FOUNDRY WORK

MERICAN SCHOOL of CORRESPONDENCE
CHICAGO ILLINOIS
U. S. A.

PART II

FOUNDRY WORK

PART II

INSTRUCTION PAPER

PREPARED BY

WILLIAM C. STIMPSON

HEAD INSTRUCTOR IN FOUNDRY WORK AND FORGING
DEPARTMENT OF SCIENCE AND TECHNOLOGY
PRATT INSTITUTE

AMERICAN SCHOOL OF CORRESPONDENCE

CHICAGO U.S.A. ILLINOIS

FOUNDRY WORK

PART II

LOAM MOLDING

The loam molder requires the greatest all-around skill in the whole range of foundry work. He must know all the tricks of core room and dry sand shop, and most of those in green sand. Added to all this he must have a practical working knowledge of the principles of drawing and must possess to a large degree the foresight of the designer.

In order to save time and lumber in the pattern shop, only a set of sweeps are provided if the mold is simple, and these with blue prints of the piece wanted, is all the molder has to work from. In intricate work, such as a modern Corliss cylinder, a skeleton pattern carrying the steam chests, etc., in accurate position is made. And in some very crooked work a pattern is furnished complete. As a rule, however, the loam molder must rely upon his own skill and ingenuity for the best method of constructing each detail of the work.

Rigging. The equipment for the loam floor varies in different shops. In Fig. 93 is shown the essential features of an equipment for sweeping up circular forms.

The **spindle** *a* should be large enough not to spring when being used, and long enough to conveniently clear the highest mold. A piece of 2-inch shafting is a handy size, for with it the sweeps may be made uniformly 1 inch less than the required diameter and placed snug to the spindle when set up and correct size of mold is ensured. This spindle should revolve smoothly in a *step b.* The step shown may be set at any convenient place on the floor. It has a long taper bearing, (see section A), capable of holding a five-foot spindle without need of any top bearing for same. The three arms serve to make the step set firm, and upon them any plate may be readily leveled up. Where a tall spindle is used the spindle socket will be more shallow, the step may be cast without arms and be bedded in the floor. The top of the spindle is steadied by the *bracket c.* This must carry a bearing *box* so designed that the spindle may be readily set in position or removed. And the bracket must swing back out of the way when any parts of the mold are to be handled by the crane.

The sweeps are attached by means of the *sweep arm d.* The detail B shows one method of clamping sweep arm to spindle by using a key. The arm is offset so that one face hangs in line with the center of the spindle. Bolting the face side of the sweep to this brings the working edge in a true radial plane. *Sweeps* are usually made from pine about $1\frac{1}{8}$ inches thick. The working edge is cut to the exact contour of the form to be swept, and then beveled so that the edge

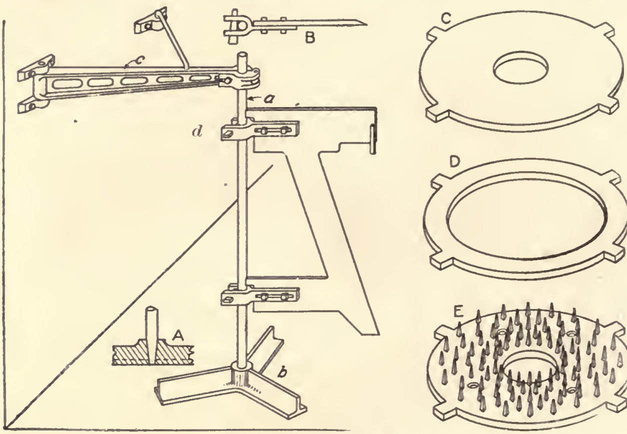


Fig. 93. Rig for Loam Work.

actually sweeping the surface is only about $\frac{3}{8}$ inch. For very accurate work or when sweeps are to be much used, the edge is faced with thin strap iron to prevent wear.

We have seen that the walls of green and dry sand molds are supported by sand packed into flasks and that these flasks may be lifted, turned up sideways or rolled completely over to suit the convenience of the workman. The facing which forms the wall of a loam mold is supported by brickwork built upon flat *plates* of cast iron, and laid in a weak mortar of "mud." From the nature of their construction, therefore, these molds must always be kept perpendicular when being handled. The parts may be raised, lowered, or moved in any direction horizontally, but they must not be tipped or rolled over.

The plates are cast in open sand molds, as illustrated in Fig. 56. Two methods are employed to provide for handling them by the crane; either *lugs* are cast on the edges of the plates (see Fig. 93, C, D, and E), or wrought *staples* are cast in the plates, as shown in the example B, Fig. 94, or in the crown plate of the main cylinder core, Fig. 97.

Three typical plates for a loam job are shown in Fig. 93. C is the *building plate;* it should be at least 18 or 20 inches larger than the

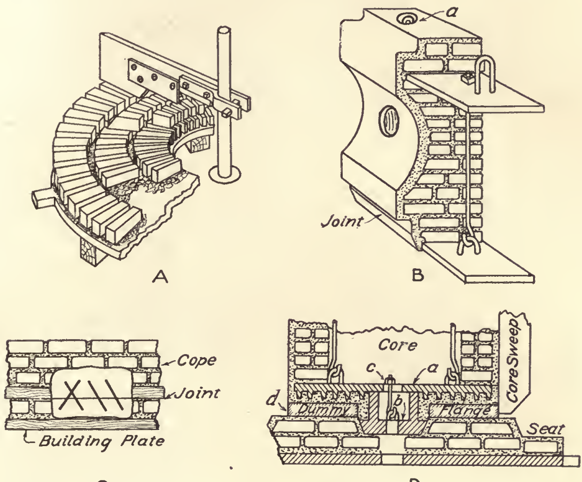


Fig. 94. Laying up Loam Work.

largest diameter of the casting to be made, and thick enough to support the weight of the entire mold without springing. D shows a *"cope ring;"* its inside diameter should clear the casting 2 inches on all sides. The face should be 8 to 12 inches wide, depending upon the height of the mold. E shows a *cover plate;* its diameter will equal the outside diameter of brickwork on that part of the mold which it will cover. Here the loam facing is placed directly on the iron, and must be supported when the plate stands vertically or is turned completely over (C, Fig. 96). To hold the loam in this way, *"fingers"* or *"stickers"* are cast on these plates. This is accomplished by simply printing the end of a tapered stick into the bed of the open mold which shapes the plates. These "sticker plates" are often used for a purpose similar to core E, Fig. 90, and shape the outer face of a picked-out flange. This is illustrated in D, Fig. 96.

Materials. Common *red bricks* are best for making loam molds. They should be free from glaze and have a uniform texture, so that

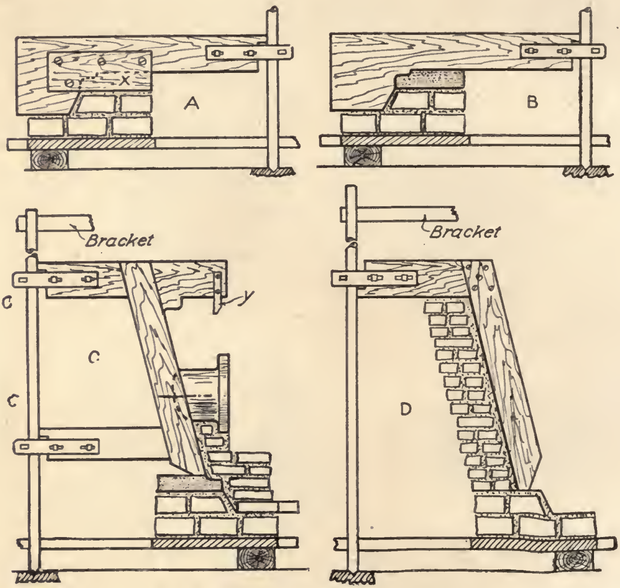


Fig. 95. Steps in Sweeping up Type Mold.

they will break clean when it is necessary to fit them to the shape. An old 12-inch half-round file makes a handy tool for cutting these bricks. Sometimes bricks are molded up from loam, and air-dried. These are much more fragile than red bricks, and may be used in pockets, or where the shell of the casting is quite thin, and ordinary brick might resist the shrinkage strain to such an extent as to endanger cracking the casting.

For laying up the brickwork, "*mud*" is used, loam facing being applied only to those surfaces which come in actual contact with the iron. Mud is made from burnt loam or old floor sand, mixed with clay wash to the consistency of mortar.

The composition of loam facing and "slip" have already been given under head of Making a Barrel Core.

Cinders are an important material in this work. Their size will depend upon their position in the mold. For working in between the bricks they should be crushed if necessary; put through a No. 4 sieve to remove smallest pieces, then passed through a No. 2 sieve to remove the larger pieces.

Principles of the Work. The names of the main parts of a loam

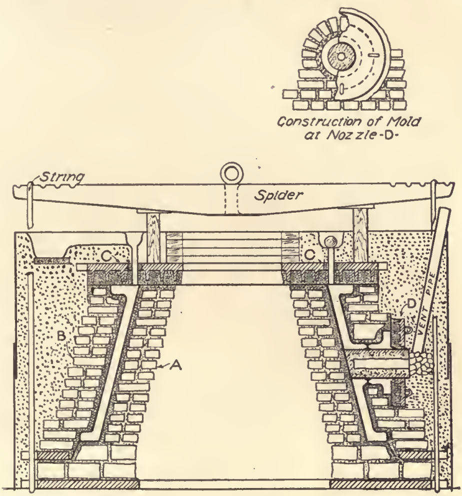


Fig. 96. Complete Typical Loam Mold.

mold differ somewhat from those applied when molding in flasks. As will be seen from the section, Fig. 96, there are three main divisions in the mold: A, which corresponds to the drag in a three-part mold is called the "*core.*" B, which corresponds to the check is called the "*cope*" in loam work. And C, which serves the same purpose as the cope of a green sand mold, is spoken of as the "*cover*" in loam molding. When the central core is actually made a separate piece as in Fig. 97, the lower part of the mold is called the "*bed*" or "*foundation.*"

In *laying up* a loam mold, set the plate central with the spindle and approximately level. Then set the sweep and finish leveling the plate until repeated measurements at the four quarters of the circle show a uniform space between the lower edge of the sweep and the surface of the plate. For the building plate this measurement should be 5 inches; for a sticker plate the sweep should clear the sticker points by ½ to 1 inch according to the thickness of the casting.

The *hands* are used in *spreading* mud or loam upon the plates or brickwork when building the mold. The bricks must always be set well apart, leaving a space at least the width of a finger between them. *Fill* in these *spaces* with fine *cinders*. The reason for this is fourfold. It facilitates *drying;* it provides good *vent;* it will *give* or *crush* sufficiently when the casting shrinks not to cause undue strain;

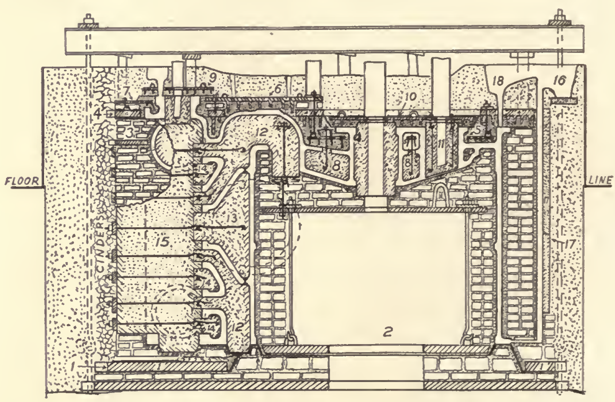


Fig. 97. Loam Mold for Marine Cylinder.

and it *reduces* the *labor* in cleaning. In each course of bricks the joints should lead as directly as possible away from the casting, but the joints should be broken between courses. These points are illustrated in the sketch A, Fig. 94. As shown, the first two courses of the core are usually set edgewise. For the rest of the core and for the cope, the bricks are laid flat. These bricks run lengthwise around the circumference, with a course of "headers" about every four to six courses.

Cinders between the bricks form the ordinary means of leading the vent from the loam facing. In confined places or "pockets," as for example, between the flange D and the main casting, Fig. 96, additional provision is made by laying long wisps of straw between the courses of bricks. The service of the straw is similar to the hay rope of a barrel core.

The *joint* in loam work is made by a plate lifting away from a loam seat or two loam surfaces separating one from another. In forming the first of these the loam seat is swept up and allowed to partially set, then the surface is brushed with oil, and parting sand thrown over it. The seat should then be soft enough to allow the iron plate to sink into it sufficiently to find a good bearing, while the oil and parting sand will prevent the loam facing from adhering to the underside of the plate. For the loam to loam joint, the same method is used, but the loam is allowed to set somewhat harder before building the joint against it. The angle of the main joint should be about 1 in 4 inches.

To insure the different parts being put together for casting in exactly the same position in which they were built, a guide surface of loam is smoothed across the joint at three or four convenient points on the outside walls of the mold. These surfaces are each marked differently with the edge of the trowel, similar to the cut at C, Fig. 94.

To properly separate and finish some molds it is necessary to lift away a portion of the mold before lifting the main part. Such a portion is called a draw-back. The draw-back is always built up in position against a pattern or sweep. With the cover plate, which on a smaller scale often serves the same purpose, (see D, Fig. 96), a flat joint is made on the outer wall of the mold, but the cover plate is swept up separately. At No. 3, Fig. 97, is shown a draw-back which carries but a few courses of brick. It may be lifted away by lugs cast in the draw-back plate with little danger of displacing its brickwork in handling.

