FOUNDRY PRACTICE

A Text Book for Molders Students and Apprentices

BY

R. H. PALMER

Molder, Foreman and Superintendent of Foundries; Formerly Instructor in Foundry Practice at the Worcester Polytechnic Institute, Worcester, Mass.

SECOND EDITION, PARTLY REWRITTEN AND ENLARGED

NEW YORK
JOHN WILEY & SONS, INC.
LONDON: CHAPMAN & HALL, LIMITED
1919

PRESS OF
BRAUNWORTH & CO.
BOOK MANUFACTURERS
BROOKLYN, N. Y.

PREFACE TO SECOND EDITION

You will find additional information and illustrations in this second edition as follows:

"Propeller Casting is Essential to Our Defense," giving a description of the rigging, flasks, molding, securing and pouring the mold to produce large propeller wheels economically.

"Casting Locomotive Superheater Cylinders."

"Casting Locomotive Slide Valve Cylinders," describing the patterns, flasks, cores, molding, setting and securing cores, gating and pouring, analysis of iron, transverse strength, and deflection.

The above I published in *The Foundry*, and my thanks are due the Publishers of *The Foundry* for permission to reproduce them.

"Casting Lathe Beds and Chilling the Ways." I have described the pattern, flasks, molding, arrangement of chills and resulting benefits.

"Making Cores for Gasolene Engine and Automobile Cylinders," showing some of the causes of defects in castings.

"Molding Large Kettles," used by manufacturers of chemicals, dye stuffs, etc., showing different methods of producing them, flasks, and special rigging to produce some styles in large quantities economically.

REGINALD H. PALMER

BRIDGEPORT, CONN.

PREFACE TO FIRST EDITION

DURING his experience as instructor in foundry practice at the Worcester Polytechnic Institute, the author was handicapped by the lack of a suitable text-book. The volume presented here follows the scheme of instruction used by him, and, beginning with the simplest type of mold, endeavors to lead the student and apprentice gradually through the more difficult lines of work in green and dry sand and loam. From the many possible examples which might have been used to illustrate the different practices, only those have been selected which are typical of the class of work to which they belong. It is recommended that the reader, whenever possible, supplement his study of this book by actually making molds of the character described in the various chapters. It is impossible to learn the art of molding by reading only.

Such other matters as the student of foundry work should be acquainted with are included in the book, these including the subjects of cupola practice, mixing and melting, cleaning and repair of castings, etc.

The author has endeavored to make a text-book for the student, apprentice, and molder, rather than a reference work for the finished foundryman. His thanks are due to Mr. Robert Thurston Kent, M.E., for editing the manuscript and reading the proofs.

R. H. PALMER.

BELMONT, ALLEGANY CO., N. Y.,
October 1, 1911.

CONTENTS

INDEX TO ILLUSTRATIONS

TABLES AND TESTS

FOUNDRY PRACTICE

CHAPTER I

THE MOLD—ITS FORM AND THE METHODS OF MAKING IT

IN all foundry practice, the *mold* is the essential feature. A mold is the form or cavity in a refractory material such as sand or loam, or in metal, into which molten metal is run or poured, and which determines the final shape of the poured metal after cooling. See Fig. 1.

While molds are made in many different materials, and of many different shapes and by different methods, yet in their essential characteristics they are all alike. They are all made from a *pattern*, which may be of wood, metal, or other material; except for the very largest molds, which are bedded in the floor of the foundry, and for certain other special kinds of molds, they are supported by and enclosed in a *flask*, which may be either of wood or metal, and which may be either rigid or hinged, the latter being known as a *snap flask;* they are formed in a material which will withstand the heat of the molten metal when it is poured into the mold, the more common materials being *sand*, either *dry* or *green*, *loam*, *plaster of paris*, and *iron*, the latter being used for *chilled work* such as car wheels, etc.; cavities in the *casting*, by which name the final product of the foundry is known, are formed by means of *cores* which may be either *baked cores*, or *green-sand cores*.

Molding operations are variously subdivided. Thus, according to size, there is what is known as *bench work*, usually for the lighter class of castings, and *floor work*, for the heavier castings. According to materials of which the mold is com-

See Glossary at back of

posed, the work is classified as green-sand, dry-sand, loam, or chilled work. Another subdivision is hand work and machine work, depending on whether the mold is made by hand or in a *molding machine.* Each of these classifications may be still further subdivided, as will be shown in subsequent chapters. In order to introduce the student to the art of molding we will consider the simplest class of mold, and discuss the various operations in its production—a green-sand mold made at the bench, with a one-piece pattern, the entire pattern being

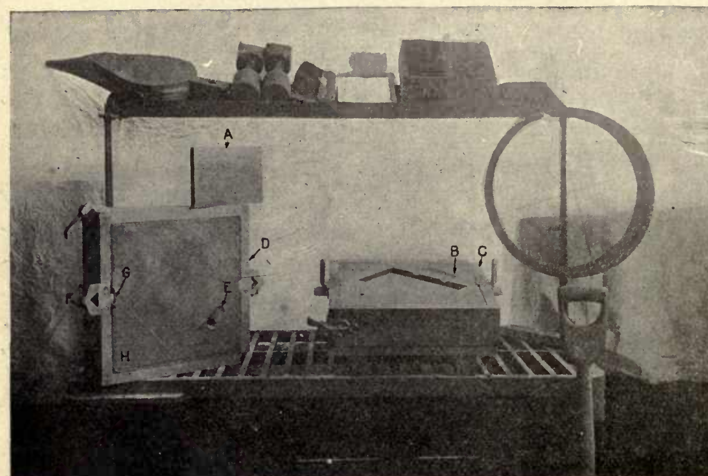
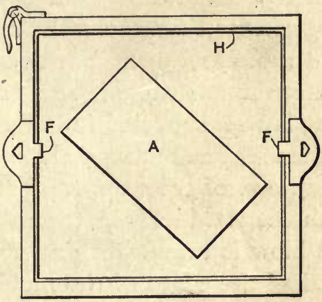


FIG. 1.—OPENED SMALL GREEN-SAND MOLD IN SNAP FLASK.

placed in one section of the flask, and made without cores or other complications.

In order that the description of the actual molding operations may not be burdened with descriptions of tools and equipment, more or less irrelevant, and yet which are used in the work, it will be assumed for the time being that the reader is familiar with these, and with their use. Each piece of equipment and every tool mentioned, however, is described in detail in Chapter XXI devoted to tools and equipment, and the reader is referred to that chapter or to the glossary, page 288, for such information as may be necessary as to render the description more explicit.

Referring now to Fig. 1, the pattern to be molded is shown at *A*. This is a rectangular block eight by five inches and five-eighths of an inch thick. It is to be molded in green sand in a snap flask, the two parts of which are shown at *C* and *D*. As the pattern is quite shallow the short sides are parallel. A deeper pattern will have a slight taper, to enable it to be withdrawn from the sand more readily. This taper is known as the *draft*. The lower portion of the mold, that contained in flask *C*, is known as the *nowel* or *drag*. The upper portion is called the *cope*. Fig. 1 also shows the usual arrangement of the molder's *bench*, comprising the grating on which the actual work is done, the sand bin below it, and the tool rack above, on which is shown the usual equipment of molder's tools, consisting of *rammers*, *brush*, *riddle*, *bellows*, and a tool box containing his small tools.



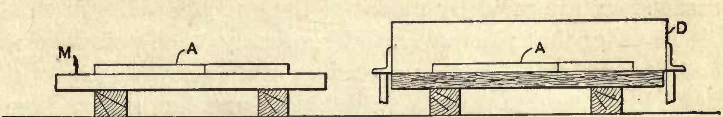


FIG. 2.—ARRANGEMENT OF PATTERN AND FLASK ON MOLD-BOARD.

In making the mold, the molder first places his *mold-board* on the bench, with the cleats on the board extending away from him, this being the most convenient position for rolling over the drag. The pattern *A* is placed on the mold-board as shown in Fig. 2, and the drag of the flask placed over it with the *pins* projecting downward on either side of the board. An iron band *H* is slipped inside the flask and rests on lugs or ears *F*, having slots cut in it to permit it to slip over these lugs. It is important that there be plenty of sand over the pattern when the mold is complete, not only to prevent the bottom board from burning but to hold the metal in the mold. In the present case, the pattern being shallow, there is no doubt on this score, but with a deeper pattern the molder will place his *strike* across the top of the drag and thus ascertain the distance between the top of the pattern and the edge of the flask, and govern his selection of the flask accordingly. Being assured that there will be a sufficient depth of sand over the pattern, sand is sifted on the pattern as it lies on the mold-board by means of the riddle until the pattern is completely covered. The molder then tucks the sand around the edges of the pattern with his fingers, but does not press it down on top of the pattern unless there is some special reason for so doing. The drag is next shoveled full of sand and heaped high. The sand is then rammed around the inside of the flask with the *peen* or sharp end of the rammers. The rammer is held at this time with the *butt* inclining toward the center of the flask, so that the blow is somewhat outward in direction, compressing the sand at the edges of the mold. More sand is then shoveled on to the flask, the rammers are reversed, and the entire surface of the mold rammed. After ramming, the surplus sand is scraped off the mold by means of the strike.

In order that the mold will bear firmly at all points on the *bottom-board*, which is next placed on what is now the top of the drag, loose sand is thrown on the mold and the bottom-board placed over it and rubbed to a firm bearing. Were this not done, and should there exist any space between the bottom-board and the mold, the pressure of the iron when poured might cause the mold to break or cause a distortion of the casting. After placing the bottom-board, the drag is rolled over, so as to bring the pattern, and also the *joint* or pin side of the flask, to the top, as shown in Fig. 1. If the sand has been properly rammed, a perfect joint can be made by rubbing the palm of the hand over the surface of the nowel. If the ramming has been imperfectly done, the sand should be tucked around the pattern with the fingers. The surface of the drag, or joint, is next brushed off with a soft brush or blown off with the bellows, the former method being preferred as it leaves the joint in better condition to receive the parting sand. *Parting sand* is now thrown over the joint to insure a good separation of the cope and drag, any excess sand being blown from the

FIG. 3.—PEENING THE SAND AGAINST THE SIDES OF THE FLASK.

FIG. 4.—BUTT-RAMMING THE SURFACE OF THE MOLD.

pattern as it would cause the casting to have a rough surface. A small amount, however, will do no harm and will prevent the sand in the cope from adhering to the pattern.

The cope *D* is next placed on the drag, the two parts of the flask being kept in their proper relation by means of the pins on the drag fitting into the ears on the cope. The iron band *H* is placed in the cope, although with this type of pattern, often called a *flat-back*—that is, a pattern molded entirely in the drag, and with a flat surface at the joint—it is not altogether necessary as there is no side pressure to be resisted. It may be stated here that these bands are necessary only in snap-flask work. The *gate-stick* which forms the hole through which the metal is poured into the mold is next placed in position, being driven down a slight distance in the sand of the drag. In ramming, it is important that the sand should be firmly rammed around the edges of the flask with the peen end of the rammer in order that it will withstand the side pressure of the molten metal. Care should also be used to keep the peen end of the rammer not less than one and one-quarter inches away from the pattern when ramming, as the sand must be porous enough to allow the gases to escape when the metal is poured into the mold. A mold can be rammed too hard and it also can be rammed too soft. The proper degree of firmness can be learned only by experience.

The gate-stick is withdrawn from the sand and the cope is next lifted from the drag and placed at one side as shown in Fig. 1. Any imperfections left on the cope which are not desired, are smoothed off with the *slicker*. These imperfections consist of excrescences on the mold due to holes or other imperfections in the pattern. In finishing the mold the cope should be perfected before the pattern is drawn from the drag, as in case of damage to the cope the sand can be knocked out and the cope rammed up a second time, whereas this would be impossible had the pattern been removed from the drag.

The hole left by the gate-stick is beveled over at the joint so that the molten iron entering the mold will not wash sand in with it. The hole left by the gate-stick at the top of the cope is reamed out to a bell-shape to facilitate pouring of the metal. The sand around the pattern is next dampened by water squeezed from the *swab*, which is passed gently around the edges of the pattern, care being taken to prevent the water from running on the pattern, which if constantly repeated, would cause the pattern to swell and become distorted. The object of wetting, or *boshing*, the sand around the pattern is to cause the various grains of sand to cohere and to prevent the sand from breaking when the pattern is withdrawn. The pattern is withdrawn by means of the *draw-nail*, which is driven into the pattern. The molder grasps the draw-nail with his left hand and, by means of a *rapping-iron*, jars the pattern loose in sand by striking the draw-nail a few sharp blows, first on one side and then on the other, close to the pattern. He then lifts the pattern vertically upward, using the draw-nail as a handle, at the same time rapping it gently with his rapping-iron. When the pattern has been lifted to a point where the molder can feel that it is free from the sand, he balances it and moves it up and down slightly to make sure that it is entirely free and then with a quick motion lifts it directly upward entirely out of the mold. It is important that the pattern be drawn straight upward, as the slightest sidewise motion will break the edges of the mold at the joint, making necessary expensive and more or less unsatisfactory repairs. The pattern being drawn, any imperfections in the mold or breaks at the joint are repaired with the *slicker*.

All imperfections having been repaired, a channel is cut in the sand from the impression in the nowel left by the gate-stick, to the mold. This channel is known as the *gate* or *sprue* and is made with the *sprue-cutter*. It is shown at *B*. At *E* a cavity is hollowed out in the cope, being known as a *cleaner*. Any dirt which may be washed through the gate with the iron will tend to rise to the surface and be caught in the cleaner and thus be prevented from passing into the mold.

These various operations having been completed, the mold is *closed*, that is, the cope is placed on the drag, the pins on the drag fitting into the ears on the cope bringing the two halves of the mold into the same relation they bore to each other when they were rammed up. The mold is then placed on the floor at a point convenient for pouring metal into it and the fastenings on the flask are loosened, the flask opened up, and removed from the mold. Weights as shown in Fig. 5 are placed on top of the cope to hold it down firmly on the drag while the metal is being poured into it and to prevent the metal from working its way out of the mold through the joint. At this point, the importance of striking the sand evenly from the top of the cope becomes evident, for, should the weight not bear evenly at all points on the surface of the cope, the pressure of the iron in the mold will lift the cope away from the drag on the side on which the weight does not bear, and allow the iron to flow out at the joint, this being known as a *run-out*. Furthermore, if the weight does not bear all over the cope, a "strained casting" or one thicker than desired will result, often causing the rejection of the casting. The molds are placed on the floor for pouring as close together

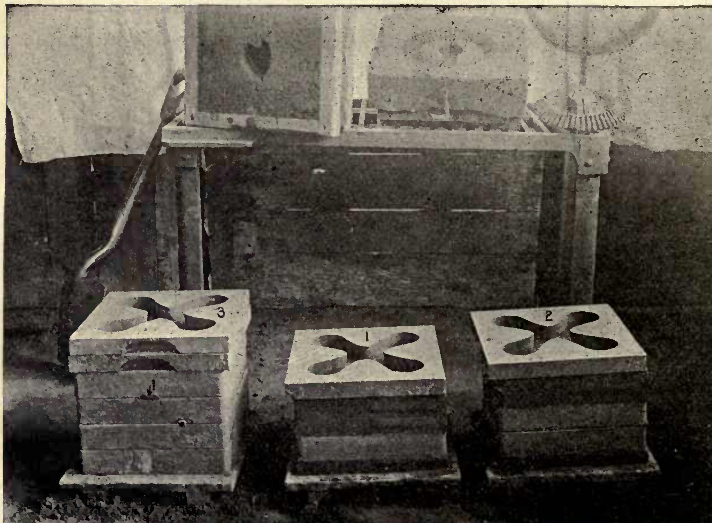


FIG. 5.—MOLDS WEIGHTED FOR POURING.

as possible as shown in Fig. 5, only enough room being left between the different rows of molds to permit the molder to pass with his ladle. Here again the importance of proper weighting is evident, since the molder is in serious danger of being burned in the event of a break-out while pouring.

MOLDING A SPLIT PATTERN

Where the pattern is of such shape that it would be inconvenient or impossible to mold it with the pattern entirely in the drag, a *split pattern* is employed. Such a pattern is shown in Fig. 6 and the mold made from this pattern in Fig. 7. This mold also illustrates the use of green-sand cores. One half the mold is in the drag and the other half in the cope. The line *B*, Fig. 6, on which the pattern is separated is known as the *parting*. Referring now to Fig. 6, the method of molding is shown. The mold board *J* is placed as was the case for the rectangular, one-piece pattern described above and the drag half of the pattern *D* is placed as shown on the mold board with

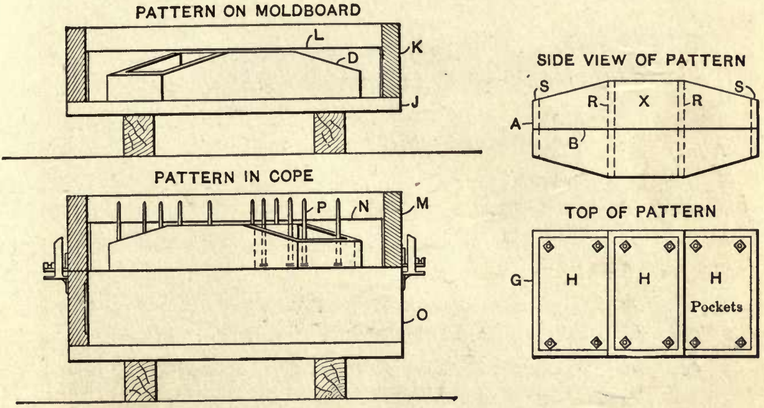


FIG. 6.—METHOD OF MOLDING A SPLIT PATTERN.

the parting down. The drag of the flask with its iron band *L* is placed in position exactly as was the case with the pattern described above. Sand is next riddled on to the pattern and tucked down with the fingers into the pockets between the ribs *R* and the ends *S* and laid up against the side of the pattern. The drag is then rammed up as in the first case, the bottom-board placed, rubbed to a bearing, and the drag turned over.

On removing the mold-board, the joint is made by rubbing the sand from around the pattern with the palm of the hand. If the sand has been properly tucked down in the pockets and around the sides of the pattern, there is no need of using a trowel. If this has not been done and the sand is too soft around the pattern, fresh sand must be tucked in and slicked with the trowel. The joint being made, the cope half of the pattern is placed on the drag half, as shown at *M*, Fig. 6, and parting sand is dusted on the sand joint. In order that the cope and drag halves of the pattern will align properly, dowel pins are provided in the cope portion as shown at *C*, Fig. 7, which fit in holes in the drag at *D*. The cope of the flask is

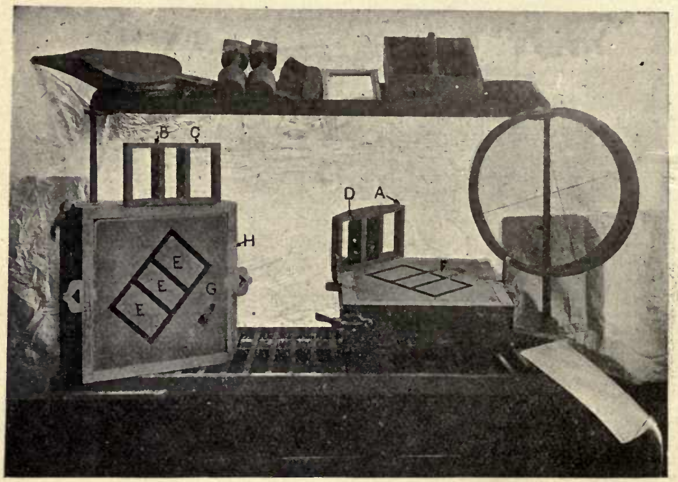


FIG. 7.—MOLD MADE FROM FIG. 6.

then set, as shown at *M*, Fig. 6, with the iron band *N* inside of it. In order to strengthen the green-sand cores, *E*, the nails *P*, Fig. 6, are placed in position. These are necessary, as the sand has not sufficient strength to sustain itself in deep pockets, such as we have here, and would break of its own weight when the pattern is withdrawn. The nails are placed after about one-half inch of sand has been riddled into these pockets in the pattern. The nails are wet and are set heads down in the corners of the pockets.

The gate-stick is next placed, sand is riddled into the cope, tucked down around the nails and pattern, and the cope is rammed up. It should be remembered when ramming, that after having peened between the sides of the flask and the pattern, and the mold is being rammed with the butt of the rammer, that the same blow struck over the top of the pattern will pack the sand harder there than it will the sand alongside of the pattern, due to the fact that there is a smaller body of sand to absorb the shock of the blow. As the molten iron fills the mold, it drives ahead of it to the highest parts of the mold, the gases and steam generated in the mold. If the sand has been rammed too hard over the pattern, these gases may have difficulty in escaping through the sand and, being pocketed in the mold, will expand and force the iron back through the gate, leaving an imperfect surface in the casting. It is essential, therefore, in ramming, that the blows struck over the pattern shall be somewhat lighter than those struck on the sand alongside the pattern.

The cope being rammed up and struck off, loose sand is thrown on top of the cope, the gate-stick is removed, and the mold-board rubbed down on the cope in a similar manner to the bottom-board on the drag. At this point, the mold is *vented* with a *vent-wire*, provided a close-grained molding sand has been used, which is not permeable enough to permit the ready escape of gases through it. The venting is done by pricking the sand full of holes over the top of the pattern. To vent a mold properly, it is essential that the molder be able to carry in his mind the shape of the pattern, and he should trace in the sand the outline of the pattern, as it lies in the flask. Care should be taken not to drive the vent-wire into the pattern, as this will damage the pattern and cause imperfect castings. After venting, the mold-board is placed and the cope is lifted from the drag and laid on its back on the board.

The pattern is next boshed and is then removed from the mold by means of a draw-nail. It is essential that the mold-board be rubbed to a firm bearing on the top of the cope, otherwise, in driving the draw-nail into the pattern, the pattern will be driven down into the back of the cope, and in this case, when the cope is turned on its side after the pattern is withdrawn, there would be danger of the sand in the back of the cope sliding out and ruining the mold.

The parts of the pattern in the cope and drag being drawn, the mold is finished with the trowel or slicker, the gate in the cope is reamed out at the top, and the gate is cut in the drag from the impression of the gate-stick to the ribs in the mold, as they form the deepest parts. (See *F*, Fig. 7.) After cutting the cleaner *G* in the cope, the mold is closed, set on the floor, and weighted ready for pouring.

Molding a Split Pattern with a Web Center

In Fig. 8 is shown a pattern somewhat similar to that in Fig. 6, with the exception that there is a web *A* at the center. The green-sand pockets in the mold formed by Fig. 6, are in this case cut off by this web. The molding of this pattern is similar to the operation of molding the pattern shown in Fig. 6. The portion of the pattern with the web is molded in the drag, with two bands *H* inside the flask. The principal difference in the operation of molding is in the placing of the nails which strengthen the green-sand cores. After the pattern has been placed on the mold-board, sand is riddled over it until it has a depth of about three-eighths of an inch in the pockets of the pattern, after which nails of the correct length are wet or clay-washed and set with the heads down in corners of the pockets. Sand is then riddled on the pattern, tucked down, and the flask rammed up as usual. The nails are set in the green-sand cores of the drag to hold the pockets down and to support the corners, since, when the drag part of the pattern is rapped and drawn, the pocket of sand may be cracked away from the drag and when the melted iron is poured into the mold it will enter the crack and float the sand against the green-sand cores of the cope, thus spoiling the casting. The nails prevent this.

Molding the cope of the pattern shown in Fig. 8, is carried out in the same manner as was the pattern in Fig. 6. In patterns having pockets too deep to allow the use of nails, wooden rods or *soldiers* are used. These must be well soaked with water before using, inasmuch as dry soldiers will absorb moisture from the sand and swell, thereby cracking the mold. After soaking, the soldiers should be dipped in clay wash to enable them to hold to the sand.

Too much emphasis cannot be laid on the fact that it is possible to ram a mold too firmly over the pattern. The proper degree of firmness can be learned only by experience, but a test can be made by applying pressure with the fingers to the finished mold. The face of the average small mold, prop-

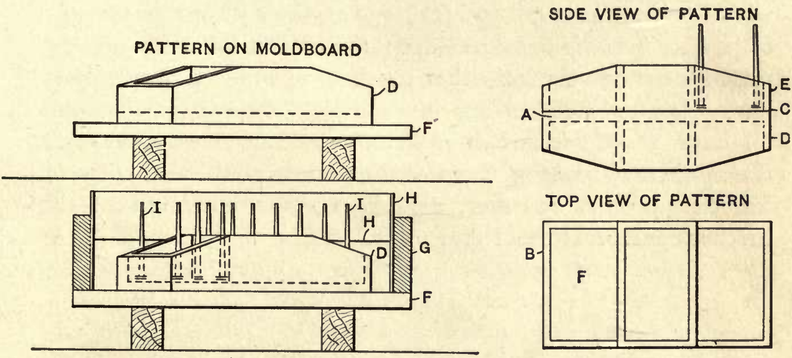


FIG. 8.—MOLDING A SPLIT PATTERN WITH A WEB IN THE CENTER.

erly rammed, will yield slightly to pressure. If it is rammed so hard that it is unyielding to finger pressure, it is certain that the gases will be unable to escape and a casting full of blow-holes will result.

We have described above three simple molding operations in green sand. They are typical of all green-sand work, except that when large castings are made, modifications in the practice are necessary. Special arrangements must be made for strengthening certain parts of the molds, and also for venting, as will be described in later chapters. The bulk of foundry molding is done in green sand, and therefore many of the later chapters will take up in detail the making of molds in this material, describing the methods to be employed and the precautions to be taken.

While green-sand molding is the most common, there are other varieties of molds employed for special purposes, which are also described in detail later in the book. Thus there is a skin-dried mold which is a green-sand mold with the surface baked by means of an oil or gas torch or a fire basket; the dry-sand mold which is a green-sand mold baked in an oven, and which is employed for making steel castings and in other situations where a particularly accurate casting is desired; the loam mold built up from a mixture of sand and clay, backed with brick work, employed for large castings where the expense of pattern work is to be avoided; the chill mold made of iron, used for car wheels and other castings in which a particularly hard, close-grained surface is desired. These various molds all have their uses which will be enumerated together with the method of making them at the proper point in this book. For the present, however, we will confine ourselves to the further consideration of green-sand molds.

CHAPTER II

MOLDING IRREGULARLY SHAPED PATTERNS—COPING DOWN—MOLDING IN A THREE-PART FLASK—THE USE OF A FALSE CHEEK—MOLDING GEARS

THE patterns described in the previous chapter have been molded on a plain mold-board, cope side down, and have been rammed up in the drag. The joint has been made by simply brushing off the sand or slicking it with the trowel, which is all that is required with a pattern having a plain cope side, which allows it to lie on the mold-board while being molded. In Fig. 9, at *C*, *D*, *E*, and *F*, are shown patterns which it would be impossible to place on a plain mold-board and ram up in the drag, since they would not remain in position on the mold-board to cause the desired portion to come in the cope. To mold a pattern of this character, it is necessary to *cope down*, in order to bring the proper portions of the pattern in the cope and drag respectively, and also to permit the pattern to be drawn from the mold.

Referring to Fig. 9, the method of molding these four patterns is shown. None of these patterns will lie in the correct position on the mold-board and, therefore, a rough bottom-board is placed on the bench and on that an *upset*, a wooden frame of the required size and depth, is placed. The opening in the lower side, adjoining the bottom-board, is a trifle larger than that in the top side. The upset is usually attached to the bottom-board with screws. Sand is riddled into the upset and is rammed in the same manner as a flask, and struck off level with the top. The patterns to be molded are placed on the sand in any desirable position. The sand is then dug out under them, so as to allow them to sink in the sand to the same depth that it is desired they shall project into the cope when this is rammed later. The sand is then roughly formed around them and a little parting sand dusted on. In Fig. 9, at *A*, is shown the bottom-board with the upset *B* attached to it, and the sand formed in place as described. The drag of the flask is next placed over the upset and is rammed up in the same manner as would be patterns laid on a plain mold-board as described in Chapter I. After rolling the drag over, this frame of wood with the sand in it, is lifted off and the parting is made to follow the shape of the

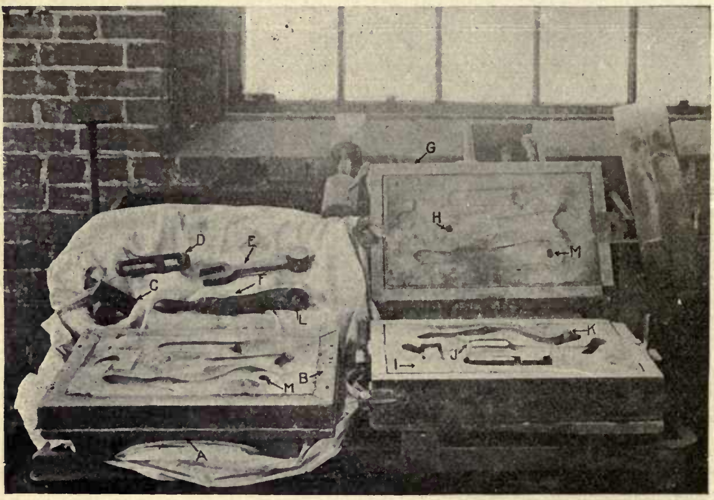


FIG. 9.—MOLDING IRREGULARLY SHAPED PATTERNS WITH A GREEN-SAND MATCH.

pattern in the drag, thus causing the sand in the cope to extend down on each side, so that the lower side of the pattern will be formed in the drag and the upper side in the cope.

The line of parting having been determined in this manner, the sand is shaken out of the upset and the frame removed from the board. The frame is then placed on the drag in the same manner as would be the cope, the side with the small opening being down. The frame is rammed up in a similar manner to a cope and the sand struck off level with the top. The bottom-board is then rubbed to a bearing and screwed to the frame. The upset is then lifted off, being now what is termed a *green-sand match,* as shown at *A*, *B*. It is evident that the patterns *C*, *D*, *E*, and *F* can easily be replaced in their respective positions in the match.

The joint of the drag is then blown off with the bellows, fresh parting sand is dusted on, and the cope is rammed up and lifted off in the ordinary manner. The cope is shown at *G*. The joint is now blown off to free it of loose sand, the patterns are boshed and drawn from the drag, after which the mold is finished and the gate *J* cut to carry the iron to each one of the impressions left by the four patterns.

The casting made from pattern *F* is to have a hole in it at *L*. This hole will be formed in the casting by means of a core which is shown set in position in the drag at *K*. The position of the core is determined by means of the *core-print L* on the pattern. This core-print will form holes in the cope and drag as shown at *M*. A vent-wire is run up through the cope from this core-print to permit the escape of gas from the core. The venting of the core itself is fully described in Chapter XIII, devoted to cores. The mold is now ready for closure, weighting, and pouring.

The green-sand match may be used many times for ramming up the drag if care is exercised in handling it and in placing the patterns. In many cases, where but one casting is wanted from a pattern, the cope is rammed up in the same manner as an upset, and the pattern is bedded down in it and the drag then rammed up. After the joint has been made, the cope is knocked out and is again rammed up to form the cope of the mold.

Molding a Hand Wheel

Let us consider the operation of molding a hand wheel, the rim of which is set some distance forward of the hub. The wheel is laid on a level mold-board and strips of wood, one-half the thickness of the rim, are placed under the drag of the flask, in order to raise it so that one-half of the rim will come in the cope. Sand is rammed around the pattern, and when the drag is rolled over and the mold-board removed, the rim of the wheel is found to be above the joint of the drag, by just the thickness of the wooden strips, this operation being termed upsetting the drag. The joint is then made and, as the hub of the pattern is lower than the rim, there will be quite a body of sand to lift out. The arms of the wheel being rounded on the edges, will add more. The parting is made by removing sand until the point is visible where the pattern begins to round under. After the joint has been made and parting sand has been rubbed on, some riddled sand is laid by hand on the slanting parting in order to make the parting sand remain in place. If the molding sand is riddled directly on the steep parting, it will slide down and carry the parting sand with it and the cope will stick to the drag and break the mold.

There will be a considerable body of sand hanging from the face of the cope due to the recession of the hub from the rim of the wheel, and it is necessary to support this by means of a soldier, a piece of wood in this case, about eight inches long, one inch wide, and half an inch thick. These soldiers are placed, after being first dipped in the wash pot, by scraping the sand from the pattern adjoining the core-print in the hub, so that there is about five-sixteenths inch thickness of sand outside the core-print. One soldier is placed between the core-print and the slanting parting and another soldier is placed on the opposite side of the print with a nail quartering from the soldier each way. This gives four supports for the sand which is firmly tucked around them and rammed in the center, using a gate-stick for a rammer. The cope is then rammed up as usual, the gate-stick being set to gate into the rim.

Coping Down Irregular Patterns

Referring to the patterns in Fig. 10, *P* is a pattern which can be molded in the same flask with *Q*. Both these patterns require coping down in order to permit the pattern being drawn from the mold. The upset is rammed full of sand and each pattern is bedded so as to throw it into the cope. The pattern *P* is placed in the upset in the position shown in Fig. 9, being set somewhat deeper than the thickness of the plate connecting the two lugs. It is parted as described above down to the middle of the bosses on the lugs, while the plate part of *Q* is placed in the upset to the depth of the plate containing the two square holes. The drag is rammed up, rolled over with the upset, and the upset removed. The joint is made and, when

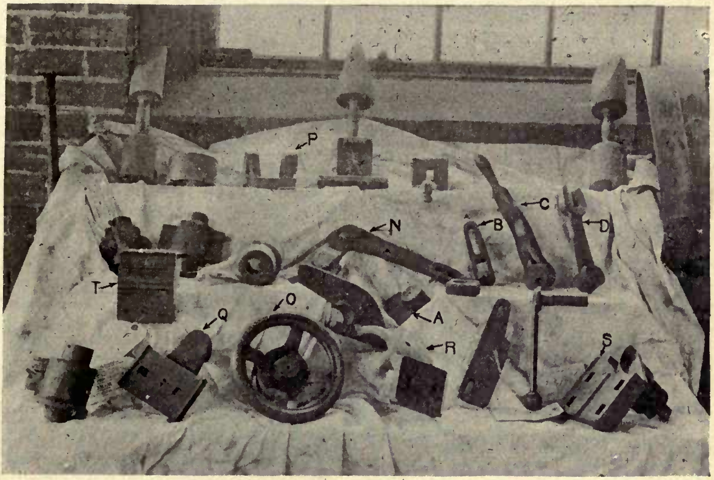


FIG. 10.—ODD-SHAPED PATTERNS WHICH ARE MOLDED BY COPING DOWN IN DRAG OR IN COPE.

ramming the cope, soldiers are used as described above, for lifting the sand around the lugs while the hanging sand over *Q* should take care of itself with a properly arranged parting.

Pattern *R* requires a flask by itself. In molding, the end which is foremost in the illustration is thrown into the cope above the joint, the other end of the pattern being kept below the joint. This pattern is upset in the cope and coped down from the drag, requiring a very irregular joint. The two square holes in the end are formed by green-sand cores. It is unnecessary to place nails in these cores to hold them as, if they are well boshed and the pattern carefully drawn, they will remain in better shape in the mold than if nailed. Often nails in small green-sand cores do more harm than good, as in rapping the pattern, when drawing it, the nails in the core hold while the sand moves, thus breaking the core. Patterns *S* and *T* may be molded in the same flask and will require some coping down. The remaining patterns can be molded together as they can be best arranged, three or four in a flask, according to the ideas of the molder.

Molding in a Three-Part Flask

Fig. 11 shows a sheave together with the method of molding it in a three-part flask. When molded in the three-part flask, the pattern is laid on the mold-board in the center of the

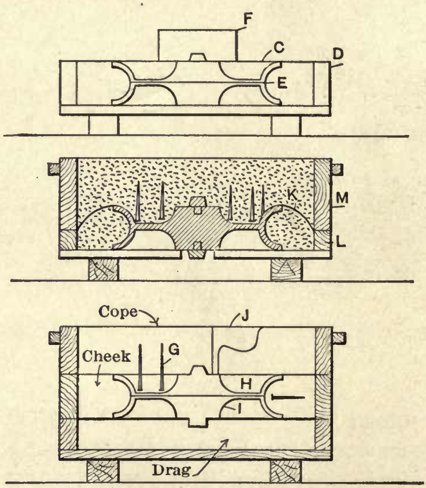


Fig. 11.—Molding a Sheave in a Three-part Flask.

cheek D, as shown at *C*, the parting of the pattern being at *E*. The cheek is rammed up around the pattern, which operation tends to force the two halves of the pattern apart and thus make the sheave thicker than desired. To prevent this, the weight *F* is placed on top of the pattern, while the cheek is being rammed. After the joint in the cheek is made, the drag *M* is placed and rammed up, nails being placed as shown. The cheek and drag are rolled over together and the second parting is made, after which the cope is rammed up, nails being set as shown at *G*. The cope is lifted off and the portion *H* of the pattern drawn, after which the cheek is lifted off, set aside, and the portion of pattern *I* drawn. After the core is set, the gate is arranged as shown at *J* in the cope.

Molding with a False Cheek

The method of molding with a *false cheek* is shown in Fig. 12. The pattern is placed on the mold-board as is shown in Fig. 11, an upset often being used instead of a cheek. After

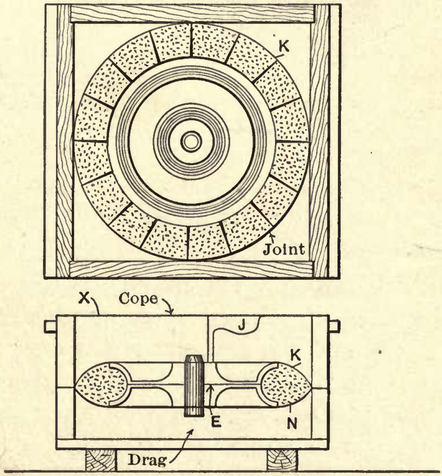


FIG. 12.—MOLDING A SHEAVE IN A TWO-PART FLASK WITH A FALSE CHEEK.

ramming up the cheek, removing the sand, and forming the parting on the line *K*, Fig. 12, the cope is placed on the cheek or upset, being raised by strips one-half the thickness of the pattern, so that, in the finished mold, half the pattern will be in the cope and the other half in the drag. The arrangement is the same at this point as shown in Fig. 11, at *L*. The board is rubbed to a bearing on top of the cope which then is rolled over, the strips removed, and a parting made at the line *N*, Fig. 12. The drag is placed and rammed up, the bottom-board is rubbed to a bearing, and the drag lifted off. Considering now the flask *X*, Fig. 12, as a whole, the false cheek is shown between the lines *K* and *N*, the cope being rammed up on one side of it and the drag on the other. The drag being lifted, one-half the pattern is drawn, the parting being on the line *E*. The mold is finished in the drag and the drag replaced, the whole flask rolled, and the cope lifted. Bearing in mind that there is only the sand forming the outside of the sheave groove to hold the cope part of the pattern up, the cope portion of the pattern is carefully drawn from the sand. The core is set, the cope finished, and the gate is punched and the basin made as shown at *J*.

Molding a Double Groove Sheave in a Three-Part Flask

Frequently it is necessary to mold a double-groove sheave when only a three-part flask is available. The method of doing this is shown in Fig. 13, being a combination of the two methods above described. The pattern is laid on the mold-board and the cheek *F* rammed up, after which the cope *G* is made. The cheek and the cope are rolled over and the false cheek *H* made with a parting at *X*, after which the drag is made. The drag is lifted, together with a portion of the pattern *L*, to which are fastened the ribs *M*. This portion of the pattern is drawn from the drag, which is finished and replaced. The entire flask is then rolled over and the cope lifted together with the cope portion of the pattern. After drawing the pattern the solid cheek is lifted from the drag and the middle part of the pattern drawn. The pattern is parted on the lines *C* and *D*. The mold is now finished and closed. It may be poured either through the hub, as was the first sheave, or it may be gated. If the grooves in the sheave are very deep, they should be supported with nails as shown in Figs. 11 and 12.

At times, the sheaves are molded by using a pattern with a core-print around it and making a set of cores in a core-box. After the pattern is drawn from the mold, the cores which form the grooves in the edge of the sheave are set. Such a core would occupy the position of the false cheek *KN*, Fig. 12.

If it is necessary to mold a sheave from a solid pattern, that is, one without a parting, the false cheek may be formed on

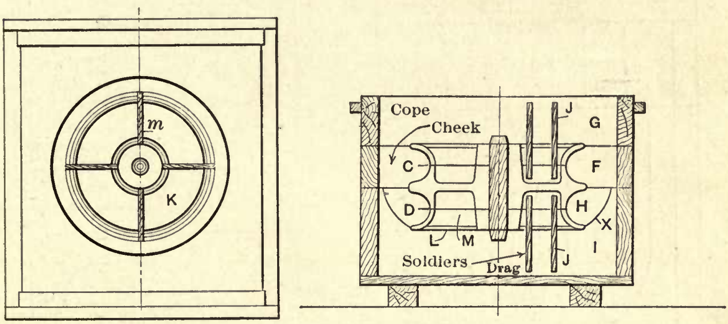


FIG. 13.—MOLDING A DOUBLE GROOVE SHEAVE IN A THREE-PART FLASK, USING A FALSE CHEEK.

two pieces of paper, cut to the shape of the circumference of the sheave, a parting being made by each sheet of paper. After the cope is lifted, the pieces of paper, having the cheek built on them, are pulled apart, thus drawing the sand sideways out of the groove. The pattern is then lifted from the mold and the two parts of the cheek are pushed together in their original form.

MOLDING SOLID SHOT

Fig. 14 shows the arrangement of the patterns and gates in molding solid shot. The four patterns are rammed up in the drag, with the bottom of the patterns flush with the surface. *Shrinkheads* or *risers C* and a pouring gate *D* are formed in the cope. After lifting off the cope, *whirl-gates F* are cut from the pouring gate to cause the iron to enter the mold tangentially. This imparts to the iron entering the mold a swirling motion, which drives the dirt collected in the mold

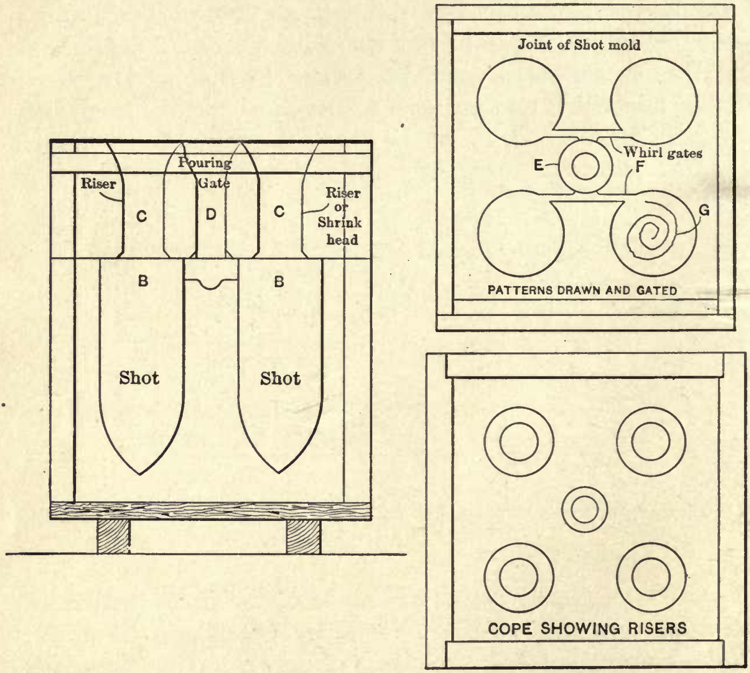


Fig. 14.—Mold for Solid Shot.

toward the center and enables it, therefore, to rise in the shrinkhead, thus leaving a clean casting. As the shrinkhead is made large enough to supply molten iron to the body of the casting when it cools and shrinks, a clean, sound casting, free from blowholes and impurities, is secured.

Gear Molding

Gear blanks, that is, the casting in which gear teeth are to be cut, must be free from dirt, blow-holes, and other imperfections to a greater degree than the usual run of castings. In molding gear blanks, the mold is usually arranged so that the iron will enter at the hub in order that the face in which the teeth are to be cut shall be as far away as possible from the iron which first enters the mold, and which may carry with it dust or dirt which will render imperfect the face of the casting.

In molding cast gears, that is, gears with the teeth cast on them, the sand must be selected with regard to the size of the teeth; the finer the teeth, of course, the finer the grade of sand that must be used. The sand having the smallest grains will naturally be selected for those gears having the smallest teeth, and as gears with larger teeth have to be molded, coarser-grained sand can be used.

The operation of molding a set of gears will now be described. The patterns being in position on the mold-board, and the drag of the flask placed, sand is riddled over the patterns with a No. 12 riddle. The sand is carefully tucked in the teeth in the gear pattern and the drag rolled over and the joint made, coping down between the arms of the gear as previously described, and the parting sand dusted on. It will be assumed that there are a number of gears to be made from the patterns, so therefore, after making the joint, the cope is placed with an iron band fitted to the inside, and is rammed up. The bottom-board is rubbed down on top of the cope, which is lifted off, placed at one side, and the snap flask removed. The cope part of the flask is then replaced on the drag and the regular cope is rammed up, lifted off, and set on its side. With a small brass tube, a hole is punched through the cope from the joint side, in the center of the mold of the hubs of the gears in the cope. After having lifted off the cope, the patterns are boshed, rapped, and drawn.

The process of rapping and drawing a gear pattern is somewhat different from the process of rapping and drawing an ordinary pattern. To rap a gear pattern sideways would distort the teeth and thus cause the finished gears to bind on each other when put in service. Furthermore, rapping the pattern sideways would tend to break the teeth in the sand from the body of sand back of them. When the pattern is withdrawn from the mold, these broken teeth would fall and make an imperfect casting. In rapping gear patterns, a raw-hide mallet is used and the pattern itself is tapped slightly, just enough to jar it free from the sand but not enough to distort or crack the teeth.

To draw the pattern, a pair of tweezers are used, being placed in the drawhole of the pattern and spread apart so as to fill the hole. Lifting on the tweezers and drawing the pattern with his left hand, the molder gently taps the pattern with his mallet and as soon as it feels free of the sand, lifts it clear of the mold with a quick vertical motion. Should any sidewise motion be given the pattern while drawing it and a tooth thereby knocked down, it will be economy to knock the mold out of the flask and make it over a second time, rather than attempt to patch up the teeth.

Care must be taken in tucking the teeth of the pattern to have the sand uniformly firm. Should soft spots be left in the sand forming the teeth, bunches will be formed between the teeth of the gear, and it will be rough. Should the sand be rammed too hard, the teeth will stick to the pattern and be broken. Hot iron must be used in pouring in order that the gear shall come out of the mold with sharp, clean teeth. A facing comprising one part of bolted seacoal and fourteen parts of fine tempered sand should be used between the teeth, otherwise difficulty will be experienced in cleaning the casting.

To return now to the cope which was first rammed up and set aside. This is known as the false cope and is to be used as a match-plate on which the patterns are laid when the second mold is made. This match or false cope is placed on top of the bench and the cope part of the flask closed around it, with the joint up. The patterns are placed in the impressions in the cope, the drag put in position, and sand riddled in on top of the cope in the same manner that the drag was made for the first mold. The false cope and drag are then rolled over together, the cope removed and set aside as in the first case, and the true cope made and finished as before. The use of the false cope in this case is to avoid making the joint every time a mold is made. Instead of using a false cope, an upset may be employed, having guides which fit the pins on the drag of the flask.

At *E* in Fig. 15, is shown a horn gate. The use of this is described in Chapter XV. After the drag has been made, the horn gate patterns are placed in position as shown and the

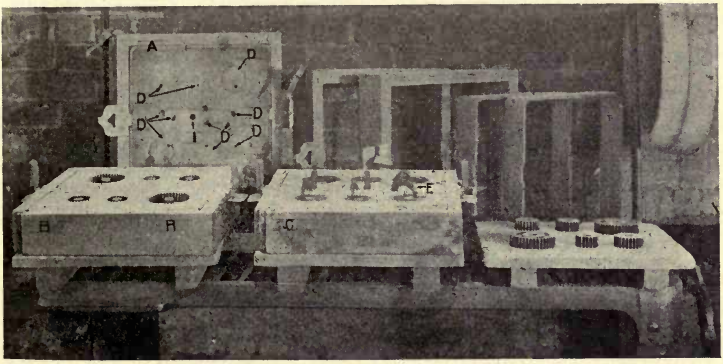


FIG. 15.—METHOD OF MOLDING GEAR WHEELS, ILLUSTRATING USE OF HORN GATE.

A, Cope of mold · *B*, drag of mold with pattern drawn; *C*, drag of mold with horn gate pattern set; *D*, opening of horn gate in cope.

cope is set on the drag and rammed up, the sand being tucked in under the horn gates. These gates are larger at one end than at the other, and after being boshed, can be removed from the sand by letting them describe a sort of semicircle as they are drawn. A gate is cut in the center of the cope and is connected with each of the horn gates leading to the various gear molds. The horn gates are placed so that the iron will flow to near the center of the gear. The green-sand cores in the molds are vented by means of a fine vent-wire before the patterns are drawn.

Molding Gears and Splitting Them

Fig. 16 illustrates the method of molding and splitting a bevel gear. The pattern is shown resting on the cope, and in molding is placed on the mold-board in the same position. The drag is placed around it with the pins down. Sand is riddled into the drag, which is next heaped full and rammed up. The flask used in this case is a *tight flask* and remains on the

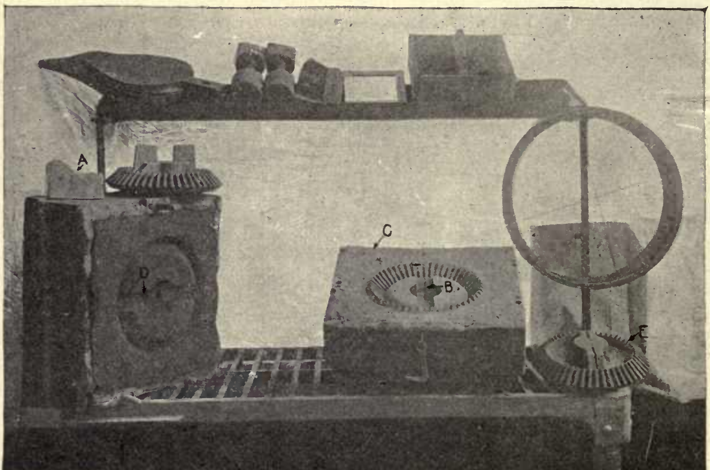


Fig. 16.—Molding and Splitting a Bevel Gear.

mold when the latter is poured, and therefore no iron band is required inside of it. Before heaping the sand into the drag, the riddled sand is tucked into the teeth of the gears. After the drag has been rammed, it is rolled over and the sand is scraped away from the pattern down to the ends of the teeth. In this case the teeth are formed on an angle on the face of the drag, and we are obliged to cope down to the ends of the teeth in forming the joint.

The cope is then made up, and after the mold has been finished and parted, splitting plates, shown at *A*, are set in the prints *B* in the mold of the hub in the drag. Pouring gates *D* are punched through the cope with a rod or tube of the proper diameter, and a pouring basin formed in the top of the cope. The following points may well be borne in mind in molding gears: In boshing a gear pattern avoid putting any excess of water on the mold, else it will be necessary to dry the pattern before using it again. Hard ramming on the point of a tooth makes a rounding instead of a sharp edge. A gear mold must be rammed firmly to stand the strain of the molten metal and to keep the teeth from becoming fat. In winter the patterns should be warmed. At all times iron patterns should be smeared with barberry tallow mixed with naphtha. The tallow should be allowed to set until the naphtha has evaporated, when it may be applied to the pattern with a stiff brush. This will enable the pattern to be drawn from the sand so as to leave a perfect mold. Mending the teeth of small gear molds seldom pays. It is usually better to make the mold over.

CHAPTER III

FLOOR MOLDING

THE term *floor molding* is applied to work which is too large for the bench and which is molded either on the side floor or on the main floor of the foundry. The term is usually applied to green-sand work. The patterns molded on the side floor are those which, while too large for the bench, can yet be handled by one or several men. Patterns molded on the main floor are usually those which require the services of a crane for handling the completed mold. Floor molding requires somewhat different equipment from bench molding and the procedure is also different. The castings being larger, the question of pouring so as to secure uniformity in the finished casting, without setting up undue strains in the metal, is also important. The matter of pouring will be discussed at the end of this chapter.

In order to illustrate the practice of floor molding, we will consider the molding the legs of a lathe bed, shown in Fig. 17. In the first place, a rigid flask is used instead of a snap flask. This is a frame of wood *C* solidly nailed together, with tie-rods extending across it as shown. Furthermore, while the sand in a small flask, say up to fifteen inches square, properly tempered, will support itself when lifted with the cope, it will break away from the flask and fall when the flask is lifted if the latter is of greater area. Therefore some provision must be made to support the sand in the cope in the larger flasks which are used in floor work. This provision takes the form of ribs, such as are shown at *E* in the cope of the flask in the background of Fig. 17. These ribs or bars extend from one side to the other of the cope, being firmly nailed in place. At intervals, to keep them from being sprung sidewise, are cross bars *M* known as *chucks*. This construction forms, in effect, a series of copes extending from side to side of the flask. In order to tie all of these copes together, and form one cope as a whole over the casting, the sand must extend under the bars and chucks; therefore, the bars are made about three-quarters of an inch less in depth than the depth of the cope. The pattern which is under consideration, is of the flat-back type, that is, no part of it will extend up into the cope. The bars then extend down to a uniform distance from the joint of the

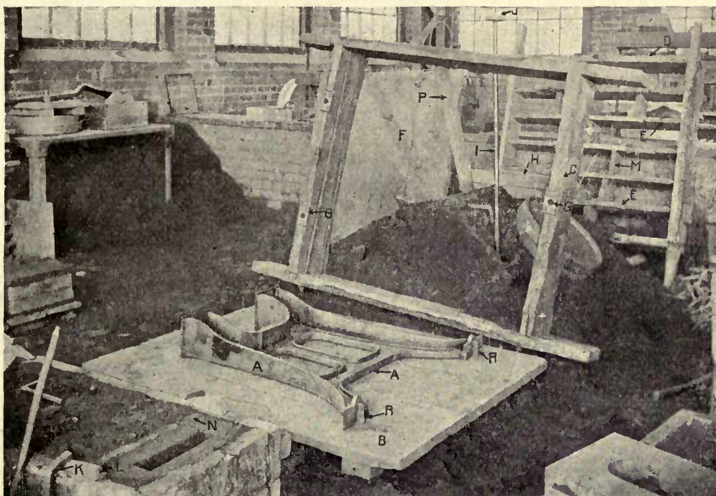


FIG. 17.—PATTERN OF LATHE-BED LEGS LAID ON MOLD-BOARD READY FOR FLOOR MOLDING.

mold. Should the pattern be of such shape that it is necessary for it to extend into the cope, a portion of the bars would be cut away to permit the pattern to fit under them, and to allow a thickness of about three-quarters of an inch to an inch of sand to come between the pattern and the bottom of the bars. The sand is necessary not only to protect the bars from coming in contact with molten iron and burning, but should the wood be allowed to form a portion of the side of the mold, molten iron coming in contact with it would tend to boil and thus make an imperfect casting. The edges of the bars are chamfered to a narrow edge at the bottom, so as to divide the sand near the joint as little as possible.

In molding the pattern shown in the illustration, the mold-board is first rubbed to a firm bearing in the sand of the floor, loose sand to a depth of about two inches first having been shoveled over the space where the molding is to be carried on. The pattern is placed on the board as shown and the drag of the flask set around it with the pin holes *G* down. Sand is riddled on the pattern and around it to a depth of about two inches and is scraped up and laid against the deep upright sides of the pattern until its entire surface is covered with riddled sand. Ten-penny nails, dipped in clay wash, are set point down, one in each corner of the pattern and the sand tucked around them. It is often advisable in a deep pattern of this character to vent the sand in the corners with a vent-wire. The sand is next shoveled in from the heap, the point of the shovel being placed close to the pattern, and the sand slid off gently into the flask, to avoid knocking the riddled sand away from the pattern. After the pattern is well covered in this manner, sand is shoveled in without further precaution to a depth of about five inches and rammed around the pattern. In ramming, the sand should be struck a sharp blow with the rammer rather than merely pushed down. In floor molding, the long-handled iron rammer is used and in this first operation is held peen down, the sand being rammed alongside the flask and around the edges of the pattern, care being used to strike not closer to the pattern than one inch. Especial care must be used when ramming the sand in the pockets not to strike the pattern or to ram the pockets too hard, which will prevent the easy escape of gases from the mold. After the sand has been rammed to a depth equal to the height of the pattern, it is vented with the vent-wire, and is often trodden down with the feet. A second lot of sand is then shoveled in and the sand outside the pattern is rammed with the butt end of the rammer and also rammed over that portion of the pattern where it lies the deepest. At this stage, the molder must use his own judgment as to how firmly the mold must be rammed and in time will be able to judge by the feeling of the sand under his rammer, whether or not the mold is rammed sufficiently hard. After second ramming, the flask is heaped full, trodden down, rammed with the butt end of the rammer, and struck off level with the top of the flask. Loose sand is then thrown on and the bottom-board rubbed to a bearing the same as in bench molding. The board is then raised and the mold well vented, after which the board is replaced and fastened by means of clamps, which extend from under the mold-board to the top of the bottom-board, being made firm by wedges driven under the toes of the clamps. The mold is then rolled over preferably to a point back of where the molding was begun. However, should the foundry be cramped for room, the flask can be twisted around and lowered on its original bed, and the drag rubbed to a firm bearing on the floor, sand having previously been thrown there for the bottom-board to bed in.

The clamps are now removed, together with the mold-board, and the molder assures himself that the pattern rests solidly on the sand in the flask. Occasionally, with a thin pattern, the pattern itself may be warped and on the removal of the mold-board, a portion of it spring up from the sand. In such a case, the spirit level should be placed on the pattern and weights used to hold the pattern level until the joint is made. After making the joint, parting sand is dusted on, the weights removed, and one-half inch of sand riddled over the joint. To locate the position of the gate and the risers which are set in the cope, balls of molding sand are placed in the position desired for the gate and risers to ascertain whether these positions will be clear of the bars and chucks of the cope, and after the joint of the flask and the pin holes have been cleaned, the cope is put in position, having been first wet or clay-washed. Some of the molding-sand balls will probably be found to come directly underneath a bar in the cope and the gate-stick and gaggers must be shifted accordingly. The gate-stick must be set far enough away from a thin pattern of this character, to avoid danger of the gate breaking into the mold when the casting is poured. Gaggers (see Fig. 138, page 214) are next set. The gaggers should be of such size as to come close to the top of the bars, but they should not project above if it can be avoided. Gate-sticks and gaggers being in place, sand is riddled through a coarse riddle to a sufficient depth in the cope to permit it to be tucked firmly around the gaggers and between the pattern and the lower edge of the bars. In doing this, the molder places a hand on either side of the bar so that his fingers can push the sand underneath the bar from either side. The sand must be tucked firmly, otherwise soft places will be left in the mold which will cause trouble when it is poured. Sand is shoveled in next to a depth of about five inches, and rammed along each bar with the peen of the rammer. The peen is then held transversely to the bar and the sand cross-rammed. More sand is shoveled into the flask and is again peened, after which the flask is heaped with sand which is rammed between the bars with the butt end of the rammer. The loose sand is now struck off from the top of the flask with a wedge, special attention being given to the detection of any gaggers which may project above the bars. Should such a gagger be struck and loosened, the sand is immediately punched down alongside the gagger until it holds firm.

The cope is then vented all over and the gate-sticks drawn, after which the cope is lifted off and placed on *set-off boxes*, that is, a box having ends and sides but no bottom or top. One edge of the flask is lowered on to these boxes, the other being raised in the position occupied by the drag in Fig. 17, being held up by a prop at the back. In this position the molder finishes it, by first feeling it all over to see that no soft spots have been left in tucking the bars, in which case they are repaired by first cutting up the sand slightly with the trowel and then pressing fresh sand into place and finishing it with the trowel. Should soft spots not be repaired, iron will force its way into them when the mold is poured and form excrescences on the casting. The cope is finished in the usual manner, breaks in the sand being repaired, and shining spots in the sand which indicate the presence of gaggers too close to the face of the mold are filled in with fresh sand. The joint in the drag is next brushed off and the pattern boshed and rapped for drawing from the sand.

Instead of using a draw-nail or a bar set in a hole in the pattern for rapping, which would assuredly damage a light pattern such as is shown, the joint is cut down in a number of places around the pattern and the butt end of a wedge placed in these cuts against the pattern. Light blows are struck with a hammer on the wedge until the pattern is freed from the sand. The sand is then built up at the spots where it was cut out and the pattern is drawn by means of eye-bolts screwed into the pattern. In drawing a pattern of the kind shown, in fact in drawing practically all patterns used in floor molding, two men are required, one at either end. These must lift the pattern at exactly the same time and each must be prepared to stop lifting at a signal from the other which is given when either notices any indication of the sand breaking on the edges of the mold as the pattern is lifted. When this happens, the sand is pressed back in place and slicked over with the trowel before the pattern is drawn any further.

The pattern being drawn, the mold is carefully looked over for imperfections and breaks in the sand. As far as possible, broken sand is carefully replaced with the fingers, pressed back into position and dampened slightly. The face of the mold is then finished with proper tools at this point, and the entire mold is gone over in a similar manner until all broken parts are repaired. Sprues are now cut from the upright gates into the mold and the mold is cleaned of all loose sand by means of the bellows and *lifters*. As any sand which will not blow off, will not wash off under the influence of molten iron flowing over it, the bellows afford an indication as to whether there are any loose parts of the mold which have been overlooked.

On a thin mold of this character, it is advisable to sprinkle a light coating of talc over which the iron will run freely and a cooler iron can therefore be used in pouring. The sprues and gates are arranged so that the iron will enter the deeper parts of the mold and also at the feet. In a mold of this character, peg-gates (see Fig. 129, page 171) are advisable. Cores are next set and the mold is closed. Five men are required for this operation with a flask of this size, one at each corner of the flask while the fifth looks in under the cope as it is closed on the drag to see that no part of the mold falls down. It is essential that all four men lift and lower the flask simultaneously, otherwise they may warp the flask and thus cause a portion of the mold to fall. The man who watches to see that this does not happen is called the "peeker."

The mold is now clamped, that is, the cope is fastened to the drag by means of clamps as shown at *K*. Fig. 17. These U-shaped pieces of iron are set with the legs of the U projecting over the edges of the cope and drag respectively, being fastened firmly in position by means of wooden wedges *L* driven under the toes of the clamps. The usual method of wedging the clamps is to pry the clamps on to the wedge rather than drive the wedge home with a hammer which might, from the force of the blow, jar the sand down into the mold.

Pouring Floor Molds

In pouring this mold, two ladles are used. The one from which the iron is to flow to the deeper part of the mold is poured a little in advance of the other. As there is no part of the casting above the joint of the flask in the cope, the rising of the iron in the gate indicates when the mold is filled. In general, in pouring side floors, the same ladles are used as for pouring bench molds. A sufficient number of ladles, however, are used to pour the entire mold at one time. This sometimes requires six to eight ladles, pouring simultaneously at different gates in order that the iron may reach all parts of the mold in a fluid condition. A large wash sink is a typical casting requiring pouring of this character. In pouring from many ladles, the men all start and stop pouring at a given signal, thus avoiding straining the casting which might occur were iron poured in the gate after the mold is filled, thus putting pressure, due to head, on the mold. Other classes of castings poured in this manner, include castings for cotton, woolen, and other light machinery.

In pouring the light and heavy molds on the side floor, large ladles are often used holding from one hundred and fifty to three hundred pounds of iron, in which case several men are required to handle the ladle. Many castings made on the side floor may require several of these ladles. It is advisable to have available, in pouring a heavy casting, approximately the exact amount of iron required. Therefore, foundries are usually supplied with a number of ladles of varying sizes so that by a combination of sizes the required amount of iron may be brought to the mold. It often is necessary to pour one portion of the mold with very hot iron and another portion with slack or cooler iron. Different gates are therefore arranged in which the two kinds of iron are poured from different ladles. Such a case occurs when a casting has both light and heavy parts; the hotter iron is fed to the light part. It is evident from the foregoing, that floor molding requires that consideration be given to other points than the actual making of the mold. It is impossible in a book of this character to lay stress on all these points and the student is urged to observe the methods of more experienced molders when gating and pouring the various kinds of castings.

Molding Pulleys and Wheels on the Floor

A common job of floor molding with green sand is shown in Fig. 18, where a wheel is to be molded and poured with a cast iron rim and hub, and with wrought-iron spokes set in the mold around which the iron flows. In the larger sizes of wheels of this character, provision should be made for pouring the rim and the hub separately. The mold is made up with the rim and hub pattern in the usual manner and after the mold has been opened and the pattern withdrawn, the wrought-iron spokes are set in place as shown. The ends of the spokes which are to come in contact with the molten iron are coated with a mixture of red lead and benzine or naphtha. The rim is first poured, and, in shrinking, forces the spokes inward. After the rim has cooled the hub is poured. Wheels of this character are made weighing up to six tons and up to ten feet diameter. It is a quite common practice to cast iron around iron or steel shafts. If the shaft should be given a coating of liquid glass (silicate of soda) prior to being placed in the mold, the iron will lie quietly against this and when cold,

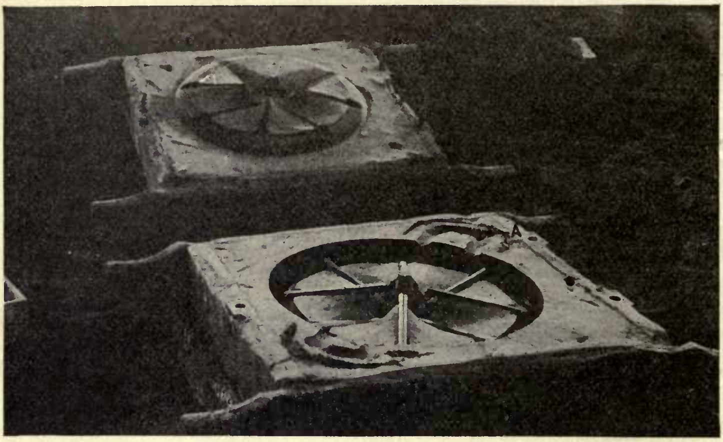


FIG. 18.—MOLDING A WHEEL IN WHICH WROUGHT-IRON SPOKES ARE TO BE SET.

a pressure of many tons will be necessary to separate the two. Aluminum paint often serves the same purpose well.

In molding pulleys, the work is now ordinarily done on machines, which will take patterns up to, say, six feet diameter. Many pulleys, however, are still molded by hand. In some foundries it is customary to have as a pulley pattern, a rim, arms loose in the rim, and a loose hub. In molding, the rim is rammed up in a cheek, which may be part of a flask or a drag staked on the floor, having enough chucks around it to hold the sand, if the mold is of sufficient size to require it. After the sand is rammed around the outside of the rim, it is rammed inside to the required depth and a hole dug at the center for the hub. The arms are placed inside the rims, at the proper distance below the top, and sand is tucked under them and around the hub, and the joint made. A lifting plate having projections of the shape of the spaces between the arms on its surface, is placed inside the pulley, the two projections between the arms being fastened together by clamps which pass over the arms and tie all the plates together. A lifting screw is usually placed in three of the plates. The inside of the pulley, over the arms, is rammed up with the gate-stick in the center as if the upper half were molded in a cope. After ramming, the pattern is drawn and the cheek lifted. The rim is finished and the cope and drag halves of the center are marked so that they can be replaced. The upper half of the center is lifted off, the hub drawn, and the arms drawn from the drag with the hub. The center core is set and the cope half closed. The rim is then blackened and rings, half to three-quarters of an inch in thickness, are laid on the center, the runner built, and the center weighted for pouring.

Molding Large Bevel Gears on the Floor

Fig. 19 illustrates the making of a large bevel-gear mold. The pattern *A* is placed on the mold-board as shown, with the drag hub *B* in the center. The cope side hub is loose and is shown at *E*. The drag is placed with the joint side down and No. 1 Albany sand mixed with seacoal in the proportion of five parts new sand to five parts old sand to one of seacoal is tempered and riddled over the pattern. The facing is tucked in between the teeth to insure that the sand teeth thus formed shall be of sufficient hardness, and surplus sand is then scraped from the face of the teeth by hand. Facing sand is next riddled over the teeth and the drag rammed. The same precautions must be observed in ramming as were observed in the making of small gears at the bench, as described in Chapter II. After rubbing the bottom-board to a bearing, the drag is vented over the pattern, care being taken to avoid puncturing the sand teeth. The drag being rolled over, the joint is made by coping down around the pattern to the bottom of the outside of the teeth as shown at *D*, the sand being pressed firmly in between the teeth with the fingers while making the parting. Parting sand is rubbed on the face of the sand teeth and the cope hub *E* placed on the center of the pattern. Facing sand is laid around the tooth part of the joint to the proper thickness for setting the gaggers, and the cope placed on the drag. Gaggers are next set around the gear to lift the hanging sand formed by the outside of the teeth and over the pattern.

Sand is then shoveled in from the heap, the flask bars are tucked, the gate-sticks set on top of the hub to form the pouring gate, and the cope rammed up. After the cope is lifted the hub *E* is drawn and the teeth around the pattern are boshed. The pattern is rapped very lightly as described in the operation of molding small gears in Chapter II, and drawn from the sand, and after the mold is finished, a light coating of talc or of lead mixed with talc, is dusted over the face of the mold. A vent-wire is passed through the core-print in the drag and core *G* of the proper diameter and length, is set after the vent hole in the tapered end has been filled with sand to prevent iron entering the vent holes. The cope is then closed on the drag. The gate-stick should be placed in the gate hole before closing the cope. The pouring basin *H* is built on top of the cope in order that a shallower cope may be used than would be necessary were the pouring basin to be built in the flask. It is thus seen that the molding of a gear on the floor is the same operation as molding a small gear at the bench, with the exception that, there being a larger body of sand contained in a larger flask, different means must be used to secure the sand. Furthermore, the flask is clamped instead of being weighted.

In the flask *N* is seen the same gear with cores set to form a split gear for fastening in place on a shaft over the end of which the gear cannot be slipped. In molding this gear, the mold is made exactly as before, but is gated so that the iron will enter on either side of the splitting cores *L* and flow up as evenly as possible on either side of them. The gates are shown at *S*. The splitting cores *L* are extremely thin and require special rodding to strengthen the sand. Instead of sand cores, iron plates, of the same shape as the splitting cores, are sometimes used, having a thick coat of blacking dried on them in the oven to protect the plate from the molten iron, and to

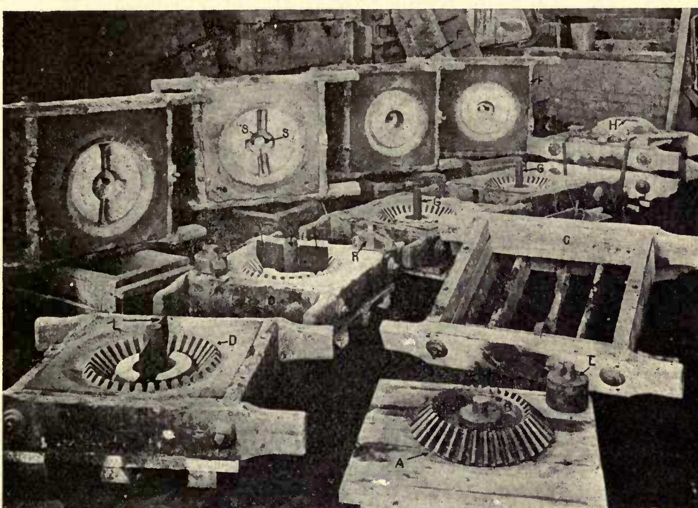


FIG. 19.—MOLDING BEVEL GEARS ON THE FLOOR.

prevent the latter from burning on the plate when the mold is formed. It is evident that the hubs for split gears must be of special design and have prints on them, not only for the center core but for the splitting core. Such hubs are shown in the flasks at *N* and *O*.

In molding straight tooth spur gears, of twenty-four inches diameter and over, it is customary to place the gear pattern on the mold-board and to throw handfuls of sand, taken from a heap alongside the mold-board, in between the teeth.

Sand rammed in this fashion forms very firm teeth. After the teeth are formed, sand is scraped away from the outside of the pattern and fresh sand is riddled into the flask and tucked up around the outside of the teeth after which the mold is rammed up as any other mold would be.

Gear patterns are often molded by using the floor as the drag and bedding the pattern in it. Usually where the face of a gear is quite deep, and the pattern has coarse teeth, nails or pieces of rods are set in the teeth of the gear. Suppose the depth of the face to be fourteen inches. After the gear is rammed up a distance of three inches, nails or spikes are laid radially in the teeth and it is rammed up three inches more, after which additional nails are inserted. The operation is repeated at a depth of nine and twelve inches. Thus the teeth formed in the sand will be fastened by the nails to the main body of sand back of the teeth. They are thus stronger and resist the strains of pouring better, and also are better able to sustain the weight of the cope. This practice is adopted only with gears of rather coarse teeth and weighing from four hundred pounds to several tons.

CHAPTER IV

LIGHT CRANE FLOOR WORK

MOLDS which are to be made under the crane, require considerable skill on the part of the molder and only the more experienced men should be entrusted with this work, inasmuch as the castings made are large and the spoiling of one, due to poor molding, involves considerable loss. A typical mold made on the floor is illustrated in Figs. 20 and 21, being one side of a wire cloth loom frame. The finished casting weighs about four hundred and fifty pounds, but in pouring it, two ladles are used in order to obtain the proper distribution of the iron in the mold.

An iron pattern *B*, Fig. 20, is used. This is placed on a mold-board which is bedded level on the floor. The drag of the flask is placed around it, joint side down. The pattern must bear firmly on the mold-board, or else wedges must be driven between it and the board, or the corners of the board wedged up until it comes in contact with the pattern. The pattern is then covered with a mixture of seacoal facing in the proportions of one part seacoal, five parts new No. 1 Albany sand and five parts heap sand. This mixture is wet with water, shoveled over, tramped down and riddled through a No. 4 sieve, after which it is riddled through a No. 8 sieve on to the pattern, being then carefully laid against the sides. Sand from the heap is then riddled through a No. 3 sieve over the facing sand, after which sand is shoveled in over the entire surface to a depth of five inches. Sand is now rammed adjoining the sides of the flask and around the pattern, the rammer being kept about one inch from the pattern, as in ramming flasks on the side floor. The sand is then rammed with the butt end of the rammer between the openings in the pattern and in the remainder of the flask, excepting immediately over the pattern, which would cause the sand to be too hard at this point. An additional five inches of sand is then shoveled in and peened down along the edges of the flask and trodden down all over the drag and afterward butted with the butt of the rammer, over the pattern, in addition to the other portions. This operation of adding sand and ramming it with the butt is continued until the flask is completely filled. It is then struck off and leveled, the bottom-board placed and rubbed to a bearing, after which the drag is vented over the pattern, the bottom-board replaced and clamped to the mold-board with the flask between them.

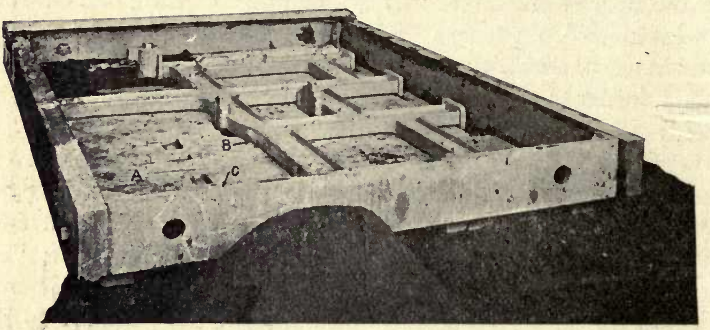


FIG. 20.—PATTERN OF WIRE CLOTH LOOM FRAME ON MOLD-BOARD READY FOR MAKING DRAG.

The total weight of the flask, pattern, and sand is about forty-four hundred pounds and the services of the crane will be required to roll it over.

A chain is placed around the drag and hooked over the crane hook, after which the crane raises the flask clear of the floor. While suspended in the air, it is turned over and lowered on the original bed of molding sand with the mold board up. The ends of the mold-board are leveled, a spirit level being used for this purpose, and sand is rammed under the cleats of the bottom-board to maintain the level. After removing the mold-board, the joint is made as in ordinary small castings.

Parting sand having been dusted on the joint, the pattern is covered with a seacoal facing to a depth of three-eighths of an inch, and the cope, previously wet down, is placed on the drag, after which gaggers are set. Gate-sticks are set and sand tucked in between the bars of the flask in exactly the same manner as is done in side floor molding.

In side floor work, considerable reliance is placed on the clay washing of the bars of the cope to retain the sand in place, but in crane floor work, the flasks being larger, careful gaggering is required, as the bars cannot be depended on to hold

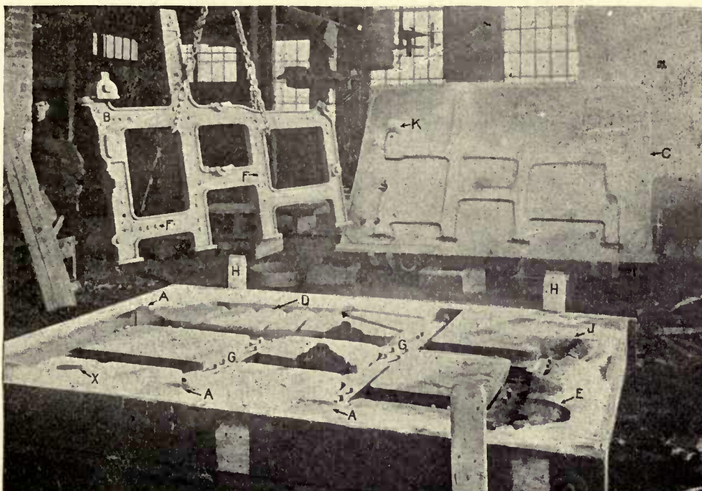


Fig. 21.—Drag of Wire Cloth Loom Frame on Floor. Cope is Standing Against Wall.

the larger body of sand. When placing the cope, should it be found that it does not bear evenly on the drag, it should be clamped down to it, or if it is too stiff to permit of this, the cope should be wedged up and care must be taken to see that this wedge is replaced when the mold is closed for pouring.

Referring now to Fig. 21, it will be noted that the top of the pattern is coped out and gaggers, with long shanks, are required to lift the hanging belly of sand in the cope. In setting these gaggers, they are placed so that they will assist in supporting each other, and in proportion to the size of the flask a greater number are used than in side floor work. After the sand has been tucked in between the bars and the pattern, sufficient sand is shoveled in between the bars of the cope to form a ramming and the cope is rammed up as in side floor work. After the top has been scraped off, the cope is well vented. The crane is then brought over the center of the

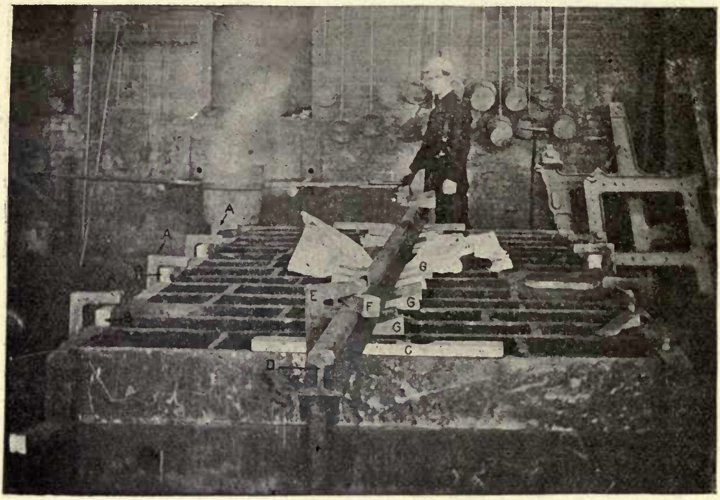


FIG. 22.—WIRE CLOTH LOOM FRAME MOLD CLAMPED READY FOR POURING AND BOUND DOWN WITH BINDER.

cope and chains are hooked into staples or eyes set in the sides of the cope flask and the cope lifted and set to one side, one edge resting on set-off boxes as shown in Fig. 21. Care must be exercised in doing this as any jar is liable to shake sand from the cope. Therefore, strain should be brought on the chains gradually, and lifting and lowering commenced slowly. It is almost invariably the case, that when the cope is lifted, some parts will be broken down. When these are repaired, the sand should be nailed to insure its remaining in place. The cope being finished, a coating of silver lead is applied, over which a light facing of talc is dusted.

The joint being brushed off, the pattern is boshed and rapped. Eye-bolts are screwed into the pattern and it is lifted from the sand by the crane, the pattern being rapped as the crane lifts it. The mold is finished and the gate *D* is cut and also a second gate at *E*. The principal body of iron enters through this and therefore it is made considerably larger than the other. Sharper iron is poured through this gate than through *E*. At *X* a gate is cut to the riser.

The mold being finished, cores are set in the prints formed by the core-prints *F* and *G* on the pattern. Sand is slicked around them and the mold coated with silver lead over which talc is dusted. The cope is now lowered on to the drag, being guided to the point where the pins enter the pin holes by the wooden guides *H*. Before lowering the cope, flour is placed on all the small cores to indicate whether or not the cope bears on them. When the cope comes to a bearing one clamp is set on each side to give the same conditions which will ensue when the mold is finally closed. The clamps are then removed, the cope lifted and examined and the cores resting in the prints *AA* placed, after which the mold is closed and clamped as shown in Fig. 22. In order to prevent the cope springing at the center, when poured, blocks of wood are set at either end of the flask and a rail clamped across them as shown in Fig. 22. Wedges are driven between this rail and the bars of the flask. Paper is laid over the top of the cope, which is lighted when the mold is poured and gases escape from the vents. The gases escaping from the vents in the drag will be lighted with a red-hot skimmer.

CHAPTER V

BEDDING PATTERNS IN THE FOUNDRY FLOOR.—MOLDING A DRAW-BENCH FRAME IN THE PIT.—MOLDING THE FRAME OF A GAP PRESS.—CASTING LATHE BEDS AND CHILLING THE WAYS

OFTEN large patterns are molded in pits in the foundry floor, cope and cheek plates being the only part of the flask used. In this way, the floor is used as a drag and a large part of the expense of flask manufacture is avoided. In case the foundry floor is damp, tanks of large size are sunk in the floor and molds made in them. If this is not done, the floor being slightly damp, the inside of the pit may be lined with tar paper. Work of this character is usually known as pit molding. Most of the molds made in pits are of green sand, although skin-dried molds are also made.

Instead of using but one pattern in the flask, the molder is, in many cases, given patterns of various sizes and shapes which he is required to mold in a certain space in the floor. For instance, at the foundry of R. Hoe & Co., New York, printing press manufacturers, it is the custom for two molders to work together, assisted by two helpers and to use a cast iron cope fourteen feet long by five and one-half feet wide, molding in the floor enough patterns to fill the space covered by the cope.

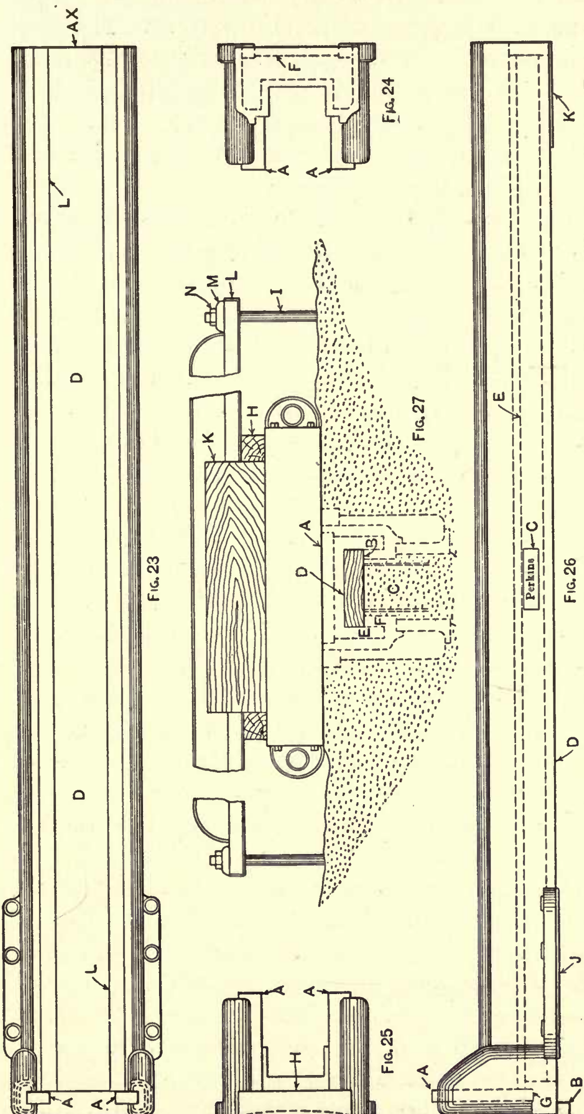
The space allotted to a molder, on work of this character, is termed his "floor." When the number of castings desired from a medium-sized pattern is small, they often are molded in a hole dug in the floor. Assume that there are several pipes to be made, each three feet long and six inches diameter. A hole is dug in the floor about four feet long, in order to allow for the core-prints in the pattern, and four and one-half inches deep. Where the flanges come on the end of the pipes, the hole is made deep enough and wide enough to accommodate them. Molding sand is riddled in the hole and the pattern placed in it with the joint side up. A long block of wood being placed on top of the pattern, the pattern is driven down into the sand the proper distance by pounding on the block, thus ramming the sand underneath the pattern. The pattern is now weighted in position and riddled molding sand laid alongside of it by hand. Sand is then shoveled in from the heap and is peened down around the pattern with the rammer. If necessary, the pattern will be rapped down and lifted out and the flange pattern fixed up, after which the pattern is replaced and the sides rammed up. The sand being rammed even with the top of the floor, the joint of the pattern is made and the cope part of the flask placed over the pattern. Parting sand is dusted on and the cope made up in the ordinary manner. Before lifting off the cope, the molder drives down in each corner of the cope on the outside, an iron rod or a wooden stake about twelve inches long to act as guide when lifting and replacing the cope. The cope is then lifted and finished, the pattern is drawn and the drag finished, after which the cope is replaced and weighted for pouring and the stakes removed when the mold is ready to pour. Instead of weighting the cope, it may be held down by bolting it by means of binders across the cope, which engage bolts rising from binders underneath the mold. This method will be described in detail in the description of the next mold.

Molding a Draw-Bench Frame in the Floor

Having described the construction of a comparatively small mold, we will now take up the process of bedding a rather large pattern in the floor. Assume that we have the pattern shown in Figs. 23–27. This is a comparatively shallow pattern, long and narrow. We will also assume that it is to be molded in a pit prepared for a much larger pattern. The pit is first dug in the foundry floor, say sixteen feet long, nine feet wide, and six feet six inches deep. Referring to Fig. 28, *binders* of cast iron, spaced four feet on centers, are placed across the bottom of the pit. The ends of the binders should be in line and the tops leveled to a straight edge, after which sand is firmly rammed between and around them. Each binder has a vertical slot in each end in which an *eye-bolt* with a nut and washer on the lower end, is slipped, as shown in the illustration. Sand is then rammed around the end of the binders and that between them is struck off level with the top. Iron plates, one inch thick, are placed on top of the binders, covering them and extending to within six inches of the eye-bolts. Six-inch square timbers are stood on end inside of each eye-bolt and on top of the binder. These pieces of timber are allowed to extend above the floor line about four inches. Sand is rammed around the bottom of them and scantling is nailed from one to the other at the top as shown. The end timbers are also tied across the ends with scantling.

