned away. Risers communicating with flow-off gates are carried up from the thickest parts of the casting, and serve for feeding the shrinkage of the casting while it is in a liquid state. Plugs of stiff clay provided with lifting hooks are placed over the risers, and weighted down to maintain a pressure of air in the mould while the metal is flowing in. These plugs are raised as soon as the mould is filled and the metal is allowed to flow through, the runners being kept full, to increase the pressure. The runners are broken up as soon as the metal in them solidifies, and the sand is cleared off the top of the mould, when the crane slings are attached to the cross-beam and the latter strained upward, the sconces knocked away from under it, and a way cleared down through the manhole to the relieving bar, which is hitched on to the crane and pulled out so as to relieve the main core and prevent any danger of the casting cracking as the metal shrinks while cooling. The sand is next dug away from behind the faceplate, the curbing removed, and the steam passage cores relieved by breaking them up as much as is possible by working through the port openings. These operations will provide for the immediate safety of the casting, and nothing more is done until the following morning, when the casting will probably still be red hot. The remainder of the sand round the outside of the mould is then cleared away, but the mould is not broken up and the casting removed until three days after it is poured, as it would not be cool enough before.

CHAPTER XIV.

CHILLED CASTINGS.

IN order that it may stand wear and tear, the surface, or some part of the surface, of a casting is often required to be very hard, while at the same time the general toughness of the casting must not be impaired. This is effected by the process of "chilling"; that portion of the mould against which the particular face of the casting required to be hard and durable lies being made of iron. When the molten metal comes in contact with the surface of comparatively cold iron, it cools rapidly and forms crystals of hard, white cast iron for a greater or less depth in from the face, according to the mixture used, or the thickness of the iron portion of the mould called the *chill*, the remaining portion of the casting being relatively grey and soft. This sudden cooling of the iron prevents the combined carbon near the surface in contact with the chill from separating out, whereas the more gradual cooling of the interior portion of the casting results in its resuming its normal condition. The chill is always heated to a temperature well above that of the atmosphere of the foundry immediately before being set in the mould, preparatory to closing for casting, as, otherwise, any moisture present in the surrounding air, which in the case of the chill being used in conjunction with a sand or loam mould, there is almost sure to be owing to any dampness left in the sand or loam being driven out, which would once condense on the surface of the chill were it not ted considerably. The chills are usually heated in the to a temperature of about 200 deg. Fah., and their faces washed with a thin coat of blacking, wetted with molasses water, before being set in the moulds. In some foundries black lead is rubbed on the chills to prevent the iron from sticking, while in others oil is used. The oil should be light and clear and must be used sparingly, as, if too much is rubbed on, or a heavy oil employed, it will burn when the molten iron comes in contact with it, and the gas generated will throw the iron back from the face of the chill, with the result that the castings will appear dirty and streaked. When the chills are in constant use, and so situated in the moulds that the iron as it enters does not strike against their faces, but rises on them in a body, a smoother surface can often be obtained on the castings by not using any oil at all. Whenever possible the mould should be arranged and set for pouring in such a way that the surface of the chill does not lie horizontally, but when

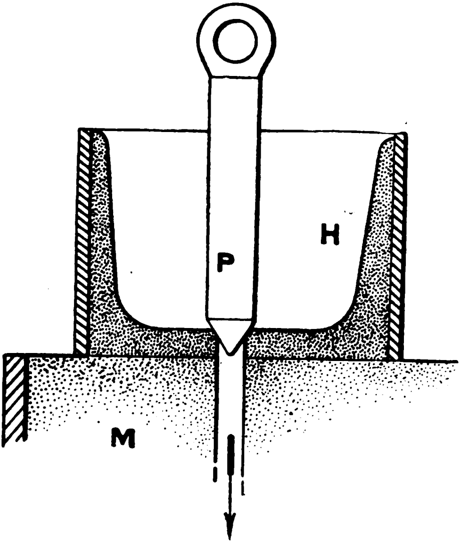

FIG. 187.

the nature of the job necessitates a horizontal position for the face to be chilled, care should be taken to make the runners and gates unusually large, and when pouring, let the metal go in with a rush, so that it may immediately cover the face of the chill with a body sufficient to counteract any tendency of the iron to bubble. To effect this it is a good plan to first pour the metal into a vessel H, fig. 187, surmounting the mould M, and then allow it to enter the mould by raising the plug P. By this arrangement the flow of metal is rapid at first, and gradually diminishes in speed as the head of metal decreases.

The chills are generally of cast iron, though in some instances wrought iron is used. An iron which makes a good chilled casting will make a good chill, and, as has already been mentioned, probably the best for the purpose is the cold-blast iron produced in Staffordshire or Shropshire. Chilled rolls and cast-iron wheels with chilled treads are, perhaps, the most important examples of chilled castings. A chilled roll for rolling plates or bars hot needs to have sufficient strength when heated to do its work. It should have a clear, hard surface, free from pinholes, cracks, or other blemishes, and sufficient depth of chill to allow of its being trued up in a lathe, say, once every week, until it has done a fair quantity of work; while at the same time the chilled portion must not be of such a nature as will shell off under fair treatment before the roll is worn out, nor must it be so soft as to wear out too soon. It will be seen that these requirements are antagonistic, since a roll made simply for strength under heat would not have the requisite hardness or depth of chill. Cast iron, to have its maximum strength, must contain about 1·8 per cent of silicon; but iron containing this quantity of silicon will not chill to any appreciable extent unless the sulphur is far above the amount that can be allowed in a chilled roll. Sulphur makes iron "hot-short," and for this reason it should not be much over 0·08 per cent in an iron used for chilled rolls, while the silicon should be kept down to about 1 per cent. Generally users ask for a certain depth of chill, some specifying to $\frac{5}{8}$ in., while others quote $\frac{3}{4}$ in. to $\frac{7}{8}$ in. for exactly the kind of work; then, again, many like to see a clearly-defined chill, whilst others prefer the chill to mingle well with the back. The depth of the chilled portion of the casting is largely influenced by the mass of metal in the chill, which, while being sufficient to conduct away the heat from the molton metal with the necessary rapidity to lower the temperature of the iron lying immediately against the chill from that at which it is poured (about 2,500 deg. Fah.) to that at which it solidifies (say, about 1,000 deg. Fah.) in a few minutes, must also be capable of absorbing the heat which will radiate from the still molten metal in the interior of the casting, in order that it may not re-melt the solidified and chilled skin.

For wheels the chills are never of less weight than the wheels themselves; usually they are from two to three times as heavy; whilst for rolls the thickness of the metal in the chill ranges from one-half the diameter in the case of the smallest rolls, say, from 4 in. to 6 in. diameter to one-third the diameter of the roll for those of from 28 in. to 30 in. diameter, the allowance for intermediate sizes being commonly $\frac{3}{8}$ in. of thickness per 1 in. diameter of roll. The thickness should never be greater than is absolutely necessary, since the thicker the metal in the chill the more liable it is to crack from the severe strain set up in it by the expansion of its inner portion when the intense and sudden heat of the molten iron first comes upon it. In the case of large chills it is usual to add to their strength by shrinking wrought-iron hoops round them.

In order to produce a uniform depth of chill, it is necessary that the roll should remain central in the mould as it cools and contracts. A plan which has been adopted for ensuring this is to make a number of grooves on the interior surface of the vertical mould, bevelled on their lower edge. Corresponding ridges are, therefore, formed on the casting, and the weight of the roll as it contracts causes it to slide down uniformly, and thereby maintain its concentric position. The grooves for the largest rolls need not be more than $\frac{3}{16}$ in. deep, so that the roll can be lifted out of the mould, and the ridges, being small, can be easily turned off.

Cast-iron car wheels with chilled treads have been largely employed in the United States for many years, while at the

present time some of the Indian and Colonial Government railways are also adopting this type of wheel in place of the steel-tyred and other types that they have hitherto used. The wheels are mostly cast with corrugated discs or plates, as shown in section at W, fig. 188, as a wheel of this form is not so liable to be subjected to an unequal strain in the metal as one cast with spokes. The design of the wheel is one of the essential factors in its manufacture, and should be left largely to the discretion of the manufacturer, for there are other considerations than the thickness of flange and shape of hub and tread which call for adjustment. A
e percentage of wheels that fail in the brackets can be
ed to poor design. Too light brackets will crack
e they cool more rapidly than the plate of the wheel,

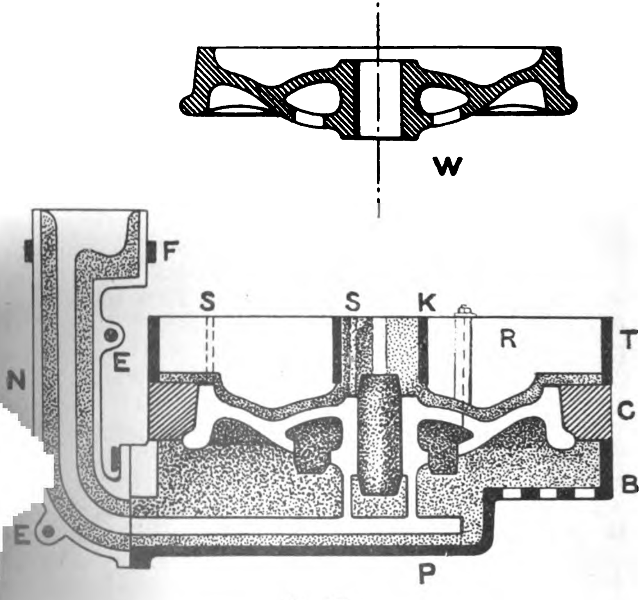

FIG. 188.

which causes a strain on them; while on the other hand too heavy a bracket will throw the strain on the plates, causing the plates to crack.

The treatment and handling of the hot wheels has also a great influence on their strength. Cold iron will produce seams in the treads and internal strains, because the molten iron sets in the mould as fast as it is poured. Hot iron, with slow and uneven pouring, produces uneven chill and internal strains; delay in getting the hot wheel into the annealing pits after being shaken out of the mould will also produce strains in the wheel by uneven contraction. To overcome these undesirable results, it is necessary to have hot iron and fast, uninterrupted pouring. The maximum limit of time occupied in pouring up a 33 in. wheel should not exceed twelve seconds. The wheels usually remain in the annealing pits for from four to five days.