If the shape of the draw-back renders it impracticable to handle it by the lower plate alone, the brickwork should be bound together by means of hook bolts which clamp on a top plate set sufficiently below the upper joint to be entirely protected from the metal. This upper plate has staples cast in it by which the whole draw-back may be lifted. At B, Fig. 94, the typical construction of such a piece is illustrated. The drawing shows one half the length of the brickwork removed to bring out more clearly the rigging used. The upper end of the second lifting staple shows at *a*, with the loam cut neatly away to allow hooking into the staple.

Where the main core will lift away or will be covered with metal over its top, it must be bound together in a similar manner. This is illustrated in the mold for the marine cylinder, Fig. 97, in which both of these conditions occur.

If a casting has an internal flange requiring thickness of metal underneath the main core, the rigging will be altered to fit these conditions, as shown at D, Fig. 94. In this sketch *a* is a sticker plate and so will carry the loam necessary to face the bottom of the core. To this the small bearing plate *b* is securely bolted by the hook bolt *c*. This plate must set directly upon solid brickwork, as it carries the weight of the entire core. On this bearing plate are cast three studs which firmly support the sticker plate at the required height above the flange surface. The sticker plate carrying this print is filled with loam or dry sand and given a first baking, then swept to a finished surface before being inverted into position. Then the remainder of the core is built up on top and bound together as in the previous example. Another way to form the bottom of this core is to sweep up a dummy flange, *d*, in mud. Set the bearing plate *b* and work in the loam around the studs to form the short "neck" to the level of the top of the flange. Then spread over this flange ½ inch of loam and bed down onto this the sticker plate which has been previously filled with loam and dried, as will be described below. Be sure that the studs on *b* bring up to a firm bearing against the plate *a*, then clamp tight with hook bolts and proceed to sweep up the body of the core.

In case a cover plate must be bedded down against a flat surface, as in the example just mentioned, or must take the impression of an irregular surface on the top of a mold or pattern, as illustrated in Fig. 97, the method to pursue is as follows: After casting, invert the plate and carefully lower it into position and make sure that all fingers clear the surface by at least ½ or ¾ inch. Now set the plate with the fingers up, fill in with loam enough to just clear their tops, leaving the proper openings for runners, risers, tie bolts, etc., and dry thoroughly in the oven. Upon removal from the oven invert and try this loam cover again on the surface it must fit; scraping away any portions which project too much. Now hoist away the cover and coat the face with clay wash. Having previously prepared the surface of the pattern with oil and any loam joint with oil and parting sand, spread an even thickness of fresh loam all over and bed the plate down upon this. The cover plate being still hot will, by the aid of the clay wash, cause the thin layer of fresh loam to dry out and stick fast to the dry loam forming the body of the plate.

BUILDING A SIMPLE MOLD

As an example of a simple loam mold consider a large casting, having the shape of the frustrum of a cone, with a flange at the top and bottom and a flanged nozzle projecting from one side. The section is clearly shown in Fig. 96.

Set the sweep, level up building plate, and building the brickwork as shown in A, Fig. 94, sweep the seat, joint, and bottom surface of flange as shown at A, Fig. 95. The lower flange may be formed by a wooden pattern furnished by the pattern maker, but it is more common to have the sweep made with the small board x, which may be removed. By doing this the exact shape of the flange may be swept up without changing the main sweep, as shown at B, Fig. 95. This dummy flange, as it is called, is swept up from fairly stiff "mud." The next step is to seat the cope ring and set the cope sweep, as shown at C, Fig. 95. This sweep shapes the mold for the outside of the casting, for the top flange, and for the top joint of the mold. Loam is thrown, a handful at a time, against the joint and dummy flange, and the engaging faces of bricks rubbed with loam and pressed into position.

When the top of the lower flange is reached in this way, the courses are laid up for about two feet before the loam is spread upon their inner surface and struck off. This method is pursued until the mold is built to its full height.

The projecting nozzle is formed by a wooden pattern; this should be well oiled, and the brickwork and loam laid up under it to support it at the proper level, as given by the center line on the pattern and corresponding line on the sweep. Such projections frequently must be supported in exact position by temporary wooden framework or "skeleton" work until the mold is built up under them.

A finger y nailed to the top member of the cope sweep, shapes the guide surfaces on the outside of the mold which are used to center the cover plate in closing the mold. A similar finger exactly the same distance from the spindle, is fastened to the sweep used to form the cover plate.

After the finishing coat of slip has been swept on the surface of the cope, a joint surface about 4 inches wide is struck off flush with the outer face of the nozzle and that pattern is drawn out.

Then the whole cope is lifted off and set on iron supports where it may be conveniently finished with black wash and slicks. It is then baked over night in the oven

The dummy flange is now entirely removed from the first part swept, the core sweep is set, see D, Fig. 95, and the center core is struck up. This core is then blackened, slicked off and baked. The cover plate is struck off with the "stickers" up, and baked so. This cover carries six 1-inch round holes through it. These holes will be just over the shell of the metal when the mold is closed. Five of them connect with the pouring basin and serve as runners, while the sixth serves as a riser.

In assembling the mold for pouring, the core is first set on a level bed of sand, the cope is accurately closed over it by the aid of the guide marks, and lastly the cover plate is closed in position. Now the whole mold is firmly clamped by blocking under the spider, from which wrought iron loops or "strings" connect under the lugs of the building plate, as shown in Fig. 96.

The small core for the nozzle is now set, resting on stud chaplets. The cover plate D is slid over the end of this core and thus holds it firmly in position.

The casing is now placed around the mold and molding sand rammed in to support the bricks against the casting pressure. At the level of the nozzle core, cinders are placed and a pipe leads off to carry away the vent gases. The sand is rammed to about 12 inches over the cover plate and in it are cut the channels connecting the pouring basin and runners. A couple of bricks are set in the bottom of the basin to receive the first fall of metal from the ladle.

In pouring, the runners must be flooded at once and kept so until the mold is full.

In heavy cylindrical castings it was formerly thought necessary to carry the shell of the casting some 6 inches higher than the top flange. This "head" served to collect all dirt and slag that perchance entered the mold with the iron. It was cut off in the machine shop and returned to the foundry as scrap.

With the increased knowledge of iron mixtures this head is now done away with in most instances.

Where a large casting is to finish practically all over, and very clean metal is therefore necessary, overflow channels, connecting with pig beds, are often constructed in modern practice. Then when pouring, the metal is not stopped until a certain percent of it has been flowed entirely through the mold. This of course tends to wash out any dirt which may have gotten into the mold when pouring began.

When the casting is cold the casing and packing sand are removed, as well as the blocking under the spider. Then the whole mold is carried to the cleaning shed where the bricks are removed and the casting cleaned.

BUILDING AN INTRICATE MOLD

As an example of a complex piece of loam work, let us consider the molding of a modern marine engine cylinder, as shown in section, Fig. 97. The example given is that of a double-ported low-pressure cylinder of a triple expansion type. In this case a full wooden pattern should be built, with core boxes for the various dry sand cores that enter into the construction of the mold.

The limits of this paper prevent our going into great detail in this matter; we will, therefore, confine ourselves mainly with an explanation of the drawing, Fig. 97. The heavy building plate has a spindle opening somewhat to one side of its middle to be under the center of the cylinder. Upon this building plate the foundation of the mold is swept, carrying the seat for the cope ring, the bottom face of the flange, and the seat for the main cylinder core. The cope ring No. 1 is made wide enough on one side to carry that part of the mold forming the steam chest. The main cylinder core No. 2, the construction of which has already been explained, is next swept up and lifted away, finished and baked. Now the cope ring is seated and the mold built and struck off for the bottom of the steam chest on a level with the bottom face of flange. Then the pattern may be set. Its position is accurately determined by the main cylinder print and the smaller prints of the steam chest which are bedded into the loam in accordance with measurements along a radial line marked off on the loam surface. With the pattern well oiled the cope is built to the height of the upper flange of cylinder; the entire back of the steam chest core print being left open. The top of the steam chest is lifted off with the draw-back No. 3, which joints at the middle of the upper steam nozzle, and carries that part of the mold to the level of the main cope joint. The two steam nozzles and the exhaust nozzle, may be made with separate cores as explained in D, Fig. 96. By using the draw-back the entire top of the chest core print is left open for convenience in setting the chest and port cores.

The top of the cylinder is jacketed, and through it pass the stuffing box and manhole openings. The flanges of these two openings connect and in the pattern are left loose. The whole top surface is so irregular that it requires three levels of sticker plates to mold it, aside from two small cover plates over flanges.

To the main cover No. 4-4-4-4 with its various length of fingers, is bolted a "crab" 5-5-5 to carry the loam below the flanges of the stuffing box and manhole; and below this again are hung the dry sand cores, No. 8-8-8, forming the jacketed part of the cylinder head. On top of the main cover is fastened a separate plate, No. 6, to shape the top of the upper steam inlet. And at No. 7 a plate with wrought iron bars cast along its edge carries the loam back of the steam chest flange. The small cover plates, No. 9 and No. 10, allow the flanges to be drawn for the parts which they mold.

The pattern is made in many parts so as to properly draw from the mold. When this has been done, all mold surfaces are carefully blackened and slicked before baking.

While the mold proper is being built, the dry sand cores should be made up by the core makers, with the necessary rods, hangers, vent cinders, etc., as described under Core Making.

The manhole core, No. 11, is made with a stop-off piece in the box to give the proper angle at the bottom of the core. It is hung to the cover and clears the main core by $\frac{1}{8}$ inch. The stuffing box core rests in a print in the main cylinder core, and is held by a taper print in the cover plate, No. 10.

The jacket cores are hung as shown. The openings made in the loam above the crab, to allow the hook-bolts to be drawn up tight, are stopped off with green sand as previously described. The inlet cores No. 12-12, the exhaust core, No. 13, and the lightening cores, No. 14-14-14, are all bolted directly through the steam chest core, No. 15, to horizontal bars which are long enough to bear against the sides of the mold at the back. The upper inlet core, No. 12, is kept from lifting under the pouring strain by being bolted to the body of the main cylinder core. Stud chaplets are also set between the inlet and exhaust cores to ensure correct thickness of metal at these points.

The vent is taken off from the main cylinder core through the stuffing box core at the top. Sometimes a small ladle full of metal is poured through this opening when the piece is being poured to ensure lighting these gases. The vent for the series of port cores is taken off by ramming a cinder bed up the entire back of the steam chest core, allowing the gases to escape at the top. For safety, also, vents are taken from the bottom of the port and chest cores by the usual pipe vent.

The provision for pouring this mold requires especial attention. Notice the construction of the main basin, No. 16. The long runner, No. 17, leading to the bottom gate, is left open on one side when the mold is built so that it may be easily finished and kept free from dirt. Its open side is closed by cover cores when the mold is rammed up.

Ten or twelve small gates like No. 18 are connected by semicircular channels with the pouring basin, but so placed that no metal shall fall on a core. With the basin arranged as shown, the bottom part of the mold is first flooded with iron. When this has been done the metal is poured in faster so that hot iron is well distributed around the shell of the casting through the small top gates. Should the mold be poured at first from these top gates, the fall of the iron through the full height of the cylinder to the lower flange might result in "cutting" the loam on that surface.

Molds of this size are usually rammed in a pit so as to bring the pouring basin conveniently near the floor. The portion above the floor level is, of course, rammed inside a casing, as described in the previous example.

To guard against uneven cooling strains in this intricate casting, the clamping pressure on the mold is relieved when the metal has solidified, but the sand is not removed from around the brickwork for several days. This allows very gradual even cooling.

It will be noticed that the piston does not work directly upon the inner walls of this type of cylinder. A separate hollow shell or lining is cast of strong, tough iron. This has outside horizontal ribs at top and bottom and middle, which are turned to fit correspondingly projecting ribs seen on the inside of the casting just under consideration. An air space is thus left between lining and main casting which forms a jacket around the bore of the cylinder.

MELTING

The subject of melting the metal which is to be poured into molds is one of the most important considerations in the foundry. It is also one which has received much attention in the last few years, the endeavor being to get away from the old rule-of-thumb methods and to arrive in the iron foundry at something near the precision in resulting metal that is already attained in the brass shops or the steel foundry.

The heat for all melting is obtained from practically the same two chemical elements—namely, *carbon* and *oxygen*, carbon coming from the fuel, be it coal, coke, oil, or gas; and oxygen coming from the air of the blast.

The design of the furnace, the kind of fuel used, and the application of the blast, vary in accordance with the peculiar properties of the different metals and the degree of heat required to melt them.

The melting of steel and of copper alloys will be dealt with under separate headings. We shall now consider only the melting of foundry irons.

Foundry iron is melted in direct contact with the fuel in a *cupola furnace*. The name was derived from the resemblance of the furnace to the cupola formerly very common on the top of dwelling houses.

The cupola consists of a circular shell of boiler plate lined with a double thickness of fire brick and resting on a square bedplate with a central opening the size of the inside of the lining. This bottom is supported some $3\frac{1}{2}$ feet above a solid foundation, on four cast-iron legs. The bottom opening may be closed by cast-iron doors, which swing up into position, and are held so by an upright iron bar placed centrally under them. These doors, protected by a sand bed, support the charge during the heat, and "drop" it out of the furnace when all the iron has been melted. The legs curve outward and the doors are hinged as far back as possible to protect them as much as can be from the heat of this "drop." Several feet above the bottom, there is a door in the side of the stack, through which the stock is charged into the furnace. At one side, level with the bottom, is the *breast opening*, at which place the fire is lighted, and in which the *tap-hole* is formed for drawing off the melted metal. The spout, protected by a fire-sand mixture, projects in front of the breast and guides the metal into the ladles. Oblong openings called *tuyeres,* are placed about 12 inches above the bed, and connect with an air-tight wind-box which surrounds the outside of the stack near the base. The tuyères direct the blast into the fuel, increasing the heat sufficiently to melt the charge. Opposite each tuyère is an air-tight sliding gate with a peephole. This allows the melter to look directly into the furnace.