On top of the iron plates is laid about five inches of molding sand, on top of which is placed a cinder bed, both firmly rammed. Over the cinder bed, straw or newspapers are placed, to keep the sand, which is later rammed on top of the cinders, from working down among them and filling the voids in the cinder bed which are depended upon to bring the gas from under the casting to pipes which extend from the cinder bed to a little below the top of the floor line, as shown in Fig. 28. In the top of the pipes, a plug of rolled bagging is placed to prevent sand entering while the mold is being rammed. This is removed before the mold is poured.

The timbers are sawed off flush with the floor line, a cord being used to give the proper alignment. This will give more accurate results than any attempt at measuring the timbers and sawing them off before placing. The pit thus prepared, is for a pattern four feet six inches deep. It can be used for a smaller pattern by simply filling the pit to a greater or less depth with sand. Referring now to Figs. 23–27, the pattern is placed on the floor in the position in which it is desired to pour it and its outline traced in the sand. This indicates the amount of space required for the pattern, which is then removed and the pit excavated to a sufficient depth to permit



Figs. 23–26.—Pattern for a Draw-Bench Frame. Fig. 27.—End Section of a Mold of Draw-Bench Frame showing Cope, Runner-box, and Binder in Position.

molding the pattern, a deeper hole being dug at one end to accommodate the projection on the pattern. The cinder bed is placed, covered with newspapers, and the gas pipes put in position. On top of the cinder bed, molding sand is rammed to conform to the line *F* of the pattern, Fig. 26. The pattern is then placed in the pit and leveled to the proper height with wedges *F*, Fig. 30.

The portion of the pattern *DD*, Fig. 26, is removable. This is removed and the remaining portion of the pattern is weighted at the ends, and facing sand tucked under the edges of the pattern. The construction of the pattern is such, that this work can be done both from the inside and the outside, while the weights hold the pattern in place. The wedges *F* are removed as they are reached in this operation. Gate cores are placed at the ends of the pattern and also upright gates. Facing sand is laid up against the side of the pattern and black sand is shoveled in around it to a depth of about five inches and is then firmly rammed, first with the peen and then with the butt of the rammer. Inasmuch as these first rammings of sand receive the greatest side strain from the melted iron when the mold is filled, this portion of the operation must be carefully done. The facing sand, lying loose at the top and adjoining the pattern, is scratched away and when the core-prints *C*, Fig. 26, are reached, the pins which hold them to the side of the pattern are removed. These pins are usually made of three-sixteenths-inch wire, one end of which is turned over and extended through the core-print into the pattern.

The outside being rammed up, the inside of the pattern next receives attention. Facing sand is laid against the sides of the pattern and black sand is rammed inside. When the sand has reached the proper height, five-eighths-inch iron rods are driven down in the green-sand core, formed inside the pattern, as shown at *G*, Fig. 30. The pattern is faced and sand rammed up in it until it is within three-quarters of an inch of the top, when the sweep *D*, Fig. 27, is used to true the facing sand in the last three-quarters of an inch. The green-sand core is vented, care being taken that the vent-wire passes through the newspapers or straw into the cinder bed. The vents are then filled with sand at the top and the face at the top of the mold is made up with the fingers. The covering boards forming the top of the pattern are then replaced and the joint is made level with the upper surface of the pattern. The joint being made, parting sand is dusted on, the cope is placed, rapped down, staked, and then hoisted off. Attention is here called to the manner in which the cope is barred through the center as shown in Fig. 31.

Facing sand is next spread over the pattern and the joint, after which the cope, first being wet down or clay-washed, is lowered into place. Gate-sticks and gaggers are set, black sand is riddled into the cope and tucked in between the bars and pattern. Sand is then shoveled into the cope to a depth of about five inches and rammed with the peen of the rammer. Enough rammings of sand are added to fill the cope level full. The final ramming of sand is butted with the rammer and the excess sand cleaned off. In ramming up the cope, the space between the lines of chucks, *CC*, Fig. 31, is not rammed up with sand, but is left open and the cope well vented.

The gate-sticks are now removed and the cope hoisted off. The joint is brushed off and the mold is vented all around the pattern at a dis-

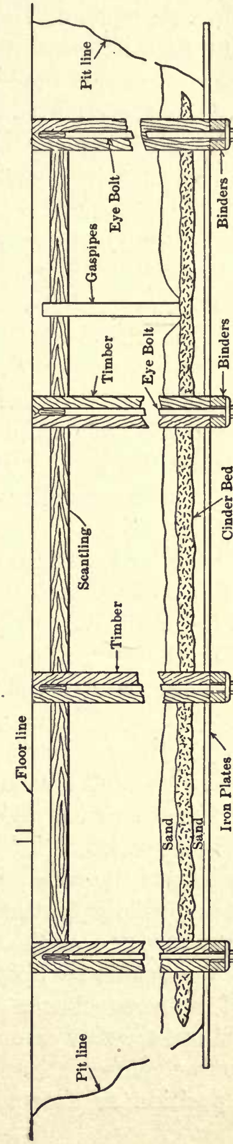


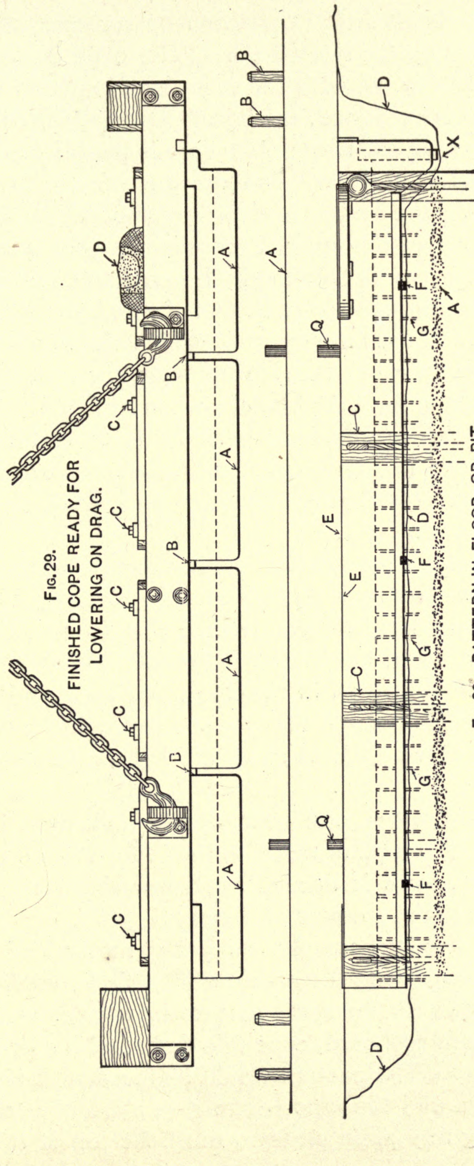
FIG. 28.—PIT PREPARED FOR MOLDING DRAW BENCH FRAME IN THE FLOOR.

tance of about one and one-quarter inches from the edge of the pattern after the latter has been boshed. The pattern is now rapped and drawn, the gate-sticks removed, and the mold finished with trowel, slicker, and lifter, and wherever square corners of sand have been left on the inside of the mold by the pattern they are rounded off to form fillets in the casting. This is a point which should always be remembered, for unless a fillet be placed in the corner of a casting, strains will be set up when the casting cools and it will have a tendency to break through the corner.

Referring to Fig. 27, at *A* will be noted a partition extending the length of the casting formed by a corresponding space in the mold. As the green-sand core *C* is struck off level at the line of pattern *B*, this core extends only partially into the pattern. The balance of the space is occupied by dry-sand cores hung from the cope. These are shown at *E* and straddle the green-sand core, leaving a space between them and the green-sand core into which the iron flows to form the partition *F*.

In order to obtain the right thickness of metal on the sides of the casting, pieces of board, of the same thickness as the casting is to be, are placed over the green-sand core, after which the cores *E* are lowered into position on these boards. After they are correctly placed, the cope, Fig. 29, is lowered over the mold, being guided to place by the stakes *B*, driven into the floor. Hook bolts are passed through the openings *A*, Fig. 31, and attached to staples provided for the purpose at *B* in the cores. Gate-sticks are placed at *O* where the gas is to escape from the cores and wedges are driven in between the bars of the cope and the top of the cores to insure the cope bearing solidly on the cores in order to hold them in position to give the proper thickness of metal when the mold is poured.

The spaces between the bars *XX* at either end of the cope, and between chucks *C C*, left open when the cope was rammed up, are now rammed with black sand and the gate-sticks forming vents are drawn. The clamps *H*, Fig. 31, are now laid in position as shown and by means of the slotted bars *D*,



FIGS. 29 AND 30.—MOLDING A DRAW-BENCH PATTERN IN THE FLOOR OR PIT.

slipped over the hook bolts to the cores, previously mentioned; the cores are firmly held in position by screwing the nuts on the bolt down on the slotted bar. The cope is next hoisted as is shown in Fig. 29 with the cores hanging from it.

The mold is examined, the boards on top of the green-sand core are removed, the name-plate core is placed, and the cores *X*, Fig. 30, set in position. Necessary repairs to the mold are made and its entire surface is given a coat of silver lead. Gates are cut to connect the upright gates in the cope with those in the floor. The cope is then finally lowered and held down with binders which span the pit. Blocks of wood are placed on the cope underneath the binders, after which the bolts *I*, Fig. 27, are hooked into the eye-bolts in the floor, the tops being set in the slots in the ends of the binders, when by screwing down the nuts, the binders are made to bear firmly on the cope. Care should be taken in tightening the binders as the nuts at the end will exert considerable leverage and crush the mold if screwed down too far.

Runner boxes, shown in Fig. 27, at the ends of the cope, are placed and *runners* built as indicated in Fig. 31. In order to avoid any great head on the casting, due to excessive height of the runner boxes, the *flow-off D* is built, which conveys any excess of iron to a basin in the floor. Gases escape from the mold through the pipes *Q*, Fig. 30, and through the gates leading from the cores. These gases are lighted as soon as they begin to flow.

Eye-bolts, timbers, and vent-pipes are all kept below the floor level in this type of mold, so that they will be out of the way. When access is needed to them, they can easily be reached by a slight amount of digging.

In order to compare the foregoing method of molding with the ordinary way of molding in a flask, consider what would be done with the same pattern in a flask. It would be placed on the mold-board, cope side down, with a drag around it as in Fig. 32. The pattern would be faced with facing sand on the outside and the sand rammed in alongside the pattern as in molding any plain pattern, until the top of the pattern

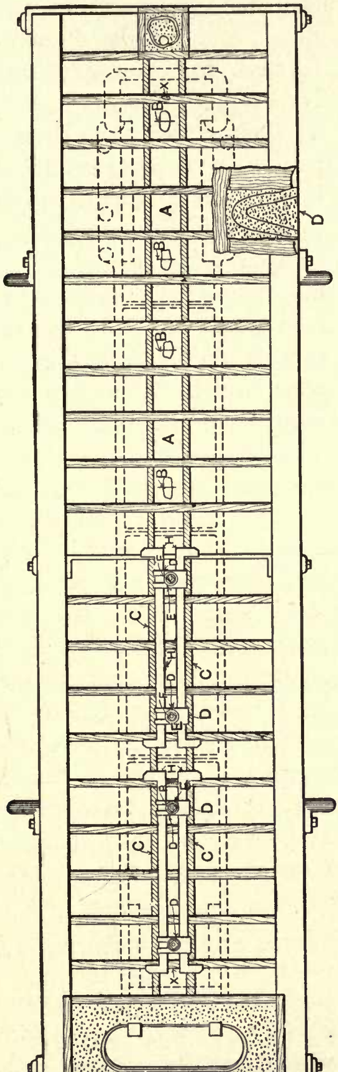


FIG. 31.—PLAN OF COPE OF DRAW-BENCH MOLD, SHOWING ARRANGEMENT OF BARS AND METHOD OF SECURING CORES.

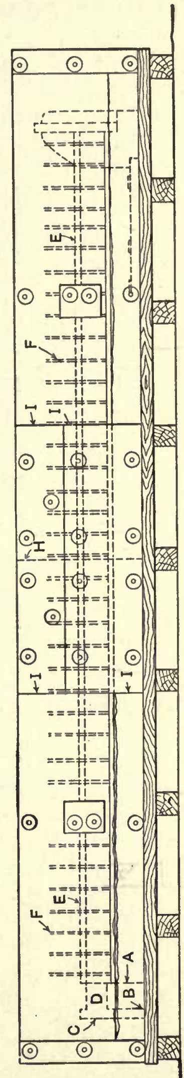


FIG. 32.—MOLDING DRAW-BENCH FRAME IN A FLASK.

is reached. The upright gates *B* and the inlet gates *D* would then be placed as shown, the inside of the pattern cleaned out, faced, and the green-sand core formed, rods being placed as before and the core vented. The remainder of the drag then would be rammed up, the sand struck off, and the bottom-board rubbed to a bearing. The bottom-board would be lifted off, channelways formed in the bottom of the drag by striking it with the strike, edge down, after which the molder would then vent the drag all over. The channelways conduct the gas from the vents to the edge of the mold. The bottom-board would next be replaced and clamped and the drag rolled over. After the joint is made, the cope is made exactly as before, the principal difference being that the cope is guided by pins on the flask instead of stakes in the floor. Fig. 33 shows the mold closed and clamped and ready for pouring.

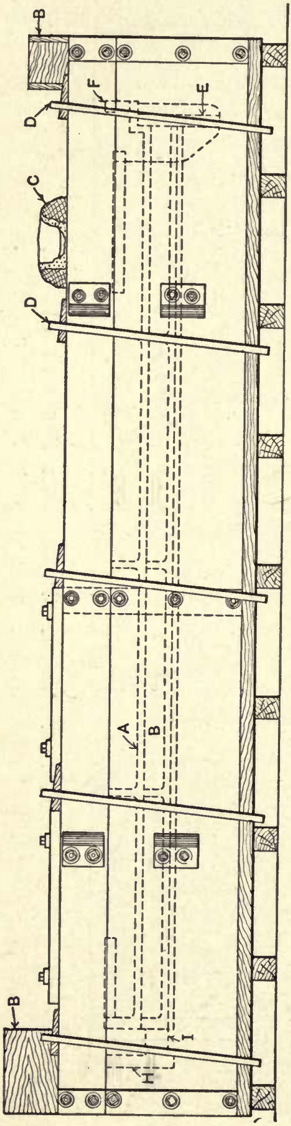
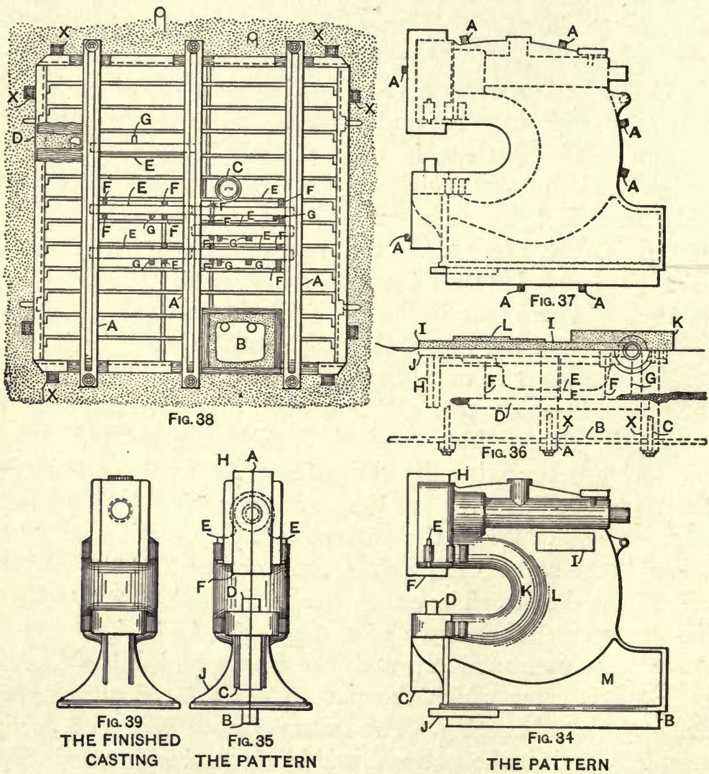


Fig. 33.—Flask Containing Draw-Bench Frame Mold Closed and Clamped Ready for Pouring.

Molding a Gap-Press Frame

In Figs. 34–37 are shown the patterns of a gap-press frame, which can be molded in the same pit used for the patterns described above. A pit is dug between the upright posts, deeper than the pattern, and the sand and cinders riddled and separated. When the hole has a depth of about 10 inches greater than the depth of the pattern, a cinder bed about three inches thick is made and gas pipes provided for carrying gas away from the bottom of the mold when it is poured. A timber *D*, Fig. 36, is placed as shown. This is used later for holding the chaplets supporting the core. Molding sand is then rammed up over the cinder bed, newspapers first having been placed on it, and shaped to conform to the under side of the pattern as nearly as possible. The pattern is then placed, being blocked and wedged to its proper position and weighted to hold it in place while sand is being rammed under it. The parting of the pattern is at *A*, Fig. 35, and that part of the pattern below the parting is bedded in the pit as shown in Fig. 36. The core-print for the main core is at *B*, Fig. 35, and a flat iron plate is placed under this print to support the weight of the heavy main core. A slab core is set so as to bear against the face of the feet, as they must be fairly true and also carry a heavy strain due to the weight of the finished casting. Sand is rammed underneath and facing is tucked under the pattern, the wedges and blocks being removed as they are reached and replaced with firmly rammed sand. When the pattern is finally resting on a bed of sand, the stakes *AA*, Fig. 37, are driven and the pattern lifted from the pit. The entire face of the mold is well vented, the vents extending down into the cinder bed. The face of the mold is then made up with the fingers and finished as far as possible, after which the pattern is replaced and rapped down to a solid bearing. The stakes are now removed, facing sand laid against the pattern, and black sand is rammed solidly around it, struck off, and the joint made. The joint being made, parting sand is dusted on the joint, and the cope half of the pattern placed on the drag. The cope, Fig. 38, is lowered over the pattern and staked in place with stakes *X*, after which it is lifted and wet down or clay-washed. The pattern is then covered with facing sand, which is laid up against any portion to which it does not adhere readily and it is also spread over the joint. A slab core is placed against the foot, this core being arranged with a staple which will permit it to be wired to the cope. Gate-sticks and risers are placed and long-stem gaggers set in position. As the pattern is heavy, it is necessary to provide some means of supporting it in the cope, since it might



FIGS. 34–39.—MOLDING A GAP-PRESS FRAME.

fall out when the cope is lifted. Accordingly, wood screws, with eyes in the end, and extending through the cope into the pattern are provided. After the pattern is covered with facing sand, black sand, to a depth of about two inches, is shoveled in and rammed with short iron hand rammers. In many large copes, such as this, the bars are stopped off some distance above the patterns and the sand is shoveled in and rammed with these rammers instead of being tucked in by hand as is the case with smaller patterns. The black sand is now filled in, in several rammings, until the top of the foot is reached. A riser for a flow-off is placed on top of the foot as it is the highest part of the mold. If gas pockets in a mold, it always does so at the highest point, and the provision of a flow-off to enable some of the iron to run away from this point, will produce a casting sound and free from blow-holes. After placing the riser, sand is filled in the flask and rammed until the cope is filled. The top is then cleaned of loose sand, well vented, and the core at the foot properly secured. Gate-sticks and risers are removed and the cope lifted off.

The cope is set up on one side and the wedges and rods in the eye-bolts, holding the pattern in the cope, are removed. The holes left by them are filled up and the cope rolled over on its back. The pattern is drawn and the cope finished and given a coat of silver lead, which is rubbed on with the hand on the heavier parts and brushed on with a camel's-hair brush on the lighter. Channelways and gates are cut in the cope, both to conduct the iron to the mold and to act as cleaners.

Before the drag portion of the pattern is drawn, the screws, holding the pattern to the base, are removed, freeing the base from the main part of the pattern. In the corner formed by the foot of the bracket, iron rods five-eighths inch diameter, are driven to support the sand when the iron flows around this corner, which is well vented down to the cinder bed. After this is done, the foot portion of the pattern is drawn and the mold finished. When finishing the drag and cope, large-headed nails are pushed into the face of the mold, around the jaw, and also around the edges of the base. This is to prevent the heavier parts of the casting from scabbing when the iron is poured. When finishing the cope and blacking it with lead, this blacking is omitted from that part of the mold forming thin portions of the casting, as there is a liability to cold-shutting the iron with a heavy facing like lead. A lighter facing, with less seacoal, is used on these portions. The mold being finished, it is gated and nails are pushed down into the sand in front of the gates, to keep the face of the mold from being cut by the iron flowing into it. At one end of the mold there is no core-print for the main core. Consequently, it must be held up by chaplets. Accordingly, these are cut to length, sharpened on one end, and driven through the sand in the floor, into the timber *D*, Fig. 36, and allowed to extend above the face of the mold a distance equal to the thickness of the casting, as shown at *F*, Fig. 36. The main core *I* is then set, one end resting in the core-print, the other being held up by the chaplet. At the end, resting in the core-print, provision is made for gas to escape through suitable vents in the mold. Cores *K* and *L* are next set and then the shaft core, one end of which rests in the core *K*, while the other is held up by a chaplet *G* in the core-print.

The cope is rolled back and the gate-stick placed in the gate hole. The runner *B*, Fig. 38, is built and an iron ring placed around the riser *C*. Two pieces of pig iron are placed on each side of the gate-stick, forming the flow-off *D*. Pieces of clay one inch diameter, and a little higher than the thickness of the casting, are formed and set on the cores at the points at which it is desired that the chaplets shall be placed. The cope is closed on the mold, and is then immediately removed and examined and repaired if necessary. It frequently happens in closing the cope over the cores that parts of the cope are broken. In order to see that the cope bears properly on the cores, flour or white sand is placed on such parts as may be doubtful of bearing properly. These will leave a mark on the dark sand of the mold on the removal of the cope. It being found that the cope bears as desired on the joint and cores, the vent-wire is run up through the cope, and chaplets are set at the points where the pieces of clay have marked the mold. The stems of the chaplets are made long enough, so that when they are pushed up through the holes in the cope made with the vent-wire they will extend about a quarter of an inch above the top of the cope and still leave in the mold a length of chaplet equal to the thickness of the casting. The chaplets are held from falling down by pieces of soft clay squeezed around the top of the stem projecting through the cope.

The vent-wire is also used to form outlets through the cope for the gas driven off from the cores. Paste is placed on the edges of the cores so that the iron cannot "fin" over them, and thus enter the vents and prevent the escape of gases which would then back into the mold and ruin the casting. It is advisable, before placing the cope temporarily, to arrange pieces of thin rope or belt lacing from the vent openings in the cores to the outside of the mold. These should be covered with sand and be below the joints. When the mold is finally closed, and just before pouring, these ropes or belt lacings should be pulled out, thus leaving a clear vent from the core. If clay be filled in around the rope or lacing before sand is filled in around them, it will be impossible for iron to enter these vents, even should it overflow the cores. In places where the cope does not bear as it should, the sand in the floor is built up or parting sand is filled in on the joint. With very large castings, what is termed a clay worm—a roll of common fire clay about fourteen inches long—is laid at the back of the gate. This being soft, it is easily flattened by the weight of the cope when it is finally closed and prevents the iron straining out the back of the pouring gate at the joint.

The cope is now finally closed and the riser *C* covered so that nothing will drop into the mold. Binders *A*, Fig. 38, are placed on top of the cope as shown, blocks of hard wood or iron being placed between the binders and the edge of the cope. The binders are held down by hook bolts engaging with the eye-bolts in the floor as before. In order to keep the main core from rising when iron is poured in the mold, the binders *E* are passed underneath the binders *A*, being held by wedges. Wedges *G* are pushed in between these binders and the top of the chaplets.

A certain disadvantage in pouring is encountered in that the jaw portion, which must be the strongest part of the casting, is heavy, while the lightest part is the leg. The iron must be poured hot enough to run to all the light parts of the casting, including the leg, and this is too hot to give the best results with the heavier portions.

Let us consider molding the same pattern in a flask. The drag portion of the pattern is placed on the mold-board and a slab core placed against the foot, while an iron plate is laid on top of the core-print. The drag of the flask is set around the pattern which is then covered with facing sand and successive layers of facing sand around the pattern of the leg. The flask is filled up with rammings of black sand and struck off. Bottom-boards are rubbed to a bearing, the drag vented, and the bottom-boards replaced. The clamps are placed in position and the drag rolled over. The cope is then finished as before.

Still another method exists of bedding which must be practiced with many different styles of patterns. The pattern is blocked and wedged to the proper height in the hole and black or heap sand is tucked and rammed under it, the blocking and wedges being removed as reached. When the pattern has been rammed completely on its under surface, it is staked and removed and the sand bed below it well vented down to the cinders. The entire face of the mold is covered with facing sand to a depth of three-quarters inch and the pattern replaced and rapped down to ram the facing sand into the bed of black sand. The vents in the black sand take care of the gas from the facing sand of which the face of the mold is made.

CASTING LATHE BEDS AND CHILLING THE WAYS

Generally speaking of chilled castings, we refer to castings which have the whole or part of one or more surfaces cast on cast-iron chills in order to obtain a very hard surface; as the tread of car wheels, jaws of stone crushers, etc.

For some purposes castings are cast on, and in chills and the surface polished.

In the production of machinery castings, as lathe beds and castings of this type, the ways are cast on cast-iron

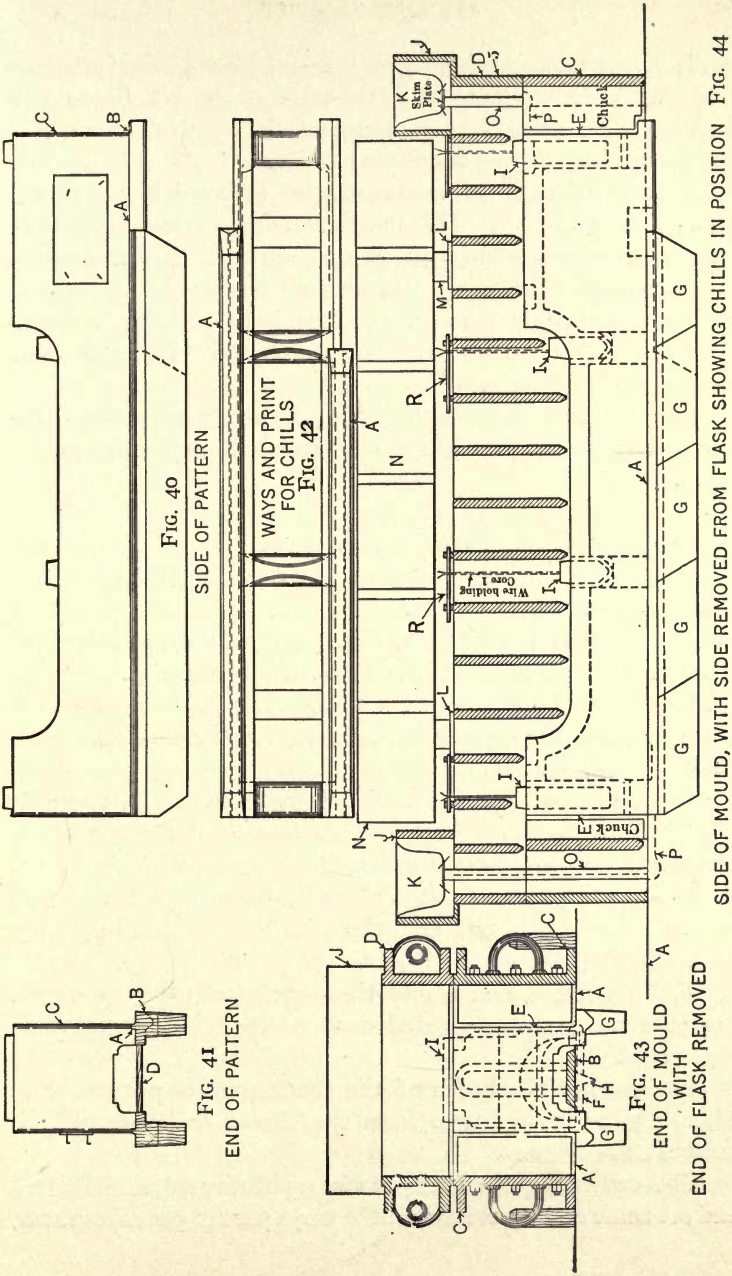


FIG. 40 SIDE OF PATTERN

FIG. 41 END OF PATTERN

FIG. 42

FIG. 43 END OF MOULD WITH END OF FLASK REMOVED

SIDE OF MOULD, WITH SIDE REMOVED FROM FLASK SHOWING CHILLS IN POSITION FIG. 44

chills in order to obtain an iron hard, of close grain, but lathe iron, while being hard and close, is to be machined and finished. This must be taken into consideration when making up the mixture of iron for these castings.

Results of this chilling are lathe beds with ways that take on a high finish. This means less lubrication is required, wear longer and reduces cutting by carriage to a minimum. Easy carriage travel saves power at all times.

The illustration shows a six-foot lathe bed for a screw-threading lathe made by The Automatic Machine Co., Bridgeport, Conn., U. S. A.

For this and longer lathe beds, the arrangement of chills and treatment of castings while cooling is explained in the following:

The pattern is made in two parts and parted on line Fig. 40, *A*, Fig. 41, *A*. Prints on the ways of pattern shown, Fig. 42, *A*, are for the chills.

The ways part of pattern, Fig. 40, *B*, Fig. 41, *B*, is bedded into the floor. This is shown, Fig. 44, below line *A*.

The parting is made at Fig. 43, *A*, Fig. 44, *A*, and the plate to carry the green sand forming the inside of the lathe bed is placed, Fig. 43, *B*.

The cheek or upper part of pattern, Fig. 40, *C*, Fig. 41, *C*, is placed on the ways part and the inside of the pattern is rammed up on the plate, Fig. 43, *B*.

The cheek part of flask is placed, and rapped down, then staked, gate sticks set, and the cheek is rammed up, Fig. 43, *C*, Fig. 44, *C*.

The parting is made, and the cope placed on the cheek, the gate sticks set, gaggered and rammed up, Fig. 43, *D*, Fig. 44, *D*.

The cope is lifted off and the cheek part of pattern, Fig. 43, *E*, Fig, 44, *E*, is drawn from the cheek, and the cheek is hoisted off.

The center of the mold made on lifting plates is lifted and set aside and finished, and the ways part of pattern drawn, and the braces holding the ways together are stopped off, Fig. 41, *D*, Fig. 43, *F*.

The mold is finished and blacked, and gated as shown, Fig. 44, *P*.

The cast-iron chills are set in the prints on ways shown, Fig. 43, *G*, Fig. 44, *G*.

The lifting plate carrying the center of the mold is replaced and guided into its right position by pins, Fig. 43, *H*.

The cheek is returned and the cores, Fig. 44, *I*, are hung in the cope with wires.

The wires are shown extending from core *I* through the cope where they are twisted around rods, Fig. 44, *R*, and wedges pushed under the rods to tighten cores up into the core prints in cope.

The cope is returned on to the cheek, and the runner boxes, Fig. 44, *J*, are placed and pouring basins, Fig. 44, *K*, are built in them.

Pieces of iron are laid on the flask, Fig. 44, *L*, to raise the cross binders so they will not crush the sand in cope or force down any gaggers extending above the bars.

The cross binders are placed, Fig. 44, *M*, extending across the cope and weights, Fig. 44, *N*, are placed on them. As the cheek and cope are resting on the floor, weights enough must be placed on the binders to hold the flask down when the mold is filling with iron.

The treatment given this style of casting while cooling varies as the sizes and weights of the castings vary, particularly the length.

As soon as possible after the mold is poured the sand is dug out from under the center chills on each side of the casting and one chill removed on each side, and the holes are filled with loose sand.

This allows the casting to cool straight.

The same treatment is given an 8-foot bed.

A 12-foot is treated the same way, but in addition the cope is removed, cheek unbolted at the corners and removed and the casting is stripped in the center and underneath for

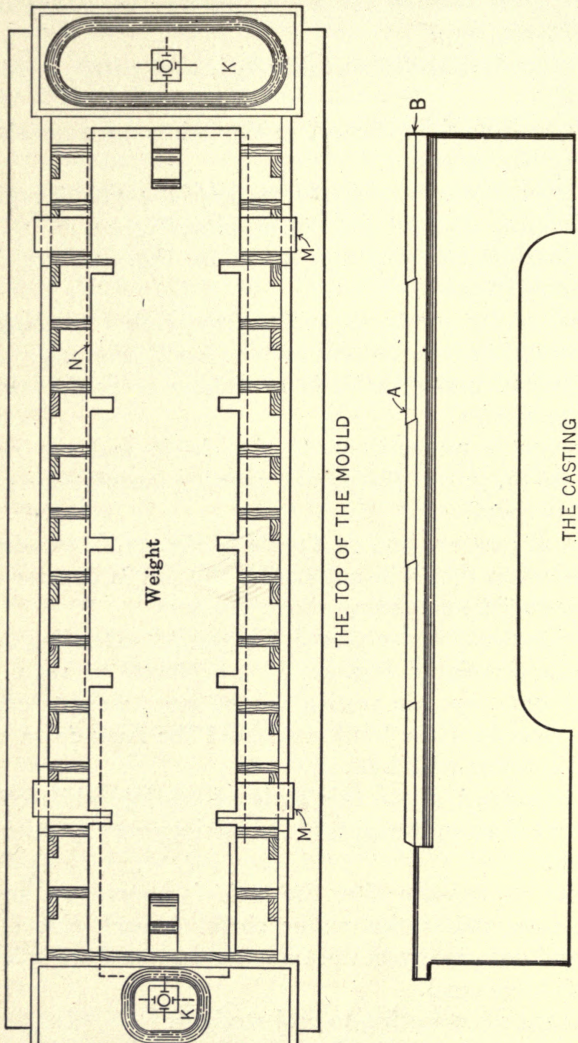


Fig. 45.

a space of 18 inches. Longer beds have two chills removed on each side, and cope and cheek, and are stripped in two places.

When the chills are placed in the prints, they are set level and straight. The expansion of the chills causes the face of the ways of the casting to have the appearance of Fig., 45 *A*.

When chilling was commenced the chills were made square on the ends, and at both ends of prints cinder pockets were formed, as it was thought the cinder pockets would give to the expansion of the chills. This theory did not work out satisfactorily, as in one case the sand gave down at cinder beds at ends and the chills forced slightly into the casting, having enough of a hold so as the chills were left in; the casting was pinching at the ends of the casting on the chills, and with the expansion of chills and shrinkage of casting, on taking the casting from the sand it was found cracked.

It was also found the chills were not heavy enough, and expanded too quickly.

Heavier chills were made, but the difficulty was not thoroughly overcome, and with square ends a chill was hard to remove. One chill beveled at the ends did not remove the trouble. The chills were then beveled as shown and made heavier. As the metal is poured at one end directly into the ways, the chills heat very quickly. How quickly one can judge by the appearance of the ways of the casting, Fig. 45, *A*.

The chills are placed in the mold so when the tool of planer is started into the casting from end Fig. 45 *B*, it does not jump from a light to a heavy cut.

The short bed is poured from one end, the longer from both ends.

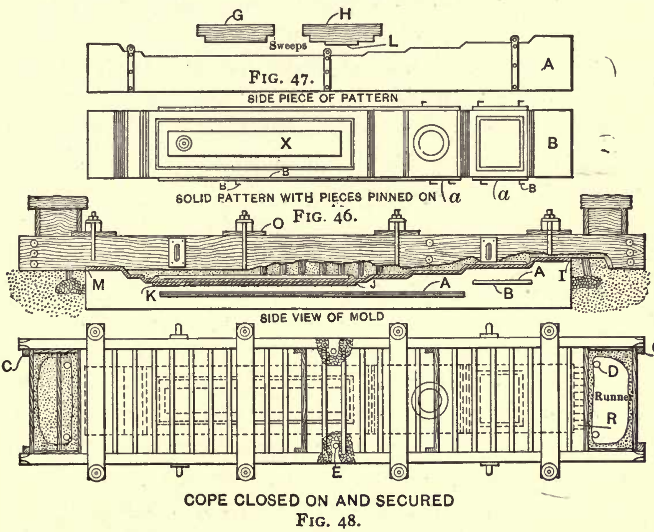
If gated above the chills at end of the casting the drop of the iron cuts the chills.

CHAPTER VI

MOLDING COLUMNS

CAST-IRON columns are still used to a certain extent to support the floors of buildings and also for ornamental purposes on the fronts. The illustrations, Figs. 46–48, show the pattern and method of molding a rectangular ornamental column. The pattern is made with separate side pieces *A* to which are attached pieces of moulding to give an ornamental finish. These are pinned on to the side pieces so that they may be removed during the process of molding. The pattern itself is made solid and is shown at *B*. In molding, the floor is used as a drag, the pit being prepared as described in Chapter V.

The pattern is placed in the pit and leveled and a facing sand, comprising one part seacoal to fourteen parts molding sand, is laid up against the pattern. Black sand from the heap is rammed firmly against the facing sand. As each successive ramming of sand is laid in the mold, the facing sand is firmly rammed against the pattern with a hand rammer and fresh facing placed against the pattern. As the sand in the mold rises to the point at which the pieces of moulding *a* are pinned to the pattern, the pins holding the moulding are withdrawn, and it is supported by the sand. The facing of the pattern and the ramming of black sand is then continued until the floor line is reached where the joint is made. The cope is now placed in position and rapped down to insure its bearing solidly on the sand. If there is but a small amount of sand around the pattern and there is danger of the mold being crushed in when securing the cope, pieces of board are placed under the cope and on the sides near the center. In this case pieces of plank are nailed to the sides of the cope and stakes are driven against them into the floor to act as guides when the cope is lifted on or off; otherwise stakes *C*, Fig. 48, are used for this purpose. The cope is then lifted off and clay washed or wet down; the pattern is brushed off, parting sand placed on the joint and facing sand riddled over the pattern, except at its center. The facing sand is left off the pattern at the center as it has a cooling effect on the iron which, in this case, will be poured from the ends of the mold. Were seacoal facing to be used at the point where the flow from opposite directions



Figs. 46–48.—Molding an Ornamental Building Column in the Sand.

meets, there would be the liability of a *cold shut* forming and thus destroying the casting. In place of the seacoal facing at this point, a mixture of old and new sand is used.

The cope is now replaced, and gate-sticks *D* and *E* set to form the pouring gates and risers. Gaggers are set and the sand shoveled in to the proper depth for tucking the bars. Extreme care must be used in this operation in castings of this character, since any soft spots left in the mold will form lumps on the casting and destroy their value for ornamental purposes. After tucking the bars, the cope is rammed up, vented in the usual way, the cope hoisted off, turned over on its back and finished. The joint is brushed off and the pattern drawn. The pieces of moulding *a* remain in the sand when the pattern is drawn, and they now are drawn inward into the mold and lifted out. Should these pieces be of any considerable depth, thus leaving a considerable body of sand hanging over them, the mold is nailed on the upper surface of the cavity left by these pieces.

The side pieces *A* are now placed in the mold, one on either side, and the center or green-sand core built. These side pieces are the same thickness as the casting is required to be. A mixture consisting of one-half old sand and one-half new sand is tempered and the side pieces faced with it. Black sand is rammed firmly against this facing until a height of about six inches below the top of the casting is reached. The sides of the core are then vented and two channelways of cinders are formed, extending the length of the green-sand core into the body of sand around the mold. In order to do this, the joint must be broken up somewhat. Pieces of pipe are placed to bring the vent from the cinder beds to the outside of the mold as described in Chapter V. The cinders used should be, roughly, five-eighths inch diameter and should not come closer than four inches to the side of the mold. After tamping them with the rammer, paper is placed over them, it also being kept back four inches from the edge of the mold. Should the paper be allowed to extend to the edge, iron would find its way into the sand through the crack formed by the paper, and raise the face of the mold.

The sand is now rammed on top of the paper to within a short distance of the top of the side pieces, when it is struck off with a sweep running on the side pieces. These latter extend above the surface so that the sweeps will not bear on the joint when used. The whole surface is then vented down to the cinder beds. The surface of the mold must be soft enough for the gas to escape easily and allow the melted iron to lie quietly on it. The casting being very thin, will be scabbed and injured should the iron boil while covering this green-sand core. Making the face of this core is usually done by hand. In order to form it to the proper height to give the correct thickness, the sweep *G* is first used. The first sweep used left the sand about three-quarters of an inch below the final face of the core. The same mixture of sand which was used to face the inside of the side pieces is now used to make up the upper face of the center. This sand is pressed lightly down in place by hand or it is thrown in handfuls down on the surface. The sweep *G* is then used to true the sand from *I* to *J*, Fig. 48. At point *J*, a recessed panel *X* is formed and sweep *H* is used to sweep the sand out to a greater depth at the center of the core, where this panel is to come. This sweep is used from *J* to *K* after which the sweep *G* is used to complete the surface from *K* to *M*. The top of the center is now finished and the side pieces drawn, fillets first being formed on the edges. The mold is then blackened over its entire surface, except at the center, with plumbago. A slight coating of talc is then dusted over the entire surface to assist the flow of iron through the mold. Gates are next cut for pouring, being shown by the dotted lines *R*, Fig. 48, and also gates to the risers. Flour or white sand is placed on the joint and the cope is lowered into position. The cope is then raised and the mold examined to see if the cope bears solidly as will be evidenced by marks in the white sand or flour, necessary repairs are made, pouring basins and heads or flow-offs from risers are built, and the cope is lowered into place. The cope may be secured either by means of binders as described in Chapter V, or it may be weighted down. Iron for a casting of this character must be poured sharp, that is, extremely hot.

A point which has been omitted in the description of the making of the mold is the provision of a camber in the pattern in order that the casting shall come straight when cooled. As the sides of the casting are thin, when the melted iron is poured the lower part of the thin side fills quickly and sets hard before the top of the casting is set. This almost instant cooling of the sides, combined with the later cooling of the top, causes the shrinkage in the sides and top to be unequal. The shrinkage of the top tends to draw the ends upward and thus give a bent casting, or to crack the casting if the moulding on the sides has been left off or if the iron is not especially soft. If the sides are heavier than the plate forming the top of the casting, the casting will cool at about the same rate in all parts and thus avoid bending. There are one or two methods of avoiding this bending of the casting. One is to make the pattern with a slight camber in it, the ends being at a lower level than the center. Another method is to force the ends of the pattern down in the mold, below the level of the center, so that, with either method, the mold itself is curved in the opposite direction to that in which the casting would curve in cooling. The same shrinkage effects will occur with the mold made in this manner, but the casting originally being curved in the opposite direction, the shrinkage in cooling will pull it straight.

By using a solid pattern and ramming it up to get the exterior surface first and then making the center by means of side pieces as described, the pattern is easier to mold and castings of the desired thickness are more likely to be obtained. The side pieces should be provided with straps and eye-bolts for drawing them out of the sand as shown in the illustration. There is but little chance to rap them while drawing, and they are usually drawn by means of a hook in the eye-bolt, the other end of the hook being attached to a lever. While bearing down on the lever, the hook or top of the eye-bolt is rapped slightly.

Molding a Round Column

In many foundries it has been the custom to use split patterns in molding round columns, drawing one-half of the pattern from the drag and the other from the cope. Other foundrymen prefer to use the solid pattern. In molding, the pattern would be laid in a frame, the drag being placed on top in the usual manner, rammed up, rolled over, and the joint made. The cope would then be rammed up and the pattern rapped through the cope, thus avoiding a seam showing on the casting. Another method would be to bed the pattern in the floor, if only a few were to be made, and to stake the cope in position as in molding the ornamental column described earlier in this chapter. Fig. 49 shows a column pattern placed on a board as described with the drag around it ready to be rammed up and rolled over.

Round columns are frequently provided with brackets to support I-beams. The column shown in Fig. 49 has such a

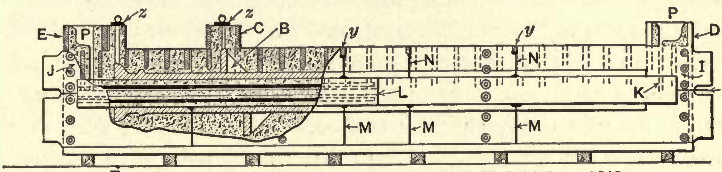


FIG. 50. SIDE VIEW OF MOLD OF COLUMN WITH BRACKETS IN COPE AND DRAG.

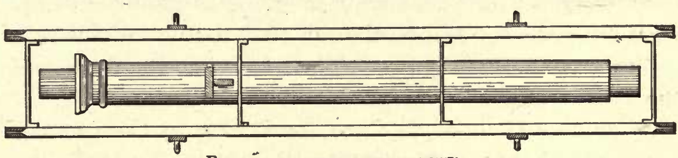
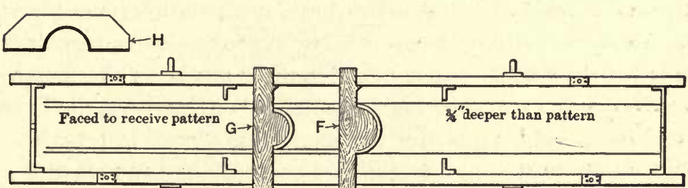


FIG. 49. COLUMN PATTERN IN NOWEL.



FIGS. 49–51.—MOLDING COLUMNS.

bracket which will be molded in the drag, while Fig. 50 shows a column with brackets to be molded in both cope and drag. This latter column illustrates some special devices adopted in molding. For instance, it will be noted that the bracket *B* extends to the top of the cope. A head of iron of greater depth than this is required in order to insure the filling of the mold of the bracket. To make the cope of the requisite depth required to provide this head, and also to provide the necessary thickness of sand over the pattern, would entail unnecessary expense and also render the flask more difficult to handle. It would also necessitate a greater amount of time to ram up the deeper cope. In order to avoid these features, the cope is simply *boxed over* at the bracket and at each end of the flask where the pouring gates are located.

In the author's opinion, the cheapest manner of molding round columns, when there are a number to be made, is to make a solid pattern and use a drag of the required length, width, and depth. The drag should be placed on the molding-board and leveled with the joint side up. Sand from the heap is rammed to a point very near the joint, but so formed as to leave a trough through the center. The sweep *F*, Fig. 51, is then used and the sand is swept out to a depth of about three-quarters of an inch greater than the half diameter of the pattern. Facing sand, mixed according to the thickness of the column, is then spread on the surface left by the sweep and the sweep *G*, raised from the joint of the flask about one-quarter inch, is used to form the facing to the shape of the pattern. The pattern, if free of brackets, is then laid in the trough so formed and rapped down until the block of wood *H*, which is used as a gauge, rests on the top of the pattern and the joint of the flask. If a bracket is to be made on the lower side of the casting, sand is dug out of the trough where the bracket is to be formed, and after the pattern is placed in position and rapped down, facing sand is laid around the bracket and sand rammed in against it and against the pattern where needed. The same gauge that was used to set the pattern is now used as a sweep to sweep the sand from each side of the pattern at the joint. The joint is vented, after which the cope is placed and rammed up with gate-sticks and risers in their proper places. The pattern is rapped through the cope, a gate-stick having been placed over a hole in the pattern, provided for this purpose. The rapping bar is entered through this hole, which, after the removal of the bar, is filled up. The cope bracket is pinned to the cope side of the pattern and when the cope is hoisted off, the bracket is found in it. In ramming up the cope, the spaces *I* and *J* between the ends of the flask and the first bar are not rammed up. The gate-sticks are set between the next two bars as at *K*. The runner boxes *D*, which are usually free from the cope, are not rammed up with the cope, but later after the mold is closed.

After the cope is rammed up, it is rolled over and the bracket has the sand secured around it, usually by means of spikes, and the bracket pattern is drawn. It is frequently advisable to ram a dry-sand core in the mold against the face of the bracket which is to be used as a seat for the I-beam. After the pattern is drawn, the face of the mold is felt and any soft spots filled up with a pipe slicker. The cope is then given a coat of silver lead and the chaplets for holding down the cores are placed as described in Chapter XIV. The joint of the drag being brushed off, a channel is formed alongside the drag which is dampened with the bosh. A vent-wire is bent and run from this channel under the pattern, thus venting under the pattern and alongside of it to the side of the flask. As the sides were previously vented toward the bottom-board, before the joint was made, the escape of gases from the drag is thus provided for. The mold is now finished and blacked.

In gating round columns, the gates are made on the ends, alongside the core on both sides of the mold. The iron fills the column poured in this manner with slacker iron than when the mold is gated along the sides. The mold being finished, the core is calipered and also the pattern. One-half the difference in diameter between the two is the distance which chaplets must project above the surface of the mold in order to support the cores in the proper position. In selecting the chaplets, it should be remembered that with a large body of iron flowing into the mold, a much larger diameter is required than for smaller cores. For a thickness of casting of one and one-half inches in the column, we would use a chaplet with a stem about one-half inch diameter. Using a lighter chaplet will probably permit the core to settle as the chaplet would soften under the influence of hot iron and the weight of the core would cause it to crush and thus permit the core to settle. On the other hand, chaplets used in the cope must be stiff enough to withstand the pressure of the core being floated upward by the entering iron. The chaplets are driven clear through the drag, into the bottom-board, which they should enter for a distance of about three-eighths of an inch. The number of chaplets to be placed in the cope and drag depends on the size and general arrangement of the cores. No fixed rule can be given except that it is better to have too many rather than too few chaplets.

It is much easier with a long column, to make and set the core in two pieces rather than in one. The cores are butted together at the center of the mold, one end resting in a core-print at either end, the other end of each piece being supported at the middle of the mold by chaplets. To prevent the cores shifting sidewise, due to iron entering one side of the mold more rapidly than the other, chaplets are placed on either side of the cores at the ends where they are butted together. These chaplets are wedged in place by a wedge driven between the end of the chaplet and the side of the flask. After placing the chaplets, flour or sand is arranged on the joint to afford a tell-tale as to whether the cope bears on the cores or on the joint. In the ends of the flask at the joint are holes through which are shoved short rods into the vent holes in the end of the column cores, as shown at *O*, Fig. 50. Sand is then rammed in the spaces *I* and *J*, after which the rod *O* is removed, leaving a clear hole from the vent of the core to the outside of the mold. Two or more vent holes are sometines left in the core, depending on its size, and as many vent rods are used as there are holes in the core. It is advisable to put a little paste on the ends of the cores before closing the mold in order to exclude iron which might find its way over the cores and thus stop the vent hole.

The pouring boxes *D* and *E* are next placed and pouring basins *P* built. These boxes are fastened by driving a nail a short distance into the cope. In securing the cope, clamps are used and binders are placed to hold the core down through the agency of the chaplets, wedges being driven between the ends of the chaplets and the binders which are clamped across the top of the flask.

The iron used in pouring should be cooled until it is quite dull for the larger and thicker columns, and it is advisable to feed the larger sizes of columns through the riser on the bracket to avoid shrinkage. Columns seldom shrink the full allowance —one-eighth inch to the foot—and for that reason column patterns are usually made with a smaller shrinkage allowance. It is important that the same iron mixture be used in pouring all the columns of a given lot, particularly ornamental columns; otherwise there will be a difference in the shrinkage, resulting in columns of varying lengths.

When molding columns of the following approximate dimensions—fourteen feet long, six inches wide, and sixteen inches deep, with a thickness of one-half to five-eighths inch —it is best to mold them on edge to avoid troubles due to the shrinkage curving the column in cooling. In many cases, castings with heavy parts must have these parts uncovered in order to permit them cooling more rapidly. The entire casting is then cooled more nearly at a uniform rate and warping is thereby avoided.

The pattern for a fluted column is usually made in quarters, and the two quarters of each half are hinged together, where a space comes between the flute and the outside, as shown in Fig. 52. A piece of flat iron is let into the joint side to hold the quarters apart and in this way form one-half of the pattern. The two halves are pinned together. In molding, the cope and drag are molded as a plain pattern. To draw the pattern, the screws holding the pieces of flat iron in place are removed and the two quarters closed together, sufficient material being cut away from each quarter to form a V-shaped opening the entire length of each half of the pattern. After closing together the pattern can be lifted out of the mold.

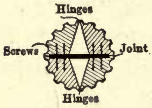


FIG. 52. — PATTERN FOR A FLUTED COLUMN.

The method of making cores for columns is described in Chapter XIII.

CHAPTER VII

MOLDING WITH SWEEPS

THE expense of pattern work for certain classes of castings of a regular form may be avoided by the use of a *sweep*. Such castings as circular boiler fronts, tank heads, pulley rims, and similarly shaped castings can easily be molded by this method. In addition, certain irregular-shaped castings may be partially swept out in green-sand molds, the balance of the mold being finished by means of pattern pieces. The sweep consists of a board, one edge of which is shaped to correspond with the surface of the casting and, on drawing it across the sand, it leaves a surface in the mold of the desired shape to make the casting.

In Figs. 53–56, the method of molding a ribbed tank cover, by means of sweeps, is illustrated. The casting is a circular piece of dished cross-section with four ears, slotted to receive bolts, placed at equal intervals around its circumference. In molding it, two or three sweeps are used, according to the ideas of the molder, and no pattern work is necessary excepting for the four ears and for the ribs on the under side of the dished portion.

In making the mold for this casting, the first operation is to set the *spindle seat* in the floor. The spindle seat consists of a socket for the spindle of the sweep, and is mounted on four cross arms, extending horizontally from the body of the socket. A hole is dug in the floor of such depth that the top of the spindle seat will come level with the floor line when the spindle seat is leveled in it. The spindle is placed in the seat and by means of spirit level is plumbed until it is truly vertical, wedges being driven under one leg or the other of the spindle seat, to throw the spindle in the necessary direction to bring it vertical. Sand is then rammed around the spindle seat until the hole in the floor is filled. The sand around the spindle is then swept off level by means of the *sweep*. This is a plain piece of board about four inches wide and of any desired length and with a beveled lower edge. Attached to one end, by means of bolts, is a finger which fits snugly over the spindle, being

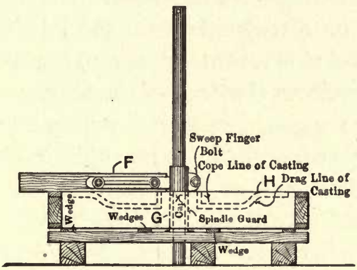


FIG. 53. SWEEPING COPE SIDE PATTERN

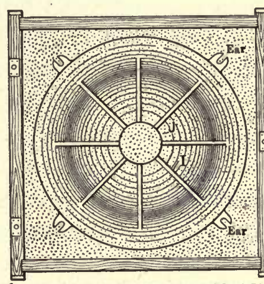


FIG. 56. COPE SIDE PATTERN WITH RIBS IN PLACE

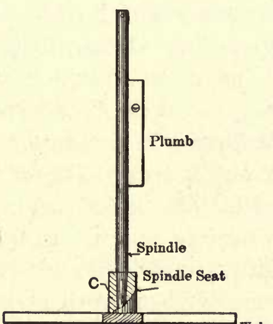
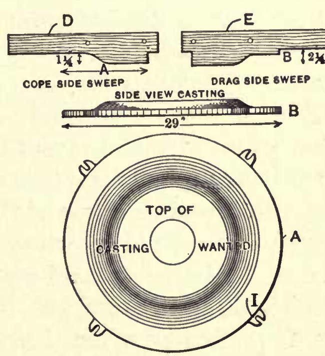


FIG. 54. SETTING SPINDLE SEAT



FIGS. 53–56.—SWEEPING A RIBBED COVER PLATE MOLD.

fastened thereto, and permits the sweep and the spindle to be revolved. The sand being rammed down around the spindle, the sweep is revolved and sweeps off any surplus sand, leaving a level and true bed of sand.

The sweep finger is then removed from the spindle and a bottom-board with a hole in the center, lowered over the spindle, or the spindle may be removed from the seat, the bottom-board placed in position, and the spindle re-inserted in the seat through the hole in the bottom-board. The drag of the flask is then placed on the bottom-board with the joint up and is wedged up a short distance by means of wedges set from the inside of the flask. The sweep for forming the cope side of the mold is bolted to the sweep finger and leveled. The end of the sweep is allowed to rest on a trowel laid on the joint of the drag while it is being leveled so that on removing the trowel, the sweep has a clearance from the drag of the thickness of the trowel. In certain cases a guard is placed around the spindle to prevent sand from passing through the hole in the bottom-board. Such a guard is shown at *G*.

Cinders are next spread over the bottom-board and covered with paper, after which the drag is rammed full of sand. When it has reached the proper height, the sweep is revolved, tracing in the sand a circular cavity of the exact shape of the bottom of the sweep. The sand should be rammed in the drag as hard as possible preparatory to this operation. When it has been struck off, after sweeping, it is slicked and parting sand is dusted over the joint, and sometimes over the face formed by the sweep. Instead of parting sand, paper is sometimes laid over the swept surface, being first wet in order to make it conform to the exact shape of the mold. The use of paper makes a very clean parting, whereas, if parting sand is dusted on, it must later be brushed off which not only tends to make a rough surface on the casting, but, if not thoroughly removed, is liable to be washed off when the casting is poured and make dirt in the casting.

The ribs which are to be cast in the cope and for which patterns are required, are placed as shown at *I* in the plan of the cope, Fig. 56, being held in place by a few nails pushed into the sand alongside of them. The spindle is then removed and the green-sand core *J* having been formed, a bunch of waste is placed in the hole left by the spindle. The cope of the flask is then placed in position, gaggers set, and the cope rammed up as for any ordinary mold, the patterns for the ears first being placed in position. After venting, the cope is turned over, the ribs and ear patterns drawn, and the edges, where the ribs unite with the body of the casting, filleted. The gates are prepared as desired and the cope is blackened with plumbago.

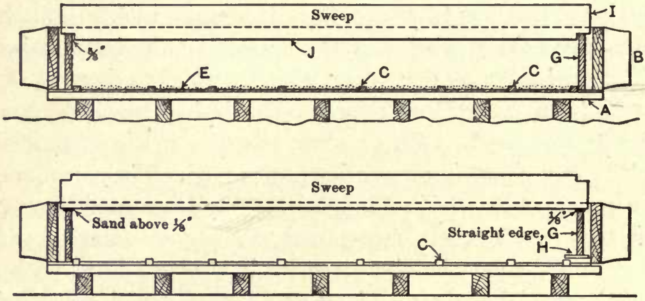
The next operation is to sweep out the drag. It will be remembered that in sweeping out the drag first, what was known as the cope sweep was used. This was for the purpose of forming a recess the exact size of the projection of sand desired in the cope. In order to give thickness to the casting, the drag must be swept out to a greater depth than was done by the cope sweep. The drag sweep used is of exactly the same shape as the cope sweep, but is as much deeper than it as the casting is thick. The drag sweep is bolted to the sweep finger, the sand is dug out from over the bunch of waste, and the waste removed from the spindle hole, after which the spindle is set. A gutter is dug from the spindle to the outside of the flask of sufficient depth to permit the sweep to rest on the trowel on the joint. The sand is dug up to about three-quarters inch below the edge of the sweep, the sweep is revolved, and the surplus sand removed. The drag is thoroughly vented down to the cinder bed, after which facing sand, properly tempered and riddled, is thrown, a handful at a time, on the face of the mold where it will stick. The entire face of the mold is covered in this manner, the sweep being revolved as the sand is thrown, in order to form a surface of the desired shape. The face is examined for soft spots which are repaired as found and the spindle is removed. The mold is finished, blackened, gated, and made ready for pouring in exactly the same manner as any other mold.

It may be well at this point to call attention to some things that should be borne in mind in sweeping molds. We have described above the method of sweeping a comparatively light casting. If instead the casting should weigh several tons rather than a couple of hundred pounds, the operations of molding would be the same, but the greater amount of metal would bring considerably greater strain on the face of the mold, particularly on the drag, and certain precautions must be observed to take care of this. After ramming up the cope as above described, the drag would be dug out in the same manner as for the lighter casting. The sweep is made so that it can be lowered three-quarters of an inch below what is to be the face of the mold or a third sweep is made, which will sweep out the sand to this depth. After digging out the sand from the drag, in the manner described, black sand is solidly rammed on the face to the line of this third sweep or to the edge of the sweep lowered below the level of the face. The surface thus formed is thoroughly vented, after which facing sand is thrown on as was done for the lighter casting, and the face of the mold is finally finished.

The object of using this third sweep or its equivalent, and making a solid face on which facing sand is built, is to provide an evenly rammed surface for the mold. If there is any difference in the strength of the mold, in different portions, the casting will be distorted. If the hard-rammed sand is left uneven when digging off the face and the facing sand simply thrown down on it as described, the molten iron filling the mold will soon discover the point at which this facing sand is the deepest and at this spot will cause the sand to give. In other places, where the sand was not cut away to the same depth, the facing will be harder and, therefore, the surface of the casting will be found to be uneven, being at the proper level over the hard portions and having projections at those points where the facing sand was deepest and therefore soft. It is evident, therefore, that by ramming the surface at a depth of three-quarters of an inch below the face of the mold, and then building the face of the mold on this surface, the pressure of the molten metal is resisted evenly over the entire surface of the mold and a casting with a true surface is the result. The lack of care in making this firm under-surface, is often responsible for the failure to obtain good results with swept up molds.

Oftentimes, patterns molded by bedding them in the floor or a flask, may have a portion of the mold made by a sweep and the balance made by placing the pattern on it and tucking the sand under those parts of the pattern which are irregular in shape. In this way, the pounding of the pattern into the bed is avoided. To illustrate this method of molding, we will consider the case of a tank bottom, eight feet long, five feet wide, and five-eighths inch thick, which is to be bedded in a flask. A bed of sand is first made on the floor where the center of the flask will rest, being made one foot wide and a trifle longer than the flask. This is made three inch thick and is trodden down firmly and is struck off with a straight edge. On this a bottom-board is placed and the drag set, being raised about five-eighths of an inch from the bottom-board by means of wedges driven between them from the inside of the flask. The bottom-board is then wedged up on one side until it has an inclination of about five-sixteenths inch in two feet. Cinders are next spread over the surface of the bottom-board and covered with paper, after which straight-edges *G*, Figs. 57 and 58, are placed and raised to the desired height by means of bricks and wedges *H*, or they may be made of sufficient depth to rest directly on the bottom-board. They are leveled and secured at the desired height and sand rammed in around them to prevent their movement sideways. Black sand is then rammed over the cinders until it is about level with the top of the straight-edges. The sweep *I* is used with the notched side down, the bottom of the sweep being notched so that the edge *J* is five-eighths inch below the edge of the straight-edge, to sweep out the sand between the straight-edges to that depth. The bed of sand is then thoroughly vented down to the cinder bed, after which a mixture of seacoal facing, in the ratio of one seacoal and fourteen sand, thoroughly tempered and riddled, is spread on the bed between the straight-edges, until its surface is slightly above the straight-edge. The sweep with the straight side down is then used, a block of wood one-eighth inch thick being placed under each edge, and the sand swept level. The blocks are removed, and one man holding an end of the sweep on the straight-edge, a man on the other end strikes the straight-edge a blow with the opposite end. The sweep is moved gradually across the width of the mold, the sand being pounded down in this way, first by the man at one end and then by the man at the other. This process will ram the sand solidly, and a casting weighing many tons can be poured on it without danger of rough spots being formed, due to soft places in the mold. The bed being made, the pattern is placed on it, weighted down, and sand rammed around the edges. The joint is made and the cope rammed up, the gates being set so that hot iron shall flow into the mold up to the last moment of pouring.

It will be recollected that, at the beginning of operations, we wedged the bottom-board so that one side of the flask was higher than the other. This was done so that the iron, in



FIGS. 57-58.—MOLDING A TANK COVER PLATE WITH A SWEEP.

pouring, would fill the lower side of the mold first and rise along the face of the mold as it fills. If the mold were to be level, the iron would cover the entire lower surface of the mold before it reached the upper surface. The lower portion of the mold would require covering with liquid iron immediately or cold shuts would result which might ruin the casting. By causing the iron to flow into the mold from the higher side, this trouble will be avoided and a slacker iron can be used. A slight coating of talc over the entire face of the mold will assist in the rapid flow of the iron.

We will now consider the case of a pattern which is to be molded in part with a sweep and the remainder tucked up. Referring to Fig. 59, the method of molding the face of the segment of a large built-up fly-wheel is shown. In molding these segments, it is desired to have the face as nearly as possible on the same circle as the finished wheel, leaving merely enough stock for finishing. Two cast-iron guides *A* are arranged to rest on timbers *B* in the flask and using a similar sweep to that described in the operation of making the tank

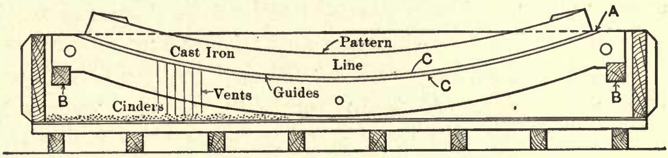


FIG. 59.—MOLDING SEGMENT OF BUILT-UP FLY-WHEEL.

bottom, a bed is made on which the pattern is to rest, the sweep being guided by the guides *A*. After the bed is made, it is vented to the cinder bed which has previously been made at the bottom of the flask and, on top of this bed, a face is built of facing sand on which the pattern is placed. In gating this mold, the pouring gates must be further apart for large-diameter wheels, say thirty feet, than for smaller wheels of

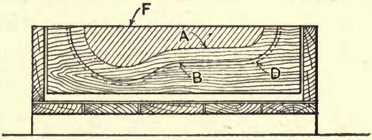


FIG. 60.—MOLDING A FORMER FOR SHEET-METAL WORK WITHOUT A PATTERN.

ten or fifteen feet diameter. With the smaller wheels, the iron flowing in and being given a quick turn due to the smaller diameter, will be given a whirling motion and will thereby cut the face of the mold, producing a scabbed casting, unless the mold is of the proper hardness.

Fig. 60 shows the method of making the mold, known as a former for sheet-metal work, without a pattern. Two boards with the size of the inside of the former cut in them as shown at *A* are set in ends of the flask and sand rammed firmly between them and swept off level with the top of the inside of the guides *A*. The pieces *F*, shown by the cross-hatching, that were sawed out from the guides along the line *A*, are then replaced and sand rammed between these pieces and the ends of the flask. Damp parting sand is slicked on to the steeper parts of the face of the mold and dry sand dusted on the flat portion. The cope is now placed on the drag and rammed up and removed. The end pieces *F* are now removed and the sand dug out between the guides. A sweep notched somewhat deeper than the thickness of casting desired as shown by the distance between the lines *AD* is used to strike the sand off along the line *D*, the sand being firmly rammed and vented. The face of the mold is built up to the line *B*, a sweep notched a distance equal to *AB* being used. The mold is finished and gated in the usual manner.

MOLDING AND CASTING LARGE KETTLES

Foundrymen are called upon by manufacturers of chemicals and dye stuffs to supply large cast-iron kettles, retorts and acid pans, varying in size and design, some of the kettles weighing twelve tons each, while some of the smaller are cast from patterns, as greater numbers may be used. The larger are usually molded with sweeps, bricks and the rough foundry rigging designed for the purpose by those accustomed to produce large kettles and retorts. The cost, storage and handling of large patterns has to be considered, also the number ordered at a time, and the number that may be ordered in the future. These questions are to be taken into consideration, as well as, How are we going to mold it? and, What is it going to cost to mold it from a pattern?

Patterns are costly, and when we count the cost of molding the large kettles from patterns, we usually find with the aid of sweeps, bricks, and the rough foundry rigging, and some patterns of parts and core boxes, we can produce the castings at less cost than with a pattern. Some very large companies have foundries of their own and use a great many. They also have many other castings which have to be replaced. The greater number of a standard size used, the larger the amount one can afford to spend in arranging rigging, —the cost of which is to be spread over a large number.

The accompanying cuts are used to illustrate different ways of molding kettles, and some of the different styles in use. Figs. 61, 62, 63 show a kettle and its jacket, known as a steam-jacketed kettle, steam being introduced between kettle and jacket. The kettle has a cover bolted to top flange with manhole and manhole cover; a shaft having wings, known as "the mixer," is revolved inside the kettle to mix the contents. The kettle is loaded and contents removed through manhole. Steam can be used inside the kettle as well as between kettle and jacket. The shaft is stepped in Fig. 61, *A* and extends up through cover. Power is applied. These kettles are often four feet and more in diameter by six feet deep, and weigh 7000 pounds and more. While the jacket for this kettle must be of correspondingly large size, as they are two separate castings. The manner of molding the two is nearly the same, and the same pit and rigging is used with the exception of grids, Fig. 65, *A* and Fig. 66, *A*, and rings. Each requires its own grid and ring. The slots in cross binder, Fig. 68, *D*, are arranged for both. The jacket has brackets, Figs. 61 and 62, *E*. The addition of these requires a change in molding when the proper height is reached in the molding.

The face of the mold is made of a dry sand mixture and both are molded in part in the foundry floor. The pit in which the mold is to be made is dug to the required depth, and the binder, Fig. 64, *A*, is placed in the bottom with rods for holding the cope down in place, Fig. 64, *B*.

In the center of the binder which is constructed to receive it, we place spindle seat, Fig. 64, *C*, and on top of *C* we place a casing, *D*, to keep loose sand out of spindle seat, and cover it. Sand is rammed around and over *A* and *C* and around

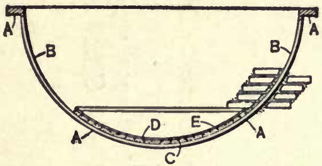


Fig. 70

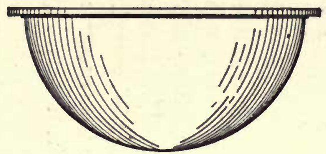


Fig. 69

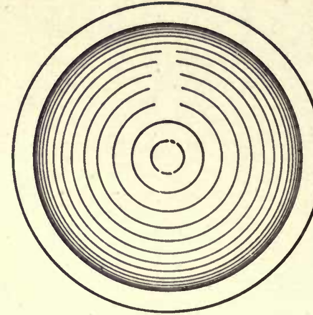


Fig. 71
LOOKING DOWN IN KETTLE

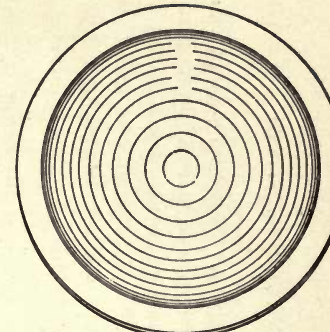


Fig. 73

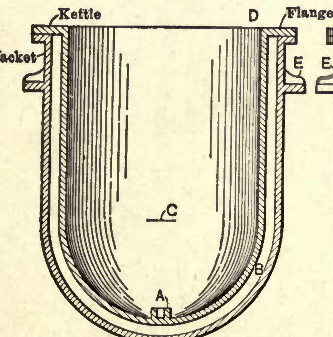


Fig. 61
STEAM JACKETED KETTLE SHOWING
KETTLE INSIDE JACKET AS USED

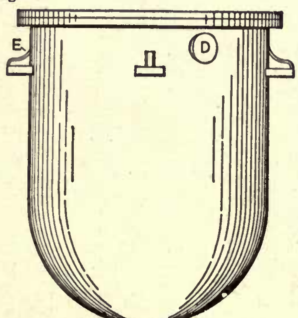


Fig. 62
KETTLE, SIDE VIEW

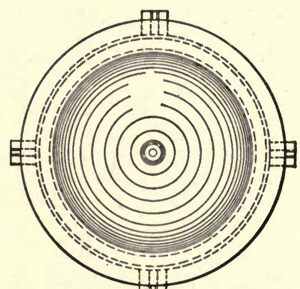


Fig. 63
LOOKING DOWN IN KETTLE

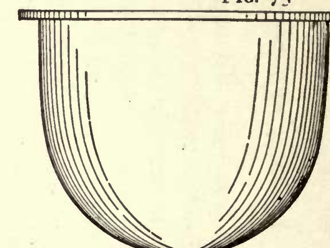


Fig. 72

D to line *E*. A cinder bed shown above extends around the bottom of mold. Gas pipe *F* is placed one end in cinders *E*, and the other end extending above or to the floor, and a

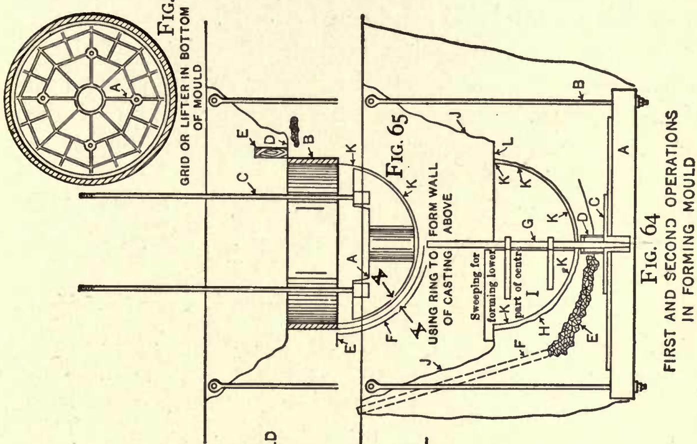


FIG. 66 GRID OR LIFTER IN BOTTOM OF MOULD

FIG. 65 USING RING TO FORM WALL OF CASTING ABOVE

FIG. 64 FIRST AND SECOND OPERATIONS IN FORMING MOULD

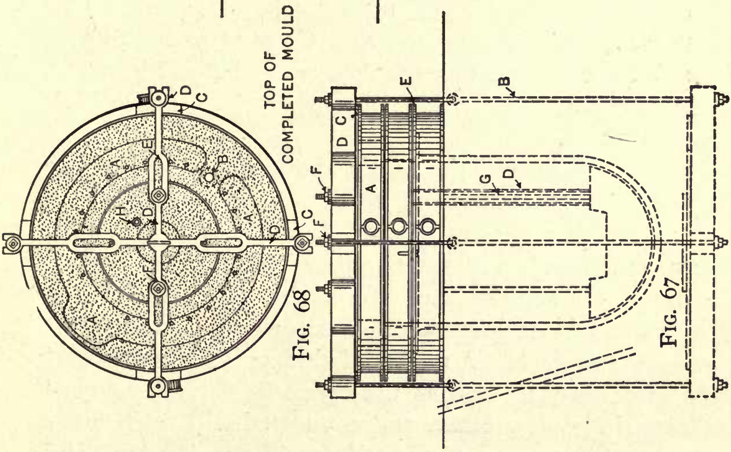


FIG. 68 TOP OF COMPLETED MOULD

FIG. 67 SHOWING MANNER OF SECURING IN MOULDING

bunch of waste placed in the top to keep out sand. This is to bring the gases from bottom of the mold.

The spindle, Fig. 64, *G*, is placed in the seat *C*, and around it two half covers, covering *D*. Some molders prefer to ram the sand around the spindle. Sand is rammed hard and roughly formed to Fig. 64, *H*.

The sweep, Fig. 64, *I*, is placed on spindle G and the sand is rammed hard, and swept to form line *K*. The sweep and spindle are removed and rags or waste tucked in hole left by removal of spindle, and sand filled over it.

We have now formed what is really the size and shape of the bottom of the inside of the kettle, or the shape and size of the bottom of the core forming the bottom of the inside of the kettle when the mold is poured, extending from the bottom to the height of Fig. 61, C.

From this point, Fig. 61, *C*, to the top of kettle, the sides are straight. Were we to sweep the sides above *C* and attempt to lift out core, we would fail.

Let us pass from Fig. 64 to Fig. 65, which is a continuation of Fig. 64. Parting sand is dampened and slicked on line *K*. Facing sand is spread over *K*, and we lower the "grid," Fig. 66, *A*, down, and sink it in this sand to within $\frac{5}{8}$ of an inch of the bottom on line *K*, and place hooks or gagers. This grid is to carry the core and the rods C are arranged to pass up through the core, and through cope and binder, Fig. 68, *D*, this core forming the inside of the kettle. The grid is filled and rammed.

To make the sides of the kettle above Fig. 65, *E*, we use a ring and form the outside of kettle as well as inside with it at the same time. Ring, Fig. 65, *B*, is placed and leveled as shown, and faced, and sand rammed around the outside to the top. To support and strengthen the sides of the mold rods are laid at intervals points towards patterns, but kept away $\frac{3}{4}$ of an inch. A pocket of cinders is formed around the ring after venting, and as the ramming extends upward one is formed above another, and connected with each other by gatesticks being rammed up and drawn out, leaving holes from pocket to pocket; in this way bringing the gas from the lower level to above the floor, as a piece of gas pipe is rammed in the sand, in the last ramming of sands the pipe extends above the floor.

When a deep mold is filling there is an upward pressure to be arranged for; pieces of pipe, as Fig. 67, *D*, may be placed around the rods in grid, as Fig. 67, *G*, extending from grid to bars of iron cope, or nearly so. There are many ways of securing with spuds and blocks, depending on what one has to work with, according to the ideas of different men.

The center is rammed up and arrangements made to bring vent from bottom of center to cope by cinders or pipes, and if the casting is gated on the outside it is easily done with cinders and gatesticks. The core is rodded as the outside, and if rods are driven down in core, the core will be all the stronger. The sand having reached the top of the ring, pieces of wood, Fig. 65, *E*, are stood up around it, and the ring pattern is drawn up with its top even with the tops of blocks. In this way, and using a spirit level the molder knows just how much of ring is below the sand, and he lightly tucks the sand around the ring, and tries his level on the pattern to keep it coming up level. Were he to have one side higher than the other, it would hardly produce a salable kettle. These operations are continued until the desired height is reached. The sticks or blocks are marked the number of times the molder is to draw the ring. When the floor level is reached a cast-iron ring is placed as Fig. 67, *E*, and the top of kettle reaches to joint of ring. A parting is made and the cope is placed, and rammed up, and removed. The flange, Fig. 61, *D*, is swept. A piece of board to form the flange is made and arranged to sweep the flange around the top of kettle, and the flange around the top of jacket is formed in the same way.

Having finished the flange, the ring, Fig. 65, *D*, is drawn out and finishing of the flange completed. The parting sand is brushed from the cope where it overhangs the flange in the drag, finished and the cope is replaced on the drag.

On the top of the cope, Fig. 67, a ring is placed *A* in this ring, the pouring basin, Fig. 68, *A*, is arranged, and riser *B* and for vent to escape from the core *H*.

To prevent the cross, Fig. 68, *D*, on top of this ring from crushing down on the sand, pieces of iron, Fig. 68, *C*, are placed on the edge of the ring.

When making the mold it is arranged for the ends of the binder, Fig. 68, *D*, to come over the rods in the floor, and allow the bolts from the grid, Fig. 65, *A*, to pass up through slots in the cross as Fig. 68, *E*.

The washers are placed, and nuts, Fig. 68, *F*, are placed and tightened.

The cope is hoisted with core forming the inside of kettle hanging to it, and is placed on supports, finished and blacked.

Corrugated iron is stood up around it; a fire is built, and the cope dried.

Let us return to the part of mold in the floor. The spindle seat is cleaned out, and spindle replaced. Another sweep takes the place of Fig. 64, *I*.

Where the sweep, *I*, was used to form the inside of kettle, this sweep takes the place of sweep *I*, and forms the outside of the kettle's bottom. Thus we have to sweep out the sand between *F* and *X*, Fig. 65. This space will be the thickness of the bottom of kettle. The sand is dug out of the bottom of the mold to the line, Fig. 65, *F*, and is given a venting to cinders *E*.

Facing sand is used to form the bottom of the mold and is swept off to line *X*. Thus *X* represents the outside of bottom of kettle, and *XX* the inside, the space between the two the thickness of bottom, as the ring is the thickness of sides.

The spindle is removed and pieces around spindle covering Fig. 64, *D*.

Cotton waste is shoved into spindle seat, and *D* rammed full of sand, and vented and covered with facing to line *X*. The gas from inside *D* passes through perforated sides into cinder bed *E*.

The mold is finished and blacked. Any molder molding these kettles will say it is not a pleasant job to be hung from the crane hook, and finish the bottom of the mold.

Molds of this kind are blacked when green and then dried.

The mold being dried, the cope is closed on drag, and manner of bolting down is shown, Fig. 67, and top of the completed mold shown, Fig. 68.

Regarding manner of gating, some foundry-men prefer to pop-gate them, as I have shown, Some, by running gate down through the core, and iron enters mold through bottom of core. Others by having one or more gates pass down on the outside of casting, and have ingates from them into the mold.

The less the skin of the casting is broken on the inside of the kettle, the longer its life in use.

The kettle, Fig. 61, is shown with a step in the bottom, *A*. This is formed with a pattern rammed up in core.

MOLDING THE JACKET TO THE KETTLE

The jacket is molded in the same manner as the kettle with another set of sweeps and grid, as it is a larger kettle with brackets on the sides to carry the kettle when it is put in use. The bosses where steam pipes are tapped in are placed as desired.

The molding operation is the same until the height is reached, at which cores having the brackets, Fig. 61, *E*, Fig. 62, *E*, formed in them, are to be placed.

In order that the molder shall know when he has drawn up the ring forming the sides of jacket the desired number of times to reach the height at which these cores are to be set, the sticks or blocks, Fig. 65, *E*, are cut to a length and marked the number of times he is to draw the ring and set cores; also height of jacket.

On drawing the ring the number of times to set the bracket cores, the molder makes a parting at top of the ring; then draws up the ring and sets the cores against the ring, spacing them as desired.

The ramming up of the drag continues until the top of the kettle is reached.

As the kettle and jacket are deep, they form a deep mold in the foundry floor. While the cope is easily dried, every molder is aware a fire-pot in a deep mold requires a great deal of attention to keep the fire going. As the space deep down is filled with dead air and draft is required, it is hard to get the bottom dried, but it must be done.

Fig. 69 shows a style of kettle, the smaller sizes being used for many purposes. These smaller sizes are cast from patterns and molded in green sand. The larger are often made with sweeps.

Fig. 70 shows one way of molding in loam. Arrangements have been made for securing the mold for pouring when the mold is completed. The spindle seat is placed with spindle in it and sweep on the spindle, and the pit is bricked up, allowing the brick to come within $\frac{5}{8}$ of an inch of face of the sweep forming the outside of the kettle.

The bricks are loamed and given the coat of slip and we have line Fig. 70, *A*. This is finished, blacked and dried, and then given a coat of charcoal blacking. A thickness of a loam mixture the thickness the kettle is to be; is swept on. This is dried and blacked and given a coat of charcoal blacking, line Fig. 70, *B*, as parting sand, partene and different partings are used to part green sand molds, so charcoal blacking is often used to part loam molds. Loam is then spread in the bottom of the mold, as *C*, and lifting plate *D*, having points or prickers on it, *E*, is lowered into the mold and sunk into loam. Loam is thrown against the sides and the bricks are forced into it. Molds of this kind are usually covered with a loamed plate and the lifting, Fig. 70, *D*, is fastened up to it so when the inside is completed, the loamed plate is placed on top and the lifting plate, Fig. 70, *D*, is fastened to it and the inside construction of kettle is lifted with the lifting plate. After the inside construction is completed and taken away, the thickness of loam representing the thickness of kettle is broken away and the mold is finished and arranged for pouring.

The drag part of such molds is often repaired or reloamed and used many times.

The kettle, Figs. 72 and 73, is molded in like manner, as Fig. 69. As there is a pitch to the sides, it is deeper and of different design.

Kettles of the smaller sizes cast in green sand are often cast bottom up, as it is the easiest way to mold them; also some of the larger sizes for special purposes, and to avoid dirt or a broken skin are cast bottom up, but the design of kettle is to be considered.

The treatment of kettles after casting varies. Small kettles cast in green sand will take care of themselves, but the larger cast in loam have to be taken care of. Green sand will give a baked mold and will expand. Shrinkage in Fig. 69, in cooling will raise the core, provided the cope is removed, but the brick work on the inside of Fig. 72 will crack a casting if a cope is removed and the brick work is left to itself, as the sides are nearly straight and the casting in cooling binds on the inside brick work.

Remember to use loam brick when bricking up the inside, and place a row of them up and down so they may be cut out after the casting is poured and is cool enough. Thus, as the casting cools it can contract, and the inside brick work will give to the contraction as the circles of brick are broken.

CHAPTER VIII

MOLDING CAR-WHEELS

CAST-IRON car-wheels having a chilled tread are cast in molds formed partly of molding sand and partly of cast-iron. The pattern used in forming the mold is what is termed a solid pattern, being made in one piece and having on it core-prints.

The flask in which the wheel is molded and cast consists of three parts: The drag in which the flange side of the wheel is molded, the wheel being poured flange side down; on top of the drag, a cheek or chill of cast-iron is placed to form the tread and part of the flange; on top of the chill rests the cope in which the face of the wheel is molded. Over the center of this is a raised part in which the pouring basin is built. The flask rests on a perforated iron bottom-board through which the gases escape from the drag. The entire flask is of cast-iron and the cope is provided with radial bars of the shape of pattern to hold the sand in the cope. The cast-iron chill is chambered and connected to a water supply for cooling the chill if required. The raised part of the cope is provided with ears to take the tops of chaplets which hold down the lightening cores around the hub of the wheel.

Oftentimes, before the wheels are molded the chill part of the flask is oiled in order to prevent it sweating, or gathering dampness from the warm sand. If this is carelessly done, or if the chill is warm, the oil may find its way to the bottom of the chill, leaving dry spots on the face on which moisture may condense and thus crack or make a bad place on the tread of the wheel. To avoid this, sometimes lead is mixed with the oil, or, instead of oil, lampblack and shellac are mixed, first killing the lampblack with alcohol. The chills are coated with this mixture, as one would black a pattern.

In molding, the pattern is placed in the chill portion of the flask with the flange side up, the face of the wheel sliding down in the chill a distance equal to the width of the tread. The flange of the wheel rests in a part of the chill which is formed to receive it. The drag is placed over the chill and the pattern is covered with a mixture of facing sand, consisting of ten parts of old molding sand from the heap, two parts of new molding sand, and one part seacoal. This mixture is riddled into the drag through a number six sieve, and the facing is laid up against the ribs and evened off to a depth of five-eighths inch over the pattern. The drag is then shoveled full of sand and peened around the edge of the flask, trodden over and butted off. The sand is next struck off flush with the top of the drag and about three-quarters of an inch of loose molding sand is thrown over the drag, after which it is vented and the bottom-board rubbed to a bearing. The bottom-board is then clamped to the flask and by means of a yoke, which is hooked to the trunnions on the chill, the flask is raised and rolled over. It is then lowered on to two rails. Care should be taken that these rails are level and at the same height, as it is important that a car-wheel mold should fill evenly with iron in order to avoid the chill cracking the wheel.

After the gate-sticks are set to form pouring gates, facing sand is riddled over the pattern and heap sand is shoveled in until the cope is filled flush with the tops of the bars. The sand is then peened between the bars, after which the cope is heaped full of sand which is trodden down and then butted off. The pouring basin is built and the sand scraped from above the bars of the cope, and the cope is vented all over and the gate-sticks removed. Cope and chill are then bolted together and hoisted by means of the yoke, leaving the pattern in the drag.