In laying out wheel foundry floors, either the chills are arranged in a circle with a jib-crane in the centre, or they are placed in parallel rows, each row commanded by a light travelling crane. An annealing pit should be placed at the end of each row. The latter system is the more common, as it affords greater economy in space. The moulds should be set level for casting to avoid uneven pressure, as this is very liable to crack the skin by bursting it open. Any feeding that may be required must be done carefully, the rods being worked slowly and not rammed down suddenly so as to cause a pressure on the contracting shell, which is liable to crack it. Fig. 188 shows a cross-section through a wheel mould, the chill C being bolted in position between the top box T and the bottom box B. The runner box N is made in two parts, held together by a ring F and bolts E, E, and is secured to a flange on the bottom box by bolts, or by clamps and wedges. The cores between the plates are supported and held in position by rods which pass through lugs in the ribs R, joining the central ring K with the periphery of the top box. In some foundries the chills are coated every cast with a mixture of varnish and shellac. This gives the tread a fine texture and lengthens the life of the chills.

The strains set up when its surface is suddenly heated and expands will sometimes cause a car wheel chill to fly in pieces before the mould is half full of metal. To avoid this, chills have been made as illustrated at fig. 189. In order that the chill may expand uniformly, and exert an equal pressure on every part of the casting, it is cast in one piece, and consists of a number of comparatively thin segments H, which are separated by a narrow space S, and are connected to a ring L by arms N. The chill is placed between the top and bottom boxes in such a manner that air passes up between the arms, and so keeps the ring L cool. The expansion of the arms and segments causes the latter to close together.

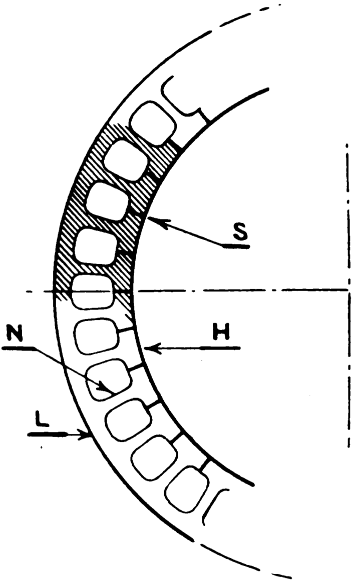

FIG. 189.

Another form of expansible chill is shown at fig. 190. This is provided with a number of chambers C, opening at top and bottom into two annular chambers E and F, through which water and steam circulate in the direction of the arrows. The chambers C are separated by cored spaces K and saw cuts S. Steam is first admitted to the mould to

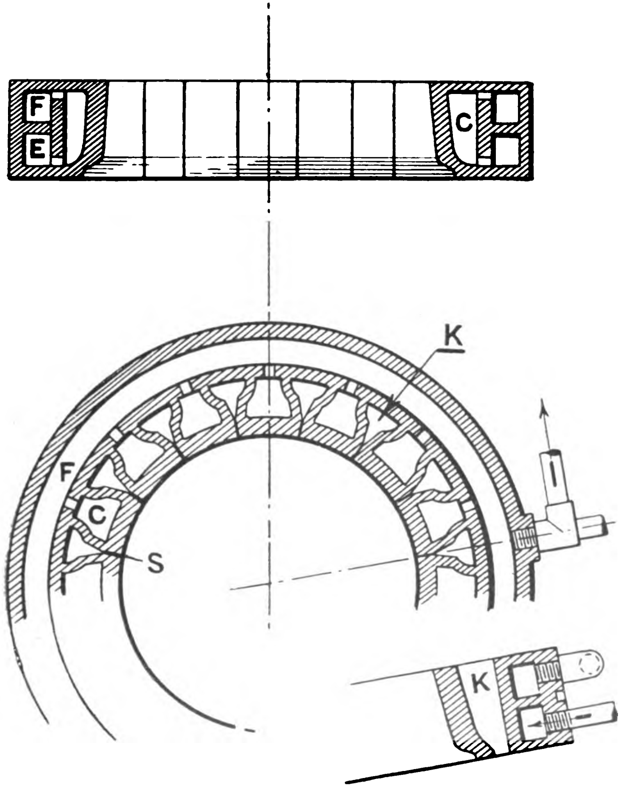

Fig. 190.

warm it, the metal is then run in, when the steam is shut off and cold water is circulated through the mould.

The success which has attended the introduction of the chilled cast-iron wheel is undoubtedly largely due to a persistency in the use of the drop and thermal tests. Manufacturers of this type of wheel will often protest against the thermal test on the score that in making wheels to meet this test they must do so at a sacrifice of the wearing qualities. This, however, is not the case, as analyses of the metal from wheels which did and which did not stand the test often show practically no difference. The difficulty, if any, lies more in uniformly applying the test, so that the molten metal poured around the wheel is at the same temperature

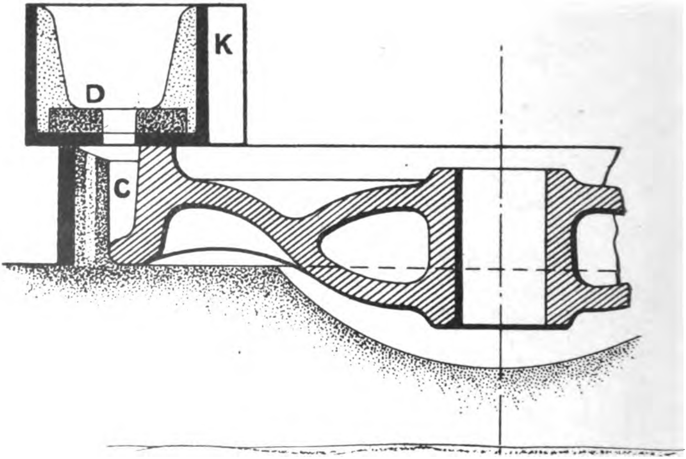

FIG. 191

in all cases. An approved method of applying the thermal test is as follows: The wheel to be tested is laid flange down in a sand bed, as shown at fig. 191, and a channelway C, $1\frac{1}{8}$ in. wide and 4 in. deep is moulded with green sand around the wheel, the clean tread of the wheel forming one side of the channelway, and the flange of the wheel its bottom. This channelway is filled to the top with molten cast iron, which must be poured from two ladles directly into the channelway, basins being formed of green sand, with a dry sand cake D, fig. 191, at their bottom, in cast-iron dishes K. The molten iron must be taken from the ladle directly after a tap for pouring wheels has been drawn from the cupola, and must be poured in to fill the channelway within one minute after the iron has been taken from the ladle containing the tap from the cupola. No puddling or cooling of the iron is permitted. Should the molten iron boil in the small ladles, they are re-filled until all indications of the boiling ceases before the channelway is filled. Two minutes after pouring ceases, an examination of the wheel is made, and if it is found cracked in the plates or through the tread, the wheels represented by the test wheel are rejected.

A wheel which will stand this thermal test will stand severe and continued brake application, and is sufficiently tough to ensure a good mileage; whereas one having a gritty, hard chill, and which fails under the thermal test, may stand the drop test or concussion in service, but will shell out quicker than a tough one, because it will not stand the heat that is caused by severe brake application. In America, the manufacturers are usually made to guarantee that the wheels which pass inspection for freight service will give five years' service or run 70,000 miles. If the wheel does not hold out this length of time, it must be replaced by the manufacturer. Comparing the limiting values for the chemical constituents of wheels previously given on page 47, with the analyses of a large number of wheels given by Mr. Henderson in a paper read before the American Society of Mechanical Engineers, at their Spring meeting, 1899, it will be seen that these limits exclude those wheels which broke through the rim in ten minutes or less under the thermal test, broke with twenty blows or less under the drop test, or gave less than two years' service. This last is important, as a wheel can easily be made to stand strains; but the wear will be unsatisfactory, and the metal must have enough chill to stand the abrasion of the track. It is possible to obtain a chill $\frac{3}{4}$ in. deep on the tread with the chemical compositions given.

The drop test is applied in two different ways, illustrated at figs. 192 and 193. Fig. 192 shows the method approved by the Master Car Builders' Association of America; and fig. 193 the "Barr" drop. It will be seen, on reference to fig. 192, that the falling weight W in the M.C.B. drop strikes the hub of the wheel, whilst in the Barr drop, fig. 193, it falls on to the single plate of the wheel. Wheels rarely fail in service in the hub or double plates, and even should a crack occur in these parts, the wheel does not necessarily become dangerous. On the other hand, if a crack occurs in the single plate P, fig. 193, the wheel immediately becomes dangerous, and will not run long before giving way entirely. For the M.C.B. drop test, the wheel is laid, flange down, on an anvil block A, fig. 192, having three supports S, on which the flange of the wheel rests. The weight striking

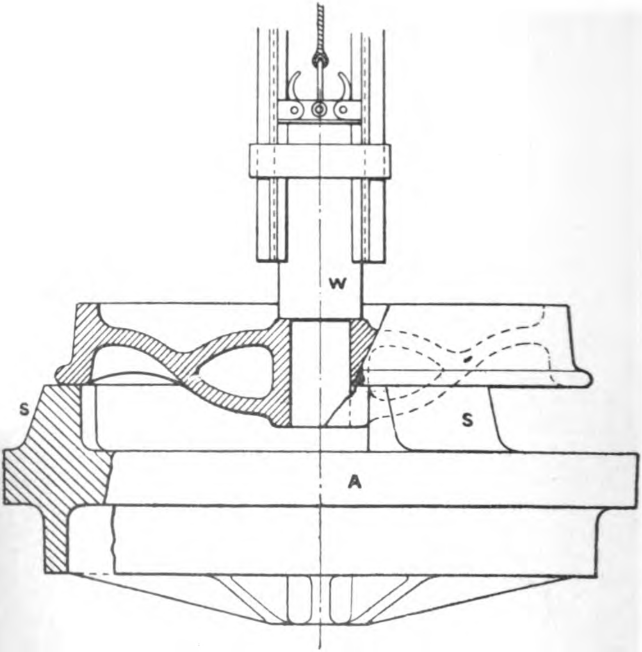

FIG. 192.

the hub allows the whole of the wheel to resist the concussion, whereas wheels tested under the Barr drop are placed flange downward on a flat surface anvil block R, fig. 193, and the wheel receives the concussion at one point only.