In the larger cupolas a second set of tuyères is arranged about 10 inches above the main ones. They are used when long heats are run off, to make up for loss of wind caused by the main tuyères becoming partially choked by slag. On cupolas over 36 inches inside lining, a *slag-hole* is provided. This is similar to the tap-hole, and is placed opposite the spout and about 2 inches lower than the main tuyères. Fig. 98 shows a section through a modern cupola furnace, and will need but little further explanation.

In lining the stack, the layer next the shell is usually made of boiler-arch brick about the size of regular fire brick. These are set on end, and should be fitted as tightly together as possible, and laid in a thin fire cement, made of very refractory fire clay and fine, sharp silica sand. The object is to fill every crevice with a highly refractory material. Specially made curved fire brick can be purchased for the inside lining, although some foundrymen use the arch brick for this lining as well. The lining over the tuyères is shaped to overhang them slightly, to prevent melted slag dropping into them during the heat. The lining burns out quickest about 22 inches above the tuyères at what is practically the melting zone. The angle shelves riveted to the shell (see cut) allow this section of the lining to be renewed without disturbing the rest of the stack.

The height of the tuyères above the bed varies with the class of work to be poured. Where the metal is tapped and kept running continuously and is taken away by hand ladles, as in stove-plate work, the tuyères are as low as 8 inches or 10 inches above the bed; while in shops where several tons of metal may be required to fill one mould, the tuyères are as high as 18 inches above the bed. The height of the spout above the molding floor also varies in the same way; for hand

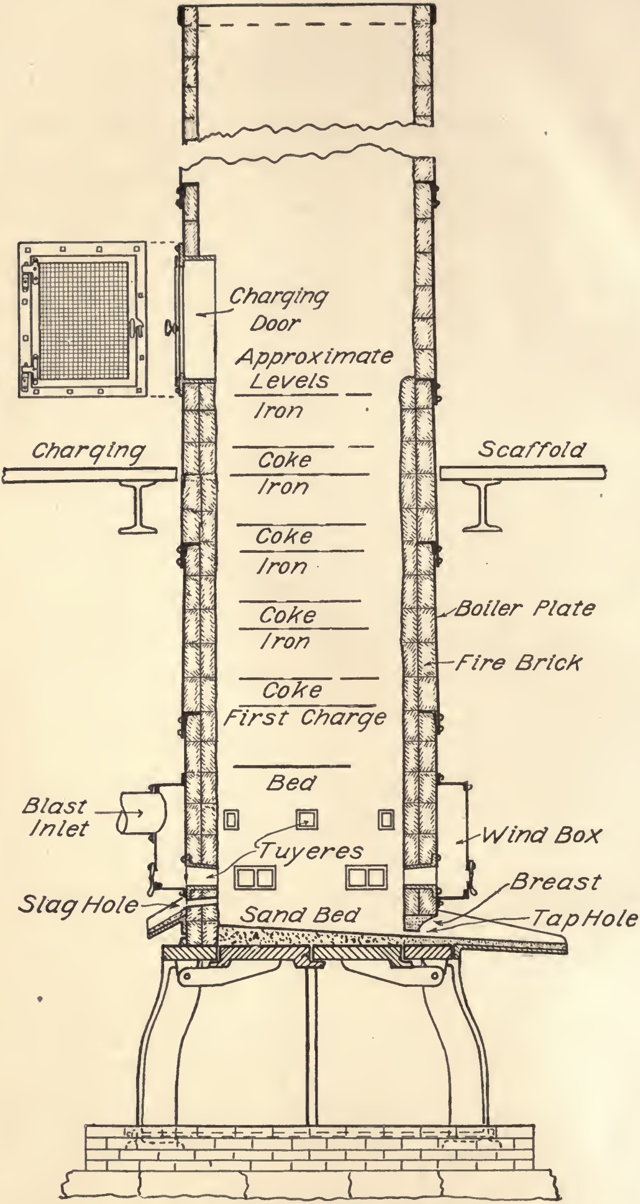


Fig. 98. Section Through Cupola Furnace.

ladle work it may be but 18 inches above the floor, while a height of 5 or 6 feet may be required to serve the largest crane ladles.

The accompanying table, prepared by Dr. Edwin Kirk, gives the approximate height and size of charging door and the practical melting capacity of cupolas of different diameters:

TABLE

Dimensions and Capacities of Cupola Furnaces

Diameter, Inside Lining Inches	Height of Cupola Feet	Size of Charging Door Inches	Melting Capacity Per Hour Tons	Melting Capacity Per Heat Tons
18	6– 7	15 x 18	¼–¾	1– 2
20	7– 8	18 x 20	½– 1	2– 3
24	8– 9	20 x 24	1– 2	3– 5
30	9–12	24 x 24	2– 5	4–10
40	12–15	30 x 36	4– 8	8–20
50	15–18	30 x 40	6–14	15–40
60	16–20	30 x 45	8–16	25–60

A platform or *scaffold* is constructed at a convenient level below the charging door, and all stock is charged into the cupola from this

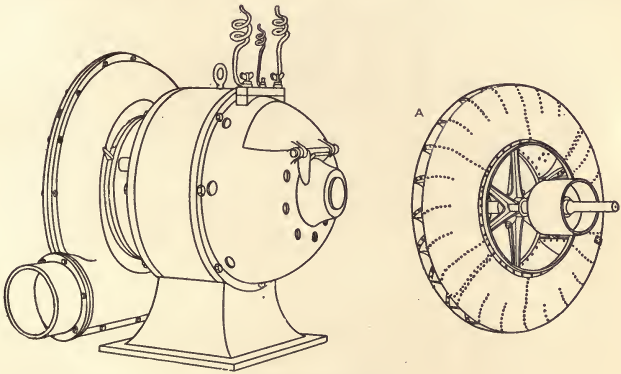


Fig. 99. Fan Blower.

platform. It should be at least large enough to store the stock for the first two charges of fuel and iron.

Blast for the cupola is furnished by either a fan blower or a pressure blower. Fig. 99 shows a modern fan blower, the blast wheel for the same being shown at A. The high speed of the blades forces the air by centrifugal action, away from the center of the shaft. The casing is so designed that the blades "cut off" as it were at the top of the main outlet, the air being thus forced through the blast pipe. The current of air is continually being drawn into the fan through the central opening around the shaft.

An idea of the speeds at which blowers should run may be obtained from the following data: An 18-inch blower, at a speed of 4,100 revolutions per minute, gives 5 ounces pressure; a 24-inch at

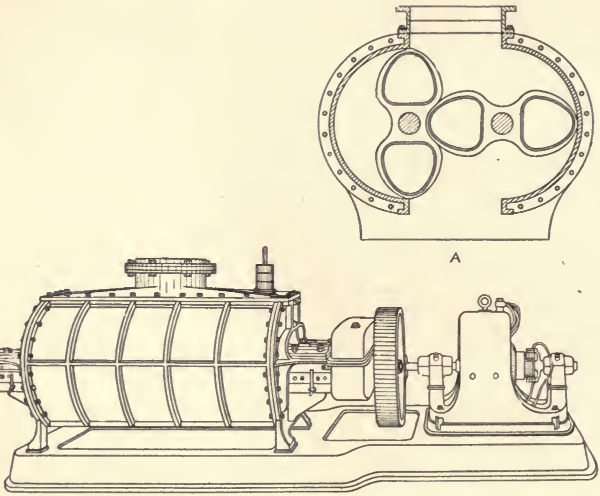


Fig. 100. Pressure Blower.

3,750 revolutions per minute gives 6 ounces pressure; a 36-inch, at 2,900 revolutions per minute gives 10 ounces pressure; a 48-inch, at 2,600 revolutions per minute gives 14 ounces pressure.

Since air is very elastic, and the pressure in this case depends entirely upon the centrifugal action of the blades, should the tuyères become clogged, the amount of air forced into the furnace will be reduced proportionately. On the other hand, it requires less power to operate the fan with reduced area of outlet than it does when the discharge is open free.

In the pressure blower shown in Fig. 100, the action is positive, as will be seen from the sectional view (A, Fig. 100). The wipers mesh into each other in such a way that they entrap a quantity of air and force it out of the opening.

The full quantity of air is therefore forced through the tuyères at all times. In such case the power necessary to operate the blower increases as the tuyères become choked and the excessive force of the blast due to choked tuyères is hard on the lining of the cupola.

The cupola should have a blast-gauge attached to the wind-box to measure the pressure of air which enters the tuyères. The pressure should be sufficient to force the air into the middle of the cupola to insure complete combustion. The unit of air-pressure is one ounce. From 8 to 16 ounces is approximately the range usual in cupolas of from 48 inches to 70 inches inside lining.

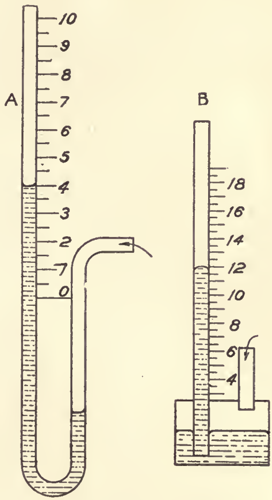


Fig. 101. Wind Gauges.

This pressure is measured by the displacement of water or mercury in a U-shaped tube. With both legs of the tube the same size as in Fig. 101, the graduations on leg A represent the pressure of double that height of liquid, as follows:

With *water:* 1.73 inches height = 1 oz. pressure; then graduations equal

$$\frac{1.735}{2} = .865 = \frac{55}{64} = \frac{7}{8}\text{ in.} - \frac{1}{64}\text{ in.}$$

With *mercury:* .127 inch height = 1 oz. pressure; then graduations equal

$$\frac{.127}{2} = .0635\text{ in.} = \frac{1}{16}\text{ in.}$$

As this would be too small for practical use, mercury gauges are made with increased area exposed to blast pressure (see B, Fig. 101) and are graduated accordingly. (Review chapter on Pressure in Molds.)

OPERATING THE CUPOLA

The following routine must be pursued each time a heat is run off in the cupola:

Clear away dump from former heat.

Chip out the inside of furnace with special hand-pick, removing the lumps of slag which collect about the lower part of the cupola walls, especially above the tuyères. Where the slag coating is comparatively smooth, do not touch it, as that is the best coating possible for the lining.

Daub up with a mixture of fire sand held together with about 1 to 4 fire clay, and wet with clay wash, to a consistency of thick mortar. Smear the surface to be repaired with clay wash; then, using the hands, plaster the daubing mixture into the broken spots in the lining, being careful to rub it in well, especially about the tuyères. The top of the tuyères should be kept slightly overhanging, for the reason already given.

The greater part of the daubing will be required from the bottom to level of melting zone, about 22 inches above tuyères.

Swing up bottom doors, and support by prop of gas pipe.

Build bottom; first cover doors with a 1-inch layer of gangway sand or fine cinders; then ram in burnt sand tempered about the same as for molds. This must be rammed evenly all over the bottom, and especially firm around the edges. Build the bottom higher at sides and back so that metal will flow toward spout. The pitch varies with size of cupola; 1 inch to the foot will answer for cupolas of 24 inches to 30 inches inside lining, while ½ that pitch will do for the larger furnaces.

The cupola bottom should be able to vent so that it will dry out quickly, and not cause the metal to "boil" before the furnace is tapped. It should be strong enough to hold its surface during the heat, but break and drop at once when the bottom is dropped. Too much pitch causes excess of pressure on the *bott,* making trouble in botting up; with too little pitch the metal will not drain well, causing a tendency to chill at the tap-hole. A little daubing mixture should be worked into the sand bottom just inside the tap-hole, to prevent breaking at this point when the tapping bar is forced through.

Lay the fire with shavings, just inside the breast; then fine kindling; then enough large kindling to make sure of lighting a layer of coke sufficient to form the bed. When the gases from the lower part of the bed burn up through, showing that the fuel is well lighted, *level up* bed with addition of a little more coke; and put on *first charge* of iron. Follow this with alternate charges of fuel and iron, to the level of charging door.

Form tap-hole; lay a bar of iron about $\frac{7}{8}$ inches round in the spout, projecting in through the breast opening; fill in breast around bar with a strong, loamy molding sand rammed hard. Recess this in well to leave actual tap-hole as short as possible.

Put on blast when ready for the metal, and leave tap-hole open. *Bott up* when the metal begins to run freely (generally about 7 minutes after blast is on). *Tap* when sufficient metal has collected to supply first ladles.

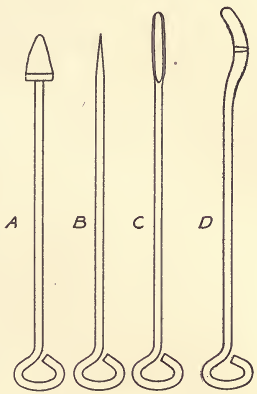


Fig. 102. Tapping Bars.

Bott clay should be mixed with about $\frac{1}{8}$ sawdust, to make it more fragile when tapping. This is made up in small balls, and shaped onto the end of the bott-stick (A, Fig. 102). The tapping bar B has simply a round taper point; C is a gouge or spoon-shape, useful for trimming sides of hole if bott does not entirely free itself when tapped.

When all the iron has been melted, *drop the bottom*, by pulling away the bar that supports the bottom doors. Throw water on the dump, by bucket or hose, to deaden the heat, and leave it to cool off over night.