The cope is finished, blackened with silver lead, and the chaplets set to hold down the ring or lightening core. The chill is given a coating of lard oil, or of shellac and lampblack, or some one of the various mixtures made for application to chills. The pattern is then drawn from the drag, which is finished and blackened with silver lead, and a vent-wire is run down through the core-prints to the bottom-board, after which one of the ring cores shown in Fig. 74 is placed with the three projections in the prints in the drag. The center core is next set. Usually the sand is first cut up to form a ring around the vent hole so that the core may press down on it and thus prevent the iron from running under the core into the vent hole. Before

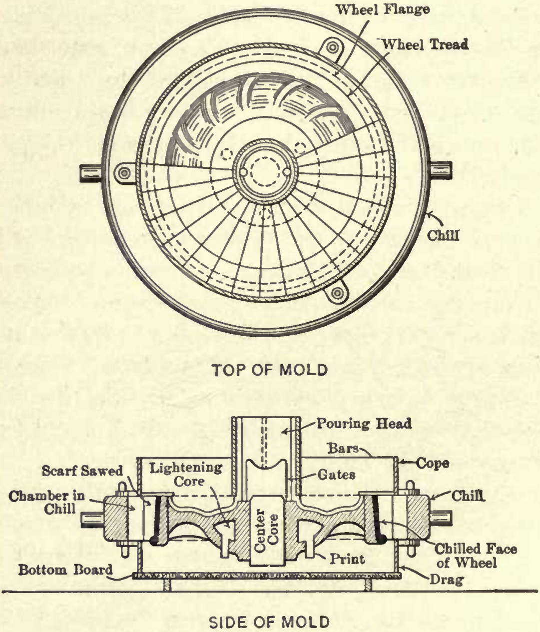


FIG. 74.—CAR-WHEEL MOLD AND CHILL.

setting the core, a vent is made through the drag to the bottom-board.

The cope and chill are next rolled over on the trunnions and lowered, chill down, on the drag, and the parts of the flask are clamped together. After the cope is closed, the chaplets are moved up and down to see that they bear properly on the top of the core they are to hold down. A wedge is placed between the top of the chaplet and the pouring basin part of the cope.

After the wheels are poured, they are allowed to stand, usually until the molder has poured six, after which they are shaken out of the mold, hoisted out of the sand by grasping the rim of the wheel with a pair of tongs, and the wheel is moved by a hot-wheel train to the annealing pits. The heads are broken off with a ram and the center cores taken out. A crane, arranged to handle two wheels at a time by means of two pair of tongs, grasps the wheels in the center and moves them over the proper annealing pit in which sixteen wheels are placed at one time and annealed by their own heat. The wheels remain in the pit four days, being taken out on the fifth day.

In pouring car-wheel molds, the iron can be poured either too hot or too cold and it is necessary that the mold fill evenly, otherwise chill cracks may result. Pouring the iron too hot will cause a variation in the depth of chill and it will also cause internal strains which are lessened or partly avoided when the iron is poured at the proper temperature, which, however, can only be learned by experience. The iron poured into the mold and running against the face of the chill is hardened on the tread of the wheel by being cooled rapidly, producing, as we find on breaking the wheel, a hard white surface which is about three-quarters of an inch deep, becoming mottled toward the inside. From the mottling, what are called legs or veins, extend into the gray-iron portion of the casting.

While the pig iron used in the manufacture of car-wheels is usually number three, or three and one-half charcoal iron, mixed with a certain percentage of old car-wheels, occasionally steel scrap or coke iron is introduced in the mixture. The Chicago, Milwaukee and St. Paul Railroad adds one pound of eighty per cent ferromanganese to the quantity of iron required to pour one wheel, in order to deepen and toughen the chill. This is added to the iron in the pouring ladle.

In the past it has been considered that the greater the amount of coke iron used in the mixture, the more distinct was the line of demarkation between the chill and the gray iron in the casting. The wheel in running would constantly strike on one spot in passing from rail to rail and the shock would finally cause the chilled part to separate from the gray-iron center on account of the mottling and legging not being sufficient to properly hold the two parts together. The gray iron would finally crumble out and leave a hole in the wheel.

When in use the application of the brake to the wheel causes the generation of heat. To determine the ability of the wheel to stand up under the application of the brake, the following test is made: From a number of wheels one is selected and placed on a green-sand bed with the flange of the wheel down. A dam of molding sand is built around it, leaving a space of about one and one-eighth inches between the dam and wheel. Into this space molten iron is poured, being taken from the cupola under the specifications of the Master Car Builders' Association, and poured into the channelway in two places. The wheel is left for a specified time, after which it is removed and examined, and from the action of this test wheel under treatment, the lot of wheels may be accepted or rejected. This test is known as the thermal test.

A second test, to determine the strength of the wheel, is made by dropping a two-hundred-pound weight a distance of nine feet on the center of a 625-pound wheel, the wheel being placed flange down on an anvil supporting only the rim. The wheel must sustain ten such blows to be accepted. A 675-pound wheel must sustain twelve blows, with a drop to the weight of ten feet, while a 725-pound wheel must sustain twelve blows from a height of twelve feet.

Formerly car-wheel foundries were equipped with jib cranes around which the wheels were molded and poured. The iron was brought to the floors in wheel ladles which were hoisted by a crane for pouring into the molds. With this arrangement of circular floors much space was necessarily unoccupied. The more modern wheel foundries have adopted what is known as the straight-line system which reduces the unoccupied space to a minimum. Typical straight-line plants are those of the Chicago, Milwaukee and St. Paul Railroad at Milwaukee, Wis., and that of the Dixon Car Wheel Foundry, Houston, Texas.

At the Milwaukee plant, the wheel flasks are arranged in straight lines across the foundry, resting on two rails, spaced twelve feet centers. The cupolas deliver to large reservoir ladles which are electrically tipped. In front of the reservoir ladles is a track extending the length of the foundry, on which two ladle trains are electrically operated from in front of the ladles to opposite ends of the foundry. The movement of the ladle trains and the tipping of the reservoir ladle is controlled from a pulpit at the cupola. Each car in the ladle train carries two ladles, which can be lifted from the car at the various pouring floors by means of overhead trolley hoists over each floor. The molds are poured from the ladles suspended from the trolleys.

After pouring six wheels, the men begin to shake them out of the molds and to deliver them by means of the overhead trolleys to the hot-wheel cars on the hot-wheel tracks extending the length of the foundry to the annealing pits where the pouring heads are broken from the wheels and the center cores knocked out.

In addition to car-wheels, many different styles of castings are produced in molds made partly of molding sand and partly of iron. Certain cotton-machinery castings are made in iron molds in order that the wearing surfaces will be chilled and thus have a harder skin as the chilling of the hot iron hardens it, due to the quick cooling. The common gray-iron casting, however, is not hardened to any great depth by pouring it against an iron surface, if the casting is of any great thickness. In order to obtain a chilled surface of any depth it is necessary to have an iron of such chemical analysis as will be affected by the chill forming a portion of the mold. See Chapter XXIII for analyses of irons for use in chilled castings.

CHAPTER IX

SKIN-DRIED MOLDS

THE skin-dried mold is made of green sand with a facing composed of varying mixtures of sand and flour and after completion the surface is dried by heat to a depth ranging from one-half inch to several inches. Thus the skin-dried mold occupies a place midway between the green-sand mold and the dry-sand mold. The class of castings which are poured in skin-dried molds, will include locomotive cylinders and stationary engine frames and cylinders. Later in this chapter we will consider the making of a skin-dried mold for a Tangye engine frame.

The molds are dried in several different manners. The smaller molds may be placed in an oven and baked until the surface has been dried to the required depth. In the natural-gas belt, heat is applied to the mold by means of a portable gas torch, and, the gas being under pressure, the flame may be directed against any portion or into a deep pocket of the mold as desired. Where gas is not available, the oil torch is frequently used for this purpose, providing compressed air is supplied to the foundry. The oil torch has the special advantage of regulation of the flame; thus an intensely hot blue flame may be used or a moderately hot large yellow flame, or any flame between these two extremes. Either crude or kerosene oil may be used, depending on the air pressure available. Sixty-five pounds per square inch is required for this work with crude oil while but twenty pounds is necessary with kerosene. In using the oil torch, some experience is necessary to obtain the best results. Too sharp and too quick a heat applied to the face of the mold, may cause the sand to blister and fall. Heat should be applied gradually and its intensity slowly increased as the mold dries out. After a time, a heat of considerable intensity may be applied without danger of burning the face of the mold.

Where neither natural gas nor the oil torch is available, fire baskets may be used for drying the mold. These are baskets made of iron in which is built a fire of charcoal or gas coke. The fire is built in them outside the mold and, when it is well alight, the basket is lowered a little at a time until it is at the proper distance from the bottom of the mold. If lowered too close to the face of the mold immediately, the mold will be damaged and a great deal of patching necessitated. When the mold is partly dried, the process can be hurried by building a moderate fire, and covering the mold.

The sand mixtures used to form the face of the mold vary with the locality. Either fire sand or ground silica rock is added to the facing mixture, depending on the kind of work. If neither is available, the facing mixtures should contain lake or hill sand. The addition of a highly refractory and coarser sand, to the ordinary molding sand, not only produces a more porous-faced mold through which steam will escape while the face of the mold is being dried, but it also assists the molding sand in resisting the action of metal. The body of a skin-dried mold should be well vented to carry off the steam and gases generated in drying. Large green-sand hanging cores are often skin-dried and scabbing thereby avoided.

Molding an Engine Bed in a Skin-Dried Mold

Fig. 75 shows an engine frame of the Tangye type which can be cast to advantage in a skin-dried mold. As there will be considerable side strain in pouring a casting of this character, necessitating a heavy flask and considerable special rigging, the mold will be made in a pit. The pit is prepared as described in Chapter V, and, when ready, the pattern is leveled in position by means of wedges and sand is rammed to within a few inches of the backbone *A* of the pattern, Fig. 76. Facing sand is then tucked and rammed below and around the sides of the backbone and continued under the remainder of the bed.

When enough is in place to hold the pattern in position, the pattern is lifted from the pit and the surfaces already finished are well vented down to the cinder bed, the sides and edges of the backbone are nailed, and the face is finished. The pattern is then replaced and is faced and rammed up with black sand to a point where the iron plate supporting the main core can be placed under the core-print. This plate should extend some distance on either side of the core-print into the sand as shown in the detail Fig. 77. After these plates are placed, facing and ramming are continued until the sand is high enough to permit placing the gate cores *B*, Fig. 76, between the jaws *C C* of the pattern. These are bedded in the sand and a cinder bed *D* placed over them, a vent pipe being inserted in the cinder bed for the escape of gas. Pouring gate cores *F* and upright gate-sticks *G* are placed at the end of the pattern. Iron rings are set around these to re-enforce them to resist the strain generated in the sand while pouring. When the sand has reached the round portion of the pattern, it is vented below the pattern and the vents are covered with cinders which, in turn, are covered with paper. The pattern is faced and sand rammed in until it has reached the floor line. Referring now to the detail Fig. 77, the method of inserting rods to strengthen the face of the mold is shown. These rods should extend to within about two inches of the face of the mold, there being four layers of rods set in a pattern of this depth. A cinder bed extending beyond the end of the cope is built alongside each edge of the pattern at *C*, Fig. 77, a short distance below the floor line. From this cinder bed vents are made with a large vent-wire down to the lower cinder bed as shown. In placing these cinder beds, they are well rammed with the butt of the rammer in order to assist in resisting the side strain when the mold is poured.

The inside of the pattern is a succession of deep pockets of sand to form the cope side and, in order to lift out these pockets of sand from the pattern, skeletons or grids are made to conform to the face of the pattern as shown in Fig. 76. These grids are secured to the cope by bolts *I*. The cope is lowered into

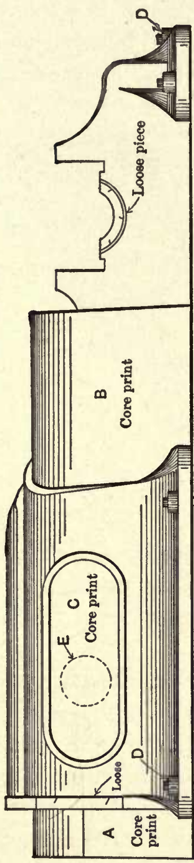


FIG. 75. SIDE VIEW OF PATTERN.

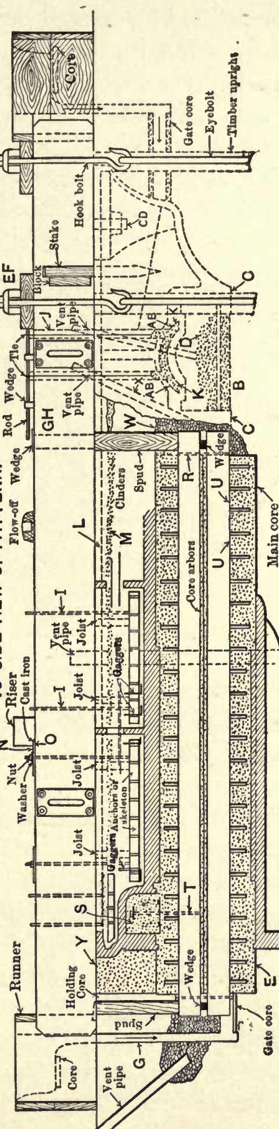


FIG. 76. MOLD WITH CORES IN POSITION.

FIGS. 75 AND 76.—MOLDING THE FRAME AND BED OF A TANGYE ENGINE.

place, being made wide enough to rest on upright timbers which extend up from the binders in the pit bottom. It is guided by stakes driven into the sand and the bolts *I* for holding the grids are then placed. The cope is next removed together with the skeleton, and parting sand is dusted on the joint and facing sand is placed inside the pattern to a depth five-eighths inch. The skeletons are then lowered into place

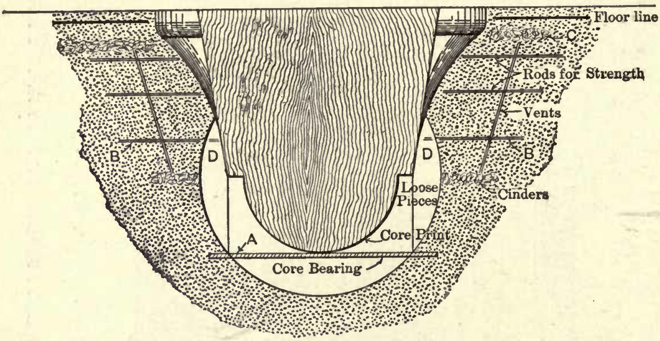


FIG. 77.—MOLD OF END OF PATTERN.

and rapped down. Gaggers are set in the skeletons exactly as though these were the barred cope flask, and on top of each skeleton pieces of joist are set to come up level to the top of the pattern.

A water pocket is to be formed in the casting underneath the jaws *C C* by means of the core *K*. On this core are four prints over each of which the gas pipe *J* is set extending to the top of the cope. These gas pipes are rammed up in the cope with the sand. The inside of the pattern is faced and backed with black sand which is rammed to the point where the green-sand core extends under the ribs *A*, Fig. 78, also shown at *L*, Fig. 76. This rib extends into the inside of the cope and causes an overhanging core to extend all around the pattern. The inside of this flange being faced, five-eighths inch rods are laid from the body of the hanging sand on the cope side to the sand under the flange, to support it. This sand is vented, the vents being brought out four inches away from the pattern and the vents covered with cinders, as shown at *M*. We now have a body of sand covering the skeletons and forming the inside of the pattern. A long channel is scooped out in the center of each pocket and these are vented to this channel which is then covered with cinders and filled with sand up to the floor level. The joint is made, parting sand dusted on, and the cope flask replaced. The bolts *I* are attached to the flask, the pipes *J* and the gate-sticks set to the cinder beds, and the joists in the pockets are wedged down to hold the skeletons firmly in position. The cope is gaggered and rammed with successive rammings of sand in the usual fashion. The cope is hoisted off with the pockets of sand, forming the inside pattern, suspended from it. It is lowered on to trestles and the sides propped up with pieces of joist to insure it against springing on account of the weight of sand suspended from it. The flanges *A*, Fig. 78, are made loose and are lifted out of the pattern with the cope. They are now removed from the sand and the cope is finished, after which it is skin-dried to a depth of an inch and a half. When finishing the cope, the edges of the pockets are nailed wherever there is any liability of the cope cutting on account of the flow of iron. A gas or oil flame is used for drying, care being taken to direct the flame into the pockets in the cope formed by the various ribs.

The pattern in the floor is next boshed, rapped, and drawn from the sand. The pieces *D*, Fig. 77, are loose and are removed from the sand after the main portion of the pattern is drawn. The various edges, where there is a liability to washing, are nailed as is also the face of the mold near the gate. The mold is then sprayed with molasses water and skin-dried with fire baskets, as described earlier in the chapter.

The main core is made in two halves, the core-print being formed by a loose piece in the core box. The two halves of the core are bolted together with the bolts *R*, but before this is done, the core *S*, which is made in a special core box, is bolted to the upper half of the main core by the bolt *T*. The vent from this core is led to the vent of the main core. Each half of the main core is made on a solid cast-iron core arbor which takes the strain due to the heavy weight of the core. The bottom of the core is rodded as shown at *U* to hold it to the arbors. This is not required with the upper half which is not suspended. The cores forming the openings in the side of the bed *E* and *C*, Fig. 75, are first placed, after which the main core is set. A special stop-off piece *B*, Fig. 78, is used to form the side of the mold at that point and, after it is placed, a bed of cinders *W*, Fig. 76, is made and vented with the pipe *X*. A spud or piece of timber is set on either end of the core arbor, being cut off level with the floor. Sand is now stopped in over the end of the core at *B*, the regular facing mixture being used against the stop-off piece, backed up with black sand rammed firmly against it. The stop-off core *Y* at the opposite end of the mold is placed as shown, cinders and the vent pipe for venting the core are laid in, and black sand rammed in back of it. After the core *Y* is set, the joint between it and the sides of the mold is filled in and dried. The core *K*, forming the water box between the jaws of the pattern, is now placed in the cope. This core is made with a staple in each round core-print, over which, it will be recollected, the gas pipes *J* were set, and rammed into the cope. Wires are inserted through these staples and threaded through the gas pipes and drawn tight to bring the core against the chaplets *A B*. The wires are then fastened to a rod at the upper end of the gas pipe and this rod is wedged up to hold the core in position against the chaplets. The pipes *J* also act as vents to the core. The edges of the pipe are covered with paste and a small amount is placed inside the pipes to prevent iron entering. Vent-wires are inserted in the pipe, after which they are filled with sand and the vent-wire withdrawn.

The bolt cores *D*, Fig. 75, are set in the prints and the shelf core, Fig. 78, *C*, is placed, after which the cope is tried on. In Fig. 75 prints are shown for the bolt cores on the cope side of the pattern. The author considers this poor practice and recommends having the cope side flush, so that the cope will

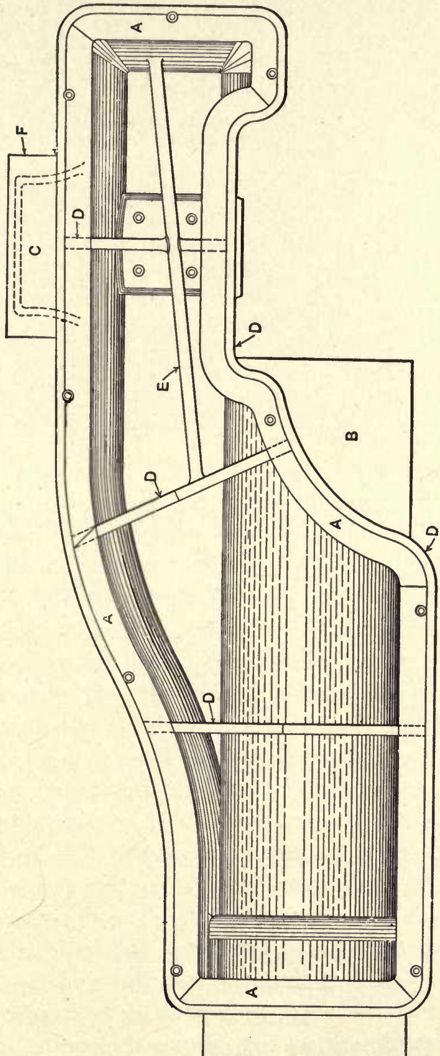


Fig. 78.—Inside of Pattern of Engine Frame.

bear on the top of the cores which should be steadied with nails set alongside the cores. This will avoid pulling down part of the cope when lifting it after trying cn. The name-plate core is next set, after which the cope is once more tried on, and, everything being satisfactory, the joint is pasted wherever the casting comes near the side of the cope, and the mold finally closed.

It will be observed that the pouring gates are outside the cope, as this makes a shorter cope and one easier to handle. The upright gates, it will be remembered, were ringed and rammed up with facing sand which is vented to permit the escape of gas from the gates.

Binders are now placed across the top of the cope and it is fastened firmly to the floor by means of the hook bolts shown connecting with the eye-bolts with the binders in the pit. One binder is placed across the spud *G H* in the cope, which is wedged down to hold the end of the main core in position. The spud at the opposite end is wedged down below the end of the flask. The facing sand is next scraped away from the upright pouring gates, where dry, and replaced with fresh sand. Runner boxes are placed in position and runners built to pour the casting from each end, cores being placed in the bottom of each runner box for the iron to fall on as it is poured. Heavy risers were placed on either side of the pattern in the cope for feeder heads and these are built out above the cope in order to give a greater head. Pieces of oiled paper are placed in the vent pipe to be lighted when pouring for purpose of igniting the escaping gases. Holes are dug at the ends of the mold, back of the runners, to permit the lip of the ladle in pouring to be as close as possible to the runner. In pouring, the ladle at the left which feeds the deepest part of the casting, is first started and afterward the ladle at the right.

The mold is filled so that the iron flows up in the risers to nearly the top of the cope, and pouring is stopped when the iron shows a tendency to rise above this point in the riser. They are kept covered until the escaping gas indicates that the mold is nearly filled, and the iron remaining in the runners is then depended on to completely fill the mold. To provide against the emergency of iron overflowing the top of the cope and finding its way into the vents, flow-offs are provided. The casting should be churned for some considerable time and the iron fed to the risers during the operation must be extremely hot. The direction of flow of the molten iron filling the mold is shown by arrows in the gates.

Shortly after the mold is filled, the iron will become set in the pouring gates and the runners may then be broken away and broken up while hot. When the casting has cooled somewhat, the binders are removed as is also the rod holding the water core in place. The nuts holding the skeletons are removed, the cope is hoisted, and the sand knocked out and allowed to fall on top of the casting, which will require about two days to cool off sufficiently to permit its being lifted from the sand.

Propeller Casting is Essential to Our Defense

Foundrymen Will Now be Required to Make Cast Parts for Ships and a Simple Method of Making Wheels is here Described

Among foundrymen generally, unusual interest is being manifested in the production of castings for ships. The tremendous shipbuilding program outlined by the government is unparalleled by any similar undertaking. Regardless of whether these vessels are built of wood or steel, they will require thousands of tons of steel, gray iron, brass, and bronze castings and the services of many casting manufacturers will have to be enlisted to whom this class of work marks a venture into an unknown field.

Owing to its unusual contour, the molding and casting of the propeller, whether by single blade or integral, seemingly presents the greatest difficulties. Naval architects, also, are inclined to vary the pitch of propellers to meet unusual conditions and the pitches are almost as numerous and varied as the sizes and weights of these castings. The responsibility of matching theory with fact devolves upon the foundryman and he frequently is called upon to meet weird specifications. To foundrymen located on the Atlantic and Pacific coasts, the production of propellers does not present many problems, but the newcomer in this line of

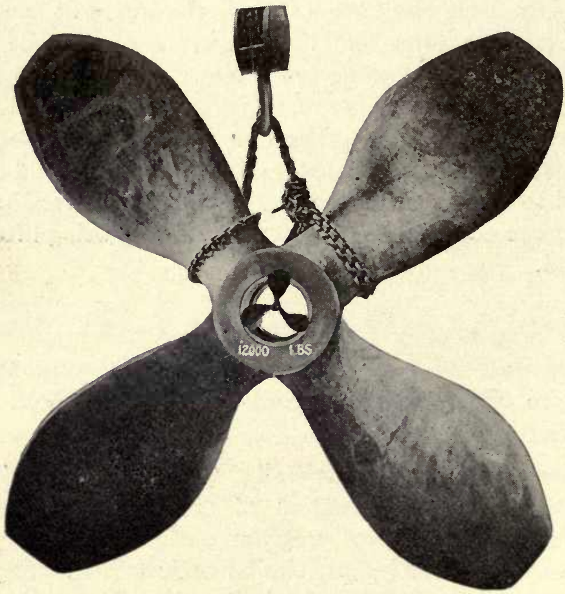


FIG. 79.—A 12,000-POUND PROPELLER FOR A PASSENGER LINER WITH A MOTOR BOAT WHEEL IN ITS BORE.

work may be compelled to carry on many experiments before he succeeds in making a sound casting. Foundrymen who have specialized in propeller work have designed many novel methods to expedite production and the system to be described is simple and reduces to the minimum the necessary flask equipment. The method of molding the hub also is novel and effects economies in labor costs.

A propeller mold with the weights removed, just before

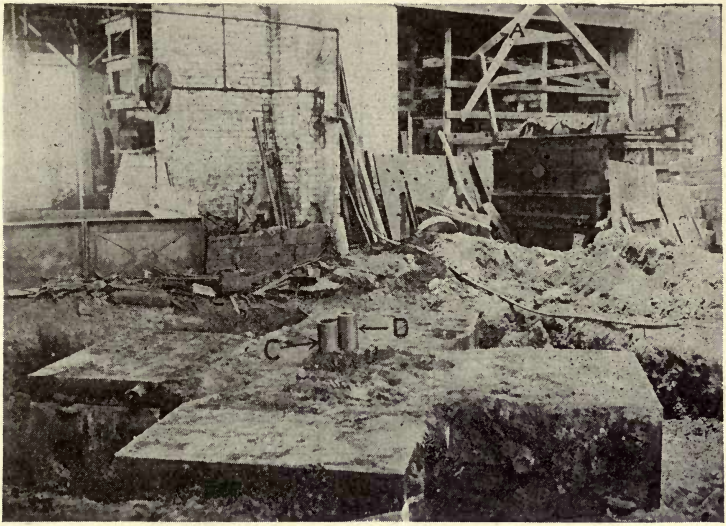


FIG. 80.—PROPELLER MOLD AFTER REMOVING WEIGHTS AND CLAMPS AND JUST BEFORE SHAKING-OUT. THE RISER AS SHOWN AT *C* AND *D* IS A PIPE PLACED OVER THE VENT IN THE CORE.

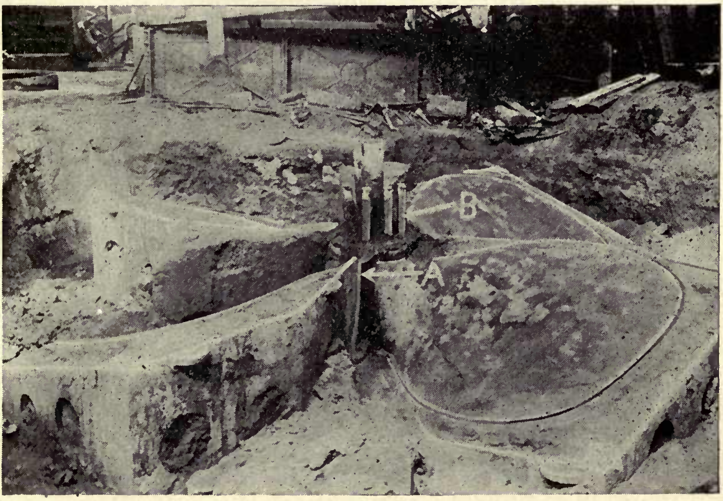


FIG. 81.—PROPELLER PARTLY UNCOVERED, SHOWING THE GATES AT *B*.

shaking-out, is shown in Fig. 80, and in Fig. 81 the cope halves of two of the blades have been removed and the gates and riser also are shown. Four flasks are used, one for each blade, which are so ingeniously joined together by the hub to make practically one flask, as illustrated in the top plan of the mold, Fig. 84.

When making the mold a core is used to form the bottom of the hub, which contains a print for the center core and a hole in its center through which the spindle is passed to its seat underneath the core. The four drag flasks then are centered around the spindle to form a cross, as shown in Figs. 80 and 84. Coke or cinder is rammed into the deep side of each flask to the line *A*, Fig. 86, and sand is rammed on top of this to a point about 4 inches below the line where the blade pattern will rest. The wood core print then is lowered over the spindle into the print in the bottom core and the pattern is lowered onto the spindle. A collar, provided with a set screw, holds the hub in place on the spindle. The blade of the pattern is held down by wood cross-pieces which are clamped to ears on the sides of the flasks. Sand next is rammed underneath the pattern blade and a joint is made conforming to the lines of the pattern. The cope half of the flask then is lowered over the pattern and the ramming of the propeller blade is completed.

Since this flask equipment is used on a wide range of sizes of propellers having varied pitches and hubs, it is necessary to resort to numerous expedients to adapt the cope flasks to these patterns. In Fig. 82 is shown an assortment of propeller patterns all of which can be molded by this flask equipment. The pattern, *A*, in the foreground, is for a propeller 11 feet 4 inches in diameter, which weighs 7500 pounds. A wheel cast from this pattern is shown on the boring machine, Fig. 83. Other patterns in Fig. 82 are for wheels from 8 to 14 feet in diameter, the latter weighing 14,000 pounds. A propeller for the steamer *New Hampshire*, one of the Long Island Sound boats of the New England Steamship Co., is illustrated in Fig. 79, and in the bore of

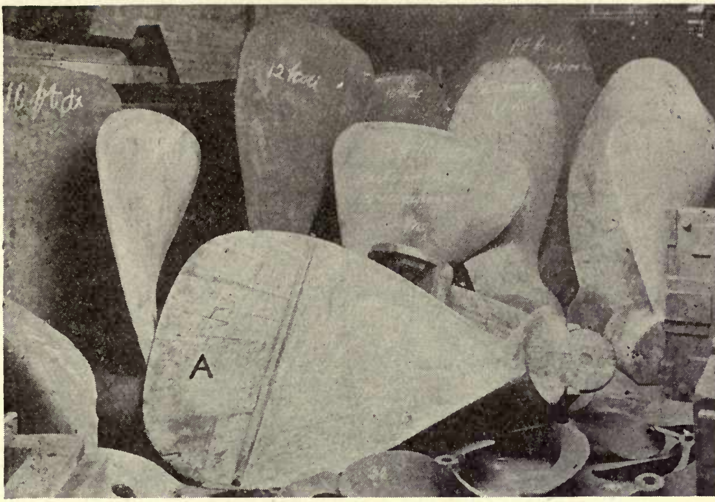


FIG. 82.—PATTERNS FOR A WIDE ASSORTMENT OF PROPELLERS THAT CAN BE MOLDED IN ONE SET OF FLASKS.

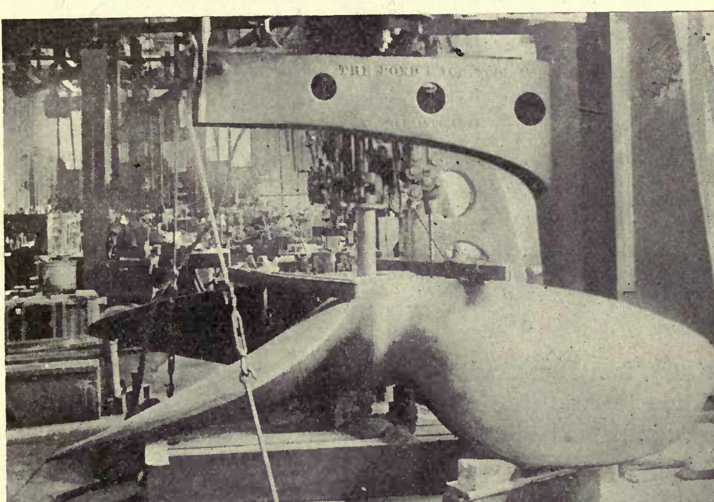


FIG. 83.—BORING A LARGE PROPELLER.

this propeller is a small wheel for a launch, also molded and cast in this foundry.

Owing to the differences in the pitch of the blades of the different patterns, the bars of the copes in many cases are as far distant from the pattern as 8 inches, and to sup-

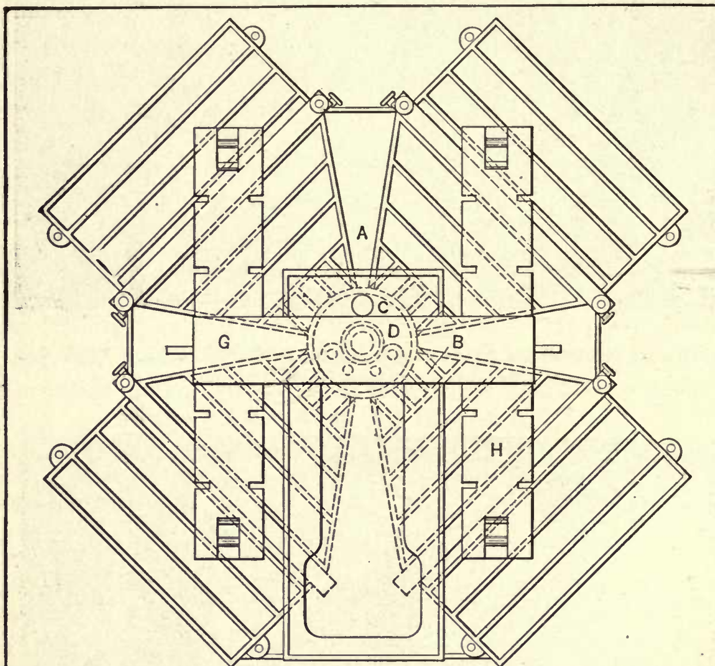


FIG. 84.—TOP OF A PROPELLER MOLD SHOWING GATES, RISER AND WEIGHTS.

port the hanging sand, chucks are hung onto the bars, in addition to rods which are bent to shape especially for this purpose. Chucks forming the points of the flasks next to the hubs are bolted in position, Fig. 84, *B*. After the cope flask has been properly prepared for the pattern, it is rammed and lifted off.

The hubs of some wheels are of such a form that the pattern can be raised on the spindle and swung around to the next drag. However, some hubs are of such a design that it is necessary to lift out the spindle before drawing the pattern.

To assure the accurate centering of the pattern in the flask for the next blade to be molded, a large wood square is employed. This device is shown at *A*, Fig. 80. The spindle passes through a hole in its center as it is lowered over the spindle to accurately locate the blade pattern in the adjcining flask. Before the pattern is drawn from the mold just made,

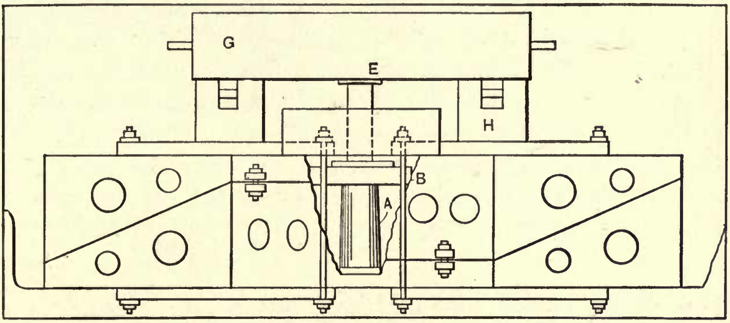


FIG. 85.—PART SECTION OF PROPELLER MOLD, SHOWING HUB CORE IN POSITION.

the parting of the drag is marked to coincide with a mark on the pattern and these lines, with the aid of the squaring device, make it possible to locate the pattern accurately in the adjoining flask. The foregoing operations are repeated for each of the blades, which are molded independently of each other. The molds then are finished, coated with blacking and dried. The copes are dried in an oven, while the drags are dried in the position in which they are molded.

After drying, the copes are replaced, but it will be noted that the four-blade molds do not form a perfect hub at the four points, *A*, Fig. 84. After the copes have been bolted to the drags, a false piece is inserted at the points, *A*, Fig. 84, to complete the hub. Sand is rammed against this false piece to complete the hub section of the mold, and removed, after which the hub is coated with blacking and dried with fire baskets.

The center core, *A*, Fig. 85, then is set in place. The part of this core, shown at *B*, forms the top of the hub of the casting. This hub core is beveled on the edge, and in molding this print in the copes, the sides are sloped to conform to the bevel on this head on the center core. After the center core is set, waste is tucked into the openings around the

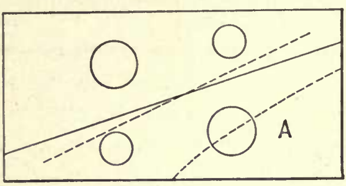


Fig. 86.—Height of Cinders and Location of Pattern in Flask.

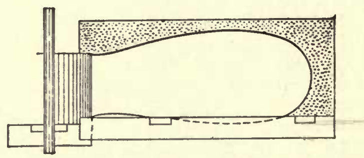


Fig. 87.—How the Pattern is Supported on a Spindle while it is being Molded in the Drag.

head of the center core and gate sticks are placed in the gate holes in the core. To form an escape for gas from the center core a piece of pipe is used between the center core and weight *D*, Fig. 84. Sand then is rammed over the core. The mold then is bolted and weighted down, as shown at *F*, *G*, and *H*, Fig. 85. The gate sticks and rises are set, the runner is built and the mold is ready for pouring. To hold down the center core, wedges *E*, Fig. 85, are driven between the weight *G* and the section of pipe to hold down the center core *A*.

CHAPTER X

DRY-SAND MOLDS

DRY-SAND molds are used for intricate castings in which the walls must be of a positive thickness or in which large bodies of metal must remain fluid for a considerable period of time. Dry-sand molds are molds made of a special mixture of rather coarse sand which are afterward dried or baked in an oven. Molds treated in this fashion possess great rigidity and will stand rather severe usage. After being baked, they may be poured in any position without damage to the mold. Dry-sand molds are principally used for steam- and gas-engine cylinders, pump, air compressor and hydraulic cylinders, printing-press cylinders and rolls, rolling mill rolls, anvil blocks, engine beds, and similar heavy castings. The following mixtures are given by West[1] as suitable sands for the different classes of castings:—

Large spur gears: 12 pails of lake sand, 12 pails strong loam sand, 4 pails molding sand, 1 to 10 pails of coke dust, 1¼ pails of flour; wet with water.

Large bevel wheels: one part molding sand, one part Jersey sand, one part seacoal to 16 parts of sand mixture; wet with thin claywash.

Engine cylinders: 6 pails molding sand, 1½ pails of lake or bank sand, 30 parts sand mixture to one part of flour; wet with claywash.

Another mixture for cylinders is 4 parts of fair loam, one part of lake sand, one part coke dust or seacoal to 14 parts sand mixture; wet with claywash according to the clayeyness of the loam. The backing used with this facing is 5 parts loam and 1 part lake sand; wet with claywash. A good mixture for ordinary work is: 1 part molding sand, 1 part bank sand; wet

[1] "American Foundry Practice," p. 353.

with claywash and use 1 part of flour to 30 parts of mixture or 1 part blacking to 20 parts of mixture.

A mixture with a clay loam for cylinder castings is as follows: 6 parts strong loam sand, 6 parts lake sand, 2 parts old dry sand, flour 1 to 40, seacoal 1 to 14; wet with water. A mixture used for rolling mill rolls: 2 parts old dry sand, 1 part baked sand, seacoal 1 to 12, flour 1 to 18; make as wet as can be worked with claywash.

The author has had good results with a dry sand composed of equal parts of coarse molding sand and coarse New Jersey fire sand. Flour or rye meal is added to this mixture in the proportion of 1 part flour to 14 parts mixture. The mass is mixed thoroughly and then dampened with molasses water made of 1 part molasses and 16 parts water. If fire sand is not available, ground silica rock may be substituted.

In molding, the pattern is faced with one of the above mixtures and the facing is backed up with what has become a burnt mixture of the facing wet with clay water, or with common black sand. The mold itself is usually made in the same manner as a green-sand mold. The flask, however, especially for large castings, is somewhat different, being made of iron with slotted holes in the side as shown in Fig. 92. These holes are for the purpose of venting the mold, five-sixteenths inch vent rods being inserted through them, extending into the mold to within a short distance of the pattern.

A typical dry-sand job is the molding of a Corliss engine cylinder, the various operations being shown in Figs. 88–97. When pouring such cylinders, they are usually poured with the steam ports vertical in order to give cleaner and sounder valve seats than would be obtained were the molds poured in any other position. In molding, the pattern *A*, Fig. 90, is placed on the mold-board with the drag around it, joint side down. Gate-sticks *B* forming upright pouring gates are set and held the proper distance away from the cylinder pattern by the sprue *C*. The pattern is faced with the dry-sand mixture, which is backed up with old sand, wet with clay water. The gate-sticks are faced and the outside of the pattern faced and rammed up with successive rammings of sand, vent rods being introduced through the slotted holes as the flask is filled, and afterward withdrawn, leaving vents throughout the mold.

When the top of the steam and exhaust chests on the pattern are reached, deep pockets will be formed by the extensions of the chest above the round of the barrel. In these are placed rods *D*, Fig. 91, which have been claywashed, to support these pockets. The sand is vented around the rods. A similar procedure is followed when the wrist-plate seat *E* is encountered. On reaching the main core-print, an iron plate is laid on the print and rammed in the mold to support the heavy center core. Facing sand is covered over the pattern and heap sand rammed in, in successive rammings, until the flask is filled. The remaining operations are carried out as they would be for any green-sand mold.

After the joint is made and the cope placed in position, with the gate-sticks and gaggers set, the cope is rammed up with vent rods in the side. On top of each port post, a large plug of the same size as the top of the core-print is placed and rammed up and, on each end flange of the cylinder, a riser is placed to serve as a flow-off. Screws for securing the cope half of the pattern in the flask are inserted, the cope is faced, and heap sand shoveled in to fill the flask and rammed up. Bars are shoved through the eyes of the screw-eyes screwed into the pattern and wedged in place and the cope is lifted off. The screw-eyes are removed and the holes left by them are stopped up, after which the joint is made and the pattern is boshed with molasses water, it then being rapped and drawn. Usually, in making the joint, the corners are nailed and sometimes the entire joint around the edge of the pattern is nailed, since there are but few bars used in the cope of a dry-sand mold.

In finishing a dry-sand mold, breaks at the corners should be repaired by first placing nails to secure the sand, after which the broken sand should be replaced with the fingers, and shaved to the shape of the mold as closely as possible. Should wet mud be laid on these breaks with a trowel, it will scab off when the mold is poured and injure the casting. After the mold is finished and before it is baked, blacking is applied. The blacking is mixed to about the consistency of cream and applied evenly over the entire surface of the mold with the swab. After it has set for a few moments, it is slicked with the trowel which is held at a slight angle to the surface. If the trowel is allowed to lie flat against the surface when the blacking is slicked, a part of the face of the mold will follow the trowel when it is lifted. Larger molds are best blacked green, that is before baking, while the smaller sizes are more satisfactory if blacked after drying. After blacking a green mold, it should be brushed over with molasses water to smooth the blacking and give a smooth surface to the casting. The gate is cut and the mold placed in a proper oven for baking, the oven used being one adapted for core work.

Referring to Figs. 96 and 97, the method of making the cores for the exhaust chambers is shown. In making this core, the iron plate *A* is placed on trestles and over this four smaller plates *B* are set, with *dryers* at each end. The *skeleton* or *grid D* is laid on these plates with the part which is to go in the dryer in place. The skeleton core box *E* is placed in position and core sand tucked under the skeleton and rammed around it. Iron rods, of at least one-quarter inch diameter, are inserted through holes in the end of the core box and rest on the vent rods lying in the post part of the core box at *F*. The core box is then rammed full and swept off on top with the sweep *G*. The core is hollowed to form the proper thickness of the cylinder barrel by means of the round surface *H* on the sweep. The ports *I* are next rammed up. Pieces of wire of the proper length, inserted in the post part of the core box, support the sand forming the core for the port at *I*. The mixture used in making this portion of the core usually has seacoal added in order to leave a clean port in the casting. Nails are placed along the top edge of the core and it is vented in the same manner as a mold. The top is slicked lightly and the vent rods withdrawn. The screws *J* are removed and the portion *K* lifted off, leaving exposed the end of the core. The holes left by the vent rods are then filled with paste to prevent iron working into them later. The screws *L* are withdrawn

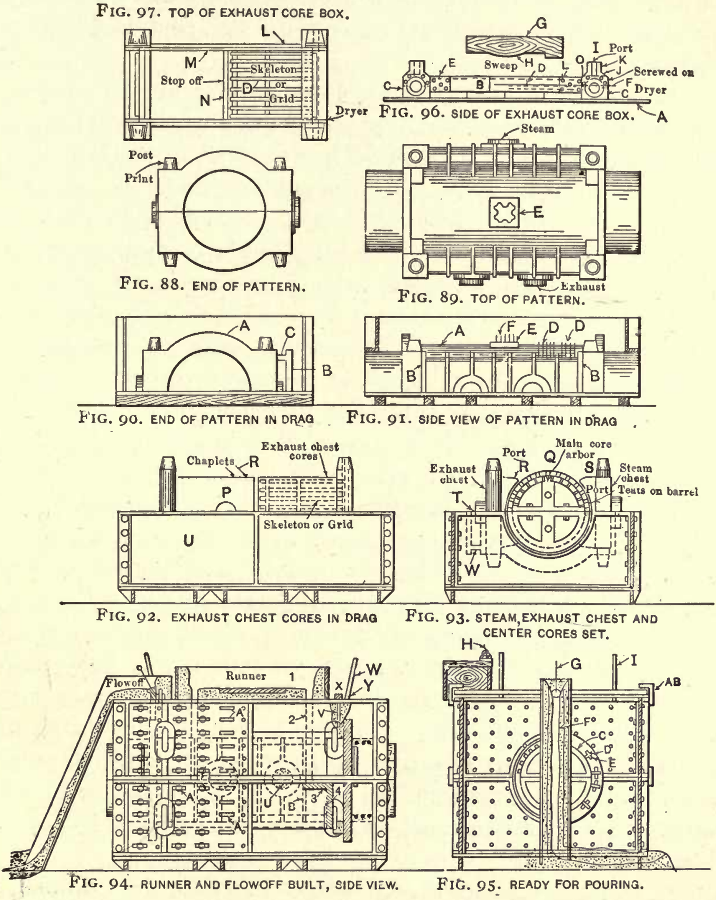


FIG. 97. TOP OF EXHAUST CORE BOX. FIG. 96. SIDE OF EXHAUST CORE BOX. FIG. 88. END OF PATTERN. FIG. 89. TOP OF PATTERN. FIG. 90. END OF PATTERN IN DRAG. FIG. 91. SIDE VIEW OF PATTERN IN DRAG. FIG. 92. EXHAUST CHEST CORES IN DRAG. FIG. 93. STEAM, EXHAUST CHEST AND CENTER CORES SET. FIG. 94. RUNNER AND FLOWOFF BUILT, SIDE VIEW. FIG. 95. READY FOR POURING.

FIGS. 88–97.—MOLDING A CORLISS ENGINE CYLINDER IN DRY SAND.

and the sides *M* removed as is also the stop piece *N*. The object of this piece is to determine the proper length of the core and it can be set at any desired point in the core box. There now only remains portion *O* of the core box to be removed and the core remains in the dryer *C* and on the plates *B*. The core is then finished all over and, if of large size, is blackened before being dried. The steam-chest core is made in one piece with the post and port at each end.

The mold, when baked, is placed in position for pouring. The drag is examined and, if properly dried, is cleaned out and the steam-chest core tried in. The vent hole in the bottom of the post is stopped to prevent iron working under the core and rising in the vents. This vent should be left open until the core is ready for use, as it is then possible to make sure that all vents are open. The exhaust-chest core is set after the steam-chest core. This core is in two pieces and a partition is formed in the middle of the exhaust chest. Consequently each core has but a single post at one end to support it and it must be supported at the opposite end by chaplets. The barrel center or main core is now placed by means of the crane and is set in between the port cores as shown in Fig. 93.

When the ports of the exhaust-chest core were made, staples were set in the back of the core where the center of the nozzle cores were to come. Wires are twisted and passed through the staples and holes in the center of the nozzle cores *T*, Fig. 93, and the exhaust-chest core is drawn tightly against the nozzle core by passing the wire through the side of the flask at *U*, Fig. 92, and twisting it around a rod which is then wedged out from the side of the flask. A vent is arranged to bring the gas from the nozzle cores, this being cut usually while the mold is green. Flour is next placed on the joint of the mold and chaplets set on the exhaust-chest cores, after which the cope is tried on.

It will be recollected that when the cope was rammed, a large plug was rammed up on top of each post core-print. When the cope is hoisted, a man looks through each of these holes and guides the tops of the posts of the chest cores into their proper print. This operation requires four men, while two more are necessary to guide the flask itself until it reaches the long guide pins on the flask. When the cope is lowered to a bearing it is clamped with a few clamps which are immediately removed and the cope once more lifted off, after which the mold and cores are examined to see that no portion is crushed by reason of the cope bearing too hard on the drag. It being determined that the mold bears satisfactorily, as shown by the flour on the joint, a line of thick paste is laid along the joint adjoining the edge of the flask and over the ends of the nozzle cores to prevent iron flowing into the vents. After the mold has been finally closed, the pouring basin is built and flow-off channels arranged from the risers.

When building the pouring basin of green sand it is usual to place a dry-sand core at the bottom of the basin at the point where the iron will fall from the lip of the ladle, since iron falling on green sand may wash the bottom of the basin into the mold with the first rush of iron. After the pouring basin is filled and the gates are choked, there is little danger of dirt entering with the iron. It is also usual to make that portion of the basin, into which the iron is poured, somewhat deeper than the basin at the entrance to the gate.

The clamps are tightened on the flask while the paste on the joint is still green, and iron plates with a hole in them are set over the top of the post cores, the holes in the plates coinciding with the vent holes in the cores. Waste is tucked around the plates to prevent sand from falling into the mold and a rod of the proper length is set on top of the plate, as shown at *V*, Fig. 94. A piece of pipe *W* is connected with the hole and sand is rammed around the pipe and rod and a binder *X* clamped across them by means of clamps *A B*. A wedge is driven between the binder and the rod *V* to hold the chest cores down. Gases escaping from the vent reach the air through the pipes *W*. Both drag and cope of the flask are provided with chipping pieces which cause a space to be left between the two at the joint when the mold is closed. Molding sand wet with molasses water is rammed in these spaces to prevent iron from breaking out when the mold is poured. A space is also left around the barrel core in order that when setting the core, it may be raised or lowered to give the right thickness of cylinder walls. In placing this core, paste was placed just inside of the edge of the flask, which dried quickly due to the warmth of the core. Before finally closing the cope, the top of the barrel core should be covered with a thick paste, immediately adjoining the end next to the flask. Thus with a reasonably tight fit for the center core, the paste will prevent any damp sand rammed between the core and mold from finding its way into the mold. The space around the core should be rammed with sand and the core barrel held down by wedges between it and the flange of the flask on the cope side. After the sand is rammed in, a plate *C*, Fig. 95, is rubbed to a bearing, pegs of iron *D* are inserted in the holes in the iron core barrel, and wedges *E* placed between the pegs and the plate. This insures against iron finding its way out around the core barrel. The method of building flow-off troughs is shown at *F*, Figs. 94 and 95. The runner box is next set and weighted with pig iron. This is the common practice, although the author recommends using a runner box with flanges on the lower edge by means of which it may be either clamped or bolted to the flask.

Cylinders molded in the manner described above, may weigh anything from a couple of hundred pounds to several tons, and the flask and other rigging must be in proportion to the weight of cylinder to be cast. Flasks for this work must be rigid as there is considerable strain brought on them from the molten iron in the mold and it is better to have a flask heavier than necessary than one which is so light that there is danger of its springing when the mold is poured. The heat of the iron must be in proportion to the size of the mold which is to be poured. A slack, dirty iron will seldom produce a satisfactory cylinder, while a heavy cylinder poured with hot iron is liable to be equally unsatisfactory. No general rule can be given to cover this point nor can one be given to govern the rate at which the iron should be poured. If iron is poured too slowly in a large cylinder, *cold shuts* may result, while too rapid pouring may wash certain portions of the mold away and produce defective castings. Experience is necessary to obtain the best results in these two respects.

Cylinders of this character are usually poured at the bottom and as near as prudent to the exhaust-chest post, as imperfections can be repaired on the exhaust side which would be impossible to remedy on the steam side. As there is usually more room around this post core, iron entering at this point has a better chance to float the dirt to the top of the cope, and it is customary to allow an extra amount of metal for finishing in order to take care of the dirt which may rise in these posts. Oftentimes, considerable excess metal is cast here to act as a shrinkhead or feeder. When pouring begins, the vents should be lighted and, when the mold is filled, a certain amount of iron should be allowed to flow through some of them. This is done to flow out any gas generated in the mold which may cause the iron to kick away from the surface, and it will thereby be enabled to lie more closely to the mold and thus give a better casting. If the cylinder is at all large, it should be churned at the flow-offs and it may also require churning on the port posts.

When pouring cylinders of slide-valve engines, the iron is usually made to enter at the lowest point so that the incoming iron will flow into the iron already in the mold and thus restrain the dirt from entering. These cylinders are cast with the valve seat down and a sounder and cleaner seat is thereby obtained, providing the mold has been properly made.

Casting a Slide Valve Locomotive Cylinder

A Three-part Flask is Employed, the Body of the Mold being Contained in the Cheek—Every Operation Involved in Setting the Cores is Detailed.

What will go down in history as the greatest railroad equipment construction program ever undertaken, has just been initiated by the government. It involves the building of more than 2000 locomotives and about 100,000 freight cars. Hundreds of thousands of tons of castings will be required and the foundries of this country will be crowded to the limit for many months while they are doing their bit. An attempt to describe all of the operations involved in the manufacture of these castings would take volumes and therefore this article will be limited to a discussion

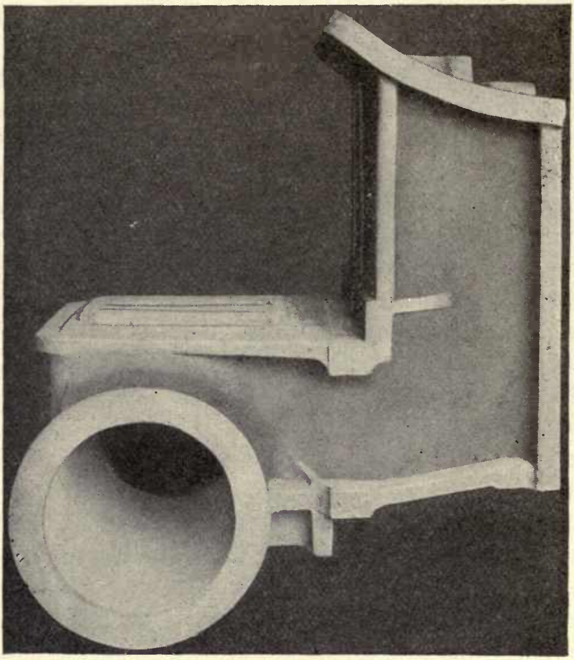


FIG. 98.—SIDE VIEW OF A SLIDE VALVE CYLINDER CASTING READY FOR SHIPMENT.

of only one cast part for a locomotive, namely, the slide valve cylinder.

Many years ago it was the practice to cast separate the saddle of the locomotive, that part on which the front end of the boiler rests, while the cylinders were bolted to either side. At that time the weight of the locomotives did not exceed 30 tons. Later development in locomotive construction provided for splitting the saddle down the center, half of the saddle having been cast on each cylinder. While the locomotive contains many cast parts that are difficult to make, the cylinder is the most intricate. Within a generation the weight of cylinders has been greatly increased. The first castings of this kind that I made weighed only 1500 pounds, whereas to-day the slide valve cylinders

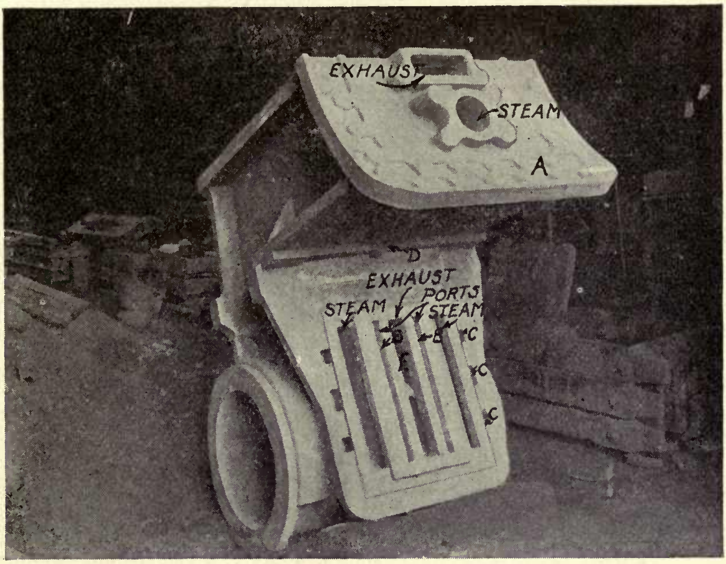


FIG. 99.—CYLINDER SHOWING STEAM ENTRANCE AND EXHAUST PORTS.

that we make in our shop weigh from 6800 to 7400 pounds. Superheater cylinders, to a large extent, are replacing the slide valve type, although a large number of the former are still in use. According to the *Railroad Man's Magazine*, locomotive No. 999, which made a record speed of 112½ miles per hour between Batavia and Buffalo, N. Y., in May, 1893, was equipped with slide valve cylinders. This record has remained unchallenged as the greatest speed performance of a locomotive.

Until recent years, when a cylinder head was broken, the casting had to be scrapped, but with the introduction and development of the welding process, these castings are now repaired at a trifling cost compared with the expense involved in replacing the broken part with a new casting. Heretofore, it also was the practice to bore the cylinders and the piston operated in the bore without bushings. Now

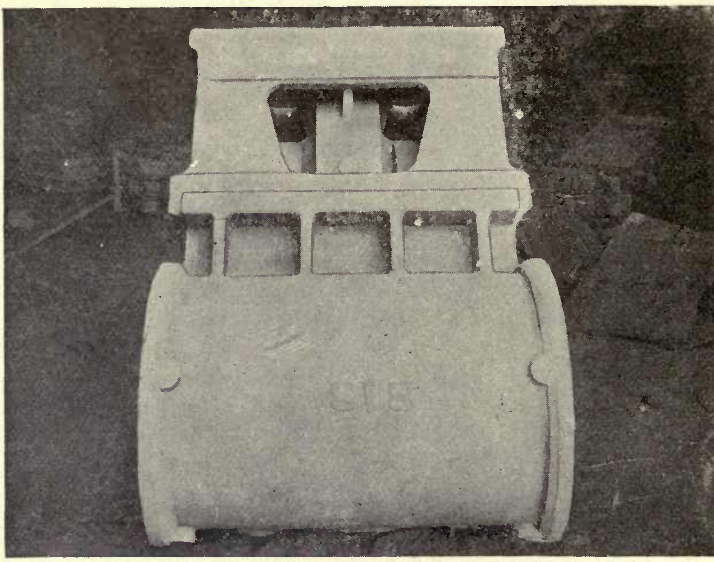


FIG. 100.—LOCOMOTIVE CYLINDER CASTING SHOWING BOTTOM SIDE OF FIG. 98.

all large slide valve and superheated cylinders are bored and bushed, and when the bushing is worn out it is easily replaced.

In the accompanying illustrations, Fig. 98, is a side view of a slide valve cylinder casting awaiting shipment to the New York, New Haven and Hartford Railroad. Fig. 99 shows the steam entrance and exhaust; also ports, and Fig. 100 is a view of the cylinder casting, the reverse of that of Fig. 98.

The pattern is molded in a three-part flask. A section of the pattern on a mold board inside of the cheek flask is

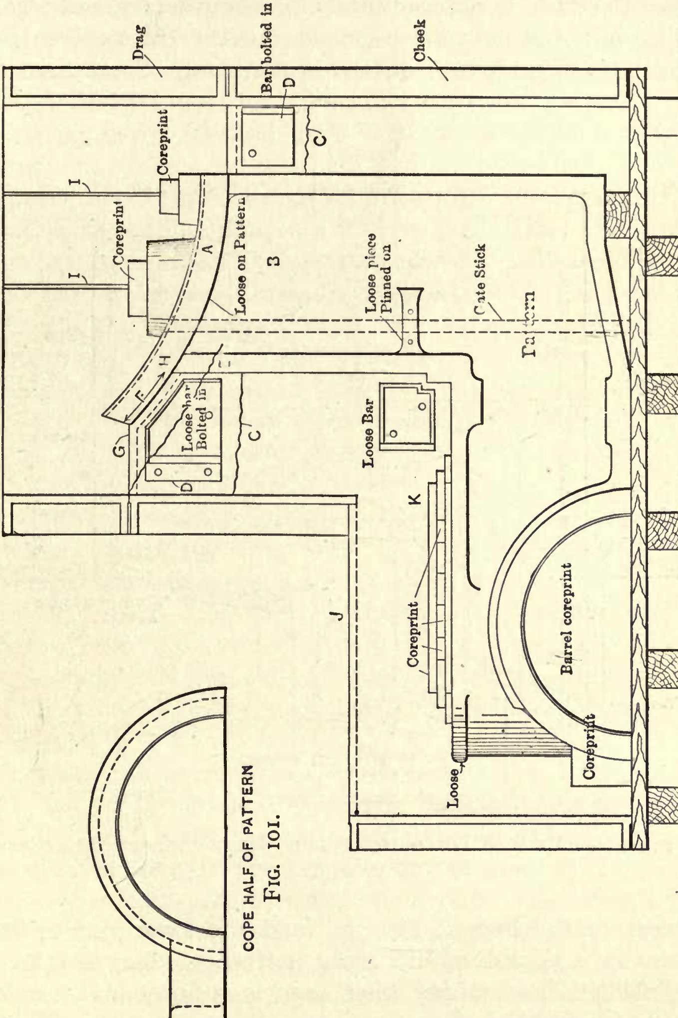


FIG. 102.—PATTERN ON MOLD BOARD INSIDE OF CHEEK FLASK.

COPE HALF OF PATTERN

FIG. 101.

shown in Fig. 102. Piece *A* of the pattern is loose on the main part of the pattern 3 and is left off during the initial ramming operations. Sand is rammed up to the lines *C* and bars *D* then bolted in place. The nuts are on the outside of the flask to prevent the bolts from turning and when shaking-out, the nuts are removed and the bolts driven in, permitting them to fall out with the sand. Sand then is

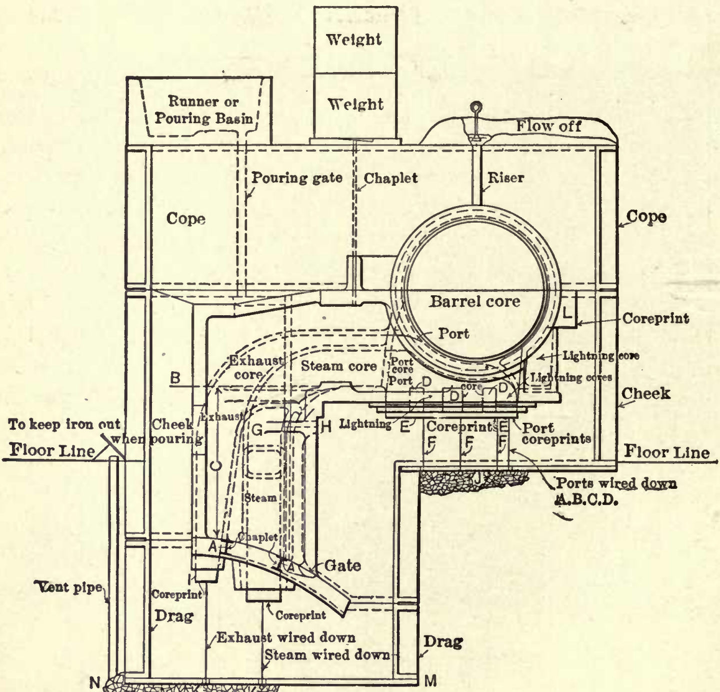


FIG. 103.—SIDE VIEW OF LOCOMOTIVE SLIDE VALVE CYLINDER MOLD AND PATTERN.

rammed to the line *E*, Fig. 102 (and the loose part of the pattern *A* is placed on the main pattern 3, being weighted to prevent it from raising when sand is rammed underneath part *F* of loose piece *A*.

When the sand is rammed to point *G*, loose piece *A* is removed and rods are driven into the sand to strengthen the mold. A fillet is formed and is nailed at *H*, Fig. 102. The drag half of the flask then is set on the cheek and rods *I* are placed in position and drag rammed. The bottom board that is placed over the cheek at *J* is slotted, the opening coinciding with the port coreprint *K*, thereby providing vents for the gas and openings for wiring the port cores down.

After the cheek and drag parts of the mold are bolted together and boards bolted on, they are rolled over and the cope section of the pattern is set in position with cap and rammed, as shown in Fig. 103. The cope part of the mold then is removed, the pattern is drawn and the cope mold is finished. The pattern next is drawn from the cheek and the cheek is finished and hoisted off drag and loose piece *A* removed from drag. The drag then is finished and nailed, the latter operation being necessary, since this part of the mold contains a number of pockets as shown at *A*, Fig. 100. The cheek and drag then are assembled and bolted together and are dried in an oven overnight before coring.

The following morning the cheek and drag are set in position for coring. The lower inside core *C*, Fig. 103, is set on chaplets and extends up to about the line *B*, forming a part of the inside of the casting. Lightening cores *D*, Fig. 103, then are fastened in place, which form the openings *C*, Fig. 100. Steam pipe cores *A*, Figs. 104 and 105, then are set. In Fig. 104, the steam pipe core *A* is shown extending from core-print *B* to *C*, where it branches down into core print *E*, Fig. 103. These are two cores joined on the dotted line *D*, Fig. 104. The production, pasting and finishing of this core requires skill, since the two port cores must be joined into one so that the port ends shall enter the proper prints. The cores must be gaged when pasted, since a variation of $\frac{1}{8}$ inch necessitates pasting over. The port cores *E*, Fig. 104, are placed on a line with the prints *E*, Fig. 103, and are pasted in place. Wires *F*, Fig. 103, are extended through and attached to rods across the bottom board to hold down the port cores also shown at *B*, Fig. 105. A core *G*, Fig. 103, forms a curved surface in the hollow of the steam core and is held in place by a chaplet, venting at *H*. This core makes the opening *D*, Fig. 100.

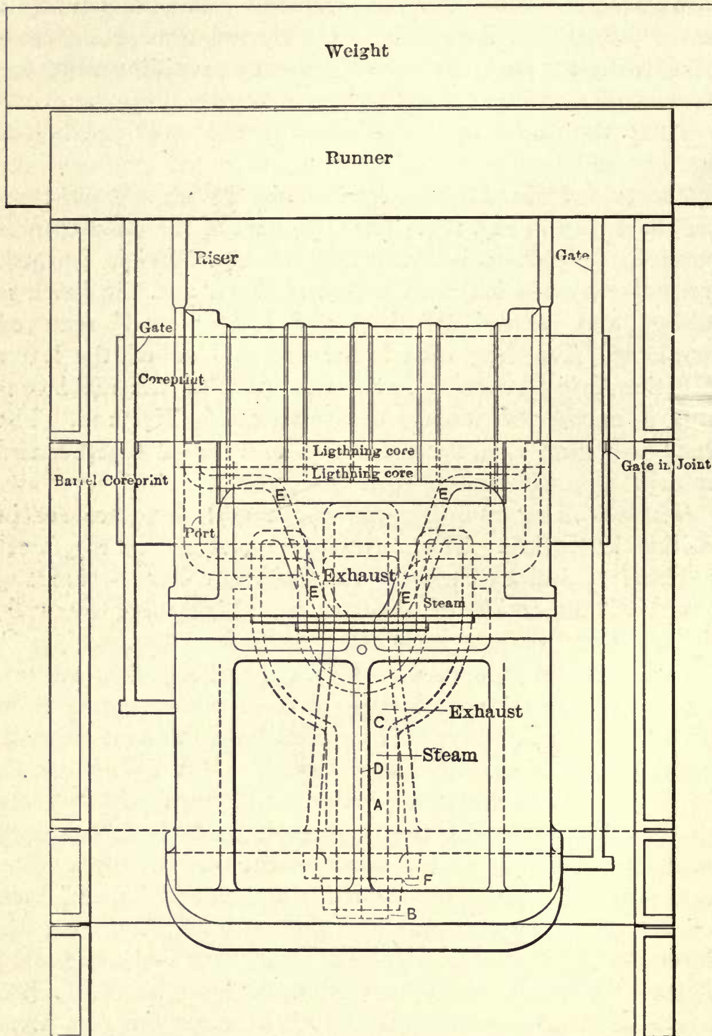


FIG. 104.—FRONT VIEW OF LOCOMOTIVE SLIDE VALVE CYLINDER MOLD WITH CORES IN PLACE.

The exhaust core *I*, Fig. 103, then is set. At *C*, Fig. 105, this core is shown extending down between the port cores into a print on a line with *E*, Fig. 103. This core makes the exhaust opening *E*, Fig. 100, while the port cores *B*, Fig. 105, make the openings *B*, Fig. 100. The port cores form the passageways for the steam to enter the cylinder from the steam chest, exhausting through a valve into the exhaust pipe,

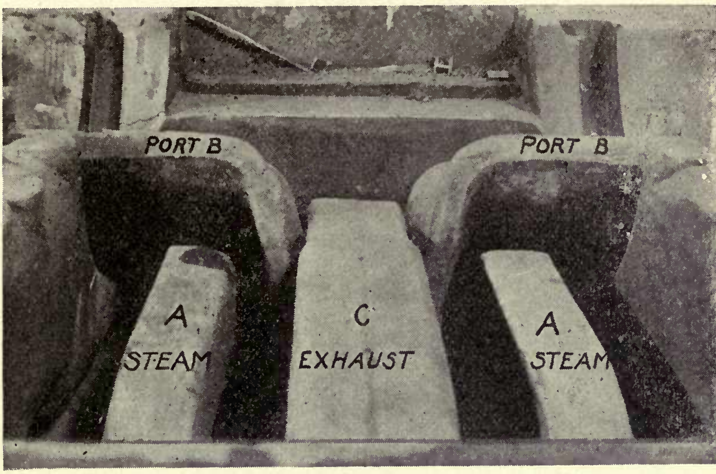


FIG. 105.—STEAM, EXHAUST, AND PORT CORES IN THE DRAG.

An enlarged view of the port core is shown at *A*, Fig. 107, on page 139.

Setting Lightening and Barrel Cores

The lightening core *L*, Fig. 103, then is set, followed by the barrel core, shown in Figs. 103 and 107. At the right and left of Fig. 105, port cores are shown at *B*, Fig. 107 and *A*. Fig. 107 illustrates how the port core *A* is curved to receive the barrel core. These port cores must be well rodded, firmly bonded, well vented, and thoroughly baked, and when the barrel core is set care must be exercised to prevent the barrel core from bearing too hard on the port cores. In casting, I prefer to have a fin form between the port and barrel cores, as a slight settling of the barrel core may crack a port core. In making and handling dry sand molds it is well to remember that "a fin is better than a crush." Green sand will yield, but dry sand will crush. The lightening core, C, Fig. 106, is set next. While the steam, exhaust, and port cores are vented at *J* and *K*, Fig. 103, the vents from the lightening cores form-

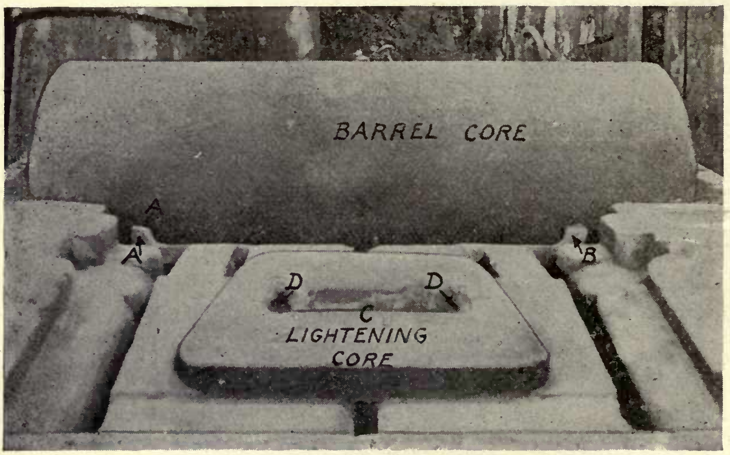


FIG. 106.—THE LIGHTENING AND BARREL CORES IN POSITION.

ing the inside of the saddle part of the cylinder casting and the outside walls of the steam pipes, are brought up through the lightening core, C, at *D*, Fig. 106. The cheek and drag section of the mold then is lifted and wires *F*, Fig. 103, are drawn taut and wedged to the bottom board. The wires holding down the steam and exhaust cores also are fastened at *K*, as will be observed from Fig. 103.

The cheek and drag part of the flask are bolted together and then lowered into a pit and sand is rammed around the flask from *N* to *M*, to floor line, Fig. 103. The cope then is tried-on, and after lifting off, a flame from an oil torch is applied to dry any paste that has been used. Chaplets should be employed as sparingly as possible, particularly for supporting cores forming live steam openings, as the metal in these parts is subjected to great pressure. On the other hand, chaplets may be employed for supporting the exhaust cores without danger of injuring the strength of the casting. All of these castings must be made to specification, their chemical and physical properties being pre-

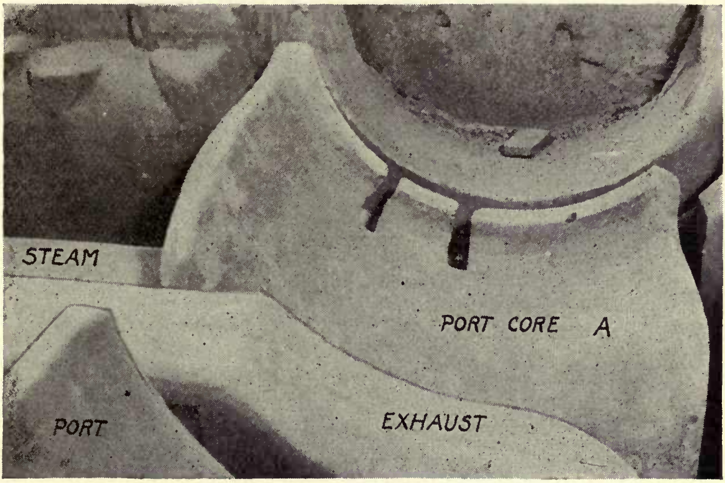


FIG. 107.—ENLARGED VIEW OF STEAM, EXHAUST, AND PORT CORES.

scribed by the railroads. Test bars cast from the same metal as poured into these cylinders developed transverse strengths of from 3600 to 4400 pounds.

MOLDING A SUPERHEATER LOCOMOTIVE CYLINDER

The Production of this Intricate Casting Involves the Setting of a Large Number of Cores, the Details of Which are Fully Described

Among the many recent improvements in locomotive design and construction, the superheater ranks as one of the most important, since it effects great economies in fuel consumption and considerably adds to the steam efficiency. The cylinders for superheater locomotives are made of gray iron, the castings being exceedingly intricate and the molding operation taxes the ingenuity of the foundrymen on account of the large number of cores that must be set. Figs. 108, 109,

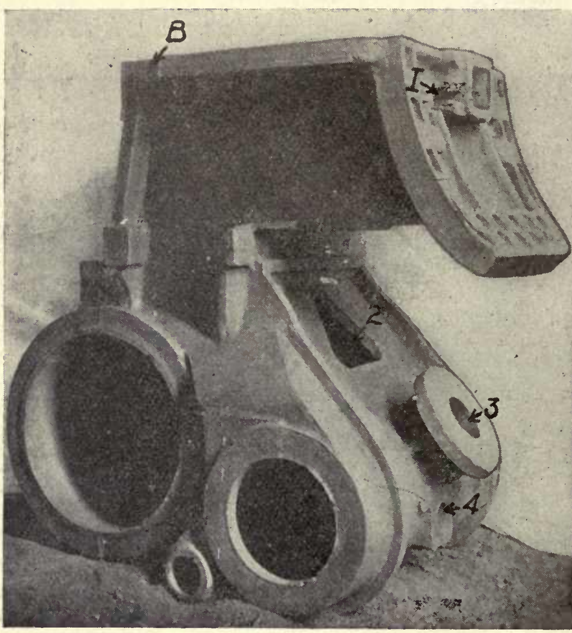


FIG. 108.—SUPERHEATER LOCOMOTIVE CYLINDER CASTING.

and 110 are different views of a locomotive cylinder casting for the New York, New Haven and Hartford Railroad.

The cylinder pattern is illustrated in Fig. 115. It consists of cope, cheek and drag sections. The saddle part of the pattern, which forms the drag, is shown at the left, Fig. 115. It contacts with the cheek at the edges *A*, shown on the drag and the cope, respectively. This forms the saddle of the cylinder on which a part of the locomotive boiler is supported. The cope part of the pattern is illustrated at *I*. Other parts of the pattern are indicated as follows: *B*, coreprint; *C*, steam pipe nozzle with coreprint; *D*; *F* is a coreprint, loose on the pattern, for the top core forming the inside of the casting; *G* is the coreprint for the piston valve core and extends up to the print *H*, for the main barrel core of the cylinder and is for core that forms a

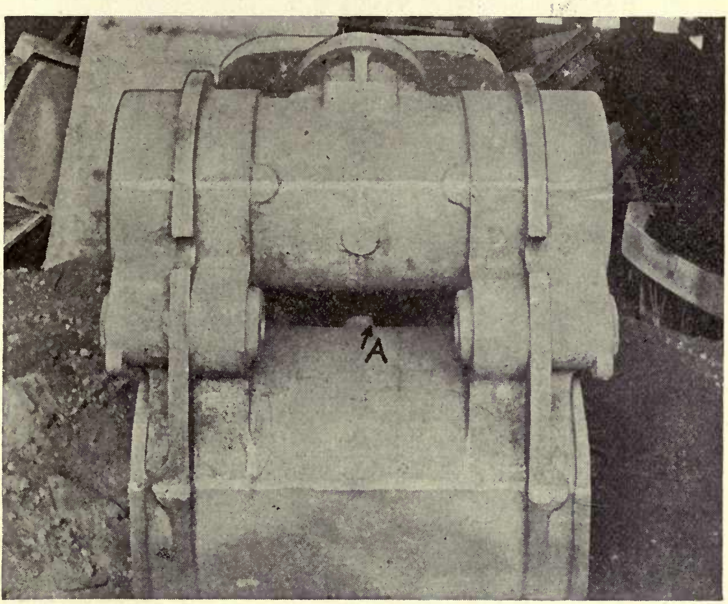


FIG. 109.—FRONT VIEW OF CYLINDER AS INSTALLED.

part of the outside of the cylinder between piston arc and main barrel core; *J* is a loose extension on the side of the pattern, which is left in the mold when the cheek part of the pattern is drawn from the mold; *K* is a coreprint for the core forming a part of the flange where the two cylinders are machined and bolted together and *L* forms the nozzle with its print *M*.

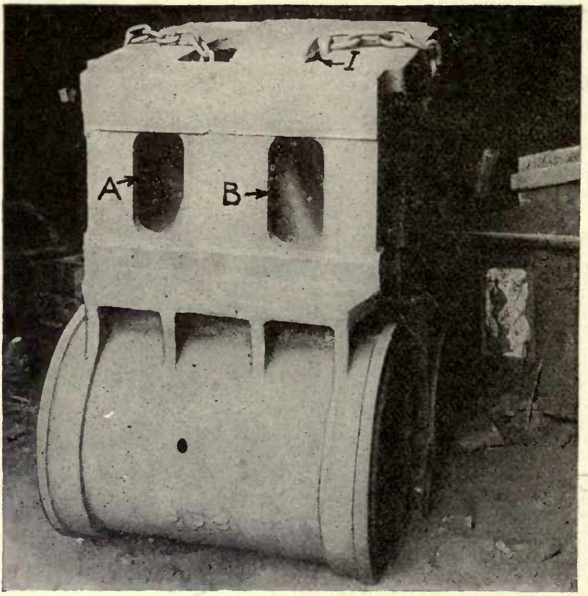


FIG. 110.—ANOTHER VIEW OF THE CYLINDER.

Molding the Drag

The cheek part of the pattern is placed on a mold board, as shown in Fig. 111, and the cheek of flask *B*, extending from *C* to *D*, is placed around it. The pattern is faced with a mixture of equal parts of coarse molding and fire sand, to which flour is added in the proportion of one of flour to eighteen of sand. This facing is backed with tempered sand from shaken-out cylinder molds, and if the sand is badly burned, it is tempered with a mixture of clay and water to restore the necessary bond. If a desirable grade of fire sand may be obtained, the proportion of molding sand in the facing mixture is reduced and is replaced by fire sand and a smaller amount of flour is added. A dry core binder also may be substituted for the flour.

When the successive rammings of sand have reached points *E* and *F*, Fig. 111, a parting is made and covering core

G is placed around coreprint *H*, Fig. 115. After this core is located, it is raised and the steam nozzle, *H*, Fig. 111, is drawn from the mold and the covering core *G* is returned to position. The ramming then is continued until the sand reaches a point where it contacts with the cast-iron bar *N* and the side bars, *M*, Fig. 111. These three bars which support the overhanging sand forming the saddle of the cylinder, are bolted to the outside of the cheek flask. The bars are attached in this way to facilitate their removal when the casting is shaken out. The nuts are removed from the bolts on the outside of the flask, the bolts are driven in and the bars slide out of the flask with the cylinder casting.

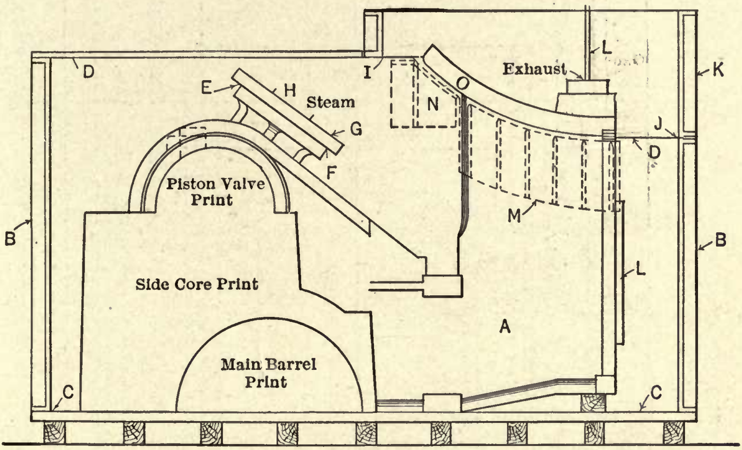


FIG. 111.—CHEEK PATTERN ON MOLD BOARD.

The saddle or drag part of the pattern, shown in Fig. 115, and illustrated at *O*, Fig. 111, then is placed in position and sand is tucked and rammed around it. When the sand is rammed to a level of *DI*, Fig. 111, one of the bottom boards is placed in position and a parting is made extending from *I* to *J*. Drag flask *K*, Fig. 111, then is set over the cheek flask and is rammed with gatestick *L* in position as indicated. The bottom board covering the drag has a hole in it through which the gatestick *L* extends, thereby forming an opening through which the exhaust core is wired in place. After the bottom board is placed over the drag, the gatestick is drawn

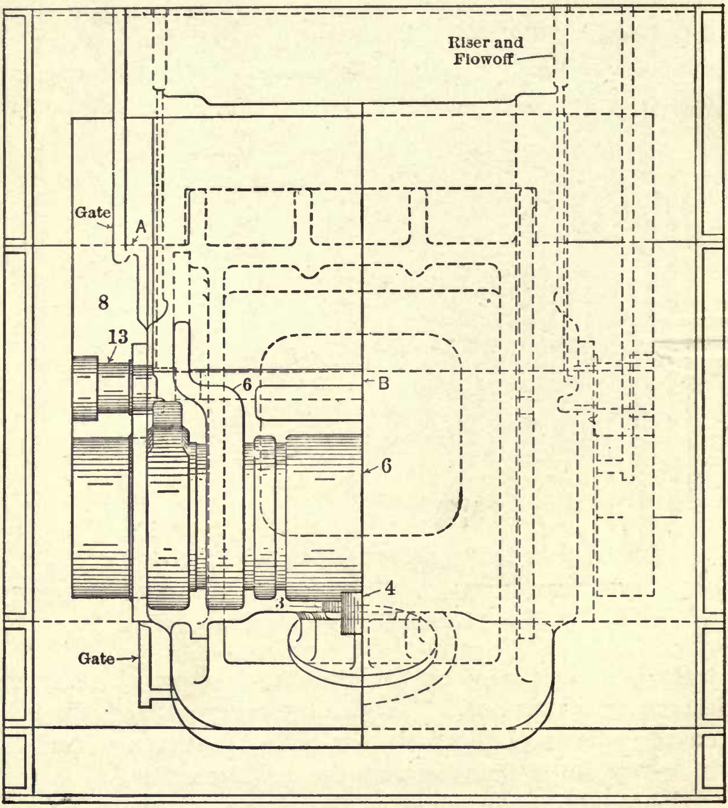


FIG. 112.—SECTION OF MOLD SHOWING GATES AND RISERS, AS WELL AS LOCATION OF SOME OF THE MAIN CORES.

out and a pocket is formed at its end underneath the bottom board. After the bottom boards are secured, the cheek and drag are rolled over.

Bolts and clamps are used for fastening together the different parts of the flask. The mold is vented somewhat but not to the extent of that required for green sand. As a rule, the quicker the generated gases can escape from a mold, the sounder the casting. When an open sand is used for backing purposes, and with a limited thickness of sand between the flask and the pattern, the free escape of the

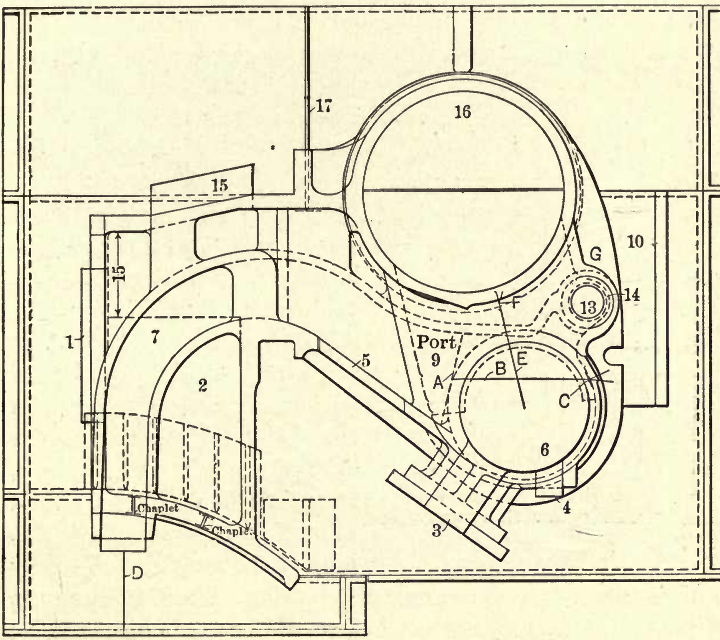


FIG. 113.—CROSS-SECTION OF THE MOLD SHOWING THE LOCATION OF THE CORES.

gases is insured and not very much venting is required if the flask has holes in the sides.

After the cheek and drag parts of the mold have been rolled-over, a parting is made and the cope section of the pattern, *I*, Fig. 115, is placed in position, Figs. 113–123. The core-print, *F*, Fig. 115, and the pattern then are covered with facing sand. After setting the gates and placing the gaggers or hooks, the cope is rammed. The cope part of the mold then is lifted off, the cope pattern drawn and the coreprint and cope are finished. The cheek pattern is drawn next and parts of the mold are secured with nails. Loose piece *J*, Fig. 115, is drawn into the mold and removed, followed by drawing coreprints *B* and *M*, Fig. 115, and coreprint and *I*, Fig. 113. These two prints are loose on the cheek pattern and remain in the sand when the main body pattern is drawn. The gates and sprues are drawn from the cheek and gates *A*, Fig. 112, are cut in the cheek. The mold is finished and is blacked while green and before drying.