In the M.C.B. test the weight W, fig. 192, is 140 lb., and drops a distance of 12 ft. It trips automatically, and the wheel must stand ten blows before being broken in two, or the entire lot of wheels is rejected. If the wheel is not broken in two with ten blows, it is hammered until broken. The depth of the chill on the broken parts of the wheel is then measured to see whether it meets with the specification. In the Barr drop the hammer weighs 100 lb., and falls through 7 ft.

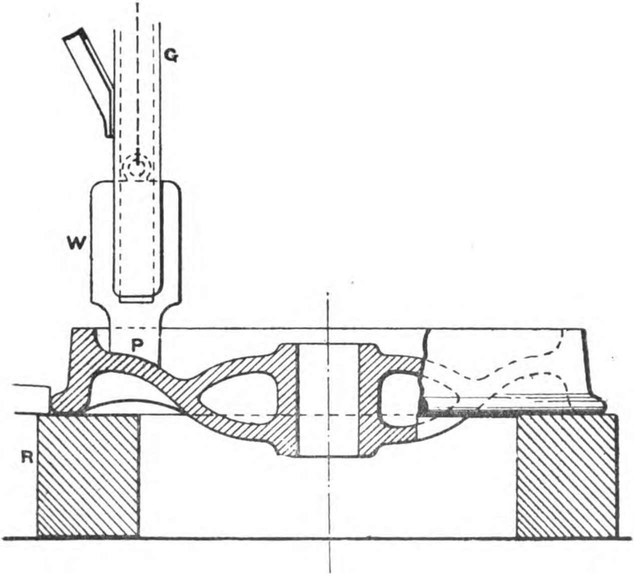

FIG. 193.

Charcoal iron is generally used for the manufacture of car wheels, although other irons have proved satisfactory in many respects, but do not give the chilling quality. Coke iron is, of course, much cheaper, and has in some instances yielded satisfactory results, but as a rule there is the trouble that it does not give the depth of chill required by the specifications of the railroad companies. Titanium has been used with some success in the mixture for car wheels, and also molybdenum, although the cost of the latter is so high as practically to prohibit its use for this purpose.

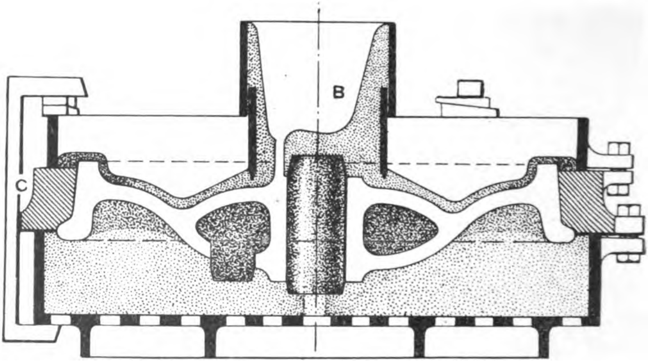

FIG. 194.

It will be noticed that the wheel mould illustrated at fig. 188 was arranged to be run at the bottom. In most wheel foundries, however, top pouring is the method employed, the moulds being arranged as shown at fig. 194, and the metal poured into the basin B, set directly over the wheel centre. A modification sometimes adopted is illustrated at fig. 195, the upper end of the central core C being cupped, and a number of gits F formed around it, as shown. This method of forming the inlet facilitates the rapid and quiet filling of the mould.

Chilled rolls are always run from below through a whirl gate conducted to the lower neck, as shown at fig. 196. The channel being led into the mould in a tangential direction, as indicated at W in the sectional plan, gives the molten metal a rotary motion around the axis of the roll as it rises in the mould. This motion carries the heavier and more pure iron outwards towards the face of the mould, while the sullage will concentrate and rise up the centre and collect in the feeding head N. Fig. 196 is a typical chilled roll mould, with necks and wabblers rammed up in dry sand from a pattern. The chill C has grooves G turned in its end faces to receive corresponding spigots formed on the flanges of the top and bottom flasks, and also three or more recesses H, fig. 196, near each end to receive the clamps for securing it between the flasks. The bottom flask parts at K L, to allow of the formation of the whirl gate. The runner box R is made in halves, held together in the same way as described in connection with the wheel mould illustrated at fig. 188, and is clamped to the bottom flask as shown at fig. 196. The cope and drag are rammed up on a cast-iron plate W, fig. 197, having grooves G turned in its upper face similar to those made in the chills, and also a central recess to receive the pattern P of neck and wabbler. The use of this plate ensures the necks being cast truly concentric with the body of the roll. Fig. 197 shows the bottom flask in course of being rammed up, the ramming having been completed up to the parting at K L.

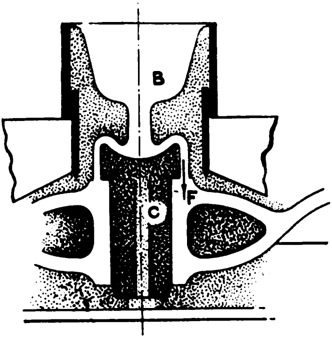

FIG. 195.

Chilled rolls, being required for so many purposes, vary considerably in size, which entails the expenditure of large sums of money to properly equip a foundry for carrying on their manufacture as a speciality. Rolls of different lengths

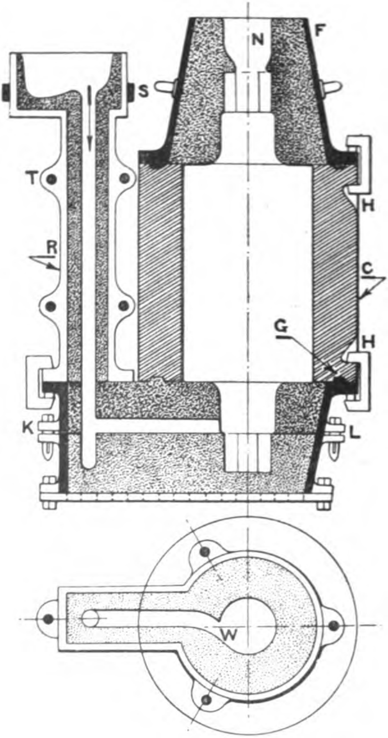

Fig. 196.

can be, and are, of course, cast in the same chill, the sand mould for the upper neck (as cast) being made in a sleeve which slides into the chill so far as is necessary to give the [illegible]ll its required length. This arrangement is shown at

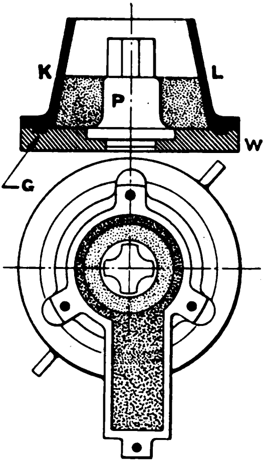

FIG. 197.

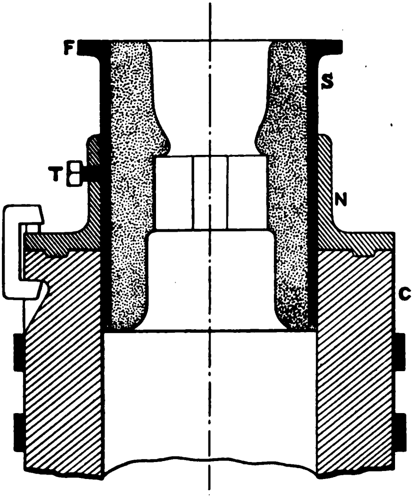

FIG. 198.

fig. 198. The sleeve S, cast with a flange F for handling purposes, slides through the sleeve clamp N into the chill C, and is held at the required height by three set screws T. These set screws are slacked back after the roll is cast, so as to allow the sleeve to sink into the chill with the contraction of the roll in cooling, thus relieving the upper neck from strain. The sleeve clamp N is formed with a spigot on its underside, which fits the groove turned in the end of the chill, and also the corresponding groove G in the plate W, fig. 199, on which the clamp is set to hold the sleeve S in position over the neck pattern P while it is being rammed up. For convenience in handling, the chills are sometimes made in sections, as shown at fig. 200, and provided with trunnions T. When made in this way, the surfaces meeting at L K, fig. 200, require to be carefully machined so that the joint is true and tight. Fig. 200 shows also a second ethod of securing the sleeve in the end of the chill, distance ces D holding it at the required height, while bolts B and nding plate P secure it in position.

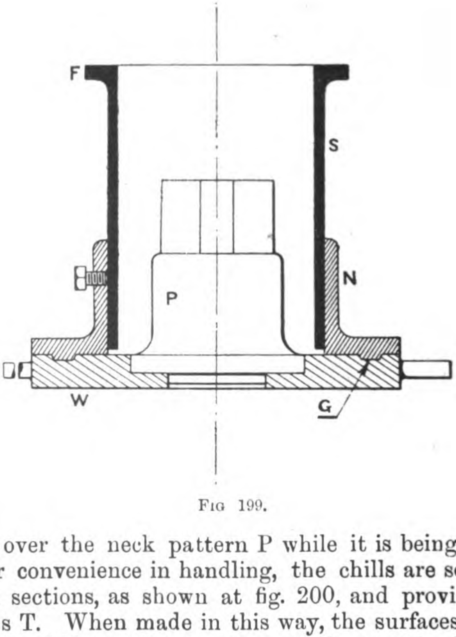

Fig 199.