FOUNDRY LADLES

As the melted metal flows from the spout of the cupola, it is caught in ladles. The sizes of these are designated by the weight of metal they will hold; they vary from 30 pounds' to 20 tons' capacity. The names of ladles relate to the method of carrying them. The accompanying table, containing references to accompanying cuts, gives compact data regarding foundry ladles;

TABLE

Data Regarding Foundry Ladles

Type of Ladle	How Managed	Capacity (pounds)	Size (inches) Top	Depth	Bott'm	Weight of Ladle
			Thickness for Lining			
Hand Ladle A, Fig. 103	Hand shank	30-50	7-8	7-8	6-7	15-16 lbs.
			¾	Side ½	½-¾	
Bull Ladle B and C, Fig. 103	Single or double shank	80-350	9-15	9-15	8-13	35-100
			1¼	½-⅝	¾-1	
Crane or Trolley Ladle Like C, with bail	Bail with single or double shank	300-2,000	14-26	14-26	12-23	115-350
			1¾	⅝-1	1-3	
Geared Crane Ladle Fig. 104	Worm gear on heavy bail	1,000-35,000	20-75	20-60	18-66	1,900-7,000
			2-4	1-4½	1½-5	

In the three columns under "Size," the larger figures give the dimensions inside of ladle shells. The smaller figures refer to the thickness of the lining at the top, sides, and bottom of the ladles.

Hand ladles are made of cast iron or pressed steel. The larger ladles are built up of boiler plate. Cast iron is poured from the top of the ladle, which should therefore be provided with lips. Ladles must be lined to protect them from burning through. Up to one ton capacity, the cupola daubing mixture is used. The bowl is smeared with thick clay wash, and the clay pressed in hard with the hands, being rubbed smooth on the inside. The lining should be kept as thin as possible, $\frac{5}{8}$ to $\frac{3}{4}$ inch on hand-ladles, 1 inch to $1\frac{1}{2}$ inches on large ones; the bottom lining from $\frac{1}{3}$ to $\frac{1}{2}$ thicker than sides, as it receives the first fall of the incoming metal.

The larger ladles are first lined with fire brick of thickness proportionate to their size, and then daubed on inside with clay mixture similar to cupola lining. The lining must be well dried before use, to drive out moisture. In stove-plate and hardware shops, where most of the pouring is done with hand ladles, a special ladle-drying stove similar to a shallow core oven is provided. A wood fire is built inside of the larger ladles to dry them out. To preserve a lining as long as possible, slight breaks are repaired daily. As with the cupola, the slag formed by the hot metal forms the best coating possible for inside lining.

POURING

The first thing to be considered here is skimming off the slag which collects on top of the metal. This should be done on larger ladles before leaving cupola, and again while metal is being poured. For this, a long iron rod is used, with blade shaped as in D, Fig. 102. This is rested across top of ladle near lip, and effectively holds the slag back; the long handle permits the skimmer to stand well back

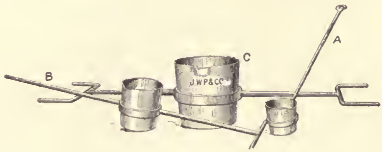


Fig. 103. Hand and Bull Ladles.

from the heat of the metal. On small ladles; skimmers are of course shorter, and the end is bent up more for convenience, as the ladles will be much nearer the floor when pouring with them.

Hand and bull ladles are shown in Fig. 103, while Fig. 104 shows a crane ladle.

Much skill is required in pouring a mold. A molder must

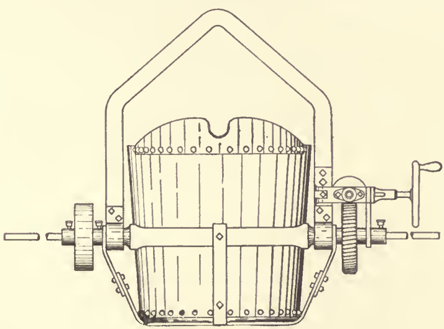


Fig. 104. Crane Ladle.

know the character of the work, and judge whether it must be poured fast or slow. In general, light work cannot be poured too fast. Heavier work is poured more slowly. Care must be exercised to keep the stream steady from the first, and not *spill* into the mold, as this may cause "cold shuts" or leave "shot" iron in the castings. The runner basin must be kept full, for gates and runners are made with this express purpose in view, as has been stated previously.

Metal must not be allowed to chill or "freeze" in the ladle, as this would destroy the lining when it came to removing the cold metal. Metal left in the ladles when the mold is full, must be poured back into a larger ladle or emptied into a convenient pig bed. These are built in a sand bed usually near the cupola, or stout cast-iron pig troughs or chills are provided. They should taper well on the inside, holding about 50 pounds each. Some are arranged to swing on trunnions for convenience in dumping. They should be smeared with a heavy oil and dusted with graphite, to prevent the metal sticking in them. It is safer to heat these pig molds as well, so that no moisture will form and cause a "kick" or explosion when hot metal is first poured into them.

CUPOLA MIXTURES

By this term is meant the proportioning of the various pig irons and scrap that make up cupola charges, with the object of obtaining definite physical and chemical properties in the resulting castings.

The requirements of castings vary; and metal that would be good if run into thin stove-plate, would be entirely too soft for heavy machine castings. Again, iron that might answer all requirements of a bed plate would not be strong and tough enough for steam cylinder work. The one in charge of this work, therefore, must so mix the different irons that his castings shall be soft enough to machine well if necessary, and at the same time be hard enough to stand the wear and tear of use.

Formerly the appearance of the fracture of a pig or scrap was the sole guide in determining mixtures. Unquestionably the fracture of iron indicates to the experienced eye much as to its physical properties. But this method of mixing has repeatedly proved misleading.

Representative practice to-day recognizes chemical analysis of the various irons as most essential to the proper mixing. Many firms now buy their pig iron, and many other allied supplies, by specification; and the chemical analysis of the iron must show that its various metalloids come within certain limited per cents.

To understand, then, these modern methods, we must consider the subject of the chemistry of iron.

CHEMISTRY OF IRON

An element, in chemistry, is a form of matter which cannot be decomposed, or, in other words, cannot be broken up into other forms by any means known to science.

Iron is such an element; but absolutely pure iron is of no commercial value; it is only when it is combined with impurities—or, as we must recognize them, other chemical elements—that mankind is interested in it.

In the forms of iron with which we are dealing, pig iron and cast iron, five elements are considered as affecting their physical properties. These elements are Carbon, Silicon, Sulphur, Phosphorus, and Manganese.

Carbon is the most important and most abundant of all the chemical elements. It forms the principal part of many substances in daily use about us, such as coal, coke, lead pencils, graphite facings, etc. In its relation to iron, it is peculiar in that it occurs in iron in two forms. One is in a chemical combination forming a hard substance with a fine grain, of which tool steel is the purest type. The other is simply a mechanical mixture forming minute facets of free carbon interposed between the crystals of the combined form. It softens cast iron, but weakens it by causing larger crystals to form. Drawing the finger across a freshly cut surface or fracture of cast iron, some of this free carbon will be rubbed off, and will show as dirt on the finger. We shall use the term *graphite* in referring to this form of free carbon, and the term *combined carbon* in referring to the element in its combined state.

Silicon of itself is a hardening element in cast iron, but on account of its marked influence upon carbon formations, it is usually considered a softener. During the cooling process, silicon retards the formation of combined carbon, thus increasing the formation of graphite in proportion to the increase of silicon. At the same time, through its own influence on iron, it preserves the fine character of the grain, and so maintains the strength of the casting. In other words, within certain limits, the addition of silicon softens castings without impairing their strength. It makes iron run more fluid, and reduces shrinkage. Silicon varies in castings from 1.50 to 2.50 per cent.

Sulphur is the most injurious element in iron. It makes castings hard, red-short, and tends to the formation of blow holes. At the melting temperature, iron will absorb sulphur from the fuel—a decided reason why foundry coke should be as free as possible from this element. Sulphur in castings should not exceed .07 per cent.

Phosphorus tends to make iron run very fluid when melted. It is a hardener. For machine castings it should not exceed 1 per cent.

Manganese strengthens, and of itself hardens iron. Chemists are beginning to consider its proportions more carefully, in the belief that under certain conditions it acts as does silicon, softening the castings while retaining their strength. It is usual to keep it below .5 per cent.

The strength of a casting and the finish which it is capable of taking, are largely dependent upon its having a fine, even grain. We have seen that the proportions between the combined carbon, the graphite, and the silicon have decided influence upon this condition. But the rate of cooling must also be taken into account. A thin casting cools rapidly, tends to increase the combined carbon, and without the influence of silicon would be hard and brittle. In a heavy casting, the metal stays liquid longer, more graphite is thrown off, and the casting is naturally softer.

Therefore light work requires a larger proportion of silicon to counteract the effect of the rapid cooling than does larger work.

Modern practice makes daily analysis for the two carbons, the silicon, and the sulphur, occasionally testing for the other elements to see that they are kept within their safe limits. Silicon, however, is used as the guide for regulating mixtures. The following shows good proportions of silicon for different classes of work:

Steam cylinders	1.70 per cent
Medium heavy work (½ inch to 2 inches thickness) . .	2.0 " "
Light work (less than ½ inch thickness)	2.50 " "

A more complete analysis of results to be aimed for is:

	Si.	P.	S.	Mn.
Automobile cylinders	2.25	1.	.075	.5 per cent
Corliss engine cylinders (1¼ to 1½ inches thickness)	1.20–1.70	Below .1	Below .095	" "

To calculate for any result, we must first know the analysis of the irons to be used in making the charge. We shall consider silicon as the guide.

With a firm keeping track of results, the proportion of silicon in their "home" scrap can be accurately estimated. With miscellaneous machinery scrap, this is more difficult. The following, however, are safe estimates:

Small, thin scrap	2 –2.4 per cent
Large scrap ranges	1.50–2 " "

The analysis of pig iron is made from drillings taken from a fresh fracture. Between the very fine grain about the chilled sides of the pig, and the very coarse grain in the center, average-sized crystals will be noticed in the fracture. It is here that the drillings for analysis should be made, as indicated in Fig. 105. About a ¾-inch flat drill is best to use, as it cuts a more uniform chip from the varying grade of pig than does a twist drill.

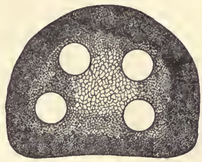


Fig. 105. Analysis Section.

To determine the analysis of a carload lot of pig iron, the following method is employed. Select ten pigs which will represent an average of the close, medium, and coarse-grained iron in the car. These pigs should be broken, and drillings taken from the fresh fracture. The drillings from these ten fractures are thoroughly mixed together, and about two ounces by weight, or a large tablespoonful by measure, is sufficient for the chemical analysis. The result is taken for the average analysis of the carload.

The smaller foundries who do not employ a chemist can get a good working analysis of their iron from the furnace from which it is bought. Or, in many cases, sample drillings are sent to a practicing chemist.

The proportions of silicon and sulphur contained in the ordinary grades of pig iron are approximately as follows:

GRADE	SILICON	SULPHUR
Ferro-silicon	7 –12 per cent	.03 per cent
Silvery	3 – 5 " "	.03 " "
No. 1 Foundry	2.50– 2.90 " "	.03 " "
No. 2 "	1.95– 2.40 " "	.04 " "
No. 3 "	1.40– 1.90 " "	.05 " "

When we have the analysis of our iron, we can proceed to calculate the mixture, bearing in mind that some of the silicon will be burned out of the iron during the heat. From .15 to .25 per cent is a fair estimate for this loss in cupolas ranging from 36 inches to 72 inches inside lining. This loss must be deducted from the final estimate.

It is proposed to make a mixture, using three of the following irons, for miscellaneous machinery castings which require about 2 per cent silicon. And we wish to use one-half scrap:

Silvery	4 per cent
No. 1 Foundry	2.65 " "
No. 2 "	2.22 " "
No. 3 "	1.75 " "
Scrap "	2.00 " "

The student should bear in mind that the sign of *per cent* means $\frac{1}{100}$ = .01. To multiply a whole number by per cent, set the point two places to the left; thus 35 per cent of 5,000 = .35 × 5,000 = 1,750.

To multiply per cent by per cent, set each point one place to the left before multiplying and the result may be expressed as per cent; thus 25 % of 35 % = 2.5 × 3.5 = 8.75 per cent.

Then we have:

A	B	C	D
No. 1	25. % ×	2.65 % =	.6625 %
No. 2	20. % ×	2.22 % =	.4440 %
No. 3	5. % ×	1.75 % =	.0875 %
Scrap	50. % ×	2.00 % =	1.0000 %

Total, 100. % of charge has 2.194 % Silicon content.
Deducting for loss in heat .20 %
1.994 % Estimated silicon in result.

Or, with a No. 2 iron and Silvery:

A	B	C	D
No. 2	45. % ×	2.22 % =	.999 %
Silvery	5. % ×	4.00 % =	.200 %
Scrap	50. % ×	2.00 % =	1.000 %

Total, 100. % of charge has 2.199 % Silicon content.
Deducting for loss in heat .17
2.029 % Estimated silicon in result.

In these examples, column A is the kind of iron; B, per cent of this iron used in charge: C, per cent of silicon in single grade of iron: D, per cent of silicon to whole charge as supplied by each grade.

One or more per cents in column B are usually decided upon before beginning calculations, and then the others are varied until the desired silicon content is obtained.

With this as a guide, it is a simple matter to find the actual weight for each grade, to make up any size of charge. For example, we wish to put 5,000 lbs. on bed and 3,000 lbs. on other charges, using first mixture:

From column B.		Bed.	Other charges.
No. 1	25 % × 5,000 =	1,250 lbs.	750 lbs.
No. 2	20 % × 5,000 =	1,000 "	600 "
No. 3	5 % × 5,000 =	250 "	150 "
Scrap	50 % × 5,000 =	2,500 "	1,500 "
		5,000 lbs.	3,000 lbs.