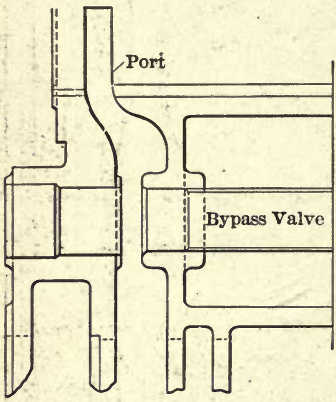


FIG. 114.—SKECTH SHOWING THE PORT AND BY-PASS VALVE.

The cheek then is lifted off the drag and the overhanging part of the mold over the saddle is finished. The saddle part of the pattern then is drawn from the drag. The pockets shown in the face of the saddle, indicated as the drag of the pattern, Fig. 115, were secured with spikes when the drag was rammed and this part of the mold consequently requires only a limited amount of repairing. Cores forming the bolt slots *I*, Fig. 108, are set before the cheek is blacked and returned and is bolted to the drag. The whole mold then is dried in an oven over night.

Setting the Cores

A large number of cores are set in the cheek and great care must be exercised in locating them properly. Dry compound is used as a binder for the heavy cores, but the port cores are made of a sand and flour mixture. The proper rodding and venting of the cores requires the attention of a skilled coremaker. The core forming the opening *I*, Fig. 110, is pasted and secured in print *I*, Fig. 113, and also is shown at *I*, Fig. 116. Core *2*, Fig. 113. is set on chaplets. Cores *3* and *4*, Figs. 112 and 113, then are placed and form openings in the casting, as shown at *3* and *4*, Fig. 108. Core *5*, Fig. 113, forms opening *5*, Fig. 108. The piston valve core *6*, Fig. 112, *6*, Fig. 117, then is placed, followed by the exhaust core *7*, Figs. 113 and 116. This core forms a Y and each end of the Y extends into the piston valve core at the dotted line

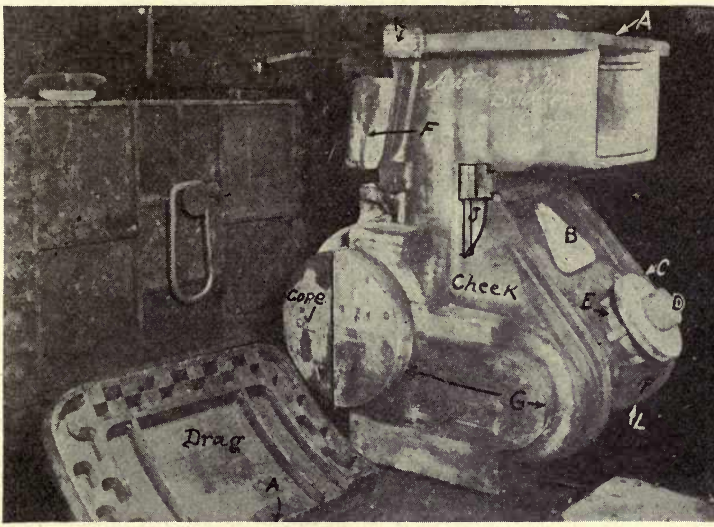


FIG. 115.—CYLINDER PATTERN DIVIDED INTO COPE, CHEEK, AND DRAG.

A, Fig. 113, being secured to the piston valve core by wire *B*, extending through piston core *6*, fastened at *C*. The joint between the cores is filled and dried. At the single end of the core, *D*, Fig. 113, a wire is extended down through the bottom board. Cores *8*, Figs. 112, 116, and 121, which form part of the outside of the cylinder between the piston and the barrel cores are set and fastened. The port cores *6*, Fig. 112, and *9*, Fig. 113, are set in coreprints in the piston core *E*, Fig. 113.

Figs. 116 and 117, are pasted and attached to the piston

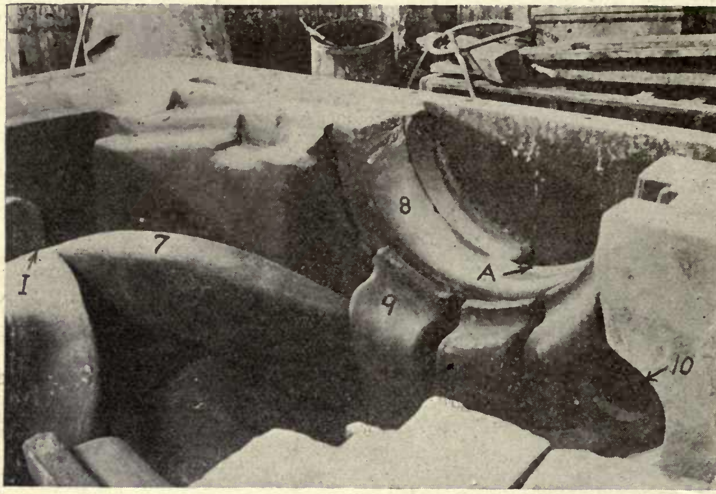


FIG. 116.—CHEEK PART OF MOLD SHOWING MAIN BARREL PRINT.

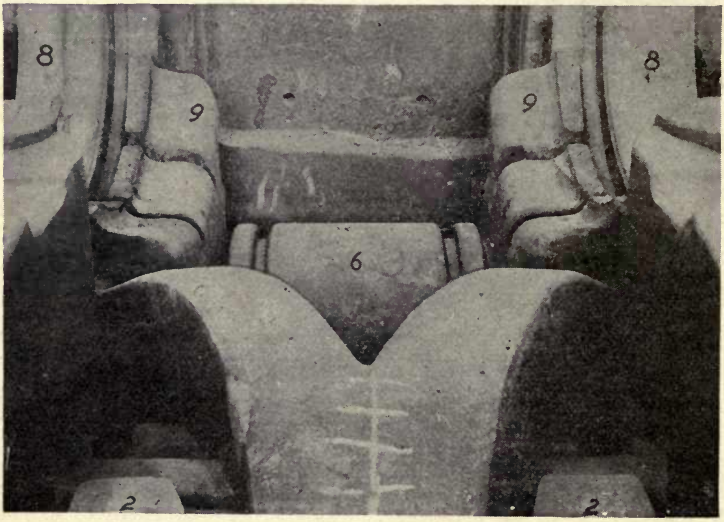


FIG. 117.—PART OF THE MOLD, SHOWING PISTON VALVE CORE AT *6*.

core by wires *F*, Fig. 113. The pockets formed at *C* and *F*, Fig. 113, are filled with sand, nailed and dried. The cheek and drag parts of the mold then are hoisted and the wire *D*, Fig. 113, is fastened. The cheek and drag are next lowered into the casting pit and cores *10*, Figs. 113, 118, and 119, are set. These cores form the wall thickness at *G*, Fig. 113, partly over the port and by-pass valve cores. Cores *12*,

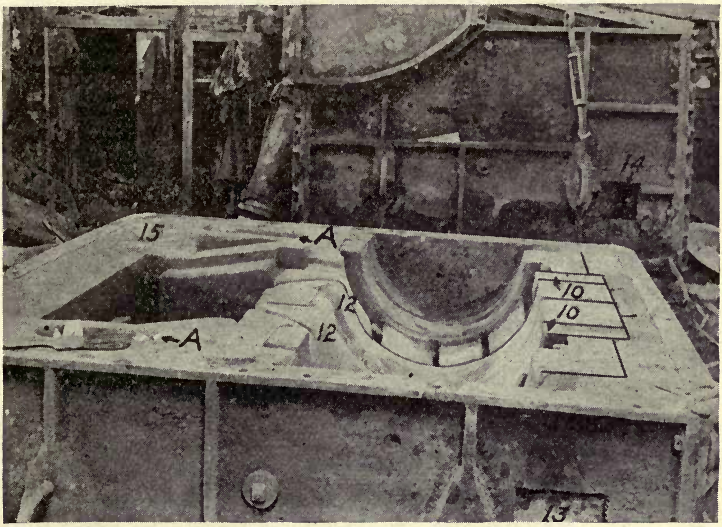


Fig. 118.—Cored Cheek before Barrel Core is Placed in Position.

Figs. 118, 119, and 120, then are set and extend down between the opening in the Y-shaped exhaust core to core 5, Fig. 113. These cores form part of the walls of the piston and the main barrels of the cylinder at the center, as they extend between the piston and the main barrel cores of the cylinder, forming the opening *A*, Fig. 109.

Setting Valve Cores

The by-pass valve cores *13*, Figs. 112 and 113, are placed in position by passing them through a square opening in the

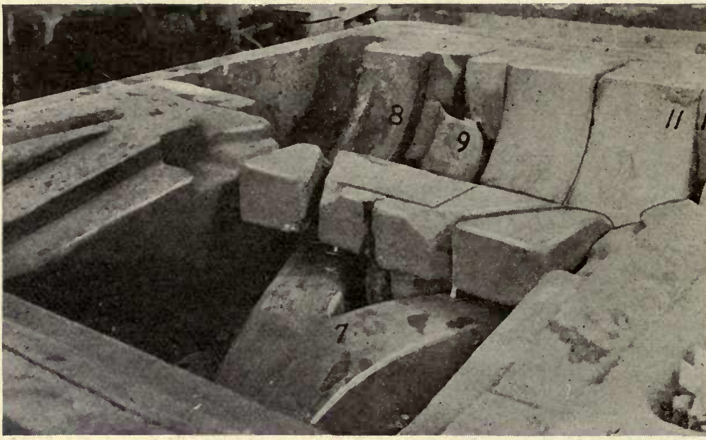


FIG. 119.—CHEEK PART OF THE MOLD, SHOWING Y-SHAPED EXHAUST CORE AT 7.

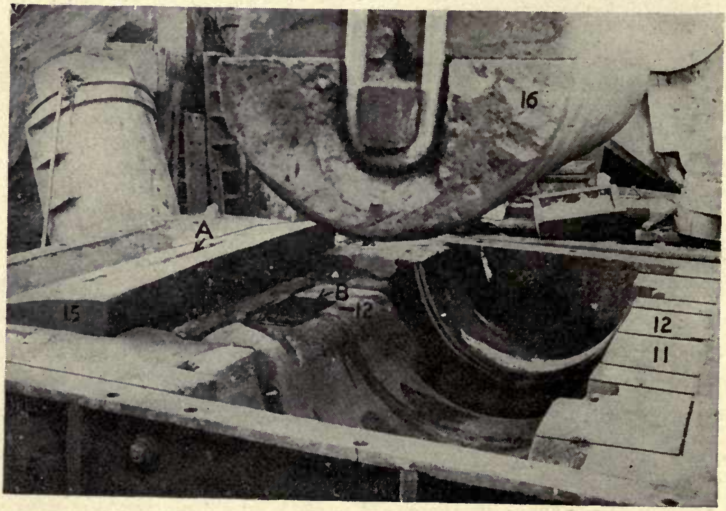


FIG. 120.—LOWERING THE MAIN BARREL CORE INTO THE MOLD.

side of the cheek shown at *13*, Fig. 118, and in another flask in the background, at *14*. These by-pass valve cores are passed through opening *10*, Fig. 116, and meet in the center of the mold at *B*, Fig. 112. Great skill is required in setting these cores, since the port cores are very light. The square opening in the flask through which these cores are passed, is covered with a plate and a rope extends through it to provide an outlet for the gas. The opening back of the

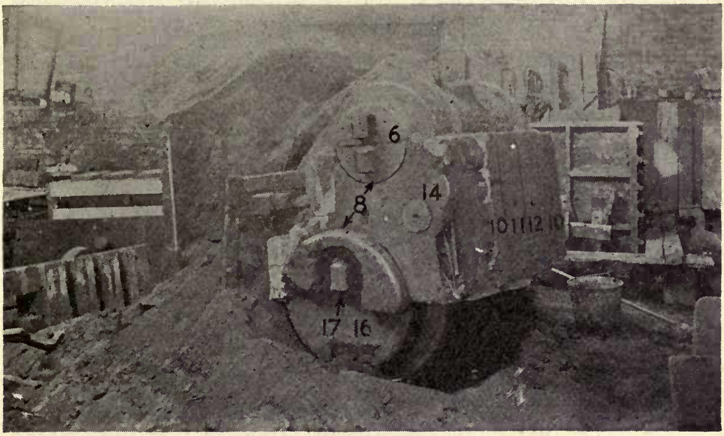


FIG. 121.—CYLINDER CASTING AS SHAKEN-OUT.

core *A*, Fig. 116, then is filled and cores *15*, Fig. 118, forming notches in the flange *B*, Fig. 108, are pasted in place. Wherever possible, all joints between the cores are filled and nearly all the cores are pasted in. The drying of the mold is completed by the use of an oil torch.

The core forming the inside of the cylinder, *15*, Figs. 113 and 120, and which cores out the openings *A* and *B*, Fig. 110, then is set in place. The vent from core *2*, Fig. 113, is brought up through this core and the gas from both escape at *A*, Fig. 120, through the cope. The plate *B*, Fig. 120, contacts with a chaplet extending through the cope and holds down core *12* at this end of the mold. In Fig. 120, the main barrel core, *16*, is being lowered into the mold. After this core is set in position, the joint is prepared and the cope is tried on. The joint then is given its final preparation and the cope is closed and clamped.

Great care must be exercised to prevent the main barrel core of the cylinder from bearing on the port cores. If

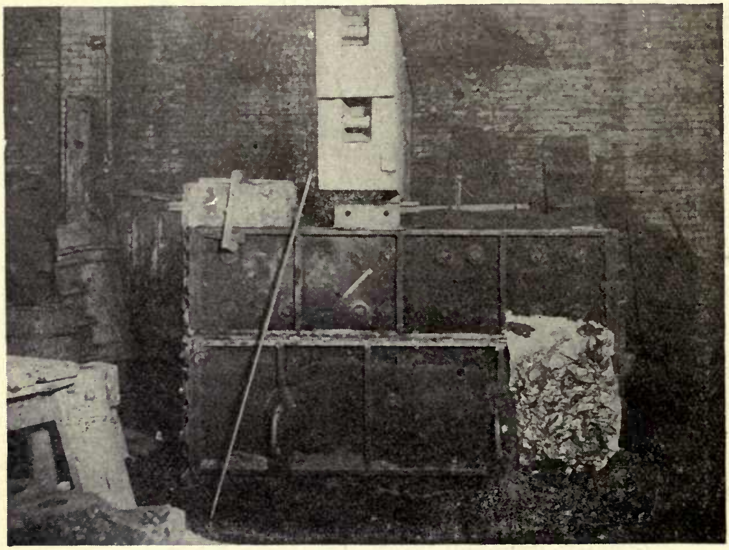


FIG. 122.—CYLINDER MOLD WEIGHTED FOR POURING.

the barrel core contacts with the port cores at any point, they are liable to be cracked when the cope is secured. To avoid the possibility of this occurrence, I prefer to have the port and barrel cores separated by $\frac{3}{32}$ inch. Also, the cope should not rest on the barrel core within 2 inches of the core iron *17*, Fig. 121. After the mold is clamped, the openings left at the ends of the main barrel core are rammed up and two heavy weights are placed across the cope, *17*, Fig. 113, to hold down the chaplets. The mold, weighted for pouring, is shown in Fig. 122, and in Fig. 121 the casting has just been shaken-out. In this view a large number of the adhering cores are illustrated.

SUPERHEATER AND SLIDE VALVE LOCOMOTIVE CYLINDERS

	Tests.			
	Bar No. 1.	Bar No. 2.	Another Bar No. 1.	Another Bar No. 2.
Phosphorus	0.36	0.38	0.384	0.380
Manganese	.56	.54	.50	.49
Sulphur	.89	.091	.096	.089
Silicon	1.58	1.66	1.40	1.33
Transverse strength, lb.	3300	3500	3400	3500
Deflection	.13	.14	.110	.125

Mixture of iron: Thomas 500, Crozier 500, Charcoal 500, Steel, 200 to a charge. Wgt. of cyl., 7300 pounds.

	Tests.			
	Bar No. 1.	Bar No. 2.	Another Bar No. 1.	Another Bar No. 2.
Phosphorus	0.518	0.550	0.408	0.408
Manganese	.56	.62	.49	.49
Sulphur	.081	.096	.110	.103
Silicon	1.93	1.74	1.59	1.47
Transverse strength, lb.	3500	4200	3700	3800
Deflection	.125	.120	.135	.135

Thomas 500, Warwickshire 540, Charcoal 400, Steel 150, as returned from laboratory.

Molding Printing-Press Cylinders in Dry Sand

Printing-press cylinders are molded in dry-sand molds and afford an interesting illustration of the use of sectional flasks. The flasks are of iron, circular, and as many are used superimposed upon one another as are necessary to give a flask of the requisite height. This class of work is interesting in that the same pattern may be used for cylinders of different lengths, the pattern being made of sufficient length to answer for the longest casting required. On account of the height of the completed mold in this class of work, it is usually convenient to make the mold in the pit in which the mold is poured.

The pattern used is shown in Fig. 123 and the completed mold with the cores in place is shown in Fig. 124. The sections of the flask are short cylinders with a flange at the top and bottom, accurately machined so that when the various sections are set one on the other, the mold will stand true and vertical. A lip *B*, Fig. 124, is cast on the interior of each section to retain the sand which is rammed in the flask. Each section is provided with a pair of trunnions *C* set in a boss *D* which is pinned to the flask with loose pins. Provision is made for bolting the various sections of the flask together at the flanges and holes are drilled in the circumference to act as vents to the mold.

Referring now to Fig. 123, the operation of commencing a mold is shown. An iron bottom-board *G* is bolted to the first section of the flask and is placed on a solid bearing in the pit. Heap sand is shoveled into the bottom of the flask and when this is at the proper height, facing sand is rammed over it and the bottom end of the pattern is bedded into it. The facing sand used is a mixture of old and new sand mixed in the proportions of one part old sand, one part fire sand, and one part coarse molding sand. With this is mixed flour in the proportion of one part flour and fourteen parts sand mixture. This is wet down with molasses water.

When the lower part of the flask is rammed full, a second section is placed on the first and as there is but little space between the pattern and the edge of the flask, it is rammed full with facing sand. A joint is made at the top of this section and the operation repeated until four of these parts are rammed up, when a parting is made. The remaining sections are then placed and rammed up as before until the last section is reached. In this section a shrink head is formed by cutting the sand back to the line *H*, Fig. 124. The pattern is drawn and the mold finished, and, if of large size, is blacked before being placed in the oven to bake.

In making cylinders up to sixteen inches diameter not more than two sections of the flask are rammed up together, and in case of the smaller sizes, but one, before partings are made as they are finished, blacked and the cores set more easily.

The core box for making the cores used in this mold is shown in Fig. 125. The core projects on one side as shown at *A* in order to cut a slot in the casting. The hub and arms of the cylinder are at the bottom of the core box. Three gate-sticks are set as shown between the arms in order to provide vents. These must be accurately placed as, when the cores are set in the mold, one above the other, these vents must form one continuous channel from top to bottom of the built-up core. Rods are set down through the core to strengthen it and three staples are inserted between the arms, for use in handling the core when it is placed. The first core to be set in the mold is made by ramming the box full of core sand and striking it off level with the top. A plate is clamped on top, the core box is rolled over, the clamps removed, and the box rapped. What is now the top of the core box is pinned to the sides. The pins are removed and the top lifted off. The sides of the box are split at *B*, being held together with clamps *C*. These are knocked off and the sides removed. The gate-sticks forming the vents are drawn and the core is left on the plate to be finished, blacked, and dried in the oven. In making the sections of the core above the first one, the upper part of the hub is formed in the bottom of the core as it sets in the mold, by using section *E*, Fig. 126, in the top of the core box before it is rolled over on the plate. The hub formed is filled with black sand which is removed after the core is baked and the space left by it is blacked.

The mold having been baked, the first section of the flask is placed in the pouring pit, resting on the binder as shown in Fig. 124, and is carefully leveled. The first section of core is set in this drag and is also leveled. This core is set in core-print at the bottom of Fig. 123, and is accurately centered. Around the vent holes and also around the vent in the center core, is placed a putty worm. The second section is placed on top of the first and the putty being soft is flattened out between the two cores and forms a dam which will prevent

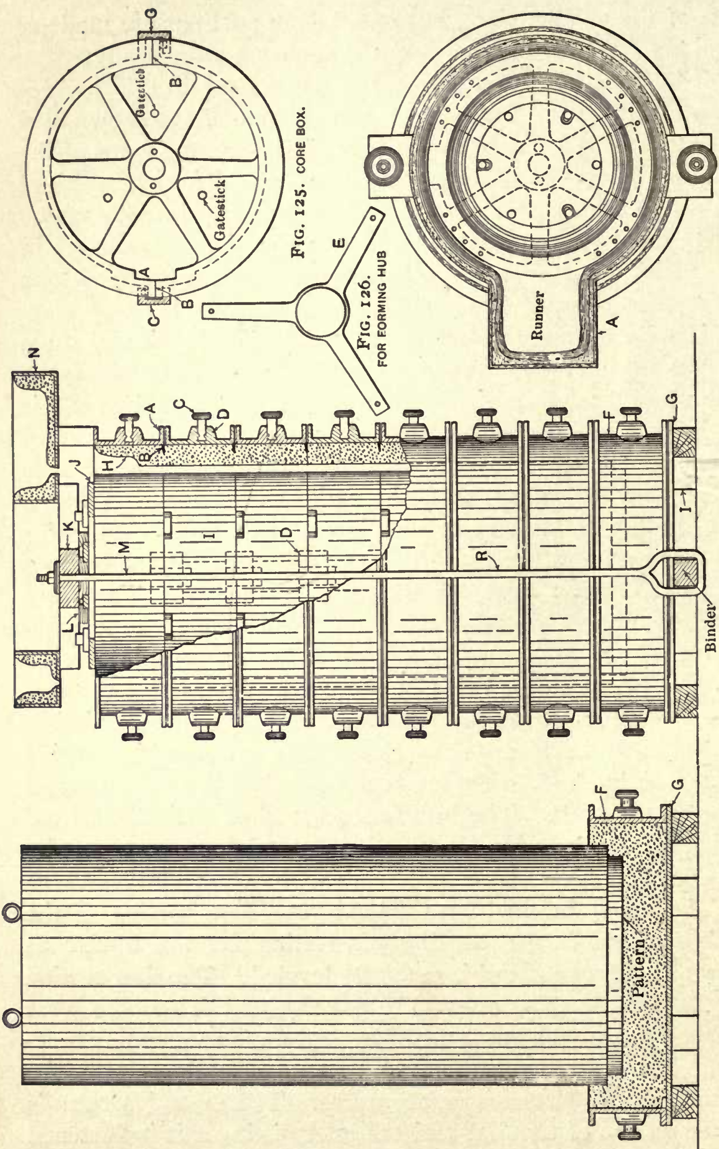


FIG. 125. CORE BOX.

FIG. 126. FOR FORMING HUB

FIG. 127. POURING BASIN IN PLACE.

FIG. 124. MOLD WITH CORES IN PLACE.

FIG. 123.

FIGS. 123–127.—MOLDING A PRINTING-PRESS CYLINDER.

iron working into the vents in the cores. Each succeeding core is set in this manner, being leveled as set. The cores being in place, the various sections of the mold are set around the core. On top of the cores is placed a clay worm and over this the plate *J*. Two blocks of wood are set on the edges of the flask, across which the top binder *K* is laid. This binder and that at the lower edge of the mold are held together by the stirrup *R*. Wedges driven between the upper binder and the plate *J* hold down the center cores. The runner *N* is set on top of the mold, this being of dry sand and set as shown. Gates in the bottom of this runner allow iron to flow into the mold all around its circumference. The mold itself is left open at the top, rendering it easy to observe when the mold is filled and to stop pouring at the proper time. This style of runner box is used for many different types of castings. It is one of the best methods of getting clean iron into the mold, as dirt in the iron tends always to rise to the surface. The iron from the runner flows from the bottom and therefore is the cleanest iron, the dirt remaining on the surface and adhering to the sides of the runner.

The hubs encased in the cores are the last parts of the casting to cool. For this reason the casting, if it is to cool evenly, must be left in the mold for a considerable period of time and when removed must be kept out of drafts until the casting has attained the temperature of the atmosphere, otherwise cracks may be found in various portions, particularly in the edges where the casting was stopped off by the projections on the core.

Fig. 128 shows a type cylinder with the cores set in sections as in the first cylinder. The hubs, however, are not tied together as in the first case owing to some peculiarity of manufacture. The pattern used is solid and, being of small diameter, the sections of the flask are rammed up one at a time, and parted at *A*, *B*, *C*, *D* and *E* for convenience in finishing, blacking, and setting the cores *F*. In closing the cores over the flask, the center cores are first set as before and sections of the mold closed around them. After the first section is in place, the remaining sections are closed two at a time, a certain amount of clearance being left between the cores in the sides of the mold and the center core. After the cores have been set and the flask completely closed, a gage is run down among the cores

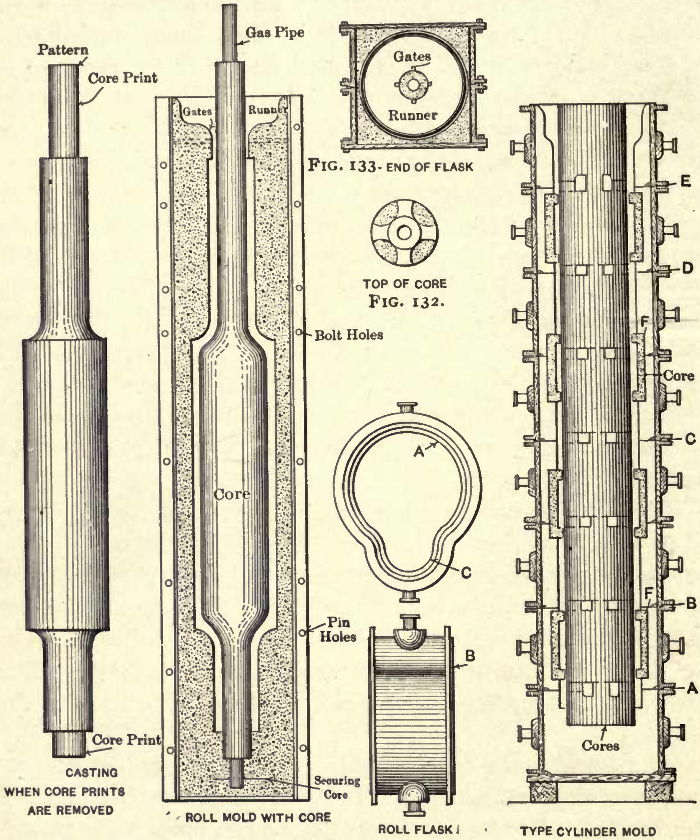


FIG. 129. FIG. 130. FIG. 131. FIG. 128.

FIGS. 128–133.—CASTING TYPE CYLINDERS AND ROLLS.

in the mold to insure that they are correctly placed. The mold is poured with the same kind of a runner as before and the same rules should be observed in pouring.

Another style of roll largely used is shown in Fig. 129, while adjoining it, Fig. 130, is the section of the mold for it with the core in place. The smaller sizes of these rolls are usually molded on their side in an iron flask, but when poured, the mold is set on end. Occasionally such molds are molded in green sands, but cleaner and sounder castings are obtained by the use of dry-sand molds in this work. The core shown is a loam core (see Chapter XI) and is fastened in the mold at the bottom by a rod passed through a hole in the gas-pipe forming the arbor on which the core is built, the rod being secured in the flask. The core thus has a chance to expand upward when heated by contact with the molten iron. After closing the mold, it is set upright and plumbed to insure its being truly vertical. The various details of runner, gates, etc., are shown in the illustration.

While many printing-press rolls are poured in the manner described above, that is, from the top, many rolls for different purposes are poured at the bottom. In this case, the flask Fig. 131 is used. This flask has a projection on the front in which a gate can be made, through which iron may be poured to enter the mold at the bottom. When the flask is plumbed, the iron, entering the mold at the bottom, rises around the core evenly, thus setting up no uneven strain on any side of the core. For molding solid rolls, square flasks are sometimes used, the gates being set in the corners of the flask and staggered somewhat in the various sections to prevent the iron having a straight drop the entire length of the mold. A sprue is cut from the gate in one flask section to that in the next to afford a continuous passageway for the iron. It is best to set a gate in the opposite corner to that down which the iron is poured and to allow this second gate to fill, since, when the roll is cooling, the side on which the gate is, through which the iron was poured, keeps that side of the roll the hottest and thereby often warps the roll in cooling, if but one gate has been used. By placing gates in opposite corners, both sides of the roll are kept equally hot and warping is avoided.

Many foundries use whirl gates in pouring solid rolls (see page 24) to force the dirt to the center of the casting, whence it will rise in a shrinkhead or riser. In making short rolls it is often more economical to make the mold in a core rather than in sand and to pour it on end. Thus a frame is made and the roll pattern molded in the frame to form a drag, and a second frame is used to form a cope. A pouring gate is arranged down the side and into the bottom of the mold together with a riser for churning. The second or cope frame is gaggered and rodded. The pattern is lifted with the top frame when it is removed, thus helping to hold the sand in place. If a core is to be used through the center, it is placed in the lower half and the top half closed on it. If the riser for churning is arranged to be one-half in each core forming the mold, it will be easy to see when the cores are properly matched. Planks or plates are clamped on each side of the core to hold the two halves together and it is placed in a hole dug in the floor and sand rammed around it.

Long rolls of small diameter with a shaft in them, are best poured in an inclined position, the iron entering at the bottom and covering the lower end of the shaft first. If bubbling or boiling occurs as the iron flows over the shaft, the bubble will follow along the shaft and enter a riser placed at its high corner, thereby insuring sound metal in the main casting. Such a shaft which is to be cast into a casting should be tinned in order to flux the iron on it. Instead of placing the mold in an inclined position for long rolls, some foundrymen favor the use of a large number of gates on the mold in order to fill it quickly with hot iron, claiming thereby to obtain a sounder casting with the core held more easily in the center, the iron covering it quickly and burning it more nearly alike at all points and exerting an even pressure under the core. Light rolls for leather and cotton machinery are often poured in this manner and good results obtained.

CHAPTER XI

LOAM MOLDING

Many of the larger and heavier castings are made in what are known as loam molds, as this class of mold is usually swept up and requires less pattern work than any other class of mold. A loam mold consists essentially of a brick backing built up on cast-iron plates, the surface of the bricks being covered with loam which is swept to the proper size and shape to form the finished mold. The loam is baked on the bricks after the mold has been finished. Castings weighing many tons are poured in this type of mold and include engine cylinders, fly-wheels, and similar heavy castings.

In making a loam mold, certain equipment is necessary and, in order that the student may understand the making of this equipment, we will assume that for the mold which we are about to consider there is none of it immediately available and that it is necessary to make it in the foundry before actual molding is begun. We will discuss the making of the mold shown in Figs. 135 to 138, which is for a large cylinder. Before commencing operations, the entire construction of the mold must be planned in advance, and provision made for tearing away and breaking down certain portions of the mold as soon as poured in order to allow the casting to shrink while cooling. Green-sand molds will crush under the shrinkage of a casting, but a loam mold, being stiffened with brickwork and iron plates, will not yield and the casting will thereby be ruptured in shrinking unless the mold is broken down sufficiently to permit shrinkage.

The cylindrical casting which we are to consider is seven feet diameter and six feet long. It is provided with flanges extending five inches from the walls of the cylinder, each flange two and three-quarters inches thick. The walls of the cylinder are two and one-quarter inches thick. As there is no equipment at hand for the making of this mold in loam, it is necessary for the molder to provide himself with a *spindle seat, bricks, sweeps, sweep fingers, carrying plates*, etc. A sketch has been provided showing the size and shape of the casting.

A rough pattern of the spindle seat, Fig. 143, is made and a casting taken therefrom. The spindle, to which the sweeps are to be fastened, is formed of a piece of cold-rolled shafting, two and three-eighths inches diameter, one end of which is tapered for a length of one foot down to one and three-eighths inches diameter. A number of collars, fitted with set screws, are made to fit snugly on the spindle. As the spindle is a tall one, it is advisable to make provision for supporting it at the top by braces to the wall as shown in Fig. 136. The *spindle* may be made either to revolve in the seat or to be fixed. In the latter case, the sweeps are held at the proper height on the spindle by collars set-screwed to the shaft below them. The brace is so constructed that it may be swung up out of the way when not in use, or to permit the lowering over the spindle of a collar. The bracing is so arranged that the spindle cannot move in any direction.

The brace for the top of the spindle is lowered into position and stayed in place with ropes and blocking. The spindle seat is molded in the floor directly under the center of the collar on the brace, its position being determined by a plumb line, a fire brick being placed under the center of the hub.

A finger pattern for the sweep finger *B* has been made and castings from it finished and bored out to the size of the spindle. One of these fingers is placed on the spindle, which is then set in the spindle-seat mold with the end resting on the fire brick. The tapered end of the spindle having previously been blackened, slack iron is poured into the mold, which is poured open. After the seat casting has set, it is covered with sand and left until the next morning, when a plank is bolted to the sweep finger and the spindle turned in the seat. Later, when the seat has cooled, the spindle is removed and the seat is properly set in the sand for beginning molding operations.

Before the mold proper can be constructed, the plates on which the mold is to be built, and which in some cases are to form portions of the mold, must be cast. The first plate to be made is the bottom or drag plate. A sand heap is leveled under one of the cranes and a bed made on it. A block of

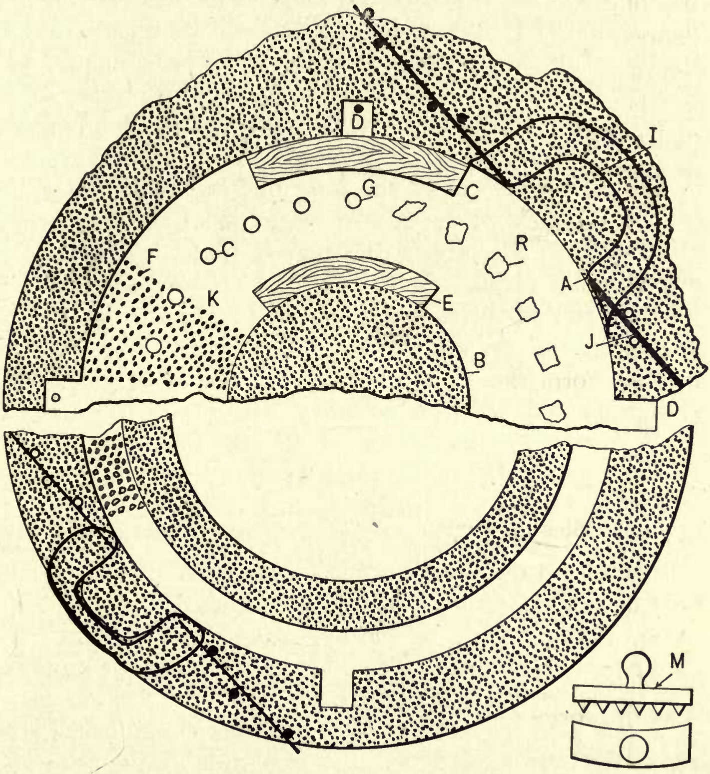


Fig. 134.—Molding the Drag Plate and Carrying Plate.

wood is bedded at the center and with a pair of trammels two circles *A* and *B*, Fig. 134, representing respectively the outside and inside diameter of the plate, are traced on the face of the bed. A piece of plank *C*, of somewhat greater thickness than the plate, has one edge formed to a section of the outer circle, and a similar plank *E* is cut to form a section of the inner circle. These two pieces of plank are successively moved around the circumference of the circle traced in the sand, and sand is rammed up against them and struck off flush with the top of the plank. We thus have formed in the sand bed a depression of the same size and shape as the desired drag plate, but of somewhat greater depth. As the plate must be handled by the crane it is necessary to cast on it four lugs *D*, which quarter the circle. These lugs are formed by placing a block of wood of the desired size and shape against the segment *C* at the proper points on the circle and ramming sand around it. A flow-off gate is cut in the sand forming the exterior circle around the mold at the desired height above the bottom of the mold to form the proper thickness of plate, in this case two and one-half inches. When the mold is poured, any excess iron will run off through this gate and maintain the thickness of the plate at the desired point. Dry-sand cores are placed to form holes in each of the four lugs *D* and weighted down. A pouring basin *I* is formed and a screen built to protect the molders from the heat when pouring the mold. The heat in this case will be intense as there will be a considerable number of square feet of iron radiating heat at 2,300 deg. F. The screen is formed by rods *J* driven in the sand, against which are placed bottom-boards or iron plates held in place by other rods driven in front of them. It is advisable to construct a second pouring basin on the opposite side of the mold from the first and pour into it a small ladle of iron at the same time that the larger basin is poured.

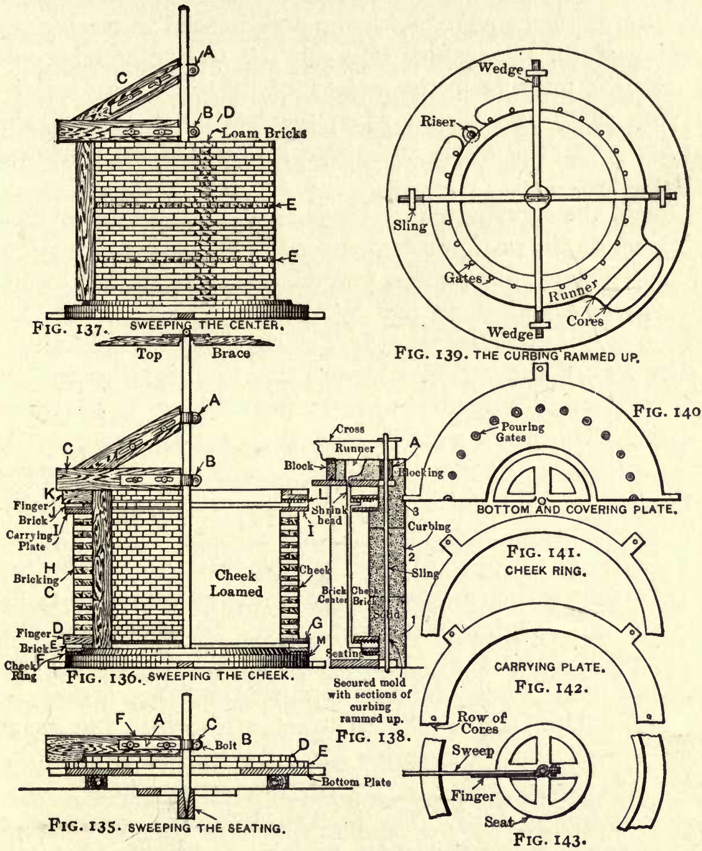
A *cope plate* is also to be made, which is similar in shape and size to the bottom plate, with the exception that pouring gates must be provided through which the cylinder mold is poured. The cope-plate mold is made in the same manner as was the bottom plate, but, after the sand has been built up around the outside and inside circles, a third circle is struck in the sand to locate the pouring gates. On this circle cores *C*, Fig. 134, of one inch greater diameter than the pouring gates are set. Some foundrymen prefer instead of cores to use pieces of coke as *H*, claiming it makes a rough hole which will hold the loam around the pouring gates better than the core. As the under side of the cope plate must be faced with loam, teeth must be cast on this face to hold the loam when it is swept on. These teeth are formed by the print *M*, consisting of a block of wood with the teeth formed on it, the face of the mold being printed all over with this block, as shown at *K*. The finished cope ring is shown in Fig. 140.

The cheek ring and carrying plates, Figs. 141 and 142, are molded and cast in the same manner as the cope plate, teeth being made in the under side to hold the loam. The carrying plates, simply being required to support the overhang of the flange of the cylinder, are made only five-eighths inch thick. After molding the carrying plates, a number of small cores are set across the plates so as to form a weak spot at either side enabling the plate to be easily broken at the proper time. The uses of these various plates will be explained as they are reached in the construction of the mold. The brick used for backing the mold are common red brick, the softer brick being preferred as they are more porous and will hold the loam better than the harder brick.

The loam mixture to be used consists of New Jersev fire sand, a sand of light yellowish color, of coarse texture nearly approaching gravel, and having a fairly high fusing point, a coarse molding sand, white pine sawdust and for bond dried and ground Jersey fire clay of high plasticity. These are mixed in the proportions: four parts fire sand, one part molding sand, one part fire clay, and one part sawdust wet with water. The sawdust is used to make a porous open mixture which will permit the easy escape of gases when the mold is poured. This loam is thoroughly mixed with a hoe and wet until it is of the proper consistency for easy handling in the mold.

The various plates having been made, the spindle seat is set in the floor and the spindle plumbed in it. The spindle is then removed and the bottom plate lowered over the seat, being permitted to rest on timbers as shown in Fig. 135. The spindle is then replaced and a finger *A* bolted to it and the plate leveled by means of the sweep, which has been previously leveled by means of a spirit-level. The molder next places a brick on the plate and raises the sweep *C* to a sufficient height to permit the brick to be laid in mortar on the bottom plate and to provide room for the loam which is to be swept on the brick. The mortar used is formed of sand and clay wet to the consistency of mortar. Bricks are now laid on the bottom plate to form the seating as shown in Fig. 135, being kept five-eighths of an inch below the edge of the sweep. After the seating has been built the bricks are covered with the loam mixture and trued off with the sweep. The sweep is cleaned off and the loam allowed to set, after which it is given a coating of *slip* consisting of four parts of molding sand and one part of fire sand wet with molasses water. The slip closes the pores of the coarse sand and gives a smooth surface to the mold. It is allowed to dry after which it is blackened. The seating is made with a slight slant at *D* to provide clearance at the parting of the cheek. The seating is sometimes dried by bolting an arm to the spindle and hanging from it a fire basket which is swung around over the seating, or at other times by means of an oil burner when compressed air is available. If there is plenty of time, the seating may be allowed to air-dry until hard enough to carry its load, the molder meantime sweeping loam on the carrying plates. In drying the seating by means of heat, it should be remembered that molding sand and molasses water mixtures will burn very quickly and care must be exercised.

After the seating is dry, it is covered with oiled newspapers in lieu of parting sand in a green-sand mold, the spindle having first been removed. Instead of the newspapers powdered charcoal mixed with water is sometimes used. The faces *D* and *E* of the seating are covered with loam, after which the cheek plate *F*, Fig. 136, is lowered, pricker side down, on the seating and loam is tucked between the seating and the plate on the line *D*, Fig. 135, and the plate leveled. The spindle is then replaced and a second finger *A*, Fig. 136, is attached to it, sweep *C* then being bolted to fingers *A* and *B*. Attached to sweep *C* are a number of loose fingers which are removed as the work progresses. This sweep as a whole forms the inside of the cheek, which in turn forms the outside of the casting.



Figs. 135–143.—Molding a Cylinder in Loam.

It is carefully plumbed in order to insure the casting being of the same diameter at the top and bottom.

Referring now to Fig. 136, at the lower end of the sweep is finger *D* to form the circle for the outside of the lower flange. Bricks *E* are bedded in the mud on cheek ring *F*, being set low enough to permit loam to be laid between their upper surface and the finger *D*, and by swinging the sweep around the circle the outside circumference of the flange is formed. The bricks are loamed and built up to the level of the top of the flange. The loam is then covered with slip and finished to receive the carrying plate, after which it is allowed to dry and become set, since it must bear the weight of the brickwork on the carrying plate and if soft when the brickwork is built the carrying plate will settle and thereby decrease the thickness of the flange.

One of the carrying plates having previously been covered with loam on the pricker side, is baked in the core oven. After the loam is hard, this plate is lowered on top of the brickwork of the mold already built and centered from the spindle. Its position is shown at *G*, Fig. 136. The cheek is next bricked up, as shown at *H*, the various courses being tied together and set back far enough from the sweep to permit loam to be swept on later. The brick work is carried to a point where it is necessary to set the carrying plate *I*, which is to carry the portion of the mold which overhangs the vertical brickwork *H*. This plate is set in loam mud, pricker side up, and the brickwork is continued upward on it to the thickness of the top flange. Loam is then swept on top of the brick on the carrying plate and on the brick around the flange. Some molders will, at this point, loam the entire face of the brickwork already built, but usually only the part forming the flange is done at this time. The loam is allowed to set, after which the finger *K* is removed and the carrying plate *L* which is to form the top of the upper flange is placed, having previously been loamed as was plate *G*. The brickwork is then continued a short distance above this plate to form a shrinkhead, being kept back a short distance in order to give a shrinkhead of greater thickness than the casting. The interior face of the brickwork is now cleaned off and the surface loamed, the brick being dampened if necessary. Loaming is performed by the molder throwing loam against the surface by the handful and truing it off with the sweep. It is evident that the loam must be worked to a proper consistency, for if too stiff it will not adhere to the brick and if too soft it will sag. After truing, the loam surface is coated with slip, usually by brushing it on with a molder's soft brush, after which the slip is floated off with the sweep. Sweep and spindle are now removed and the loam and slip allowed to set, after which blacking is applied to the entire surface with a swab, and slicked off with a trowel, being finally finished with a camel's-hair brush and molasses water.

By means of the cross, shown in Fig. 139, which is attached to the crane, the cheek is lifted off, parting from the seating at *M* and *N*. Slings from the four extremities of the cross are passed under the four lugs on the cheek plate, the slings being kept as close to the outside as possible. The cheek is then lowered on the carriage of the core oven, and, as the loam on the under side of the cheek ring is not dry, the ring is blocked up under the lugs. The cheek is then placed in the core oven and baked hard.

The spindle is now replaced and the center built. When constructing the center it should be borne in mind that the casting will shrink about one-eighth inch per foot, or in the present case, where the circumference of the casting is about twenty-two feet, two and three-quarter inches. Provision must therefore be made for the brickwork to crush as this shrinkage takes place, otherwise the casting will be ruptured. There is therefore provided a number of loam bricks, that is bricks formed of the loam mixture used in the mold, and a vertical row of these is built into the center. The fingers *A* and *B*, Fig. 137, being replaced on the spindle, the sweep *C* is bolted to them and plumbed, the inner edge being set the required distance from the center to give the desired inside diameter of the casting.

The location of the loam bricks is shown at *D* in Fig. 137. Oftentimes when strength is desired in the cheek a double thickness of brick is used, in which case but a single thickness may be used in the center. The cheek is required to resist an outward bursting pressure in pouring and a stronger construction than for the center is necessary for it. Both cheek and center must be built so that they will be rigid while the mold is being poured, but the center must be so constructed that it will give when the casting has set and is contracting.

After bricking up, the center is loamed and finished as was the cheek. It is then dried either in the core oven or by means of a fire basket or an oil flame. The covering or cope plate is then prepared by sweeping loam on the pricker side, after which a circle is described in the loam to mark the location of the pouring gates, which were filled with loam when the plate was prepared. While the mold is drying, the curbing, consisting of sheets of boiler plate formed in a circle, is prepared. These circles are made in halves and for the mold under consideration three are required. If the mold is to be poured in a pit, however, no curbing is necessary. The diameter of the curbing is such that it will completely encircle the mold outside of the lugs on the various plates.

The center being dried, it is placed level on a sand bed either on the floor or in a pit as desired and the cheek ring lowered over it to its place on the seating. Before removing the cheek from the seating for drying, notches were cut in both the cheek ring and bottom plate to locate them with reference to each other, and in replacing the cheek these notches are matched so that in the assembled mold the various parts have the same relation to each other that they had when first built. The covering plate is then set, being located in its proper position by measurement and by looking through the pouring gates. Sometimes a seating is swept in the cheek to locate the cover plate, but in a mold of the kind under consideration this is usually unnecessary. The cross is now set on the cover plate as shown in Fig. 139 resting on blocking, on either side of the pouring gates as shown in Fig. 138. A curb of boiler iron is set against the inner set of blocks, after which slings are passed over the ends of the cross and under the lugs on the bottom plate and wedged up, thus tying the mold together. Wads of cotton waste are inserted in the gate holes to prevent any dirt from falling into the mold and the first section of curbing *I* is set. Sand is rammed between this curbing and the brickwork, a compressed-air rammer being used, if it is available. The ramming should be done uniformly, preferably by a number of men all around the mold, so that the brickwork will not be strained unevenly. After the sand has been rammed a short distance above the first carrying plate, straw is laid against the brickwork and sand rammed around it, the straw forming a vent. The second curb is rammed as was the first, but when the third and upper curb is placed considerable care must be exercised in ramming sand under the overhang and up to the top of the covering plate. The wads of waste are removed from the pouring gates and gate-sticks are inserted. The overhang is vented with a vent-wire and the vents adjoining the curb are brought, by means of cinders or straw, to a point where a gate-stick may be rammed in the sand to form a vent from the cinders or straw, after which sand is rammed to the top of the curbing and the runner built as shown in Fig. 139. A riser may be formed through one of the gate holes as shown, but usually castings of this character are poured without a riser, as it is easy to tell when the mold is full by the action of the iron in the runner.

The casting being poured, the iron in the runner is broken as soon as it has set and steps are immediately taken to provide for the shrinkage of the casting. The two top sections of curbing are unbolted and taken apart. At the same time another workman with a long chisel is cutting through the strips of loam brick built into the center so that the latter may crush as the casting contracts. As soon as the curbing is removed, the wedges holding down the cross are knocked out and the slings removed from it. The sand is cleared from under the overhanging plate forming the upper flange of the casting, and with chisel-pointed bars the bricks are pried out from under this plate at the points where the rows of small cores were set when it was made in order to provide a weak spot where the plate could be easily broken. The plate is broken with a sledge and the two halves pulled out from the mold or a course of brick is removed from under the plate. which enables the casting to contract in a vertical direction without danger of breaking off the upper flange. These same plates may be used in a second similar mold if desired, by bolting them together across the break, or by sweeping them up separately in the mold.

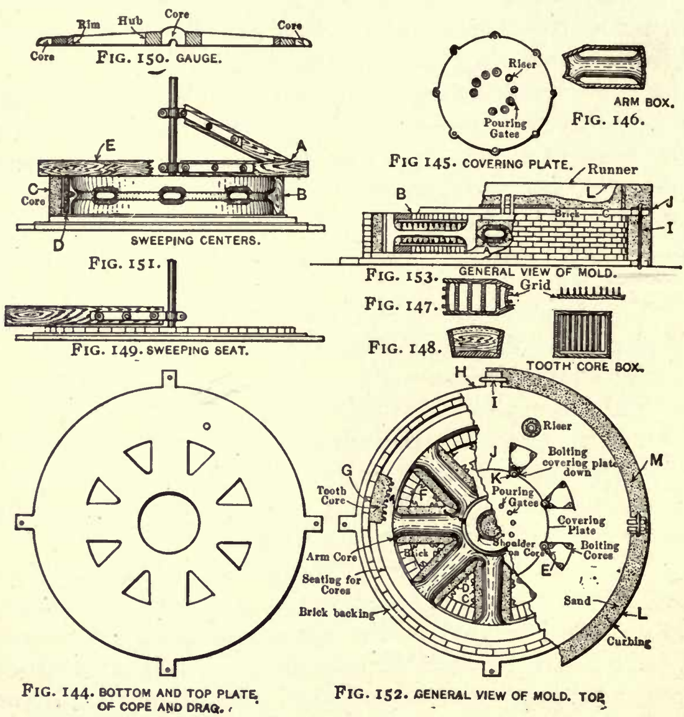
In loam molds of this character, plates of different shapes are cast and loamed and then used to carry overhanging parts where the flanges or other overhang is too wide to be carried by bricks. Cores also are often used for the same purpose, especially where it is necessary to cut the mold away to permit shrinkage of the casting. Loam work is sometimes considered expensive, but in many cases castings can be made in loam much more cheaply than in green or dry sand when the cost of pattern work, flasks, and necessary rigging is considered. Where a great many castings are made in loam the work is necessarily done much more cheaply than in foundries where loam work is of comparatively infrequent occurrence.

In molding certain classes of castings in loam a skeleton is often furnished with some solid parts attached to it, patterns being furnished for these parts. A portion of the mold may be swept and a portion bricked up against solid parts of the pattern. Thus the barrel of a steam cylinder may be swept and the steam and exhaust chests formed by solid patterns, the brickwork being carried against these parts. In this case the steam and exhaust chests will be tied together at the top and bottom by the flanges of the cylinder and by the wrist-plate stand and any parts formed on the barrel of the cylinder. The seating is swept and the parts that are to form the lower end of the cylinder are bricked and loamed, after which the pattern parts are set and the cheek plate arranged on the seating as in the mold previously described. The cheek is bricked up and the pattern being well greased or oiled, the rounding portion of the cylinder is built up to it, after which loam is placed against the pattern. Bricks are then dipped in water, rubbed in the loam, and laid against the loam on the pattern, and loam mud grouted in between the various bricks. The sides of the cylinder are continued upward and, to strengthen the brickwork, iron plates are built in at intervals. The outside ends are built last, as they have to be removed to allow the setting of the chest cores. After the cheek is built it is hoisted off and the center built as in the first mold considered. Instead of patterns, skeletons, which are guides on which sweeps are used to form the faces desired, may be bricked in.

In casting large fly-wheels for engines, if there are many to be made, the wheel may be hoisted out of the mold, leaving a bricked-up rim in good shape for a second pouring, only the loam face requiring repairs. If the loam is so injured that it is not possible to repair it, it is carefully removed, the face of the brick cleaned with a wire brush and dampened, and the proper thickness of loam swept on. Thus the time of bricking up is saved. While it was formerly customary to make the face of large pulleys in loam, they are now often made in green sand or with cores.

Figs. 144–152 show the method of constructing the centers of loam molds for heavy balance wheels and heavy gears. The bottom plate is shown in Fig. 144, the cope plate being similar, with the exception that cored holes are provided for risers. The cover plate for the hub and arm core box are shown in Figs. 145 and 146 respectively. Fig. 147 shows grids which are used to strengthen the arm core, while Fig. 148 illustrates a core box for forming the gear teeth.

The method of sweeping the seating is illustrated in Fig. 149. If the lower part of the hub is to be formed by means of a core, this is placed at the center and bedded down with a spindle rising through the core-print. If it is to be swept up in loam this operation is performed when the seating is swept. After the seating has set, the gage, Fig. 150, is used to set the sweep *A*, Fig. 151, by which the center is formed. The brick-work is swept to the proper height and the cores *A* and *B*, Fig. 153, which form the arms are placed. They are kept back a sufficient distance to allow the sweep to pass them. The corners are usually rubbed off to permit the loam to adhere later. The brickwork, Fig. 152, *F*, is built in between the arm cores, being set so that a coating of loam can be swept over the face. As the tops of the cores are reached, they are bricked over, the bricks being laid in a mixture of loam mud with quite open joints. When loaming the bricks they should not be dry and better results will be obtained if the bricks are rubbed with loam before they are laid. After loaming, a coating of slip is brushed on, after which the face of the mold is blackened



FIGS. 144–153.—MOLDING A FLY-WHEEL IN LOAM.

and the whole center thoroughly dried. While drying the center, the covering plates should be loamed and the cores for forming the teeth made.

Before proceeding further, let us examine the arm cores, which are shown at *B* in Fig. 153. These are made with grids to stiffen them, and in many cases the grids are provided with ears which project beyond the edge of the core. When the two halves of the core are dry they are bolted together by means of these ears, thus forming a pipe through which the metal flows from the hub, where it is poured, to the rim.

The center being dried is replaced as shown in Fig. 151, the portion *B* of the sweep being removed and replaced with the piece *D*. The inner edges of the tooth cores are set against this piece as it is revolved around the spindle. As it is extremely important that the center be replaced after drying in the exact position in which it was made, guides must be provided to insure its being returned to this position. It is better to dry the center in place, even if it is inconvenient, rather than to remove it and dry it in the oven. The tooth cores being in place, a wall of brickwork is built up back of them and dried out sufficiently hard to support the covering plate, which is placed as shown in Figs. 152 and 153, and is held in place by stirrups or slings *I* wedged in place. The center core is set in the core-print, the under side being covered with paste to prevent iron working under it. The hub plate covering the center of the mold is arranged with holes for pouring gates and risers and, after loaming, is set. This is provided with a beveled edge which guides it to place in a beveled seating swept in the mold. It is covered with paste where it bears on the center core. After bolting this plate in place as shown, gate-sticks are placed, the curbing set, and sand rammed between it and the mold. The runner is then made as shown at *L* and iron balls, each provided with a handle, are placed over each gate. In pouring the runner is filled with iron, after which these balls are lifted and the iron permitted to flow into the mold from the bottom of the pool in the runner. As dirt will rise to the surface of the iron, this practice insures that only clean iron will enter the mold.

After the mold has been poured and the iron set, usually the next day, the center covering plate should be removed and the core dug out. The brickwork should then be removed from between the arm cores, although these will crush sufficiently to prevent breaking of the arms as the casting shrinks in cooling.

When building brickwork for loam molds in which a large amount of metal is to be poured, the brickwork is built solidly around the mold with cinders laid in between the bricks to provide vents. It is necessary to have a solid structure to resist the pressure of the metal and this would be impossible were the bricks to be laid with rather open joints as is done in smaller molds. It is also necessary, however, that the mold be thoroughly vented and this is accomplished by the cinders which are laid in between two layers of loam mortar between each course of brick. In building the cheek of a loam mold it is advisable to lay whole brick on the outside and small pieces on the inside against the loam, thus providing a large number of joints close to the mold to act as vents. Conversely, in building the center the small pieces of brick should be laid on the outside and the whole brick on the inside of the center.

Loam molds are especially susceptible to *buckles* and *scabs*. A scab is formed by a portion of the loam scaling from the face of the mold, leaving a cavity which forms a rough irregular projection on the casting. The loam which scales off frequently lodges against some other portion of the mold and thus forms a cavity in the casting. The cause of this scaling is usually the failure to properly clean the face of the brick before loam is applied. It is also frequently caused by the use of brick which have been used for a considerable period and have become burned hard. The loam adheres with difficulty to the glazed surface thus formed. Another cause of scaling, especially over flanges, is the failure of the molder to properly dry out the deep bed of loam, steam thus being generated when the casting is poured which forces the loam from the face of the mold in escaping. A buckle is formed by steam being generated as above, but not in sufficient quantity to rupture the loam. It may, however, expand and force the loam outward a short distance from the surface of the mold and thus make a depression in the casting.

MOLDING A LARGE KETTLE, MAKING THE DRAG, AND COPE PARTS AT THE SAME TIME

Large quantities of these kettles are used and heavy expense has been incurred for a rigging to produce them quickly and economically.

In molding these kettles one molder and helper are making the drag, while another molder and helper are making the cope, and the cope can be closed on the drag and mold made ready for pouring very quickly.

For making the cope a cemented pit is formed, the size inside corresponding with size of the inside of the kettle as Fig 154, *A*.

The core oven carriage has a spindle seat in its frame, Fig. 155, *A*.

A grid, Fig. 154, *B*, having prickers on its face, and vent holes in it, is placed on the core oven carriage, and coated with a loam mixture, Fig. 155, *B*, and sweep, Fig. 155, *C*, used to form it to the desired size.

The spindle is removed and the hole left by the spindle is plugged and loamed over and the grid dried in the oven.

This grid is then placed in the bottom of the cement or concrete pit, Fig. 154, *B*, Fig. 155, *B*, and loam is placed against the sides, and the bricks are forced into the loam, Fig. 154, *A*. This operation continues until Fig. 154, *B*, is reached; a row of loam brick, Fig. 154, *R* to *S*, is built in the brick work, then a cast-iron plate is bedded in the loam on top of the brick work, Fig. 154, *C*.

The cope, Fig. 154, *D*, is placed and wedges, Fig. 154, *E*, are placed between bars in the bottom of the cope and plate *C*, Fig. 156, Fig. 154, *C*.

The pop gates and pouring basin, Fig. 154, *F*, are built in the cope, as the cope is filled and rammed.

The cross binder, Fig. 156, *H*, is placed on top of the cope with the rods, Fig. 154, *H* and *I*, hanging in it.

Fig. 157, as a whole, shows the top of cope. *C* plate, *E* wedges, *F* bars of cope, *G* cross binder, *I* bolts.

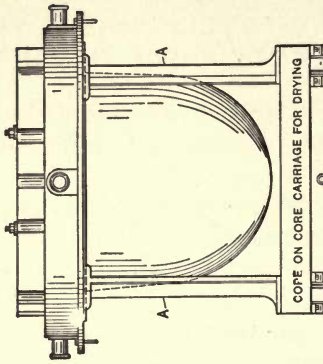


FIG. 158. COPE ON CORE CARRIAGE FOR DRYING

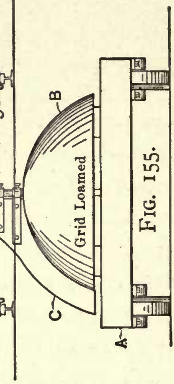


FIG. 155. SWEEPING LOWER PART OF COPE OR LOAM AN GRID

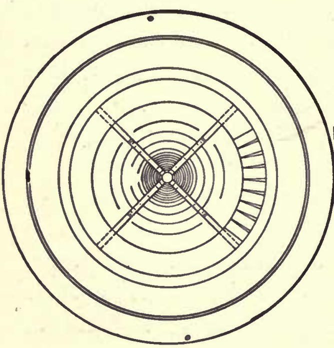


FIG. 159. LOOKING DOWN IN CEMENT OR CONCRETE FORM FOR MOULDING COPE

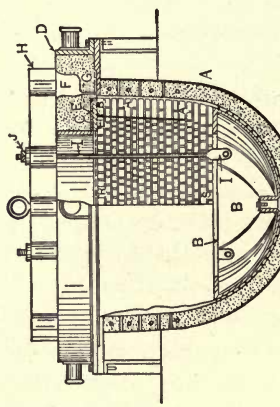


FIG. 154. SIDE VIEW OF CONCRETE FORM IN WHICH COPE IS FORMED

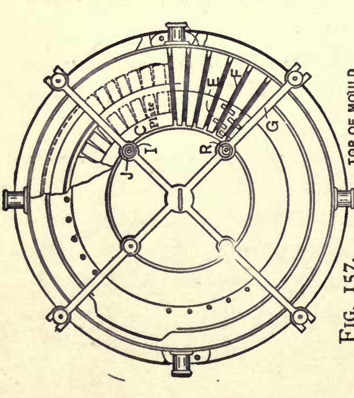


FIG. 157. TOP OF MOULD

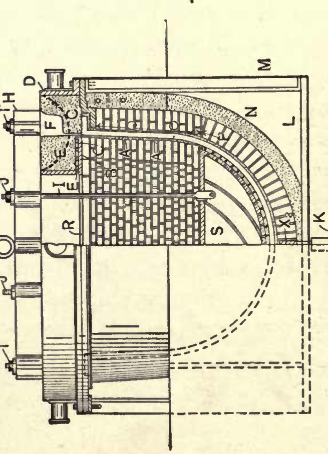


FIG. 156. SIDE OF MOULD ¼ SHOWS CROSS-SECTION

MOULDING COPE AND DRAG AT THE SAME TIME

At the lower end the bolts divide and straddle the ribs of the grid. There are holes in each side, matching the holes in rib of the grid so a large pin is pushed through holes. The nuts at Fig. 154, *J*, are tightened and the cope is lifted with center of kettle hanging to it. This is lowered on to supports on a core oven carriage, Fig. 158, *A*, and the cope is dried in the oven.

While the molder and helper have been making the cope, a second molder and helper have been loaming the drag. In Fig. 156 we have spindle seat *K*, foundation plate *L*, ties between foundation plate and plate forming the joint of drag *M*, concrete flask or drag *N*, with holes through the sides for vent to escape, common soft brick *O*, cast-iron brick *P* to *P*, and on the ends of the cast-iron brick, next the casting, there are projections for holding the loam to the brick.

As soon after a casting is taken from the mold as a molder can work, he gets into the mold or drag and removes the loam, and goes to work putting on fresh loam, and sweeps it to shape. The spindle is removed and plug, Fig. 156, *X*, dropped in place and loamed over.

Some molds requiring only patching when castings of this type are made in loam.

One can judge from the following something of what a molder must be able to withstand. There is usually so much heat in the brick that it will dry or bake the loam, and one can see he must work very quickly or his loam will stiffen too fast.

The cope and drag being ready, the cope is lowered on the drag and bolted down, and is ready for pouring.

After pouring, the loam bricks are cut down, Fig. 156, *R* to *S*, the nuts, Fig. 156, *J* and *T*, removed, and runner broken up while hot, and removed. The cross hoisted off, and the cope.

When the runner, Fig. 156, *F*, is broken up, some of the pop gates might hold against the shrinkage, and give trouble. To avoid this, the cope is lifted and swung to one side and plate *C* removed. The casting is covered with sand. As the bottom is rounding, it will raise the center *with grid*.

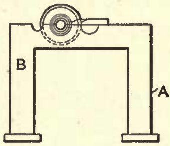
Loam Mixtures

It is practically impossible to lay down any fixed rules for the mixing of loam, as requirements for different classes of work vary greatly, as do the qualities of the material obtainable in different parts of the country. However, the following mixtures used by the writer have given satisfaction:—

1. One part coarse Jersey molding sand
   Two parts coarse Jersey fire sand
   One part white pine sawdust mixed with seven parts of the above mixture. Mix with a thick clay wash formed of clay of high plasticity.
2. Four parts fire sand
   One part Jersey molding sand
   One part ground clay
   One part white pine sawdust
   Wet with water, mix well, and allow to stand for two days, after which it should be again mixed before using.
3. Mixture for a ten-ton cylinder mold.
   One part Jersey molding sand
   Four parts Jersey fire sand
   One part of rye meal to twenty parts of the sand mixture wet with sour beer.
4. Mixture for a three-ton cylinder mold.
   One part Millville (New Jersey) gravel
   One part coarse molding sand
   Mix with water.
5. Mixture for slip.
   Four parts coarse molding sand
   One part fire sand
   Wet with molasses water and pass through a fine riddle.

Sweeping Loam Cores

The illustration Fig. 160 shows how a loam core may be swept up on a gas-pipe *arbor*, being built around a *hay rope* center. This core is one that vents easily and the gas escapes freely from one end to the other. A horse A B with semicircular notches in the upper surface is used as shown. A gas-pipe arbor is placed in corresponding notches at either end of the horse, a crank being set-screwed to one end of the arbor. Numerous holes are bored at intervals in the gas-pipe to allow the escape of gases from the core to the interior of the pipe. Hay rope which may be either twisted by the molder or purchased from a foundry supply house is wound on the arbor, a thin cast-iron plate *F* being set at the middle point of the arbor to prevent the hay rope being forced up toward the end of the core by the pressure of the iron when the mold is poured. The hay rope is wound firmly on the arbor, but without sufficient strain to break it, to approximately the shape of the



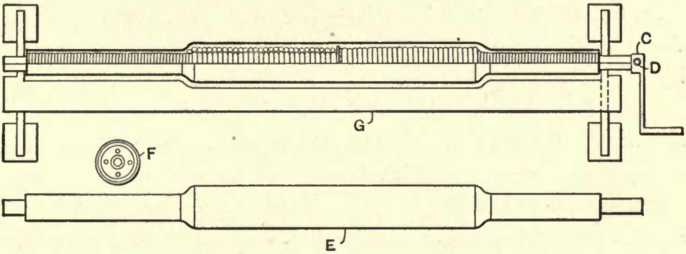


FIG. 160.—SWEEPING A LOAM CORE.

finished core *E*. After the rope has been wound on, coarse, clayey loam is rubbed well into the rope, a good way being to revolve the arbor and with a round piece of iron rub the loam into the rope. After this is done, loam should be applied thickly to the core and swept off to the proper size and shape by revolving the core against the sweep or strike *G*, which has a beveled edge and is used with the beveled side up. The core is then dried, after which it is replaced on the horse and once more revolved, this time a brick being rubbed lightly on its face in order to roughen it for the coat of slip which is swept on the surface. The core is then blackened and dried once more in the oven. The same mixtures of loam and slip are used in these loam cores as in loam molds described above.

CHAPTER XII

MOLDS FOR STEEL CASTINGS

THE subject of steel castings requires an entire book in itself, as it involves not only questions of molding but also those of steel melting and making, including open-hearth furnace and Bessemer converter practice. The author proposes in this book to treat only of the problems of making molds for steel castings and for further information regarding the entire subject the reader is referred to the excellent work, "Open Hearth Steel Castings," [1] by W. M. Carr, and also to the splendid papers, "Converter *vs.* Small Open Hearth," [2] by the same author.

Steel is a more difficult metal to cast than iron as the shrinkage is greater, being about one-quarter inch per foot as compared to one-eighth inch per foot for cast-iron. It also has a shorter period of fluidity and expels a greater quantity of gas. Molds for steel castings are made in much the same manner as for iron castings of similar size and shape. Two principal differences are noted, however, the first being the quality of the sand used, and the second the number and size of shrink-heads and risers.

Molds for steel castings are made of a mixture of silica sand and silica clay, a highly refractory mixture. This is necessary as the temperature of the molten steel ranges from 2,900 to 3,000 degrees Fahr. Molding sand of this character requires the addition of a certain amount of bonding material to cause it to hold together while the mold is being made, finished, and baked. Silica clay is used for this purpose, being added to the sand after drying and grinding. After mixing together the mass is wet with molasses water and tempered.

[1] The Penton Publishing Co., Cleveland.

[2] *The Foundry*, Nov. and Dec., 1907, Jan., 1908.

Mr. Carr, in "Open Hearth Steel Castings," gives the following typical analysis of a molding sand for steel castings:

Silica	98.5 %
Alumina	1.40%
Iron oxide	0.06%
Lime	0.20%
Magnesia	0.16%
Combined water	0.14%
Alkalies	0.25%

The color is often white or slightly tinged with yellow. Color is not necessarily a guide to the quality of molding sand but is an indication. In the same work is given a typical composition of fire clay for use with the above sand:

Silica	60	to 66 %
Alumina	25	to 20 %
Iron oxide	0	to 2 %
Lime	0	to 1 %
Magnesia	0	to 1 %
Alkalies	0	to 2 %
Combined water	7.50	to 10.50%

Mr. Carr also says, "The value of fire clay depends largely upon a low content of alkalies and a freedom from carbonates of lime. Oxide of iron has a strong fluxing effect, but its presence below three per cent is harmless." In a certain steel works, the face of the molds for steel castings is made from the following mixture:

Silica fire clay	One part
Crushed silica rock	Five parts
Silica sand	Eleven parts

Dampen with molasses water.

This mixture is used for molding castings for heavy miter gears and other castings weighing up to 1,500 pounds. For smaller castings the same facing mixture is used, but is adulterated with burned sand from the heat.

The mold for a steel casting is rammed up and the pattern drawn in the usual manner. Flat surfaces, however, if of any considerable extent, are nailed after finishing by pushing shingle nails into the surface, leaving the heads flush with the face of the mold. The nails will prevent the face of the mold from being scabbed or cut by the fluid steel washing over it when the mold is filling. A coating of ground quartz, ground to the fineness of flour and mixed with molasses water, is applied to the face of the mold with a swab or a soft brush. The mold should then be placed in an oven and baked. After baking the molds are closed and clamped for pouring in the usual fashion, excepting that the steel, instead of being poured over the lip of the ladle as is the case with iron castings, is poured through a gate in the bottom of the ladle, thus preventing the slag floating on top of the steel from entering the mold, and giving a cleaner and sounder casting.

On account of the great shrinkage of steel in cooling from the liquid to the solid state, risers of liberal proportions must be provided over all the relatively massive portions of the casting, to act as reservoirs of steel to supply the casting with liquid metal as it shrinks in the mold. Should these not be of ample size and quantity, cavities will result in the finished casting.

Molds for steel castings must also be made with provisions for crushing wherever pockets are formed in the casting in order to take care of the great shrinkage. The baked mold of silica sand is an extremely rigid structure, which will offer great resistance to crushing, and unless provision is made to relieve this rigidity as the casting cools, it will crack the casting at the corners of the pockets, or if the casting is heavy enough to prevent cracking, undesirable shrinkage strains will be set up in it which will have a weakening effect. It is therefore advisable to construct in the pocket of sand a pocket of cinders which may be formed by placing a box in the center of the sand pocket which is withdrawn after the mold has been rammed and the cavity filled with cinders, after which the mold is completed. Provision, of course, must be made for venting this pocket by one of the methods previously described. With this construction the sand will be crushed into the cinder pocket, as the casting cools, and thus prevent all strains on the latter. Another method of providing for shrinkage is to construct the mold so that certain portions of it will break down easily, as the casting cools and contracts. The more porous that either mold or core can be made for a steel casting and yet resist the action and pressure of the molten metal, the easier the gas can escape and also the easier will the mold crush and thus prevent shrinkage strains and afford sound castings.

Another feature which must be borne in mind in making steel castings is that when one part of a casting is light, and another part adjoining it relatively heavy, the light part will draw metal from the heavier part as the former shrinks in cooling. Provision must be made by means of an ample shrinkhead to make up the deficiency of metal in the heavy part, caused by this action.

In making cores for steel castings it should also be borne in mind that while the same binder may be used for a core for a steel casting as for an iron one, the sand used must have a much higher fusing point for steel than for iron. While the sand which will give satisfactory results to the iron casting may be strong enough to resist the heat of the steel so far as the shape of the casting is concerned, yet it may fuse and adhere to the casting, making it difficult to remove from the interior of the cored surface. Cores for steel castings are rodded and vented the same as for iron castings.

CHAPTER XIII

DRY-SAND CORES

CAVITIES in castings are formed by *cores* which are made either of green sand, as described in previous chapters on molding, or of dry sand, mixed with a binder and baked in an oven to render them hard and to fix their shape. Cores are usually made in a *core box* of wood or metal, the interior of which is hollowed to the shape of the exterior of the core. As considerable gas is generated when the cores are surrounded with hot metal in pouring the mold, they must be well vented to permit the escape of this gas. The cores are set in the mold, their location being determined by *core-prints* on the pattern. The iron entering the mold fills it and flowing around the cores is formed in the desired shape with cavities or hollow places the exact shape of the cores. Typical dry-sand cores are shown in Fig. 161, and Fig. 162 shows the core box for making core No. 12 together with the method of inserting rods in the core for strengthening it. We will later in this chapter discuss the various operations of core making, but we will now consider the various mixtures from which cores are made. In the various parts of the country, the core sands used vary as regards their chemical analyses and range from a very fine sand to a coarse gravel. For very small cores, coarse molding sand may be wet with molasses water, but core sand, as the term is generally understood, is a very different material from ordinary molding sand. In the first place, molding sand has bond and cohesion while core sand has none. For making small cores, a sharp, angular-grained sand is preferred, although a round-grained sand with high permeability and a large amount of porosity will give good results if a good binder is used to hold it together. The fine sand used in small cores will withstand the heat of the metal in small castings, but, under the influence of the greater amount of heat, continued for a considerable period in larger castings, the fine sand will be burned and the core crumbled. Thus in core making, as in molding, coarser sand must be used as the casting increases in size, the coarser sands usually having greater resistance to fusion. Another reason for the use of coarser sands with large castings, is that a greater amount of gas is generated from the larger body of metal and more provision must be made for its escape. The larger sands, being more porous, furnish this provision.

Inasmuch as good core sand has no bond whatever, and water added to it would not cause it, after baking, to retain a shape to which it might be molded, it is necessary to add to the sand some material to act as a binder. The binder not only will hold the core sand in shape during and after molding, so that it may be removed from the core box and placed on an iron plate for baking, but, under the influence of heat, will bind the separate grains of sand together in a firm, hard mass, which will preserve its form when set in the mold and resist the action of the hot metal. When the core is removed from the casting it should leave square corners, and hold in it the exact shape of the core when it was set in the mold.

There are a variety of core binders on the market, and there are others in common use in foundries, the principal ingredients being wheat flour, rye meal, powdered rosin, and linseed oil. Dry and liquid core binders must be obtained from foundry supply houses or from manufacturers. For a core which is to be made and set in the mold a short time before pouring, a mixture of New England hill sand and flour can be used, mixed in the proportions of one part flour to sixteen parts sand. This should be tempered with water and riddled through a No. 8 sieve to remove lumps. These cores will absorb dampness somewhat rapidly and, if the cores are to remain in the mold for any length of time, a mixture of eighteen parts sand to one part flour wet with a mixture of one part molasses and sixteen parts water must be used. This will produce a harder, firmer core than before, which will resist the dampness of the mold for a longer period.

If a core is desired which will resist moisture still longer, one part linseed oil to fifty parts sand, passed through a mixing machine, will give good results. By increasing the oil to one part in thirty-five still better results are obtained. Hill sand contains matter which is not found in lake or river sands and these last will absorb binder and produce cores with a smaller quantity than the hill sand. When tempering the sand for use, if it is made too damp the cores will swell and be ruined when baked in the oven. On the other hand, the core must be sufficiently wet with oil or molasses water to bake right. The degree of wetness necessary is impossible of description and can be learned only by experience.

For small cores for brass or composition castings, a fine sharp sand is necessary. For the cores in Fig. 161, fine New England hill sand, or lake sand of Pennsylvania may be used. New Jersey sands usually have a slight amount of bond and the finer sands require a smaller amount of binder than usual.

One part flour or rye meal added to sixteen parts of any of the above sands has been a common mixture for many years in all parts of the country. The amount of sand is increased or diminished as the cores increase or decrease in size. The sand is wet with a mixture of one part molasses and sixteen parts water, and after the cores are molded they are baked to a deep brown color.

Since the introduction of dry and liquid core binders, eighteen parts sharp core sand and eighteen parts old or burned core sand, mixed with one part of binder and wet with molasses water will give good results for large-size cores. For pump and small engine castings, a mixture of twenty-five parts sharp sand and twenty-five parts burned sand and one part linseed oil, thoroughly mixed in a mixing machine, will make excellent cores. For making a core for a large engine barrel, a mixture of four parts coarse New Jersey fire sand and two parts of coarse molding sand to which is added flour in the proportion of one part flour to twelve parts sand should be well riddled and wet with molasses water and thoroughly tempered.

A word regarding the qualities of the various sands will not be amiss at this point. The New England hill sand is large-grained quartzite. It resembles the lake sand largely, although hill sand contains a certain amount of alumina while lake sand is a clear wash sand. These sands may be largely used for small cores, but to withstand high heat for any length of time, they must be mixed with a refractory sand as ground silica rock or New Jersey fire sand. River sands are dredged from the bottoms of rivers. In the western part of New York is found a sand which resembles hill sand or river sand, but it is mixed with slate which fuses the sand and renders it hard to remove from castings. New Jersey sands differ from all other in being more refractory. They may be obtained in many different grades of fineness and are especially suited to large cores in heavy bodies of metal.

In regard to binders many experiments have been conducted to determine if a portion of the old core sand could be used, but it was found that flour and rye meal would not give satisfactory results when used as a binder in cores made partly of old sand.

It was found that a core binder having a pitch or tar body would permit the use of a large percentage of old core sand and thus effect a saving. In order that a core binder should be considered good, it must not only bind the core sand in the green state but bind it still better when baked, so that the cores will hold their corners and be blackened if necessary, in order that the core will stand the intense heat and separate easily from the casting when it is cool, especially in the corners and in other portions hard to reach.

For core-making machines, flour has proved an unsatisfactory binder as it gums the machine and the cores stick. It has been found that by using an oil binder the sand could be easily passed through the tube of the machine and satisfactory cores made.

In making a core of the simpler form, such as shown at 1, 2, 3, or 4, Fig. 161, a core box of wood or metal is tucked or rammed full of sand of the proper mixture and the sand leveled off flush with the top of the box. The box is then covered with an iron plate called a *core plate*, and rolled over so that the plate is underneath. The box is rapped to free it from the sand core and is then carefully lifted, leaving the core on the plate. Plate and core are then placed in an oven and baked.

The other cores shown in Fig. 161 are more complicated, although the general method of making them is the same. In

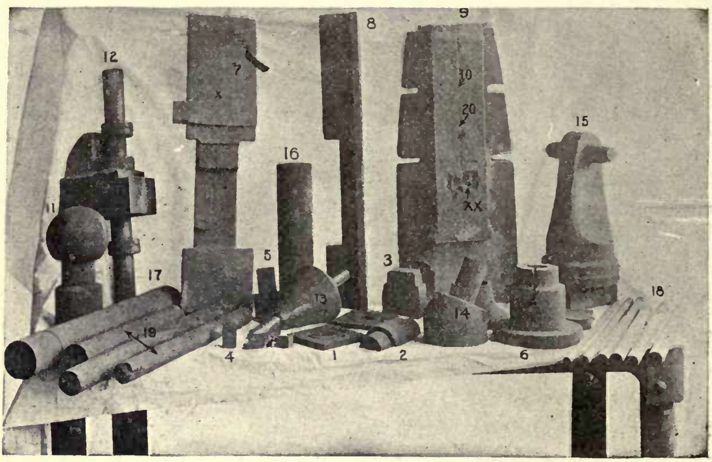


FIG. 161.—TYPICAL CORES.

order to form a core of the desired shape it is often necessary to make it in a number of pieces and afterward fasten these together by various means according to the size and character of the core. For instance, core 7 is made in halves, each half requiring a special box. After drying, the two halves are cemented together with paste, the joint between the two being the line X. The side view of this core is shown at 8.

As the sands and binder of which the cores are made, give off large quantities of gas when the molds are poured, great care must be exercised, especially with the larger cores, in providing ample vent channels for the escape of this gas. These channels are arranged to lead the gas from all parts of the core to a main vent whence they are conducted into vent channels in the sand forming the mold itself. If the cores are improperly vented the gases generated will be imprisoned and may burst the core with disastrous effects on the casting. Consider core 11. After the core box is filled with sand and rammed, it is slicked level with the top, and a channel is cut lengthwise in each half of the core. From this channel, holes are formed, leading to the deeper parts of the core to conduct the gases to this main vent. The two halves of the core are cemented together, the paste being laid entirely around the edge of one half with the exception of the space immediately over the end of the main vent. The paste must not be allowed to get into the vent and close it, or the gas will be imprisoned in the core. After the two halves are cemented together, a mixture of fine molding sand and molasses water, known in the foundry as *slurry*, is rubbed on the joint between the two halves in order to smooth it and avoid making a seam on the interior of the casting. This operation is known as *slurrying* the cores. Referring to the remaining cores shown in Fig. 161, cores Nos. 9, 11, 13, 14, and 15 are made in halves and afterward pasted together. Special attention is called to core 9 as it illustrates the practice adopted where it is impossible to bring the main vent out at the end of the core. This is often the case where iron is flowed over the ends of the cores and it is necessary to bring the vent to the most convenient point for the escape of gases. In the core under consideration, the main vent is brought out of the core at 20. The iron flows around the greater portion of the core. That portion on which the numbers are inscribed forms the print resting in the core-print on the mold. At *XX* are seen two staples through which wire may be threaded to hold the core in place when it is suspended from the cope.

While cores may be of any shape, the position they occupy in the mold may subject them to heavy strain and their proportions at times may be such that the heavier part must be supported by a light portion. Such a case is core 12. With a core of this character, rods are set in the core when it is made to strengthen it. The core box for this core is shown in Fig. 162 at *A*. At *B* is shown the opposite half of this core box partially filled with sand mixture, with the strengthening rods set in position to support the various parts of the core. These rods are covered either with claywash or paste, to make the sand adhere to them and bake hard on them. *C* is the completed

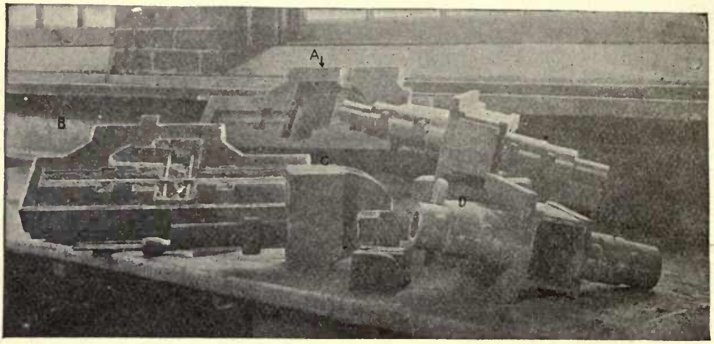


FIG. 162.—CORE BOX, SHOWING METHOD OF RODDING AND VENTING CORE.

core, being identical with that shown at 12, Fig. 161. At *D* is the finished casting showing the cavities formed by the cores *C*.

The size of the strengthening rods is increased with the size of the core, and with the larger sizes the rods will not suffice and resort must be had to grids or skeletons of cast-iron made to conform with the shape of the core. These are either used alone or in connection with rods. When making these grids, it should be borne in mind that iron shrinks one-eighth of an inch per foot when passing from the molten to the solid state, and in using heavy, strong grids in cores, these must not be allowed to approach close to the sides or ends of the cores, lest the iron in the casting in shrinking bind on the grid which tends to expand with the heat, and thus be cracked or broken. In making these grids, a bed of molding sand is usually made in the floor and the core box laid on the bed and its outline traced; after which the shape of grid necessary to fit the inside of the box is cut out of the sand. Grids for heavy engine castings, and the like, require patterns and in some foundries a special floor is reserved for the molding of grids.

In order to allow the larger sizes of cores to be compressed by the shrinking of the casting, pockets are formed of coke or cinders in the core which is made strong enough to resist the strains of pouring and yet sufficiently weak to compress with the shrinkage of the casting. These compression pockets also act as vents to carry gas from the core and often have vents from more distant parts led to them by means of wax tapers.

Wax tapers are made of a thread coated with wax or paraffine similar to a candle. They are laid in the core wherever desired and sand rammed around them. When the core is baked in the oven, the wax melts and is absorbed by the sand, leaving a hole in the core, through which the gas escapes from the surrounding sand. By the use of wax tapers, vents can be made in the core wherever desired with but little trouble and expense. Wax tapers are used in such cores as locomotive cylinder ports and others in which it would ordinarily be difficult to lead a vent around a corner. They are also used to a considerable extent in very thin cores and their use is becoming quite general.

Many cores do not require rodding. Among these are what are ordinarily termed stock cores, which are generally round and of different diameters. These are made up in quantities of varying length and are cut off to the length required. When used in a vertical position, they seldom require to be strengthened with rods; but when set horizontally, rods are required if the cores are of any length in order to prevent them breaking or springing when the mold is poured. When set in pulleys, it is usually best to rod the core as there is a considerable length exposed to iron.

Often cores of irregular shape, when made in quantities, are baked in what are known as core *dryers*. This is simply a cast-iron box of the same shape as the core in which the core is placed when it is removed from the core box, instead of being set on a core plate. The advantage of the core dryer is, that there is no possibility of the core losing its shape, while drying.

In recent years, the importance of mixing the different binders with the core sand has been appreciated, and mixing machinery has been generally introduced in the larger foundries. In these machines, oil is fed to the mixture automatically in the desired proportions, to give the best result. The importance of preparing the sand for use has long been recognized in foreign countries and much attention has been given to it.

Cores for gasoline and automobile cylinders, manifolds and jacketed pipes require more than average attention. Cores for large castings in general do not require the same attention given proportioning mixtures of sands, selection of sands and binders, proportioning of sands and binders that is required by some of this class.

Jacket cores for this class of castings are of thin cross-section, usually surrounded by comparatively thin walls of metal and the core must be rodded and vented properly to withstand the strain while the mold is filling with the molten metal. Channel ways and vents must be properly arranged for the gases generated inside the core when the hot metal is flowing around it to escape. The rods securing the core must be arranged so they can be easily removed from the casting when cool, and this last is not always easily done.

The quality of sand selected is usually the best and at the same time cheapest sand found in that locality by the smaller foundries. Thus Lake sand may be used, Hill sand, Beach sand, and ground silica rock. But all will agree that a clean washed sand is preferable. Core sands are treated extensively on pages 183–189.

Fig. 163 shows cores used in cylinders in style of engine shown in Fig. 164.