Practically the same methods prevail in so far as the mechanical manipulation goes in nearly all chilled roll foundries, yet by slight variations in the mixture of irons employed, and in the details of practice which are perhaps not well understood by the manufacturers themselves, rolls are produced the performance of which in actual practice differ widely. A great deal has been done in the way of improving the working qualities of the rolls, but there still remains much to be accomplished. When in use the rolls should be kept cool by a copious supply of tepid water, as otherwise the quick succession of hot blooms will soon cause the temperature of the body of the roll to rise to that of oxidation, while that of the necks must of necessity be kept low by a good supply of water in order that the lubricant may not burn off or the brasses cut. The consequence is, that an unequal expansion takes place in the body and the neck, developing a weakness which eventually shortens

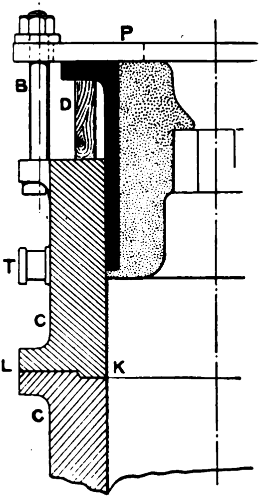

FIG. 200.

the life of the roll. In many hot-rolling sheet mills these conditions still prevail, no attempt being made to cool the body of the rolls, but a good supply of water is provided to keep the necks as cool as possible. Disaster is often averted in such instances by the fact that the rolls are made with necks of abnormally large diameter, approaching 80 per cent of that of the roll.

When a roll breaks at the neck it is usually at the end corresponding with the top of the casting, and is often primarily due to its having been cast with too small a shrink head, or to bad feeding. A plan successfully adopted in more than one roll foundry is not to use feeding rods at all, but make the feeding heads long, without a neck, and of the full size of the wabblers. When casting, as soon as the metal rises in the mould to the level of the top of the upper wabbler the pouring is stopped, and the feeding head above is filled up with hot iron brought direct from the cupola in hand ladles. The surface of this hot iron in the feeding head is covered with sand, and the feeding of the casting proceeds without any further handling. Such heads are cut off the castings in the lathe.

A roll casting should remain in its mould until perfectly cool. Many failures of chilled rolls might be traced to defective treatment in their early history. Too often, in the rush of every-day practice, they are taken out of the moulds in a condition in which the interior must be more or less plastic—at all events at a very high temperature. They are run out, perhaps into a yard, where they may even be exposed to rain, treatment which is quite sufficient to establish a want of that physical uniformity which is so essential to the good life of a chilled roll.

At one time it was generally held that white or chilled iron had no degree of hardness, and that the depth of chill determined the hardness. Professor A. Ledebur, in a paper read before the Iron and Steel Institute,* shows clearly that this is not so, and explains the reason why similar depths of chill do not present similar degrees of hardness. He points to the fact that the carbon may exist in at least

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* *Journal of the Iron and Steel Institute.* No. 2. 1893.

three states, which he describes as (i.) hardening carbon; (ii.) carbide carbon; and (iii.) graphite and temper carbon.

Professor Ledebur gives the following analyses of the chilled portion of two rolls A and B, which stood well, and suggests that it may be accepted that good chilled castings should never contain any much larger percentage of hardening carbon than was found to be present in roll A, as their brittleness would otherwise become too great.

	Roll A.	Roll B.
	Per cent.	Per cent.
Hardening carbon	0·58	0·45
Carbide carbon	2·43	0·46
Graphite and temper carbon	0·19	1·93
Total carbon	3·20	2·84
Silicon	0·83	0·80
Manganese	0·15	0·16
Phosphorus	0·88	0·88
Sulphur	0·10	0·10

Such a division of the carbon will doubtless enable chemistry to account for some physical effects which so far have not been intelligently explained.

For chilled work the total carbon should be as high as possible, as the greater the percentage of carbon, the higher can it be thrown into a combined state by the other metalloids, chiefly sulphur, manganese, and phosphorus; and hence the more carbon present the deeper can work be chilled, all other elements remaining fairly constant.

Although at the present time the most general practice is to obtain hardness by means of sulphur, there are many foundrymen alive to the fact that, wherever manganese can be applied to affect the carbon in preference to sulphur, better results in casting and the product may be expected. Manganese has the effect of making the chill less liable to chill-crack from heat than when the chill is chiefly promoted by sulphur, and also causes a more gradual change from the white to grey in chilled castings. The action of manganese, if not used in sufficient quantity, may often be neutralised by the sulphur it expels; hence its power to increase hardness is considered by some to be unimportant.

The degree of hardness of the chilled portion of a casting is often as important as is its depth, and probably chemistry has proved of greater benefit in making suitable mixtures for the various classes of chilled castings than for any other line of work. The success of chilled work is undoubtedly more dependent upon the use of a proper grade of iron than is the case with grey iron castings, for with the latter a considerable deviation from the most suitable mixture will often do no more injury than entail some extra labour in machining or in finishing the castings; whereas if the mixture for chilled work departs much from the best to be attained the castings will generally prove worthless, owing to the chilled portion not being of the depth or hardness suitable for the required purpose. For this reason this branch of ironfounding requires a more than usually extended system of tests. When cupola melting is employed it is customary in some foundries to test each tap from the cupola to the mixing ladles before any portion of it is allowed to be poured into a mould. The test sought at this early stage is, of course, only to ascertain the chilling quality of the iron, and for this purpose a bar about 2 in. square by 6 in. long is cast with one side against a chill. This cools very rapidly, and is assisted in doing so by being immersed in water, after which it is broken. Should the depth of chill not be what is required, the iron is either poured into moulds for castings other than those for which it was melted, or is modified with special irons, when, if the proper result is not accomplished, the iron is poured into pig beds, and later returned to the cupola and melted again. Comparatively little can be done to change the composition of cupola melted metal after it has been tapped, whereas in melting iron in an "air furnace," as has already been explained under "Reverberatory Furnaces," there is a chance to change its composition from what a "chill test" might prove it before the iron would be tapped or poured to a mould.

Chilled work at the present time forms no small part of ironfounding, as, besides the more important classes of work already mentioned, chilled castings are now largely employed for various other purposes, such as crushers for breaking ores, die presses and anvils, frogs and switches for railroads, axle bearings, railway chairs, furnace bars with chilled fuel faces, and many other classes of work required to stand wear and tear, and not especially needing machining.

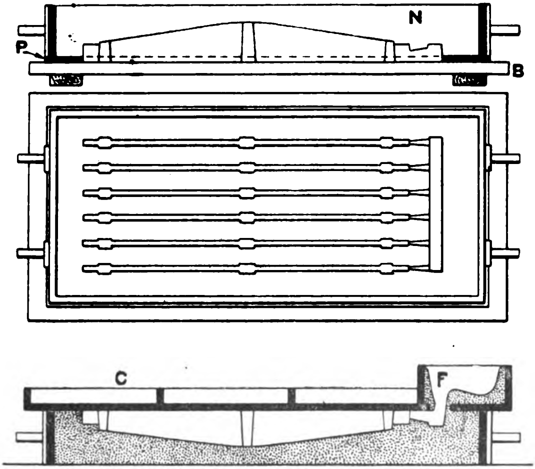

Fig. 201.

Fig. 201 illustrates a method of moulding and casting firebars with a chilled fuel surface. A number of the firebar patterns are secured face downwards on to a board B, a stripping plate P is placed over them, and the flask N laid on, filled with sand, and rammed up. The whole is then inverted, the patterns withdrawn through the stripping plate, which is also removed and replaced by the chill C, into which water is poured.

Castings resembling ordinary chilled castings are now made by a method of centrifugal casting introduced by

P. Huth.* The mould is caused to rotate, and then hard metal is poured in. This flies to the sides, and softer and more ductile metal is afterwards poured into the hollow centre, thus giving the casting a soft core and a hard face.

CHAPTER XV.

MALLEABLE CASTINGS.

ALTHOUGH the fundamental principles of the malleable cast-iron process were published by Réamur as early as the year 1722, it was not carried on as an industry until much later. The industry has, however, developed so rapidly in recent years that its product, now adapted to an almost unlimited variety of work, is a recognised and highly-essential article of commerce. In this connection malleable cast iron occupies a place between grey cast iron and wrought iron, possessing a higher tensile strength than the former, with somewhat less elongation than the latter.

The generally-accepted theory of the malleable cast-iron process is to decarburise the metal by means of a sesquioxide, which will impart a portion of its oxygen to the carbon in the metal at a red heat, forming C O, which is given off, thus extracting the carbon. The oxidising reagents usually employed are rolling-mill scale and red hematite ore. Mill scale requires no grinding or other preparation than to oxidise or rust it, as the common saying is. This is best done with a weak solution of sal-ammoniac. Care should be taken in selecting scale as low in sulphur as possible, and free from foreign matter. When ore is employed it is used several times, but either requires to have the addition of some fresh unburnt ore every annealing, usually three or four parts of spent ore being mixed with one of raw ore ground to the size of a pea, or is oxidised by prinkling the spent packing, spread on the floor, with a eak solution of sal-ammoniac. The spent packing is, of

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* See Stahl und Eisen, vol. xvii., pp. 572, 573.

course, finely divided, as it falls through the crevices in the tumbling barrels, into which the whole charge is placed.

Briefly stated, the conduct of the process is as follows: Castings, made from white or mottled pig iron low in silicon, phosphorus, and sulphur, are packed with mill scale or with ore in covered cast-iron annealing boxes. These latter, when charged, are stacked in piles in some form of direct-fired furnace, and subjected to an even temperature of about 1,850 deg. Fah. for a period of from eight hours or so to as many days, according to the size and character of the castings, when the furnace is cooled down gradually, and the boxes withdrawn and allowed to get quite cold before being emptied. The packing must be done evenly, care being taken that the castings do not come in contact one with another at any point, for should this occur the annealing will not proceed properly. Small articles can be almost completely decarburised, and thus rendered malleable throughout; while larger ones can be greatly increased in toughness by decarburisation from the outside for some distance inward.