PRINCIPLES OF MELTING

Combustion cannot take place without oxygen, of which the air is the most abundant source of supply. For example, in the incandescent electric light, a strip of carbon is heated to a white heat; but it does not consume, or burn up, because all air has been exhausted from within the globe.

In the cupola furnace, both coal and coke are used as fuel. They consist largely of carbon, and, after being lighted by the kindlings, are kept at a glowing red heat by the natural draft through the open tuyères. The blast supplies the oxygen necessary for a melting heat. The quantity of air forced in by the blast cannot be entirely taken up by the layers of fuel immediately above the tuyères; thus complete combustion does not take place until a distance of 18 to 23 inches above the tuyères is reached. This is termed the *melting zone*. It is the aim of the melter to keep the top of his bed as nearly as possible at this level, so that the iron resting on it shall be exposed to this intense heat and melt rapidly.

As the fuel of the bed burns away, this level tends to be lowered. But the iron on top of it melts, and drops to the bottom of the cupola; and the subsequent charge of coke restores the level of the bed for the next charge of iron; and so on.

FUEL

Both anthracite coal and foundry coke are used in the cupola. Coal, owing to its density, will carry a heavier load than coke, but it requires greater blast pressure, and will not melt as fast as coke. Coke, for foundry use, should be what is known as "72-hour" coke, as free as possible from dust and cinders. Coke is made up of a sponge-like "coke" structure which is almost pure fixed carbon, and an open, "cellular" structure which makes it especially valuable as a furnace fuel because it is so readily penetrated by the blast.

A representative analysis of a strong 72-hour coke is as follows:

Moisture	.49 per cent
Volatile matter	1.31 " "
Fixed carbon	87.46 " "
Sulphur	.72 " "
Ash	10.02 " "
Cellular structure	50.04 per cent
Coke structure	49.96 " "
Specific gravity	1.89
Heat units per pound	12,937

FUEL TO IRON

The proportions of the bed fuel, first charge of iron, and subsequent charges of fuel and iron, vary greatly with the size and design of the cupola, the grade of fuel used, and the method of charging.

To determine the right amount of fuel for the bed, the most practical thing to do is to "cut and try," especially with a new equipment.

For a 36 to 48-inch cupola, average 22 inches above the tuyères, with a 10-ounce blast to start with, the best way to proceed is to chalk off this distance inside the cupola before daubing up. Then, from a ½-inch rod of iron, bend a shape like Fig. 106. The distance *a* equals the distance from the mark inside cupola to about 4 inches above bottom of charging door. When the coke is well lighted, before charging the iron, level off bed according to this gauge. The safe side is to have the bed too high. If the bed is too high, it will show by slow but hot metal; if too low, the metal will be dull. After first heat, the height may be adjusted until proper melting is obtained; then try always to work to same height. The weight and character of the coke charged on the bed should be carefully noted.

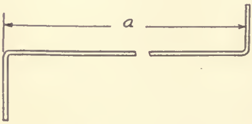


Fig. 106. Bed Gauge.

No fixed rule for general application can be given for proportioning the alternate charges of iron and fuel. From 4 to 6 pounds of iron may be melted to one of heavy coke on the bed; about ⅓ less, for light coke.

Intermediate charges of coke should be just sufficient to preserve the upper level of the bed. The layer will usually be about 6 inches thick. Its weight should be carefully taken.

Subsequent charges of iron may be made 8 or 10 pounds to one pound of coke put between charges.

The action of the furnace must be carefully watched, with the aim to make it melt the iron charged as rapidly as possible and bring it down white hot. Also, bring the ratio of iron to fuel as low as may be, without sacrificing either of these other objects.

SAND MIXING

When a mold is poured, the intense heat of the iron burns out those properties in the sand which give it its bond, making it necessary that a certain proportion of new sand shall be mixed with the heap sand and used as facing. See explanation in earlier paragraphs.

The facing sand should be mixed daily for the molders by one or more of the laborers, at a place convenient to the storage sheds and molding floors. A hard, smooth floor of clay or of iron plates is a great advantage.

The proportions of the different sands are measured by shovel, bucket, or barrowful, and spread over each other in flat layers, sufficient water being sprinkled on to temper the pile. The sand is then cut through once with the shovel, then put through a No. 2 sieve, all lumps being broken up and refuse thrown out. It is next put through a No. 4 sieve, and thrown in a pile ready for use.

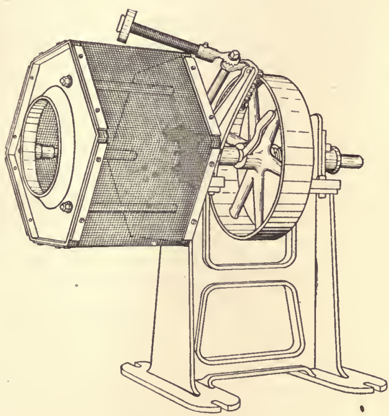


Fig. 107. Rotary Sieve.

When this work is done by hand, the ordinary screen sieve commonly employed by masons is used for the riddling, and a round foundry riddle for the final sifting. To reduce the labor of this, the riddle is slid back and forth on a pair of parallel bars supported conveniently above the storage pile.

There are two classes of labor-saving machines used in mixing facings, core sand, etc.—those which mix by riddling, and those which mix by a combined breaking and stirring action. There is great variety in the styles of these machines on the market. The illustrations show the typical mechanical devices in use.

Fig. 107 is made with wire on one or both ends, and is driven by belt or connected motor. Sand shoveled into the central opening is sifted in a pile on floor, or direct into barrow. The rubber hammer on top automatically raps each face of sieve as it revolves, knocking the meshes free from sand.

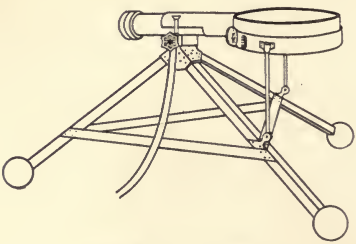


Fig. 108. Sand Shaker.

Fig. 108 shows one of the latest labor savers in this line. Here a foundry riddle is supported in a metal ring attached to the piston of the machine. It is made to vibrate rapidly by means of compressed air or steam. These shakers

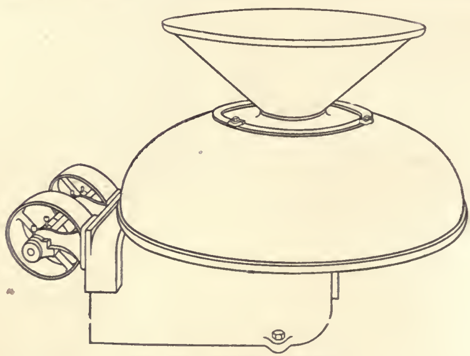


Fig. 109. Centrifugal Mixer.

are made with portable tripod, as shown; they are also made stationary or are fastened on a post by means of a swivel joint, to be swung over a wheelbarrow or over a molding machine, and out of the way again when not in use.

Fig. 109 shows a centrifugal mixer. Inside of the umbrella casing a horizontal plate about 12 inches in diameter and carrying a number of vertical steel pin about 6 inches long, is fastened to the top of a short upright shaft driven by a belt running inside of the casing shown at the base of the machine. The machine runs about 1,500 R. P. M.; and sand shoveled into the hopper is very evenly broken up by the pins and thrown against the steel hood, breaking and shattering any lumps of clay or loam and making a very uniform mixture. The hopper may easily be removed to clean the plate. The machine is used for the final mixing.

Fig. 110 shows a foundry grinder or facing mill. It is the type of mill used for mixing loam. Either the pan or the rollers are at-

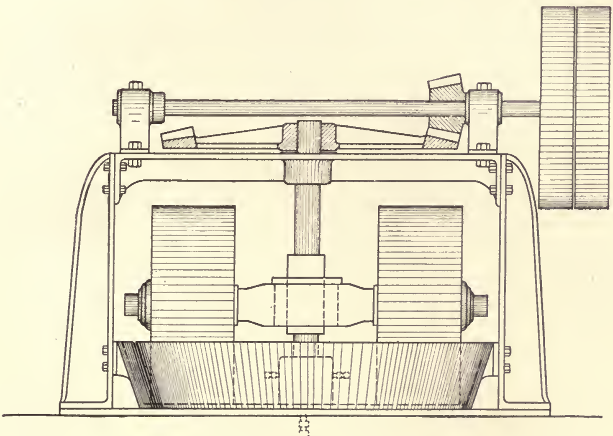


Fig. 110. Facing Grinder.

tached to the driving shaft and made to revolve, crushing and mixing whatever is shoveled into the pan. Frequently, a stout blade, something like a plowshare, is fixed between the rollers, and prevents the mixture caking to the bottom of the pan. The faces of the rolls are of very hard or of chilled cast iron to withstand wear.

When the loam mixture is sufficiently ground, it must be shoveled from the pan, and delivered to the molders or stored temporarily. It will "set" if stored too long.

This is the type of mill used in the steel foundries, for grinding the facing materials. The various sands are dumped into the pan at one side, and, when ground sufficiently, are shoveled directly from the pan into a centrifugal mixer. This prepares them for use.

CLEANING CASTINGS

After a casting has solidified in the mold, the flask should be removed, leaving the casting in the sand. For light bench work and snap flask work, the mold is lifted bodily and the sand dumped on the pile, the bottom boards piled in one place, and the cases piled in another ready for the next day's work. As the molds are dumped, the castings are removed from the sand and piled at edge of gangway. When all castings have been removed from the sand, the gates are broken and thrown in a pile by themselves. When cold enough to handle, the castings are removed to the cleaning room, and the gates and sprues to the scrap pile. With heavier floor work, the clamps are removed as soon as the casting has set; the flask is rapped with a sledge hammer and stripped off the mold, leaving the castings to cool gradually in the sand. Sometimes a sharp blow is given on top of the runner while it is still red; this breaks it off before the flask is shaken out. At a red heat, cast iron is very weak and can easily be broken.

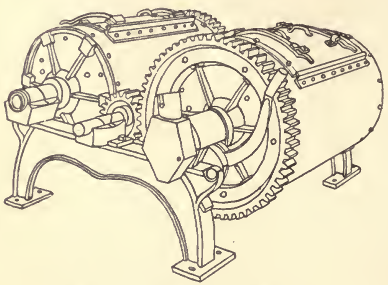


Fig. 111. Dustless Tumbling Barrel.

The most effective way to clean small castings is in a rattling barrel. Fig. 111 shows a modern set of dustless barrels. The shell of the barrel is $\frac{3}{8}$-inch boiler plate riveted to cast-iron heads, with a door arranged to be entirely removed for packing and dumping. The bearings are hollow, and from one end the dust is drawn off through a galvanized iron pipe. This pipe connects with an air-tight wooden chamber (Fig. 112) varying in size with the number of barrels connected with it. In this chamber hang a number of cloth-covered screens. An exhaust fan is connected to this chamber at the opposite end from the inlet pipe.

When the fan is in operation, a strong current of air is drawn through the barrels and through the chamber. The dust, entering the chamber, settles on the screens, so that but little dust escapes to the outside air.

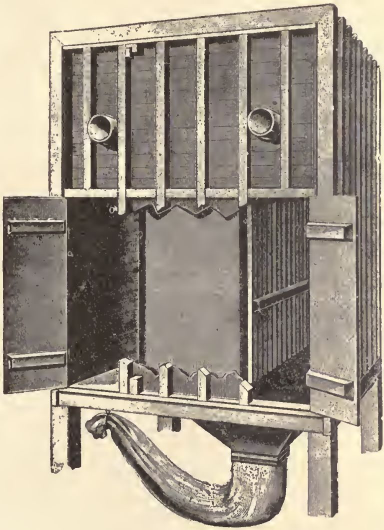


Fig. 112. Dust Collector for Tumbling Barrel.

When necessary, the exhaust is stopped, and, by means of a crank on the outside of the dust chamber, the screens are shaken and the dust drops off, when it can be removed through a trap into an ash can or wheelbarrow.

The driving shaft carrying the pinion revolves all the time, and any barrel may be thrown over into gear or drawn out of gear by the operation of a hand lever. The barrels should run about 25 R. P. M. Each barrel should be packed as full as possible with several shovelfuls of gates, shot iron, or hardened stars thrown in with the castings. The cleaning is accomplished in from twenty minutes to half an hour by the scouring action of castings, scrape, etc., rubbing against one another. Castings up to 50 or 100 pounds can be rattled but only those of a similar character as to design or weight should be packed in together; otherwise the lighter castings will be broken by the heavier. When removed from the barrel, the work should show a smooth, clean surface of an even gray color.

From the rattlers, castings go to the grinding room, where projecting gates or other slight roughness is removed on the emery wheel.

Heavy castings are cleaned by hand, by pickling, or by sand blast.

When cleaning by hand, the worst of the sand is rapped off by light hammering, the remainder scraped off with old files and steel wire brushes (Fig. 113, A). Some shops rub off finally with broken pieces of coarse emery wheel. Risers and fins are removed with cold chisels. The pneumatic chisel shown in Fig. 113, B, is used as a time-saver. Where work is light enough to handle, small fins are removed by emery wheels; medium coarse wheels will cut faster on cast iron than fine ones, and will hold their shape better.

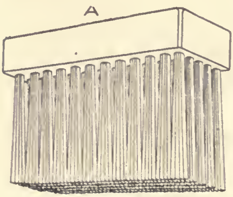


Fig. 113 A. Steel Bristle Brush.