Fig. 163, *A*, and Fig. 165, *A*, Lower half of jacket core. The parts of jacket core are shown in Fig. 165, placed together

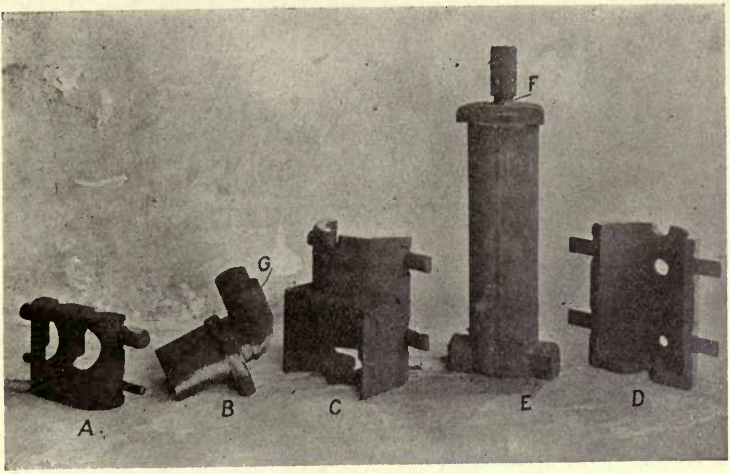


FIG. 163.

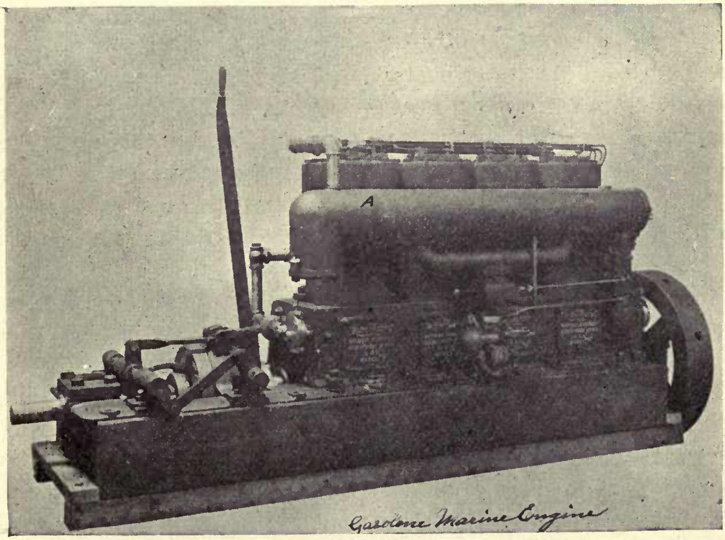


FIG. 164.—GASOLINE MARINE ENGINE. AUTOMATIC MACHINE COMPANY, BRIDGEPORT, CONN., U. S. A.

showing the whole jacket core, Fig. 165, *F*. The exhaust core is shown in Fig. 163, *B*; Fig. 165, *B*. The middle part of jacket is shown, Fig. 163, *C* Fig. 165, *C*, and the cope part Fig. 163, *D*, Fig. 165, *D*. The core forming the bore of cylinder or barrel is shown, Fig. 163, *E*, Fig. 165, *E*. –

The jacket core, Fig. 166, *F*, as shown assembled when placed in the mold is reversed. Part *A* being placed down in the mold.

In making the jacket cores, the wires strengthening the cores, Fig. 163 *A* and *D*, are brought into parts of cores extending on both sides. Thus, when cleaning the castings, the wires are pulled out of these holes in the sides of the casting, Fig. 166 at *A* and *B*.

For venting, wax tapers are used and the vent is brought through these side parts of core. The gas being brought out through holes in the lower part for the lower, and in the upper for the upper core. Thus when the parts are placed on top of each other, as Fig. 165, *F*, any iron finning in between the two halves does not get into the vents.

The rods coming into these side parts must also be strong enough to hold these cores down and take care of the upward strain on core while the mold is filling, as no chaplets are used to hold the jacket core down. In the center of Fig. 166 are seen two castings from the same pattern. Casting Fig. 166, 1 lying on its side, end towards us showing hole *C* formed by neck of barrel core, Fig. 163, *F*, also holes Fig. 166, *F* in casting 1, made by ends of core Fig. 163, *B*.

These cores are made of salt-water beach sand. One part core oil to forty-five sand mixed by hand. Were a regular sand mixer used, one to fifty would be as good.

Now for one of the most important operations, *baking the core*. In baking cores of this kind, they should be baked to a good mahogany brown. That is, to as near burning yet without burning as possible. A core that is baked so it is a white-livered core will throw out more gas than one baked to as near burning as possible without burning, and if it is slightly burned, but yet will stand up to the work, so much

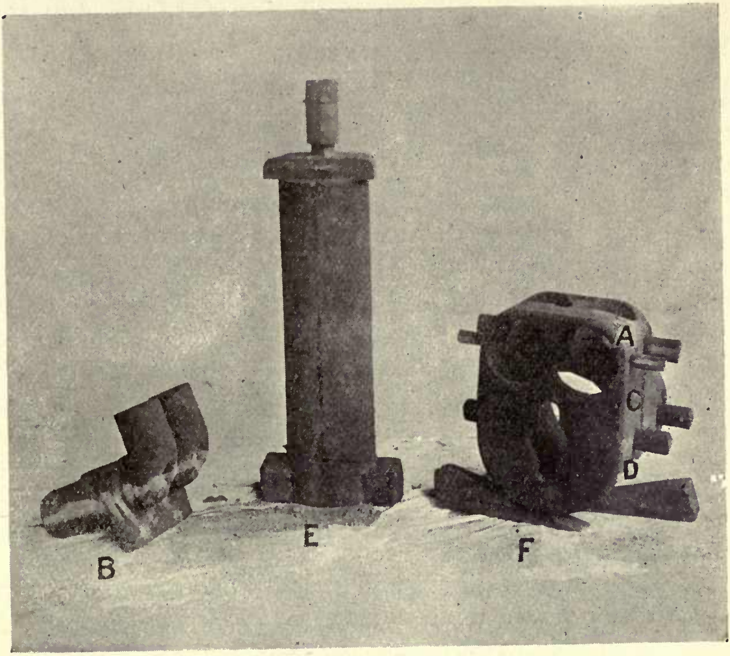


FIG. 165.

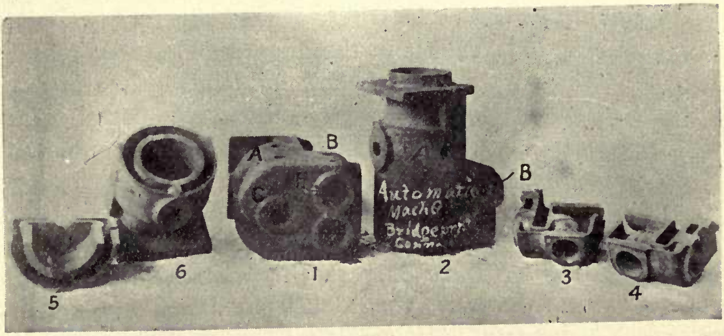


FIG. 166.

the better, as you have gotten rid of more of the elements that create gas and tend to produce an unsound casting.

I have known of many castings, as automobile cylinders, manifolds, and like castings, being defective through poorly baked cores in a large foundry.

A man high in authority in this plant told me, " We are losing a good many of the above castings through cores blowing and sand holes in castings." I had seen some of the cores they were using. Bake your cores before setting, not by pouring iron around them to obtain castings, and in these castings, you will have less blow holes as they, being of thin cross-section, require pouring with hot metal in order to run them. (Especially if your phos is too low.) The hot metal will take grains of sand from the cores and these grains collecting together form the sand hole. If the core is baked to a good hard brown crust, and then blown off with warm air, this trouble will be greatly lessened. Bake your cores! Don't dry them!

The pieces of casting 3 and 4, and 5 and 6, Fig. 166, are pieces of a cylinder, same as 1 and 2, which has been sawed apart to see the thickness of jacket and other parts. Fig. 166, 3 and 4, placed together with 5, form the end of cylinder 1, lying toward you, Fig. 166, 6 placed back of them, matched to them, and you have 1 as a whole, or if you choose to stand them up, 2.

In placing in the mold which is made in a three-parted flask, core Fig. 163, *A* is set in the drag and *B* is then set part *G* of *B*, passing down through hole in *A* into prints in drag. The cheek is closed on and core *C* is set. The barrel core *E* is then set, and last core *D*. Thus you have the whole of Fig. 165, *F* set in the mold with *B* and *E* passing through proper openings.

The pipe casting, Fig. 164, *A*, is also water-jacketed.

Closely allied to molding machines, are machines for making cores. In fact, the development of the molding machine, increasing as it did the output of foundries, demanded better facilities for furnishing cores in the quantities required than were possible with the ordinary hand equipment of the core room. The machines most commonly used are for the purpose of forming stock cores, and consist of a screw which forces the core mixture through a tube of the proper diameter to form the core. The length of the tube has a direct influence on the quality of the core, the hardness of the finished core being increased as the length of the tube is increased. Cores often come from the machine too hard for the purpose desired and the fault can be remedied by shortening the tube; the machines are also arranged to make triangular, octagonal, and elliptical cores with satisfactory results. The machines form a vent hole through the center and, if desired, insert a rod lengthwise of the core to strengthen it. The core comes from the machine perfectly straight and is delivered on a plate with grooves in it to keep the core in shape. Liquid core binders are generally used with machines and cores up to eight inches diameter can be made in certain types. The sand used is as a rule new sand, only a small amount of burnt core sand being added. This is mixed with oil in the proportions of forty or fifty parts of sand to one of oil.

The use of machines for making stock cores has enabled their length to be increased to about eighteen inches instead of twelve as formerly. It has also enabled more perfect cores to be secured. Formerly, round cores were made in half boxes and the halves pasted together. Now they are either made in whole boxes or by machine. Cores made in halves and pasted together are slightly elliptical in cross section and therefore not as good as the machine-made cores.

Cores, after molding, are baked in any one of the standard core ovens which are on the market. These ovens are heated by gas, oil, or coke, as may be most convenient. Core ovens for the larger-size cores are provided with tracks on which flat cars, or cars carrying racks on which the cores are placed, may be run into the oven for baking. In certain types of core oven, the door is in one piece and slides upward, being counterbalanced. In others it is in the form of a roller curtain. In the smaller types, the doors are hung on hinges.

The core ovens of the Dickson Car Wheel Co., Houston, Texas, represent good practice. The cores in dryers are placed on racks on a large carriage which is run into one of three ovens by means of a transfer table. The floor of the oven consists of iron plates, cast with two-inch holes in them. The fire box is located back in the oven below the level of the oven floor. Heat from the fire is drawn under the floor and passes up through holes in the plate as well as from plates into the core oven. About two hours and a half are required to dry a car load of cores.

The even distribution of heat in core ovens has been given considerable attention. Unevenly distributed heat causes considerable annoyance, to say nothing of giving poor results in baking cores. In many ovens it has been necessary to set the cores as high up in the oven as possible in order to dry them, and in handling large cores this has caused much trouble and loss of time. At the foundry of the Allis-Chalmers Co., the large ovens are fired at the back in a specially built fire box and the heat drawn through an opening in the back of the oven. Special flues are arranged to draw the heat to various parts of the oven as desired. Other designs include fire pots placed in the corner of the oven and lowered as close as possible to the floor. In still other ovens a series of flues are run under the floor and, in most of the larger ovens, flues are provided to carry off the steam from the core. These are closed at a certain stage and the heat confined to the oven.

While the greater number of cores used are made in more or less expensive boxes, or by machines, it is sometimes desirable to make a core as cheaply as possible, few being required. For such cases core boxes often are made separable at two diagonally opposite corners, and having no top or bottom, as shown in Fig. 167. In use the box is placed on a core plate, being held together by the core-maker and filled with core sand. After slicking off with the trowel, the box is removed, leaving the core on the plate.

Again cores known as "cake cores" or "cover cores" are called for, these being used as "covering cores." They are made in a box consisting of a frame, of the required size and depth on the inside, as Fig. 168. Sometimes these cores require rodding to strengthen them, and often they are made of a strong mixture, and kept on hand. If for covering the rim of a pulley and shaped as shown in Fig. 169, they are given a coat of blacking on one side, and the larger cores are vented from the opposite side. These cores are used blackened side down.

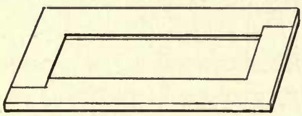


FIG. 167-CORE BOX FOR AN INEXPENSIVE CORE

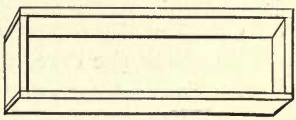


FIG. 168-CORE BOX FOR A COVER CORE

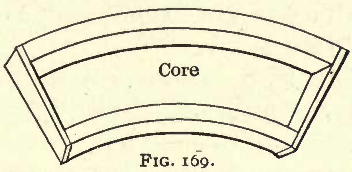


FIG. 169.
CORE BOX FOR A COVER CORE FOR A PULLEY

FIGS. 167–169.

Some cores are swept by means of guides and sweeps. Thus a cylinder core of considerable size may be swept in either of these ways.

Fig. 170 shows a barrel or center core made in this manner. The straight edge *A*, Fig. 171, is clamped to the core plate *B*, and the core arbor *D* is placed in position, being raised on the core plate one inch as seen at *C*, Fig. 174. Cinders or molding sand *E*, Fig. 171, are placed as shown and the core-sand mixture is rammed around the arbor until it is as high as the top of the arbor. Rods *F*, Fig. 171, are driven down alongside the arbor to hold the sand which is to hang below the arbor. Sometimes these arbors are cast with prongs extending below the backbone *O* of the core arbor to hold the hanging sand to the arbor, but arbors can also be used without them, and the sand can be held as above. Care should be used that the rods do not come high enough to interfere with the passing of the sweep over them when the core is swept. At times, if there is a large body of sand hanging, these rods are bent to a hook shape and used as a gagger *C*, Fig. 173, one end being hooked under the arm of the backbone, and the other end coming near the top of the core as it is swept forms an inverted gagger, so that the sand is held firmly to the arbor. False ends, cut from boards, shown at *A* and *B*, Fig. 173, are now set on edge on the ends of the arbor at *F* and *G*, Fig. 171, and the sand is rammed over the arbor between these ends. The sweep *A*, Fig. 172, is used to shape the core, the part *C* pressing against the inside edge *E* of straight-edge *D*, as the sweep is moved lengthways of the core. The core is well vented down to the cinders *E*, Fig. 171, the vent holes are filled, and core trued with the strike, and finished with the trowel. It is usually blacked while green and the blacking slicked.

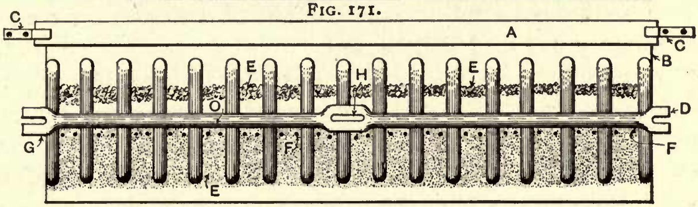
If the core is long, one or two gate-sticks are set over the hole *H*, Fig. 171, to form an opening. When the lower half is dried and rolled over, the top half is dried, after which the upper half is rubbed on the lower half and the core brought to size. If molding sand has been used to form the channels for the vent, it is now removed. The core, when found to caliper the right diameter, is pasted together, and the joint is slurried as were the smaller cores. In addition, a long core is bolted together in the center as well as at the ends.

The top half of the core is made exactly as the lower half was, but as it is not rolled over, there is no hanging sand, and no rodding is required. In rolling over the lower half of a large core, a bed of molding sand usually is made on the floor and the core rolled over on it. In doing so care must be exercised that the edge is not broken. If cinders are used for the vent, they are left as rammed up in the core as they form a porous mass through which the gas escapes easily.

When the core is bolted together in the center, the heads of the bolts are covered with the core-sand mixture, and in order to hold this sand in the hole formed, spikes are driven into the sides. These places are blackened over and the core

FIG. 170.

FIG. 171.



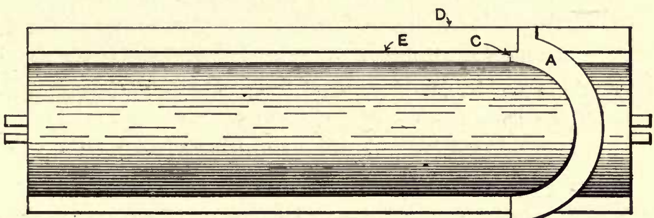


FIG. 172.

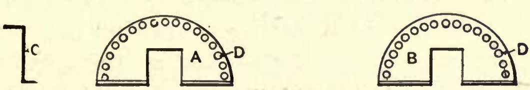


FIG. 173.

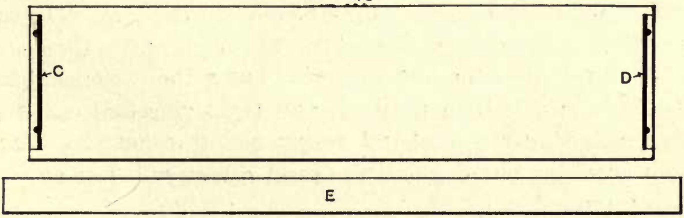


FIG. 175.

FIG. 174.

FIGS. 170–175.—SWEEPING CORES ON AN ARBOR.

placed in the oven to dry the paste and blacking. If the nole in the center of the halves is large, it is well to put cinders at the bottom of the core so that the gases will escape through them from this portion. When filling in the sand it should be vented down to the cinders; as, in order to have a sound, clean cylinder barrel, it is important that the center core be thoroughly dry and well vented.

Another method of venting a core is to have holes in the end pieces, as *D*, Fig. 173, and when the core sand is rammed high enough three-eighths inch rods are placed through these holes, extending about eight inches beyond the ends of the core. When the half of the core is finished the rods are withdrawn, leaving vent holes near the surface, but still so far down that the iron cannot enter them. In some foundries these ends, Fig. 173, are made of cast-iron and are arranged to be bolted to the core plate. When such is the case, the arbor *D*, Fig. 171, is claywashed and placed on the plate, and ends, Fig. 173, bolted to the plate. The ends *A* and *B* have slots to accommodate the arbor. The sand is rammed up to the proper height on the arbor, hook rods or gaggers being used as in the first case, or when the sand has been rammed high enough, straight rods may be driven down between the arms on the arbor. Rods to form vents are run through the holes in the ends *A* and *B*, these rods extending beyond the core. The sand is rammed above the ends over the vent-rods and is then swept off level by the sweep *E*, Fig. 175, using the ends as guides. The half core is then finished, and the strike laid down flat over each vent-rod, and rod drawn out, thus keeping the rod from breaking out through the sand sideways. The ends are then removed.

The finished half core is seen at *A*, Fig. 174, resting on the core plate *B*, with the core arbor *C* projecting from it. In order to hoist the core up with the plate, holes *D* are cored in the plate.

It will be seen in sweeping cores that by having a core plate arranged in this way, formed cores of different diameters may be swept by having the plate ends of proper size, and having the outline of the core wished made in the sweep or strike, at times called *strickles*, as shown at *A* and *B*, Fig. 176.

In many of the large foundries making steam-engine castings, it is the custom to sweep up the center or barrel core on

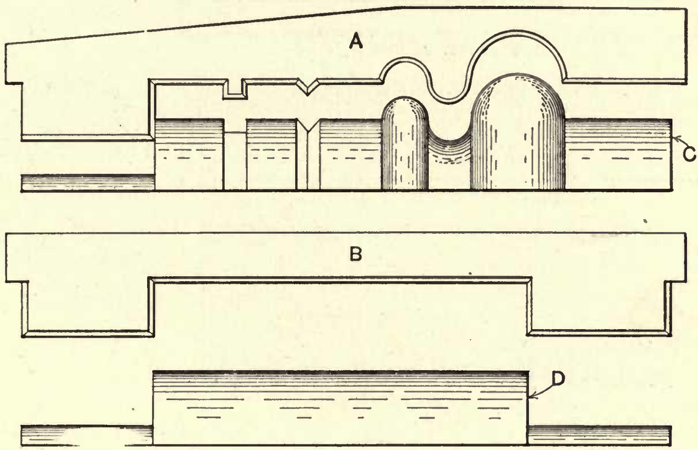


FIG. 176.—MAKING A FORMED CORE BY MEANS OF A STRICKLE.

large core barrels made of cast-iron, thus effecting a saving of core sand, labor, and time of drying. Some of these barrels are cast in halves, and when the two have been covered with the core-sand mixture and dried, they are bolted together. Fig. 178 shows one-half of the core barrel *A* resting on core plate *C*, with removable ends *B* bolted to the core plate. An end is shown, Fig. 179, and *D*, Fig. 180, with horns for holding the sand to the barrel, and between the horns are the holes through the barrel *E* for bringing the vent to the inside of the barrel. In use, the core barrel is first given a coating of claywash, and is placed on core plate *C*, Fig. 178, and the ends *B* are bolted to the barrel or plate.

A mixture is made of four parts of coarse New Jersey fire sand, and two parts of coarse molding sand, to which is added flour in the proportion of one flour to twelve of sand, and after the mixture has been well mixed and riddled, it is wet with molasses water in the proportion of one part molasses to sixteen parts water, and thoroughly tempered. The core-maker then uses it by placing double handfuls of the mixture on the

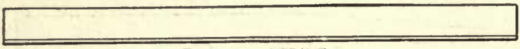


Fig. 181. STRIKE

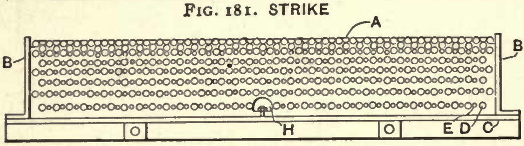


Fig. 178. THE BARREL WITH HORNS ATTACHED

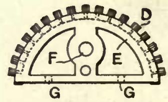


Fig. 180.

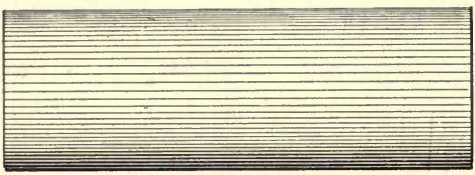


Fig. 177. THE FINISHED CORE

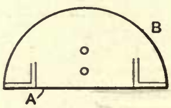


Fig. 179.

Figs. 177–181.—Barrel Cores Made on Core Barrel with Horns.

core barrel, and with his fingers pressing it down in between the horns. In some cases a bench rammer is used to ram it down on the core barrel, depending on the length of the horns. The sweep, Fig. 181, is then used to true the core to the size wished. In passing it over the core the first and second time, places will be found requiring attention and hand work to made them solid. This is done and the sweep passed over the core until it is of the right size, when the core is blackened and slicked. This half is placed in the oven or on a carriage and the ends *B* removed to be used in sweeping another half.

When the bottom half is dry, a piece of shafting is run through the holes in the ends, and this half is turned on the bar *F*, Fig. 180, and the joint is pasted. The top half having some of the sand scraped away at the joint to bevel it, it is placed on the lower half and the two bolted together at *G* and *C*, Fig. 180. If the core is of too great length to trust the ends alone to hold, it is bolted together at *H*, Fig. 178.

The joint is next filled and pasted, the joint blackened, and the core dried in the oven. When the core is in use in the mold, the barrel expands and allowance must be made for this, as the cylinder is shrinking at the same time, and the horns may bind on the inside of the cylinder, rendering it difficult to remove the core barrel.

In making cores for small castings when there is but a small amount of iron surrounding the core which is made of fine sand, the casting soon cools and the core is easily rapped out, leaving usually a smooth enough hole for ordinary purposes in the casting. But as the cores increase in size and the amount of metal surrounding them increases in thickness and weight, causing burning of the core, it becomes necessary to protect the face of the core to prevent the iron from burning it, or in some cases from destroying its face and producing a rough casting. This is done by coating the core with a coat of blacking. This may be silver lead, wet with molasses water, or the same lead wet with clay water. Red New Jersey fire-clay is generally used in the clay water, but blue clay, as found in many parts of the United States, will answer if sufficiently refractory. The blacking protects the core from the intense heat of the iron, so that when the casting is cleaned, the sand is easily freed from it and the casting is found to be of the shape of the core set in the mold. See Chapter XXII, relative to facing materials.

CHAPTER XIV

SETTING CORES AND USING CHAPLETS

CAVITIES in castings are formed by means of cores of green or dry sand, the dry-sand cores being made as described in Chapter XIII. The dry-sand cores are set in the mold in core-prints formed by projections on the pattern which locate the cores accurately in regard to the rest of the mold. As the pressure of the iron in filling the molds would tend to float the core to the top of the mold, it must be held down by *chaplets*, as shown in Figs. 183 to 185. If the core is long or if the casting is of such shape that the core is supported by the core-print at only one end, it is necessary to use chaplets to support it at the opposite end or at various points along its length. In Fig. 182 are illustrated various forms of chaplets, each one of which has its special uses and is adapted to various classes of work.

The chaplets *A* to *F* are formed of perforated sheet tin, and will resist a heavier crushing stress than would be imagined. The chaplet *A* with one flat and one concave side is used to support a round core above a flat surface, or *vice versa*. Chaplet *B*, with one concave and one convex surface, is used with a round core in a cylindrical mold. The chaplet *C* is similar to the one shown at *F* and is used in situations similar to those requiring *B*, but, having four side walls and being larger, will resist a greater crushing stress. Chaplets *D* and *E* are used either over or under cores for holding them down or supporting them, *E* being used in the heavier classes of work. These chaplets are used on the lighter classes of castings, although they can be used on rather heavy work if desired, the thickness of metal of which they are formed being varied to suit the requirements of the case. The chaplet shown at *H* is what is known as a water back or front chaplet and is used to

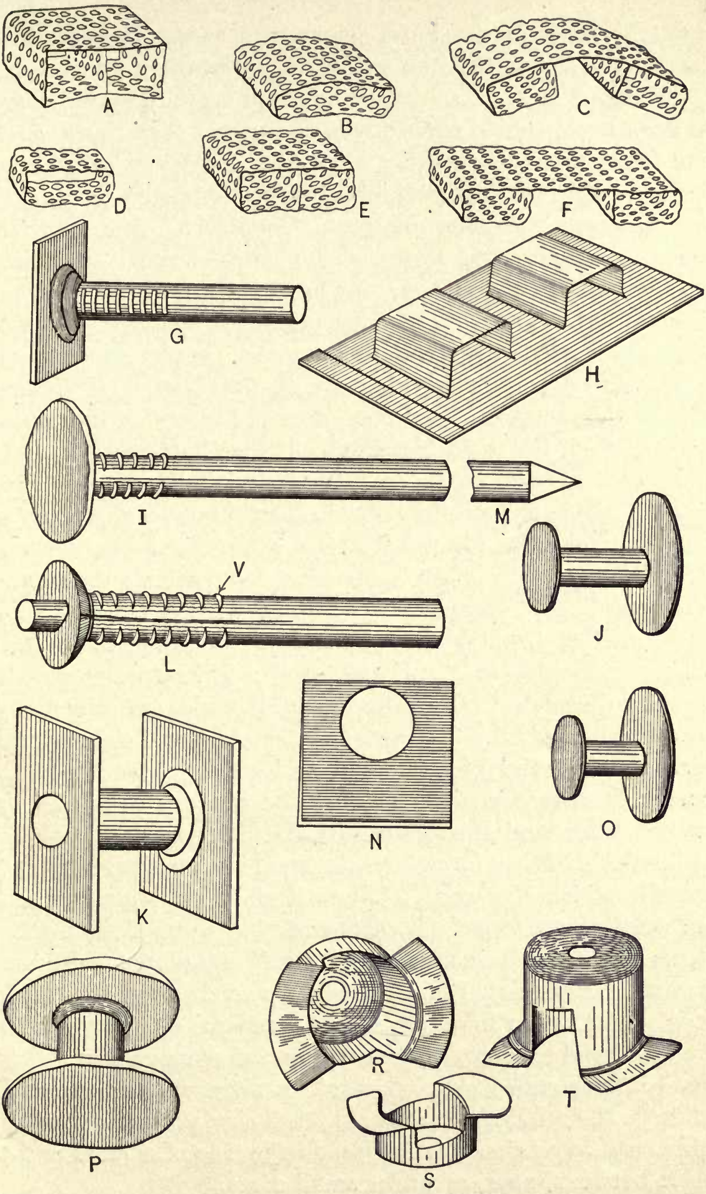


FIG. 182.—TYPES OF CHAPLETS.

hold the cores in the water backs of stoves. It is made of material to which the iron will readily flux when poured.

Chaplets *I*, *J*, *K*, *L*, and *M* are used on the heavier classes of work both to hold cores down, to support them in the mold and to prevent their moving sideways. They are used in connection with castings weighing many tons and in various combinations with one another. Chaplets *G* and *I* are the most commonly used types. They are composed of a head with a shank or stem which may be either pointed as shown at *M* or blunt. They are usually provided with serrations *V*, near the head, which will prevent the chaplet in any way from being driven or working out of the casting if by any chance the metal of the chaplet does not fuse with that of the casting when the mold is poured. If the chaplets *G* or *I* are to be used to support the core, the stem is pointed and driven through the drag into the bottom-board about a quarter of an inch. Chaplet *G* is formed of a stem with a flat head riveted to it, while chaplet *I* is made in one piece by upsetting the stem to form the head. Chaplet *L* is formed with a pin projecting above the head, which may be inserted in holes in the plate of a chaplet similar to *K*, which has shoulders on the stem to prevent the plate from sliding up on it under the pressure of the entering metal. The stem of the chaplet *L* is projected through the sand of the mold and either driven into the bottom-board or wedged against the binder, as will be described later, and thus transmits the pressure on chaplet *K* to the flask. *P* is a forged chaplet used in situations similar to those in which *K* is used. Larger heads may be desired than are possible on forged chaplets and, by using double-ended stems similar to those used in chaplet *K* and plates of different sizes as *N*, a chaplet of any desired size and shape may be made. It is advisable, in foundries doing a general class of work, to keep on hand a supply of these stems and plates. *J* and *O* are small double-ended chaplets used for the same purpose as *K*, while *R*, *S*, and *T* are chaplets of small size, pressed out of tin, which are convenient for nailing on the side of a mold and to place between, over, or under small cores.

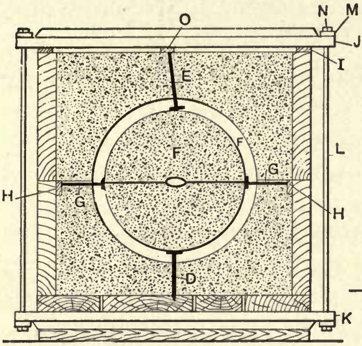
Chaplets used in steam-, water-, gas-, and air-cylinder castings are always tinned where they come in contact with the molten iron, the tin acting as a flux and causing the chaplet to unite with the metal of the casting and thus form a joint which will not leak under pressure.

Referring now to Figs. 183–185, we have respectively an end section, a plan, and a sectional plan of a cylindrical mold with a cylindrical core, which illustrate the method of placing the core and using the chaplet. Assume the pattern to be ten inches diameter and the core to have a diameter of eight inches, the thickness of the wall of the casting thus being one inch. A gauge *A* or *B* is made, with the notch *C* cut one inch deep and sufficiently wide to fit over the edge of the chaplet. The thickness of sand being ascertained by pushing the vent-wire through the mold where the chaplet is to be set, there is added to this length the thickness of metal of the casting plus one-quarter inch which the chaplet will be driven into the bottom-board, and the stem is cut off to the proper length and pointed. The chaplet is then driven down through the sand into the bottom-board and the head allowed to project one inch above the surface of the mold, this height being determined by the notch in the gages *A* or *B*. The bottom of the notch is set against the head of the chaplet and the top of the notch should rest on the surface of the mold. The mold in question is for a column eight feet long. The core-prints at either end of the mold are six inches long and, therefore, the core is cut off to a length of nine feet. To prevent sagging, it is supported at the middle by a chaplet placed in the mold as described above. To prevent the core from moving sideways, chaplets *G* are placed on either side of the core as shown, a channel being cut in the sand at the joint and a wedge driven between the flask and the blunt end of the stem, which is cut about three-eighths inch short of the distance between the core and the inside of the flask. Side chaplets and wedges are then covered with sand and the joint left in its former condition.

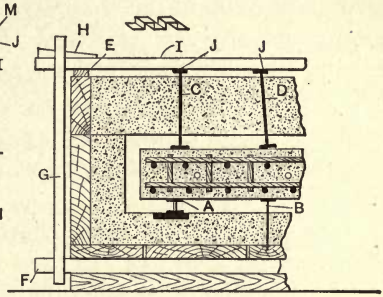
The thickness of sand in the cope over the pattern is then ascertained, and to it is added the thickness of metal in the casting. A chaplet is cut off to this length and the end of the stem left blunt. A large vent-wire is used to make a hole through the sand at the spot where the chaplet is to be placed, and after the chaplet has been inserted in this hole it is held in position by pinching the sand around it at the top of the cope, after which the cope is closed on the drag. The molder then moves the chaplet up and down to make sure that it bears on the core, after which strips of wood *I* are laid on the edge of the flask and a binder *J* laid across the cope over the top of the chaplet. The binder *J* is fastened to binder *K* under the bottom-board and the two held together with rod bolts *L*. A wedge *O* is then driven firmly between the binder and the top of the chaplet to hold the latter tightly against the core, but not so firmly as to drive the latter into the core. The wedge should not be driven until after the binders have been tightened; otherwise the chaplet might be driven into the core or force it down lower than desired.

The chaplet *E*, Fig. 183, is purposely shown set in the wrong position in order to illustrate a common fault in setting chaplets, which must be avoided. Unless the stem of the chaplet is driven truly vertical through the sand, the chaplet will bear on a single point and when the strain due to the pouring of the mold comes on it, it will either bend or be forced into the core. In any event the core will rise more or less in the mold and render the casting thinner on that side than it should be. It is necessary that the chaplet have a firm bearing on the core and, to do this, it must stand vertical.

Fig. 186 illustrates the use of several different types of chaplets. At *A* is a double-ended chaplet resting on a piece of a baked core set in the sand in the drag, placed there for the special purpose of holding it. At *B* is a single-end, long-stem pointed chaplet, such as we have just described. In the cope, at *C*, is a chaplet set correctly, while at *D* is a similar one set incorrectly. Instead of binders and bolts, clamps are used for securing the cores. Strips of wood *E* are laid on the edge of the flask and over them a bar or piece of wood *J* passing over the tops of the chaplets. The clamp *G* is placed to hold these



END SECTION OF MOLD
FIG. 183.



USE OF VARIOUS CHAPLETS
FIG. 186.

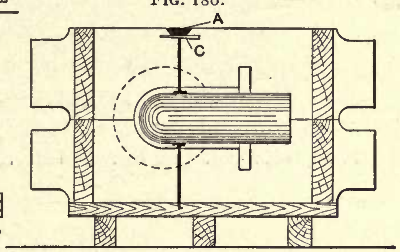
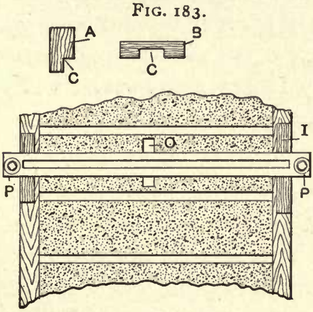
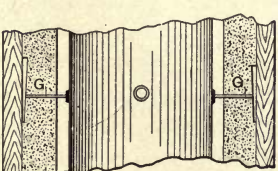


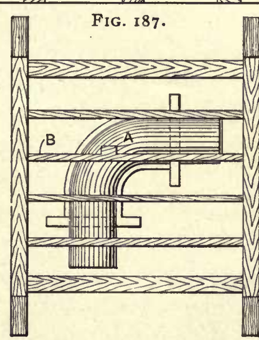
FIG. 187.



PLAN OF MOLD
FIG. 184.



SECTIONAL PLAN OF MOLD
FIG. 185.



MOLD FOR A QUARTER TURN
PIPE ELBOW
FIG. 188.

FIGS. 183–188.—SETTING CHAPLETS.

bars *E* and the bottom-board *F* together, the clamp being wedged in place by the wedge *H*. Wedges *J* are inserted between the top of the chaplets and the bar *I*. This core does not require any side chaplets. It will be observed that, this mold being quite deep in the cope, there will be a considerable lifting tendency due to the high head of metal. The bar *I* must, therefore, be made heavy enough to resist any tendency to spring; otherwise the core will lift and iron may enter the vent.

Figs. 187 and 188 show the mold for a quarter-turn pipe elbow. After the cope has been made, an iron bar *B* with a lug *A* projecting from its side is placed in the top of the cope at the point where the chaplet is to be placed, the stem of the chaplet coming under this lug. The stem of the chaplet is cut to such a length that it will fit snugly against this lug and project into the mold the proper distance to give the necessary thickness of metal, or the stem may be cut short and a wedge *C* driven between the bar *B* and the chaplet.

CHAPTER XV

GATES AND GATING

As many castings required from a single pattern are small, it obviously would be poor economy to mold each casting separately. It would not improve matters much to have a number of similar patterns separate from each other and mold them all in the same flask. The general practice in foundries, when many similar small castings are to be made, is to string them on a gate, as it is termed. Saddlery, shelf hardware, and small machine parts are made in this fashion. This method is indispensable in the making of castings for interchangeable machinery, as castings can be made truer to pattern when they are gated than when they are molded singly.

The process of gating is as follows: A single master pattern is made with an allowance, perhaps, for finishing. From this master pattern are made the requisite number of castings to fill a flask. These castings are finished to the pattern size and are then attached to a gate as shown at *A*, *B*, *C*, *D*, and *E*, Fig. 189. They are arranged, according to the shape of the casting, in such a manner as to permit the greatest possible number to be placed in a flask, and they are also attached to the gate in the best method for pouring.

When ready for use, a *match-board* is made of plaster of Paris or of litharge and sand mixed with linseed oil. This match-board in appearance resembles the green-sand match-board made in the upset, shown in Fig. 9. The match-board corresponds to the cope as the pattern is placed on it, cope side down, when molding is begun. The drag is rammed up over the match-board exactly as in any other pattern, pockets being secured with nails or soldiers in the usual manner. As a rule, however, patterns which are gated in this fashion, are so arranged that they may have the sand riddled on them and be rammed up without any other work. After rolling over the drag, parting sand is dusted on as soon as the match is lifted. Should the match be any the worse for wear, a thin layer of sand may adhere to the pattern. The gate should then be rapped slightly to jar this sand loose, after which it may be blown away with the bellows. As a rule, however, it is better

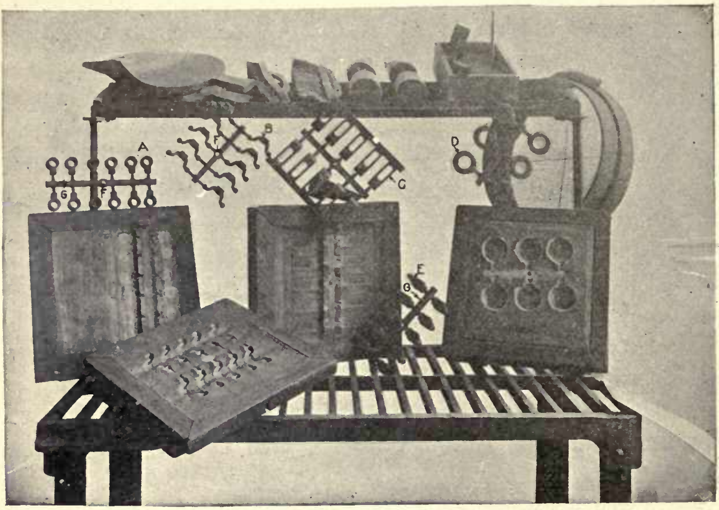


FIG. 189.—METHODS OF GATING PATTERNS.

to have a new match-board made than to work with one with which this procedure is necessary.

A small hole is left at the center of the gate, being clearly shown in the illustration. The gate-stick is set in this hole and the cope is then rammed and struck off. The gate-stick is withdrawn, but, before lifting off the cope, the molder places a bar through the gate-hole in the pattern and raps it gently, thus jarring the pattern loose in the cope and drag at the same time. By doing this, the pattern is jarred an equal amount in both cope and drag and the finished casting will be found to be without evidence of a seam or parting at the joint. In order that it may be possible to jar a pattern in this manner, the cope and drag must be tight, that is, they must have no motion with relation to each other, due to the pins on the flask being loose in the pin-holes. The gate of patterns is then drawn from the drag without further rapping. This is usually done by screwing a *drawpeg* in the rapping hole, or if the patterns are gated many times, pins are provided in the pattern for this purpose. Gates of patterns are seldom boshed in the drag as, on the drag side, steady-pins, shown at *G*, Fig. 189, are provided. These are round pins of small diameter, extending below the deepest part of the pattern to guide it when the pattern is drawn from the sand and thus avoid breaking the sand and altering the shape of the casting. The object of arranging the pattern on gates is to have the pattern, when drawn, leave a perfect mold, as there must be no stopping to repair broken molds if the maximum output and quality of castings is to be obtained. Patterns are gated usually for machine work, in which case they are arranged so that they can be attached to a vibrator in which compressed air is used for rapping; a greater output is thereby obtained.

Patterns are often gated on match-plates as shown in Fig. 190. Where there are many castings to be made, half of the pattern is mounted on one side of the plate and half on the other, for the cope and drag respectively. The plate itself is usually of cast-iron planed to one-quarter inch thickness. In mounting the patterns, they are, wherever possible, finished and the two halves are drilled through so that they will match as desired. One-half of the pattern is then placed in the desired position on the match-plate and used as a jig for drilling the match-plate. The other half of the pattern is attached to the opposite side of the plate and, the holes in the plate and the two halves of the pattern being aligned, the two halves of the pattern will correspond exactly in position with each other. The halves of the pattern are fastened to the match-plate by pins extending through the pattern and the plate. The gate is also attached to the drag side of the plate as shown at *D* in Fig. 190. The patterns on either side of the match-plates *A* and *B* in this illustration are alike, although this is not necessarily a characteristic of match-plate patterns. For instance, the pattern *C* differs on the two sides of the plate.

In molding with match-plates, the cope of the flask is placed directly on the bench, joint side up. The match-plate is set on the cope and the drag on the match-plate, the pins of the drag extending through tight holes in the match-plate. The arrangement of the flask and match-plate is shown at *C*, Fig. 190. The drag is rammed up first, the bottom-board

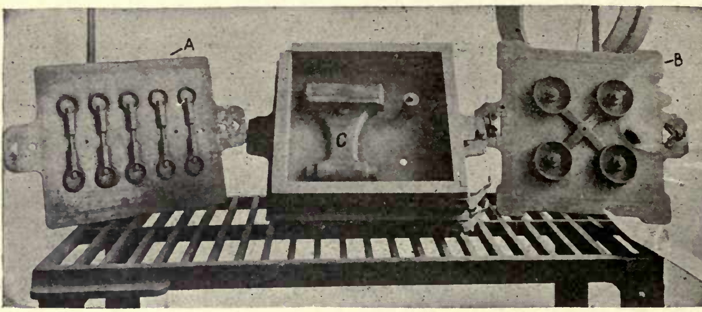


FIG. 190.—GATING PATTERNS ON MATCH-PLATES.

rubbed to a bearing, and the entire flask rolled over. The gate-stick or gate-pin is set, the cope rammed up, struck off, and the gate-pin removed. The match-plate is rapped and the cope removed, being guided off the pattern by the flask pins. The match-plate is next removed, it also being guided by the flask pins. Rapping the match-plate jars the sand alike in cope and drag.

In foundries where compressed air is used, the air is usually piped to the benches, so that in hand molding compressed air may be used for vibrating all match-plate patterns, it being possible to attach vibrators to any match-plate. Match-plates also are commonly used on molding machines. It is possible, by using match-plates, to increase the output of a foundry to a remarkable extent when compared with single-pattern molding handled one-half a pattern at a time. In making match-plates, it is usually best to cast the match-plate with the patterns on it at the same time.

The process of casting the match-plate, with patterns on it, is as follows: Consider the match-plate *A*, Fig. 191. The patterns, ten in number, are split through the center, forming a cope and drag half for each pattern. The drag halves are placed on the mold-board in the position shown, joint side down, and the drag is made and rolled over. The joint is carefully made, and the cope is rammed up, the gate-stick being set far enough away from the patterns to allow for making a plate around them and gating into it. The cope is lifted off and carefully finished, as much parting sand being removed as possible. An upset or frame, of the thickness that is desired for the match-plate, and of the same size as the flask with which it is to be used, is placed on the joint of the flask and around the patterns, and a frame, the size and shape of the match-plate desired, is placed. This is shown at *B*. The sand is then cut and roughed between the frames *B* and the sides and ends of the upset, which has been placed on the joint of the drag *C*. This keeps in position the sand that is built on the top of the sand joint, between the drag and the frame *B*. This sand is piled on by hand and struck off level with the top of the upset on the joint of flask *C*, and the frame *B* forming the match-plate, is then drawn from the drag.

The process consists essentially in molding the patterns in the flask and, after drawing them from the cope and drag, of deepening the drag by adding one-quarter of an inch of sand at the joint. A mold of this character naturally requires greater care in finishing than an ordinary mold, inasmuch as it is to form a casting, which will be used as a master pattern, and any imperfections in this casting will be repeated many times over in the castings made from it as a pattern. In pouring this mold, one side is usually raised slightly as shown, by the wedge *K*, so that the iron entering the mold may fill one side first and flow up over the face of the drag a little at a time. With this arrangement, hot iron is always flowing down to meet the iron rising along the face of the mold, and sharper castings are the result. Certain shapes of castings are made better by permitting the iron to flow in at the lower side of the mold and using a higher head to force it up over the face of the mold as soon as possible. Further details regarding gating and mounting patterns on match-plates are given in Chapter XIX, on molding machines.

Types of Gates

In addition to the arrangement of patterns, as described above, the term "gating" is also applied to the method of leading iron into the mold. The arrangement of the gate is important, as on it often depends whether or not a clean, sound casting will be obtained. Fig. 192, 1 and 2 show the plan and sectional elevation of a gate, arranged to clean the iron as it flows into the mold and to prevent impurities in the casting. Referring to the plan, a *set gate* is placed at either corner of the pattern, being set in position when the pattern is first laid on the mold-board. A short distance behind the set gate, are placed the two *skim gates A*, which are provided with core-prints for *skim cores*. The gate-stick is placed in the cope at *B*, and when the cope is lifted from the drag the gate *C* is placed in the cope. This extends from the gate *B* to each of the skim gates and a channel is cut in the drag under the skim gate, the sand being softened where the iron is to drop in it. The channel is cut still further to connect the skim gate *A* with the set gate and a core is set in the skim gate, being marked "skim core" in the plan. The action of these various gates is as follows: Iron being poured fast enough to fill or "choke" the gate *B*, fills the gate *C*, which assists in restraining any dirt in the iron. The iron entering gate *A*, shown in the plan, and flowing underneath the core, is skimmed by the core and the dirt is still further restrained. The round part of the set gate continues this action and the iron, flowing through a deep thin channel into the mold, has but little chance to carry dirt or scoria with it into the mold. As dirt or scoria in iron has a tendency to rise to the surface, the molder can, by

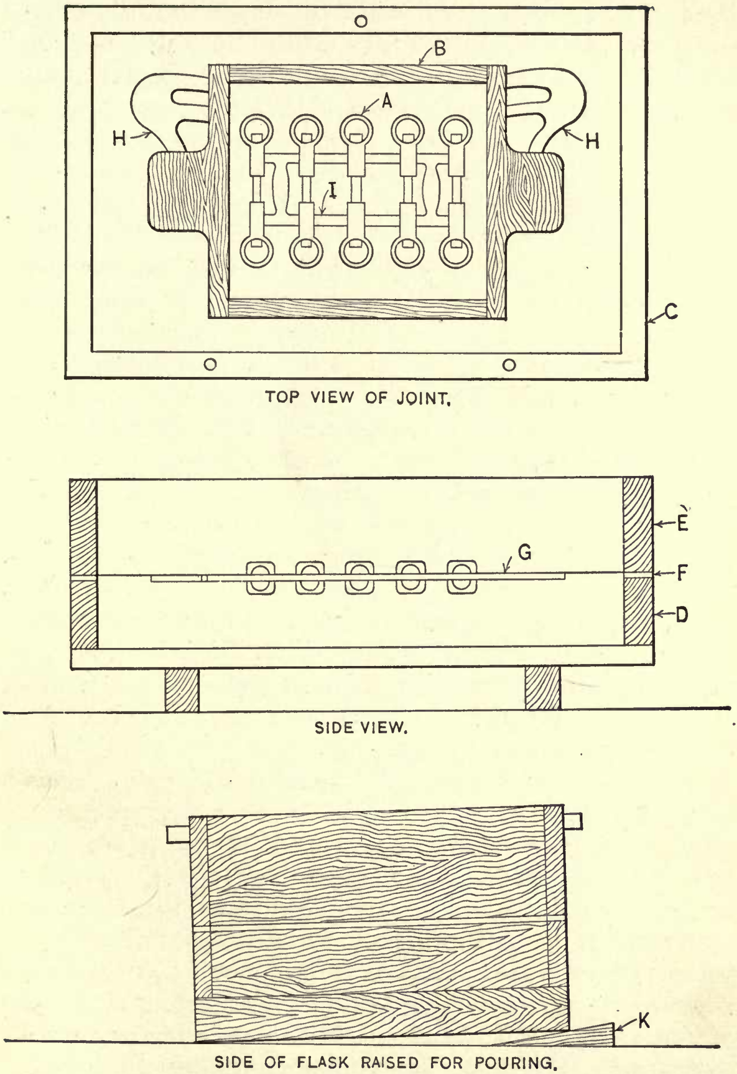


FIG. 191.—CASTING A MATCH-PLATE AND PATTERNS.

contriving his gates to present pockets or skimming arrangements similar to the one described above, prevent a large amount of these impurities from passing into the mold with the iron. An arrangement sometimes used is similar to that just described, with the exception that the skim gates are omitted, the set gates being depended on to dam the iron and thus hold back the scoria. It is, however, necessary to keep the gate *B* choked, inasmuch as the scoria, being more fluid than the iron, will flow along the surface of it if it is given a chance to enter the cross gate, and thus get into the mold. As a general rule, a shallow, wide gate will permit more impurities to enter the mold than will a deep, narrow one. The arrangement of the gates, shown in plan and elevation in Fig. 192, 1 and 2, is shown in perspective at 3, and the course of the iron can be traced through it. Many styles of skim gates are on the market, some of them being patented.

A *peg gate* is shown in Fig. 192, at 4 and 5. This consists of a basin cut in the cope, from which a number of small upright gates extend down through the cope to a basin cut in the drag, whence a wide gate allows the iron to enter the mold. Fig. 192, 6, shows a gate commonly used where it is not necessary that the iron be kept particularly clean. This is mostly used for such castings as building plates and general rough work. It consists simply of the upright gate and a channel cut from the bottom of this gate to the mold.

The *horn gate* is shown at 7. The uses of this gate are many. In pouring small gears, it is used to bring the iron into the mold, either over or under the teeth of the gear, as described in Chapter II, and it is also used as a skim gate. As shown in the illustration, the iron flows down the upright gate and then through cross gates in either direction to the horn gates, whence it enters the mold. As the iron flows down the semicircular portion below the mold, the upper surface of the gate acts as a dam. The tendency of the dirt in the iron will be to flow with it until the gate is filled at the bottom, and then to back up in that portion of the horn gate adjacent to the cross gate, thus permitting clean iron only to enter the mold.

The *flat gate* used by stove and sink molders is illustrated in Fig. 192 at 9. This type of gate is used for pouring thin castings, such as stove tops and bottoms and similar classes

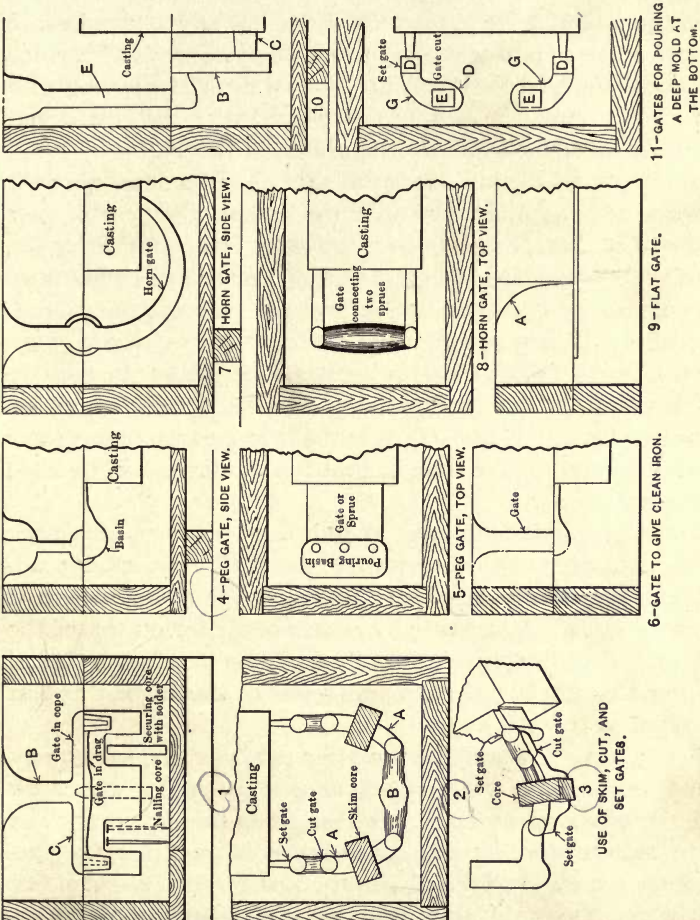


FIG. 192.—GATES.

of work. On sinks, a number of these gates are used at one time. As the thin castings cover a large surface, it is difficult to cut a thick enough gate in the thin edge of the casting to properly fill the mold and at the same time one which will break away from the casting, when cool, without breaking with it a portion of the casting itself. Gates of this character are also used with molds of cast-iron hollow-ware and with building facers. They may be made of any desired width but are narrow, not exceeding three thirty-seconds of an inch at the point where they adjoin the casting. In pouring with this type of gate, the iron is not poured directly into it, but is allowed to strike at about the point marked *A*.

In molds where it is desirable that the iron enter near the bottom, such as molds for steam cylinders, the type of gate shown in Fig. 192, at 10 and 11, is used. In making this gate, two upright gates are laid in the drag, four or five inches from the pattern, and between these and the pattern, the gates *C* are placed. When ramming up the cope, two upright gates, somewhat offset from those in the drag, are made, the relative position of the two being shown at *D* and *E*. These are connected by the channel *G* cut in the drag and a pouring basin is cut in the top of the cope so that both gates *E* will be filled at the same time.

In pouring rolls and large, round, solid castings, *whirl gates* are used to give the iron entering the mold a whirling tendency and thus throw any dirt in it toward the center, where it can work out of the casting by means of a riser on top of the casting. The whirl gate is usually made by causing the metal to enter the mold at the circumference of the casting and at a tangent to it.

The gating of a mold is a matter that must be left largely to the judgment of the molder, depending on the character of the mold, as many considerations enter this subject. The temperature of the iron has considerable influence on the gating, since hot iron will flow faster than cool iron. The rapidity with which the mold must be filled, depending on the character of castings, must also be considered. In certain types of mold, the iron must enter at different places in order to fill all parts of the mold properly. Castings wnich have both heavy and light parts must often have separate gates of different sizes leading to the parts of different weights. Where a wide plate is to be cast, a gate may be cut across the entire end of the casting, or along one side, and from this gate a number of *ingates* or *sprues* cut from it to the casting, so that the iron will cover the entire surface of the mold rapidly.

In pouring some large molds with peg gates, from a basin, it is customary to use iron balls with handles, dipped in thick blacking and dried, to stop off each peg gate, one ball being placed over each gate, when building the green-sand runner. The iron is poured into the basin and first one ball and then another is lifted to permit the iron to flow down through the gates as desired. In this way the dirt is held in the basin, clean iron flowing into the mold from the bottom of the basin.

CHAPTER XVI

RISERS, SHRINKHEADS, AND FEEDING HEADS

A RISER is a hole cut in the cope of a mold to permit the iron to rise above the highest point of the casting. It serves a number of purposes. It enables the molder to see when the mold is filled and thus warns him when to stop pouring to avoid straining the casting. It may be used to avoid pocketing gas in a high part of the mold by being placed on this high point of the casting. It may be used as a *flow-off*, being placed at the highest part of the casting. If metal is permitted to rise and flow out of the mold, through this flow-off, a softer casting will be produced, at the point where the riser is attached, than would be the case were the metal permitted to simply rise up and fill the mold. A riser placed near thin parts of castings at the joints of molds, connected to these thin parts by a gate, the iron being allowed to flow through these gates into the riser, will often insure castings more nearly true to the shape of the pattern than would be the case were the riser omitted.

Large risers are used for *shrinkheads* or *feeding heads.* Large bodies of iron, while solidifying, require a certain amount of molten iron to be fed to them in order that the casting may entirely fill the mold, inasmuch as iron shrinks when solidifying. Feeding heads or large risers are provided with large gates between the riser and the casting. The gate must be of such size that the iron in it will not become solid before the casting solidifies. It is essential that the iron be permitted to flow freely from the feeder head to supply all deficiencies due to the shrinkage of the iron in the mold.

Castings, up to a certain size, may be fed from feeder heads by gravity, if the feeder or shrinkhead is properly proportioned. With larger castings, a gravity feed would require a basin at the top of the riser of inconvenient size and to avoid this and use a smaller riser, which may be easily broken from the casting, *pumping* or *churning* is resorted to. The molder will place on top of the casting, or at times alongside of it, a riser of sufficient diameter to permit the entrance of an iron rod. This riser is connected with the mold proper by a larger gate. After the mold has been poured, the iron rod is inserted in the riser and moved up and down and around the sides of the riser. Molten iron is poured into the riser constantly, and, by means of the rod, the hot iron is kept in motion in the riser and gate and prevented from solidifying until after the casting itself has set or *frozen*. As the casting shrinks in solidifying, it draws on the liquid in the riser for sufficient iron to make up the shrinkage and fill the mold completely. The operation above described is known as churning or pumping. When the pumping rod is first pushed down into the riser, care should be taken not to allow it to come in contact with the sand forming the bottom of the mold, and thus tear up the sand which might find its way back into the mold and thus spoil the casting. In moving the iron around in the riser, the opening kept clear should be as large as possible. The churning rod should be struck every few moments with a short bar of iron to prevent a ball of iron from forming on it at the point where it enters the riser. If the casting is of such size that a considerable time is required for churning, extra churning rods should be provided for use when the ball forms, as it will do eventually. The churning rods should be heated before use to prevent their freezing the riser when they are inserted in it. As the riser is to furnish hot metal to the rest of the casting, it must be kept hot longer than any other portion. In churning large castings, it is advisable to fill the top of the churning head with powdered charcoal to exclude the air from the surface of the iron.

CRAPTER XVII

TREATMENT OF CASTINGS WHILE COOLING

Often castings which have been molded and poured correctly are found to be warped and distorted on their removal from the sand. This may be due either to improper design or to improper treatment of the casting before it is removed from the sand. If a heavy part of the casting immediately adjoins a light part, the latter will solidify first and the heavy porticn, cooling later, will shrink and tend to draw away from the lighter portion. If the casting does not rupture in this operation, strains may be set up which will warp the casting out of shape and thus render it worthless. This contingency may often be avoided by exposing the heavier part of the casting to the air, thus making it cool more rapidly while the cooling of the lighter portion is retarded, the entire casting thus becoming solid at about the same time. Shrinkage strains are thereby avoided and the casting is removed from the sand true to pattern. The cooling of the lighter parts is retarded often by covering them deeply with sand at the same time that the heavier parts are exposed to the air.

Oftentimes it can be predicted from the shape of the pattern the method in which it will cool and the extent to which it will be distorted if allowed to cool normally. This distortion can be avoided and the effects of unequal cooling counteracted by distorting the pattern in the opposite direction an amount equal to that distortion it would assume in normal cooling. Thus, in casting columns, the pattern is made with the ends relatively lower than the middle portion. The mold is made with the middle of the column higher than the ends which cool last. They are thus thrown up as the casting cools and if the right amount of camber has been given to the pattern the column will be perfectly straight when cold. The same method is followed in casting the copings for the top of brick walls. Cornice work for buildings is usually molded with a camber in the same manner. The castings are usually made with lips at the edges, for bolting together, combined with moldings. The lips on the edges of the plates are often on opposite sides of each edge, and the pattern is arranged on the mold-board crooked in the opposite direction from which it will crook when cooling. Thus one edge will be crooked in one direction and the other in the opposite direction and when the casting is cold these edges will be straight and parallel. Lathe beds, up to fourteen feet in length, are molded with a camber, as the ends tend to rise in cooling. A lathe bed thirty feet long, however, is so heavy that the casting in shrinking will not lift the ends and therefore these beds are cast with the center down.

Many castings of different lengths must be kept covered at the ends in cooling while the sand is dug away from them at the center. Often if a casting is of such size and shape that it must be left overnight in the sand it is advisable to dig the sand away from around the gates. This is to permit the casting to shrink while cooling without being held by the gates, and thereby having a piece at or near the gates torn out or a crack started due to the rigidity of the structure held in one position by the gates.

In certain classes of work it is not sufficient to retard the cooling of the thin parts. An artificial supply of heat must be provided. Such a case is the casting for a disk crank of a stationary engine which consists of an engine crank surrounded by a web, the crank and counterbalance being hidden on the inside by a plate. This casting is molded with the plate face down and the pockets of sand to form the crank and counterbalance are lifted out with the cope. After pouring, the cope is lifted as soon as possible and the sand dug out of these pockets, leaving only enough sand in them to protect the casting. Molten iron is then poured into these pockets or pig beds and covered with sand, after which the cores in the hub and crank-pin hole are dug out. Thus the thinner portions are continuously supplied with heat until the entire casting has cooled uniformly. If this precaution is not adopted, the crank disk will either be found cracked when it is taken from the sand or strains will be set up which will cause the disk to fail when it is forced on the engine shaft by hydraulic pressure.

Castings of U-shaped section should be gated together at the top, as in cooling the tendency is for the bow to cool first and thus draw the legs of the casting apart, which tendency is resisted by the gates, which cool first. If it is impossible to gate the casting in this manner, the bow portion should be uncovered at the earliest possible moment while the legs of the U should be kept covered and their cooling retarded.

Pulleys for power transmission, with thin rims, should have the center core removed as soon as the metal has set, especially if the pulley is of large diameter. Often a pulley that is required in a hurry is removed from the sand while the hub is still red-hot. This condition of affairs will cause a heavy strain on the arms and will frequently pull them from the rim. To avoid this condition the sand is dug away from the cope over the hub as soon as possible and water poured into the hole formed by the core. The rim and arms are kept covered and the heat retained in them as long as possible. Large fly-wheels and balance-wheels are often cast with the hubs split by means of cores, the rim being cast solid. As the rim contracts the two parts of the hub are forced together and cracking of the arms and rim is avoided. Conversely to the above cases, if the rim is heavy and the center comparatively light the rim must be uncovered and cooled more rapidly than the center.

Plates cool first at the edges and frequently are found checked. This condition can be cured by removing the cope as soon as the casting has solidified, knocking the sand from the cope down on the casting and cutting channels in it diagonally across the plate from opposite corners, thus permitting the center to cool in advance of the edges.

Where castings are made with heavy rigid cores in them they may be ruptured by shrinking on these cores. Thus, jacketed cylinders having light jacket walls and heavy barrels must have the cores removed promptly to prevent the barrel cracking away from the jacket. Cored cylinders frequently have internal strains set up in them by shrinking on the cores, and when the first roughing cut is made on them in the machine-shop these strains are relieved and warp the casting, which as a result must be annealed.

In situations where a circle of iron of one thickness has another circle of greater thickness cast inside it, there is considerable danger of cracking owing to the thicker circle cooling last and pulling away from the lighter outside one. To offset this tendency considerable ingenuity is sometimes required. Usually there is one particular spot in castings of this character which always gives trouble and, in a certain case, this was obviated by placing a chill at a particularly heavy part and chilling the iron as it was poured so that it cooled relatively faster than at the other portions of the casting.

In loam molds, provision for shrinkage is made by inserting in the mold loam bricks which crush under the contraction of the metal, and also by the insertion of iron plates in the mold which can be pulled out as soon as the casting is poured and thus provide ample space in which the metal may shrink. The larger the casting and the faster the cooling, the greater is the relative contraction, and this must be borne in mind when making the mold, in order that proper provision may be made for taking care of this contraction.

After the casting has been removed from the sand, care must be exercised in its treatment until it has cooled down to room temperature. A large casting which may be exposed to a chilling draft on one side, such as might come from a door communicating with outdoors in the winter time, would cool more rapidly on that side than on the other and thus crack just as surely as it would in the mold had no provision been made for crushing the cores. Printing-press cylinders exposed to unequal temperatures on opposite sides are especially liable to warping.

The composition of the iron of which the casting is composed also has an influence on its treatment after pouring. Light castings of machine parts are usually removed from the sand immediately after the mold is poured. These castings are high in silicon and low in sulphur, manganese, and combined carbon. A coating of sand frequently adheres to such castings in proportion to the thickness, protecting them from the air. However, if air does come in contact with the casting, the high silicon and the high graphitic carbon content prevent the formation of a hard scale. On the other hand, if the sulphur and manganese contents are high the reverse will be true and a hard scale will form on the castings if the air is permitted to strike them before they have cooled to room temperature. It is therefore advisable to leave them in the sand until they are cold, especially if they are to be machined later. Should it be necessary for any reason whatever to remove them from the sand promptly they should be poured with iron of a silicon content about twenty points higher than ordinarily.

The thinner the wall of the casting to be machined the greater is the danger of removing it from the sand too quickly and of forming on the surface of it a hard scale. When uncovering such castings, to equalize the cooling, a small amount of sand should be allowed to remain on surfaces which are to be machined. This will prevent direct contact with the air and thus avoid scale and yet will permit the rapid escape of heat.

Castings which are found to be crooked on removal from the sand may be straightened by heating them to a red heat and then weighting them so that the casting will be bent in the opposite direction. Lathe beds and similar castings may be treated in this manner, the ends being placed on solid bearings, the casting arching upward and being heated at the center until it is red hot, after which it is weighted and allowed to cool. Many times castings may be straightened by peening on the hollow side, thus closing the grain of the iron and forcing the ends down.

CHAPTER XVIII

CLEANING CASTINGS

FOR cleaning castings from the sand which adheres to them after pouring, three general methods are in use: rattling them in a tumbling barrel, pickling, and sand blasting. In rattling, the castings are placed together in a horizontal barrel which is revolved and the castings fall over and over and against one another, and the sand and scale are gradually pounded from the surface. This method, however, produces a hard skin on the surface of the casting which renders it more difficult to machine, and pickling in sulphuric, muriatic, or hydrofluoric acid is more generally resorted to for castings which are later to be subjected to machine processes. Sand blasting consists in directing against the casting, by means of air under a pressure of from sixty to one hundred pounds per square inch, a jet of sharp sand which abrades not only the burned sand but also the hard surface of the casting.

In rattling, the castings are placed in the barrel until it is nearly full, together with "stars" or "picks," which are small, irregularly shaped pieces of hard iron, and the barrel closed and revolved. The castings falling on each other and on the "stars" knock from the surface all the burned sand and scale and polish each other. In rattling together such castings as legs for machines it is advisable to pack the castings in with blocks of wood to hold them apart and allow the "stars" to do the abrading and polishing when the barrel is revolved. Heavy castings of this character are liable to become broken if placed in the barrel loose. If the barrel is not well filled with castings it is advisable to fill the remainder of the space with blocks of wood if the castings are of light character.

For many purposes rattling is insufficient to clean the casting properly. If a casting has been made in raw sand without any facing, the sand will apparently be burned on it. Rattling will not remove this burned sand properly and pickling is necessary. The pickling bath is placed in a stone or wooden trough and may consist of sulphuric acid diluted in the proportions of one part acid to seven parts water, or of muriatic acid and water, or one part of hydrofluoric acid to twenty parts of water. The castings should remain in the pickling bath about twelve hours and then should be well washed with clear water. As much of the sand as possible should be removed from them before placing them in the bath. Gears are cleaned best by first subjecting them to a sand blast, which loosens the sand in the corners of the teeth, and then pickling them.

The following information concerning the use of hydrofluoric acid is given in a pamphlet issued by the General Chemical Company. "Until quite recently castings have been cleaned either by mechanical means or by dilute sulphuric acid. Sulphuric acid loosens the sand by dissolving the iron from under it. On the other hand hydrofluoric acid dissolves the sand itself, and therefore acts more promptly, takes much less acid, and does not cause a loss of iron. For cleaning castings that are to be galvanized, tinned, enameled, nickel-plated, or painted, hydrofluoric acid is vastly superior to sulphuric or muriatic acid because it leaves a purer metallic surface and does not rust the plating or work through the paint. Hydrofluoric acid dissolves more readily than sulphuric or muriatic acid, the ordinary rust and magnetic (black) oxide that forms on the surface of heated iron. The strength at which the acid is used varies with the kind of iron to be cleaned and the time in which it is to be finished, but generally it is used in the proportions of one gallon of acid to twenty or twenty-five gallons of water. The acid should be poured into the water and well stirred. Such a solution will clean ordinary castings in from one-half hour to one hour. If used of half this strength —one gallon of acid to fifty gallons of water—it will take several hours. Hydrofluoric acid is used cold, but should be kept above the freezing point. The bath can be used repeatedly by adding about one-third the original quantity of acid before charging again with iron. If it is desired to keep the iron bright it should be washed with water at about 200° Fahr. immediately after coming out of the acid so as to dry quickly. By this means all trace of the acid is eradicated and all chance of corrosion or tarnish resulting is obviated. If washed with cold water the casting will remain wet for some time and rust. A little lime may be added to the wash water. For immersing and removing castings from the bath, wooden boxes with holes in the sides have been used with good results. By this means the sand is retained at the bottom of the boxes and is removed with the castings, thus saving the strength of the acid when not in use. Spent, weak acids should be discarded and the tanks cleaned every month. In removing stoppers from vessels containing the acid, care should be exercised, as sometimes gas is generated from the action of the acid on the lead in which it is enclosed which may cause some of the acid to be thrown out if the corks are removed hastily. The acid is neither explosive nor inflammable. As strong acid will cause inflammation wherever it comes in contact with the skin it should be handled as carefully as other acids. Rubber gloves are the best protection, but if acid has splashed on the skin it should be washed off with water and diluted borax or sal soda solution, or with aqua ammonia which will prevent injury."

CHAPTER XIX

MOLDING MACHINES

Where there are a number of molds to be made from one pattern, it is frequently advisable to use a *molding machine* for this purpose. Molding machines are made in a number of varieties, each designed for some specific purpose. Thus we have the *power squeezer* and the *hand squeezer*, the *split-pattern squeezer*, the *jarring machine*, also known as a *jolt rammer*, and the *roll-over machines*, which are made to operate entirely by hand, or to use power for rolling over and drawing the pattern, the ramming being done by hand, or to use power both for ramming and for rolling over and pattern drawing. Each machine has its particular field in which it will do better work than one of the other types.

Where the ramming time is a large factor in the time required to make the mold, one of the squeezer machines or jarring machines is advisable. However, if the mold is such that the finishing time is the largest factor, a machine which will draw the pattern should be adopted. This brings us to the split-pattern machine which, however, is limited in its application to patterns which can be split on a true plane and molded one-half in the cope and the other half in the drag, or to one of the roll-over machines operated either by hand or by power. In selecting the machine to save ramming time the character of the mold to be made is the chief consideration. As the squeezer machine packs the sand to the density required for the mold by pressure applied at the outside surface of the mold, it is not well adapted to molds having deep bodies of sand, since in this case the sand will have the greatest density at the outer surface instead of against the pattern as is required. On the other hand, the jarring machine in which the sand itself forms the ramming medium is well adapted to molds in which there are large pockets of hanging sand.

Having thus considered the general properties of molding machines, we will now consider each type in detail. First in the list is the hand squeezer. This consists simply of a frame carrying a yoke, a plate on which the mold-board is set and which can be elevated toward the yoke by means of a hand lever operated by the molder. The flask is placed on the mold-board with the pattern in it in the proper position and sand is riddled over the pattern until it is covered. Sand from the heap is then shoveled in and struck off flush with the top of the flask, a bottom-board fitting within the flask is placed on top of the mold and the whole contrivance elevated against the yoke by means of the hand lever. This operation compresses the sand in the flask to the required density and the mold is then lowered to the original position, turned over, and the pattern drawn. It may be drawn either in the usual manner by means of a draw-nail which is rapped by the molder, or the pattern may be mounted in a *vibrator frame* as described later and vibrated by means of compressed air while it is being drawn. This latter method gives much the better molds.

Power Squeezers.—Of much greater capacity and scope is the power squeezing machine shown in Fig. 193. This is a machine designed especially for molding light snap-flask work. It consists of a yoke carried between two uprights, the yoke being adjustable to suit varying depths of flasks; a power cylinder for elevating the table of the machine on which the mold-board and the flask are mounted; a lever for controlling the admission of air to the power cylinder, and a connection for operating the *vibrator* by compressed air. The yoke in the type of machine illustrated is mounted on trunnions enabling it to be swung back out of the way for placing and removing the flasks and the molds on the table. The patterns are usually mounted in vibrator frames or on match-plates to render the operation of drawing them easy and accurate. Machines of this character require about four cubic feet of free air per minute for their operation.

The operation of making the mold on this machine with the patterns mounted on a vibrator frame is as follows: A hard-sand match is formed, on which patterns mounted in a vibrator frame are set. This match is placed on the table of the machine and the drag portion of the flask set in position and sand riddled over the pattern until the latter is covered. Sand is then shoveled in until the flask is filled, the excess sand being struck off with the bottom-board, which is next placed over the flask and the yoke of the machine is drawn forward to its vertical position. Air is then admitted to the power cylinder and the table elevated, thus squeezing the sand in the flask against the yoke. The air is exhausted from the cylinder and the mold lowered to its original position, the half-flask pattern and hard-sand match then being rolled over. The match is next removed, after which parting sand is shaken on the mold and the cope half of the flask put in place, filled with sand, and squeezed in the same manner as the drag. This completes the ramming operations and the sprue is cut with a brass tube used as a sprue cutter.

The vibrator is now started and the molder grasping the cope by its handles lifts it from the drag. The snap flasks used with these machines have accurately fitted pins of considerable length which act as guides when the pattern is drawn, the vibrator frames or match-plates having ears which fit closely to these pins, thus being guided vertically upward from the mold. After the cope has been lifted off and set aside, the vibrator is once more started and the pattern is drawn by lifting the vibrator frame in its guides. The pattern being drawn, the mold may be closed, the snap flask removed, and the mold set on the floor ready for pouring.

To make hard-sand match to use with the vibrator frame, the latter is put in the cope flask and rammed up. The parting is made in green sand and lycopodium is dusted on the parting between the green sand and the preparation forming the match. The match frame which is beveled to hold the match in place is set over the pattern and clamped firmly so that it cannot move during the ramming operation. The portion of the pattern projecting into the frame is rammed

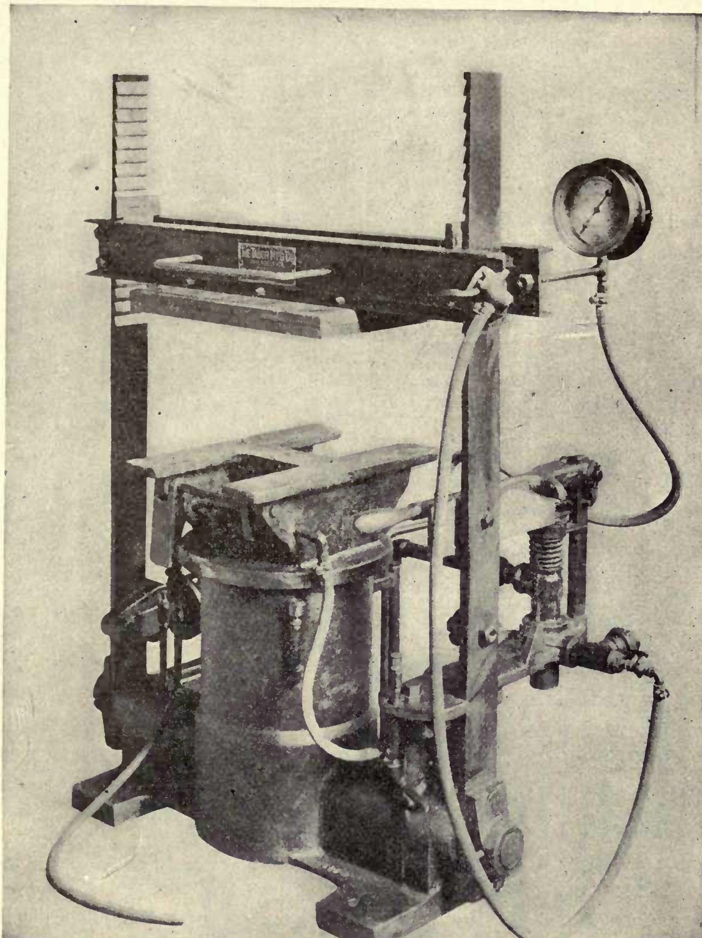


FIG. 193.—POWER SQUEEZER MOLDING MACHINE.

up exactly as would be done for bench molding, with sand made up of fifteen pounds of new burnt molding sand, riddled through a No. 30 sieve, into which has been kneaded a mixture of one quart of boiled linseed oil and four ounces of litharge. The match and the green-sand half-mold are rolled over and the cope taken off. The pattern is drawn and any parts of the match which may have broken in drawing are mended, after which the match is dried in a warm place for about twelve hours when it may be coated with thin shellac.

Instead of using a hard-sand match, aluminum match-plates, with the patterns cast one-half on either side of the plate, may be used, especially if the patterns have an irregular parting and exceptionally good castings are required. The advantage of these aluminum match-plates is that the whole mold may be squeezed at one operation and, furthermore, there is no possibility of the cope and drag shifting in relation to one another. To make an aluminum match-plate, a mold of the patterns is made in a flask large enough to accommodate the size of plate necessary. Master patterns should be used which have been made with the proper allowance for shrinkage and finish. Great care should be taken in making this mold in order to avoid any unnecessary finishing in the plate. Strips of wood the thickness of the plate required are placed on the parting of the drag before the mold is closed and a false parting of sand built up to the level of these strips. The strips are then removed, the mold is closed and poured, after which the plate may be finished with a wire brush or scraper. After attaching suitable handles and guides to the ends, the plate is ready for use.

To make a mold by means of this plate, the flask is put together on the table of the machine with the plate between the two halves, the drag side being uppermost. Parting sand is dusted on the plate and the drag filled with sand, the first portion being riddled in until the patterns are covered. The bottom-board, being used first to strike off excess sand, is placed in position, after which the flask is rolled over, the cope filled with sand, and the mold squeezed. The cope is then lifted off, the vibrator being used, after which the pattern plate is also lifted. The sprues having been cut before lifting the cope, the mold may now be closed ready for pouring.

Instead of the two methods above described, *paraffine boards* may be used for mounting the pattern where there are not a great number of molds to be made from one set of patterns. They are especially desirable in flat-back work or for split-pattern work. The paraffine board is usually made of oak and is boiled in paraffine for forty-eight hours to prevent it warping in contact with damp sand. It is mounted in a vibrator frame and the patterns fastened to it by means of wood screws, having first been located in position by means of dowel pins. Where castings are to be made from split-patterns in large quantities, a three-sixteenths inch steel plate may be used. The patterns are mounted one-half on each side of the plate and the entire mold is squeezed at one time as is the case with aluminum match-plates. In mounting the patterns, the corresponding halves should be finished together so that they will match at the parting. A hole should be drilled and slightly countersunk before the two halves are separated. After separation, one half should be laid in the desired position on the steel plate and used as a jig in drilling the latter. After the drilling is completed the corresponding half-patterns should be placed on the opposite side of the plate and the two parts riveted to the plate by means of a brass rod inserted through the drilled holes and riveted into the countersink.

The illustration, Fig. 194, shows the method of suspending patterns in a vibrator frame. A carrier of sheet brass one-eighth inch in thickness is soldered or sweated to the pattern, being attached to the runners if possible. Carriers are then rigidly fastened to the vibrator frame by first inserting them in a slot in the frame and drilling two three-sixteenths-inch holes through both frame and carrier and fastening them together by means of a snugly fitting brass pin. The pattern is next placed in the vibrator frame and holes drilled in the carriers on the pattern. The carriers on the pattern and those in the frame come together, and the carriers in the frame are drilled to correspond with holes already drilled in the carriers on the pattern. The slot in the vibrator frame should then be filled with wax to prevent the mold from crumbling at the edges.

The vibrator is simply a small compressed-air hammer striking a large number of blows of uniform intensity per minute, the head of this hammer being attached to the vibrator frame or match-plate to communicate the blows of the hammer to the pattern. The blows are such that the size of the mold is not enlarged to any extent, but they simply overcome the friction of the pattern against the sand, and enable the drawing of a pattern which has no draft.

Split-Pattern Machines.—Fig. 195 illustrates a special type of molding machine adapted for split-pattern work. It is especially adapted to patterns which are symmetrical, in which case both cope and drag may be molded from one pattern plate containing a double set of half-patterns, those on one side of the mold in the cope matching those on the opposite side in the drag. In using this machine it is customary to make as many drag portions of the molds as may be required, placing them on the floor in position for pouring, after which the copes are formed and closed on the drags. If cores are required in the mold, they are, of course, set before the copes are made. It will be observed that the machine is similar in appearance to the power squeezer described above. It is, however, provided with an arrangement for drawing the pattern either by hand or power and also either by raising the mold away from the pattern or by drawing the latter down through a *stripping plate.*

To make a mold on this machine, the patterns, which are mounted on a steel plate, are set on the table of the machine, the flask placed around them, being accurately located by means of dowel pins on the machine, and it is filled with sand and squeezed in the usual manner. After squeezing, the mold is lowered to its original position and the vibrator started. The operator then presses down on a pattern-drawing lever, if a hand-draft machine, or admits air to the drawing cylinder,

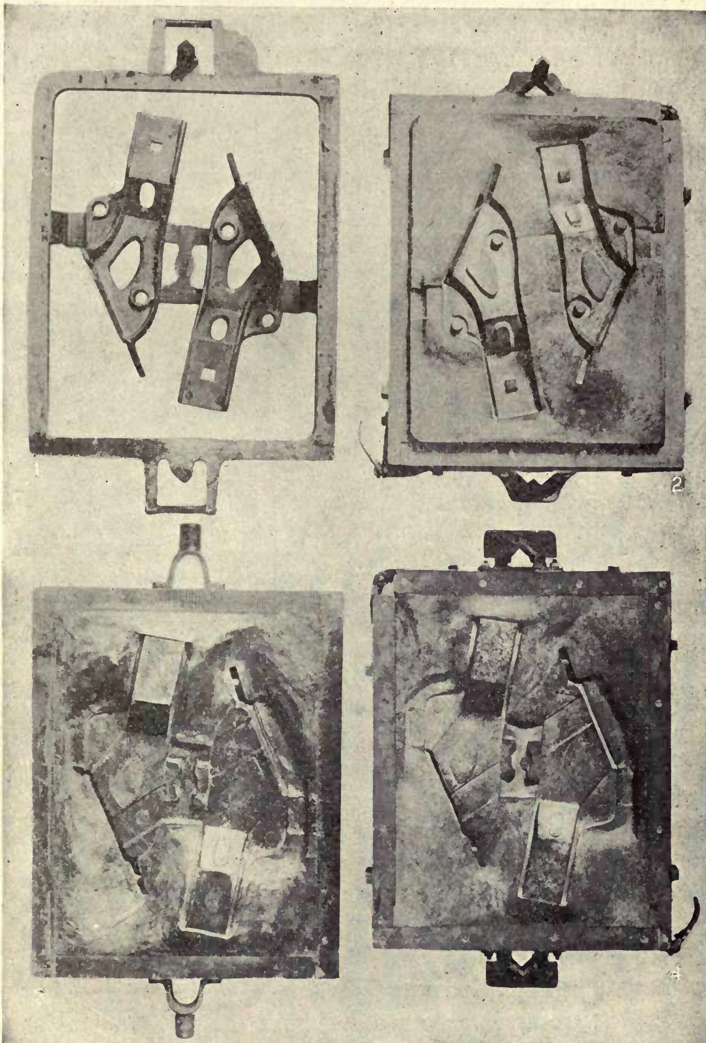


FIG. 194.—1, Mounting Patterns in a Vibrator Frame; 2, Hard-Sand Match for Same Patterns; 3, Cope of Mold Made from these Patterns; 4, Drag of Mold.

if a power-drawing machine, which elevates the outer portion of the table on which the flask is carried clear of the patterns, when the half-mold may be removed from the machine and set on the floor. The operation of making copes and drags on this machine is similar, except that in the case of copes the location of the sprue is indicated by a button on the bottom board which marks a depression in the sand where the gate is to be cut by means of the sprue cutter. When used with a stripping plate, the patterns are drawn downward through the stripping plate, the mold remaining stationary.

The illustration, Fig. 196, shows the method of *stooling* patterns molded on this type of machine where there are large bodies of hanging sand which would be liable to drop when the pattern is drawn. Such bodies are those forming the green-sand cores of the stuffing boxes in the illustration. A hole is cut in the pattern plate the exact size of the green-sand core or through the pattern and pattern plate according to the requirements of the case. A *stool*, made usually of cold-rolled steel and of the exact size of the core, is attached to a *stool plate* underneath and in exact alignment with the holes in the pattern plate. When the mold is elevated to draw the pattern the steel plate rises with the tables of the machine and the stools support the hanging green-sand cores as shown until they are entirely clear of the pattern.