The major portion of the carbon content of white cast iron exists as the carbide Fe_3C, which easily breaks down under the conditions which prevail during annealing to what Professor Ledebur calls "temper carbon," and this is slowly oxidised to CO by the influence of the packing, and is burned to CO_2 at the box joints. At the end of the process the carbon remaining in the casting is nearly all graphitic, due of course to the fact that graphitic carbon is very slowly oxidised. This graphitic carbon found in the castings after annealing, although capable of being separated from the iron, and also chemically determined in the same manner as the graphite which solidifies out from grey iron during cooling, differs from the latter, however, in that it has none of the bright scaly lustre, and its combustion is far more difficult. It is in fact the allotropic form of graphite to which Professor Ledebur has given the name "tempering graphite carbon." This change in the condition of the carbon, in irons of different compositions, occurs at different temperatures, but the range is not great, lying between the melting points of silver and copper, and may, therefore, be approximately taken as 1,850 deg. Fah. For irons of similar composition the length of time the full heat is required to be continued to complete the annealing effect in any casting depends upon the sectional area of the casting.

The chemical and physical condition attending the formation of this allotropic graphite during the annealing process, and its probable molecular form, as well as the position it occupies in the structure of the casting, which differs so remarkably from the position occupied by graphite in grey cast iron, are fully described in a paper by Mr. Charles James, read at the Franklyn Institute, Philadelphia, in 1897. The change is effected by the process of diffusion, and affords a striking example of the solution of one solid in another at temperatures below the melting point of either. By prolonged heating this allotropic form of graphite becomes changed to graphite identical with that found in grey iron, when it occupies a similar position in the iron structure, and greatly injures its physical qualities, so that over annealing should at all times be carefully avoided.

The only change, except loss of silicon, effected by the annealing process is one of condition in the carbon, and for this to be satisfactory the chemical composition of the castings to be annealed must be suitable. They should contain but little graphitic carbon, which implies that the iron used in their manufacture should be low in silicon, although silicon exerts a great influence upon the carbon during the annealing process, its presence being, in fact, a necessary condition to the carbon change. With very low percentages of silicon in the castings it becomes difficult, or even impossible, to effect the carbon change, no matter how long the iron is exposed to the heat treatment.

From the results of some experiments recently carried out by Mr. Charles James, it would appear that the relative amount of carbon that can be changed in condition during annealing is approximately directly proportional to the amount of silicon present. Of these experiments the following may be cited:—

A casting having a thickness of about five-sixteenths of an inch, and weighing less than 1 lb., was selected, and on analysis showed—

Combined carbon	2·08 per cent.
Graphitic carbon	none.
Silicon	0·42 per cent.
Manganese	0·05 per cent.

This casting was subjected to the usual treatment, but after being annealed for 3½ hours, still had a hard appearance with a white fracture, and showed no graphitic carbon on analysis. It was then returned to the oven and annealed for a further 3½ hours, after which its appearance was still unaltered, and the casting contained only a trace of graphitic carbon. Subjected to a third annealing of 3½ hours, the casting was still hard and had a white fracture, and the analysis gave—

Combined carbon	1·90 per cent.
Graphitic carbon	0·14 per cent.

Thus only 0·14 of 1 per cent of the combined carbon had been changed to the graphitic state after the casting had been exposed to the full annealing temperature for a period of 10½ hours, and besides which it had passed three times through the much longer period of heating and cooling. The percentages of carbon, silicon, and manganese were all comparatively low in this example, but in others, when both carbon and manganese were present in the castings in fairly high percentages, the castings, after repeated annealings, remained white and brittle.

That the extent of the change is governed by the amount of silicon present is indicated by the following analyses, made after annealing, of three samples, which were all selected from the same cast, annealed in the same furnace, at the same time, and under identical conditions:—

	A.	B.	C.
	per cent.	Per cent.	Per cent.
Combined carbon	1·49	1·57	1·87
Graphitic carbon	1·40	1·33	1·03
Manganese	0·126	0·130	0·126
Silicon	0·56	0·45	0·31

In all three samples the total carbon and the manganese are practically the same and of comparatively high percentage, while the silicon varies, and with it the condition of the carbon, which is less and less changed as the percentage of silicon in the iron decreases.

With a suitable amount of silicon present, castings with low or comparatively low carbon, such as the one forming the subject of the first analysis given above, and which contained 2·08 per cent, can have the condition of their carbon content readily changed by annealing. As the result of direct experiment with a comparatively low carbon iron containing 1·94 per cent of combined carbon, a trace of graphitic carbon, 0·64 per cent of silicon, and 0·09 per cent of manganese before being annealed, showed, after being annealed for 3½ hours, an entire absence of combined carbon, a little under 2 per cent of graphitic carbon, 0·62 per cent of silicon, and 0·11 per cent of manganese.

The influence which manganese exerts upon the carbon during the annealing process is of a different character to that exerted by silicon, and has not nearly so marked an effect on the carbon change. Silicon acts directly upon the carbon, compelling it to change its condition, whereas the action of manganese is only indirectly upon the carbon through the silicon which it protects from oxidation. Comparatively high manganese in this way assists the carbon change and shortens the time necessary for its completion.

Manganese is also said to be a safeguard against scaly castings. It frequently happens that where a number of small castings are annealed in ferric oxide in the same box some will scale and some not. In such cases it will invariably be found that apart from faulty packing of the castings, those which are scaled contain a lower percentage of manganese than is usual in good castings. Thus in one particular case known to the author, a scaly casting showed 0·082 per cent, while a good casting packed and annealed with it in the same box showed 0·27 per cent of manganese.

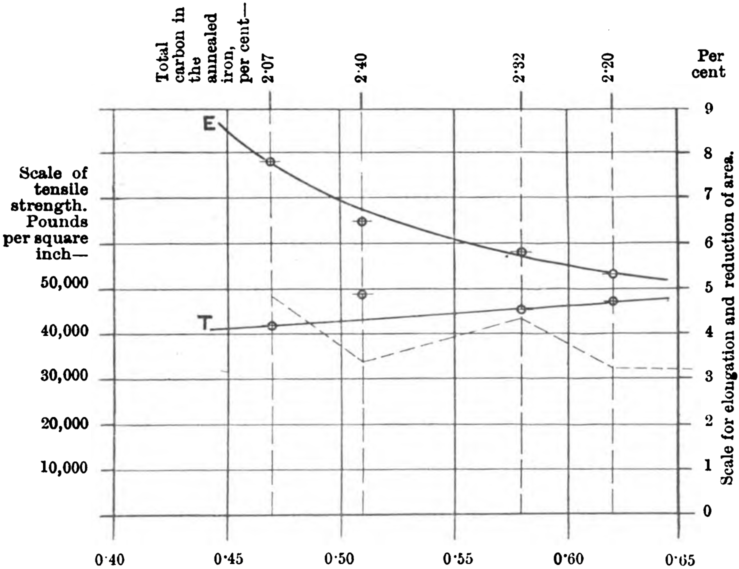
Phosphorus, if not above 0·15 per cent, is a very useful agent, as it helps to maintain fluidity in the metal. An excess of this element is liable to harden the product after annealing. Coke iron rarely contains more than 0·18 per cent of phosphorus. As in other branches of ironfounding, sulphur in appreciable quantities is extremely deleterious to the product, being, in fact, the worst feature in malleable iron casting. The most destructive features of high sulphur and phosphorus are the small cracks, like incisions, over the surface of castings. In physical tests these cracks play a considerable part in the questions of elongation and reduction of area. While it is quite possible to secure a high tensile strength with these elements high, yet elongation will be small, and the iron will have a short, sharp break. This is shown by the following results of tests carried out in the ordinary course of business, with samples of iron after annealing, at a malleable ironfoundry in America :—

	A	B	C	D
Total carbon, per cent	2·42	2·72	2·67	3·01
Sulphur, per cent	0·047	0·052	0·058	0·061
Phosphorus, per cent	0·216	0·272	0·172	0·197
Ultimate tensile strength, pounds per square inch	47,620	49,500	51,000	49,000
Reduction of area, per cent	2·02	1·07	0·82	1·23
Elongation in a length of 6 in., per cent	1·83	3·0	1·50	2·33

In offering malleable castings to the commercial user, an article possessing ductility rather than abnormally high tensile strength is what its physical tests should show. A very good specification would be: Ultimate tensile strength 42,000 lb. to 45,000 lb. per square inch, with an elongation in a length of 6 in. of not less than 6 per cent.

In the early days of malleable castings charcoal iron was exclusively employed owing to its uniform low sulphur, due to the purity of the fuel used; whereas in coke iron there is no one metalloid (barring silicon) which shows such variety. With the rapidly-increasing tonnage demand of more recent years, coke iron has necessarily been introduced, and in many quarters has entirely superseded charcoal.

The charcoal iron originally used for malleable castings was cold-blast iron, but at the present time, whatever is still used, is warm blast. It is claimed by some that charcoal iron possesses the quality of having its carbon more intimately associated with the iron, so to speak, than is the case with coke iron, and for this reason the combination is said to be effected earlier and easier. This is a great advantage in the casting of light work, making it possible to pour the metal while its silicon content is still practically undiminished, thereby guaranteeing a hot penetrating liquid. With an all-coke mixture for light work, with its carbon in an almost free state, a large quantity of its silicon is burnt out while endeavouring to effect the combination of its carbon. This feature presents itself repeatedly in practice, for such metal will often be hot enough to pour, yet is kept in the furnace because tests show graphitic carbon, thus compelling the melter to hold the heat longer than should be necessary. A heat should be so calculated chemically that when the carbon is in combination it should be just the point for tapping out. The state of the carbon in the casting prior to annealing depends almost entirely upon the silicon the latter contains, and the casting temperature. As previously explained, silicon holds the carbon in certain ratios. There cannot be high silicon and low carbon in the iron, as these two elements must act jointly in eliminating each other. The presence of too much silicon gives the finished castings a steely fracture; if above 0·75 the metal may show high tensile strength, but with little elongation. Fig. 202 gives the results of a number of tests showing the influence of silicon in the annealed castings as affecting tensile strength and elongation. These specimens were all cast from mixtures of practically the same composition, the differences in the finished castings being due to variations in working. The total loss of silicon from the original mixture to the annealed castings—the major portion of which takes place during melting, and the balance during [illegible]nealing—will be about 40 per cent when the mixture is [illegible]perly worked. The results of an interesting series of [illegible] bearing on this point are shown plotted on the diagram, fig. 203. These tests were taken from regular heats, and the percentages of other metalloids remained practically constant, sulphur averaging 0·043 per cent, phosphorus 0·124 per cent, and manganese 0·58 per cent. Where there was a decided loss in silicon the percentage of elongation was good, while the tensile strength was well maintained. As regards the effect of the casting temperature, assuming a proper amount of silicon to be present, a very simple experiment can be made to demonstrate its importance. From a quickly made heat, dip out off the top of the bath sufficient of the metal to make a fairly heavy sectional casting. Do this at the same time that the heat is



Percentage of silicon present in the iron after annealing.