It is when castings must be cleaned by hand, that value of a good facing dust shows itself. With the proper facing, the sand cleaves readily from the casting, leaving a fine-looking, smooth surface. With poor facings, on the other hand, the iron burns into the sand, making it hard to clean, and leaves a rough surface on the work.

Fig. 113 B. Pneumatic Chisel

Pickling is a method of cleaning resorted to where there is much machining to be done on a casting. The work is placed in a pile on a suitable platform, and dilute sulphuric acid is thrown over it during one day, frequently enough to keep it well wet. The platform should be arranged to drain the acid back into the vat. Acid is diluted from 1 to 8, to 1 to 10. After about 12 hours' bath with acid, the castings are washed clean with hot water. The acid acts on the hard skin of

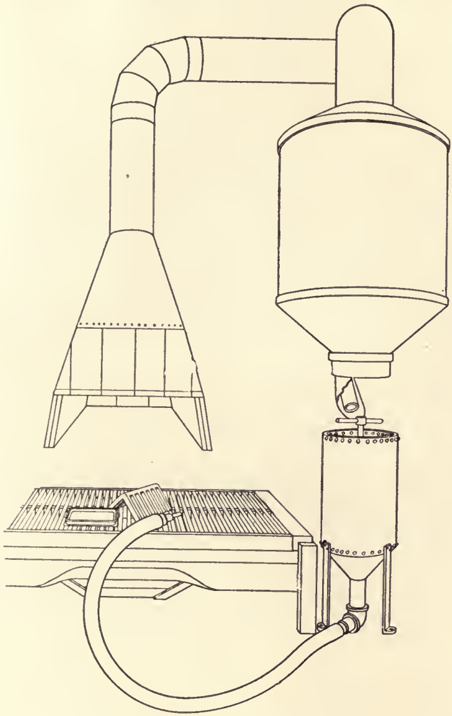


Fig. 114. Sand Blast.

oxide of iron, which forms when the iron strikes the damp sand, and eats through this skin to the iron itself.

The washing water should be hot enough to warm the castings sufficiently for them to dry rapidly without rusting. The acid must be thoroughly washed off, or it will continue to eat into the iron and cause a white powder (sulphate of iron) to form on the surface.

An excellent arrangement for a pickling department is to have the "trough" arranged on skids which will allow it to be rocked endwise. This will drain into the pickle vat when acid is being thrown on, and drain to the gutter when the castings are being washed. Sheet lead is the best protective covering for small pickle troughs, but it is expensive and not durable enough to stand for heavy work.

For castings of such shape and size that they cannot well be rattled, but are too small to be cleaned by hand, the sand blast has been used to advantage in many shops.

Fig. 114 gives an idea of the arrangement of the cleaning stall. Castings are placed on the wooden grating. By means of compressed air, a sharp silica sand is forced through a strong rubber hose and directed against the castings. The nozzle is of hardened steel. The operator wears a helmet supplied with fresh air by an air-hose, to protect his eyes and lungs from the clouds of fine dust. An exhaust hood is arranged also to take off as much of the dust as possible.

The manual labor of this method is practically reduced to noth-

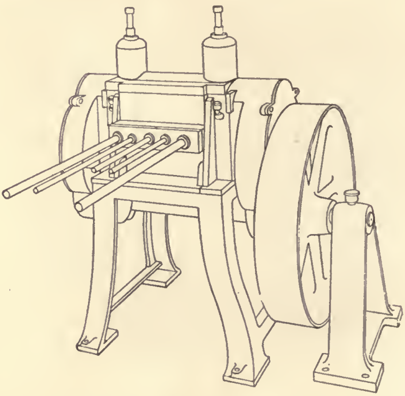


Fig. 115. Core Rod Straighteners.

ing, aside from handling the castings. The system, however, requires the installation of a rather considerable equipment, which has debarred its use in many foundries.

In removing cores, the bars become very much bent. In such shape they were formerly scraped or refitted to suit new cores, with a hammer and block of iron. Fig. 115 shows a very practical power machine which delivers the bars perfectly straight. The machine consists of a pair of rolls, with different sizes of grooves turned in them, which pull a rod through a flaring mouthpiece and deliver it through a corresponding eye on the opposite side. The machines are made in different sizes, and will take rods from $\frac{1}{4}$-inch to $\frac{3}{4}$-inch diameter.

STEEL CASTINGS

This class of work has developed within the last few years, and, beginning with the heavier parts of marine and engine construction, is now crowding the field of drop forgings.

Steel castings are malleable, and are very much stronger than iron ones.

The principles of molding involved are similar to those in other classes of molding, but practice is varied to meet special conditions.

The art of making steel castings may be divided into three heads: (1) Preparation and melting of the metal; (2) Making and pouring the molds; (3) Heat treatment of finished castings. As the first and third heads come more properly under other departments, we shall here simply outline these processes, dealing in detail with the second heading only.

This branch of foundry work has developed to a great extent since the early nineties. The metal is similar in mixture, method of melting, and physical properties to that which is poured into ingot molds for forging purposes. The graphitic carbon is entirely burned out; the strength of the metal is therefore very much greater than that of cast iron. Combined carbon, manganese, and silicon are the elements depended upon for this strength. Sulphur and phosphorus are kept very low. A typical analysis shows:

C.	Mn.	Si.	S.	P.
0.27%	0.85%	0.35%	0.020%	0.025%

Owing to the purity of this form of iron, about 50 per cent more heat is required to melt it than is necessary in the case of pig iron—or about 3,300° F. When melted, the metal runs much more sluggish than cast iron; and, on account of the absence of graphitic carbon, it does not expand at the moment of solidifying, and therefore will not take as sharp an impression.

To insure as perfect an impression as possible, the molds are constructed with a good head of metal in risers, and they are poured under pressure. The shrinkage is double that of iron; the risers are made very large, and are placed directly on the casting to insure feeding well. Great care must be exercised that neither mold faces nor cores bind during cooling, as such binding might cause a flaw.

When two surfaces meet at right angles, the corner will remain hot longest, and the sides will shrink away, tending to cause a fracture at *a*, Fig. 116. To overcome this, thin webs are cut by the molder about every 4 inches or 6 inches—shown at *b*. These cool first, and hold the adjacent sides in position, preventing them from pulling away from each other. The internal strain due to this cooling is relieved by the annealing. After the casting is annealed, the webs are cut away.

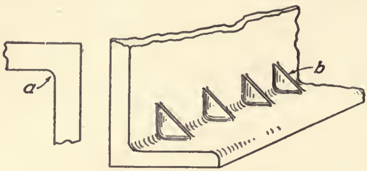


Fig. 116. Shrinkage Webbs.

STEEL FACING MIXTURES

To withstand the high heat, pure silica sand is used as the basis of the facing mixtures for steel molds. Pure quartz or silica rock is quarried, and reduced to a sand form through a series of rock crushers.

At the foundry the necessary bond is given by the addition of fire clay and molasses water. These are thoroughly mixed with the sand in a facing mill and mixer (Figs. 109 and 110). A typical mixture is as follows:

1 barrow Silica Sand;
3 pails powdered Fire Clay;
Temper with molasses water.

Where quartz sand is very expensive, the mixtures made as follows will reduce the cost. The old crucibles and fire brick should be crushed separately in the mill before mixing.

Ingredients	For Castings up to 2 ins. Thick.		For Castings over 2 ins. Thick.	
	I	II	III	IV
Old facing sand	8 parts	12 parts	1 part	
Old crucibles	2 "		10 parts	
Fire Brick	2 "		5 "	
Fire clay	2 "	1 part	3 "	1 part
Coke	1 part		1 part	
Silica sand		5 parts		5 parts
Graphite		2 "		

Temper with molasses water.

For *facing wash*, these mixtures are ground very fine, and thinned with molasses water.

Core sand for steel work is practically the same mixture as the mold facing. For thin metal a somewhat less refractory natural sand may be added to reduce cost of mixture.

For *small round or flat cores*, $\frac{1}{20}$ part rosin, with silica sand, tempered with molasses water, makes a good core. It should, however, be thoroughly burnt.

For *core wash* mixture, use 3 parts Silica flour; 1 part Ceylon graphite; molasses water.

STEEL FLASKS

Flasks for steel work are built up of cast iron (see Fig. 4). Full-length crossbars are bolted in the cope, 6 inches to 8 inches on centers, depending on size of flask. Short crossbars are fastened between these as needed, say 12 inches to 16 inches on centers (see Fig. 117).

Oblong bolt holes 4 inches on centers are cast in the sides of the flask and in all crossbars. Slots to correspond are cast in flanges of bars, so that they may be readily removed or shifted when fitting cope to pattern.

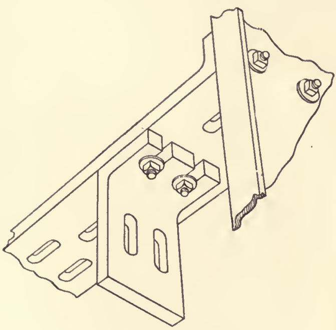


Fig. 117. Short Crossbar.

The holes for pins should be drilled to template in all flasks of the same size, so that copes and drags may be interchanged. Flask pins are slipped through holes temporarily when flask is being closed or opened. On large work the cope is bolted to drag while being rammed.

The bottom plate is of cast iron, and is clamped to flange of drag with short clamps and steel wedges.

Flasks of from 18 inches to 48 inches in length have two handles bolted on ends to lift them with. Larger flasks have trunnions, rockers, or U-shaped handles cast on the sides.

For details of cast-iron flask, see Fig. 4.

Fig. 118 shows type of convenient small flask built up of channel and angle iron, size 14 by 20 to 24 by 48 inches. The same tools are

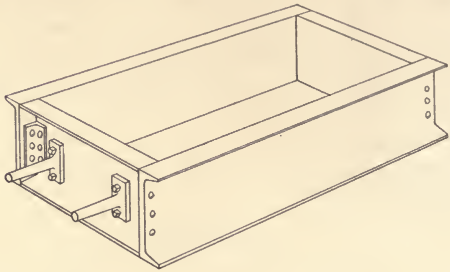


Fig. 118. Small Flask for Steel Molds.

used for packing and finishing mold as described in connection with iron molding.

PACKING THE MOLD

In packing the mold, place the pattern on board and cover with $1\frac{1}{2}$ to 3-inch of facing, depending on size of job. Tuck well with fingers. The facing is used as prepared by the mixer, not sifted. Set drag on board, shovel in heap sand, and ram mold somewhat harder than for iron. "Strike off" and seat bottom plate, fastening it firmly to flange of drag with clamps or bolts. Roll the mold over, and remove mold board

Press with the fingers all over the joint surface, especially around the pattern, to make sure of firm packing.

If soft places are found, they should be tucked in with facing sand.

When needed repairs are made, slick the joint all over. Use burnt core sand for making the parting. Try on cope and adjust bars to fit pattern. Clay wash the cope before packing. Put on necessary facing over joint and pattern. Set the gate on joint, but place risers directly on pattern. Set necessary gaggers, shovel in heap sand, and ram the cope. Vent well, lift cope, moisten edges, and draw pattern.

In finishing the mold, nails are used freely (about $1\frac{1}{2}$ to 2 inches apart), driven in with heads flush with surface of sand. This is to prevent the cutting of the surface by the rush of hot metal when mold is poured.

It is at this stage that the thin webs previously mentioned, are cut into the corner fillets where needed. The whole surface of the mold must be smoothly slicked over with trowel and convenient slicks.

When this is done, paint on the facing wash with a very flexible long-bristled brush. Fig, 119 shows section of mold for a shrouded

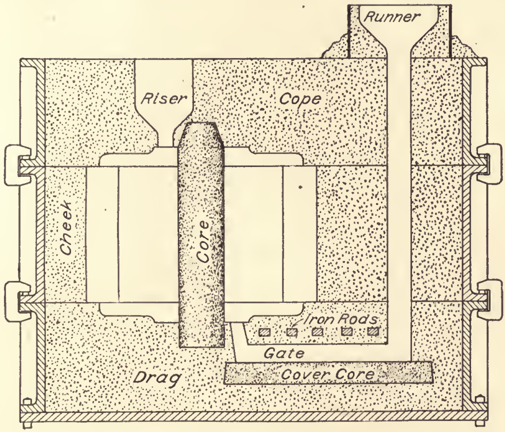


Fig. 119. Section Through Steel Mold.

pinion, and illustrates points above mentioned. The runner is lead in at the bottom by use of a cover core, as described in dry-sand molding.

Molds for steel should be more than dried; they should be thoroughly baked, to drive off every particle of moisture. This prevents the steel boiling in the mold and causing imperfections in the casting.

Where but little machine work is to be done on small work up to 1¼ inches thick, the molds may be made up in wooden flasks and poured green. For this class of work, only pure quartz sand and fire clay are used, tempered with molasses water. These may be made up and poured on the same day.

STEEL CORES

Where cores must be made in halves, one set of half-cores may be made and baked. The other half is then made and rolled over directly on the baked half. Fire clay wash is used to cement the joint. This method allows the joint between halves of core to be nicely slicked down.

Cores for steel molds are made up in boxes similar to those used in the iron foundry. Although using special sands, the cores are strengthened with iron rods, vented with cinders, and provided with convenient hangers for lifting, as described in previous paragraphs.

Steel cores must be more collapsible than those for iron, on account of the excessive shrinkage of the metal. This is provided for in the mixture of the sand used, and by thoroughly backing the core to reduce the effect of the binding materials to a minimum.

MELTING

The melting of steel is a science by itself, and cannot be dealt with adequately in a paper of this character. Only a very brief description of the process will be given.