The mounting of the two halves of a symmetrical pattern for use in a split-pattern machine is a job requiring considerable care and great accuracy. The recommended method is the use of a transfer plate. The first operation is to make a pattern plate for the machine and drill in it two dowel holes located on the center line of the plate. The halves of the various patterns are doweled together before finishing, after which they are numbered and separated. The halves without dowel pins are arranged on one side of the pattern plate and used as jigs to drill that side of the plate. A transfer plate somewhat wider than half the width of the pattern plate is next made by first drilling holes to match the center-line holes of the pattern plate. Transfer and pattern plates are now

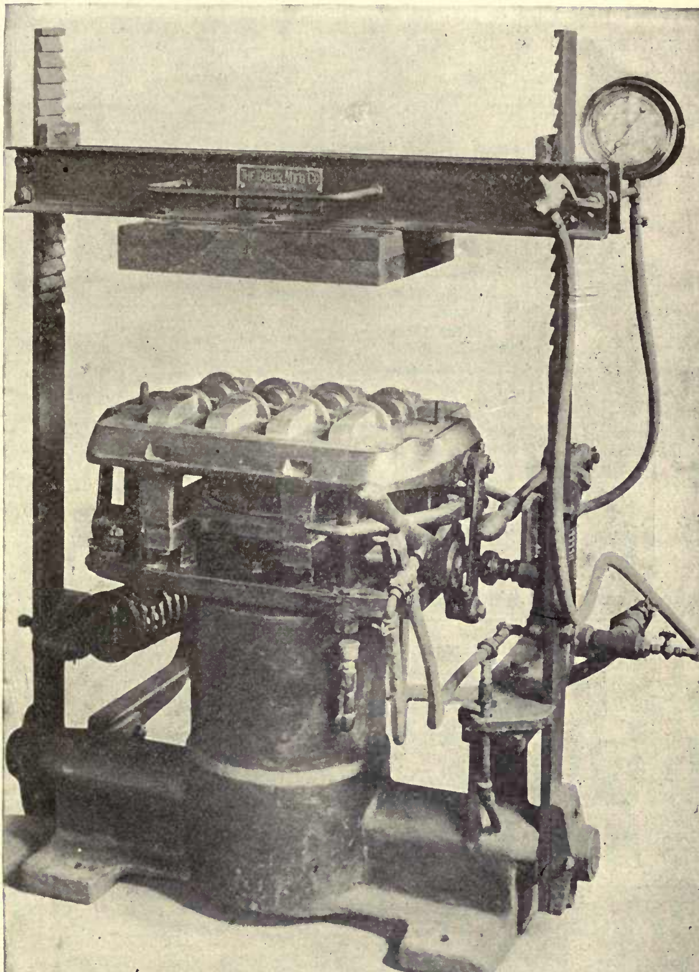


FIG. 195.—SPLIT-PATTERN MOLDING MACHINE.

fastened together, being located with reference to each other by means of dowel pins in the center-line holes. Using the pattern plate as a jig, holes are drilled in the transfer plate to correspond with those drilled in the pattern plate, after which the transfer plate is turned over, not around, so that what was its upper surface is now its lower one and it is once

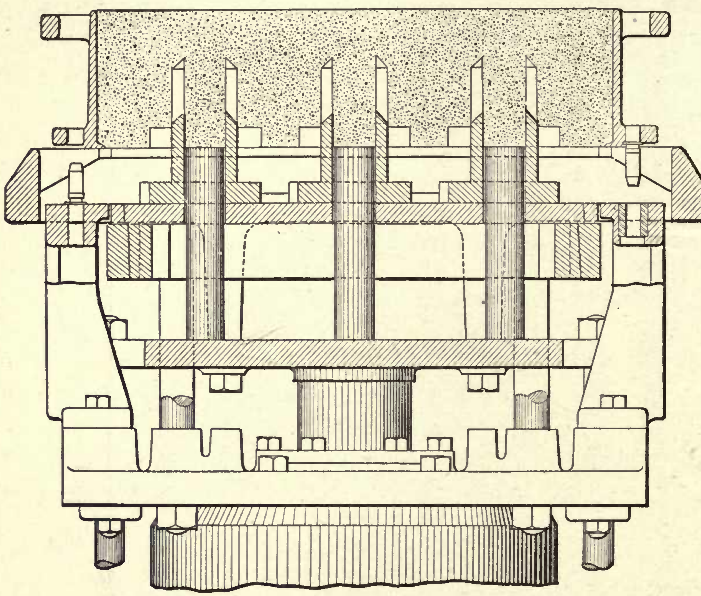


FIG. 196.—STOOLING PATTERNS ON A SPLIT-PATTERN MACHINE.

more placed on the pattern plate, the dowels inserted in the center-line holes, and it is used as a jig to drill the holes in the undrilled side of the pattern plate. The two sets of holes in the pattern plate will thus be symmetrical around the center line, and when the half-patterns are doweled to this plate molds made from them will match perfectly.

Jarring Machines.—For large deep work in which the ramming time is of considerable importance, or for large cores, the jarring machine is of especial importance. This machine requires heavy flasks and large quantities of sand. It consists essentially of a table of massive construction which may be elevated any desired distance by means of air pressure and then suddenly dropped. The pattern, flask and sand are carried on this table, which when it is dropped falls more rapidly than do the former. The inertia of the sand and flask striking the table after the latter has come to rest causes the sand to be firmly packed in the mold. The density to which the sand can be packed varies with the length of drop and the efficiency of the machine increases with the drop and decreases with the dead weight handled over and above the weight of the sand. The machine, to secure best results, must be solidly constructed in the table, and in operation there must be no movement between the pattern, sand, and flask which will tend to pull the sand apart or to fracture the sand into various layers. Badly fitted pattern boards or patterns which are too light for their work, flasks which are crooked, or a light table on the machine will tend to cause such fractures. In ramming a mold on this type of machine it is only necessary to place the pattern in position, set the flask around it, riddle sand over the pattern, and open the air valve. After the table has been given a sufficient number of strokes to ram the sand to the proper density, the mold may be removed and finished by any of the approved methods.

The latest development in connection with the jarring machine is the shockless jarring-machine, a cross section of which is shown in Fig. 197. This is a machine in which the impact of the mold on the table is absorbed within the machine itself instead of being transmitted to the foundation and thence to the surrounding floors and buildings. One great disadvantage of the plain jarring machine is, that in ramming large molds, involving heavy masses of sand, vibrations are set up for a considerable distance around the machine and these vibrations are not only disagreeable to the workers but may also shake down the sand in completed molds, thus doing considerable damage. These vibrations in the case of the machine under consideration are eliminated by means of an anvil mounted in a cylinder and supported on long helical steel springs. The table is elevated by compressed air admitted to the jarring cylinder to raise the table. At a predetermined point in the table movement, the air is automatically cut off, and expanding, raises the table still further. The air from the jarring cylinder exhausts into the anvil cylinder and the jarring table falls by gravity. At the same time, the anvil being re-

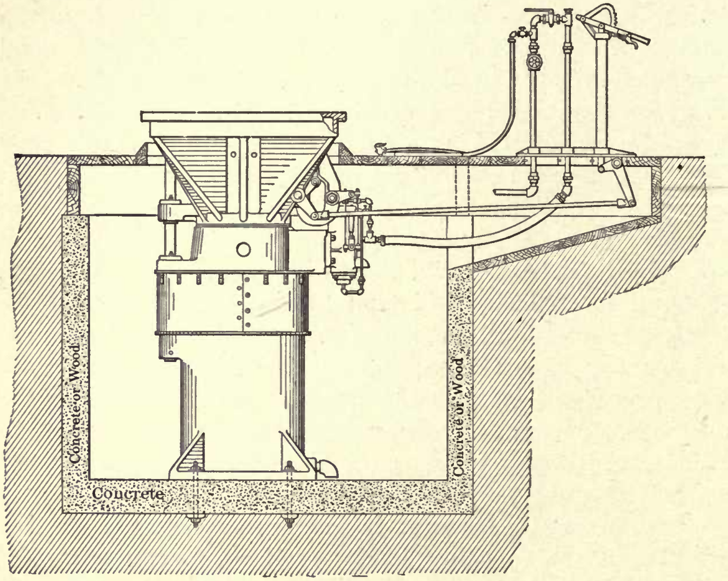


FIG. 197.—SHOCKLESS JARRING MACHINE SET UP IN PIT.

lieved of a considerable portion of its load, is thrown upward by its supporting springs to meet the falling table. The velocity with which it rises is increased by the air expanded from the jarring cylinder into the anvil cylinder. The anvil and the table are brought to rest by their impact upon each other, giving great ramming effect upon the sand but without giving vibration to the surrounding floors, the vibrations being absorbed by the springs and air under the anvil. Machines of this character are built to ram molds weighing as much as 50,000 pounds.

Roll-over Machines.—A roll-over machine in which the pattern, flask, and mold are rolled over and the pattern drawn by hand is shown in Fig. 198. The great advantage of the roll-over machine is that it is portable and follows up the sand pile as it is consumed, leaving behind it completed molds as is

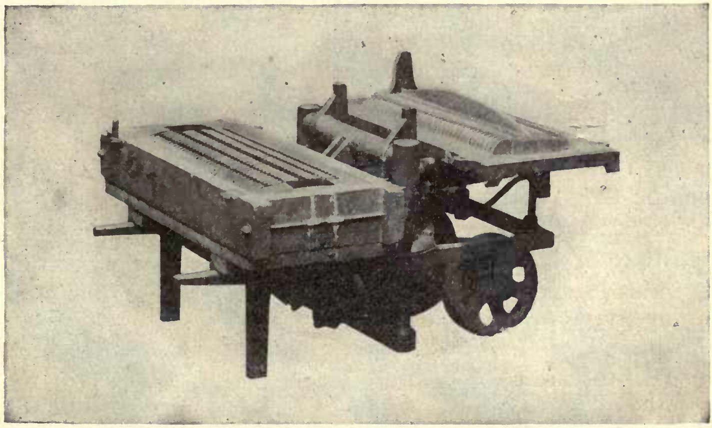


FIG. 198.—PLAIN HAND ROLL-OVER MACHINE.

done in hand molding. It is especially valuable for making intricate molds from straight patterns with little or no draft, and avoids entirely any patching or finishing of molds. A typical pattern molded on a roll-over machine is a grate-bar pattern forming about one hundred and fifty deep green-sand cores. This would be a most difficult mold to make and draw by hand and the time required for finishing would be no small item. However, with the roll-over machine, patching and finishing of the mold is the exception and the output of such a machine on work of this character far exceeds that of hand molding.

The machine consists essentially of a frame on which the mold-board with the patterns is attached. This frame is carried on trunnions, which in turn are supported on sliding frames mounted on accurately machined guides. The frame can be revolved about these trunnions through a half-circle in order to roll the mold over and bring it in position for drawing the pattern. This latter operation is accomplished by means of a lifting lever which raises the frame with the mold-board and pattern attached vertically upward, it being guided by the sliding frames working on the guides before mentioned, thus enabling parallel patterns to be drawn without the aid of draft. Should by any chance any portion of the mold become broken in drawing the pattern, the guides enable the patterns to be replaced in the mold with exactness, after which the mold can be mended much more quickly and satisfactorily than otherwise.

In molding with this machine, the pattern board is placed on the hinged frame and clamped to it. The flask is then placed on the pattern board, its location being determined by pins on the latter. The flask is then filled and rammed as in floor or bench molding and the mold struck off. The bottom-board is then next rubbed on the mold and clamped to the pattern board. The hinged frame is then rolled over until the bottom-board rests on the equalizing cradle. The pattern-drawing lever is next drawn down until the stops on the hinged frame engage the stops on the frame of the machine and the flask is allowed to settle by gravity on the cradle. The clamps are then released and the vibrator started, after which the pattern is drawn by lifting the pattern board clear of the mold by means of a pattern-drawing lever, the frame and pattern board being guided vertically upward by means of a guide on the machine. As soon as the pattern is clear of the mold, it is rolled back to its original position, a new flask placed on the machine, and the operations repeated. An advantage of this type of machine is that it can be kept at work continuously, as the completed mold can be removed by a couple of laborers at their convenience while the molder is ramming up the new mold. The occupation of the cradle by the completed mold does not interfere in the least with the operations of the molder in making a second mold.

When the molds to be made on this type of machine become of large size, it is beyond the ability of the molder and his helper to roll over the heavy flask full of sand by hand, or to withdraw the pattern by hand. In such cases a power cylinder operated by compressed air is added, as shown in

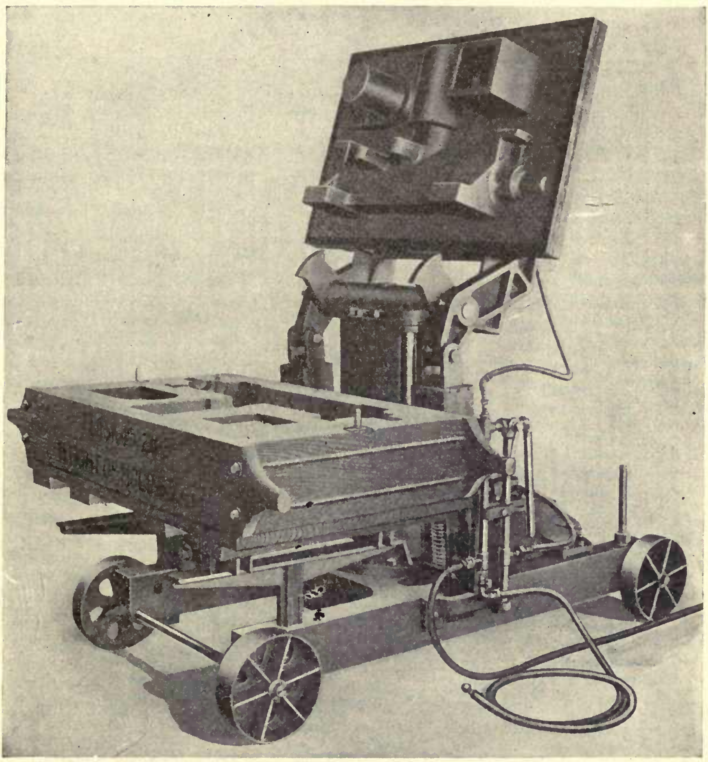


FIG. 199.—POWER ROLL-OVER AND POWER DRAFT MOLDING MACHINE.

Fig. 199, to perform these operations. Otherwise the making of the molds is carried on exactly as before. A still further development of this type of machine is the addition of a jarring machine to the power roll-over attachment, for ramming the molds. This combination gives a machine of the

TABLE I—Description of Operation Molding Drag and Cope (Part of Plow)

Flask 13″ x 17″. 4″ Drag, 4½″ Cope. Hand Molding at Bench

Item	Detailed Instructions	Element Time per Piece Hand Mold
1	Preparation	....
2	....	....
3	....	....
4	Pick up hard-sand match and put on bench	0.04
5	Pick up pattern and put on hard-sand match	0.04
6	Pick up drag and put in place	0.07
7	Shake parting on pattern	0.08
8	Pick up riddle and put on flask	0.02
9	Fill riddle with sand, one shovel full	0.04
10	Riddle sand on pattern	0.08
11	Fill drag with sand (three shovels full)	0.08
12	Peen around edge of drag and butt ram some. (With shovel butt.)	0.10
13	Put two more shovels full in drag	0.06
14	Butt ram	0.30
15	Strike mold off with bar, ⅜×1×36 in. long	0.10
16	Pick up bottom-board and place in position	0.08
17	Roll mold over	0.08
18	Remove hard-sand match	0.07
19	Blow sand off mold (with bellows)	0.07
20	Repeat operations 6 to 10 inclusive for cope	0.29
21	Fill cope with sand, 4 shovels full	0.10
22	Repeat operations 12 to 15 inclusive for cope	0.56
23	Mark sprue hole. (With cope board.)	0.05
24	Cut sprue hole	0.12
25	Rap pattern. Spike going through sprue hole into pattern	0.49
26	Round sprue	0.10
27	Remove cope mold	0.09
28	Blow pattern off with bellows	0.09
29	Draw pattern from mold by hand	0.45
30	Patch up mold. (With slick.)	0.30
31	Close mold	0.12
32	Remove snap flask from mold	0.07
33	Remove mold to floor	0.07
	....	4.20
	Number four riddle	....
	....	....
	Weight of shovel .... 5 lbs.	....
	Weight of sand .... 16 lbs.	....
	Total weight .... 21 lbs.	....

TABLE II—DESCRIPTION OF OPERATION MOLDING DRAG AND COPE (PART OF PLOW)

Flask 13″ x 17″. 4″ Drag, 4½″ Cope. Power Squeezer

Item	Detailed Instructions	Element Time per Piece Mach. Mold.
1	Preparation	....
2	....	....
3	....	....
4	....	....
5	Pick up hard-sand match and put on table of machine	0.04
6	Pick up pattern and put on hard-sand match	0.04
7	Pick up drag and put in place	0.07
8	Shake parting on pattern	0.08
9	Pick up riddle and put on flask	0.02
10	Fill riddle with sand	0.04
11	Riddle sand on pattern	0.08
12	Fill up drag (three shovels full.)	0.08
13	Peen around edge of drag. (Butt of shovel.)	0.05
14	Strike off with board and put in place	0.07
15	Bring yoke over and squeeze (sixty lbs. pressure.)	0.06
16	Roll mold over. (On table.)	0.08
17	Start vibrator and remove hard-sand match	0.03
18	Blow off with compressed air	0.05
19	Repeat operations from 7 to 11 inclusive for cope.	0.29
20	Fill up cope, four shovels	0.10
21	Repeat operations 13, 14, and 15 for cope	0.18
22	Remove cope board	0.03
23	Blow mold off with compressed air	0.05
24	Cut sprue hole	0.08
25	Start vibrator and lift cope	0.12
26	Blow mold off with compressed air	0.05
27	Start vibrator and draw pattern	0.10
28	Close mold	0.12
29	Remove flask	0.07
30	Stop off carrier	0.06
31	Place mold on floor	0.06
	....	2.10
	....	....
	Number four riddle	....
	....	....
	Weight of shovel .... 5 lbs.	....
	Weight of sand .... 16 lbs.	....
	Total weight .... 21 lbs.	....

highest efficiency and one which saves in not only the ramming but the finishing time, and which has an output far in excess of anything possible by other means. It, however, is adapted for situations where there are a vast number of heavy and complicated castings of similar size and shape to be made.

When to Use a Molding Machine.—The question of whether or not the use of a molding machine would pay can be decided accurately only by means of a detailed time-study of the various operations of making a mold by hand and by machine. This time-study would show the amount of time saved by the machine and it is then simply a question of whether there are sufficient castings to be made from a given pattern, the total saving on which would aggregate a sufficient amount of time to warrant the expense of the machine. It should be borne in mind in this connection that a molding machine can usually be run by lower-priced men than are required for making molds by hand. An instance of a time-study on hand molding and on machine molding of the same pattern was given by Mr. Wilfred Lewis, in a lecture before the Franklin Institute in April, 1911. With his permission, the author presents these time-studies together with Mr. Lewis's comments thereon. (See pages 252–253).

In the tables the time given for each individual operation is in hundredths of a minute. By carefully timing, with a stop-watch, each operation of making a mold, it can quickly be observed what motions are unnecessary and by comparing the time study of the hand mold with that of the machine mold, it is easily determined the amount that can be saved by one method as compared with the other. In the two tables presented, the time for molding a part of a plow in a flask 13 by 17 inches, with a 4-inch drag and a 4½-inch cope, both by machine and by hand is given. Comparing these two tables, it will be seen that items 4 to 11 [the item numbers here refer to the table of hand molding] must be done in the same way and will consume the same amount of time, 0.05 minute, whether the mold is made by hand or by machine. Item 12 must be done more thoroughly and consumes more time in hand molding, and item 13 is not required at all in machine molding. Item 14, butt-ramming, 0.30 minute, is equivalent to squeezing by power but consumes five times the time. Item 15, striking off, is performed after ramming, and requires 0.03 minute longer than striking off the unrammed sand on the machine. Item 16 is not required in machine molding. Item 17, rolling over, is the same in both cases. Items 18 and 19 require 0.14 minute, compared with 0.08 minute when compressed air is used on the power machine. Items 20 and 21 are identical for hand or power molding. Item 22 requires 0.56 minute against 0.18 by power. Item 23 is not performed by power as a separate operation and item 24 is the same in both cases. Rapping the pattern, item 25, requires 0.48 minute as compared to 0.12 minute, consumed in starting the vibrator and lifting the cope at one operation on the machine. Item 26 is the same in both cases. Item 27, removing the cope requires 0.09 minute. Item 28, to blow off the pattern, requires 0.04 minute longer with bellows than with compressed air and drawing the pattern, item 29, requires 0.35 minute longer in hand molding than by machine. Item 30, patching, requiring 0.30 minute is not called for in machine work. Items 31, 32, and 33 are the same in both cases, and in molding with the machine an additional operation, stopping off the carriers, 0.06 minute is required. The total time required for making a mold by hand is 4.20 minutes, whereas the machine will do it in 2.10 minutes or exactly one-half the time. Should a vibrator be used on the patterns in making the mold by hand, the total molding time will be considerably reduced, but still enough in excess of the machine time to warrant the installation of machines, provided the casting is to be made in sufficient quantities. Similar studies to the above, if made on any class of molding, will soon tell the best method of work. Time studies may also be applied to two different methods of hand molding or two different methods of machine molding to ascertain which is the most economical.

CHAPTER XX

MENDING BROKEN CASTINGS

CASTINGS are frequently broken in service or they may have some portion defective when made. Unless the break is a very bad one or the defective portion of wide extent it is possible to repair the casting by one of a number of methods. Up to comparatively recent times the only method of making such repairs was by means of the process of burning. More recently, however, the Thermit process and the oxy-acetylene flame have placed in the hands of the foundrymen new tools of high efficiency.

The process of burning a casting is shown in Fig. 200. Assume that a casting with a small projecting arm *D* has had this arm broken as shown. The two parts are bedded into the floor and a parting made exactly as would be done in ramming up a pattern. A shallow cope is set over the broken casting and its position fixed by means of stakes, after which parting sand is riddled on the joint and two gate-sticks set, one a little longer than the other, on either side of the break. The cope is then rammed up and lifted off and the small broken part rapped and drawn from the mold. The broken end is then ground off for a distance of about one-quarter inch and the surface nicked all over with a chisel. This piece is now returned to its place in the mold and a sprue is cut between the two vertical gates leading to the space between the broken ends of the arm. The cope is then replaced, the gate-sticks withdrawn, and by means of snap-flask weights *A*, a deep pouring basin is built above the smaller gate *B* and an outflow *H* is built over the larger gate *G*, this outflow leading to a large basin *I*.

The theory of burning broken castings involves the flowing through the break of very hot iron which will eventually fuse

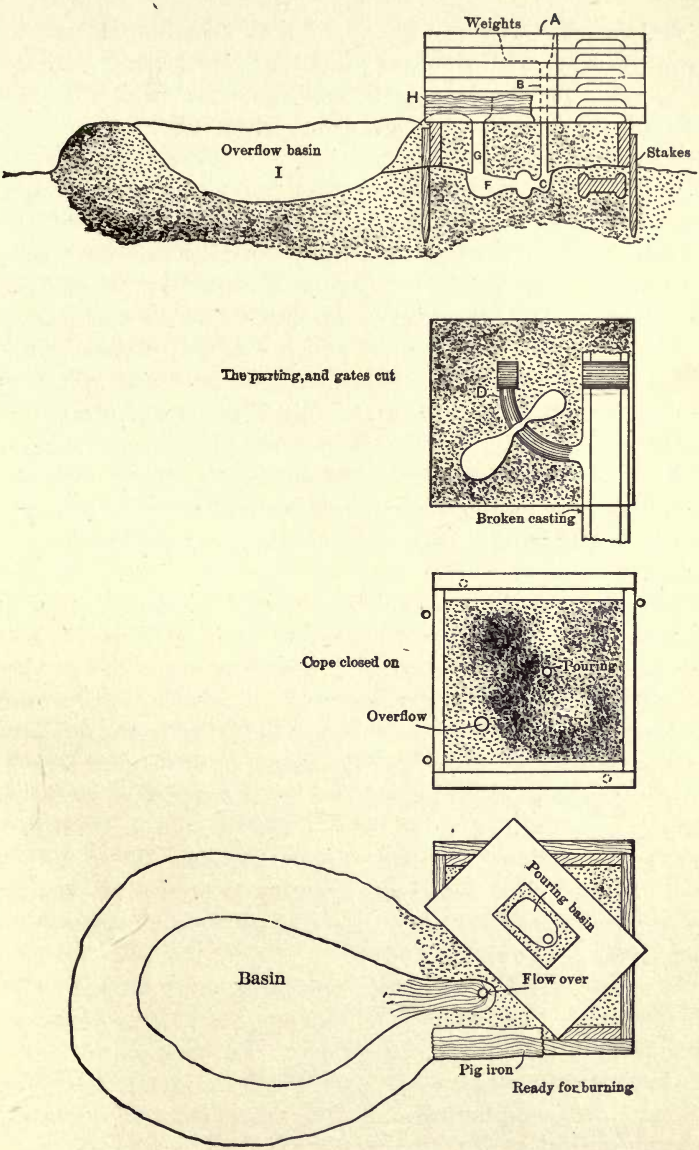


FIG. 200.—MENDING A BROKEN CASTING BY BURNING.

the ends of the broken casting, and then allowing the casting to cool together with the iron which has been poured through the break. The broken parts and the fresh iron will then be found to have solidified in a firm homogeneous mass. The surplus iron around the break is chipped off and the repaired casting is as serviceable as one that has never been broken. The inflowing gate is made considerably smaller than the outflow in order that the iron may flow freely through the break. Should it be retarded in its flow it is liable to chill and fail to melt the ends of the broken casting, in which case a hard glazed surface would be formed which would be more difficult of repair than the original break. It is also important that the pouring basin be at a considerable elevation above the outflow gate in order that there may be a high head to cause the iron to flow rapidly through the break. Care must be taken that the ends of the break are given a sharp jagged surface as the molten iron will not fuse a smooth surface so readily.

If the casting is of such shape that it cannot be readily removed from the sand as in the case just described, grooves may be cut through the break by a milling machine or chisel and after the sprues are cut the sand is carefully blown from these grooves and the cope replaced and the operation proceeds as before. If a portion of a casting of cylindrical section is lost, it can be repaired by bedding the casting in the sand and making a cylindrical mold above the broken portion, the mold being made of sufficient depth to allow for a shrink-head, after which a sufficient quantity of iron is allowed to flow through the mold to fuse the end of the casting and it is then permitted to solidify.

It is not possible to repair breaks of every character by this method. The burning on of a corner or an arm is usually accomplished with but little trouble. To burn metal into a hole in the centre of a casting, particularly if the latter be thin, is a more difficult proposition. The actual burning operation is accomplished easily, but trouble is encountered when the repair cools. The unequal shrinkage of the liquid metal and the moderately heated solid casting surrounding it renders it difficult to make a perfect joint between the two parts and the new metal frequently pulls away from the old. This trouble may sometimes be remedied by preheating the metal of the casting up to about 400° Fahr. before burning, and placing the repaired casting in an oven of this temperature as soon as the burn is made, and cooling it gradually.

Another method of burning is to surround the break with dry-sand cores about an inch above the casting, an outlet being cut in the core so that hot iron can be poured directly on the break and flow off over a notch cut in the core. From one hundred to one hundred and fifty pounds of very hot iron is poured in a thin stream on the break and around the place to be mended. By means of a small rod the action of the iron is ascertained. This method is usually practiced on flat surfaces.

The iron used in repairing breaks in this manner must be extremely soft, especially if the casting is to be machined later. The higher the combined carbon in the iron the harder will be the burned spot. The iron in the casting itself affects to some extent the quality of the iron in the break.

Thermit Welding.—The introduction of the Thermit process has rendered possible the repair of broken castings which was impossible under the older method. Thermit is a mixture of fine aluminum filings and iron oxide, which, when set on fire, gives a temperature of about 5,000° Fahr., the aluminum uniting with the oxygen of the iron oxide. There is thus formed a very pure iron and a slag consisting principally of aluminum oxide. If this is allowed to flow on a casting the intense heat will melt the casting wherever the mixture comes in contact with it and, on cooling, the iron from the Thermit will unite with the iron of the casting and form a homogeneous uniform mass. It is this feature that is taken advantage of in the making of repairs to broken castings by means of Thermit. A typical repair by this method is that of a locomotive driving-wheel with broken spokes. The wheel is laid on the floor and the broken parts are placed as nearly in their original position as possible with a small space left between them at the break. A mold is formed around the break, the parts of which are heated with an oil burner. After they have been brought to the proper temperature the funnel containing Thermit is placed over the part to be repaired, a steel plug being inserted at the bottom of the funnel. A special ignition powder is set on top of the Thermit and lighted and after the combustion of the Thermit is complete the plug is pushed up into the funnel and the iron which has been formed by the combustion of the Thermit is allowed to flow down over the break, the slag flowing into a basin made to receive it. Repairs made by this method are extremely strong, frequently being of greater strength than the original casting.[1]

Oxy-acetylene Welding.—Welding by means of the oxy-acetylene flame has been successfully used in the repair of many difficult castings. Acetylene gas when burned in a blow-pipe with oxygen gives the highest temperature known excepting the electric arc, approximating 6,000° Fahr. This flame can be regulated so that it may be drawn down to a fine point which localizes the heat generated by it to a very limited area. It is this fact that makes possible its use in the repair of castings. The broken parts are brought together and a groove is chipped along the break, the sides of the grooves having an angle of about forty-five degrees from the vertical. The oxy-acetylene flame is played on this groove until the metal in it is fused. A soft iron wire is then melted by placing its end in the groove and allowing the flame from the oxy-acetylene torch to play upon it, when it unites with the metal fused from the casting. On cooling the break will be found to be repaired quite perfectly and the strength of the repaired joint will approximate from 85 to 100 per cent. of the strength of the original casting. Considerable care is required in the manipulation of this process and detailed directions are given for the use of the apparatus by the makers. These directions would

[1] The use of Thermit is covered by United States and foreign patents and complete directions for its use should be obtained from the owners of the American rights, the Goldschmitt Thermit Co., New York.

be out of place here and the reader is advised to consult with the manufacturers of this apparatus before attempting to make use of this process. The leading manufacturers of this apparatus are the Davis-Bournonville Company, New York, The Nelson Goodyear Company, New York, and the Linde Air Products Company, Buffalo.

14

CHAPTER XXI

MOLDING TOOLS

THE tools most commonly used by molders are shown in the illustrations Figs. 201 and 202.

The *shovel* is used for cutting up the sand heap and for filling the flask.

The *water pail* is used for supplying water to wet down the sand for tempering and also for wetting the swab or bosh on the floor molding.

The *riddle* is a sieve used for sifting the sand on to the surfaces of the pattern when starting a mold. The size of the riddle is given by the number of meshes to the running inch. Thus, a No. 8 riddle has eight meshes to the inch and a No. 4 riddle, four. The particular riddle used depends on the character of casting to be made, the finer castings with considerable detail on their surface requiring finer sand and, therefore, a finer riddle.

Rammers, used for pounding the sand around the pattern in the flask, are, for the heavier class of castings, made of iron, although sometimes they are made with a wooden handle with a cast-iron butt at one end and a cast-iron peen at the other end. The small rammers used in bench work are usually made of maple, although sometimes they are made of cast-iron.

The *strike* is used to scrape the extra sand not wanted from the top of the cope or drag and also for leveling the loose sand placed in the bottom of the larger drags before placing the bottom-board. It is usually a thin strip of bar iron, two to three inches wide.

Clamps, used for holding together the cope and drag of the completed mold or for clamping together the mold-board and the bottom-board on either side of the drag when the latter is rolled over, are of many styles and sizes. They are shown at 6, 7, and 8 of Fig. 201. They are made of either wrought-iron or cast-iron and are wedged on the flask by means of the wooden wedges 10. The *wedges* for side-floor use are usually of soft wood and for the heavier work either of hard wood or iron.

The *bellows*, 11, are used to blow parting sand from the pattern and also to blow loose sand and dirt from the mold.

Gaggers are L-shaped pieces of wrought or cast iron. They are shown at 12, Fig. 201, and are used to hold up deep pockets of sand in the mold, which, if unsupported, would fall of their own weight. The gaggers are clay-washed and the friction of them against the body of the sand is sufficient to prevent them falling on account of the weight of sand on the pocket they are supporting.

Soldiers are sticks of wood of varying thickness, used for much the same purposes as gaggers. In certain places, they will hold up sand better than gaggers and can be used in pockets in many places where gaggers would be impracticable.

Trowels, shown at 14, 15, and 16, Fig. 202, are of many different styles and sizes to suit the individual taste of the molder. In floor work, the trowel is used for making the joint on a mold, and it is used in all classes of work for finishing, smoothing, and slicking the flat surfaces of the mold.

Vent-wires are shown at 17, 18, and 19, being steel wires, upset on one end and having a handle on the other. They are used to perforate the mold to permit the escape of gases from it when the casting is poured. They are also used to form holes for gas to escape from cores in the mold to the outside of the mold.

The *bosh* or *swab*, 20, is made of hemp, teazled out to a point at one end and bound with twine at the other to hold it together. It is used to flow a small amount of water around the edge of the pattern in the sand, before the pattern is rapped for drawing from the mold. The bosh will hold considerable water and the amount which it delivers to the sand can be regulated by the pressure the molder applies when squeezing it. Boshes are also used to apply wet blacking to dry-sand molds when they are to be blacked green, that is before the mold is dried, and the blacking slicked.

The soft brush, 21, is used to brush off the pattern and the joint of the mold. The hard brush, 51, is used to spread beeswax or tallow on metal patterns and to brush and clean out between the teeth of gears and similar patterns.

The *rapping* and *clamping bar*, 22, is usually a bar of steel from three-quarters to seven-eighths inch diameter and two feet long. It is pointed at one end to enter rapping plates in a pattern and is flattened and turned up at the other end for convenience in tightening clamps on a flask. For rapping large patterns, the size of the bar is of course increased.

Draw-screws, 23, 24, and 25, are eye-bolts threaded on one end. They are used for drawing large wooden patterns from the sand, being screwed into holes, left for that purpose, in the pattern. They are also used for drawing metal patterns.

The *draw-spike*, 26 and 27, is a piece of steel, sharpened at one end for driving into a wooden pattern to rap and draw it. It is principally used in bench work for drawing small patterns.

Lifters, 28, 29, 30, are used for clearing of loose sand deep places in molds. They are of different lengths and sizes, one end being turned at right angles to the stem, this portion being termed the heel. The straight, flattened portion is known as the blade. The blade and heel are also used to slick the sides of the mold where they cannot be reached in finishing by the trowel or slicker. The heel is also used to slick the bottom of deep places after the sand has been removed.

Slickers, 31, 32, and 33, are formed with blades of varying widths, with the other end of the tool turned to form a heel somewhat similar to the lifter. It is used for lifting loose sand in shallow parts of the mold and for slicking down when patching broken edges. The blade is used to build sand on, to form corners to the proper shape. This tool is used more by molders than any other except the trowel.

Corner tools, 34, are used to slick the corners of molds where a slicker or the heel of a lifter will not do satisfactory work. Corner tools are made with different angles for special work, being usually formed of cast-iron by the molders and polished.

Bead slickers, 35 and 36, are of special shapes and sizes. They are used to slick what are termed beads or hollow places in a mold. They are usually made of steel or composition metal and seldom of cast-iron.

Flange tools, 37, are used for slicking flanges on pipes or cylinders. The rounded ends of the flange tool are made of different radii for use on different flanges. They are usually made of steel.

Spoon slickers, 38 and 39, have spoon-shaped ends and are used to slick rounding surfaces in a mold. They are usually made with one end larger than the other.

Pipe tools, 40 and 41, are used to slick pipe molds in the plain rounding part. Some are made as in the illustration and others are formed more in the shape of a spoon. They are also used on any cylindrical work for facing the interior of cylindrical surfaces. They are usually of cast-iron with a handle set vertically in the center.

Hub tools, 43, 44, 45, and 46, are used in any cylindrical portion of a mold, such as hubs of pulleys or other portions which are too small to permit use of a pipe slicker. One end is turned at right angles for use in lifting sand from the bottom of the hub in order to slick it. The back of the heel being rounded, the hub tool can be brought in close to the edge of the mold for finishing. They are made of steel or composition metal.

The *double-ender*, 47, comprises a slicker at one end and a spoon slicker at the other. They are usually made to the molder's order and are used by bench molders on small molds.

The *camel's-hair brush*, 48, is used to brush dry blacking on the face of the mold.

The *wooden gate-pin*, 49, sometimes called a sprue, is a round tapered pin used to form the gate extending through the cope into which iron is poured into the mold. They are of

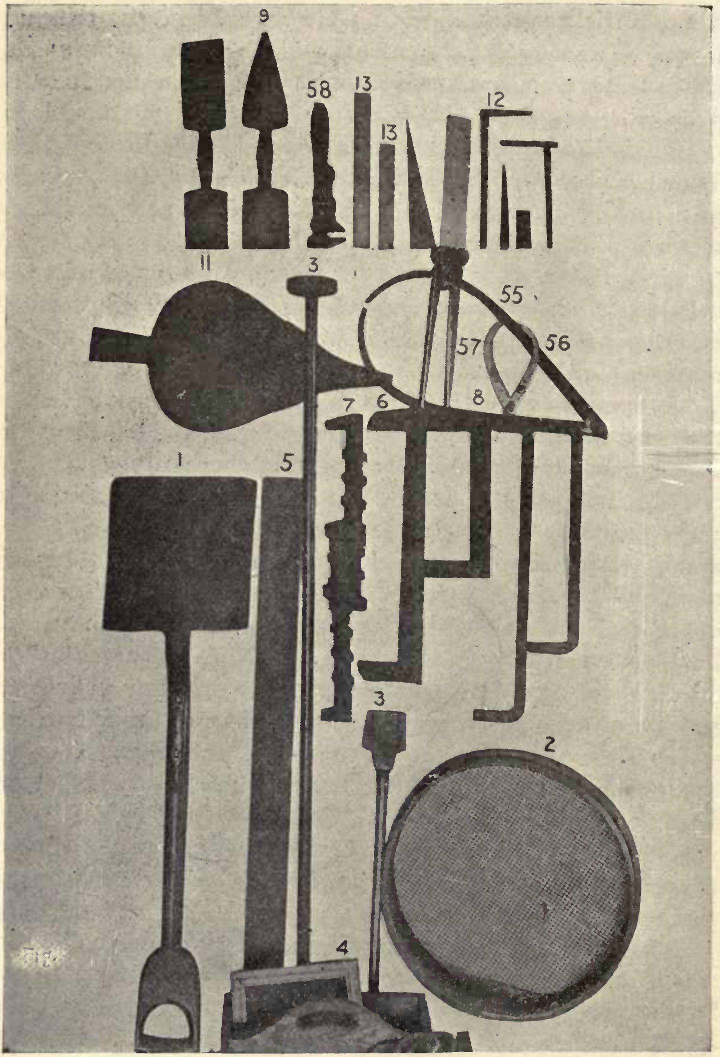


FIG. 201.—MOLDER'S TOOLS.

1, Shovel; 2, riddle or sieve; 3, iron rammer; 4, tool box; 5, strike; 6–8, clamps; 9, hand rammer; 10, wedges; 11, bellows; 12, gaggers· 13, soldiers; 55–56, calipers; 57, cutting nippers; 58, monkey wrench.

FIG. 202.—MOLDER'S TOOLS.

14–16, Trowels; 17–19, vent-wires; 20, bosh or swab; 21, soft brush; 22, rapping or clamping bar; 23–25, draw-screws; 26–27, draw-spikes; 28–30, lifters; 31–33, slickers; 34, corner tool; 35–36, bead slickers; 37, flange tool; 38–39, spoon slickers; 40–41, pipe tools; 42, button tool; 43–46, hub tools; 47, double-ender; 48, camel's-hair brush; 49, wooden gate-pin; 50, rapping iron; 51, hard brush; 52, spring draw-nail; 53, 54, sprue cutters.

the size required by the class of mold, and occasionally may be square or octagonal in cross section.

The *rapping iron*, 50, is used to rap or jar gated patterns in the mold. It is commonly used in connection with the rapping bar, 22, which is entered through the hole in the cope made by the gate-stick. The bar entering a hole in the striking gate on which the patterns are soldered, it is struck with the rapping iron to jar the pattern at the same time in both the cope and drag.

The *spring draw-nail*, 52, is used for drawing small patterns. It consists of two pointed rods, joined together with a spring, which forces the points outward. It is used for drawing small patterns by inserting the points of the two rods in a hole in the pattern, the points being pressed together; on releasing the points, they spread apart and give sufficient grip on the pattern to draw it.

The *gate* or *sprue cutter*, 53, is a piece of sheet brass bent to a semicircle on one edge. It is used to cut the channel in the drag from the hole left by the gate-stick to the mold.

Another form of sprue cutter is shown at 54, being a cylindrical metal tube used to cut the gate in the cope when the gate-stick has not been used.

Calipers are more used by the core-maker than the molder. The molder uses them to verify the sizes of cores in order to make the proper size of core-print and also to obtain the length of smaller cores. The calipers in this case are set at the proper length and the core filed to fit. This is important in dry-sand work, since, as there is no give to a dry-sand mold, it will be crushed if the core is too large when the mold is closed.

Cutting nippers, 57, are used to cut the smaller wires in core-making to the desired length.

The *monkey wrench* is used to screw down rod bolts to hold binders with which the mold is fastened and also to tighten bolts in iron flasks.

CHAPTER XXII

MOLDING SANDS

MOLDING *sand* is a sand possessing those qualities which enable it to be tempered and formed to definite shapes which it will retain when molten metal is poured in it, and which has the requisite chemical composition to enable it to resist fusion from the heat of the molten metal. Molding sand must also have sufficient permeability to permit the free escape of gases from the mold while it is filling with metal, without scabbing or otherwise injuring the surface of the mold. The sand also should be capable of being retempered and used for successive molds without the addition of new sand to provide bond.

Molding sand is found in large deposits in the United States in the states of New York, New Jersey, Ohio, Indiana, Illinois, Missouri, and Kentucky. It is also found in smaller deposits in Michigan, Wisconsin, Connecticut, and Massachusetts. The characteristics of the sands from these different localities vary and they are not all suited to every grade of work. Combinations or mixtures of sands from one locality with those from another, will often give a desired grade and quality of molding sand when none of the component sands is suitable.

The principal requirements of a good molding sand are: resistance to fusion; bond; permeability and porosity. An excess of lime—one per cent or more—will lower the power of the sand to resist fusion. If present as a silicate, it will combine with the silica and alumina of the sand under the influence of the heat of the molten iron, and will vitrify and form a scale on the casting. Permeability, or ability to permit the passage through it of gases formed in the mold while filling with metal, is one of the most important qualities of molding sand. There is a difference between permeability and porosity. The porosity of a sand is the ratio of voids or pore spaces to the total volume of the sand, while the permeability depends on the area of the passage ways through the sand formed by these voids. Air fills the pores in the mold, and this when heated during the pouring of the metal, expands. The sand must have sufficient cohesion or bond to resist the pressure due to this expansion, and it also must have sufficient permeability to permit the escape of the contained air and of the gases generated in pouring. The greater the ease with which the air and gases escape, the less need there is for a strong bond. In green sand, more or less water is contained in the mold which is converted into steam in casting, and this also must escape. If these various fluids cannot escape easily through the mold or core, blow holes are formed and the casting is injured. A molding sand, therefore, must not only have cohesion between its particles to withstand certain strains, but it must at the same time possess the desired permeability.[1]

The experiments of King[2] show that the finer-grained sands, even when the grains are approximately the same size, have greater pore space than the coarser sands when both are equally tamped. The average pore space of seven samples of No. 100 quartz sand[3] was 36.6 per cent., while that of three samples of No. 20 sand was 33.9 per cent. The same experiments show that sharp, angular sands have a greater pore space than rounded sands of the same size, indicating apparently the greater difficulty of making angular grains pack well. It was also found that the smallest pore space was obtained when two sands of rounded grains, but of quite dissimilar diameters, were mixed in about equal proportions by weight. The theoretical minimum pore space of sand with spherical grains is 25.95 per cent., and only once in these ex-

[1] Annual Report of the State Geologist of New Jersey, 1904, page 199. Report on molding sands.

[2] Nineteenth Annual Report of the Director of the U. S. Geological Survey, II., pages 209–215.

[3] Sand retained on a sieve with 100 meshes to the inch but passing an 80-mesh sieve.

periments did the pore space fall below this minimum. From these experiments, the conclusions can be drawn that (*A*) pore space can be reduced by tamping, but the theoretical minimum can be reached but rarely; (*B*) under equal treatment, mixed sands of different grain diameters give lower pore space than do sands of uniform grain, the degree of rounding being the same; (*C*) angular sands have more pore space than rounded sands, other things being equal; (*D*) the least pore space may be expected when the round grains are about equally divided between large and small with no intermediate sizes. It is evident that the closer the packing of the grains, the less the permeability, and, other things being equal, coarse sands are more permeable than fine, and angular sands more so than rounded.

Chemical analysis, while determining the amount of bond in the sand, and also its resistance to fusion, does not determine whether or not a good casting can be produced with a certain sand. Microscopic tests are also necessary, as these will reveal the shapes of the grains of sand, whether the grains are flattened, rounded, or angular which in turn determines how closely the mold can be rammed and still permit the gases, generated in pouring, to escape. A sharp angular grain is of the utmost importance, since with this grain the sand can be firmly rammed around the pattern and yet give a porous and permeable mold. With a strong open sand, a poor molder will often make a better casting than will a good molder using a sand lacking in permeability. A molding sand with grains nearly round, while making a good mold, requires more attention than the other.

If heavy castings are to be made, the sand must withstand a high degree of heat for a considerable period and, to resist fusion, a sand containing more silica and less bond is required. The refractoriness of sand depends upon its silica content, but the bond decreases as the silica increases. When the sand available for large castings is considered too close in texture to have sufficient permeability and refractoriness, silica sand or ground silica rock is sometimes added to open up the molding sand.

TABLE I

Locality	Use	Silica (SiO_2) Per cent	Alumina (Al_2O_3) Per cent	Ferric Oxide (Fe_2O_3) Per cent	Lime (CaO) Per cent	Magnesia (MgO) Per cent	Potassium Oxide (K_2O) Per cent	Soda (Na_2O) Per cent	Comb. Water Per cent
Not stated[1]	Fine snap work	81.50	9.88	3.14	1.04	0.65	Undeterm.	Undeterm.	3.00
" "[1]	Medium work	84.86	7.03	2.18	0.62	0.98	"	"	2.20
" "[1]	Coarse sand, heavy machine casting	82.90	8.21	2.90	0.62	0.00	"	"	2.85
" "[1]	Heavy machinery in dry-sand molds	79.81	10.00	4.44	0.70	0.88	"	"	2.89
England[2]		92.91	5.85	1.25	tr.				
Germany[2]		92.08	5.41	2.50	tr.				
France[2]	Bronzes	91.91	5.68	2.18	0.41				
Germany[2]		91.61	2.11	2.53	tr.				
"[2]		90.62	6.67	2.70	tr.				
"[2]		90.25	4.10	5.51	0.23				
"[2]		88.00	2.78	3.77	0.73				
England[2]		87.60	7.70	3.60	0.96				
"[2]		86.68	9.23	3.42	0.96				
Italy[2]		83–77	8.2–7.7	4–2.8		.73–.38	5.78 to 3.17		
Germany[2]	Artificial mixture ground in ball mill for finest work.	79.02	13.72	2.4		0.71	4.58		
Japan[3]		67.60	17.64	1.6[a]	0.86	1.41	3.69	0.14	
Albany[3] No. 1	Before using	80.88	14.03		0.74	MnO_2–0.22			2.54
"[3]	After use	80.55	14.47		1.66	MnO_2–1.33			

[1] W. Ferguson, *Iron Age*, vol. lx, 1897, p. 16. A–Fe_2O_3. [2] E. C. Eckel, Twenty-first Report State Geologist of New York, 1901, p. 93. [3] S. H. Hamilton, Laboratory New Jersey Geological Survey. [a] Fe O – 2.3%.

The table herewith has been derived from the reports of various State Geologists. It indicates the chemical composition of various grades of molding sand together with the uses to which they are best adapted.

TABLE II shows the analyses of molding sand from different parts of the United States. Of these Nos. 1 and 2 are stove-plate sands, while 3 and 4 are used for general work.

TABLE II

	1 Per Cent	2 Per Cent	3 Per Cent	4 Per Cent
Silica	79.36	79.38	84.40	85.04
Alumina	9.36	9.38	7.50	5.90
Ferric oxide	3.18	3.98	2.52	3.18
Lime	0.44	1.40	0.06	0.06
Magnesia	0.27	0.54	0.21	0.14
Potash	2.19	1.80	1.29	1.65
Soda	1.54	1.04	0.65	0.83
Titanic oxide	0.34	0.44	0.44	0.78
Water	2.02	2.50	1.49	1.57
Moisture	0.74	0.80	1.76	1.11

The following analysis of a sand with an angular grain formation will prove a good sand for stove-plate work. For light bench castings, however, it should have more bond.

TABLE III

	Per Cent
Silica	80.98
Alumina	9.50
Oxide of iron	3.90
Lime	0.60

The following analyses of molding sands are from the joint report of B. H. Hamilton and H. B. Kummel, on "Molding Sands of New Jersey."

TABLE IV

Unused No. 1 Albany Sand

	Per Cent
Silica (SiO_2)	80.88
Alumina (Al_2O_3) / Iron oxide (Fe_2O_3)	14.03
Lime ($CaCO_3$)	1.32
Combined water	2.54
Specific gravity	2.65
Pore space	43.3
Tensile strength	4.31 lb. per sq. in.

Pan, 80; clay adhering, 5.5; fineness, 95.00.

Albany Stove-Plate Sand

Pan, 77; clay adhering, 1 + ; fineness, 95; specific gravity, 2.65; pore space, 41.55 per cent.

New Jersey Molding Sands

I. Sand for brass molding and light malleable castings—pan, 84.5; clay adhering, 2.5; fineness, 95.2; pore space, 43 per cent.

II. Stove-plate sand—pan, 71.36; clay adhering, 0.565; fineness, 88.4; pore space, 37 per cent.

III. General foundry work—pan, 11.5; clay adhering, 3.0; fineness 72.2; pore space, 37 per cent.

IV. Heavy castings—pan, 13.89; fineness, 72.2; specific gravity, 2.633; pore space, 37 per cent.

V. Lumberton Loam No. II—pan, 44.42; clay adhering, 10.27; fineness, 85; pore space, 47.4 per cent.

Coxsackie (N. Y.) No. 2 Sand

Pan, 52.52; clay adhering, 5.0; fineness, 83.9; pore space, 33 per cent.

The character of casting to be made governs the selection of the molding sand to be used. Small, thin castings for ornamental work, having on their surfaces a series of lines, depressions, and projections, require a very fine-grained molding sand. A coarse sand, used in this connection, will not only refuse to reproduce the design but will leave rough surfaces and imperfect lines on small castings. For molding very fine castings in bronze, what is known as French sand is necessary. See analyses in Table I.

In the United States a sand known as Windsor Locks (Conn.) is used in making castings for chandelier and similar fine composition work. A sand used for bronze, brass, or other composition castings is not subjected to as high a temperature as that used in iron casting, owing to the lower melting point of the composition metals, and, therefore, castings may be permitted to remain in the mold until cooled. For brass and small iron castings, a grade of sand known as No. 00 Albany sand is frequently used instead of Windsor Locks sand. Among these classes of castings are toys, shelf hardware of the lighter kind, small novelties, name-plates, and small gears. Sands of similar texture to these two are found in Kentucky, Ohio, and Indiana.

For somewhat heavier castings, in general bench work, No. 0 Albany sand is used. The most commonly used sand in the Eastern States is No. 1 Albany sand. It may be used for nearly all kinds of castings, both brass and iron and for castings of considerable size. When used for composition or brass castings, it is made somewhat drier than when used for iron, as composition metals will not lie quietly against a damp surface and a scabbed face will result. For boiler fronts, cab brackets for locomotives, and general light castings on bench or side-floor work, cotton and woolen machinery castings and small tool castings, highly permeable sand should be used.

No. 2 Albany sand, or sand of a similar grade, is largely used for side-floor work and for some of the heavier castings molded under a crane. It may be used for castings weighing several tons. As much depends on the skill of the molder as on the sand when making molds for castings whose weight is measured in tons. A scabbed casting may often result from improper venting of the mold, especially where the iron remains in a molten state for any length of time after pouring. The sand is often blamed for poor results whereas they rightly should be traced to the ignorance of the molder in regard to vents and passageways through which gas may escape from the mold.

Lathe beds, locomotive and small-engine castings, made in green sand, may be molded in a sand of similar analysis to that of Coxsackie No. 2. Albany sand No. 3, or Albany sand No. 4, are quite similar to this Coxsackie No. 2 sand, although it is somewhat coarser. They are used for printing-press frames, planer beds and tables, drop-press beds, shear frames, beds for stone crushers, engine beds, and the heavier machine-tool castings. It is also used as a component in mixtures for skin-dried and dry-sand molds and for core-sand mixtures.

As the sand becomes coarser, its bonding properties which give cohesion decrease, and the silica content, which aids in resisting fusion, increases. Many castings molded in green sand remain in a liquid state for a considerable period after pouring. They also require churning, pumping, or feeding with hot iron, during which period the sand is constantly absorbing heat from the casting. Hence, the resistance to fusion must be great and also the cohesiveness to prevent the sand crumbling under the intense heat to which it is subjected. It is therefore evident that the selection of the proper grade of molding sand for making any given class of castings, requires a knowledge of chemical analysis and of the granular formation. While any of the larger foundry-supply houses, as The S. Obermayer Co., Whitehead Bros., or J. W. Paxson & Co., will supply a good grade of sand for any given class of castings, the foundryman should have a general knowledge of the properties of molding sand in order to obtain the best results with the different classes of castings which he is required to make.

In making castings with a very smooth surface, a sand that has been previously used will give a better surface than a new sand, fresh from storage. It is presumed, of course, that the used sand has sufficient strength, molding sand becoming "rotten" or weakened by constant use. If it is necessary to use new sand, it is advisable to first spread it on the floor and then flow molten iron over it to burn it. The following day, some of the old sand from the heap should be mixed with this sand and used as a facing on the mold.

Molding sand, as it comes from the pit where it is mined, contains a certain amount of vegetable or animal life. The sand must be burned to get rid of this. As an instance of what may happen in an unburned sand, the case of a large mold which remained unpoured for a number of days after finishing may be cited. This mold was made of new sand and on being opened, prior to pouring, it was found that a number of plants were sprouting from the face of the mold. Considerable time was lost and no little expense incurred in going over the face of the mold to repair the damage caused. The importance of properly preparing molding sand, to prevent occurrences of this character, is becoming recognized and machinery is now on the market for such purposes.

Molding sand, after being used a certain length of time, loses its bond or cohesion. Every time a casting is removed from the mold, a certain amount of sand adheres to it and is thereby lost. New sand is added to the sand heap, not only to make up for this loss, but to restore the bond to the older sand. New molding sand is of a yellowish or reddish yellow appearance, ranging to a deep reddish brown due to the presence of oxide of iron. Molding sand which has been used gradually assumes a deep black color, due to the presence of the seacoal facing which is burned into the sand.

When the sand heap becomes very black in color, mechanical tests should be applied and, if found lacking in strength, the sand should be renewed. A mold made of sand of low strength is liable to have the face washed from it by the inflowing iron or, in closing the mold, a portion of the sand is liable to drop.

Foundrymen have many methods of testing the physical quality of molding sands. For instance, a foundryman will take a handful of tempered sand, squeeze it in his hand to form an elongated mass. He then suspends it by one end from between his thumb and forefinger. If it breaks off from its own weight, it is not considered a strong sand. If, however, it hangs together, thus indicating strength, there may be an excessive amount of clay present. Therefore, a small portion is wet and rubbed between the thumb and forefinger, the amount of clay being judged from the stickiness of the sand as shown in this operation. Frequently, an open mold is made of the sand under consideration and after feeling it to determine the hardness, iron is poured on it and its action observed. The test gives a very close estimate of the value of the sand. While these different tests have their value to the experienced foundrymen, they are not in any case equal to a microscopic and chemical examination of the sand. Generally, if a sand in use in a foundry is satisfactory to those in charge of the practical operations, it is unwise to change, as there is considerable liability of many castings being lost before the molders become accustomed to the new sand.

The report of the Board of Geological Survey of the State of Wisconsin, in 1907, says regarding molding sands: "Unfortunately no standard method of examination or testing has been adopted by the foundrymen, much as this is to be desired. A few buy their sand on the basis of composition; others specify sands of a certain texture or both texture and composition may be considered. The majority of foundrymen, however, depend upon the judgment of their foreman who, in many cases, uses empirical methods for determining the value of the material. If the fears expressed by many foundrymen are well founded, the time may not be far distant when the supply of high-grade sands will be exhausted and the production of artificial materials, by the admixture of sand and clay, will be necessary."

Preparation of Sand for Molding.—After the flasks in which the previous day's castings were made have been shaken out and the castings removed from the sand, the sand is wet down. The molder or his helper do this with a pail of water, throwing the pail around in a circular path and tipping it so that the water will fly over the edge on one side and form a thin sheet covering quite an area. This operation is continued until, in the judgment of the molder, the sand is sufficiently damp. If, in molding on the previous day, the sand has shown insufficient strength, new molding sand is at this point added to the heap, it being spread over the entire surface. The sand is then "cut over" with the shovel. As each shovelful of sand is thrown, a twist is given to the shovel to spread the sand as much as possible. Lumps are broken up with the flat or under side of the shovel. Any dry portions, which are encountered in cutting the sand, are moistened, care being taken to avoid making the sand too wet. An excess of moisture in the sand will cause the metal in the mold to bubble or "kick," whereas sand that is too dry will crumble when the pattern is drawn. It is difficult, if not impossible, to describe a properly tempered sand, which is determined by the sense of touch of the molder. This can be acquired only by experience.

As sand may remain in a flask for some little time after the mold has been poured, it may bake hard in the flask. When the mold is shaken out, the sand will be found to have formed in a mass of large and small lumps. These must be broken up before water is applied, otherwise moisture will not soak in when the sand is wet down. The effect of not breaking these lumps becomes evident when molding. If one of these lumps is broken up while sand is being riddled over the pattern, a small shower of dry sand will fall into the mold and will fail to cohere to the tempered sand. The result will be a rough, a broken casting. The more thoroughly sand is tempered and cut over, the more easily it will be worked by the molder.

Information regarding the molding sands, fire sands, and fire-clay of various States, can be obtained from the State Geologists and Mineralogists. The more important reports on these subjects are as follows:

Pennsylvania. "Report of Topographic and Geologic Survey Commission, 1906–1908." "Annual Report of the Secretary of Internal Affairs, Pennsylvania, Part III, Industrial Statistics, 1907."

Wisconsin. "Bulletin 15. The Clays of Wisconsin and Their Uses."

Michigan. "Report of the State Board Geological Survey, 1907."

New Jersey. "Report of the Geological Survey of New Jersey, 1904."

New York. "Clay Industries of New York, 1895." H. Ries. "Clays of New York; Their Properties and Uses." H. Ries. "Mining and Quarry Industry of New York." D. H. Newland, 1905, 1906. "Mining and Quarry Industry of New York, 1906, July, 1907." "Mining and Quarry Industry of New York." D. H. Newland, 1907, 1908.

Missouri. "Missouri Geological Survey Report. Sand and Clays." Wheeler.

Facing Materials

For forming the surface of molds, it is often necessary to use a different material from molding sand. There are many facings on the market, the more common ones being seacoal, plumbago, powdered charcoal, talc, and gashouse carbon.

Seacoal.—Seacoal is a facing made from bituminous coal. It obtained its name from the fact that coal was formerly brought to London by sea, and became known as seacoal in contradistinction to coal brought in overland. The name has clung to it, although in a strict sense it is meaningless.

Most of the seacoal facing manufactured in this country is made from coal mined in Westmoreland County, Pa. A good gas coal is required for manufacturing first-class seacoal facing, as it must contain a high percentage of volatile matter, with a low percentage of ash and other impurities. The writer is indebted to the S. Obermayer Co. for the following information regarding seacoal: Coal of approximately the following analysis is used: Fixed carbon, 60.52 per cent.; water, 1.37 per cent.; volatile matter, 34.75 per cent.; sulphur, 0.678 per cent.; ash, 21.675 per cent. The coal is prepared by being ground, screened, and bolted to the degree of fineness desired.

For use in molds for the heavier castings, most foundrymen prefer it ground to what is termed "gunpowder." This grade is also used on medium crane, and heavy side-floor work. The finest ground and bolted seacoal facing is used on light work where intricate designs are traced on the face of the pattern. Seacoal is used in the foundry, mixed with molding sand in different proportions according to the class of castings to be made.

For castings one-quarter of an inch thick it is used mixed in the proportions of one part of seacoal and twelve parts of sand, depending somewhat on how sharp the iron is to be poured, and with lesser amounts of sand to one part of seacoal for the heavier castings.

For castings one-eighth of an inch thick, as for certain classes of cotton machinery and in the teeth of fine gears which are hard to free from sand with pickle, it is mixed in the proportion of one part seacoal to twenty parts of sand, while on car-wheels it is used one of seacoal to nine of sand. It often is used in front of a gate where there is supposed to be danger of iron cutting the mold as it enters.

One part of seacoal to five parts coarse molding sand is about as strong as it can be used. It is well tore member, when using strong seacoal facing sand, to use the vent-wire freely, as, the stronger the facing, the more gas there is to escape.

In mixing seacoal facing for green-sand work, the sand should be used as dry as possible, and when the proper proportion of seacoal has been added to the sand, it should be shoveled over in order to mix it thoroughly, and then riddled. If flour is to be added to the mixture it is added at the same time as the seacoal. The mass is wet down and turned over in order to mix it, and is tramped to force the component parts together, and to break up the lumps. It is next passed through a No. 8 sieve. For some of the larger castings a little flour is added, say, one part flour to twenty-five parts sand for a mold that is to be skin-dried, and one of flour to thirty-two of sand where it is not skin-dried, this usually being done when a poorer grade of molding sand is used which is deficient in bond.

When mixing the seacoal and sand it is well to remember that if mixed too strong, or if too much seacoal is used in proportion to the amount of sand, the casting will be "veined" or "mapped."

Seacoal is not used generally to produce an especially smooth surface on castings, although, if a little lead be used with seacoal facing, there will be produced a fairly smooth casting.

Plumbago.—Among the many facings used in the foundry to give the castings a clean, bright surface, and to prevent the sand from burning on to the face of the casting, there is no greater favorite than the facing known as plumbago; silver lead and Ceylon lead stand high. There are large quantities of Ceylon lead used in the manufacture of foundry facings, and the richer they are in it, the better the results obtained. The pure material gives the smooth surface desired in machinery castings, it being applied after the mold is faced with the seacoal facing.

Ceylon lead or graphite is "native carbon in hexagonal crystals, also foliated or granular masses, of black color and metallic luster, and so soft as to leave a trace on paper." It is often called plumbago or black lead. Ceylon graphite of high grade for facing purposes should analyze about as follows: moisture, 1.20 per cent.; alumina, 3.06 per cent.; silica, 16.14 per cent.; oxide of iron, 5.90 per cent.; lime, 0.90 per cent.; graphitic carbon, 72.80 per cent.

The bulk of Ceylon graphite imported for foundry facings runs between 50 to 60 per cent graphitic carbon. For thin castings the lead is usually placed in a bag which is shaken over the mold, the lead passing through and falling lightly on the face of the mold until enough has been applied to give the desired result. After it has been brushed with a camel's-hair brush, the mold is blown out with the bellows to remove any lead not adhering to the face of the mold.

In molds for very thin castings the lead at times cannot be brushed on. In such cases a little charcoal is dusted on top of the mold and the pattern is printed back, the charcoal keeping the lead from sticking to the pattern and spoiling the face of the mold. Or it may be dusted on and blown off as the condition and form of mold may require. Thicker castings, however, require the aid of seacoal facing. With such molds, the lead is sometimes brushed on with a camel's-hair brush, light, quick strokes being used. Again, on the heavier castings it may be rubbed on with the hand and then lightly brushed off; also it is often slicked on with the trowel and slicker.

For blacking dry-sand molds lead is sometimes wet with molasses water, and brushed on, and the heavier castings are usually blackened with a mixture made to the consistency of cream and laid on with a swab. After the blacking has been allowed to set, the face of the mold is slicked all over with tools, and then lightly brushed with molasses water to give it a finishing smoothness. It is also used in the same way for blacking cores.

On loam molds, it is advisable to boil and add a little common starch to the blacking mixture, and to slick the blacking green on the face of the mold. The starch will prevent the blacking from flaking off in thin sheets. Clay water is sometimes used instead of starch.

German lead is sticky on green-sand molds when used alone and requires a coating of charcoal over it to prevent it from adhering to the tool. It is largely used for mixture with other blackings, to make a wet blacking for dry-sand and loam molds. It will peel heavy castings when used properly.

Mexican and Austrian leads, or graphite, are used by many in place of Ceylon lead, as they are much cheaper, but do not work as nicely on the heavier class of castings, or give them the attractive color or surface that Ceylon lead does. They do not resist heat and protect the mold like Ceylon lead.

Blackstone and Valley Falls lead, also called Rhode Island facing, is a carbonaceous mineral which is neither coal nor lead, but when ground fine and applied to the face of a mold is capable of protecting it from the intense heat of the molten metal. It is naturally sticky and, if shaken on to the face of a mold through a bag and slicked, requires a coating of charcoal to prevent it from sticking to the tools. It was, and is still, used to some extent as a facing for stove-plate molds, by being shaken on to the mold through a bag, after which a coating of charcoal is shaken on top of it and the pattern replaced. This is called "printing back the pattern." It is also used with other blackings to make wet blacking, for dry-sand and loam work.

Lehigh blacking consists of Lehigh coal ground fine and is used to mix with other blackings to make wet blacking for dry-sand and loam work.

Coke blacking is coke ground fine for mixing with other blackings for making wet blacking.

Charcoal blacking or powdered charcoal is used on green-sand molds over other blackings which would stick to tools. It is used in stove-plate work when printing back to prevent other blackings from sticking to the patterns. It may be used as a facing for dusting on very light work, but it requires something to cause it to adhere to the face of the mold. For this reason it is used in place of parting sand at times, to part molds in making very light castings. It is used, too, in mixtures of wet blacking to keep the tools from sticking to the blacking and to allow the blacking to be slicked, which could not be done if charcoal were not used.

Talc or soapstone, sometimes called white plumbago, is used in mixtures of blacking for cores and for dry-sand work. It will give a coating capable of resisting a high degree of heat, and when shaken on the face of a mold after the mold has been given a coating of lead, or other blacking, the iron will run on it farther and smoother than it will without it. In this way cold shuts may be avoided. Castings made in molds in which it has been used show something of a cream color when coming from the sand, instead of the handsome blue shade shown when Ceylon lead is used.

Gashouse carbon facing is carbon taken from the gas retorts and ground. It is one of the best facings for mixing with others for wet blacking for cores, dry-sand, and loam molds.

Fire sand is a highly refractory silica sand used in making molds for iron and steel. In the foundry it is used to mix with coarse molding sand to form mixtures for making dry-sand and loam work and to make mixtures for facing molds of cylinders for steam- and gas-engines. Of the larger sizes, hydraulic and pump cylinders, rolls and castings requiring to be sound and clean, or to have a positive thickness of walls or where on account of the weight or for some special reason it may be considered safer to make the casting in dry rather than in green sand.

As a base to work from there may be used seven parts good coarse molding sand and seven parts coarse New Jersey fire sand mixed, to which is added one part flour and after the whole has been thoroughly mixed it should be wet with molasses water mixed in the proportion of one part molasses to fourteen or sixteen parts water.

The mixture is varied according to the quality and grade of sands and flour for the grade of work. This sand is also mixed with other sands for making large cores where the cores are to be subjected to intense heat from large bodies of metal. It is also used for making the hearth for reverberatory furnaces, being wet with claywash or mixed with ground clay dry, and then wet. It is also valuable for forming mixtures for daubing large ladles, or in lining large cupolas.

CHAPTER XXIII

IRON AND ITS COMPOSITION

IRON, the metal most generally used in the foundry, is one of the chemical elements. The iron of commerce, however, is not pure metal, but is a compound of iron with various metalloids such as carbon, silicon, phosphorus, sulphur, manganese, etc. Each of these exercises an important influence on the structure of the iron, the latter principally through their action on the carbon, which is, without doubt, the most important element entering into the iron. The percentage of carbon in the iron determines its grade and also whether it comes under the classification of iron or steel. These points will be discussed in more detail later.

The iron of commerce when examined under the microscope has a structure closely allied to granite in appearance. It is composed of two definite substances, known to the metallurgists respectively as *ferrite* and *cementite*. The former is pure metallic iron and is soft, weak, and very ductile. The latter is a chemical compound of iron and carbon, is harder than glass and very brittle. It, however, has great strength to resist gradually applied pressure. The relative proportion of ferrite and cementite in any given iron determines its grade.

Carbon.—The total amount of carbon in cast-iron ranges from 3 to 4 per cent. It exists in the iron in three states, namely: combined carbon which is the carbon in the carbide of iron forming the cementite; free carbon, also known as graphitic carbon, which exists in the form of small flakes of pure carbon entangled in the crystals of ferrite and cementite; and tempering graphite carbon into which combined carbon is gradually changed by the prolonged application of heat. This last is relatively unimportant compared to the other two.

The combined carbon has the effect of increasing the hardness, shrinkage, and brittleness of cast-iron. The strength of the iron increases with the amount of combined carbon up to about 1 per cent of the latter. Above 1 per cent, combined carbon tends to decrease the strength of the metal.

The graphitic carbon tends to soften and weaken the iron if present in quantities of over 3 per cent. If the iron contains 1 per cent or more of combined carbon, being at the same time low in graphitic carbon, any additions of the latter will increase the strength of the casting. The amount of graphitic carbon in a casting is increased with the size of the casting, and it is also increased when the casting is held a long time in the mold at high temperature; in other words, when it is cooled slowly. This is due to the action of the combined carbon changing to temper graphite as explained above.

Silicon.—The tendency of silicon in cast-iron is to soften the casting. It acts by changing combined carbon into graphitic carbon and also by counteracting the effect of any sulphur which may be present and which exercises a hardening effect upon the iron. The silicon also may act to increase the strength of the iron when the latter is high in combined carbon, as it tends to reduce brittleness. If, however, the addition of silicon is such as to reduce the combined carbon to below 1 per cent it will seriously weaken the iron. If present in quantities over 3.5 per cent it changes the character of the iron entirely, the iron becoming silvery in color instead of gray and also becoming brittle and weak. Manganese present in the iron will, like sulphur, react with the silicon and decrease the effect of the latter on the iron.

Sulphur.—Sulphur present in the iron reacts with the carbon present to form combined carbon and thereby increases the hardness, brittleness, and shrinkage of the casting. In addition to its action on the carbon it also has in itself a weakening effect on the iron. On account of its effect on the shrinkage, patterns which are made for use with iron high in sulphur must have a greater shrinkage allowance than the usual one-eighth inch per foot, otherwise the casting will be smaller than desired. The sulphur should never be permitted to increase beyond 0.1 per cent, as any excess of this amount will render the iron brittle and weak unless other elements are present in sufficient quantity to counteract it. The iron will be dangerously brittle even with such a low quantity as 0.06 per cent sulphur if the amount of silicon present is less than 1 per cent.

Phosphorus.—The general effect of phosphorus is to increase the fluidity of the iron. In small quantities, say below 0.7 per cent, it has but little effect on the strength of the iron, but if present in quantities of 1 per cent or more the effect is decidedly weakening. Like silicon it acts to increase the softness of the iron and also to decrease the shrinkage. On account of its increasing the fluidity of the iron, it is a desirable element when thin castings such as stove plates are to be made, as the iron will flow freely to all parts of the mold before cooling. It is also valuable in ornamental castings of thin section which have on their surface fine lines and sharp projections. The iron containing phosphorus will flow freely into these lines and projections and reproduce the pattern perfectly.

Manganese.—Manganese when present in quantities of 2 per cent or more increases the hardness of the iron. When present in small quantities, say 0.5 per cent or less, it tends to counteract the effect of the sulphur present and thus acts as a softener. In quantities of from 0.5 per cent to 2.0 per cent it changes graphitic carbon to combined carbon and thus acts as a hardener. A peculiar property of manganese, and one wherein it differs from most of the other constituents of iron, is that it will combine with iron chemically in almost all proportions. In quantities of 10 to 30 per cent in the iron it forms spiegeleisen and when present in quantities of over 50 per cent the alloy is known as ferro-manganese. These alloys are used as additions to iron and steel in the ladle after they have been melted in the cupola or other furnace to make up deficiencies in the metal and to act as softeners or to toughen the metal as the case may require. Manganese also acts to increase shrinkage. While ordinary pig iron usually contains not over 4 per cent of carbon, this quantity can be increased in the presence of manganese, which increases the solubility of carbon in iron. The property of manganese to toughen and harden cast-iron is taken advantage of in the casting of chilled rolls, on which a hard surface is desired. It is added in quantities of about 1 per cent. It must not be permitted to exceed 0.4 per cent if softness is required in the finished casting. Another effect of manganese is to decrease the magnetism of iron and it must therefore be avoided in castings for electrical machinery, as iron with 25 per cent manganese is totally devoid of magnetism.

Miscellaneous Impurities.—Other metals often encountered in iron are as follows: *Aluminum* in quantities of from 0.2 to 1.0 per cent will increase the softness and strength of white iron. Added to gray iron it softens and weakens it. *Vanadium*, in quantities of 0.15 per cent, will increase the strength of iron, acting as deoxidizer and also alloying with the iron. *Titanium*, when added in quantities of 2 to 3 per cent of a titanium-iron alloy containing 10 per cent titanium, will increase the strength of the iron from 20 to 30 per cent. Its action is to combine with any oxygen or nitrogen present in the metal and thus purify it. The titanium oxide or nitride passes off and no titanium remains in the metal. After the metal has been totally deoxidized, further additions of titanium have no effect. Aluminum, vanadium, and titanium are all added to the iron in the ladle after melting, in the form of alloys of these metals with iron. *Copper* when present in quantities of 0.1 to 1.0 per cent closes the grain of cast-iron, but has no particular effect as regards brittleness.

Grading of Pig Iron

Up to quite recent times, pig iron was graded by the foundrymen and blast-furnace operators largely according to the appearance of the fracture obtained when a pig was broken. As the appearance of the fracture depends on the relative quantities of graphitic and combined carbon present, this method gave a fairly close approximation to the quality of the iron. In more recent years, however, grading by fracture has been largely superseded by the method of grading by analysis. The designations of pig iron according to grade vary in different sections of the country. Thus in Pennsylvania and eastern parts of the United States grades are known as Nos. 1 and 2 Foundry, Gray Forge No. 3, Mottled No. 4, White No. 5. Intermediate grades are designated by the addition of the letter X to the grade of the higher number. Thus an intermediate grade between Nos. 2 and 3 would be known as No. 3X. The following table from Kent's "Mechanical Engineers' Pocket-Book," eighth edition, page 414, gives the analyses of the five standard grades of northern foundry and mill pig iron:

TABLE V.—ANALYSES OF FOUNDRY IRONS

	No. 1	No. 2	No. 3	No. 4	No. 4B	No. 5
	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
Iron	92.37	92.31	94.66	94.48	94.08	94.68
Graphitic carbon	3.52	2.99	2.50	2.02	2.02	.....
Combined carbon	0.13	0.37	1.52	1.98	1.43	3.83
Silicon	2.44	2.52	0.72	0.56	0.92	0.41
Phosphorus	1.25	1.08	0.26	0.19	0.04	0.04
Sulphur	0.02	0.02	trace	0.08	0.04	0.02
Manganese	0.28	0.72	0.34	0.67	2.02	0.98

The characteristics of the above irons are given in the same work as follows:

No. 1 Gray.—A large, dark, open-grained iron, softest of all the numbers and used exclusively in the foundry. Tensile strength low. Elastic limit low, fracture rough, turns soft and tough.

No. 2 Gray.—A mixed, large and small, dark grain, harder than No. 1, and used exclusively in the foundry. Tensile strength and elastic limit higher than No. 1. Fracture less rough than No. 1. Turns harder, less tough, and more brittle than No. 1.

No. 3 Gray.—Small, gray, close grain, harder than No. 2, used either in the rolling mill or foundry. Tensile strength and elastic limit higher than No. 2. Turns less hard, less tough, and more brittle than No. 2.

No. 4 Mottled.—White background dotted closely with small black spots of graphitic carbon. Little or no grain. Used exclusively in the rolling mill. Tensile strength and elastic limit lower than No. 3. Turns with difficulty, less tough and more brittle than No. 3. The manganese in the No. 4B pig iron replaces part of the combined carbon, making the iron harder and closing the grain, notwithstanding the lower combined carbon.

No. 5 White.—Smooth, white fracture, no grain. Used exclusively in the rolling mill. Tensile strength and elastic limit lower than No. 4. Too hard to turn and more brittle than No. 4.

For making chilled castings a special grade of iron is required, one which has a gray fracture when cooled slowly, but which when cast against a chill will show white iron for a certain depth on the side which was rapidly cooled by reason of its contact with the iron chill. See the analyses of chilled castings, Table VIII, pages 294–5.

Specifications for Foundry Pig Iron

In May, 1909, the American Foundrymen's Association adopted standard specifications for foundry pig iron and recommended that all pig iron for foundry use be bought by analysis. It recommended sampling each carload of iron, taking therefrom one-half of a sand-cast pig or one machine-cast pig for every four tons in the car. Drillings should be taken fron these pigs to represent as nearly as possible the composition of the pig as cast and an equal quantity of the drillings from each pig should be mixed to form the sample for analysis. When the elements are specified, the following percentages and variations are to be used. Opposite each percentage of the different elements a syllable has been affixed so that buyers by combining these syllables can form a code word for telegraphic use.

TABLE VI

Silicon		Sulphur		Total Carbon		Manganese		Phosphorus	
Per Cent	Code	(Max.)	Code	(Min.)	Code	Per Cent	Code	Per Cent	Code
		0.04	Sa	3.00	Ca	0.20	Ma	0.20	Pa
1.00	La	0.05	Se	3.20	Ce	0.40	Me	0.40	Pe
1.50	Le	0.06	Si	3.40	Ci	0.60	Mi	0.60	Pi
2.00	Li	0.07	So	3.60	Co	0.80	Mo	0.80	Po
2.50	Lo	0.08	Su	3.80	Cu	1.00	Mu	1.00	Pu
3.00	Lu	0.09	Sy			1.25	My	1.25	Py
		0.10	Sh			1.50	Mh	1.50	Ph

Percentages of any element specified one-half way between the above are designated by the addition of the letter *x* to the next lower symbol. Thus *Lex* means 1.75 silicon. The allowed variations are silicon 0.25, phosphorus 0.20, manganese 0.20. The percentages of phosphorus and manganese may be used as maximum or minimum figures when so specified. An example of the use of the above code is as follows: Li-si-pa-ma represents an iron of the following analysis—Silicon 2.00, sulphur 0.06, phosphorus 0.20, manganese 0.20. For market quotations, an iron of 2 per cent silicon with a variation of 0.25 per cent either way and maximum sulphur content of 0.05 is taken as the base and the following table may then be

TABLE VII

Sulphur	Silicon									
	3.25	3.00	2.75	2.50	2.25	2.00	1.75	1.50	1.25	1.00
0.04	B+6C	B+5C	B+4C	B+3C	B+2C	B+ C	B	B−1C	B−2C	B−3C
0.05	B+5C	B+4C	B+3C	B+2C	B+1C	B	B−1C	B−2C	B−3C	B−4C
0.06	B+4C	B+3C	B+2C	B+1C	B	B−1C	B−2C	B−3C	B−4C	B−5C
0.07	B+3C	B+2C	B+1C	B	B−1C	B−2C	B−3C	B−4C	B−5C	B−6C
0.08	B+2C	B+1C	B	B−1C	B−2C	B−3C	B−4C	B−5C	B−6C	B−7C
0.09	B+1C	B	B−1C	B−2C	B−3C	B−4C	B−5C	B−6C	B−7C	B−8C
0.10	B	B−1C	B−2C	B−3C	B−4C	B−5C	B−6C	B−7C	B−8C	B−9C

filled out as part of a contract. In this table *B* or base represents the agreed price for a pig of 2 per cent silicon and of lower sulphur content than 0.05. C is a constant differential to be determined at the time the contract is made.

Analyses of Castings

A committee of the American Society for Testing Materials in 1908 recommended that the sulphur in light gray-iron castings be not allowed to exceed 0.08 per cent; in medium castings not over 0.10 per cent; in heavy castings not over 0.12 per cent. A light casting is one which has no section over one-half inch thick and a heavy casting has no section less than two inches thick. The same society in 1905 specified for metal in cast-iron pipe four grades of pig iron as follows: No. 1, silicon 2.75, sulphur 0.035; No. 2, silicon 2.25, sulphur 0.045; No. 3, silicon 1.75, sulphur 0.055; No. 4, silicon 1.25, sulphur 0.065. A variation of 10 per cent either way in the silicon is permitted and of 0.01 per cent in the sulphur above the standard is allowed.

In June, 1910, the American Foundrymen's Association published a report by Dr. John Jermain Porter, showing tentative standards or probable best analyses of a large variety of iron castings. This report was abridged in tabular form as reproduced below in *Industrial Engineering* in August, 1910. The definitions of light and heavy castings conform to those given in the above paragraph. The most desirable percentage of silicon depends largely on the exact thickness of the casting and the practice followed in shaking out. The effect of purifying alloys and the use of steel scrap were not considered in compiling the report. In many cases a wide range of compositions is permissible and compatible with the best results, and in such cases the question of cost will be the first element to be considered. The sources of information in compiling this table were published works, replies to inquiries sent to members of the association, and private notes of Dr. Porter.

TABLE VIII.—Analyses of Castings

Class of Casting	Si Per Cent	S Per Cent	P Per Cent	Mn Per Cent	C (Comb.) Per Cent	C (Total) Per Cent
Acid-resisting castings (stills, eggs, etc.)	1.00-2.00	0.05-*	0.40-*	1.00-1.50	....	3.00-3.50
Agricultural machinery, ordinary	2.00-2.50	0.06-0.08	0.60-0.80	0.60-0.80	....	....
Agricultural machinery, very thin	2.25-2.75	0.06-0.08	0.70-0.90	0.50-0.70	....	....
Annealing boxes, etc	1.40-1.60	0.06-	0.20-	0.60-1.00	....	....
Automobile castings	1.75-2.25	0.08-	0.40-0.50	0.60-0.80	....	....
Balls for ball mills	1.00-1.25	0.08-	0.20-	0.60-1.00	....	....
Boiler castings	2.00-2.50	0.06-	0.20-	0.60-1.00	....	....
Car castings, gray iron	1.50-2.25	0.08-	0.40-0.60	0.60-1.00	....	....
Chilled castings	0.75-1.25	0.08-0.10	0.20-0.40	0.80-1.20	....	....
Chills	1.75-2.25	0.07-	0.20-0.40	0.60-1.00	....	....
Crusher jaws	0.80-1.00	0.08-0.10	0.20-0.40	0.80-1 20	....	....
Cutting tools, chilled	1.00-1.25	0.08-	0.20-0.40	0.60-0.80	....	....
Cylinders:						
Air and ammonia	1.00-1.75	0.09-	0.30-0.50	0.70-0.90	....	3.00-3.30
Automobile	1.75-2.00	0.08-	0.40-0.50	0.60-0.80	0.55-0.65	3.00-3.25
Gas-engine	1.00-1.75	0.08-	0.20-0.40	0.70-0.90	....	3.00-3.30
Hydraulic, heavy	0.80-1.20	0.10-	0.20-0.40	0.80-1.00	....	low
Hydraulic, medium	1.20-1.60	0.09-	0.30-0.50	0.70-0.90	....	low
Locomotive	1.00-1.50	0.08-0.10	0.30-0.50	0.80-1.00	....	....
Steam-engine, heavy	1.00-1.25	0.10-	0.20-0.40	0.80-1.00	....	low
Steam-engine, medium	1.25-1.75	0.09-	0.30-0.50	0.70-0.90	....	....
Dies, drop-hammer	1.25-1.50	0.07-	0.20-	0.60-0.80	....	low
Diamond polishing wheels†	2.70	0.063	0.30	0.44	1.60	2.97
Electrical machinery (frames, bases, spiders), large	2.00-2.50	0.08-	0.50-0.80	0.30-0.40	0.20-0.30	low
Electrical machinery, small	2.50-3.00	0.08-	0.50-0.80	0.30-0.40	0.20-0.30	low
Engine castings:						
Bed-plates	1.25-1.75	0.10-	0.30-0.50	0.60-0.80	....	....
Fly-wheels	1.50-2.25	0.08-	0.40-0.60	0.50-0.70	....	....
Fly-wheels, automobile	2.25-2.50	0.07-	0.40-0.50	0.50-0.70	....	....
Frames	1.25-2.00	0.09-	0.30-0.50	0.60-1.00	....	....
Pillow blocks	1.50-1.75	0.08-	0.40-0.50	0.60-0.80	....	....
Piston rings	1.50-2.00	0.08-	0.30-0.50	0.40-0.60	....	low
Fire pots and furnace castings	2.00-2.50	0.06-	0.20-	0.60-1.00	....	low
Grate bars	2.00-2.50	0.06-	0.20-	0.60-1.00	0.30-	low
Grinding machinery, chilled castings for	0.50-0.75	0.15-0.20	0.20-0.40	1.50-2.00	....	....
Gun-carriages	1.00-1.25	0.06-	0.20-0.30	0.80-1.00	....	low
Gun iron	1.00-1.25	0.06-	0.20-0.30	....	0.80-1.00	low
Hardware (light) and hollow ware	2.25-2.75	0.08-	0.50-0.80	0.50-0.70	....	....
Heat-resistant iron (retorts)	1.25-2.50	0.06-	0.20-	0.60-1.00	0.30-	low
Ingot molds and stools	1.25-1.50	0.06-	0.20-	0.60-1.00	....	....
Locomotive castings, heavy	1.25-1.50	0.08-	0.30-0.50	0.70-0.90	....	....
Locomotive castings, light	1.50-2.00	0.08-	0.40-0.60	0.60-0.80	....	....
Machinery castings, heavy	1.00-1.50	0.10-	0.30-0.50	0.80-1.00	....	low
Machinery castings, medium	1.50-2.00	0.09-	0.40-0.60	0.60-0.80	....	....
Machinery castings, light	2.00-2.50	0.08-	0.50-0.70	0.50-0.70	....	....
Friction clutches	1.75-2.00	0.08-0.10	0.30-	0.50-0.70	....	low
Gears, heavy	1.00-1.50	0.80-0.10	0.30-0.50	0.80-1.00	....	low
Gears, medium	1.50-2.00	0.09-	0.40-0.60	0.70-0.90	....	....
Gears, small	2.00-2.50	0.08-	0.50-0.70	0.60-0.80	....	....
Pulleys, heavy	1.75-2.25	0.09-	0.50-0.70	0.60-0.80	....	....
Pulleys, light	2.25-2.75	0.08-	0.60-0.80	0.50-0.70	....	....
Shaft collars and couplings	1.75-2.00	0.08-	0.40-0.50	0.60-0.80	....	....
Shaft hangers	1.50-2.00	0.08-	0.40-0.50	0.60-0.80	....	....
Ornamental work	2.25-2.75	0.08-	0.60-1.00	0.50-0.70	....	....
Permanent molds	2.00-2.25	0.07-	0.20-0.40	0.60-1.00	....	....
Permanent mold castings	1.50-3.00	0.06-	....	0.40-	....	....

* Affixed hyphens indicate that the percentages present should be under those given.

TABLE VIII.—ANALYSES OF CASTINGS—*Continued*

Class of Casting	Si Per Cent	S Per Cent	P Per Cent	Mn Per Cent	C (Comb.) Per Cent	C (Total) Per Cent
Piano plates	2.00-2.25	0.07-	0.40-0.60	0.60-0.80	....	....
Pipe	1.50-2.00	0.10-	0.50-0.80	0.60-0.80	....	....
Pipe fittings	1.75-2.50	0.08-	0.50-0.80	0.60-0.80	....	....
Pipe fittings for superheated steam lines	1.50-1.75	0.08-	0.20-0.40	0.70-0.90	....	low
Plow points, chilled	0.75-1.25	0.08-	0.20-0.30	0.80-1.00	....	....
Propeller wheels	1.00-1.75	0.10-	0.20-0.40	0.60-1.00	....	low
Pumps, hand	2.00-2.25	0.08-	0.60-0.80	0.50-0.70	....	....
Radiators	2.00-2.25	0.08-	0.60-0.80	0.50-0.70	0.50-0.60	....
Railroad castings	1.50-2.25	0.08-	0.40-0.60	0.60-0.80	....	....
Rolling mill machinery:						
Housings	1.00-1.25	0.08-	0.20-0.30	0.80-1.00	....	low
Rolls, chilled	0.60-0.80	0.06-0.08	0.20-0.40	1.00-1.20	....	3.00-3.25
Rolls, unchilled (sand-cast)†	0.75	0.03	0.25	0.66	1.20	4.10
Scales	2.00-2.30	0.08-	0.60-1.00	0.50-0.70	....	....
Slag car castings	1.75-2.00	0.07-	0.30-	0.70-0.90	....	....
Soil pipe and fittings	1.75-2.25	0.09-	0.50-0.80	0.60-0.80	....	....
Stove plate	2.25-2.75	0.08-	0.60-0.90	0.60-0.80	....	....
Valves, large	1.25-1.75	0.09-	0.20-0.40	0.80-1.00	....	....
Valves, small	1.75-2.25	0.08-	0.30-0.50	0.60-0.80	....	low
Water heaters	2.00-2.25	0.08-	0.30-0.50	0.60-0.80	....	....
Wheels, large	1.50-2.00	0.09-	0.30-0.40	0.60-0.80	....	....
Wheels, small	1.75-2.00	0.08-	0.40-0.50	0.50-0.70	....	....
White iron castings†	0.50-0.90	0.15-0.25	0.20-0.70	0.17-0.50	2.90	2.50

† But one or two analyses available—no suggestion made.