NOTE.—Curve E shows the percentage of elongation of annealed specimens measured on a length of six inches.

Curve T shows their ultimate tensile strength in pounds per square inch, and the dotted line the approximate reduction of area.

FIG. 202.—Diagram showing influence of silicon on the ductility of malleable cast-iron.

Percentage of silicon—

	In mixture.	In annealed castings.	Loss
	0·88	0·52	0·36
N	0·73	0·48	0·25
H	0·79	0·52	0·27
	0·77	0·59	0·18
	1·09	0·90	0·19
A	0·79	0·68	0·11
B	0·77	0·66	0·11
C	0·79	0·68	0·11
	0·76	0·73	0·03

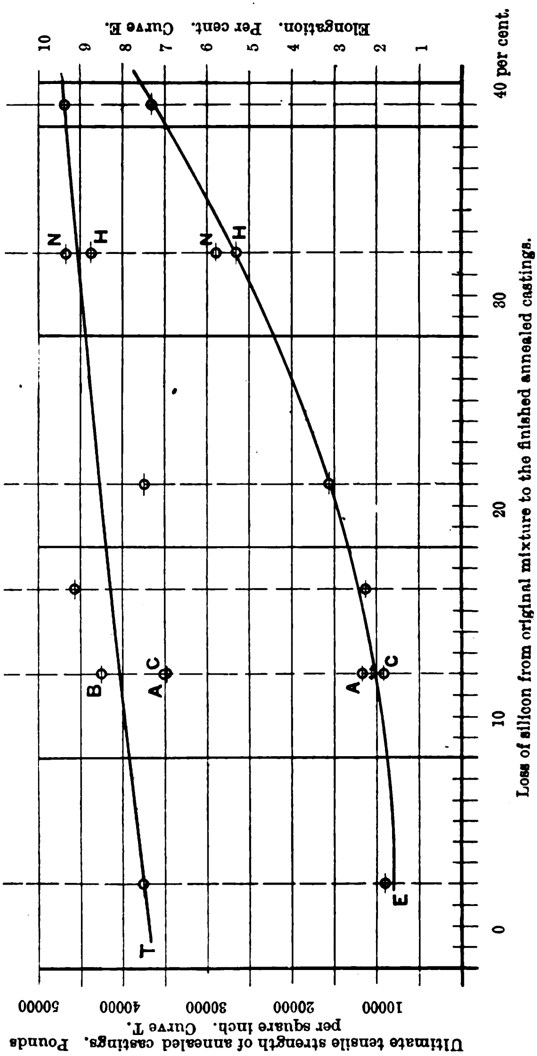


FIG. 203.—DIAGRAM SHOWING EFFECT OF LOSS OF SILICON.

tapped, and pour the first iron into a similar casting. The first will be white, and the other nearly grey. The silicon of both castings will, or should be, identical, yet the difference in temperature between top and bottom of the bath is sufficient to make a good iron of the first and a failure of the second. Here then is "high" and "low" iron in the same heat, and the wise man pours the first of the tap into light work and the end of the heat into the heavier castings. A reverberatory furnace charged with, say, 10 tons of metal, and taking something like half an hour to run out, cannot produce metal which may be called uniform. As soon as the metal has been brought up to the requisite heat to ensure all the carbon being in combination, the quicker it is discharged from the furnace the better will be the ensuing product. After this heat point has been reached, the continued blast necessary to maintain the heat in the metal to a suitable point for pouring works havoc with those metalloids which affect fluidity, but, on the other hand, enhances the chance of a better iron physically by serving to reduce the carbon and silicon. Thus we realise how impossible it is for a reverberatory furnace product to rival open-hearth steel as regards uniformity, or even in many cases that of a well-managed cupola on grey iron. When carbon and silicon have been reduced to a certain specified point in open-hearth steel practice, the charge is drawn in bulk, and there is, therefore, no further chance for a chemical or molecular change.

In grey iron cupola practice, the fact that fresh raw material is constantly coming in contact with fuel insures, in a way, uniformity of the grade of metal at the tap hole. In an air furnace the length of time that the molten iron is kept in contact with the flame incident to pouring of necessity affects the molecular conditions, and accounts for many variations met with in the annealed castings. The difference in the grade of the first and last metal of an air furnace heat is not so marked with light work mixtures as with those for heavy work. With the latter, the first metal drawn off from the furnace will generally be of more open grain, producing less ductile castings after annealing than the last, owing to its being higher in total carbon, etc. The following tests, taken in each instance from the extremes of a number of heats, demonstrates this fact clearly :—

	A.		B.		C.		D.	
	First iron.	Last iron.	First iron.	Last iron.	First iron.	Last iron.	First iron.	Last iron.
Silicon	0·89	0·72	0·72	0·68	0·68	0·62	0·91	0·62
Total carbon	3·29	3·07	3·37	3·09	3·42	3·27	3·52	3·23
Tensile strength, pounds per square inch	43,000	42,000	52,000	46,000	49,000	42,000	46,500	42,700
Percentage of elongation in a length of 6 in.	3·33	3·33	3·37	5·23	2·93	4·27	4·33	6·16

The cupola is not used very extensively in the production of malleable casting, except for light work of thin sections. It cannot be successfully employed for heavy work, owing to the difficulty experienced in combining carbon sufficiently to ensure the possibility of pouring large castings, and also from the fact that there is no method of puddling or mixing metal except in the tapping ladle. The chief advantage of cupola melting is economy in fuel consumption, which is no mean consideration, while its great drawback is the proclivity of cupola metal to absorb impurities from the fuel, principally sulphur.

The increasing need for economy of production marks the present as essentially a coke-iron period, and, considering the desirability of using all coke iron, it is suggested that the coming ideal melting furnace of the future for malleable work is a modified form of the Siemens-Martin type of open-hearth furnace.

Open-hearth furnaces are already in use in malleable iron foundries employed on heavy work, and are producing some of the most remarkable iron on record. At one foundry an ordinary Siemens-Martin acid open-hearth furnace is employed. The whole heat of eight tons is tapped into a reviously heated ladle, the time occupied being less than ne minute. In this way the iron, after being refined to the sired point, is immediately removed from any possible rther chemical or molecular change, and the resultant castings show a remarkable degree of uniformity as compared with the product of an ordinary air furnace. A few samples of the results of physical tests obtained are given below :—

	A.	B.	C.
Ultimate tensile strength, pounds per sqnare inch	48,000	49,000	52,000
Elongation in a length of 6 in. .... per cent	7·0	6·5	7·33
Reduction of area ....per cent	11·12	10·12	6·42

The suggested modified open-hearth furnace would resemble the ordinary Siemens furnace, in that its heat conditions would be as readily controlled, producer gas being employed as in the steel furnaces. The regenerative chambers would also be retained, but it would have for a lining a dolomite composition which would aid the elimination of phosphorus and sulphur, leaving the manganese and silicon free to act upon the carbon. Such a lining would last at least four months, as compared with that of an air furnace, which is considered to have done well if 18 heats, representing about one week's work, are melted before it requires renewal. There would also be absolutely no danger arising from an all-coke mixture, and castings could be offered far superior to any produced by the best charcoal iron extant.

Fig. 204 will serve to explain the action of the regenerative furnace. The source of heat is a hydro-oxygen flame, the hydrogen being usually from the carburetted hydrogen of coal gas, and the oxygen from atmospheric air. These gases, before they are combined, are heated by the exhaust heat of the furnace, which, in the ordinary reverberatory furnace passes directly to the chimney, but in the regenerative furnace is utilised to heat a chamber or chambers composed of brick checker work. The atmospheric air is introduced by means of a valve AV, fig. 204, and the gas supply through the gas valve G V. In the sketch, fig. 204, the mixture is indicated by the arrows to be entering the right hand side R of the furnace. Becoming ignited as it passes up the passage way leading from the regenerative chambers *b b*, the resulting flame is directed by the roof on to the metal, and any heat which is not absorbed by the latter passes away by the left side L of the furnace, and is largely intercepted by the regenerators *a a* on that side, the products of combustion passing to the chimney at about 300 deg. Fah., or at a temperature about 400 deg. to 500 deg. lower than that at which they enter the regenerator chambers.

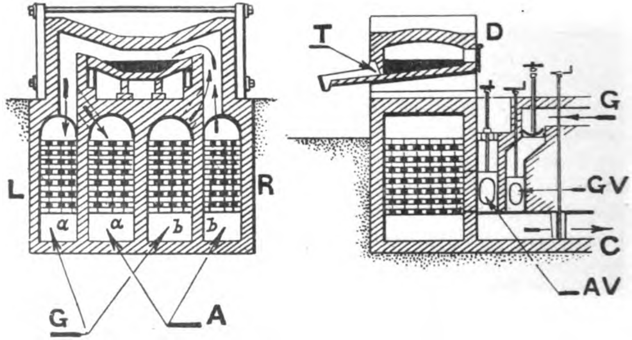


FIG. 204.—Siemens Regenerative Furnace.

G V, Gas valve.
A V, Air valve.
D, Charging door.
T, Tap hole.
C, Outlet to chimney.
G, Gas supply.
A, Air supply.
a a and *b b*, Regenerator chambers.