The main feature is the difference in application of heat. Metal is melted in what is termed the *Open Hearth* furnace, a sectional plan

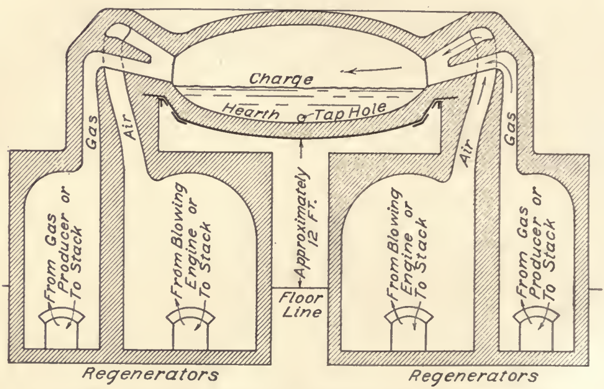


Fig. 120. Section Through Open Hearth Furnace with Regenerators.

of which is shown in Fig. 120. The charge of *scrap steel* and pig iron is placed on the central hearth. Heat is obtained by producer gas supplied with air-blast. Both gas and air are heated in one set of regenerators before entering the combustion chamber. The flame plays on top of the charge, and the waste gases pass off through the other regenerator section of the furnace, heating up its brickwork. The direction of the gases is changed about every twenty minutes. The regenerator is practically a tunnel about 15 feet long, filled with brickwork built up as shown in Fig. 121. About 4 heats a day are run from the furnaces.

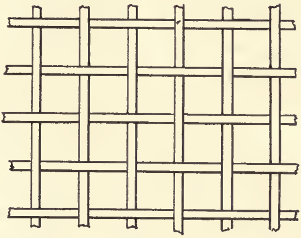


Fig. 121. How Brick is Set in Regenerator.

Samples of the bath are analyzed at intervals during the heat. Guided by these analyses the proper proportions of ores, fluxes, and pig are added to the bath to give it the right composition, a typical analysis of which has been given.

DRAWING THE HEAT

When the bath is in proper condition, the entire charge, be it 5 tons or 40 tons, is drawn off into a ladle previously heated by a special gas-burner. This ladle is lifted by the crane and carried to the pouring floor.

In order to secure the soundest metal free from pent gases or slag, all steel for casting purposes is tapped from the bottom of the ladle. The stopper is carried by a stiff round bar encased in fireclay tubing. This passes through the liquid metal (see Fig. 122), and may be raised or lowered by an arm attached to a rack-and-pinion mechanism bolted to the outer shell of the ladle and operated by means of a large hand wheel. The ladle is swung into position with tap-hole directly over pouring head. Four men hold the ladle steady with long iron rods. The metal thus enters the mold under the head of pressure of all the steel above it in the ladle.

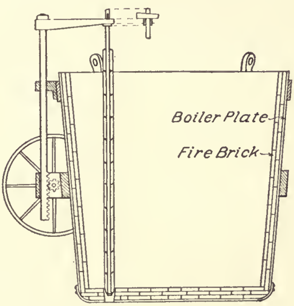


Fig. 122. Section Through Steel Ladle.

When all steel is drawn from ladle, the latter is swung on its side near furnaces, the stopper is removed, and all slag possible is racked out. The ladles must be repaired after each heat, often to the extent of replacing one-half of the thin fire-brick lining.

The casing of the stopper will last for but one heat, as the rod is sure to get bent out of shape. The rods are repaired by a blacksmith before recasing them.

SETTING UP STEEL MOLDS

This is usually done by a different set of men from those employed to make the molds.

For convenience in pouring, runner boxes (Fig. 123) are rammed up in small, round, sheet-metal boxes, using a wooden pattern to form the hole. These are baked in the oven.

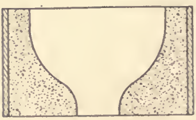


Fig. 123. Runner Box for Steel Mold.

When the molds are properly dried, they should be removed from the oven, placed on the pouring floor, and have the dust blown out with compressed air.

Now set the cores, close the mold, and clamp along joint flange. Set runner box over runner, and tuck heap sand around to prevent leakage.

This box serves simply as a funnel-shaped mouth to the runner. In pouring, the mold is filled only to the level of top of risers. The metal drains from the runner box, thus allowing it to be used more than once.

CLEANING STEEL CASTINGS

Steel castings do not run as smooth as cast-iron ones, but they have this advantage: If they show only slight surface defects, the metal may be peened over with a hammer to improve appearance.

The intense heat makes the metal burn into the sand greatly, so that cleaning is much more difficult. The sand often must be almost cut from the castings by means of long cold chisels, struck with sledges. Pneumatic hammers are used to a large extent in cleaning and in removing fins and slight projections. Where shrinkage webs will show, they must be cut out. Steel will not break off as does cast iron. The heavy gates and risers must be removed by metal saws (see Fig. 124) or by drilling a number of 1-inch holes side by side through the base of the riser and then breaking it off. The castings are generally annealed before the risers are cut off.

ANNEALING

In all steel castings of any size, cooling strains will develop on account of the shrinkage. These should be relieved by annealing. In suitable trench-like ovens, the steel is heated to a dull redness.

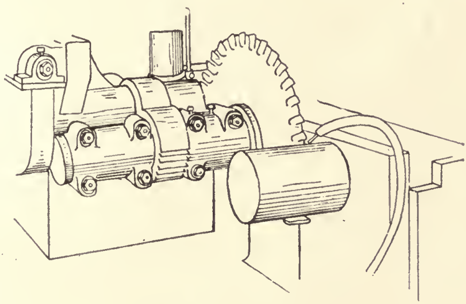


Fig. 124. Cutting off Riser.

This allows the grain to assume normal conditions. The heating is usually done with a wood fire. Overheating renders the grain coarse, and weakens the casting. Proper heat treatment materially increases strength and toughness, as indicated by the following figures:

Tensile Strength		Elongation	Reduction of Area
Raw	80,360	13.31%	16.2%
Annealed	81,767	27.6 %	40.4%
Improperly annealed	79,421	14.3 %	17.8%

This shows that the work which is properly annealed is not only actually stronger, but is tougher and will stand more hard usage.

BRASS WORK

Cast iron and steel, which we have previously considered, are two forms of the same metal—iron. The difference in their physical characteristics is due solely to a variation in the proportions of certain elements or metaloids combined with the iron.

The metals to be dealt with in this section are termed *Alloys*—that is, mixtures of two or more separate metals.

The common alloys in use in the foundry for casting various machine parts are made from combinations of Copper, Tin, and Zinc, and are called *Brass* or *Bronze.*

Although the term Brass is held by some authorities to cover any of these combinations, the general classification accepts *Brass* as an alloy of *Copper* and *Zinc,* and *Bronze* as an alloy of *Copper* and *Tin.* In some sections the latter is spoken of as *Composition.*

Bronze has been used by man in all ages. Centuries before the Christian Era the Egyptians employed it for making coin, armor, and weapons, as well as household utensils, and statuettes of their gods. Analyses of many of these ancient relics show the composition to be almost identical with the bronzes of the present day. Brass also was in use before the time of Christ, but unquestionably bronze was of earlier origin.

A short discussion of the separate metals will help in understanding the properties of their alloys.

Copper has a red color; it is hard, ductile and very tough. It melts at about 2000° F., but it is difficult to make castings of the pure metal. Copper does not rust as does iron, and is one of the best conductors of heat and electricity. For this reason it is largely used in sheet form as a sheathing metal, and in the form of wire or rods, for electrical transmission. *Casting Copper* is put on the market in ingots of special form weighing from 18 to 25 pounds each.

Tin is a white lustrous metal, very malleable, but lacking tenacity. It may be reduced extremely thin by rolling, as is shown by tin foil. It melts at 450° F. When a bar of tin is bent it will give a crackling sound known as the "cry", which at once distinguishes it from other metals such as solder, lead, etc., which have similar external appearance. It is put on the market in pigs weighing about 30 pounds and also in bars of about 1 pound each. Its cost is approximately fifty per cent more than copper and five times as much as zinc. Tin may be cast unalloyed, and is sometimes used to run pattern letters or small duplicate patterns cast in zinc chill molds. The addition of one third to one half by weight of lead gives a cheaper metal, however, and one that will run equally well.

Tin mixed with copper gives greater fluidity, lower melting point, and greater strength, changing the color from red to bright yellow. Serviceable alloys may contain as high as 20 per cent tin. This gives a metal of golden yellow color, very hard, tough, and difficult to work.

With larger percentages of tin the color shades to gray, the metal is hard, brittle, and has little strength, and has no value for engineering purposes.

Zinc has a bluish white color; it is hard, but weak and brittle. The fracture shows very large crystals of characteristic shape. It melts at about 700° F., and shrinks but little in cooling. For this reason it may be used to cast directly for small metal patterns to form chills from which soft metal castings may be made for duplicating these patterns. If exposed to the air at high temperatures, zinc will "volatilize," that is, turn to a gas and burn. It burns with a bluish flame, and throws off clouds of dense white smoke. For this reason great care must be used to keep the air away from it as much as possible when being melted or mixed in an alloy, for aside from the loss of metal, an oxide is formed in the mixture which impairs the quality of the alloy.

Zinc is known in commerce under two names. When rolled into sheets it is called *Zinc*; when in ingot form for casting, it is called *Spelter*. These ingots are flat, approximately 8 x 17 x 1 inch thick, and weigh about 30 pounds. In this form they may be easily broken in small pieces for convenience in charging.

Zinc may be added to Copper in a very wide range of proportions, the alloy increasing in hardness and losing ductility with the increase in the proportion of zinc. The color changes from the red of the copper to a full yellow when one third zinc is used. Further additions of zinc change the color to red, yellow, violet, and gray. The alloys are serviceable up to 40 or 50 percent of zinc.

When Zinc is mixed with melted metal, considerable reaction or boiling takes place. This tends to make a more thorough mixture and to drive impurities to the surface. For this reason a small proportion, 2 to 3 per cent of zinc, is often stirred into bronze mixtures after the pot is drawn.

Lead has a bluish white color, and considerable lustre when freshly cut. It is malleable, soft and tough, but very weak. It melts at about 600° F.

Lead is not used by itself as an alloy with copper. A very small proportion may be added to the standard mixture for brass or bronze. It will cause them to run more fluid in pouring, and be softer for machining. For this reason lead is added to bearing mixtures to advantage. But it tends to deaden the color and reduce the conductivity of the metal for electrical purposes.

Proportion of Mixtures. The figures in the following table are given in percentages on one side for convenience in comparison and for figuring large heats. The beginner, however, will generally melt but one or two pigs of copper at one time. These he will weigh first and then figure the other portions of his mixture from this weight. In this case a formula given in pounds and ounces is much simpler.

Percentages				USE	Lbs.	Ozs.		
Copper	Tin	Zinc	Lead		Copper	Tin	Zinc	Lead
83.	12.	2.5	2.5	Gun metal for bearings. A very tough hard mixture.	1	2½	½	½
85	7.	5.	3.	Steam or Valve metal. Cuts freely, very tough, resists corrosion.	1	1¼	¾	½
90	5.	5.		Composition. For general use on small machine parts.	1	1	½	
90	6.	3.	1.	Bronze for Art work. Rich color, runs fluid at comparatively low heat.	1	1	½	¼
66.5	33.5			Common Yellow Brass. Good for general run of machine castings.	1		8	
66.	33.		1.	Same as above. Will machine a little easier.	1		8	½
1.80	64.70	33.35	1.	Anti Friction metal. For journal boxes.	1/18	32	16	½
	66.		34.	Good mixture for small patterns. Runs well, shrinks little.		2		1

From what has been said it will be understood that it is possible to vary these mixtures to meet special conditions. To harden or toughen an alloy increase the tin; to soften it reduce the tin. The same is true with zinc, but it will require larger proportionate changes in this metal to effect similar results in the alloy.

Phosphorus is not a metal, but is a very active chemical element manufactured from bone-ash. It has such an affinity for the oxygen of the air, that in its pure state it must be kept under water, because the slightest scratch would cause it to burn fiercely. It forms the principal substance used in making the heads of matches.

As a rule it is never used in the foundry in its pure state. For the production of *Phosphor Bronze* castings there are several combined forms of phosphorus on the market. The most convenient of these is known as *Phosphor Tin.* This is metallic tin carrying various fixed percentages of phosphorus of which 5 per cent is one very common proportion. Knowing the amount of phosphorus carried by the tin, the exact proportion for the entire alloy may be readily calculated.

This element should not be used in alloys containing zinc or lead.

It acts as a flux, combining with any oxidized or burned impurities in the bath of metal and driving them to the top. It tends to make the tin crystalline in form, in which condition it unites more firmly with the copper. It apparently unites chemically with copper, making that metal harder. The proportion of phosphorus should not exceed .75 per cent, while .25 to .40 per cent are safer proportions.

Two typical mixtures, using 5 per cent phosphor tin, are as follows:

PHOSPHOR BRONZE MIXTURES

For a Tough Alloy	For a Hard Alloy		For a Tough Alloy	For a Hard Alloy
90. %	87.50 %	Copper	9 lbs.	$8\frac{3}{4}$ lbs.
9.75	12.25	Tin	$\frac{1}{2}$ lb.	$\frac{3}{4}$ lb.
.25	.25	Phosphorus		
		Phosphor Tin	$\frac{1}{2}$ lb.	$\frac{1}{2}$ lb.
100.	100.	Totals	10 lbs.	10 lbs.

MATERIALS

Natural molding sands are used for brass-work. They are usually finer than sands used in iron-work, because brass parts are generally small and often have fine detail which must be brought out very sharp in the mold. For this reason also the sands should have more alumina or bond than iron sands.