Mr. W. J. Keep in the *Trans. A. S. M. E.*, Vol. XXIX, writes as follows regarding the analyses of iron for various classes of service:

Hard Iron for Heavy Work.—Castings for compressor cylinder-valves, high-pressure work, etc. Chemical composition: Silicon 1.20 to 1.50, sulphur under 0.09 per cent, phosphorus 0.35 to 0.60 per cent, manganese 0.50 to 0.80 per cent.

Medium Iron for General Work.—Castings for low-pressure cylinders, gears, pinions, etc. Chemical composition: Silicon 1.50 to 2.00 per cent, sulphur under 0.08 per cent, phosphorus 0.35 to 0.60 per cent, manganese 0.50 to 0.80 per cent.

Soft Iron.—For general car and railway castings, pulleys, small castings, and agricultural work. Chemical composition: Silicon 2.20 to 2.80 per cent (with less, the castings are hard, and with more they are too weak). For large castings, 2.40 per cent is a good average. Sulphur under .085 per cent, phosphorus, under 0.70, manganese under 0.70 per cent.

Iron for Frictional Wear.—Castings for brake shoes, friction clutches, etc. Chemical composition: Silicon 2.00 to 2.50 per cent, sulphur under 0.15 per cent, phosphorus under 0.70 per cent, manganese under 0.70 per cent. The addition of spiegeleisen increases hardness.

The method of calculating the mixtures of the various brands of pig iron available for cupola charges to obtain the analyses as given in the above notes and table will be explained in Chapter XXIV.

Shrinkage of Cast-Iron

The common allowance for shrinkage of cast-iron in cooling from the liquid to the solid state is one-eighth inch per foot. As has been shown above, however, the percentage of the various elements alloyed with the iron has an important effect on the shrinkage. Mr. Keep says: "The measure of shrinkage is practically equivalent to a chemical analysis of the silicon. It tells whether more or less silicon is needed to bring the quality of the casting to an accepted standard of excellence." Mr. Keep published in the *Trans. A. S. M. E.* the following table showing the variation in shrinkage with the size of bar on which his experiments were made and with the variation in the silicon contents of the iron. See also the Appendix, page 369.

TABLE IX.—Shrinkage of Cast-Iron

Silicon	Size of Square Bars Shrinkage, Inch, per Foot				
Per Cent	½ inch	1 inch	2 inch	3 inch	4 inch
1.00	0.178	0.158	0.129	0.112	0.102
1.50	0.166	0.145	0.116	0.099	0.088
2.00	0.154	0.133	0.104	0.086	0.074
2.50	0.142	0.121	0.091	0.072	0.060
3.00	0.130	0.109	0.078	0.058	0.046
3.50	0.118	0.097	0.065	0.045	0.032

CHAPTER XXIV

THE CUPOLA AND ITS OPERATION

For melting iron for foundry use two types of furnaces are commonly used, the *cupola* and *reverberatory* or "*air*" *furnace.* Of these the cupola is the most widely used, although the reverberatory furnace is becoming very popular for certain classes of work. There are many different cupolas on the market which vary only in details of design. In principle they are all alike. A typical cupola is shown in Fig. 203. As will be observed it is a straight shaft furnace open at the top and bottom, lined with fire-brick, provided with a door at about the middle of its height through which the *charge* is introduced and with *tuyeres* near the bottom through which air is blown to consume the fuel which is charged to melt the iron. The opening at the bottom is closed by hinged cast-iron doors which are dropped at the end of the day's run in order to permit the unconsumed fuel and the residue of iron in the cupola to fall out and be removed. Molten iron is taken out through a hole at the bottom and *slag* is removed through a hole in the opposite side and at a slightly higher level than the iron *tap-hole.* The cupola is encircled near its base by a chamber, known as the *wind-box,* communicating with the tuyeres. The fan or pressure blower furnishing air to the cupola delivers it to this wind-box whence it finds its way through the tuyeres into the cupola. It is in the arrangement of the tuyeres that the various cupolas of different makers differ principally from each other. It would be out of place in a book of this character to enter into a discussion of the various details of construction of different cupolas and the reader is referred to the catalogues of the various foundry-supply houses for information on this subject.

Taking up the construction in detail of the cupola shown in

Fig. 203, the shell *A* is formed of separate rings of boiler plate riveted together with angles *E* riveted to the interior at intervals to support the fire-brick lining *L*. The shell is carried on a cast-iron bed-plate ring *B*, which is in turn supported by the cast-iron legs *S*. The opening in this ring is closed by a pair of hinged drop-doors, which when closed are held in place by a rod, or spud, wedged between them and the floor. At *F* is seen the wind-box encircling the cupola communicating with the tuyeres *H* and *J*. At *G* is the blast-pipe connecting the fan or blower with the wind-box. At *C* is the *breast* built around the tap-hole *T* through which iron is removed from the cupola, it flowing through a spout *R*. The slag-hole and spout are shown at *W*. Iron and fuel are introduced into the cupola through the *charging door D*, and in practice this door is usually at the level of the second floor of the foundry or a platform is built around it. Cleaning doors are built on either side of the wind-box to permit the removal of any slag or iron which may flow through the tuyeres into it. Opposite each tuyere a peep-hole *P* is provided, which is covered when not in use by a swinging cast-iron cover. By using these peep-holes the melter can ascertain in a measure how the cupola is operating. The tuyeres are of cast-iron and flare inward as shown in the plan, Fig. 204.

The height of the tuyeres above the bed plate varies according to the class of work done in the foundry. The number of rows of tuyeres also ranges from one to three. Thus stove-plate work does not require a great depth of iron to be maintained in the *basin*, as the space between the bottom of the cupola and the tuyeres is known. Consequently, the tuyeres can be set at a lower level than in a cupola melting iron for heavy engine castings where a great volume of metal may be required at one time. The advantage of using two or more rows of tuyeres is that gases may be distilled from the fuel and escape without coming in contact with air blown through the lower row. They must, however, pass through air blown through the upper tuyeres and thus become completely consumed. The double row of tuyeres, therefore,

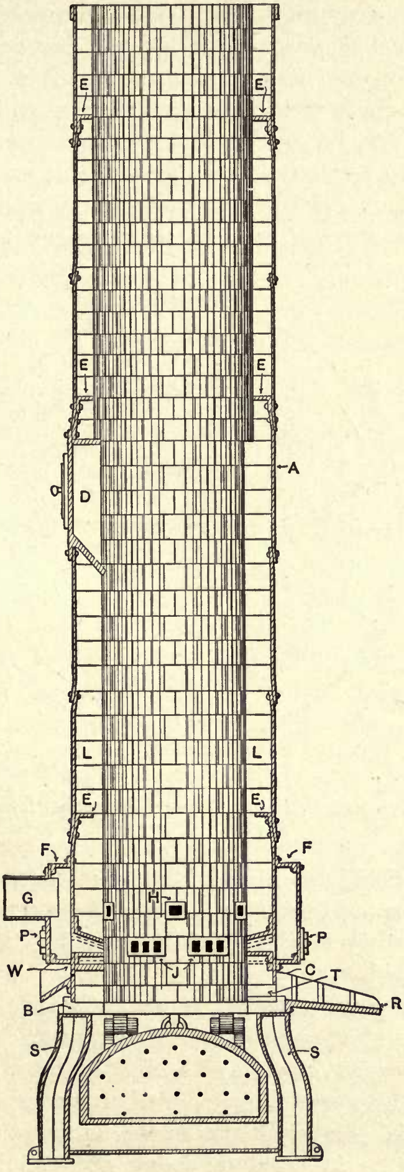


FIG. 203.—A CUPOLA.

renders possible economical operation and quick melting, inasmuch as no fuel is wasted. When running small heats the upper row of tuyeres may be shut off by means of a damper. Also if the cupola is melting more rapidly than is desired, the upper tuyeres may be shut off and the amount of air furnished the cupola may be diminished by means of a damper in the blast-pipe. Thus the melting rate of the cupola is always under control of the melter. An arrangement is also provided

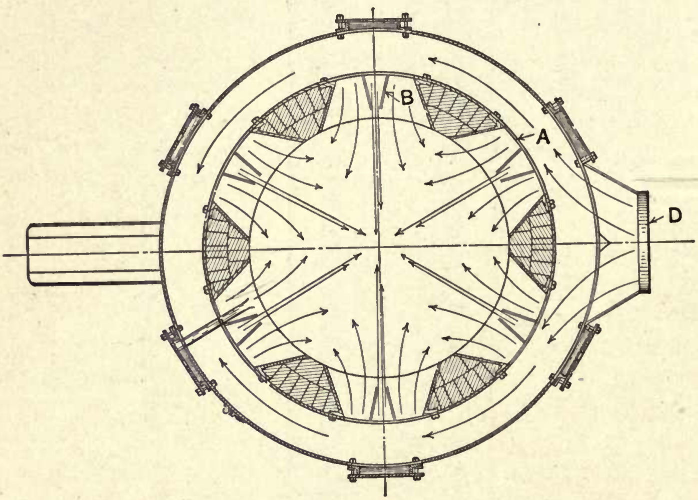


FIG. 204.—SECTIONAL PLAN OF CUPOLA THROUGH LOWER TUYERES.

whereby iron rising too high in the basin before tapping will run through a spout into the wind-box where it will melt a lead plug and fall to the floor, thus giving warning that the cupola should be tapped.

Cupolas may use either coke or anthracite coal for fuel, coke being the most generally used. In preparing the cupola the bottom doors are closed and a sand bottom, usually composed of gangway sweepings or similar material, is built on them. This is tempered the same as molding sand and rammed down as in molding, being rammed harder at the bottom than at the surface. It is inclined toward the tap-hole so that the tendency will be for all iron to drain out. The fire in the cupola may be lighted either with wood or by means of a gas or oil burner. In the former case shavings are laid on the bottom with enough wood over them to insure thorough ignition of the coke. A bed charge of coke is placed in the cupola before any iron is charged and this is of considerably greater weight than the subsequent charges of coke which are charged alternately with charges of iron. A portion of this bed charge is laid on the wood and after it is thoroughly ignited the remainder of it is introduced into the cupola, only enough being reserved to level off the top of the bed charge before introducing iron.

When the coke is to be ignited by means of a gas or oil burner a space is left in front of the breast opening and one or two channel ways are formed, leading nearly to the back of the cupola, by pieces of coke laid end to end, through which the flames of a burner will pass. The channels are covered with pieces of coke, and one-half to one-third of the bed charge placed. The burner is then laid in the spout of the cupola and kept back from the breast opening a distance of about four inches. It is lighted and regulated so that the flame at the burner will be blue, changing to purple tipped with yellow. It is kept on until the coke is thoroughly ignited, usually a period of thirty minutes with the oil burner and somewhat less with the gas. On its removal, the breast is built as will be described later and the *blast* turned on to thoroughly ignite the entire charge of coke on the bed. When the blast is put on, the remainder of the bed charge is introduced into the cupola with the exception of enough reserved to level it before charging the iron.

When the fire is visible through the coke, as viewed from the charging door, and the bed charge is leveled, charging should begin, as the fire should not be permitted to burn red hot. If the coke appears to be burning more freely on one side than on the other some of the coke reserved for leveling is thrown on that side and the peep-holes opened or closed to force the air to the side which has burned the least. The more evenly the coke is burned the better will the cupola melt and the better will be the grade of iron obtained for the mold.

The breast is now built in and the tap-hole formed. Three different methods of doing this are in general use. When the shavings and wood used to fire the cupola have burned away the coke will settle down on the sand bottom in front of the breast opening. Any coke that may have fallen into the opening is removed and a tapered iron pin is laid in the tap spout, small end in, projecting into the cupola. With small pieces of coke a wall is built in front of the burning coke and in front of this wall the same mixture of fire-clay mud that is used for lining the cupola (see page 310) is rammed, after which the iron pin is withdrawn, leaving a tap-hole in the breast. The wall of coke soon ignites and dries out the breast. The second method consists in building the wall of coke as before, leaving quite a space in front of it. Wet shavings are forced against the coke, after which the pin is placed and the fire-clay breast rammed up as before. The third method utilizes a board with a notch in its lower edge which fits over the tap-hole pin and which is laid against the wall of coke. The breast is built against this board. Instead of fire-clay mud, some melters will use for the breast a mixture of molding sand wet with claywash, while others make use of any natural loam which may be found in the vicinity.

The breast being in, it must be ascertained that the top of the bed charge is at the correct height. Every cupola has a melting zone above the tuyeres where it is the hottest, this zone being known as the melting zone. In a cupola which has been running for some time, this melting zone is easily ascertained by the condition of the lining which will be burned away to a certain extent as shown in Fig. 205. A rod with one end bent to a right angle to hang on the edge of the charging door may be provided, its length being such that it will drop in the cupola to the highest point of the melting zone. The bed charge should then be brought up to the lower end of this

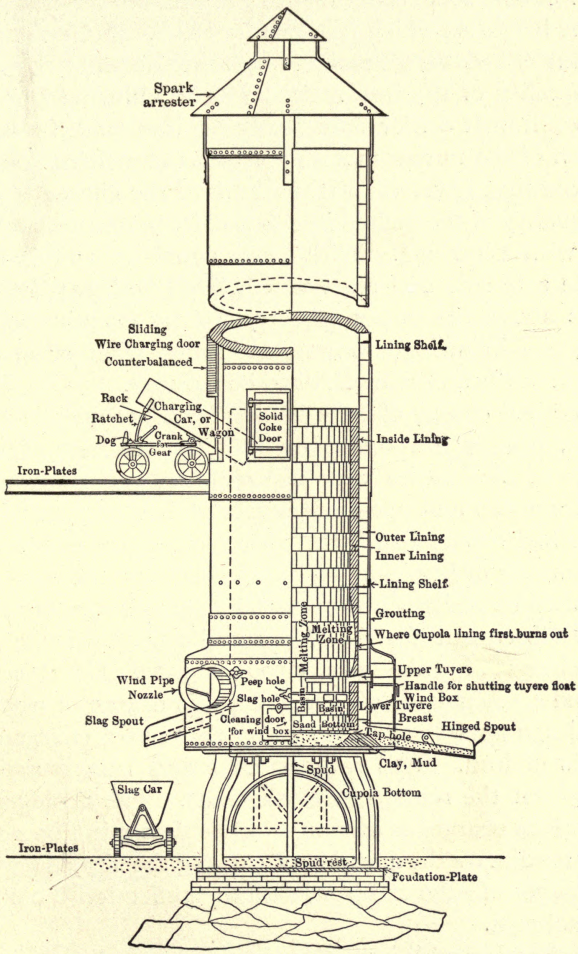


FIG. 205.—CUPOLA CHARGING ARRANGEMENT. Also shows effect of wear on lining.

rod. The use of a small amount of coke in the bed charge will lower the melting zone and a large amount will raise it. With a new cupola some experimenting is necessary to ascertain the proper height at which best results will be obtained before the amount of bed charge and its height are definitely determined. The quality of the iron melted will be influenced by this, as scrap will melt earlier than heavy pig iron, and if a large proportion of the former material is used the melting zone should be somewhat lower than if the bulk of the charge is pig iron. The quality of the melted iron is usually better with a high bed than with a low one. With a new cupola it is advisable to be on the safe side and start with a high bed, say twenty-two inches above the upper tuyeres, and by examination of the lining the following morning determine whether or not the amount of the bed charge should be reduced.

The bed charge of coke having been brought to the right height, iron is introduced on it. The amount of the first charge of iron varies with different melters, ranging all the way from two and one-half pounds of iron per pound of coke in the bed charge to four pounds of iron per pound of coke. The amount of iron charged depends also on the total amount of iron to be melted in the heat and this also governs the size of the subsequent charges of iron and coke. Assume that our first charge of coke was 1,500 pounds. On this will be charged 4,500 pounds of iron. On this charge of iron will be placed 250 pounds of coke and on the coke a charge of 2,500 pounds of iron. This ratio of coke and iron is maintained throughout the remainder of the heat. The arrangement of the various charges of coke and iron is shown in Fig. 206. We will later discuss the question of varying the size and weight of the charges of coke and iron, with their effect on the operation of the cupola.

In charging with iron, the pig iron is usually placed in the cupola first, and on top of this the scrap. The scrap being free from scale usually melts more rapidly than the pig iron, and the pig iron being charged so as to reach the melting zone first, the two are usually melted at about the same time. The charging of coke and iron alternately continues until the cupola is filled to the desired height or the amount of iron needed for the heat has been charged. If the cupola will not hold enough iron for the heat, after it has been filled to the level of the

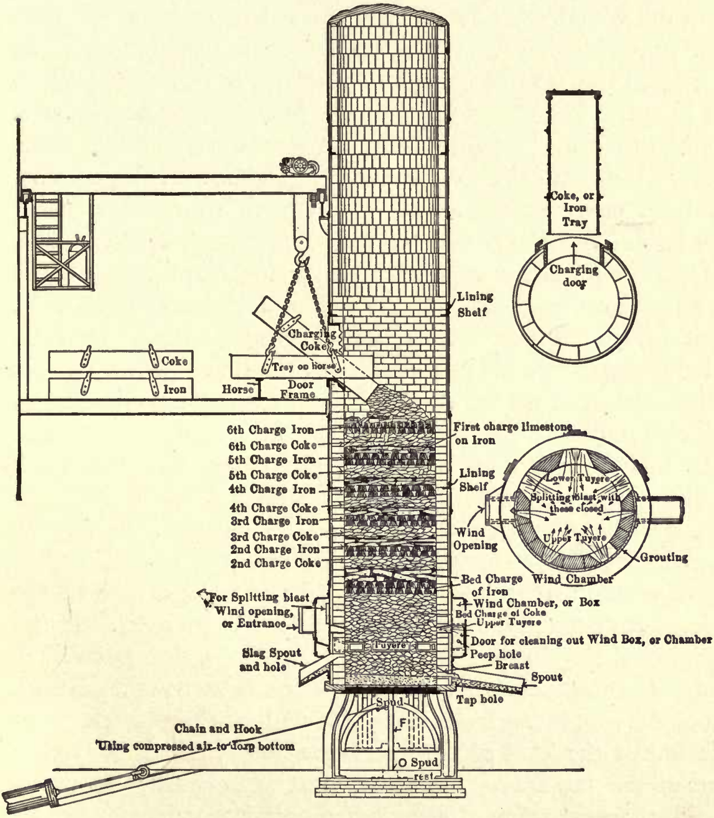


FIG. 206.—CUPOLA CHARGING ARRANGEMENTS. Also shows arrangement of coke and iron charges.

charging door, subsequent charges are added as the bed settles, due to iron being withdrawn through the tap-hole and the coke burning away. If heavy scrap is used it is generally charged with the second lot of iron, a little coke being mixed with it to assist in its rapid melting.

A certain amount of slag is required in cupolas to prevent the iron from being burned away by the action of the blast. It is also necessary to prevent the molten iron in the basin from being decarbonized. Frequently the coke will contain sufficient impurities to form slag enough to protect the iron, but with clean iron and fuel slag will not form in sufficient quantities in small heats. It is therefore necessary to introduce a material to form slag; and limestone, marble dust or fluor-spar, or any other material containing lime, should be charged with the iron, commencing at about the fifth charge and using approximately sixty pounds of limestone per ton of iron. The particular amount, however, depends on local conditions, being governed by the analysis of the fuel and iron and also by its effect on the lining. Sufficient slagging material must be added to insure the slag being sharply fluid, and yet any excess of limestone will attack the fire-brick lining of the cupola and will also influence to a certain extent the quality of the iron melted. If marble dust is used, six pounds per ton of iron will usually give a good slag of sufficient quantity.

Certain foundrymen do not slag their cupolas, these being larger than are necessary to give the amount of iron needed at any one time. However, if the cupola is to be driven to the limit of its capacity, slagging is absolutely essential. If the quantity of slag formed is not too great, it may be allowed to remain in the cupola until the end of the heat. As it rests on top of the iron in the basin none of it will run out of the tap-hole unless the level of the iron is lowered to below the upper edge of the tap-hole. However, if it is necessary to use a considerable quantity of slagging material, provision must be made to remove it through the slag-hole continuously. If allowed to accumulate, it may bridge or scaffold above the tuyeres and give trouble in the operation of the cupola.

The cupola being charged, it will be well to allow it to stand for about half an hour before the blast is put on. The lower charges will then be heated to such an extent that when the blast is put on melting begins rapidly and evenly and continues at a uniform rate throughout the heat. The blast being put on, iron shortly begins to run sluggishly from the tap-hole which has been left open. It becomes hotter and hotter until finally it is perfectly fluid. The melter then closes the tap-hole with a *bod* of fire-clay and allows the iron to accumulate in the basin until there is a sufficient quantity to pour the first lot of molds. Should the tap-hole be closed as soon as the iron began to flow, the iron might cool in the bottom of the cupola and harden in front of the tap-hole, making it extremely difficult to tap the cupola later. In tapping the cupola care must be taken that the tap-hole be kept free of slag and iron, and also that while boding up, or closing the tap-hole with clay, parts of each bod are not left around the tap-hole each time, thus building it out from the breast. If this care is not taken, it will eventually become difficult or impossible to bod up the cupola, and the iron will run out until the cupola is empty.

The clay to form the bods for the tap-hole should be one that will not bake too hard, else it will require a tapping bar and a sledge to drive the bod out of the hole when it is desired to tap the cupola. The clay used should be one that will bake hard enough to hold the iron, yet one which will break comparatively easily. If the clay alone bakes too hard, white-pine sawdust, seacoal, or similar material may be added to it. The tapping-bar must be kept clean and pointed, which can be accomplished by holding the end in the stream of iron flowing from the cupola. Before making the hole in the breast, the clay on the breast around the bod should be slightly cleaned with the point of the tap-rod, which will prevent trouble due to the bods building out on the breast. In closing the tap-hole the rod with the bod of clay on the end should be held above the stream of iron, and the bod forced down. If it is attempted to force the bod up through the iron, it is liable to be washed from the rod, which may cause serious trouble before it can be replaced.

After the cupola is in operation, the pouring-spout should be observed closely to ascertain when it is necessary to open the slag-hole. When nearly all the iron has run from the basin during a given tap, a small quantity of slag may appear on the surface of the iron as it flows down the spout. This is evidence that by the time the basin has filled with iron for the next tap a considerable quantity of slag will have accumulated on top of the iron. Shortly before the next tap, therefore, the *slag-hole*, which has been closed with a bod of molding sand and molasses water, is opened and the slag permitted to escape. After the slag has once commenced to run freely, the slag-hole will take care of itself, the slag rising on top of the iron as it collects in the basin, and flowing out through the slag-hole whenever it rises to that level.

It is customary to charge a few hundred pounds more of iron into the cupola than are required to pour all the molds, as the last iron out of the cupola always has more or less slag on it, which would render defective castings which later must be machined. Consequently the last castings to be poured should be those of a rough character requiring no machining. If all the castings are to be of a good character the iron cannot be totally drained from the cupola for them and the last few hundred pounds are run into ingot molds or pig beds. When all the iron has been drained from the cupola, the spud is knocked from beneath the bottom doors or pulled out by means of a compressed air attachment, and the coke in the cupola falls to the floor. In most large foundries a series of iron hooks are placed under the cupola, points upward, so that the mass of coke may be pulled from under the cupola by means of a chain and a compressed air hoist, thus tearing the mass apart and distributing it so that it can be readily quenched by a stream from a hose and considerable coke thereby saved. It is absolutely essential that the spot on which the mass from the cupola drops be perfectly dry. Otherwise there will be a generation of steam which in expanding will throw the red-hot coke in all directions, burning the workmen and doing damage to the building. Occasionally, when the drop takes place, all the material above the tuyeres does not come with it, being scaffolded in the cupola. However, as the coke burns away during the night this material will fall, although occasionally it has to be poked down by means of bars inserted through the peep-holes in the tuyeres or broken down by pigs of iron thrown through the charging door. This latter occurrence happens most often when the cupola is not slagged.

The following day the lining of the cupola should be inspected and repaired before it is charged for that day's run. Cupolas are built with either a single or double lining, the first consisting of a lining of heavy cupola blocks of fire-brick, the second of two rows of fire-brick one inside the other. The advantage of the double lining is that it is considered to give greater protection to the shell, while the single lining permits relining to be accomplished more quickly than does the double lining. It, however, requires more careful watching than the other and may, if not attended to, break through at a time when the cupola is in operation, which will be evidenced by the shell becoming red hot opposite the hole in the lining. If possible, this spot should be cooled by a plentiful application of cold water to the shell and the cupola kept in operation until the heat is finished. However, if the red spot shows a tendency to enlarge, the blast should be shut off and the bottom dropped. It is sometimes possible to repair temporarily a break in the lining while the cupola is in operation by throwing in fire-brick and fire-clay mud through the charging door immediately above the place where the hot spot shows. These will fuse and find their way into the break and repair it sufficiently to finish the heat. Wetting down of the shell should continue nevertheless until the heat is ended.

The care of the lining and the method of charging have much to do with the life of the cupola. The fact that the lining burns out rapidly is not necessarily an indictment against the brick of which it is composed, but may indicate lack of care on the part of the melter. In lining the cupola for the first time, a space of about five-eighths inch should be left between the back of the brick and the shell of the cupola, and grouting—a thick claywash—poured in behind them. The fire-brick composing the lining are set in a thick claywash, termed butter. The brick should be laid as closely together as possible and the rows buttered together. The brick are grouted at the back to avoid chipping where they come against rivets in the shell, and they must be carefully fitted around the tuyeres and lining shelves. Otherwise they are laid up in regular rows, with broken joints. The lining below the level of the charging door is considerably thicker than it is above, as this portion of it not only has to resist the more intense heat but also the abrasion of the fuel and iron. Frequently the lining above the charging door is composed simply of common red brick of good quality. After the lining is completed it should be thoroughly dried out by a fire built in the bottom of the cupola.

A lining built as above must be repaired after each heat with a mud composed of sand and clay wet with water, all foreign matter which may be clinging to the lining being first removed with a pick or chisel, care being taken not to break away the surface of the lining if it can be avoided. The mud is applied by throwing it in handfuls against worn spots in the lining and afterward smoothing it with a trowel so as to conform as closely as possible with the original shape of the lining. The slag-hole is formed by placing a gate-stick at the proper point and daubing mud around it, afterward removing the stick and filling the opening with a mixture of sand and molasses water. The cupola lining will require but little repairing during the first few heats, but after a long period of operation holes of considerable size may be burned in it and these should be filled with small pieces of fire-brick and the mud laid in around them. The space to be repaired in a cupola usually extends some three or four feet above the tuyeres as shown in Fig. 205, and also in Fig. 207, the latter illustrating the method of making certain classes of repairs. When the variety of clay available for lining repairs is of poor quality, a large quantity of sand of high fusion should be mixed with it to render it more refractory. If the fusing point of the clay is low, the mud repair may melt and run down and choke the tuyeres as shown in Fig. 207. Again, the daubing may become broken away and permit the charge to enter in back of it as shown in the same illustration, finally breaking the lining away and scaffolding the cupola. When this occurs the iron melts slowly, as the charge cannot work its way down to the melting zone and it is necessary to drop the bottom and thus lose the

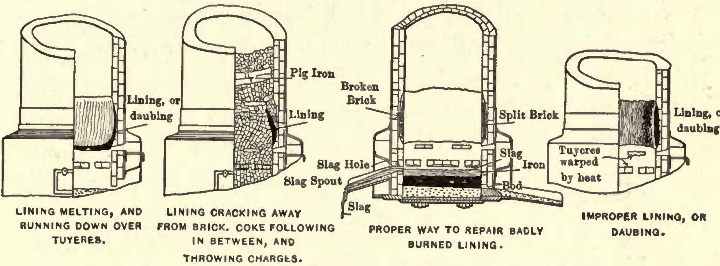


FIG. 207.—FAILURES OF CUPOLA LININGS AND CORRECT AND INCORRECT METHODS OF MAKING REPAIRS.

heat. The proper method of making extensive repairs to the lining is also shown in this illustration.

A great deal of useful information regarding the operation of the cupola is given by Bradley Stoughton in an article in *The Foundry* in October, 1907. Mr. Stoughton divides the cupola into four zones: (1) The *crucible zone* or *hearth* extending from the bottom of the cupola to the tuyeres. (2) The *tuyere zone* where the blast comes in contact with and burns the red-hot coke. This is the zone of combustion. Its upper limit depends on the blast pressure, and the higher the pressure the greater will be the height of the zone. The top of the zone should never be allowed to go 15 to 24 inches above the tuyeres. (3) The *melting zone* where all melting takes place. It is situated immediately above the tuyere zone and the lower part of it overlaps the latter. Iron of the charge should begin to melt as soon as it enters the melting zone and should finish melting at a point about seven inches lower down, the iron and coke sinking as the latter burns away. Each charge of iron should enter the melting zone just before the last previous charge is completely melted at the bottom. (4) The *stack* extending from the melting zone to the level of the charging door. Its function is to contain the material, permitting it to absorb heat and thus prepare itself for the action at the lower level.

The blast pressure should depend on the size of the cupola, but present practice favors a pressure of not over one pound per square inch, diminishing to one-half pound in the smaller sizes of cupolas. As one pound of coke requires about sixty cubic feet of air for burning it, the size of the blower necessary may be calculated. Makers of blowers advocate pressures and volumes too high for good cupola practice. If the pressures and volumes advocated by them are adopted unqualifiedly, the melting zone will be raised and the iron oxidized, due to its greater drop to the hearth through the incoming blast.

Melting should begin within fifteen minutes of the time that the blast is put on. If it takes longer than this the bed charge of coke has been made too high and coke is wasted. The first layer of iron should be completely melted in eight to ten minutes. The thickness of the various layers of coke should be such that the next layer of iron should enter the melting zone just as the previous one is melted. If the layers of coke are made thicker than this, coke is wasted. If the iron layer is too thick the last of the layer will melt near the tuyeres and will oxidize excessively and be cold. The fact that the iron layers are too thick may be noted by the iron running first hot and then cold from the cupola spout.

It is important to watch the flames from the stack. Too great a volume of blast is indicated by a "cutting" or oxidizing flame, and also by the projection of sparks from the slag-hole. If the layers of iron and coke are too thin, there will be two charges of iron in the melting zone at one time. This will be made evident by the iron flowing more freely from the cupola spout at one time than another. If very hot iron is desired the coke layers must be made thicker, with a consequent diminution in the rate of melting.

Concerning the absorption of sulphur by the iron from the fuel, Mr. Stoughton says that the absorption will range from 0.020 to 0.035 per cent and that pig-iron with a sulphur content of 0.08 per cent will give castings in which the sulphur will range from 0.10 to 0.115 per cent. The sulphur will be higher in the first iron to come down than in the iron obtained at the middle of the heat because of the extra amount of coke in the bed charge. The iron obtained at the end of the heat will also be higher in sulphur because of the greater loss of metal at the end of the run due to better oxidizing conditions and consequently greater concentration of the metal. Silicon to the extent of 0.25 to 0.40 per cent may be burned out of the iron in its passage through the cupola. An allowance must be made for this in calculating the character of the charge.

In this same article, Mr. Stoughton published a table of comparative cupola practice which is reproduced below. Commenting on this table, Mr. Stoughton says that a mixture of coal and coke, or an inferior coke gives slow melting and a poor fuel ratio. The next striking evidence from the table are the figures given by the relation of the tuyere area to the speed of melting. If an average iron is melted in cupolas whose area is less than 6.56 times the tuyere area, we have a melting speed of 22.56 pounds per minute. For lesser proportional tuyere areas the figure is 18.57 pounds. Slow melting in cupola No. 8 is evidently due to the low height of the stack, which caused the iron to reach the melting zone before it was sufficiently preheated. A large proportional tuyere area means that the blast passes through the tuyeres with less resistance and with lower velocity. An important figure in the table is the relation between the speed of melting and the height of the charging door above the tuyeres, divided by the diameter of the cupola. The average melting speed where this ratio is over 2.5 is 24.12 pounds per minute. When the ratio is under 2.5, the melting speed drops to 19.15 pounds per minute. An exception to this rule is shown by cupolas Nos. 6 and 3. Cupola No. 6 melts faster due to its larger proportional tuyere area, while cupola No. 3 melts slower due to its lower proportional tuyere area. The average speed of melting with cupolas of more than 12 ounces blast

TABLE X.—COMPARATIVE CUPOLA PRACTICE

	1	2	3	4	5	6	7	8	9	10	11	A-1	A-2	A-3	A-4	Aver.
Cupola, diameter, inches....	27	35	42	44	54	54	56	58	60	60	72	32	42	44	48	—
Height of tuyeres above sand bottom, inches.	12	7	11	12	7½	14	25	16	2	12	24	11	12	9½	14	12.6*
Height of charging door above tuyeres, inches.	106	120	139	109	103½	113	141	92	112	114	142	133	132	84½	103	116*
Height of charging door above tuyeres ÷ diameter.	4.0	3.4	3.3	2.5	1.9	2.1	2.5	1.6	1.9	1.9	2.0	4.1	3.1	1.9	2.1	2.5*
Cupola area ÷ tuyere area ..	3.97	5.66†	9.62	4.53	6.58	5.45	2.85	4.83	10.47	6.73	5.76	4.96	5.77	7.68	12.56	6.56*
Blast pressure, ounces.......	9	16	8	9½	13	14	16	16	8	8	13½	16	12	13	8	12*
Class of work..............	Job	Plate	Light Job and Plate	Boiler Plate	Stove Plate	Boiler and radiator	Rolls	Fittings and job	Plate	Sanitary and Plate	Electrical	Gas-engine	Job	Pump and job	Medium light	
Melting ratio..............	4.0	7.5	7.6	8.8	6.9	7.5	8.3	6.8	7.5	7.6	10.0	6.4	6.2	7.2	7.8	7.3*
	Coke	Coke	Coke	Coke	Coke	Coke	Coke	Coke	Coke	Coke	Solvay coke	Light coke	Coal and Coke	Coal and Coke	Coal and Coke	
Height of fuel bed above tuyeres, inches.	20	21	15	33	24	32	40	14	30	22	6†	21	11	25	22.5	22.5*
Thickness of fuel charges after bed charge, inches.	8.4	7.0	3.8	6.1	6.9	10.4	9.6	8.0	3.8	6.5	7.8	7.3	9.5	3.9	5.8	7.0*
Thickness of iron charges after bed charge, inches.	3.3	6.5	3.5	6.3	6.3	8.4	8.8	7.3	3.4	6.8	9.0	6.0	7.0	4.7	5.3	6.4*
Time after blast before iron comes down, minutes.	7	15	5	15	10	20	5	15	1	15	15	10	15	15	7	11.3*
Time to melt each iron charge after bed, minutes.	3.25	8.5	5.7	9.0	10.0	11.0	12.0	12.0	5.5	11.0	13.5	7.7	....	9.5	13.8	9.46*
Iron melted per minute, per sq. ft. of cupola area, lb.	30.98	23.20	18.19	21.30	18.87	22.64	21.60	18.14	18.80	18.40	20.06	10.2	....	15.53	11.54	21.11**

* Including A-1, A-2, A-3, A-4. ** Exclusive of A-1, A-2, A-3, A-4. † Two rows of tuyeres.

pressure is 20.75 pounds per minute, while the rate with less than 12 ounces is 21.53. The divergence here is not great enough to establish a rule, but it is sufficient to discredit the theory that a high blast pressure necessarily gives fast melting.

This last statement is apparently borne out by an article by Mr. W. B. Snow, published in *The Foundry* in August, 1908. Mr. Snow gives a table showing the record of capacity and the blast pressure of a number of cupolas as follows:

TABLE XI.—Capacity and Blast Pressure of Cupolas

Diameter of lining, in.	44	44	47	49	54	54	54	60	60	60	74
Tons per hour	6.7	7.3	8.4	9.1	7.7	8.8	10.2	12.4	14.8	13.8	13.0
Pressure, oz. per sq. in.	12.9	16.4	17.5	11.8	13.6	11.0	20.8	15.5	16.8	12.6	8.7

Mr. Snow says that for a given cupola and blower the melting rate increases with the square root of the pressure. Thus a cupola which melts nine tons per hour with a pressure of 10 ounces will melt about ten tons with a pressure of 12.5 ounces and 11 tons with 15 ounces. The power required varies as the cube of the melting rate, so for 11 tons $(11 \div 9)^3 = 1.82$ times as much power will be required as for 9 tons. Thus large cupolas and blowers using light pressures have a distinct advantage.

The ratio of iron to fuel in the cupola is shown by a series of tables in the eighth edition of Kent's "Mechanical Engineers' Pocket-Book," page 1227. These are taken from the charging list of several stove foundries.

TABLE XII

Bed of fuel, coke	1,500 lb.
First charge of iron	5,000 lb.
All other charges of iron	1,000 lb.
First and second charges of coke, each	200 lb.
Four next charges of coke, each	150 lb.
Six next charges of coke, each	120 lb.
Nineteen next charges of coke, each	100 lb.

Thus for a melt of 18 tons, 5,120 pounds of coke are required, giving a melting ratio of 7 to 1. If the amount of iron melted is increased to 24 tons, the melting ratio of 8 pounds of iron to one of coke is obtained.

TABLE XIII

Bed of fuel, coke	1,600 lb.
First charge of iron	1,800 lb.
First charge of fuel	150 lb.
All other charges of iron, each	1,000 lb.
Second and third charges of fuel, each	130 lb.
All other charges of fuel, each	100 lb.

For an 18-ton melt, 5,060 pounds of coke are needed, the melting ratio thus being 7.1 pounds of iron to one pound of coke.

TABLE XIV

Bed charge of coke	1,600 lb.
First charge of iron	4,000 lb.
First and second charges of coke, each	200 lb.
All other charges of iron, each	2,000 lb.
All other charges of coke, each	150 lb.

Thus 4,100 pounds of coke will be required to melt 18 tons of iron, giving a melting ratio of 8.5 to 1.

TABLE XV

Bed charge of fuel, coke	1,800 lb.
First charge of iron	5,600 lb.
All charges of coke, each	200 lb.
All charges of iron, each	2,900 lb.

The melting ratio in a melt of 18 tons is 9.4 pounds of iron to one pound of coke, 3,900 pounds of fuel being used.

TABLE XVI

Bed of fuel, coal	1,900 lb.
First charge of iron	5,000 lb.
First charge of coal	200 lb.
All other charges of iron, each	2,000 lb.
All other charges of coal, each	175 lb.

The melting ratio in a melt of 18 tons is 7.7 pounds of iron to one pound of coal, 4,700 pounds of coal being used.

Calculating Cupola Mixtures.—To produce uniformly good castings, materials must be uniform and all supplies including pig iron, coke, etc., should be analyzed and their composition determined. By calculating charges which have been put into the cupola, and comparing these calculations with the analyses of good castings made from these charges, melting losses and changes in composition of the iron occurring in the cupola, can be ascertained. After the melting factor has thus been determined, proper mixtures can be made and the cupola can be studied to still further improve the quality of its output. What follows in regard to this subject is abstracted from a lecture by Dr. Richard Moldenke, before the students of the Case School of Applied Science.

If the analysis of a series of good boiler castings shows that they should contain about 1.90 per cent silicon, not over 0.05 per cent sulphur, and not over 0.40 per cent phosphorus, the carbon and the manganese being those of normal irons, then the mixture must contain the silicon wanted, plus that burned out during the melting (about 0.25 per cent). The sulphur of the mixture must be at least 0.01 per cent lower, as this amount is always added by unavoidable contact with the fuel. The phosphorus need be but slightly lower, as the melting acts somewhat in the way of concentration, the bulk of the heat becoming 4 to 7 per cent smaller, which percentage is called the melting loss.

In calculating mixtures we must deal with the following elements: Pig iron, scraps of various kinds, the fuel, and the limestone flux. The pig iron may have been cast either in the sand bed of the blast furnace or in chill molds, and it may be either charcoal, coke, or anthracite iron, depending on the fuel with which it is smelted. Furthermore, it may be either cold-blast or warm-blast charcoal pig iron. The order of excellence is from the finest cold-blast charcoal iron down to the poorest cinder-made, hot-blast coke iron. Cupola mixtures may contain only one variety or can be built up from twenty-three pig-iron ingredients.

The scrap used may be either made in the foundry or bought. The former is simply the bad castings, the gates and sprues of previous melts, and we should know all about it. The bought scrap, however, will often upset all calculations as to quality, when used in too great a quantity. In addition we may add steel scrap to strengthen castings and then malleable scrap, wrought-iron scrap, cast-iron borings, steel borings, etc.

The chemical composition is the basis of all preparations and mixtures for building up a heat for castings. The preparation of a mixture begins when the pig iron is received in the foundry yard. The metal should be piled in such a way that the foundryman may be sure of uniform material when he uses it. This is best done by spreading the first car-load of a given composition in a long row of pigs. The next car-load goes on top of this and so on till the pile is man high. Another pile is then commenced. By drawing from the end of the first pile, an average of all the car-loads thus stacked is obtained and one analysis will do for many car-loads of pig iron. In this way one can use specifications to an advantage, for, with a given class of work, such as miscellaneous car castings, it is possible to specify, say, four grades of iron containing, respectively, silicon contents of 1.75, 2.00, 2.25, and 2.50. Of the two extremes, but little will be wanted, but the bulk will be 2.25 silicon iron. Now by placing all car-loads with less than ten points of silicon below that required on the next lower pile, a satisfactory arrangement is obtained and one can build up a mixture at the desk and be sure that it will work out right.

In general, the more scrap used, the cheaper the mixture, but also the greater the melting loss. A good mean is usually 60 per cent pig and 40 per cent scrap. This is for general jobbing castings, as special classes of work often require pig iron only. In calculating a mixture, suppose that the limit for silicon be 2.15 per cent in the castings, then the 0.25 per cent lost in melting added to this will give us a requirement of 2.40 per cent silicon in the mixture. Assume the cupola to be charged in 4,000-pound layers of metal with the coke-to-iron ratio one to eight. Of these 4,000 pounds of metal which should, at 2.40 per cent silicon contain 96 pounds of silicon, the pig iron is to form 60 per cent of the charge or 2,400 pounds, and 40 per cent or 1,600 pounds should be scrap. Scrap usually contains less silicon than the castings of the particular class from which the scrap originated and, therefore, for our purpose, the scrap may be considered to contain 2.00 per cent silicon, or 32 pounds. The pig iron must contain the other 64 pounds and hence must have an approximate silicon content of 2.65. This example, which by the way is of soft machine castings of medium size, shows that the yard must contain irons of higher silicon contents than those given above. They should run in this case 2.00, 2.25, 2.50, and 2.75 per cent. We note that with pig irons averaging 2.65 per cent silicon desired, the mixture will be from irons between the 2.50 and the 2.75 limits. A simple trial calculation shows that 2,000 pounds of the 2.75 mixture and 400 pounds of the 2.50 silicon iron will give the proper results. The mixture table is as follows:

1,600 lb. scrap, 2.00 per cent Si		32.0 lb. Si.
2,000 lb. pig iron, say Warwick, 2.75 per cent Si		55.0 lb. Si.
400 lb. pig iron, say Clifton, 2.50 per cent Si		10.0 lb. Si.
4,000	Average 2.40	97.0

It is advisable to have in the foundry yard a quantity of iron containing 4.00 to 5.00 per cent silicon to correct a sudden tendency downward of the silicon in the mixture as the result of an improper working of the cupola or furnace. This also enables us to use lower silicon and therefore cheaper irons in the mixture. However, this is not conducive to the best results which are obtained by putting into the cupola as nearly as possible what is desired to obtain from it.

In charging steel scrap, this must be selected from boiler-plate, structural material, or steel castings if obtainable. It must be neither too thick nor too thin, otherwise an irregular melting will result. Twenty-five per cent is a good amount to use for very strong work. It can be increased to 40.00 per cent if desired, but anything above 25.00 per cent will take up so much carbon from the fuel that the value as a reducer of the total carbon is gone. Where much steel is used, from 2.00 to 4.00 per cent of ferro-manganese should be put in the ladle, as the added steel raises the melting point of the metal and the ferro-manganese is able to act as a deoxidizer which is impossible with the low temperatures of ordinary gray iron.

Sulphur must be kept low or there will be trouble with light castings. The calculation of sulphur in a mixture is similar to that given above for silicon, but if precautions are taken to keep the pig iron low in sulphur, this element need not be considered in mixture calculations. Not only do we have to contend with sulphur in the iron but also in the fuel. From 0.01 per cent to 0.07 per cent is added to the iron in the cupola, depending on the sulphur in the fuel. It seems that only the sulphur which is in the ash of the coke enters the iron and especially when the heat is run cold. It is therefore best to use plenty of fuel to get a good hot iron, and most of the sulphur will be driven off before it has a chance to combine with the iron.

While the importance of silicon and sulphur has been specially dealt with, it is their effect on the relations on the carbon content of the iron that is really aimed at. Whether a piece of iron is gray and soft, gray and hard, mottled or white and amenable only to the emery wheel depends to a large extent upon the proportion of combined carbon present. Thus in 3.3 per cent total carbon of which 0.2 is combined and 3.3 per cent is graphitic, the casting is practically a 20-carbon steel, although it is a soft gray-iron casting. If the total carbon is diminished to 2.80 per cent with the combined carbon the same, we have a much stronger iron, yet one which is easily machined. If the combined carbon is increased the matrix becomes a tool steel with whatever graphitic carbon is present to weaken the metal. This casting, however, is now hard to machine. Increase the combined carbon to the full amount of the total carbon, and we have a white iron such as is used for rolls, malleable castings, etc., and which usually require subsequent treatment to make them serviceable. The state of the graphitic and combined carbon in the casting is the result of several variable conditions. The silicon content when above 1.75 per cent makes gray to black fractures in a casting, and when below may make fractures ranging from light gray to dead white. The second variable is the thickness of the casting which controls the cooling rate after the metal is poured. Lastly, the temperature of the melt has its effect, a hot pour making a harder iron than a cool one.

The making of a good mixture is not a guarantee that the castings will be right, for, after tapping, there are many opportunities to spoil good work. The metal may be poured too hot or held too long before pouring. The molds may be badly vented and the iron may be poured so that it will shot or so that slag enters the mold. Hence the necessity of coolness and good judgment in applying remedies for manifest evils lest greater ones result.

The following method for calculating mixtures for the cupola is given in *The Foundry*, October, 1907: "It is required that the analyses of the iron from the cupola be as follows: Silicon 1.60 per cent, phosphorus 0.70 per cent, sulphur less than 0.10 per cent, manganese less than 0.50 per cent. Previous experience with iron and coke shows, due consideration being given to local melting conditions, that the approximate loss of silicon in the cupola will be 0.25 per cent and of manganese 0.10 per cent, the sulphur increasing at the same time 0.03 per cent. The iron and the scrap to be charged, therefore, must have an average analysis as follows: Silicon 1.85 per cent, phosphorus 0.70 per cent, sulphur less than 0.07 per cent, manganese 0.60 per cent. A table similar to that given below is then made, showing various weights of metal to be charged, the analyses of the different metals, and the weight of silicon, sulphur, phosphorus, and manganese contained in a given quantity of each iron. From the classes of metal available to form the mixture, selections are made of the proper quantity to give the respective amount of silicon, sulphur, phosphorus, and manganese necessary to give the desired average composition. The weight of each element is found by multiplying the percentage of each element in the different classes of material charged by the weight of that material, and by dividing the total weight of each element by the total weight of the material charged, the percentage composition of the mixture is determined. By making adjustments of the pig iron and scrap, mixtures of any desired analysis can be made."

TABLE XVII.—MATERIAL TO BE CHARGED AND METHOD OF FIGURING

	Lb.	Analysis Per cent				Weight of *			
		Si	S	P	Mn	Si	S	P	Mn
Steel scrap	400	0.10	0.07	0.10	0.60	0.40	0.28	0.40	2.40
Machinery scrap	2,000	1.70	0.10	1.00	0.60	34.00	2.00	20.00	12.00
High sulphur Southern	1,600	0.70	0.10	1.50	0.30	11.20	1.60	24.00	4.80
No. IX	1,600	3.00	0.03	0.80	1.25	48.00	0.48	12.80	20.00
No. 3 foundry	4,000	1.75	0.07	0.30	0.60	70.00	2.80	12.00	14.80
High silicon	800	3.50	0.025	0.07	0.60	26.00	0.20	0.56	4.80
Total	10,400	....	.....	....	....	191.60	7.36	69.76	68.00
Percentage	......	....	.....	....	....	1.84	0.071	0.67	0.65

* Multiply the weight of each kind of material by the percentage of the element in it and divide total weight of each element by total weight of material. By relative adjustment of pig iron and scrap, mixtures for any desired analysis can be made.

CHAPTER XXV

THE AIR-FURNACE AND ITS OPERATION

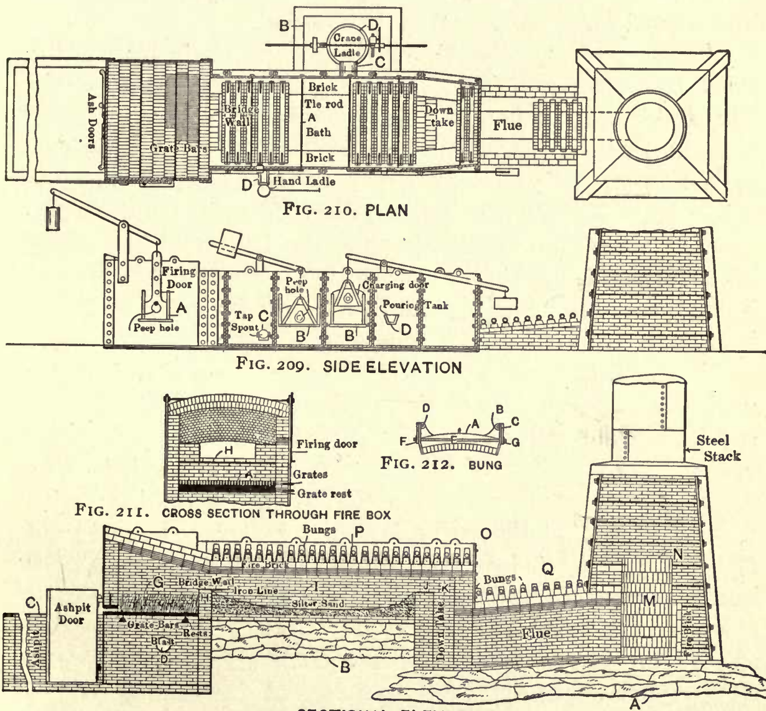
INSTEAD of the cupola, the air-furnace, more properly known as the reverberatory furnace, is used for melting iron for foundry practice, especially where malleable castings are to be made. The air-furnace has a number of advantages over the cupola and also certain disadvantages. These advantages may be summed up as follows: It is economical of fuel, can be cheaply constructed and easily repaired. It may be started at any time from the cold condition and can be quickly cooled after use. It requires no expensive auxiliary machinery, such as blowers, gas producers, etc. Its principal disadvantage is that it consumes a greater length of time to melt the same tonnage than the other forms of melting apparatus and the metal coming out of it at the end of a heat is liable to be burned. The most serious disadvantage is that the action of the flame in the furnace is such as to noticeably increase the sulphur content of the iron, an amount of 0.3 per cent frequently being added when the coal used is high in sulphur. Furthermore, metal cannot be long held in an air-furnace after it is ready for pouring unless the quality required is not of the first importance. This necessarily limits the size of the furnace.

The illustrations, Figs. 208–212, show a typical air-furnace. At the extreme front of the furnace is a fire-box *G*, containing grate-bars on which the coal for melting the metal is burned. Behind this and separated from it by a bridge wall *H*, is the bath or hearth *A*. This is built on a stone foundation over which are laid two courses of fire-brick, these being covered with a thick layer of silica sand to form the hearth. At the rear of the bath is another wall forming, with the end of the furnace, a down-take leading to a flue which conveys the waste gases to the stack. The roof of the furnace over the fire-box is of arch form and slants downward toward the bridge wall as shown. The roof over the bath is formed of cast-iron *bungs* constructed, as shown in Fig. 212, of iron castings with the tie rods *F* extending across them, which when the bung is lined with fire-brick are tightened to hold the fire-brick in place. These bungs may be lifted off the furnace to permit charging, which is done by laying the iron on the hearth. Tapping spouts are provided in the side of the furnace, as are also charging doors through which material may be placed in the furnace if desired. The flames, rising from the fire on the grate-bars, are deflected by the sloping roof so that they strike and play upon the metal in the hearth, thus melting it down to a liquid for pouring.

The hearth is composed of silica sand which is sintered before the furnace is put in operation. Sand is rammed down on top of the brick to a depth of about two inches. The bungs are then put in place and the furnace fired until the sand fuses together. When the first layer has set another layer is shoveled in and the operation repeated, the process continuing until the hearth is of the necessary thickness, which ranges from six to eight inches. The hearth must be so formed that the iron will run on it toward the tapping spout. If this is not done a hoe must be used to empty all pools left in the bottom when the furnace is drained. A good mixture of sand for the hearth is two parts of silica sand, with a silica content of 95 per cent or more, to one part of ground silica rock.

The shape of the hearth is important, as there may be a thin feather of metal around the edge of the hearth, which may become badly burned during the course of operations. If the bottom is cut away to a certain extent, around the edge of the bath, the metal may then be given a thickness of two or three inches at this point, which, in connection with the slag covering it, will suffice to prevent burning. Three spouts at different levels are recommended by Dr. Moldenke in order that the iron at the surface of the bath may be tapped first and burning thereby avoided.

When preparing the furnace for the day's heat, the bungs are removed and the furnace thoroughly cleaned out. If the sand below the hearth has been injured, it is re-formed and repaired, this being done while the furnace is hot so that the new sand will bake on the old. The hearth is then made up



FIGS. 208–212.—TYPICAL AIR-FURNACE.

with a mixture of fire-sand and red clay. Red clay should be used sparingly, as it has a tendency to crack in drying, permitting the iron to flow down underneath the surface and float the bottom up. In charging the furnace, sprues are usually placed on the hearth first, being spread evenly over the bottom. Over them the pig-iron is piled, half the charge at each end of the furnace. This method of charging permits the iron to melt gradually, which would not occur were all the metal to be thrown in promiscuously and the charge would require perhaps an hour longer to melt it.

Westmoreland County (Pa.) coal is advised for firing an air-furnace. The best practice gives about four pounds of iron melted for every pound of fuel burned.

As the melting proceeds, test-plugs are made by pouring metal into the molds, formed with a plug one inch in diameter. These plugs are broken and the fracture examined. If there is a mottled appearance to the fracture or if black specks appear in it, the graphitic carbon is too high and must be reduced by holding the metal in the furnace longer. The mottled appearance indicates that the silicon in the metal in the furnace is too high or that the temperature of the furnace is too low. The charge should be ready for pouring about four hours after charging is complete.

The principal use of the air-furnace is making iron for malleable castings. For this purpose a sharp, white iron is required, which, after casting, is annealed in proper annealing ovens. The molding of malleable castings is carried on in practically the same manner as for gray-iron castings, with the exception that the gating is so arranged that the mold will fill quickly, as white iron does not remain fluid as long as gray iron. Instead of providing risers over heavy portions of malleable castings, as is done in gray-iron work, a chill is often set against the heavy part. The iron cools quickly against the chill, and the light and heavy portions of the casting cool at about the same time. This eliminates strains and gives a clean sound casting.

The subject of malleable castings is too wide and complicated to be treated in detail in a book of this character. The reader is referred to "The Production of Malleable Castings,"[1] by Dr. Richard Moldenke, which is the most complete work on this subject and goes into every detail of malleable practice.

[1] The Penton Publishing Co., Cleveland.

CHAPTER XXVI

THE BRASS FOUNDRY

CONNECTED with many manufacturing establishments are brass foundries in which are made castings from the non-ferrous metals, such as bronze, brass, aluminum, etc. The molding operations are carried on in practically the same manner as for gray iron, finer sand, however, being used. The metal being poured at a lower temperature than iron does not destroy the sand as iron does. The larger castings in brass are molded in dry sand and in loam exactly as is done for iron. As the shrinkage of the non-ferrous metals and alloys is greater than that of iron, more attention must be given to provisions for allowing the shrinkage of the casting in the mold and also larger shrinkheads must be provided than is usual with iron castings. The pouring temperature of the metal has an important influence on the character of the finished casting. Very hot metal will find its way into the pores of the sand and produce a rough casting. The temperature at pouring should be so low as to barely permit the metal to flow and yet produce a smooth casting. This temperature in turn depends largely on the composition of the alloys.

Instead of melting in a cupola, the metal in the brass foundry is melted in a crucible or a reverberatory furnace, the latter using coal, coke, oil, or gas for fuel. The crucibles for melting brass, or similar non-ferrous compositions, are made of clay and graphite, the crucible being formed and then baked to calcine the clay. Before using, the crucibles should be seasoned by allowing them to stand in a warm dry place for a considerable period, after which they are gradually heated up to a temperature of 255° Fahr. in an annealing oven, remaining in the oven from 45 to 60 hours.

In Fig. 213 is shown one of the older types of coal-fired crucible furnace. This is set in the brick-pit *A*, and is carried on grate-bearers as shown. The coal or coke is placed inside the fire-brick lining and the crucible *E* bedded in it. The furnace is set with its top practically flush with the floor and it is connected at the upper end with a flue *G*. In commencing

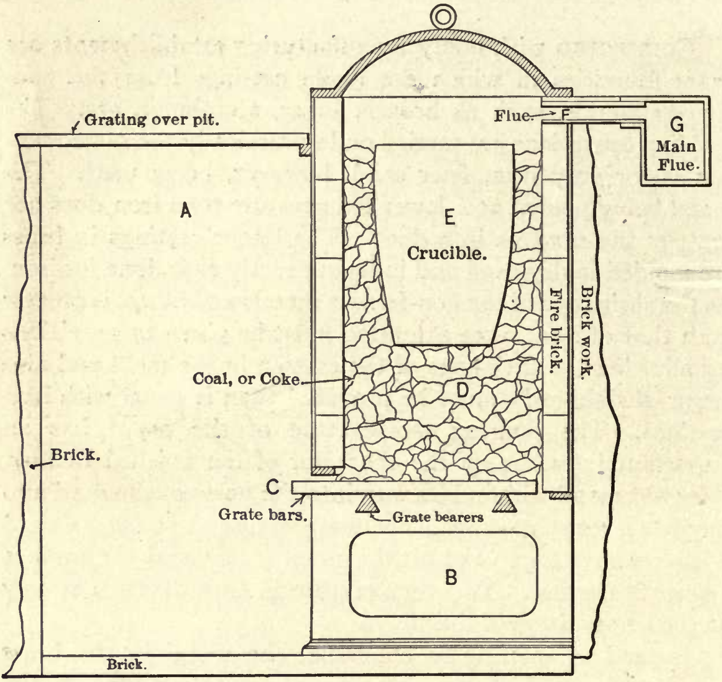


FIG. 213.—CRUCIBLE BRASS FURNACE.

operations with this furnace, a good bed of coal is placed on the grate, over which the crucible is set while the coal is being fired in order that it may heat up gradually. Copper ingots, or ingots of other metal which it may be desired to melt, are placed in the crucible, being so arranged that they will not wedge with each other, and in expanding crack the crucible. After the copper has melted, the metal requiring the next lower degree of heat is added, and after this is melted the other metals to form the alloy are placed in the crucible. When the mixture is entirely melted, the crucible is lifted from the furnace by means of a special pair of tongs which encircle the crucible and the metal is skimmed with a birch-rod or a wrought-iron skimmer. For pouring, the crucibles are carried in a wrought-iron shank and care should be taken that the

FIG. 214.—THE OPEN-FLAME FURNACE.

crucible be completely emptied of metal, otherwise it will be badly damaged.

In place of the coal-fired crucible furnace just described, open-flame furnaces illustrated in Fig. 214 are in wide use. Oil and air are admitted through the trunnions at a pressure of about 65 pounds per square inch. The flame from the oil plays directly on the metal in the furnace. Open-flame furnaces have the disadvantage of causing large losses of metal through oxidation unless great care is taken in the control of the furnaces. A further development of the oil- or gas-fired furnace is shown in Fig. 215. This furnace is known as the crucible-tilting furnace, the metal being melted in a crucible set in the fire-brick chamber forming the furnace proper and flames from the oil or gas playing around the furnace as shown. The metal is thus protected from the oxidizing effect of the flame, and the melting loss, with proper regulation of the furnace, is low.

The pouring temperature of alloys used in the brass foundry being low, the metal should be poured in the molds as promptly as possible after melting. The castings, on removal from the sand, are cleaned by pickling.

The brass foundry requires a book in itself for its proper

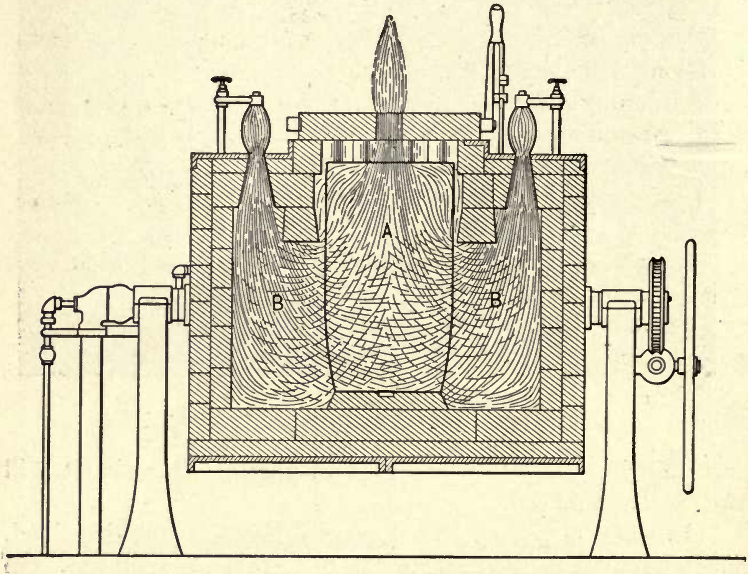


FIG. 215.—THE CRUCIBLE-TILTING FURNACE.

treatment. No small part of such a book would be given over to the composition of alloys and the mixtures for making them. Every brass founder has his own ideas on these mixtures and their number is legion. The writer has successfully used the mixtures given below for the purposes mentioned. For a very complete treatise on this subject see "Practical Alloying,"[1]

[1] The Penton Publishing Co., Cleveland.

by J. F. Buchanan. See also tables in the Appendix, pages 367 to 369.

Alloy for stationary engine work: ingot copper, 9 pounds; tin, 1 pound; zinc, 1 ounce.

Composition for heavy work: ingot copper, 46 pounds; tin, 7 pounds; spelter, 3 pounds; lead, 1⅛ ounces.

A tough yellow metal: copper, 12 pounds; spelter, 4 pounds; lead, ¾ pound; tin, ¾ pound.

Another yellow metal: copper, 20 pounds; zinc, 8 pounds; lead, 1 pound.

Babbitt metal for heavy bearings: copper, 2 pounds; antimony, 2 pounds; tin, 72 pounds.

Hardening metal for heavy bearings: tin, 2 pounds; used with 1 pound of a mixture of the following proportion: copper, 12; antimony, 24; tin, 27.

A hard bronze: copper, 88; tin, 6; zinc, 4; lead, 2; phosphor-tin, 2.

Gun-metal: copper, 44; tin, 4; lead, 1; phosphor-tin, 1.

Gun-metal: copper, 88; tin, 8; zinc, 4; lead, 2.

Phosphor-bronze: copper, 88; tin, 7; zinc, 4; lead, 2; phosphor-tin, 1.

Phosphor-bronze, medium hardened: copper, 100; zinc, 12; tin, 4; lead, 1½.

Yellow brass: copper, 4; zinc, 1; lead, $\frac{1}{16}$.

CHAPTER XXVII

FOUNDRY EQUIPMENT

Ladles.—A variety of ladles for transferring the molten iron from the melting furnace to the molds is used in the foundry, ranging in size from the small hand-ladle holding twenty-five pounds of iron to ladles containing as much as fifty tons which are used in steel and heavy iron foundries and are handled by the crane. Smaller ladles are made of cast-iron with lugs to which handles are fitted, while the larger ones are constructed of steel plates riveted together and provided with trunnions by means of which they are suspended from the crane. The ladles of all sizes are lined with fire-clay of the same grade as is used to line the cupola to protect the bottom and sides from the molten iron. The smaller hand-ladles are of such size that they may be carried by a single molder and are used for pouring the lighter castings made in bench molds and also for feeding risers and shrinkheads in castings which require churning or pumping. The next larger size of ladle is known as the double-shank ladle and is carried and poured by two men. Larger ladles than these are used either for pouring heavy castings or for transporting large amounts of iron to central points in the foundry whence the iron is conveyed in hand or double-shank ladles to the molds. These ladles are handled by means of tramways or cranes. The largest-size ladles holding upward of one ton are handled exclusively by cranes and are usually lined with fire-brick over which fire-clay is daubed. Before using, the ladle should be thoroughly dried and heated either by means of an oil-torch or a fire built in it. Any moisture in the lining will become steam when the molten metal is poured into it, and start an agitation in the metal which may seriously damage the lining and permit the molten metal to come in contact with the metal of the ladle, thus burning a hole through it and allowing the molten metal to escape and do serious damage. Most ladles used in the foundry pour over the lip, but for steel castings an opening is provided in the bottom of the ladle, closed by a suitable plug which is removed when the mold is to be poured and the steel is taken from the bottom of the ladle. Occasionally the lip of the ladle is made higher than the rest of the rim and a hole is cut through it through which the iron is poured. The lip thus acts as a skimmer and prevents slag from flowing with the iron into the mold. When filling large ladles the iron is covered with charcoal or some refractory material to exclude the air and thus prevent oxidation.

Flasks.—Flasks for use in the foundry are made either of iron or wood. Wooden flasks should be made of substantial material, as they are liable to burning and in a short time if made too light will be completely burned away at the joint and run-outs of the mold will be frequent. For very heavy castings, iron flasks are more generally used and these are made so far as possible so that the different parts will be interchangeable with one another. Thus the pin-holes are bored in the flanges to a template and the pins are located by the same template. Thus any number of flasks of the same size can be piled one on the other to form cheeks and copes. The ends are usually made so that different flasks can be butted one to another and a long flask thus formed. For side-floor work, the flasks are usually made to conform to the shape of the pattern, thus diminishing the amount of sand rammed in the flask and making it lighter for the molder to handle. Large iron flasks should be provided with slotted holes in the sides through which bolts may be passed to hold bars in place. By this means the bars can be arranged as desired to suit the necessities of the pattern in hand. Iron flasks should be made sufficiently heavy to prevent springing under the pressure of the metal in the mold. It is a mistaken idea that because a flask is of iron there is no spring to it. However, it is not necessary to make the sides of the flask of uniform thickness to resist the tendency to spring: ribs cast on the sides will serve the purpose just as well and make a lighter construction. Trunnions should be made preferably of steel cast into the sides of the flask rather than of cast-iron cast in one piece with the flask. The flask should always be of such size that there is ample sand between it and the pattern, not only to protect the flask from the molten iron, but to absorb the gases given off in pouring. In many cases when iron flasks are made, lugs are arranged on each end of the cope and drag so that they will come in line with each other. Holes are bored in these lugs and a rod run through them to form a guide for lifting the cope over high parts of the pattern. Steel flasks are coming into use, being light and serviceable, but on account of their lightness they heat rapidly and may warp out of shape, in which case it is difficult to restore them to their original form. I-beams are also frequently used to form the sides of the flask. Flasks for molding-machine work are frequently of iron, although for small castings the wooden snap flasks, of which there are a number of varieties on the market, are in general use. It is advisable to plane the edges of iron flasks where good work is expected and the pins should be carefully fitted.

Tumbling Barrels.—Tumbling barrels are made in a variety of shapes and sizes. The square tumbling barrel, or rattler, is convenient for a number of varieties of castings and is often made of cast-iron with cast-iron heads and provided with cast-iron stays extending from end to end. Rattlers are often made with the sides in sixteen or more segments, any one of which may be replaced when worn out or broken. They are often combined with a sand-blast arrangement whereby sand is blown under air pressure into the rattler through one of the trunnions to assist in cleaning the casting. Often rattlers are made with wooden staves supported by iron stays on the outside, or the iron rattler may be lined with wood. Exhaust-pipes should be connected to each rattler through which a fan may remove the dust incident to their use. A very popular form of tumbling barrel for small castings is the open tilting tumbling barrel, which may be tilted

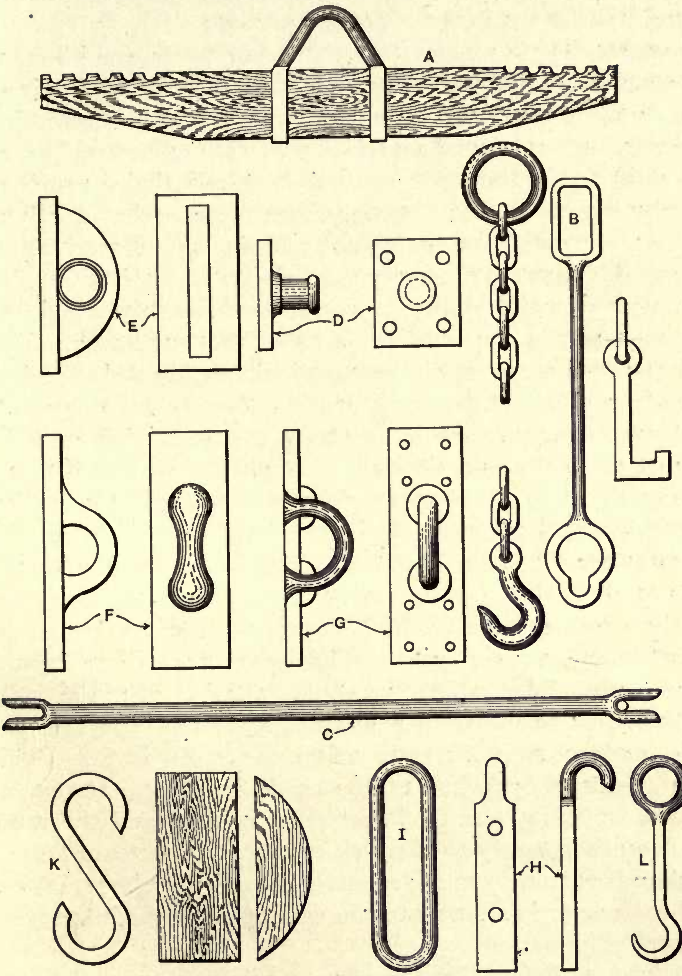


FIG. 216.—FOUNDRY RIGS.

to discharge the tumbled castings and elevated to an inclined position for rattling. A stream of water is directed into this barrel while in use in order to prevent dust.

Cranes.—Up to comparatively recent times, the jib-crane operated by a hand-winch was almost exclusively used in iron-foundries. These were extremely limited in their application and were useless beyond a circle of which the crane arm formed the radius. In the more modern foundries they have been largely displaced by the traveling crane, either hand or electric, depending on the weight and amount of work done. The most important feature in an electric crane for foundry use, aside from its ability to carry the maximum weight of casting made in the foundry, is its control apparatus. This must be such as to permit very gradual starting and stopping, and of operation at extremely low speeds. In drawing large patterns from the molds by means of the crane, they must be started gradually and slowly. Too quick a start will break the mold. Also, in rolling over copes of large sizes, a sudden start will shake the sand out of the mold and, in lifting, the operator must be able to stop the crane the moment that the cope is vertical and before it has swung clear of its support on the opposite edge. Furthermore, exact control must be maintained over the crane when pouring castings from a crane ladle. The molder must be able to tilt the ladle continuously to maintain a uniform stream of iron into the mold and to stop instantly when the mold is full. This requires the co-operation of the crane operator. Instead of cranes, traveling electric hoists may be used and the same considerations apply to them as to cranes. It would be out of place here to discuss the relative features of different cranes and the reader is referred to the catalogues of manufacturers for such information.

Foundry Rigs.—The foundry requires a miscellaneous equipment of small rigging for handling flasks, ladles, etc., for setting cores and securing molds for pouring. A variety of this equipment is illustrated in Figs. 216 and 217. *A* is a yoke and *B* is one of the slings used with it for handling copes

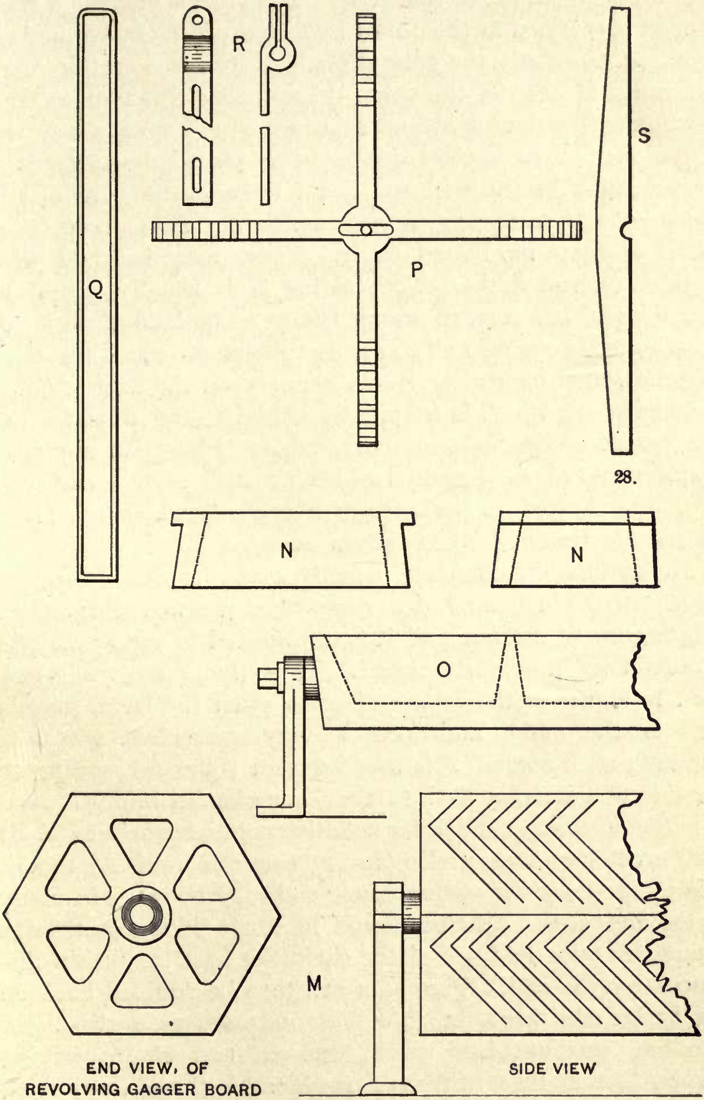


FIG. 217.—FOUNDRY RIGS.

and drags by means of the crane. The yoke is made of a solid timber suspended at the center by means of iron straps and an eye. Occasionally the yoke is made of iron or a section of an I-beam. Instead of the yoke, the spreader *C* is used in connection with a double strand chain which is hooked on to the trunnions of a flask, the spreader being placed above the flask at the right height with the chain links in the slots of the spreader. If trunnions are not cast on the flask, loose trunnions *D* may be bolted to it. These may be used with wooden or iron flasks. The casting *E* is usually bolted to the sides of the cope to permit chains to be hooked to it for hoisting the cope off and to act as rockers on which the flask may be rolled over after it has been set on the floor. *F* is a form of staple which is frequently bolted to the flask for the purpose of accommodating crane chains, while *G* is a similar staple made of steel around which an iron plate is cast. *H* is a hook bolted to the sides of a cope on which the crane chains are fastened when only a straight lift is desired. *I* is a loop forged from steel, usually made in sets of four, to place over each handle of a cope, when it is necessary to lift it by means of a crane and it is not desired to use any of the attachments previously noted. These loops are frequently used to slip over the arbors of cores when the latter project beyond the mold, and form a very convenient means of handling such cores. *J* is a convenient roller for nailing to the side of a wooden flask to act as a rocker in rolling it over. *K* is a convenient S-hook for handling copes, connecting short chains, setting cores, and removing castings from the molds. *L* is a core-hook for setting cores, and may be made in many styles and sizes. Chains should be made with a link large enough to take the hook of the chain, set back a certain distance from the end. The chain can then be doubled back on itself with the hook in this link and used as a sling. In handling medium-sized work, one or two chains having turnbuckles in them will save considerable time in adjusting for any given lift.

Straight-edges of various lengths with holes bored in them so that they can be hung up when not in use are serviceable tools to have in the foundry. A gagger-board is a useful piece of equipment for molding gaggers. A bed of molding sand is spread as nearly level as possible and the gaggers arranged on a board are pressed down into this bed and the board leveled with a spirit-level. On lifting the board a series of gagger-molds are left in the sand, which may be filled with molten iron and the gaggers formed. In Fig. 217 a revolving gagger-board is shown at *M*. The drum is molded plain and slab-cores forming the gagger-molds are set on the faces. As fast as one side is poured the drum is revolved and the next side brought to the top and poured. *N* is an ingot mold without a bottom in which slack iron from the hand-ladles is poured. It is set in loose sand, placed on the floor, and when filled with slack iron is picked up and moved to a new location. *O* is a larger ingot mold for receiving slack iron and also the iron from the cupola at the end of the heat. *P* is a cross used for hoisting portions of a mold such as the center of the loam mold described in Chapter XI, and *Q* is one of four slings used with this cross. *R* is a finger for attaching sweeps to a spindle, and *S* is a straight-edge used by loam molders, the notch in the center being fitted around the spindle.

GLOSSARY

AIR-FURNACE—A furnace for melting iron, principally used in malleable practice; see *reverberatory furnace.*

ARBOR—A bar or mandrel used as the center on which is built up a core.

ANNEAL—To soften or render ductile a casting by the application of heat in connection with a carbonaceous material packed around it. The final process in malleable work.

BAKED CORE—A dry-sand core which has been subjected to heat, usually in an oven, to render it hard and to fix its shape: the opposite of *green core.*

BARS—Ribs placed across the cope portion of a flask.

BASIN—The portion of a cupola below the tuyeres in which the molten iron collects.

BATH—The iron on the hearth of an air-furnace.

BEAD SLICKER—A tool for finishing a hollow place in a mold.

BED CHARGE—The first coke charged into a cupola.

BELLOWS—An ordinary small bellows used for blowing sand from the joint of a mold, and for blowing it from deep pockets in the mold.

BENCH—The framework table at which small molds are made.

BENCH WORK—Molds of such small size that they can be made at the molder's bench.

BINDER—A bar of wood or iron, with slotted ends to receive bolts, placed across a cope to hold the cope on the drag.

BLACK SAND—Heap sand.

BLAST—The supply of air to a cupola.

BOD—A ball of clay for closing the tap-hole.

BOSH—See *swab.*

BOTTOM-BOARD—A board placed on the under side of a mold.

BREAK-OUT—A rupture of a mold permitting metal to flow out at the joint. Also called *run-out.*

BREAST—The portion of the lining of a cupola immediately surrounding the tap-hole.

BRICKS, FIRE—Bricks made of fire-clay used for cupola and air-furnace lining.

BRICKS, LOAM—Bricks formed of a loam mixture, to set in a mold and to permit the easy crushing of the mold under the shrinkage of the casting.

BRUSH—A brush used for sweeping sand from the joint of molds.

BUCKLES—Swellings in the surface of a mold due to the generation of steam, below the surface, which cannot escape.

BUNG—A section of roof of an air-furnace.

BUTT—The large round end of a rammer.

CALIPERS—A measuring tool for ascertaining the outside diameter of cylindrical bodies.

CAMEL'S-HAIR BRUSH—A brush for applying blacking to the surface of molds.

CARRYING PLATES—Iron plates used to support certain portions of loam molds.

CASTING—The product of the foundry obtained by pouring molten metal into a mold.

CEMENTITE—The constituent of commercial iron consisting of iron chemically combined with carbon.

CHAPLET—A piece of metal, shaped in various ways, placed in a mold to support a core.

CHARGE—The iron and fuel placed in a cupola or air-furnace.

CHARGING DOOR—The opening in a cupola or air-furnace through which fuel and metal are introduced.

CHEEK—The portion of a mold, made in three parts, intermediate between the cope and drag.

CHILL—An iron surface, sometimes water-cooled, of a mold, used to chill the molten iron rapidly and thus produce a hard surface on the casting.

CHILLED WORK—Castings made in a chill mold.

CHUCK—Small bars set between the cross bars of a flask.

CHURNING—See *pumping*.

CLAMPING BAR—A bar used to tighten clamps on a flask.

CLAMPS—Devices for fastening copes and drags together.

CLAYWASH—A wash formed of clay dissolved in water.

COLD SHUT—An imperfection in a casting due to the metal entering the mold by different sprues, and cooling, failing to unite on meeting.

COPE—The upper half of a mold.

COPE DOWN—To build projecting bodies of sand on the surface of the cope to form surfaces of the casting which are below the level of the joint of the drag.

COPE PLATE—An iron plate used to support certain portions of loam molds.

CORE—A body of sand, either green or dry, placed in a mold to form a cavity in the casting.

CORE BOX—A box in which cores are formed.

CORE PLATE—A flat iron plate on which green cores are placed for baking.

CORE-PRINT—The cavity in a mold in which the ends of cores are set. Also the projections on a pattern which form and locate the prints in the mold.

CORNER TOOL—A tool for slicking the corner of a mold, inaccessible to the ordinary form of finishing tools.

CRUCIBLE ZONE—The basin of a cupola.

CUPOLA—A shaft furnace for the melting of iron; the iron and fuel being charged in alternate layers, and combustion promoted by air blown in at the bottom of the furnace.

DOUBLE-ENDER—A molding tool consisting of a combined slicker and spoon-slicker.

DRAFT—The taper given to the sides of a pattern to enable it to be easily withdrawn from the mold.

DRAG—The lower half of the mold.

DRAWING THE PATTERN—Lifting a pattern from the sand of a completed mold.

DRAW-NAIL—A pointed rod of iron or steel driven into a wooden pattern to act as a handle to withdraw it from the sand in a mold.

DRAWPEG—A draw-screw.

DRAW-SCREW—A rod screwed into a pattern to act as a handle for drawing the pattern.

DRAW-SPIKE—See *draw-nail.*

DRYER—A metal form, of the same shape as a core, in which the latter is placed while being baked.

DRY SAND—Sand which has been baked in an oven after having been formed into a mold.

DRY-SAND MOLD—A mold which has been baked in an oven to fix its shape permanently, and to give it a hard surface.

EARS—The lugs on the cope part of a flask into which the pins on the drag fit.

EYE-BOLT—A bolt with a ring welded at one end.

FALSE CHEEK—A body of sand in a mold, occupying the same position and performing the same functions as a cheek, but contained within the cope and drag, although separate from it.

FEEDING-HEAD—See *shrinkhead.*

FERRITE—The constituent of commercial iron consisting of pure iron. See *cementite.*

FIRE-BRICK—See *bricks, fire.*

FLANGE TOOL—A tool for furnishing the edges of flanges in a mold.

FLASK—The frame-work of wood or iron in which the sand is packed while being molded around a pattern.

FLAT-BACK—A pattern with a flat surface at the joint of the mold. Thus a flat-back pattern lies wholly within the drag and the joint of the cope is a plane surface.

FLAT GATE—A wide gate with a narrow opening into the mold, used for pouring thin flat castings. See Fig. 129.

FLOOR MOLDING—See *floor work.*

FLOOR WORK—Molds large enough to require molding on the floor of the foundry.

FLOW-OFF—A channel cut from a riser to permit metal to flow away from it when it has risen in the riser to a certain predetermined height.

FLUX—A fusible material, containing lime, such as limestone, charged in the melting furnace to combine chemically with and carry off impurities from the molten metal.

FOUNDRY—A shop where castings are made.

FROZEN IRON—Iron which has solidified.

GAGGERS—Rods of wrought- or cast-iron, with one end bent at a right angle, used to support hanging bodies of sand in a mold.

GATE—The hole in the cope through which metal is poured into the mold.

GATE-STICK—A stick set in the cope while it is being rammed to form the passage into the mold through which the molten metal is poured.

GATING PATTERNS—Arranging patterns on a backbone so that sprues will be formed by the backbone and its connection to the pattern when the mold is made.

GREEN CORE—A core which has not been baked.

GREEN SAND—Ordinary molding sand which has not been baked or otherwise been subjected to heat treatment, except by coming in contact with molten metal in the mold.

GREEN-SAND CORE—A core made of green sand.

GREEN-SAND MATCH—A false cope in which the patterns are placed while the drag is being made. Its object is to avoid the making of a difficult joint on each mold where there are a number of castings to be made from one pattern.

GRID—See *skeleton.*

HAND SQUEEZER—A molding machine in which the sand is compressed to the proper density by pressure applied by hand to the outer surface of the mold.

HAY-ROPE—A rope made of twisted hay, used to form the basis of cores made on arbors.

HEAP SAND—Green sand from the foundry floor.

HEARTH—That portion of an air-furnace on which the iron is melted.

HEAT—The melting period of a cupola or air-furnace.

HORN GATE—A semicircular gate to convey iron over or under certain parts of a casting, so that it will enter the mold at or near the center. Also used as a skim gate.

Hub Tool—A tool for finishing the mold of pulley hubs.

Jarring Machine—A molding machine in which the sand is packed by the sand, pattern, and flask being raised and dropped upon a table, the sand itself forming the ramming medium.

Joint—The portion of the mold where the cope and drag come together—the upper surface of the drag and the lower surface of the cope.

Jolt-rammer—See *jarring machine.*

Lifter—A molder's tool with a flat end at right angles to the stem, used to lift loose sand from deep pockets in the mold.

Loam—A mixture of molding sand and clay used for making loam molds. See Chapter XI.

Loam Bricks—See *bricks, loam.*

Loam Mold—A mold built up of brick-work, iron plates, etc., covered with loam which is afterward baked on.

Machine Molding—The operation of making molds on a molding machine.

Malleable Casting—A hard brittle casting of white iron, which is rendered tough and malleable by annealing under certain conditions.

Melting Zone—The portion of the cupola above the tuyere zone in which the iron is fused.

Mold—The formed cavity in sand or other material into which molten iron is poured to obtain a casting of any desired shape. The term is usually applied to the body of sand surrounding the cavity.

Mold-board—The board on which the patterns are laid when making the drag of a mold.

Molding Machine—A machine, operated either by hand or power, for making molds.

Molding Sand—Sand suitable for forming into molds. See Chapter XXII.

Nowel—See *drag.*

Paraffine-board—A board impregnated with paraffine on which patterns are mounted for use on the molding machine.

PARTING—The plane on which a pattern is split.

PARTING SAND—A fine, sharp, dry sand dusted on the joint of a mold to prevent the cope and drag adhering to each other.

PATTERN—The object of wood, metal, or other material whose shape it is desired to reproduce in metal. The sand of the mold is formed around the pattern, which is later withdrawn, leaving a cavity of its exact size and shape to be filled with molten metal.

PEEN—The flat-pointed end of a rammer. Also, the operation of ramming with the peen end of a rammer, as *peening* the sand.

PEG GATE—A round gate leading from a pouring basin in the cope to a basin in the drag, whence sprues lead to the mold. See Fig. 192.

PINS—The projections on the drag of a flask which guide and hold it in position with relation to the cope.

PIPE TOOL—A tool for finishing the surface of pipe molds.

POURING BASIN—A basin formed in the cope into which the iron is poured.

POWER SQUEEZER—A molding machine in which the sand is compressed to the proper density by pressure, applied by compressed air to the outer surface of the mold.