After a time the bricks become white hot, when the valves A V and A G are reversed, thus allowing the gas and air to enter first the chambers *a a* on the left side L of the furnace, and leave on the opposite side. Doing so it is evident that the heat which was absorbed in the last operation by the left-hand regenerators *a a* is now taken up again by the entering gases, and the checker brickwork of the right-hand regenerator chambers *b b* in its turn receives the rejected heat.

By this means a large amount of heat is made useful which would otherwise be wasted, the valves being reversed regularly whenever the bricks acquire too much heat.

The open-hearth furnace, when used for malleable, can be operated at a much higher temperature than air furnaces, and the make up of a heat may include a higher percentage of wrought scrap, which, by reason of its low carbon, forms an attractive feature in the mixture. The flame being very intense oxidises the metal rapidly, and the combination of carbon is effected long before the metal is hot enough to flow.

The suggestion of a basic lining for furnaces melting iron for malleable castings is not new. In 1891 such a lining was used in an air furnace at the Chattanooga Malleable Iron Works in order that coke irons containing too high a percentage of both silicon and phosphorus for the ordinary acid hearth might be used. The castings produced were of excellent quality, but the fact was developed that the ordinary air furnace was not suitable for a basic lining made of shrunk dolomite if it was to be chilled off every day after tapping. The metal changed, and became refined more rapidly on the basic than on the acid hearth. In fact, with heats of 8 to 10 tons run through a small tap hole, and caught in hand ladles, as usually practiced, the last half of the metal would be refined too much and become too sluggish to pour the castings successfully. This difficulty was encountered with 6-ton heats, and led to the adoption of the steel works practice of tapping the metal rapidly through a large hole into a storage ladle, from which the metal was re-poured into the small hand ladles, and from them into the moulds.

Besides the advantage possessed by the regenerative open hearth furnace of the possibility of melting iron away from the contaminating impurities contained in coal and coke, it also shows great economy of fuel over other types, and where malleable iron founders are not afraid of the expenditure of the necessary capital there can be no doubt as to the possibility of reducing the cost of production by introducing a basic-lined, open-hearth gas furnace, working with regenerators. The best results would be obtained with a tilting furnace, operated continuously. Liquid metal charges would also be required if a large output is desired from one furnace, so that in the absence of liquid blast-furnace metal a cupola would be necessary to melt the pig iron.

The method of operation would be as follows: Assuming we have a tilting furnace of about 12 tons capacity. In this furnace a heat of eight tons would be refined to the desired point to make satisfactory castings, but instead of tapping this into the ladles, four tons—preferably of liquid metal—would be added to the refined metal in the bath. The percentage of silicon in the added metal should at least be twice as high as in the refined liquid metal in the bath. The result would be that the impurities in the four tons would be immediately reduced by mixture alone, and the action of the oxide of iron in the slag would rapidly bring the silicon and carbon of the entire bath down again to the point required for good castings. As soon as this condition was obtained, the furnace would be tilted and four tons poured out, when the operations just described would be repeated again and again. Slag would, of course, be drawn off the bath through the slag spout as often as desired, or slag-forming fluxes added if found necessary. Working under these conditions a furnace charged with liquid metal would make four tons of refined metal in rather less than an hour. It could, of course, be purified in considerably less time, but would probably not have attained the necessary degree of fluidity. If the silicon in the added liquid metal is high it will add heat to the bath by its oxidation, and so reduce the time required for bringing the bath up to the desired point. The output would thus reach some 28 to 32 tons of refined metal per shift, and would necessitate continual pouring off throughout the day. The furnace would also have to be kept hot, and charged with solid stock during the night, so that the bath would be ready to receive the liquid metal for the next day's work.

The leading advantages of the basic lining, as applied to malleable work, may be summed up as follows:—(i.) Greater uniformity of product; (ii.) shortening of the period of annealing; and (iii.) the enlargement of the sources of raw material—coke irons of more or less irregular silicon contents, and having high sulphur and phosphorus becoming adaptable, since both sulphur and phosphorus can be reduced, which is exactly the opposite to what is occurring with present practice, in which phosphorus constantly increases in the acid hearth from the waste of iron due to re-melting and oxidation from the air blast. This has to be rectified by the use of pig iron containing less phosphorus than the sprues and wasters re-melted.

The composition of the furnace charges for malleable work is generally regulated by the silicon content, which usually varies from about 0·90 per cent to 1·25 per cent, according to the description of castings to be made; the higher percentages of silicon being employed when very hot and fluid metal is required.

As soon as the charge has completely melted the bath is well rabbled, to obtain as complete a mixture as possible. Some of the metal is then dipped out, and test pieces cast, which, when solidified, are rapidly cooled and broken. These usually show a grey or highly mottled fracture, and the subsequent operations are conducted accordingly. The fining and final heating of the metal generally occupy from 30 to 45 minutes, being continued until a similar test piece is obtained free from all traces of grey iron.

The heat treatment of the metal during melting has a very important bearing upon its developed tensile strength, elongation, &c. The generation of excessive temperatures in the melting furnace, due generally to an excess volume of air being introduced, will cause the metal to oxidise after melting. In this way the choicest iron will turn out poor material. The chances of burning are not so great with heats charged with high silicon iron as with those in which the metal is low in silicon, as the former has an element of contained heat to balance heat of blast while melting, which the low silicon charge lacks. Superheated metal, or metal not high enough in silicon to hold fluidity, is readily discernible in ladles by the rapidity with which it sets. In air furnace practice for light castings of small sections, where it becomes a question of pouring iron sufficiently hot to run patterns, the combination of carbon is effected to a great extent by rapid cooling in contact with damp sand.

In the case of heavy castings of large sections the carbon must be combined in the furnace before tapping, and the mixture must contain smaller percentages of silicon, thus reducing the initial heat of the metal. This permits the metal in large castings to set quickly. Were there a high percentage of silicon present in heavy work mixtures, the castings would retain fluidity long enough to allow graphitic carbon to precipitate and be disseminated throughout the castings, which therefore would be grey and worthless. A very reliable test for the quantity of silicon present is the shrinkage of a test bar, and for this purpose the bar should be of as small a section as it is practicable to make, say ½ in. square and exactly 12 in. long. Such bars cool so quickly that the variation in the test record more nearly agrees with variations in silicon than with bars of any other size. A micrometer reading is made of the length of the bar before annealing to ascertain the shrinkage, which is a well-established mechanical analysis for silicon.

The diagram, fig. 205, gives approximately the relation between the shrinkage of the test bar and the percentage of silicon present in the iron, for bars of four different sections. With the aid of this diagram, and knowing the shrinkage of any one size of test bar, the percentage of silicon in the iron may be determined approximately, and also the corresponding shrinkage of a bar of different section. Or a founder knowing the size of castings that he wishes to make, and the shrinkage that is desirable, can find from the diagram the percentage of silicon that the castings must contain. This question of shrinkage is often of considerable importance, as, for instance, in agricultural machine parts, many of which have to fit snugly over others, and must, therefore, be made of metal in which the correct amount of shrinkage is assured.

To determine the approximate percentage of silicon in any iron mixture, locate on the ½ in. square line on the diagram, fig. 205, the ascertained shrinkage of a ½ in. square test bar cast from the mixture, and this will give the pproximate percentage of silicon that should produce such inkage. For example, suppose the test bar shows a nkage of 0·178 in.; then from the diagram we find the percentage of silicon in the mixture to be 1 per cent. If the test bar had a section of 2 in. by 1 in., the shrinkage for a 1 per cent silicon content in the mixture would, we find from the diagram, have been 0·131 in., and for a bar 2 in.

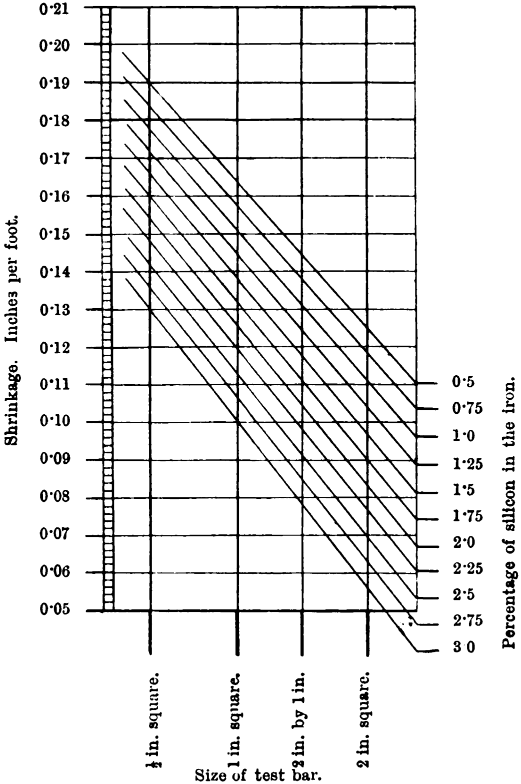


FIG. 205.—Diagram giving approximate shrinkage of test bars.

square 0·111 in. per foot. The shrinkage so found is that of the hard iron. The metal in annealing expands, and the finished castings rarely show more than the customary 0·10 in. per foot shrinkage of grey-iron castings.