PUMPING—The action of feeding iron to a casting from a shrinkhead by forcing it in with a rod moved up and down in the shrinkhead.

RAMMER—The tool used by the molder for packing sand in a flask around a pattern. They are made of wood in the smaller sizes, known as hand rammers, and of iron in the larger sizes.

RAMMING—The action of packing sand around a pattern in a flask to form a mold.

RAPPING—The action of jarring a pattern in the sand to free it so that it may be drawn from the mold.

RAPPING IRON—An iron bar used to strike the draw-nail in order to jar the pattern preparatory to drawing.

REVERBERATORY FURNACE—A furnace for the melting of iron, the iron and fuel being separated. The fuel is burned in a fire-box, separated from the iron on a hearth by a bridge wall. A sloping roof deflects the gases of combustion down on the iron and thus melts it. Largely used in malleable work.

RIDDLE—A sieve for sifting sand on a pattern.

RISER—A gate formed over a high portion of a mold to act as an indicator when the mold is filled with metal, and also to act as a feeder to supply iron to the casting as it shrinks in passing from the liquid to the solid state.

ROLL-OVER MACHINE—A molding machine in which the mold is rolled over before the pattern is drawn.

RUNNER—A deep channel formed in the top of a cope, connecting with gates, into which the molten metal is poured.

RUNNER BOX—A set-off box in which a runner is formed.

RUN-OUT—See *break-out.*

SCABS—Imperfections in a casting due to portions of the surface of a mold breaking away.

SET GATE—A gate pattern used to form a gate or sprue, set against the pattern.

SET-OFF BOX—A small box, open at the top and bottom, fastened to the top of a cope to contain portions of a mold projecting above the cope.

SHRINKHEAD—A large riser containing a sufficient body of metal to act as a feeder as the metal of the casting contracts in solidifying.

SHOT—Globules of metal formed in the body of a casting, and harder than the remainder of it.

SKELETON—A metal framework on which a flat core is built.

SKIM CORES—Cores set in skim gates to act as skimmers.

SKIM GATE—A sprue so arranged as to skim any impurities from the surface of the molten iron as it flows into the mold, and restrain them from entering the mold.

SKIN-DRIED MOLD—A green-sand mold whose surface has been baked for a depth of an inch or more.

SLAG—The earthy impurities fused in the melting furnace, together with the fused flux charged with the fuel and metal.

SLAG-HOLE—The opening in a cupola through which slag is withdrawn.

SLICKER—An elongated, flat, thin piece of steel used for smoothing the surfaces of molds.

SLIP—A wash applied to the surface of loam molds.

SLURRY—The mixture used to fill in the joints of cores.

SLURRYING—The process of filling in the joints of cores.

SNAP FLASK—A flask hinged at the corners, and separable at one corner, so that it may be opened and removed from around a completed mold.

SOLDIER—A wooden stick or rod, claywashed, used to support bodies of hanging sand, or large green-sand cores.

SPINDLE—The rod or center on which a sweep is revolved.

SPINDLE SEAT—The socket in which the spindle revolves.

SPLIT PATTERN—A pattern made in two or more parts.

SPLIT-PATTERN SQUEEZER — A squeezer type molding machine, either hand or power, adapted to molding split patterns.

SPOON SLICKER—A finishing tool for a mold, the end of which is made of spoon shape.

SPRING DRAW-NAIL—A tool for drawing patterns, especially gear patterns, by gripping the inside of the hole in the hub.

SPRUE—The channels leading from the gate to the mold. Also, the metal which solidifies in these channels after the casting has cooled.

SPRUE CUTTER—A piece of metal, used to cut channels in the joint to conduct iron from the pouring gate to the mold. Also a brass tube used to cut the pouring gates in the copes of machine-made molds.

STACK—The portion of a cupola extending from the top of the melting zone to the level of the charging door.

STOOL—The support for a green-sand core on a molding machine.

STOOLING—The process of supporting green-sand cores in machine molding while the pattern is being drawn.

STOOL PLATE—The plate on a molding machine on which stools are mounted.

STRICKLE—A strike with a form cut in one edge to form a regular surface on a mold.

STRIKE—A flat bar of iron or wood used for striking or sweeping excess sand from the top of a mold.

STRIPPING PLATE—A plate on a molding machine on which the mold is made and through which the patterns are drawn from the mold.

SWAB—A limp brush made of teazled hemp rope used for wetting molds around the edges of patterns; *swabbing*, the action of applying water to a mold.

SWEEP—A piece of wood or iron revolved about a center to form the surface of a mold.

SWEEP FINGER—The metal piece by means of which the sweep is attached to the spindle.

TAP-HOLE—The opening in a melting furnace—cupola or air—through which molten metal is withdrawn.

TIGHT FLASK—A flask with a rigid framework—the opposite of *snap flask*.

TROWEL—A molder's tool used for slicking the surface of a mold.

TUYERES—The openings in a cupola through which air is blown.

TUYERE ZONE—The portion of a cupola in the region of the tuyeres, where combustion takes place.

UPSET—A shallow frame set over a flask in which is formed a green-sand match.

VENT—A small hole formed in a mold to permit the escape of gas from it.

VENT-WIRE—A wire used for making vents.

VIBRATOR—A device for rapping patterns by compressed air.

VIBRATOR FRAME—A frame in which patterns are mounted when they are to be drawn in connection with a vibrator.

WHIRL GATE—A gate or sprue arranged to introduce metal into a mold tangentially, and to thereby give it a swirling motion.

WIND-BOX—The chamber surrounding a cupola through which air is conducted to the tuyeres.

APPENDIX

TABLE XVIII.—Circumferences and Areas of Circles

Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.
1	3.1416	.7854	3 9/16	11.192	9.9678	6 1/4	19.635	30.680
1/16	3.3379	.8866	5/8	11.388	10.321	3/8	20.028	31.919
1/8	3.5343	.9940	11/16	11.585	10.680	1/2	20.420	33.183
3/16	3.7306	1.1075	3/4	11.781	11.045	5/8	20.813	34.472
1/4	3.9270	1.2272	13/16	11.977	11.416	3/4	21.206	35.785
5/16	4.1233	1.3530	7/8	12.174	11.793	7/8	21.598	37.122
3/8	4.3197	1.4849	15/16	12.370	12.177	7	21.991	38.485
7/16	4.5160	1.6230	4	12.566	12.566	1/8	22.384	39.871
1/2	4.7124	1.7671	1/16	12.763	12.962	1/4	22.776	41.282
9/16	4.9087	1.9175	1/8	12.959	13.364	3/8	23.169	42.718
5/8	5.1051	2.0739	3/16	13.155	13.772	1/2	23.562	44.179
11/16	5.3014	2.2365	1/4	13.352	14.186	5/8	23.955	45.664
3/4	5.4978	2.4053	5/16	13.548	14.607	3/4	24.347	47.173
13/16	5.6941	2.5802	3/8	13.744	15.033	7/8	24.740	48.707
7/8	5.8905	2.7612	7/16	13.941	15.466	8	25.133	50.265
15/16	6.0868	2.9483	1/2	14.137	15.904	1/8	25.525	51.849
2	6.2832	3.1416	9/16	14.334	16.349	1/4	25.918	53.456
1/16	6.4795	3.3410	5/8	14.530	16.800	3/8	26.311	55.088
1/8	6.6759	3.5466	11/16	14.726	17.257	1/2	26.704	56.745
3/16	6.8722	3.7583	3/4	14.923	17.721	5/8	27.096	58.426
1/4	7.0686	3.9761	13/16	15.119	18.190	3/4	27.489	60.132
5/16	7.2649	4.2000	7/8	15.315	18.665	7/8	27.882	61.862
3/8	7.4613	4.4301	15/16	15.512	19.147	9	28.274	63.617
7/16	7.6576	4.6664	5	15.708	19.635	1/8	28.667	65.397
1/2	7.8540	4.9087	1/16	15.904	20.129	1/4	29.060	67.201
9/16	8.0503	5.1572	1/8	16.101	20.629	3/8	29.452	69.029
5/8	8.2467	5.4119	3/16	16.297	21.135	1/2	29.845	70.882
11/16	8.4430	5.6727	1/4	16.493	21.648	5/8	30.238	72.760
3/4	8.6394	5.9396	5/16	16.690	22.166	3/4	30.631	74.662
13/16	8.8357	6.2126	3/8	16.886	22.691	7/8	31.023	76.589
7/8	9.0321	6.4918	7/16	17.082	23.221	10	31.416	78.540
15/16	9.2284	6.7771	1/2	17.279	23.758	1/8	31.809	80.516
3	9.4248	7.0686	9/16	17.475	24.301	1/4	32.201	82.516
1/16	9.6211	7.3662	5/8	17.671	24.850	3/8	32.594	84.541
1/8	9.8175	7.6699	11/16	17.868	25.406	1/2	32.987	86.590
3/16	10.014	7.9798	3/4	18.064	25.967	5/8	33.379	88.664
1/4	10.210	8.2958	13/16	18.261	26.535	3/4	33.772	90.763
5/16	10.407	8.6179	7/8	18.457	27.109	7/8	34.165	92.886
3/8	10.603	8.9462	15/16	18.653	27.688	11	34.558	95.033
7/16	10.799	9.2806	6	18.850	28.274	1/8	34.950	97.205
1/2	10.996	9.6211	1/8	19.242	29.465	1/4	35.343	99.402

TABLE XVIII.—*Continued*

Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.
11 ⅜	35.736	101.62	17 ½	54.978	240.53	23 ⅝	74.220	438.36
½	36.128	103.87	⅝	55.371	243.98	¾	74.613	443.01
⅝	36.521	106.14	¾	55.763	247.45	⅞	75.006	447.69
¾	36.914	108.43	⅞	56.156	250.95	24	75.398	452.39
⅞	37.306	110.75	18	56.549	254.47	⅛	75.791	457.11
12	37.699	113.10	⅛	56.941	258.02	¼	76.184	461.86
⅛	38.092	115.47	¼	57.334	261.59	⅜	76.576	466.64
¼	38.485	117.86	⅜	57.727	265.18	½	76.969	471.44
⅜	38.877	120.28	½	58.119	268.80	⅝	77.362	476.26
½	39.270	122.72	⅝	58.512	272.45	¾	77.754	481.11
⅝	39.663	125.19	¾	58.905	276.12	⅞	78.147	485.98
¾	40.055	127.68	⅞	59.298	279.81	25	78.540	490.87
⅞	40.448	130.19	19	59.690	283.53	⅛	78.933	495.79
13	40.841	132.73	⅛	60.083	287.27	¼	79.325	500.74
⅛	41.233	135.30	¼	60.476	291.04	⅜	79.718	505.71
¼	41.626	137.89	⅜	60.868	294.83	½	80.111	510.71
⅜	42.019	140.50	½	61.261	298.65	⅝	80.503	515.72
½	42.412	143.14	⅝	61.654	302.49	¾	80.896	520.77
⅝	42.804	145.80	¾	62.046	306.35	⅞	81.289	525.84
¾	43.197	148.49	⅞	62.439	310.24	26	81.681	530.93
⅞	43.590	151.20	20	62.832	314.16	⅛	82.074	536.05
14	43.982	153.94	⅛	63.225	318.10	¼	82.467	541.19
⅛	44.375	156.70	¼	63.617	322.06	⅜	82.860	546.35
¼	44.768	159.48	⅜	64.010	326.05	½	83.252	551.55
⅜	45.160	162.30	½	64.403	330.06	⅝	83.645	556.76
½	45.553	165.13	⅝	64.795	334.10	¾	84.038	562.00
⅝	45.946	167.99	¾	65.188	338.16	⅞	84.430	567.27
¾	46.338	170.87	⅞	65.581	342.25	27	84.823	572.56
⅞	46.731	173.78	21	65.973	346.36	⅛	85.216	577.87
15	47.124	176.71	⅛	66.366	350.50	¼	85.608	583.21
⅛	47.517	179.67	¼	66.759	354.66	⅜	86.001	588.57
¼	47.909	182.65	⅜	67.152	358.84	½	86.394	593.96
⅜	48.302	185.66	½	67.544	363.05	⅝	86.786	599.37
½	48.695	188.69	⅝	67.937	367.28	¾	87.179	604.81
⅝	49.087	191.75	¾	68.330	371.54	⅞	87.572	610.27
¾	49.480	194.83	⅞	68.722	375.83	28	87.965	615.75
⅞	49.873	197.93	22	69.115	380.13	⅛	88.357	621.26
16	50.265	201.06	⅛	69.508	384.46	¼	88.750	626.80
⅛	50.658	204.22	¼	69.900	388.82	⅜	89.143	632.36
¼	51.051	207.39	⅜	70.293	393.20	½	89.535	637.94
⅜	51.444	210.60	½	70.686	397.61	⅝	89.928	643.55
½	51.836	213.82	⅝	71.079	402.04	¾	90.321	649.18
⅝	52.229	217.08	¾	71.471	406.49	⅞	90.713	654.84
¾	52.622	220.35	⅞	71.864	410.97	29	91.106	660.52
⅞	53.014	223.65	23	72.257	415.48	⅛	91.499	666.23
17	53.407	226.98	⅛	72.649	420.00	¼	91.892	671.96
⅛	53.800	230.33	¼	73.042	424.56	⅜	92.284	677.71
¼	54.192	233.71	⅜	73.435	429.13	½	92.677	683.49
⅜	54.585	237.10	½	73.827	433.74	⅝	93.070	689.30

TABLE XVIII.—*Continued*

Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.
29 ¾	93.462	695.13	35 ⅞	112.705	1010.8	42	131.947	1385.4
⅞	93.855	700.98	36	113.097	1017.9	⅛	132.340	1393.7
30	94.248	706.86	⅛	113.490	1025.0	¼	132.732	1402.0
⅛	94.640	712.76	¼	113.883	1032.1	⅜	133.125	1410.3
¼	95.033	718.69	⅜	114.275	1039.2	½	133.518	1418.6
⅜	95.426	724.64	½	114.668	1046.3	⅝	133.910	1427.0
½	95.819	730.62	⅝	115.061	1053.5	¾	134.303	1435.4
⅝	96.211	736.62	¾	115.454	1060.7	⅞	134.696	1443.8
¾	96.604	742.64	⅞	115.846	1068.0	43	135.088	1452.2
⅞	96.997	748.69	37	116.239	1075.2	⅛	135.481	1460.7
31	97.389	754.77	⅛	116.632	1082.5	¼	135.874	1469.1
⅛	97.782	760.87	¼	117.024	1089.8	⅜	136.267	1477.6
¼	98.175	766.99	⅜	117.417	1097.1	½	136.659	1486.2
⅜	98.567	773.14	½	117.810	1104.5	⅝	137.052	1494.7
½	98.960	779.31	⅝	118.202	1111.8	¾	137.445	1503.3
⅝	99.353	785.51	¾	118.596	1119.2	⅞	137.837	1511.9
¾	99.746	791.73	⅞	118.988	1126.7	44	138.230	1520.5
⅞	100.138	797.98	38	119.381	1134.1	⅛	138.623	1529.2
32	100.531	804.25	⅛	119.773	1141.6	¼	139.015	1537.9
⅛	100.924	810.54	¼	120.166	1149.1	⅜	139.408	1546.6
¼	101.316	816.86	⅜	120.559	1156.6	½	139.801	1555.3
⅜	101.709	823.21	½	120.951	1164.2	⅝	140.194	1564.0
½	102.102	829.58	⅝	121.344	1171.7	¾	140.586	1572.8
⅝	102.494	835.97	¾	121.737	1179.3	⅞	140.979	1581.6
¾	102.887	842.39	⅞	122.129	1186.9	45	141.372	1590.4
⅞	103.280	848.83	39	122.522	1194.6	⅛	141.764	1599.3
33	103.673	855.30	⅛	122.915	1202.3	¼	142.157	1608.2
⅛	104.065	861.79	¼	123.308	1210.0	⅜	142.550	1617.0
¼	104.458	868.31	⅜	123.700	1217.7	½	142.942	1626.0
⅜	104.851	874.85	½	124.093	1225.4	⅝	143.335	1634.9
½	105.243	881.41	⅝	124.486	1233.2	¾	143.728	1643.9
⅝	105.636	888.00	¾	124.878	1241.0	⅞	144.121	1652.9
¾	106.029	894.62	⅞	125.271	1248.8	46	144.513	1661.9
⅞	106.421	901.26	40	125.664	1256.6	⅛	144.906	1670.9
34	106.814	907.92	⅛	126.056	1264.5	¼	145.299	1680.0
⅛	107.207	914.61	¼	126.449	1272.4	⅜	145.691	1689.1
¼	107.600	921.32	⅜	126.842	1280.3	½	146.084	1698.2
⅜	107.992	928.06	½	127.235	1288.2	⅝	146.477	1707.4
½	108.385	934.82	⅝	127.627	1296.2	¾	146.869	1716.5
⅝	108.778	941.61	¾	128.020	1304.2	⅞	147.262	1725.7
¾	109.170	948.42	⅞	128.413	1312.2	47	147.655	1734.9
⅞	109.563	955.25	41	128.805	1320.3	⅛	148.048	1744.2
35	109.956	962.11	⅛	129.198	1328.3	¼	148.440	1753.5
⅛	110.348	969.00	¼	129.591	1336.4	⅜	148.833	1762.7
¼	110.741	975.91	⅜	129.983	1344.5	½	149.226	1772.1
⅜	111.134	982.84	½	130.376	1352.7	⅝	149.618	1781.4
½	111.527	989.80	⅝	130.769	1360.8	¾	150.011	1790.8
⅝	111.919	996.78	¾	131.161	1369.0	⅞	150.404	1800.1
¾	112.312	1003.8	⅞	131.554	1377.2	48	150.796	1809.6

TABLE XVIII.—*Continued*

Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.
48 ⅛	151.189	1819.0	54 ¼	170.431	2311.5	60 ⅜	189.674	2862.9
¼	151.582	1828.5	⅜	170.824	2322.1	½	190.066	2874.8
⅜	151.975	1837.9	½	171.217	2332.8	⅝	190.459	2886.6
½	152.367	1847.5	⅝	171.609	2343.5	¾	190.852	2898.6
⅝	152.760	1857.0	¾	172.002	2354.3	⅞	191.244	2910.5
¾	153.153	1866.5	⅞	172.395	2365.0	61	191.637	2922.5
⅞	153.545	1876.1	55	172.788	2375.8	⅛	192.030	2934.5
49	153.938	1885.7	⅛	173.180	2386.6	¼	192.423	2946.5
⅛	154.331	1895.4	¼	173.573	2397.5	⅜	192.815	2958.5
¼	154.723	1905.0	⅜	173.966	2408.3	½	193.208	2970.6
⅜	155.116	1914.7	½	174.358	2419.2	⅝	193.601	2982.7
½	155.509	1924.4	⅝	174.751	2430.1	¾	193.993	2994.8
⅝	155.902	1934.2	¾	175.144	2441.1	⅞	194.386	3006.9
¾	156.294	1943.9	⅞	175.536	2452.0	62	194.779	3019.1
⅞	156.687	1953.7	56	175.929	2463.0	⅛	195.171	3031.3
50	157.080	1963.5	⅛	176.322	2474.0	¼	195.564	3043.5
⅛	157.472	1973.3	¼	176.715	2485.0	⅜	195.957	3055.7
¼	157.865	1983.2	⅜	177.107	2496.1	½	196.350	3068.0
⅜	158.258	1993.1	½	177.500	2507.2	⅝	196.742	3080.3
½	158.650	2003.0	⅝	177.893	2518.3	¾	197.135	3092.6
⅝	159.043	2012.9	¾	178.285	2529.4	⅞	197.528	3104.9
¾	159.436	2022.8	⅞	178.678	2540.6	63	197.920	3117.2
⅞	159.829	2032.8	57	179.071	2551.8	⅛	198.313	3129.6
51	160.221	2042.8	⅛	179.463	2563.0	¼	198.706	3142.0
⅛	160.614	2052.8	¼	179.856	2574.2	⅜	199.098	3154.5
¼	161.007	2062.9	⅜	180.249	2585.4	½	199.491	3166.9
⅜	161.399	2073.0	½	180.642	2596.7	⅝	199.884	3179.4
½	161.792	2083.1	⅝	181.034	2608.0	¾	200.277	3191.9
⅝	162.185	2093.2	¾	181.427	2619.4	⅞	200.669	3204.4
¾	162.577	2103.3	⅞	181.820	2630.7	64	201.062	3217.0
⅞	162.970	2113.5	58	182.212	2642.1	⅛	201.455	3229.6
52	163.363	2123.7	⅛	182.605	2653.5	¼	201.847	3242.2
⅛	163.756	2133.9	¼	182.998	2664.9	⅜	202.240	3254.8
¼	164.148	2144.2	⅜	183.390	2676.4	½	202.633	3267.5
⅜	164.541	2154.5	½	183.783	2687.8	⅝	203.025	3280.1
½	164.934	2164.8	⅝	184.176	2699.3	¾	203.418	3292.8
⅝	165.326	2175.1	¾	184.569	2710.9	⅞	203.811	3305.6
¾	165.719	2185.4	⅞	184.961	2722.4	65	204.204	3318.3
⅞	166.112	2195.8	59	185.354	2734.0	⅛	204.596	3331.1
53	166.504	2206.2	⅛	185.747	2745.6	¼	204.989	3343.9
⅛	166.897	2216.6	¼	186.139	2757.2	⅜	205.382	3356.7
¼	167.290	2227.0	⅜	186.532	2768.8	½	205.774	3369.6
⅜	167.683	2237.5	½	186.925	2780.5	⅝	206.167	3382.4
½	168.075	2248.0	⅝	187.317	2792.2	¾	206.560	3395.3
⅝	168.468	2258.5	¾	187.710	2803.9	⅞	206.952	3408.2
¾	168.861	2269.1	⅞	188.103	2815.7	66	207.345	3421.2
⅞	169.253	2279.6	60	188.496	2827.4	⅛	207.738	3434.2
54	169.646	2290.2	⅛	188.888	2839.2	¼	208.131	3447.2
⅛	170.039	2300.8	¼	189.281	2851.0	⅜	208.523	3460.2

TABLE XVIII.—*Continued*

Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.
66 ½	208.916	3473.2	72 ⅝	228.158	4142.5	78 ¾	247.400	4870.7
⅝	209.309	3486.3	¾	228.551	4156.8	⅞	247.793	4886.2
¾	209.701	3499.4	⅞	228.944	4171.1	79	248.186	4901.7
⅞	210.094	3512.5	73	229.336	4185.4	⅛	248.579	4917.2
67	210.487	3525.7	⅛	229.729	4199.7	¼	248.971	4932.7
⅛	210.879	3538.8	¼	230.122	4214.1	⅜	249.364	4948.3
¼	211.272	3552.0	⅜	230.514	4228.5	½	249.757	4963.9
⅜	211.665	3565.2	½	230.907	4242.9	⅝	250.149	4979.5
½	212.058	3578.5	⅝	231.300	4257.4	¾	250.542	4995.2
⅝	212.450	3591.7	¾	231.692	4271.8	⅞	250.935	5010.9
¾	212.843	3605.0	⅞	232.085	4286.3	80	251.327	5026.5
⅞	213.236	3618.3	74	232.478	4300.8	⅛	251.720	5042.3
68	213.628	3631.7	⅛	232.871	4315.4	¼	252.113	5058.0
⅛	214.021	3645.0	¼	233.263	4329.9	⅜	252.506	5073.8
¼	214.414	3658.4	⅜	233.656	4344.5	½	252.898	5089.6
⅜	214.806	3671.8	½	234.049	4359.2	⅝	253.291	5105.4
½	215.199	3685.3	⅝	234.441	4373.8	¾	253.684	5121.2
⅝	215.592	3698.7	¾	234.834	4388.5	⅞	254.076	5137.1
¾	215.984	3712.2	⅞	235.227	4403.1	81	254.469	5153.0
⅞	216.377	3725.7	75	235.619	4417.9	⅛	254.862	5168.9
69	216.770	3739.3	⅛	236.012	4432.6	¼	255.254	5184.9
⅛	217.163	3752.8	¼	236.405	4447.4	⅜	255.647	5200.8
¼	217.555	3766.4	⅜	236.798	4462.2	½	256.040	5216.8
⅜	217.948	3780.0	½	237.190	4477.0	⅝	256.433	5232.8
½	218.341	3793.7	⅝	237.583	4491.8	¾	256.825	5248.9
⅝	218.733	3807.3	¾	237.976	4506.7	⅞	257.218	5264.9
¾	219.126	3821.0	⅞	238.368	4521.5	82	257.611	5281.0
⅞	219.519	3834.7	76	238.761	4536.5	⅛	258.003	5297.1
70	219.911	3848.5	⅛	239.154	4551.4	¼	258.396	5313.3
⅛	220.304	3862.2	¼	239.546	4566.4	⅜	258.789	5329.4
¼	220.697	3876.0	⅜	239.939	4581.3	½	259.181	5345.6
⅜	221.090	3889.8	½	240.332	4596.3	⅝	259.574	5361.8
½	221.482	3903.6	⅝	240.725	4611.4	¾	259.967	5378.1
⅝	221.875	3917.5	¾	241.117	4626.4	⅞	260.359	5394.3
¾	222.268	3931.4	⅞	241.510	4641.5	83	260.752	5410.6
⅞	222.660	3945.3	77	241.903	4656.6	⅛	261.145	5426.9
71	223.053	3959.2	⅛	242.295	4671.8	¼	261.538	5443.3
⅛	223.446	3973.1	¼	242.688	4686.9	⅜	261.930	5459.6
¼	223.838	3987.1	⅜	243.081	4702.1	½	262.323	5476.0
⅜	224.231	4001.1	½	243.473	4717.3	⅝	262.716	5492.4
½	224.624	4015.2	⅝	243.866	4732.5	¾	263.108	5508.8
⅝	225.017	4029.2	¾	244.259	4747.8	⅞	263.501	5525.3
¾	225.409	4043.3	⅞	244.652	4763.1	84	263.894	5541.8
⅞	225.802	4057.4	78	245.044	4778.4	⅛	264.286	5558.3
72	226.195	4071.5	⅛	245.437	4793.7	¼	264.679	5574.8
⅛	226.587	4085.7	¼	245.830	4809.0	⅜	265.072	5591.4
¼	226.980	4099.8	⅜	246.222	4824.4	½	265.465	5607.9
⅜	227.373	4114.0	½	246.615	4839.8	⅝	265.857	5624.5
½	227.765	4128.2	⅝	247.008	4855.2	¾	266.250	5641.2

TABLE XVIII.—*Continued*

Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.
84 ⅞	266.643	5657.8	90	282.743	6361.7	95 ⅛	298.844	7106.9
85	267.035	5674.5	⅛	283.136	6379.4	¼	299.237	7125.6
⅛	267.428	5691.2	¼	283.529	6397.1	⅜	299.629	7144.3
¼	267.821	5707.9	⅜	283.921	6414.9	½	300.022	7163.0
⅜	268.213	5724.7	½	284.314	6432.6	⅝	300.415	7181.8
½	268.606	5741.5	⅝	284.707	6450.4	¾	300.807	7200.6
⅝	268.999	5758.3	¾	285.100	6468.2	⅞	301.200	7219.4
¾	269.392	5775.1	⅞	285.492	6486.0	96	301.593	7238.2
⅞	269.784	5791.9	91	285.885	6503.9	⅛	301.986	7257.1
86	270.177	5808.8	⅛	286.278	6521.8	¼	302.378	7276.0
⅛	270.570	5825.7	¼	286.670	6539.7	⅜	302.771	7294.9
¼	270.962	5842.6	⅜	287.063	6557.6	½	303.164	7313.8
⅜	271.355	5859.6	½	287.456	6575.5	⅝	303.556	7332.8
½	271.748	5876.5	⅝	287.848	6593.5	¾	303.949	7351.8
⅝	272.140	5893.5	¾	288.241	6611.5	⅞	304.342	7370.8
¾	272.533	5910.6	⅞	288.634	6629.6	97	304.734	7389.8
⅞	272.926	5927.6	92	289.027	6647.6	⅛	305.127	7408.9
87	273.319	5944.7	⅛	289.419	6665.7	¼	305.520	7428.0
⅛	273.711	5961.8	¼	289.812	6683.8	⅜	305.913	7447.1
¼	274.104	5978.9	⅜	290.205	6701.9	½	306.305	7466.2
⅜	274.497	5996.0	½	290.597	6720.1	⅝	306.698	7485.3
½	274.889	6013.2	⅝	290.990	6738.2	¾	307.091	7504.5
⅝	275.282	6030.4	¾	291.383	6756.4	⅞	307.483	7523.7
¾	275.675	6047.6	⅞	291.775	6774.7	98	307.876	7543.0
⅞	276.067	6064.9	93	292.168	6792.9	⅛	308.269	7562.2
88	276.460	6082.1	⅛	292.561	6811.2	¼	308.661	7581.5
⅛	276.853	6099.4	¼	292.954	6829.5	⅜	309.054	7600.8
¼	277.246	6116.7	⅜	293.346	6847.8	½	309.447	7620.1
⅜	277.638	6134.1	½	293.739	6866.1	⅝	309.840	7639.5
½	278.031	6151.4	⅝	294.132	6884.5	¾	310.232	7658.9
⅝	278.424	6168.8	¾	294.524	6902.9	⅞	310.625	7678.3
¾	278.816	6186.2	⅞	294.917	6921.3	99	311.018	7697.7
⅞	279.209	6203.7	94	295.310	6939.8	⅛	311.410	7717.1
89	279.602	6221.1	⅛	295.702	6958.2	¼	311.803	7736.6
⅛	279.994	6238.6	¼	296.095	6976.7	⅜	312.196	7756.1
¼	280.387	6256.1	⅜	296.488	6995.3	½	312.588	7775.6
⅜	280.780	6273.7	½	296.881	7013.8	⅝	312.981	7795.2
½	281.173	6291.2	⅝	297.273	7032.4	¾	313.374	7814.8
⅝	281.565	6308.8	¾	297.666	7051.0	⅞	313.767	7834.4
¾	281.958	6326.4	⅞	298.059	7069.6	100	314.159	7854.0
⅞	282.351	6344.1	95	298.451	7088.2			

TABLE XIX.—Spheres

(Some errors of 1 in the last figure only.)

Diam.	Surface.	Volume.	Diam.	Surface.	Volume.	Diam.	Surface.	Volume.
1/32	.00307	.00002	2 3/8	17.721	7.0144	6 3/8	127.68	135.66
1/16	.01227	.00013	7/16	18.666	7.5829	1/2	132.73	143.79
3/32	.02761	.00043	1/2	19.635	8.1813	5/8	137.89	152.25
1/8	.04909	.00102	9/16	20.629	8.8103	3/4	143.14	161.03
5/32	.07670	.00200	5/8	21.648	9.4708	7/8	148.49	170.14
3/16	.11045	.00345	11/16	[22.691	10.164	7	153.94	179.59
7/32	.15033	.00548	3/4	23.758	10.889	1/8	159.49	189.39
1/4	.19635	.00818	13/16	24.850	11.649	1/4	165.13	199.53
9/32	.24851	.01165	7/8	[25.967	12.443	3/8	170.87	210.03
5/16	.30680	.01598	15/16	27.109	13.272	1/2	176.71	220.89
11/32	.37123	.02127	3	28.274	14.137	5/8	182.66	232.13
3/8	.44179	.02761	1/16	29.465	15.039	3/4	188.69	243.73
13/32	.51848	.03511	1/8	30.680	15.979	7/8	194.83	255.72
7/16	.60132	.04385	3/16	31.919	16.957	8	201.06	268.08
15/32	.69028	.05393	1/4	33.183	17.974	1/8	207.39	280.85
1/2	.78540	.06545	5/16	34.472	19.031	1/4	213.82	294.01
9/16	.99403	.09319	3/8	35.784	20.129	3/8	220.36	307.58
5/8	1.2272	.12783	7/16	37.122	21.268	1/2	226.98	321.56
11/16	1.4849	.17014	1/2	38.484	22.449	5/8	233.71	335.95
3/4	1.7671	.22089	9/16	39.872	23.674	3/4	240.53	350.77
13/16	2.0739	.28084	5/8	41.283	24.942	7/8	247.45	366.02
7/8	2.4053	.35077	11/16	42.719	26.254	9	254.47	381.70
15/16	2.7611	.43143	3/4	44.179	27.611	1/8	261.59	397.83
1	3.1416	.52360	13/16	45.664	29.016	1/4	268.81	414.41
1/16	3.5466	.62804	7/8	47.173	30.466	3/8	270.12	431.44
1/8	3.9761	.74551	15/16	48.708	31.965	1/2	283.53	448.92
3/16	4.4301	.87681	4	50.265	33.510	5/8	291.04	466.87
1/4	4.9088	1.0227	1/8	53.456	36.751	3/4	289.65	485.31
5/16	5.4119	1.1839	1/4	56.745	40.195	7/8	306.36	504.21
3/8	5.9396	1.3611	3/8	60.133	43.847	10	314.16	523.60
7/16	6.4919	1.5553	1/2	63.617	47.713	1/8	322.06	543.48
1/2	7.0686	1.7671	5/8	67.201	51.801	1/4	330.06	563.86
9/16	7.6699	1.9974	3/4	70.883	56.116	3/8	338.16	584.74
5/8	8.2957	2.2468	7/8	74.663	60.663	1/2	346.36	606.13
11/16	8.9461	2.5161	5	78.540	65.450	5/8	354.66	628.04
3/4	9.6211	2.8062	1/8	82.516	70.482	3/4	363.05	650.46
13/16	10.321	3.1177	1/4	86.591	75.767	7/8	371.54	673.42
7/8	11.044	3.4514	3/8	90.763	81.308	11	380.13	696.91
15/16	11.793	3.8083	1/2	95.033	87.113	1/8	388.83	720.95
2	12.566	4.1888	5/8	99.401	93.189	1/4	397.61	745.51
1/16	13.364	4.5939	3/4	103.87	99.541	3/8	406.49	770.64
1/8	14.186	5.0243	7/8	108.44	106.18	1/2	415.48	796.33
3/16	15.033	5.4809	6	113.10	113.10	5/8	424.50	822.58
1/4	15.904	5.9641	1/8	117.87	120.31	3/4	433.73	849.40
5/16	16.800	6.4751	1/4	122.72	127.83	7/8	443.01	876.79

TABLE XIX.—*Continued*

Diam.	Surface.	Volume.	Diam.	Surface.	Volume.	Diam.	Surface.	Volume.
12	452.39	904.78	24¼	1847.5	7466.7	38½	4656.7	29880
¼	471.44	962.52	½	1885.8	7700.1	39	4778.4	31059
½	490.87	1022.7	¾	1924.4	7938.3	½	4901.7	32270
¾	510.71	1085.3	25	1963.5	8181.3	40	5026.5	33510
13	530.93	1150.3	¼	2002.9	8429.2	½	5153.1	34783
¼	551.55	1218.0	½	2042.8	8682.0	41	5281.1	36087
½	572.55	1288.3	¾	2083.0	8939.9	½	5410.7	37423
¾	593.95	1361.2	26	2123.7	9202.8	42	5541.9	38792
14	615.75	1436.8	¼	2164.7	9470.8	½	5674.5	40194
¼	637.95	1515.1	½	2206.2	9744.0	43	5808.8	41630
½	660.52	1596.3	¾	2248.0	10022	½	5944.7	43099
¾	683.49	1680.3	27	2290.2	10306	44	6082.1	44602
15	706.85	1767.2	¼	2332.8	10595	½	6221.2	46141
¼	730.63	1857.0	½	2375.8	10889	45	6361.7	47713
½	754.77	1949.8	¾	2419.2	11189	½	6503.9	49321
¾	779.32	2045.7	28	2463.0	11494	46	6647.6	50965
16	804.25	2144.7	¼	2507.2	11805	½	6792.9	52645
¼	829.57	2246.8	½	2551.8	12121	47	6939.9	54362
½	855.29	2352.1	¾	2596.7	12443	½	7088.3	56115
¾	881.42	2460.6	29	2642.1	12770	48	7238.3	57906
17	907.93	2572.4	¼	2687.8	13103	½	7389.9	59734
¼	934.83	2687.6	½	2734.0	13442	49	7543.1	61601
½	962.12	2806.2	¾	2780.5	13787	½	7696.7	63506
¾	989.80	2928.2	30	2827.4	14137	50	7854.0	65450
18	1017.9	3053.6	¼	2874.8	14494	½	8011.8	67433
¼	1046.4	3182.6	½	2922.5	14856	51	8171.2	69456
½	1075.2	3315.3	¾	2970.6	15224	½	8332.3	71519
¾	1104.5	3451.5	31	3019.1	15599	52	8494.8	73622
19	1134.1	3591.4	¼	3068.0	15979	½	8658.9	75767
¼	1164.2	3735.0	½	3117.3	16366	53	8824.8	77952
½	1194.6	3882.5	¾	3166.9	16758	½	8992.0	80178
¾	1225.4	4033.7	32	3217.0	17157	54	9160.8	82448
20	1256.7	4188.8	¼	3267.4	17563	½	9331.2	84760
¼	1288.3	4347.8	½	3318.3	17974	55	9503.2	87114
½	1320.3	4510.9	¾	3369.6	18392	½	9676.8	89511
¾	1352.7	4677.9	33	3421.2	18817	56	9852.0	91953
21	1385.5	4849.1	¼	3473.3	19248	½	10029	94438
¼	1418.6	5024.3	½	3525.7	19685	57	10207	96967
½	1452.2	5203.7	¾	3578.5	20129	½	10387	99541
¾	1486.2	5387.4	34	3631.7	20580	58	10568	102161
22	1520.5	5575.3	¼	3685.3	21037	½	10751	104826
¼	1555.3	5767.6	½	3739.3	21501	59	10936	107536
½	1590.4	5964.1	35	3848.5	22449	½	11122	110294
¾	1626.0	6165.2	½	3959.2	23425	60	11310	113098
23	1661.9	6370.6	36	4071.5	24429	½	11499	115949
¼	1698.2	6580.6	½	4185.5	25461	61	11690	118847
½	1735.0	6795.2	37	4300.9	26522	½	11882	121794
¾	1772.1	7014.3	½	4417.9	27612	62	12076	124789
24	1809.6	7238.2	38	4536.5	28731	½	12272	127832

TABLE XIX.—*Continued*

Diam.	Surface.	Volume.	Diam.	Surface.	Volume.	Diam.	Surface.	Volume.
63	12469	130925	75½	17908	225341	88	24328	356819
½	12668	134067	76	18146	229848	½	24606	362935
64	12868	137259	½	18386	234414	89	24885	369122
½	13070	140501	77	18626	239041	½	25165	375378
65	13273	143794	½	18869	243728	90	25447	381704
½	13478	147138	78	19114	248475	½	25730	388102
66	13685	150533	½	19360	253284	91	26016	394570
½	13893	153980	79	19607	258155	½	26302	401109
67	14103	157480	½	19856	263088	92	26590	407721
½	14314	161032	80	20106	268083	½	26880	414405
68	14527	164637	½	20358	273141	93	27172	421161
½	14741	168295	81	20612	278263	½	27464	427991
69	14957	172007	½	20867	283447	94	27759	434894
½	15175	175774	82	21124	288696	½	28055	441871
70	15394	179595	½	21382	294010	95	28353	448920
½	15615	183471	83	21642	299388	½	28652	456047
71	15837	187402	½	21904	304831	96	28953	463248
½	16061	191389	84	22167	310340	½	29255	470524
72	16286	195433	½	22432	315915	97	29559	477874
½	16513	199532	85	22698	321556	½	29865	485302
73	16742	203689	½	22966	327264	98	30172	492808
½	16972	207903	86	23235	333039	½	30481	500388
74	17204	212175	½	23506	338882	99	30791	508047
½	17437	216505	87	23779	344792	½	31103	515785
75	17672	220894	½	24053	350771	100	31416	523598

TABLE XX.—Weight and Specific Gravity of Metals
(Kent's "Mechanical Engineers' Pocket-Book," eighth edition)

	Specific Gravity, Range According to Several Authorities	Specific Gravity. Approximate Mean Value Used in Calculation of Weight	Weight per Cubic Foot, lbs.	Weight per Cubic Inch, lbs.
Aluminum	2.56 to 2.71	2.67	166.5	0.0963
Antimony	6.66 to 6.86	6.76	421.6	0.2439
Bismuth	9.74 to 9.90	9.82	612.4	0.3544
Brass: Copper + Zinc				
80 20	7.8 to 8.6	8.60	536.3	0.3103
70 30		8.40	523.8	0.3031
60 40		8.36	521.3	0.3017
50 50		8.20	511.4	0.2959
Bronze { Cop., 95 to 80; Tin, 5 to 20 }	8.52 to 8.96	8.853	552.	0.3195
Cadmium	8.6 to 8.7	8.65	539.	0.3121
Calcium	1.58	1.58	98.5	0.0570
Chromium	5.0	5.0	311.8	0.1804
Cobalt	8.5 to 8.6	8.55	533.1	0.3085
Gold, pure	19.245 to 19.361	19.258	1200.9	0.6949
Copper	8.69 to 8.92	8.853	552.	0.3195
Iridium	22.38 to 23.	22.38	1396.	0.8076
Iron, Cast	6.85 to 7.48	7.218	450.	0.2604
Iron, Wrought	7.4 to 7.9	7.70	480.	0.2779
Lead	11.07 to 11.44	11.38	709.7	0.4106
Manganese	7. to 8.	8.	499.	0.2887
Magnesium	1.69 to 1.75	1.75	109.	0.0641
Mercury 32°	13.60 to 13.62	13.62	849.3	0.4915
Mercury 60°	13.58	13.58	846.8	0.4900
Mercury 212°	13.37 to 13.38	13.38	834.4	0.4828
Nickel	8.279 to 8.93	8.8	548.7	0.3175
Platinum	20.33 to 22.07	21.5	1347.0	0.7758
Potassium	0.865	0.865	53.9	0.0312
Silver	10.474 to 10.511	10.505	655.1	0.3791
Sodium	0.97	0.97	60.5	0.0350
Steel	7.69* to 7.932†	7.854	489.6	0.2834
Tin	7.291 to 7.409	7.350	458.3	0.2652
Titanium	5.3	5.3	330.5	0.1913
Tungsten	17. to 17.6	17.3	1078.7	0.6243
Zinc	6.86 to 7.20	7.00	436.5	0.2526

* Hard and burned.
† Very pure and soft. The specific gravity decreases as the carbon is increased.
In the first column of figures the lowest are usually those of cast metals, which are more or less porous; the highest are of metals finely rolled or drawn into wire.

TABLE XXI.—Melting-points of Various Substances

(Kent's "Mechanical Engineers' Pocket-Book," eighth edition)

The following figures are given by Clark (on the authority of Pouillet, Claudel, and Wilson), except those marked *, which are given by Prof. Roberts-Austen, and those marked †, which are given by Dr. J. A. Harker. These latter are probably the most reliable figures.

Sulphurous acid	− 148° F.
Carbonic acid	− 108
Mercury	−39, − 38†
Bromine	+ 9.5
Turpentine	14
Hyponitric acid	16
Ice	32
Nitro-glycerine	45
Tallow	92
Phosphorus	112
Acetic acid	113
Stearine	109 to 120
Spermaceti	120
Margaric acid	131 to 140
Potassium	136 to 144
Wax	142 to 154
Stearic acid	158
Sodium	194 to 208
Iodine	225
Sulphur	239
Alloy, 1½ tin, 1 lead	334, 367†
Tin	446, 449†

Cadmium	442° F.
Bismuth	504 to 507
Lead	618*, 620†
Zinc	779*, 786†
Antimony	1150, 1169†
Aluminum	1157*, 1214†
Magnesium	1200
NaCl, common salt	1472†
Calcium	Full red heat.
Bronze	1692
Silver	1733*, 1751†
Potassium sulphate	1859*, 1958*
Gold	1913*, 1947†
Copper	1929*, 1943†
Nickel	2600†
Cast-iron, white	1922, 2075†
" " gray	2012 to 2786, 2228*
Steel	2372 to 2532*
" hard	2570*; mild, 2687
Wrought-iron	2732 to 2912, 2737*
Palladium	2732*
Platinum	3227*, 3110†

TABLE XXII.—Strength of Ropes.

(A. S. Newell & Co., Birkenhead. Klein's Translation of Weisbach, vol. iii, part 1, sec. 2)

Hemp		Iron		Steel		Tensile Strength, Gross Tons
Girth, Inches	Weight per Fathom, Pounds	Girth, Inches	Weight per Fathom, Pounds	Girth, Inches	Weight per Fathom, Pounds	
2¾	2	1	1			2
		1½	1½	1	1	3
3¾	4	1⅝	2			4
		1¾	2½	1½	1½	5
4½	5	1⅞	3			6
		2	3½	1⅝	2	7
5½	7	2⅛	4	1¾	2½	8
		2¼	4½			9
6	9	2⅜	5	1⅞	3	10
		2½	5½			11
6½	10	2⅝	6	2	3½	12
		2¾	6½	2⅛	4	13
7	12	2⅞	7	2¼	4½	14
		3	7½			15
7½	14	3⅛	8	2⅜	5	16
		3¼	8½			17
8	16	3⅜	9	2½	5½	18
		3½	10	2⅝	6	20
8½	18	3⅝	11	2¾	6½	22
		3¾	12			24
9½	22	3⅞	13	3¼	8	26
10	26	4	14			28
11	30	4¼	15	3⅜	9	30
		4⅜	16			32
		4½	18	3½	10	36
12	34	4⅝	20	3¾	12	40

TABLE XXIII.—Pitch, Breaking, Proof, and Working Strains of Chains

(Bradlee & Co., Philadelphia)

Size of Chain, in.	Pitch, in.	Approx. Wt. per Ft. lb.	Outside Width, in.	D. B. G. Special Crane			Crane		
				Proof Test, lb.	Average Breaking Strain, lb.	Ordinary Safe Load. General Use, lb.	Proof Test, lb.	Average Breaking Strain, lb.	Ordinary Safe Load. General Use, lb.
1/4	25/32	3/4	15/16	1,932	3,864	1,288	1,680	3,360	1,120
5/16	27/32	1	1 1/8	2,898	5,796	1,932	2,520	5,040	1,680
3/8	31/32	1 1/2	1 5/16	4,186	8,372	2,790	3,640	7,280	2,420
7/16	1 5/32	2	1 1/2	5,796	11,592	3,864	5,040	10,080	3,360
1/2	1 11/32	2 1/2	1 13/16	7,728	15,456	5,152	6,720	13,440	4,487
9/16	1 15/32	3 3/10	2	9,660	19,320	6,440	8,400	16,800	5,600
5/8	1 23/32	4 1/10	2 3/16	11,914	23,828	7,942	10,360	20,720	6,900
11/16	1 13/16	5	2 3/8	14,490	28,980	9,660	12,600	25,200	8,400
3/4	1 15/16	6 2/10	2 9/16	17,388	34,776	11,592	15,120	30,240	10,087
13/16	2 1/16	6 7/10	2 3/4	20,286	40,572	13,524	17,640	35,280	11,760
7/8	2 3/16	8 3/8	2 15/16	22,484	44,968	14,989	20,440	40,880	13,620
15/16	2 7/16	9	3 3/16	25,872	51,744	17,248	23,520	47,040	15,680
1	2 1/2	10 1/2	3 3/8	29,568	59,136	19,712	26,880	53,760	17,927
1 1/16	2 5/8	12	3 9/16	33,264	66,538	22,176	30,240	60,480	20,160
1 1/8	2 3/4	13 5/8	3 13/16	37,576	75,152	25,050	34,160	68,320	22,770
1 3/16	3 1/16	13 7/10	4	41,888	83,776	27,925	38,080	76,160	25,380
1 1/4	3 1/8	16	4 3/16	46,200	92,400	30,800	42,000	84,000	28,003
1 5/16	3 3/8	16 1/2	4 3/8	50,512	101,024	33,674	45,920	91,840	30,617
1 3/8	3 9/16	19 1/4	4 9/16	55,748	111,496	37,165	50,680	101,360	33,780
1 7/16	3 11/16	19 7/10	4 3/4	60,368	120,736	40,245	54,880	109,760	36,583
1 1/2	3 7/8	23	5 1/8	66,528	133,056	44,352	60,480	120,960	40,327
1 9/16	4	25	5 5/16	70,762	141,524	47,174	65,520	131,140	43,187
1 3/4	4 3/4	31	5 7/8	82,320	164,640	54,880			
2	5 3/4	40	6 3/4	107,520	215,040	71,680			
2 1/4	6 3/4	52 3/4	7 5/8	136,080	272,160	90,720			
2 1/2	7	64 1/2	8 3/8	168,000	336,000	112,000			
2 3/4	7 1/4	73	9 1/8	193,088	386,176	128,725			
3	7 3/4	86	9 7/8	217,728	435,456	145,152			

The distance from center of one link to center of next is equal to the inside length of link, but in practice $\frac{1}{32}$ in. is allowed for weld. This is approximate, and, where exactness is required, chain should be made so.

For Chain Sheaves.—The diameter, if possible, should be not less than thirty times the diameter of chain used.

Example.—For 1-inch chain use 30-inch sheaves.

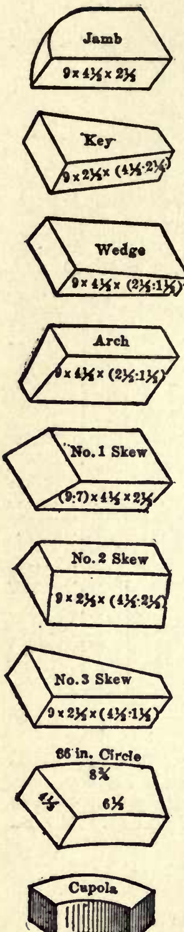
TABLE XXIV.—Analyses of Fire-clays

(Kent's "Mechanical Engineers' Pocket-Book," eighth edition)

Brand	Titanic Acid, TiO_2	Silica, SiO_2	Alumina, Al_2O_3	Moisture, H_2O	Iron, Fe_2O_3	Lime, CaO	Magnesia, MgO	Potash, K_2O	Soda, Na_2O	Total Impurities	Loss
Mt. Savage[1]	....	50.46	35.90	12.744	1.50	0.13	0.02	Trace		1.65	....
Mt. Savage[2]	1.15	56.80	30.08	10.50	1.12	....	....	0.80		1.92	....
Mt. Savage[3]	1.53	44.40	33.56	14.575	1.08	Tr.	0.11	0.247		1.47	....
Mt. Savage[4]	....	56.15	33.30	9.68	0.59	0.17	0.12	....	....	0.88	....
Strasburg, O	0.45	55.87	41.39	......	1.60	0.40	0.30	0.29	0.20	2.79	....
Cumberland, Md	1.15	56.80	30.08	7.69	1.67	....	....	2.30	....	3.97	....
Woodbridge, N. J	....	67.84	21.83	5.98	1.57	0.28	0.24	2.24	....	4.33	....
Carter Co., Ky	....	68.01	24.09	3.03	1.01	3.01	....	....	....	4.02	....
Clearfield Co., Pa	....	48.35	36.37	10.56	2.00	0.07	0.12	2.54		4.73	....
Clearfield[5] and	....	44.80	39.00	14.70	0.30	0.20	1.00	....		....	....
Cambria Cos., Pa.[6]	....	51.50	44.85	1.94	0.33	0.23	1.15	....		....	....
Clinton Co., Pa	1.46	63.18	23.70	6.87	1.20	0.17	0.47	2.52		4.55	SO_2 0.19
Clarion Co., Pa	1.02	44.61	38.01	13.63	1.25	0.08	0.41	1.74		3.47	....
Farrandsville, Pa	....	45.26	37.85	13.30	2.03	0.08	0.02	1.26		3.59	0.20
St. Louis Co., Mo	....	67.47	19.33	10.45	2.56	0.41	0.07	1.07		5.14	....
Stourbridge, Eng	....	73.82	15.88	6.45	2.95	Tr.	Tr.	0.90		3.85	....

[1] Mass. Inst. of Technology, 1871. [2] Report on Clays of New Jersey. Prof. G. H. Cook, 1877. [3] Second Geological Survey of Penna., 1878. [4] Dr. Otto Wuth (2 samples), 1885. [5] Flint clay from Clearfield and Cambria counties, Pa., average of hundreds of analyses by Harbison-Walker Refractories Co., Pittsburg, Pa. [6] Same material calcined. All other analyses from catalogue of Stowe-Fuller Co., 1907.

TABLE XXV.—Sizes of Fire-Brick



9-inch straight	9 × 4½ × 2½ inches.
Soap	9 × 2¼ × 2½ "
Checker	9 × 3 × 3 "
No. 1 Split	9 × 4½ × 1¼ "
No. 2 Split	9 × 4½ × 2 "
Jamb	9 × 4½ × 2½ "
No. 1 key	9 × 2½ thick × 4½ to 4 inches. wide. 112 bricks to circle 12 feet inside diam.
No. 2 key	9 × 2½ thick × 4½ to 3½ inches wide. 65 bricks to circle 6 ft. inside diam.
No. 3 key	9 × 2½ thick × 4½ to 3 inches wide. 41 bricks to circle 3 ft. inside diam.
No. 4 key	9 × 2½ thick × 4½ to 2¼ inches wide. 26 bricks to circle 1½ ft. inside diam.
No. 1 wedge (or bullhead)	9 × 4½ wide, 2 × 2½ to 2 in. thick, tapering lengthwise. 102 bricks to circle 5 ft. inside diam.
No. 2 wedge	9 × 4½ × 2½ to 1½ in. thick. 63 bricks to circle 2½ ft. inside diam.
No. 1 arch	9 × 4½ × 2½ to 2 inches thick, tapering breadthwise. 72 bricks to circle 4 ft. inside diam.
No. 2 arch	9 × 4½ × 2½ to 1½. 42 bricks to circle 2 ft. inside diam.
No. 1 skew	9 to 7 × 4½ to 2½. Bevel on one end.
No. 2 skew	9 × 2½ × 4½ to 2½. Equal bevel on both edges.
No. 3 skew	9 × 2½ × 4½ to 1½. Taper on one edge.
24-inch circle	8¼ to 5⅛ × 4½ × 2½. Edges curved, 9 bricks line a 24-inch circle.
36-inch circle	8¾ to 6½ × 4½ × 2½. 13 bricks line a 36-inch circle.
48-inch circle	8¾ to 7¼ × 4½ × 2½. 17 bricks line a 48-inch circle.
13½-inch straight	13½ × 2½ × 6.
13½-inch key No. 1	13½ × 2½ × 6 to 5 inch. 90 bricks turn a 12-ft. circle.
13½-inch key No. 2	13½ × 2½ × 6 to 4⅜ inch. 52 bricks turn a 6-ft. circle.
Bridge wall, No. 1	13 × 6½ × 6.
Bridge wall, No. 2	13 × 6½ × 3.
Mill tile	18, 20, or 24 × 6 × 3.
Stoke-hole tiles	18, 20, or 24 × 9 × 4.
18-inch block	18 × 9 × 6.
Flat back	9 × 6 × 2½.
Flat back arch	9 × 6 × 3½ to 2½. 22-inch radius, 56 bricks to circle.
Locomotive tile	32 × 10 × 3. 34 × 10 × 3. 34 × 8 × 3. 36 × 8 × 3. 40 × 10 × 3.

Tiles, slabs, and blocks, various sizes 12 to 30 in. long, 8 to 30 in. wide, 2 to 6 in. thick.

Cupola brick, 4 and 6 in. high, 4 and 6 in. radial width, to line shells 23 to 66 in. diameter.

A 9-inch straight brick weighs 7 lb. and contains 100 cubic inches. (= 120 lb. per cubic foot. Specific gravity 1.93.)

One cubic foot of wall requires 17 9-inch bricks, one cubic yard requires 460. Where keys, wedges, and other "shapes" are used, add 10 per cent in estimating, the number required.

One ton of fire-clay should be sufficient to lay 3,000 ordinary bricks. To secure the best results, fire-bricks should be laid in the same clay from which they are manufactured. It should be used as a thin paste, and not as mortar. The thinner the joint the better the furnace wall. In ordering bricks, the service for which they are required should be stated.

TABLE XXVI.—NUMBER OF FIRE-BRICK REQUIRED FOR VARIOUS CIRCLES

Diam. of Circle		Key Bricks					Arch Bricks				Wedge Bricks			
		No. 4	No. 3	No. 2	No. 1	Total	No. 2	No. 1	9-inch	Total	No. 2	No. 1	9-inch	Total
ft.	in.													
1	6	25	....	....	....	25	....	....	....	....	....	....	....	....
2	0	17	13	....	....	30	42	....	....	42	....	....	....	....
2	6	9	25	....	....	34	31	18	....	49	60	....	....	60
3	0	....	38	....	....	38	21	36	....	57	48	20	....	68
3	6	....	32	10	....	42	10	54	....	64	36	40	....	76
4	0	....	25	21	....	46	....	72	....	72	24	59	....	83
4	6	....	19	32	....	51	....	72	8	80	12	79	....	91
5	0	....	13	42	....	55	....	72	15	87	....	98	....	98
5	6	....	6	53	....	59	....	72	23	95	....	98	8	106
6	0	....	....	63	....	63	....	72	30	102	....	98	15	113
6	6	....	....	58	9	67	....	72	38	110	....	98	23	121
7	0	....	....	52	19	71	....	72	45	117	....	98	30	128
7	6	....	....	47	29	76	....	72	53	125	....	98	38	136
8	0	....	....	42	38	80	....	72	60	132	....	98	46	144
8	6	....	....	37	47	84	....	72	68	140	....	98	53	151
9	0	....	....	31	57	88	....	72	75	147	....	98	61	159
9	6	....	....	26	66	92	....	72	83	155	....	98	68	166
10	0	....	....	21	76	97	....	72	90	162	....	98	76	174
10	6	....	....	16	85	101	....	72	98	170	....	98	83	181
11	0	....	....	11	94	105	....	72	105	177	....	98	91	189
11	6	....	....	5	104	109	....	72	113	185	....	98	98	196
12	0	....	....	...	113	113	....	72	121	193	....	98	106	204
12	6	....	....	...	117	117	....	....	....	....	....	....	...	....

For larger circles than 12 feet use 113 No. 1 Key and as many 9-inch brick as may be needed in addition.

TABLE XXVII.—Weight of Castings Determined from Weight of Pattern

(Rose's "Pattern-makers' Assistant")

A Pattern Weighing One Pound, Made of—	Will Weigh when Cast in				
	Cast-iron.	Zinc.	Copper.	Yellow Brass.	Gun-metal.
	lbs.	lbs.	lbs.	lbs.	lbs.
Mahogany—Nassau ..	10.7	10.4	12.8	12.2	12.5
" Honduras	12.9	12.7	15.3	14.6	15.
" Spanish..	8.5	8.2	10.1	9.7	9.9
Pine, red............	12.5	12.1	14.9	14.2	14.6
" white..........	16.7	16.1	19.8	19.0	19.5
" yellow.........	14.1	13.6	16.7	16.0	16.5

TABLE XXVIII.—Dimensions of Foundry Ladles

The following table gives the dimensions, inside the lining, of ladles from 25 lbs. to 16 tons capacity. All the ladles are supposed to have straight sides. (*Am. Mach.*)

Capacity	Diam.	Depth	Capacity	Diam.	Depth	Capacity	Diam.	Depth
	in.	in.		in.	in.		in.	in.
16 tons	54	56	3 tons	31	32	300 lb.	11½	11½
14 "	52	53	2 "	27	28	250 "	10¾	11
12 "	49	50	1½ "	24½	25	200 "	10	10½
10 "	46	48	1 ton	22	22	150 "	9	9½
8 "	43	44	¾ "	20	20	100 "	8	8½
6 "	39	40	½ "	17	17	75 "	7	7½
4 "	34	35	¼ "	13½	13½	50 "	6½	6½

TABLE XXIX.—Composition of Alloys in Every-day Use in Brass Foundries

(*American Machinist*)

	Copper	Zinc	Tin	Lead	
	lbs.	lbs.	lbs.	lbs.	
Admiralty metal	87	5	8	.....	For parts of engines on board naval vessels.
Bell metal......	16	.....	4	.....	Bells for ships and factories.
Brass (yellow)...	16	8	.....	½	For plumbers, ship and house brass work.
Bush metal.....	64	8	4	4	For bearing bushes for shafting.
Gun-metal......	32	1	3	.....	For pumps and other hydraulic purposes.
Steam metal....	20	1	1½	1	Castings subjected to steam pressure.
Hard gun-metal.	16	.....	2½	.....	For heavy bearings.
Muntz metal....	60	40	.....	.....	Metal from which bolts and nuts are forged, valve spindles, etc.
Phosphor bronze.	92	.....	8 phos. tin		For valves, pumps, and general work.
" "	90	.....	10 "	"	For cog and worm wheels, bushes, axle bearings, slide valves, etc.
Brazing metal...	16	3	.....	.....	Flanges for copper pipes.
" solder...	50	50	.....	.....	Solder for the above flanges.

TABLE XXX.—USEFUL ALLOYS OF COPPER, TIN, AND ZINC

(Selected from numerous sources)

	Copper.	Tin.	Zinc.
U. Navy Dept. journal boxes and guide-gibs =	6.	1	¼ parts.
	82.8	13.8	3.4 per cent.
Tobin bronze	58.22	2.30	39.48 " "
Naval brass	62	1	37 " "
Composition, U. S. Navy	88	10	2 " "
Brass bearings (J. Rose)	64	8	1 parts.
	87.7	11.0	1.3 per cent.
Gun-metal	92.5	5	2.5 " "
" "	91	7	2 " "
" "	87.75	9.75	2.5 " "
" "	85	5	10 " "
" "	83	2	15 " "
Tough brass for engines	13	2	2 parts.
	76.5	11.8	11.7 per cent.
Bronze for rod-boxes (Lafond)	82	16	2 slightly malleable.
" " pieces subject to shock	83	15	1.50 0.50 lead.
Red brass ... parts	20	1	1 1 "
" " ... per cent.	87	4.4	4.3 4.3 "
Bronze for pump casings (Lafond)	88	10	2
" " eccentric straps "	84	14	2
" " shrill whistles	80	18	......2.0 antimony.
" " low-toned whistles	81	17	......2.0 "
Art bronze, dull red fracture	97	2	1
Gold bronze	89.5	2.1	5.6 2.8 lead.
Bearing metal	89	8	3
" "	89	2½	8½
" "	86	14	
" "	85¼	12¾	2
" "	80	18	2
" "	79	18	2½ ½ lead.
" "	74	9½	9½ 7 lead.
English brass of A.D. 1504	64	3	29½ 3½ lead.

TABLE XXXI.—Composition of Various Grades of Rolled Brass, etc.

(Kent's "Mechanical Engineers' Pocket-Book," eighth edition)

Trade Name	Copper	Zinc	Tin	Lead	Nickel
Common high brass	61.5	38.5	.....	....	.....
Yellow metal	60	40	.....	....	.....
Cartridge brass	66⅔	33⅓	.....	....	.....
Low brass	80	20	.....	....	.....
Clock brass	60	40	.....	1½	.....
Drill rod	60	40	.....	1½ to 2	.....
Spring brass	66⅔	33⅓	1½	....	.....
18 per cent German silver	61½	20½	.....	....	18

The above table was furnished by the superintendent of a mill in Connecticut in 1894. He says: While each mill has its own proportions for various mixtures, depending upon the purposes for which the product is intended, the figures given are about the average standard. Thus, between cartridge brass with 33⅓ per cent zinc and common high brass with 38½ per cent zinc, there are any number of different mixtures known generally as "high brass," or specifically as "spinning brass," "drawing brass," etc., wherein the amount of zinc is dependent upon the amount of scrap used in the mixture, the degree of working to which the metal is to be subjected, etc.

TABLE XXXII.—Shrinkage of Castings

(Kent's "Mechanical Engineers' Pocket-Book," eighth edition)

The allowance necessary for shrinkage varies for different kinds of metal, and the different conditions under which they are cast. For castings where the thickness runs about one inch, cast under ordinary conditions, the following allowance can be made:

For cast-iron,	⅛ inch per foot.	For zinc,	5/16 inch per foot.
" brass,	3/16 " " "	" tin,	1/12 " " "
" steel,	¼ " " "	" aluminum,	3/16 " " "
" mal. iron,	⅛ " " "	" britannia,	1/32 " " "

Thicker castings, under the same conditions, will shrink less, and thinner ones more, than this standard. The quality of the material and the manner of molding and cooling will also make a difference.

Mr. Keep (*Trans. A. S. M. E.*, vol. xvi) gives the following "approximate key for regulating foundry mixtures" so as to produce a shrinkage of ⅛ in. per ft. in castings of different sections:

Size of casting	½	1	2	3	4	in. sq.
Silicon required, per cent	3.25	2.75	2.25	1.75	1.25	per cent
Shrinkage of a ½-in. test-bar	0.125	0.135	0.145	0.155	0.165	in. per ft.

TABLE XXXIII.—Sizes of Pipes for Tumbling Barrels, Inches Diameter

(Data Sheet of *The Foundry*, Feb., 1910)

Diameter of Mill, Inches	Length of Barrel, Inches				
	36	48	60	72	84
24	4	4	5	6	6
30	4	4	5	6	6
36	5	5	6	6	7
42	6	6	6	7	8
48	6	6	7	8	8

TABLE XXXIV.—Diameter of Exhaust Fan Inlets for Tumbling Barrels

(Data Sheet of *The Foundry*, Feb., 1910)

Diameter of Pipe to Mill, Inches	Number of Mills Inlet Diameter, Inches									
	1	2	3	4	5	6	7	8	9	10
4	4¾	6½	6½	8½	8½	10½	10½	12	12	12
5	5½	6½	8½	10½	12	12	14	14	16	16
6	6½	8½	10½	12	14	14	16	18	18	20
7	6½	10½	12	14	16	18	18	20	22	24
8	8½	12	14	16	18	20	22	24	24	27

TABLE XXXV.—Steel Pressure Blowers for Cupolas (Average Application)

(American Blower Co.)

No. of Blower	Dia. of Wheel, in.	Width Periphery, in.	Circum. of Wheel, ft.	Dia. Outlet, pipes, in.	Area of Outlet, sq. ft.	Oz.	2	3	4	5	6	7	8	9
						In.	3.46	5.19	6.92	8.65	10.38	12.12	13.83	15.56
						H.P. constant at 1000 cu. ft.	1.242	1.86	2.48	3.19	3.73	4.35	4.95	5.58
1	14½	1⅜	3.80	5¾	0.18	R.P.M.	1960	2400	2770	3095	3390	3666	3915	4150
						C.F.	361	434	500	560	610	665	708	752
						H.P.	0.45	0.81	1.24	1.74	2.28	2.89	3.51	4.20
2	17	1⅝	4.45	6¾	0.2485	R.P.M.	1675	2050	2362	2645	2895	3130	3340	3540
						C.F.	498	600	691	774	843	916	978	1038
						H.P.	0.62	1.12	1.72	2.40	3.15	3.99	4.84	5.79
3	19½	1⅞	5.11	7¾	0.327	R.P.M.	1460	1785	2060	2300	2520	2730	2910	3085
						C.F.	655	789	910	1018	1110	1207	1286	1365
						H.P.	0.82	1.47	2.26	3.16	4.15	5.25	6.36	7.62
4	22	2⅛	5.76	8¾	0.4176	R.P.M.	1292	1582	1825	2040	2235	2420	2585	2740
						C.F.	838	1006	1162	1300	1415	1540	1643	1746
						H.P.	1.04	1.87	2.88	4.03	5.28	6.70	8.14	9.74
5	24½	2⅜	6.41	9¾	0.519	R.P.M.	1162	1422	1640	1835	2010	2175	2320	2460
						C.F.	1040	1250	1442	1612	1760	1915	2040	2166
						H.P.	1.30	2.33	3.58	5.00	6.57	8.34	10.10	12.10
6	27	2⅞	7.06	10¾	0.63	R.P.M.	1055	1290	1490	1665	1825	1975	2105	2233
						C.F.	1262	1520	1750	1960	2135	2375	2475	2630
						H.P.	1.57	2.83	4.34	6.08	7.96	10.10	12.25	14.12
7	32	3⅜	8.39	12½	0.852	R.P.M.	889	1087	1255	1405	1535	1660	1775	1880
						C.F.	1705	2055	2366	2650	2890	3140	3350	3555
						H.P.	2.12	3.83	5.86	8.23	10.78	13.66	16.60	19.83
8	37	3⅞	9.70	14	1.069	R.P.M.	769	940	1085	1212	1328	1446	1533	1625
						C.F.	2140	2575	2970	3325	3620	3940	4200	4460
						H.P.	2.66	4.79	7.36	10.3	13.5	17.15	20.00	24.90
9	42	4⅜	10.98	16	1.396	R.P.M.	679	830	958	1072	1172	1270	1355	1435
						C.F.	2800	3370	3880	4340	4730	5150	5500	5825
						H.P.	3.48	6.27	9.63	13.46	17.65	22.40	27.25	32.50
10	47	4⅞	12.30	17½	1.67	R.P.M.	606	742	855	956	1048	1133	1210	1280
						C.F.	3350	4025	4640	5200	5660	6160	6570	6970
						H.P.	4.17	7.5	11.5	16.12	21.12	26.80	32.55	38.90
11	52	5⅜	13.6	19¼	2.02	R.P.M.	548	670	774	865	947	1025	1093	1160
						C.F.	4050	4870	5610	6290	6850	7450	7950	8440
						H.P.	5.03	9.06	13.9	19.5	25.55	32.40	39.33	47.10
12	57	5⅞	14.92	21	2.405	R.P.M.	500	611	705	789	863	934	996	1056
						C.F.	4820	5800	6700	7490	8160	8870	9460	10040
						H.P.	6.00	10.78	16.62	23.25	30.45	38.60	46.85	56.10

TABLE XXXVI.—Steel Pressure Blowers for Cupolas (Average Application)

(Continued)

No. of Blower	Dia. of Wheel. in.	Width Periphery, in.	Circum. of Wheel, ft.	Dia. Outlet, pipes, in.	Area of Outlet, sq. ft.	Oz.	10	11	12	13	14	15	16
						In.	17.28	19.02	20.75	22.5	24.22	25.95	27.66
						H.P. constant at 1000 cu. ft.	6.20	6.82	7.44	8.07	8.69	9.30	9.92
2	17	1⅝	4.45	6¾	0.2485	R.P.M.	3740	3920	4090	......	......	......	......
						C.F.	1093	1148	1196	......	......	......	......
						H.P.	6.78	7.83	8.9	......	......	......	......
3	19½	1⅞	5.11	7¾	0.327	R.P.M.	3255	3415	3570	3710	3955	3985	4120
						C.F.	1440	1510	1575	1642	1700	1762	1820
						H.P.	8.93	10.3	11.72	13.26	14.75	16.4	18.05
4	22	2⅛	5.76	8¾	0.4176	R.P.M.	2890	3030	3163	3290	3420	3535	3650
						C.F.	1840	1930	2012	2095	2175	2250	2325
						H.P.	11.40	13.16	14.96	16.9	18.9	20.9	23.1
5	24½	2⅜	6.41	9¾	0.519	R.P.M.	2595	2720	2845	2960	3075	3180	3280
						C.F.	2280	2395	2500	2605	2700	2800	2885
						H.P.	14.13	16.33	18.6	21.05	23.45	26.05	28.66
6	27	2⅞	7.06	10¾	0.63	R.P.M.	2355	2470	2580	2685	2790	2885	2980
						C.F.	2770	2910	3033	3165	3280	3395	3500
						H.P.	17.18	19.85	22.6	25.55	28.50	31.55	34.7
7	32	3⅜	8.39	12½	0.852	R.P.M.	1983	2080	2170	2260	2345	2430	2510
						C.F.	3750	3930	4110	4276	4430	4590	4730
						H.P.	23.25	26.80	30.6	34.5	38.5	42.7	47.
8	37	3⅞	9.70	14	1.069	R.P.M.	1715	1800	1880	1955	2030	2100	2170
						C.F.	4700	4930	5150	5360	5560	5760	5940
						H.P.	29.15	33.66	38.33	43.25	48.30	53.55	59.
9	42	4⅜	10.98	16	1.396	R.P.M.	1515	1590	1660	1728	1792	1855	1916
						C.F.	6150	6450	6730	7010	7270	7525	7760
						H.P.	38.15	44.00	50.15	56.60	63.2	70.	77.
10	47	4⅞	12.30	17½	1.67	R.P.M.	1352	1418	1480	1540	1600	1655	1710
						C.F.	7350	7715	8055	8390	8700	9010	9300
						H.P.	45.60	52.66	60.0	67.66	75.6	83.9	92.25
11	52	5⅜	13.6	19¼	2.02	R.P.M.	1222	1282	1340	1393	1447	1498	1546
						C.F.	8900	9330	9750	10140	10520	10890	11220
						H.P.	55.20	63.6	72.5	82.0	91.5	101.2	111.33
12	57	5⅞	14.92	21	2.405	R.P.M.	1113	1168	1220	1270	1318	1363	1410
						C.F.	10580	11100	11600	12080	12520	12960	13380
						H.P.	65.5	75.70	86.33	97.5	109.0	120.5	132.75

TABLE XXXVII.—CAPACITY OF STURTEVANT HIGH-PRESSURE BLOWERS

Number of Blower	Capacity in Cubic Feet per Minute, ½-lb. Pressure	Revolutions per Minute	Inside Diam. of Inlet and Outlet, Inches	Approximate Weight, Pounds *
000	1 to 5	200 to 1000	1⅜	40
00	5 to 25	375 to 800	1½	80
0	25 to 45	370 to 800	2½	140
1	45 to 130	240 to 600	3	330
2	130 to 225	300 to 500	4	550
3	225 to 325	380 to 525	4	760
4	325 to 560	350 to 565	6	1,080
5	560 to 1,030	300 to 475	8	1,670
6	1,030 to 1,540	290 to 415	10	2,500
7	1,540 to 2,300	280 to 410	10	3,200
8	2,300 to 3,300	265 to 375	12	4,700
9	3,300 to 4,700	250 to 350	16	6,100
10	4,700 to 6,000	260 to 330	16	8,000
11	6,000 to 8,500	220 to 310	20	12,100
12	8,500 to 11,300	190 to 250	24	18,700
13	11,300 to 15,500	190 to 260	30	22,700

* Of blower for ½ lb. pressure.

TABLE XXXVIII.—Speed, Capacities, and Horse-power of Sirocco Fans

(American Blower Co.)

The figures given represent dynamic pressures in oz. per sq. in. For static pressure, deduct 28.8 per cent; for velocity pressure, deduct 71.2 per cent.

Diam. Wheel		1/4 Oz.	1/2 Oz.	3/4 Oz.	1 Oz.	1 1/4 Oz.	1 1/2 Oz.	1 3/4 Oz.	2 Oz.	2 1/2 Oz.	3 Oz.
in.											
	Cu. ft.	155	220	270	310	350	380	410	440	490	540
6	R.P.M.	1,145	1,615	1,980	2,290	2,560	2,800	3,025	3,230	3,616	3,960
	B.H.P.	.0185	.052	.095	.147	.205	.270	.34	.42	.58	.76
	Cu. ft.	350	500	610	700	790	860	930	1,000	1,110	1,220
9	R.P.M.	762	1,076	1,320	1,524	1,700	1,866	2,020	2,152	2,408	2,640
	B.H.P.	.042	.118	.216	.333	.463	.610	.77	.95	1.32	1.73
	Cu. ft.	625	880	1,080	1,250	1,400	1,530	1,650	1,770	1,970	2,170
12	R.P.M.	572	808	990	1,145	1,280	1,400	1,512	1,615	1,808	1,980
	B.H.P.	.074	.208	.381	.588	.82	1.08	1.36	1.66	2.32	3.05
	Cu. ft.	975	1,380	1,690	1,950	2,180	2,400	2,590	2,760	3,090	3,390
15	R.P.M.	456	645	790	912	1,020	1,120	1,210	1,290	1,444	1,580
	B.H.P.	.115	.326	.600	.923	1.29	1.69	2.14	2.61	3.65	4.8
	Cu. ft.	1,410	1,990	2,440	2,820	3,160	3,450	3,720	3,980	4,450	4,880
18	R.P.M.	381	538	660	762	850	933	1,010	1,076	1,204	1,320
	B.H.P.	.167	.470	.862	1.33	1.85	2.43	3.07	3.75	5.25	6.9
	Cu. ft.	1,925	2,710	3,310	3,850	4,290	4,700	5,070	5,420	6,060	6,620
21	R.P.M.	326	462	565	652	730	800	864	924	1,032	1,130
	B.H.P.	.227	.640	1.17	1.81	2.53	3.33	4.18	5.11	7.15	9.4
	Cu. ft.	2,500	3,540	4,340	5,000	5,600	6,120	6,620	7,080	7,900	8,680
24	R.P.M.	286	404	495	572	640	700	756	807	904	990
	B.H.P.	.296	.832	1.53	2.35	3.28	4.32	5.44	6.64	9.3	12.2
	Cu. ft.	3,175	4,490	5,500	6,350	7,100	7,780	8,400	8,980	10,050	11,000
27	R.P.M.	254	359	440	508	568	622	672	718	804	880
	B.H.P.	.373	1.05	1.94	2.98	4.16	5.48	6.90	8.44	11.8	15.5
	Cu. ft.	3,910	5,520	6,770	7,820	8,750	9,600	10,350	11,050	12,350	13,550
30	R.P.M.	228	322	395	456	510	560	604	645	722	790
	B.H.P.	.460	1.30	2.40	3.68	5.15	6.75	8.53	10.4	14.5	19.1
	Cu. ft.	5,650	7,950	9,750	11,300	12,640	13,800	14,900	15,900	17,800	19,500
36	R.P.M.	190	269	330	381	425	466	504	538	602	660
	B.H.P.	.665	1.87	3.44	5.30	7.40	9.72	12.25	15.0	20.9	27.5
	Cu. ft.	7,700	10,850	13,300	15,400	17,170	18,800	20,300	21,700	24,250	26,600
42	R.P.M.	163	231	283	326	365	400	432	462	516	566
	B.H.P.	.903	2.55	4.69	7.24	10.1	13.3	16.7	20.4	28.5	37.5
	Cu. ft.	10,000	14,150	17,350	20,000	22,400	24,500	26,500	28,300	31,600	34,700
48	R.P.M.	143	202	248	286	320	350	378	403	452	495
	B.H.P.	1.18	3.32	6.10	9.40	13.1	17.2	21.75	26.6	37.1	48.8
	Cu. ft.	12,700	17,950	22,000	25,400	28,400	31,100	33,600	35,900	40,200	44,000
54	R.P.M.	127	179	220	254	284	311	336	359	402	440
	B.H.P.	1.49	4.20	7.75	11.9	16.6	21.9	27.6	33.7	47.1	62.
	Cu. ft.	15,650	22,100	27,100	31,300	35,000	38,400	41,400	44,200	49,400	54,200
60	R.P.M.	114	161	198	228	255	280	302	322	361	396
	B.H.P.	1.84	5.20	9.58	14.7	20.6	27.0	34.1	41.6	58.2	76.5
	Cu. ft.	18,950	26,800	32,850	37,900	42,300	46,400	50,100	53,600	60,000	65,700
66	R.P.M.	104	147	180	208	232	254	275	294	328	360
	B.H.P.	2.23	6.30	11.6	17.8	24.9	32.7	41.2	50.4	70.4	92.6
	Cu. ft.	22,600	31,800	39,000	45,200	50,600	55,200	59,600	63,600	71,200	78,000
72	R.P.M.	95	134	165	190	212	233	252	269	301	330
	B.H.P.	2.66	7.48	13.7	21.2	29.6	38.9	49.0	59.8	83.6	110.
	Cu. ft.	26,400	37,350	45,800	52,800	59,100	64,700	70,000	74,700	83,500	91,600
78	R.P.M.	88	124	153	176	197	215	233	248	278	305
	B.H.P.	3.10	8.77	16.1	24.8	34.7	45.6	57.5	70.2	98.	129.
	Cu. ft.	30,800	43,400	53,200	61,600	68,700	75,200	81,200	86,800	97,100	106,400
84	R.P.M.	81	115	142	163	182	200	216	231	258	283
	B.H.P.	3.61	10.2	18.7	28.9	40.4	53.0	66.8	81.7	114.	150.
	Cu. ft.	35,250	49,800	61,000	70,500	78,800	86,400	93,300	99,600	111,200	122,000
90	R.P.M.	76	107	132	152	170	186	201	214	241	264
	B.H.P.	4.14	11.7	21.5	33.1	46.2	60.7	76.7	93.6	131.	172.

TABLE XXXIX.—Capacity of Rotary Blowers for Cupolas

Cu. Ft. per Rev.	Revs. per Min.	Tons per Hour	Suitable for Cupola In. Diam.*
1.5	200	1	18 to 20
	400	2	
3.3	175	1	24 to 27
	335	2	
6	185	2	28 to 32
	275	3	
10	200	4	32 to 38
	250	5	
13	150	4	32 to 40
	190	5	
	175	6½	
17	150	5	36 to 45
	205	6½	
	250	8½	
24	166	8	42 to 54
	200	10	
	240	12	
33	150	10	48 to 60
	180	12	
	210	14	

Cu. Ft. per Rev.	Revs. per Min.	Tons per Hour	Suitable for Cupola In. Diam.*
45	135	12	54 to 66
	165	15	
	200	18	
57	130	15	60 to 72
	155	18	
	185	21	
65	140	18	66 to 84
	160	21	
	185	24	
84	125	21	72 to 90
	145	24	
	160	27	
100	120	24	84 to 96
	135	27	
	160	30	
118	115	27	Two cupolas 60 to 66
	130	30	
	140	33	

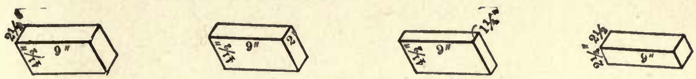
* Inside diam. The capacity in tons per hour is based on 30,000 cu. ft. of air per ton of iron melted.

TABLE XL.—Diameters of Blast Pipes

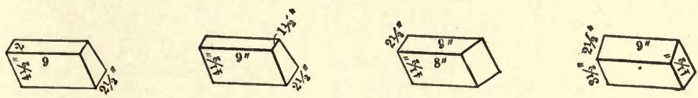
(B. F. Sturtevant Co.)

Tons of Iron per Hour	Inside Diam. of Cupola, Inches	Cubic Ft. of Air per Minute	Length of Pipe in Feet													
			20		40		60		80		100		120		140	
			Diameter of Pipe with Drop of													
			¼ Oz.	½ Oz.	¼ Oz.	½ Oz.	¼ Oz.	½ Oz.	¼ Oz.	½ Oz.	¼ Oz.	½ Oz.	¼ Oz.	½ Oz.	¼ Oz.	½ Oz.
1	23	500	6	5	7	6	7	6	8	7	9	8	9	8	9	8
2	27	1,000	8	7	9	8	10	9	11	9	11	10	12	11	12	11
3	30	1,500	10	8	11	10	11	10	12	11	13	11	13	12	14	12
4	32	2,000	11	9	12	11	13	12	14	12	15	13	15	14	16	14
5	36	2,500	12	10	14	12	15	13	15	14	16	14	17	15	17	15
6	39	3,000	13	11	15	13	16	14	17	15	18	15	18	16	18	16
7	42	3,500	13	12	15	13	17	15	17	15	18	16	19	17	20	18
8	45	4,000	15	12	16	15	18	15	18	16	19	17	20	18	21	18
9	48	4,500	15	13	17	15	18	16	19	17	20	18	21	19	22	19
10	54	5,000	15	13	18	15	19	17	20	18	21	18	22	19	23	20
11	54	5,500	16	14	18	16	20	17	21	18	22	19	23	20	23	20
12	60	6,000	17	14	19	17	20	17	21	19	22	20	23	21	24	21
13	60	6,500	17	14	19	17	21	18	23	19	23	20	24	21	25	22
14	60	7,000	18	15	20	18	22	19	23	20	24	21	25	22	26	23
15	66	7,500	18	16	21	18	22	19	24	21	25	22	26	22	27	23
16	66	8,000	18	16	22	18	23	20	24	22	26	22	26	23	27	24
17	66	8,500	18	16	22	18	23	20	24	22	26	22	27	24	28	24
18	72	9,000	18	17	22	18	24	21	25	22	27	23	27	24	28	25
19	72	9,500	20	17	23	20	24	22	26	23	28	23	28	25	29	26
20	72	10,000	20	18	23	20	25	22	27	23	28	24	29	25	30	26
21	78	10,500	21	18	24	21	26	23	27	23	29	25	30	26	30	26
22	78	11,000	21	18	24	21	27	23	28	24	29	26	30	27	31	27
23	78	11,500	21	19	25	21	27	24	28	25	30	26	30	27	31	27
24	84	12,000	22	19	25	22	28	24	28	25	31	26	31	27	32	28
25	84	12,500	22	19	26	22	28	24	29	26	31	27	32	28	33	28
26	84	13,000	22	19	26	22	28	24	29	26	31	27	32	28	33	28
27	90	13,500	23	20	26	23	28	24	30	26	31	27	32	28	34	28
28	90	14,000	23	20	27	23	29	25	30	27	32	28	33	29	34	29
29	90	14,500	23	20	27	23	29	26	31	27	32	28	33	29	34	30
30	90	15,000	24	21	27	24	29	26	31	27	32	28	34	30	35	30

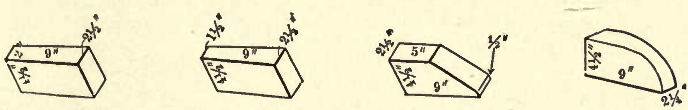
FIREBRICKS



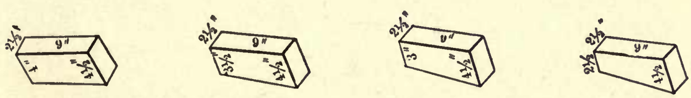
9″ Straight 9″ × 4½″ × 2½″ | 2″ Brick 9″ × 4½″ × 2″ | Split Brick 9″ × 4½″ × 1¼″ | Soap 9″ × 2½″ × 2¼″



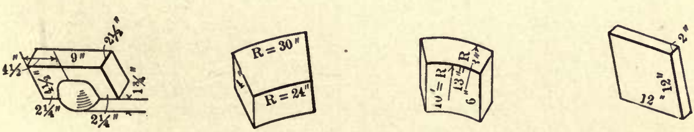
No. 1 Arch 9″ × 4½″ × 2½″ × 2″ | No. 2 Arch 9″ × 4½″ × 2½″ × 1½″ | End Skew 9″ × 8″ × 4½″ × 2½″ | Side Skew 9″ × 4½″ × 3½″ × 2½″



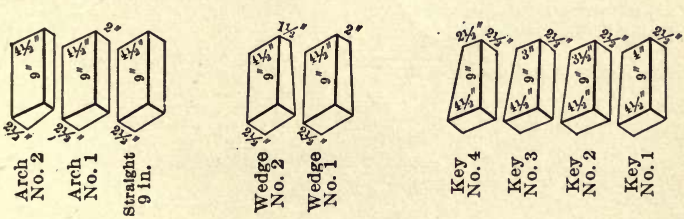
No. 1 Wedge 9″ × 4½″ × 2½″ × 2″ | No. 2 Wedge 9″ × 4½″ × 2½″ × 1½″ | Angle 9″ × 4½″ × 2½″ × ½″ | Jamb Brick 9″ × 4½″ × 2½″



No. 1 Key 9″ × 4½″ × 4″ × 2½″ | No. 2 Key 9″ × 4½″ × 3½″ × 2½″ | No. 3 Key 9″ × 4½″ × 3″ × 2½″ | No. 4 Key 9″ × 4½″ × 2½″ × 2½″



Baffle 9″ × 4½″ × 2½″ | Shell Brick No. 112 | Brass Fur. Brick No. 26 | Baker Tile



INDEX