Turning again to the characteristic feature of the malleable iron process, viz., the annealing; the operation is a lengthy one, and many unsuccessful attempts have been made to shorten it. As already mentioned, its duration varies with the mixtures used and the size of the castings made. A number of types of annealing ovens are used, of which probably the most efficient is that in which the furnace is situated along one side, the gases entering the oven near the top, passing across, down the opposite side, and out through ports at the floor level to the flues underneath the floor, and finally to the stack. Thus all sides of the furnace are heated to a nearly uniform temperature. The ovens, when charged, should be heated up slowly, so as not to bring the heat to its highest point before the metal is ready to receive it, and their temperature during the progress of an anneal should be maintained constant, as a steady continued heat is one of the first necessities for ensuring soft castings, while irregular temperatures will at once affect the quality of the iron, and destroy all chances for successful work, though the initial metal may have been all that could be desired. And again, much is ensured in the quality of the castings by the time allowed the ovens to cool down. Annealing ovens may be fired with any fuel which will furnish the necessary degree of heat. Coke, coal, oil, or producer gas can all be made to work satisfactorily. Uneven working is more likely to occur in plants where coal or coke is used, as with such fuels it is all but impossible to regulate the heat; whereas, with oil or gas, barring occasional changes in pressure, the heat is uniform. The correct temperature for the ovens, as determined by previous successful anneals, is maintained by the frequent use of a thermometer, or a pyrometer. A simple form of the latter instrument, known as the "Brown" annealing oven pyrometer, was introduced in the year 1893. This instrument is illustrated at fig. 206. The principle employed is that a thin strip of platinum is brought in a few seconds to the full temperature of the oven, and being connected by a rod to the mechanism in the head, moves the pointer in proportion to the expansion of the strip. The strip of platinum S, fig. 206, is hung within the heavy frame

F, which is only heated a few hundred degrees while the temperature of the platinum is going up 2,000 deg. Such a pyrometer is readily available, without any preparation whatever to indicate temperatures, but must be cooled off, which takes about 20 minutes before it can be used again.

Two years later Mr. Brown introduced his water-current pyrometer, illustrated at fig. 207. This will at once be seen to be a natural development of the instrument shown at fig. 206. It only required the heavy solid frame F of the earlier instrument to be kept from melting away, and a stationary pyrometer for registering temperatures up to 3,000 deg. was accomplished. This Mr. Brown did by running a stream of water through it. Referring to fig. 207, the water enters at N, flows through the loop P up the stem E, and out at O. A platinum expansion bar S, hung in the loop P, is connected by a rod with the indicating pointer. This pyrometer must not be confounded with water-current pyrometers, in which a pipe carrying a current of water is led through a furnace, and the temperature of the water indicated by a thermometer. A prominent defect in all pyrometers, based on the latter principle, and one which is often overlooked, is that a current of heated gas, at say 2,000 deg., passing over a water pipe, will increase the

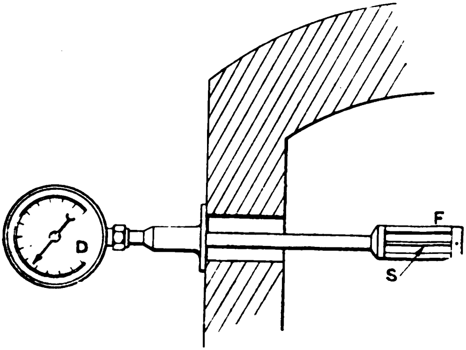


FIG. 206.

temperature of the latter more as the velocity of the gas increases. This is provided for in the Brown pyrometer through the rod which passes from the expansion strip to the pointer. This rod takes its temperature from the water current, and serves to neutralise any error due to a rise or fall in the temperature of the frame E.

Some malleable ironfounders are substituting sand or fire-clay for oxidised packing, and claim that equally good results

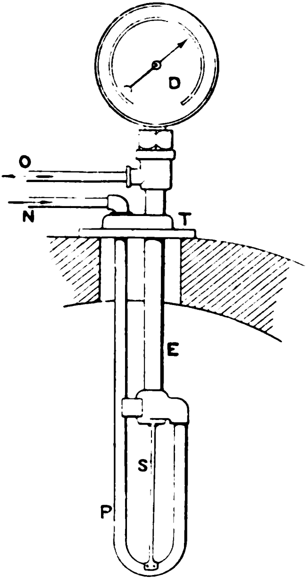
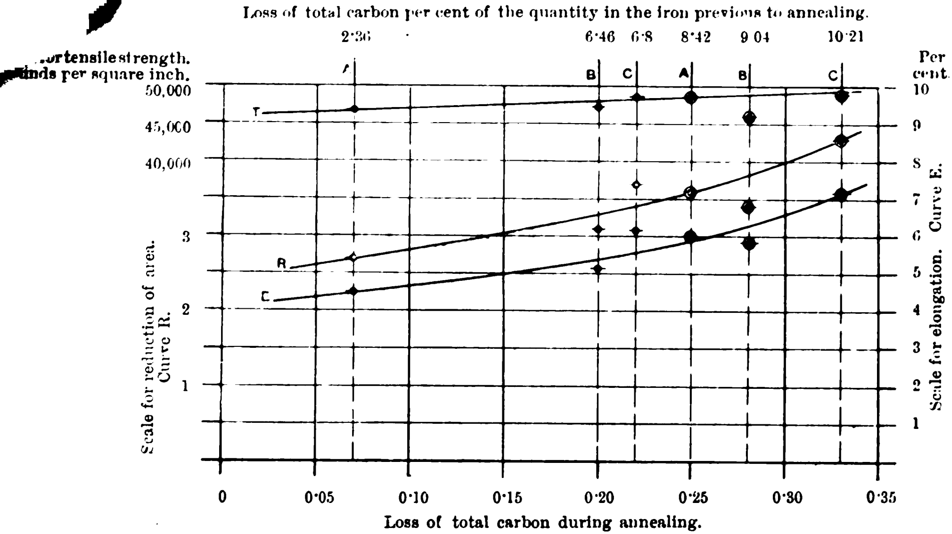


FIG. 207.

re obtained. With light work this may be to a great extent ue, but with heavy work the discontinuance of charging cking invariably proves to be a costly practice in the end. th prepared packing the castings are softer, and have a er percentage of elongation and greater reduction of area. [illegible] following table the results of direct experiment in this ion are given. One set of test pieces was taken and packed in unprepared packing, while a second and similar set was packed in charged packing. These test pieces were poured in each instance from same heats, from same ladles, and in similar moulds, and were packed in the annealing ovens with the heat conditions alike for both.

A	Annealed in prepared packing.	Annealed in unprepared packing.
Total carbon in iron before annealing........per cent	2·97	2·97
Total carbon in iron after annealing ....per cent	2·72	2·90
Loss of carbon in anneal	0·25	0·07
Tensile strength of annealed iron ....lbs. per sq. in.	48,600	46,800
Elongation in a length of six inches ....per cent	6·0	4·5
Reduction of area ....per cent	3·6	2·7
B		
Total carbon in iron before annealing........per cent	3·10	3·10
Total carbon in iron after annealing ....per cent	2·82	2·90
Loss of carbon in anneal	0·28	0·20
Tensile strength of annealed iron .....lbs. per sq. in.	45,900	47,400
Elongation in a length of six inches ....per cent	5·83	5·16
Reduction of area ....per cent	3·4	3·1
C		
Total carbon in iron before annealing........per cent	3·23	3·23
Total carbon in iron after annealing ....per cent	2·90	3·01
Loss of carbon in anneal	0·33	0·22
Tensile strength of annealed iron......lbs. per sq. in.	48,900	48,600
Elongation in a length of six inches ....per cent	7·16	6·16
Reduction of area ....per cent	4·3	3·7

These results are shown plotted on the diagram, fig. 208, those referring to the test pieces annealed in charged



NOTE.—Curve T shows the ultimate tensile strength of the annealed samples in pounds per square inch.
Curve R shows the percentage of reduction of area.
Curve E shows the percentage of elongation measured on a length of 6 in.

FIG. 208.

packing being indicated by two concentric circles, while those for the samples annealed in unprepared packing are indicated by the black dots. This diagram shows very clearly the effect charging the packing has upon the loss of carbon during the annealing process, and also on the physical qualities of the annealed iron.

The preparation of the patterns and moulds for malleable work calls for special consideration. The former require to be well proportioned, and to have all corners filleted with adequate radii. Sharp angles are specially to be avoided, as the iron always shrinks from the angle in two directions, and so would produce either a depression or a crack. Any change from a heavy section to a lighter one must be made very gradual. As the strength of malleable iron castings lies largely in the skin, it is well to expose as much surface as possible. For brackets it is thus preferable to use a number of thin ribs instead of one thick one. Round sections should be avoided, as practice has demonstrated this to be the weakest form. Instances are known to the author where patterns were so unequally proportioned that very special precautions had to be taken to guard against fracture of the castings in cooling, the only resource in some cases being to cool them down in a previously heated furnace over night. The breaking of light malleable castings is often due to bad gating, and can sometimes be remedied by changing the place of gating, or by breaking off the gates as soon as the mould is filled. When two or more branch gates attach to a casting that is liable to fracture by unequal contraction, it is important that the runner should be nicely proportioned in section to the section of the casting, and when possible the branch gates should be so thin as to break themselves instead of breaking the casting. The runner in malleable work should always be in the cope, thus constituting an effective feeder. Most malleable work is "gated work"—that is to say, the gates are attached to the patterns under the direction of an experienced man. In some foundries it is still the practice for the moulders to gate their own moulds, and here the man who has previously worked in exclusively grey-iron foundries needs to bear in mind that the iron used shrinks considerably more than grey iron, and for this reason special skill and care are demanded to ensure the mould being gated so as to successfully compensate for shrinkage. The iron employed, though quite fluid when at a white heat, solidifies very rapidly; for this reason it is customary to employ feeders entirely enclosed by the sand of the mould, and of considerably greater bulk than the part of the casting that is liable to be defective through shrinkage. The branch gate should not be run from the extreme bottom of the feeder, since the moist sand chills the iron to such an extent as to render the contents of the branch gate liable to become solid before the moment of solidification in the casting. Usually about one-fourth of the bulk of the feeder is made to extend below the branch gate. The feeder should also be set as close to the casting as practicable, the branch gate for light work not being more than about ½ in. long, and preferably of circular section. In some castings it becomes very difficult to feed sufficiently to compensate for shrinkage. In such cases a chill may be used to solidify the iron at a particular point, and so prevent depression or fracture.

The malleable cast iron industry, although comparatively speaking still in its infancy, is undoubtedly of great importance. Never before has any metal known to the iron-casting industry attained the position already occupied in the commercial world by the malleable casting, while perhaps the most gratifying feature connected with its manufacture arises from the fact that wherever it has been introduced it has invariably developed, to the exclusion of other metals.

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