This increase of bond is possible because the metals entering the mold are not as hot as iron, therefore do not require as much vent, but they have a greater tendency to "cut" the mold.

For the general run of work the whole heap is kept in good condition by the frequent addition of new sand, but on large work a facing mixture is used similar to the Iron Foundry.

Burnt sand, powdered charcoal and partimol are all good *parting materials.* The last two are best on small work, as they make a cleaner joint. They are not blown off of the patterns, because they make a good facing for the mold.

The brass molder uses practically the same kinds of tools, such as shovels, sieves, rammers, and molder's tools generally, as already described.

Snap Flasks may be used, but the pins, hinges and catches must be kept in careful adjustment so that the parts of the mold shall register

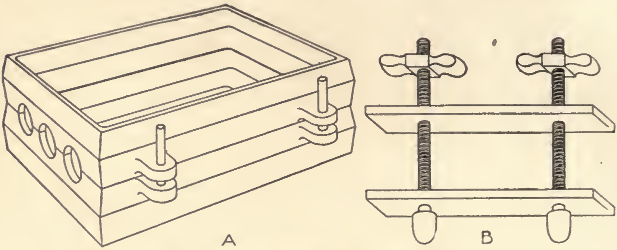


Fig. 125. (A) Flask for Brass.—(B) Screw Clamp.

perfectly. The same is true of the larger box flasks for floor work.

The most typical *brass flasks* are of cast iron with accurately fitting round steel pins. See Fig. 125 A. They have holes on the joint at one end of the flask so that the mold may be set upright when pouring.

This gives a decided additional pouring pressure with a minimum thickness of sand over the castings.

Boards without cleats support the sand in the flask and the whole

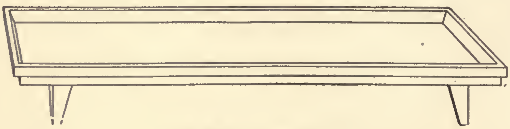


Fig. 126. Spill Trough.

is clamped before setting on end by means of some form of double screw clamp similar to the illustration, Fig. 125, B.

Great care is taken in the brass shop to save all shot and spilled metal possible. To this end, when the molds are to be poured on end they are leaned against a cast iron *Spill trough* shown in Fig. 126. There should be a 1-inch layer of sand over the bottom of this tray. The crucible is held over it when pouring the molds, thus making it possible to conveniently catch any metal that is spilled.

For thin work the face of the molds are *skin dried* to drive off the moisture before the metal enters the mold. *Drying stoves* similar to Fig. 127, are used for this purpose. When the mold is finished the two halves are carefully sprayed with a weak molasses water, and the

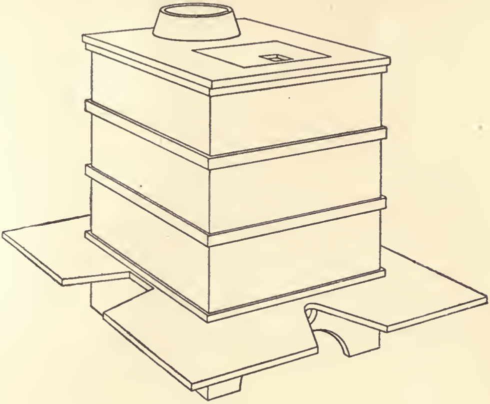


Fig. 127. Drying Stove.

flask is set on end on the wide platform with the face of the mold next the stove. When sufficiently dry the mold is closed and poured at once.

PRINCIPLES OF THE WORK

Brass work deals as a rule with smaller quantities in every way than does iron work. The patterns are generally smaller and the brass molder takes particular pride in making all his joints so neat that hardly a fin will show on his castings. The matter of catching the shot metal has been mentioned. Up to the introduction of the oil-melting furnace it was customary to heat a pot of metal for each molder. These heats were comparatively small, so that he would make up possibly six or eight molds, then draw his pot and pour them; running in this way several heats in a day.

Using the furnace, several heats are run each day, but a much larger quantity of metal is melted at each heat, so that the work of several molders is poured with exactly the same metal.

A mold for brass should be rammed about the same as for iron. On name plates and thin work, after the initial facing of sifted sand has been properly tucked with the fingers, the flask is filled heaping full of sand. Then by the aid of a rope hanging down from the ceiling, the molder springs up on top and packs the mold with his feet, the weight of his body giving the right degree of firmness to the sand. Stove-plate molders often pack their flasks in the same way.

The main difference between making up molds for brass and those for iron are due to three causes: Brass melts at a lower heat; it does not run as fluid as iron; it has about double the shrinkage of iron.

For these reasons the sand may be somewhat less porous and still vent sufficiently, if risers are placed to allow for the escape of the air. On bench work the vent wire is not used.

The runners for brass should be larger than for iron, and the gates, instead of being broad and shallow, should be more semicircular in section. Pouring molds on end gives the pressure necessary to force a more sluggish metal to take a sharp impression, and the heavy runners shown in the following examples serve to feed the casting as it shrinks.

Forms of skimming gates, as explained in an early section, are used to advantage on work of a very particular nature.

EXAMPLES OF WORK

To illustrate more clearly some of the typical methods of brass work, let our first example be a thin flat plate with decoration in low relief on one side.

Place the pattern face down, a little below the center of flask. Sift on facing through a No. 16 sieve, then tuck, fill and pack as previously described. Roll over and make a joint. Now cut a half section of the main runners and risers, but do not connect them with the mold at this stage. Dust on parting material from a bag, and ram the other half of flask just hard enough to stand handling. Separate flask; spray face of mold with weak molasses water, and dust on it from a bag some finely powdered pumice stone, or any fine strong sand, and over this a little parting dust. Now replace this half over the pattern and re-ram to the required firmness and again separate and this time draw the pattern.

The impression of the runners and risers cut in the first half of the mold will show as ridges on the second half packed, and serve as guides for cutting the runners to a full round section. Connect the gates in four places, as shown in Fig. 128 A. Skin dry the mold and it will be ready to close and pour.

Dusting fine sand on the face of the mold then reprinting, as it is termed, ensures a very smooth, perfect mold face. Where the mold

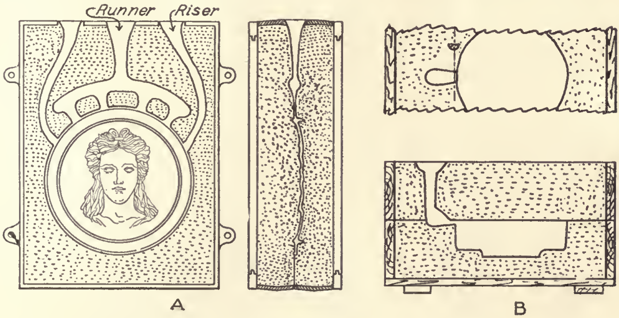


Fig. 128. (A) Mold for Thin Plate.—(B) Mold for Heavy Plate.

is not skin dried, *flour* is dusted over the face, allowed to stand for a short time, and then blown off. This makes a good facing.

Cutting the heavy runner over the top of the thin plate ensures a sufficient supply of clean hot metal to the gates under pressure enough to force the metal into every detail of the mold before it has time to chill.

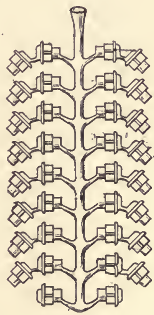


Fig. 129. Duplicate Gated Work.

B, Fig. 128, shows the difference in construction of gate when a heavier piece is cast with the flask setting horizontally. The gate proper is cut in the drag, but a good feeding head is cut out of the cope side to keep the metal in the riser liquid until the casting has solidified.

For duplicating work the sand match, oil match, or follow board are used, the same as for iron work.

Fig. 129 shows a typical set of castings run from the end and made from gated patterns set in an oil match. Steady pins are placed on the gates to facilitate a clean lift.

Cores for brass work are made up as previously described. To give a smoother surface on the small cores about one third molding sand is often mixed in with the beach sand of the stock mixture.

CLEANING

When the castings are taken from the sand they should be rapped smartly to free all loose sand, then, if machining is to be done on them, they should be plunged, while hot, into water. This softens the castings. This method is used also to *blow out* cores from small work.

A Sprue Cutter, shown in Fig. 130, is part of the equipment of a brass foundry. These machines are made to operate by foot as shown or by power. With them the castings are cut neatly and quickly from the runners.

Brass does not burn into the sand as much as iron, therefore, in many shops, the small castings are brushed clean before being cut from the gates, by means of a *circular scratch brush* mounted on a spindle similar to a polishing wheel.

A good method of cleaning brass and bronze is by *pickling*. Make a mixture of 2 parts common nitric acid and 1 part sulphuric acid, in a stone jar. Place the piece to be cleaned in a stone *dipping basket*, Fig. 131, and dip once into the acid, then wash off in clean water and dry in sawdust.

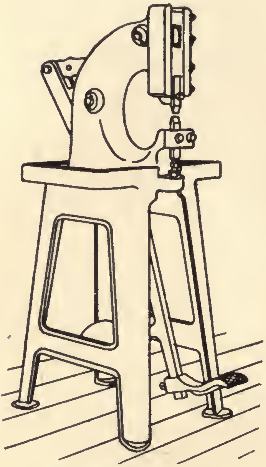


Fig. 130. Sprue Cutter.

Fig. 131. Dipping Basket.

In many cases brass chips and filings will be turned back to the foundry to be remelted. The smallest portions of steel or iron in these would prevent their being used in this way, as they make extremely hard spots in the castings.

Fig. 132 shows a *magnetic separator* which effectively removes all steel and iron chips. The brass chips and sweepings from the machine shop are placed in the hopper of this machine. They are caused to be spread out on one side of a slowly revolving brass covered drum, A. Inside of this brass shell are strong magnets which hold the steel and iron chips to the surface while the brass chips drop off into a tote box. A stiff brush at the back of the cylinder removes the iron chips and they drop into a separate box.

MELTING

All alloy metals burn if exposed to the air while melting, and especially zinc and tin. To prevent this burning the brass melter

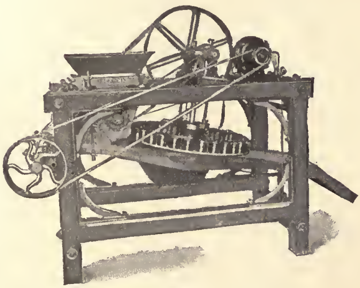


Fig. 132. Magnetic Separator.

endeavors to control the draft in his furnace so that all oxygen entering the gates will combine with the fuel, so that gases which may reach the metal shall contain no free oxygen.

For this reason the ordinary brass furnace is a natural-draft furnace, although a forced draft is often connected below the grates to make combustion independent of atmospheric conditions.

The metal does not come in direct contact with the fuel, but is contained in fire-clay pots called crucibles, which are bedded in the fire. Hard coal or coke is used for fuel.

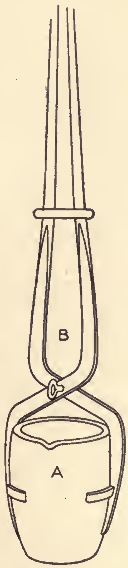


Fig. 133. (A) Crucible. (B) Tongs.

These *crucibles*, Fig. 133, A, are manufactured from a very refractory fire-clay mixture and are strong and tough even at a high temperature. They are lifted in and out of the furnace by the tongs shown at B, Fig. 133. For the larger sizes a crane is used for hoisting the pot.

Crucibles are made in a great variety of sizes, as they are used in many different metal industries, from that of the jeweler to that of the steel manufacturer. They are classed by number, the following table gives data regarding a few sizes.

SIZES OF CRUCIBLES

Nos.	Holding Capacity Liquid Measure			Height Outside	Diameter at Top Outside	Diameter at Bilge Outside	Diameter at Bottom Outside	Capacity in Weight of Water
	Gal.	Qt.	Pt.	Inches	Inches	Inches	Inches	Pounds
0				2	1½	1⅝	1¼	
0000				3	2⅜	2½	1¾	
6		1		6½	5¼	5⅛	3¾	2.08
12		2		8	6¼	6¾	5	4.16
30	1	1	1	11	8⅝	9¼	6½	11.5
60	3			14	10⅜	11⅝	8	25.
90	4			15⅞	11½	12½	9	33.3
300	12	2		22	16¼	17½	12½	104.

The melting capacity of any of these sizes may be obtained by multiplying the figure given in the column "Weight of Water" by the specific gravity of metal to be used.

New crucibles should always be *annealed* before using, that is, brought very slowly to a low red heat. This drives out any moisture absorbed from the air since coming from the kiln in which they were baked. Disregard of this generally results in a cracked crucible.

Natural Draft Furnaces are usually called brass furnaces, and may be bought on the market made up in single complete units.

Fig. 134 illustrates one of a battery of several furnaces connecting with a common flue. The top is on a level with the molding floor. The sketch shows clearly the principles of construction. A cast iron bottom, plate A, with a circular opening, carries a shell of boiler plate lined with fire brick. The diameter of the inside lining should be 6 inches larger than the crucible to be used. A top plate, with a similar opening, binds the whole together. On one side, below the top, an opening, B, which may be formed by a cast iron box, connects with the flue or stack. Two heavy ribs, cast on the bottom plate, rest on a pair of rails as shown, and these rails are supported by suitable piers of brickwork, about two feet high, so that ashes may be conveniently removed when the furnace is dumped. In the space between the bottom plate and rails, made by the ribs, the grate bars, C, are set. These bars are loose and may be pulled out when it is desired to dump the fire for the day.

Operation. In running off a heat a bed of freshly lighted fuel about 8 inches deep is made over the grate bars. The crucible, packed

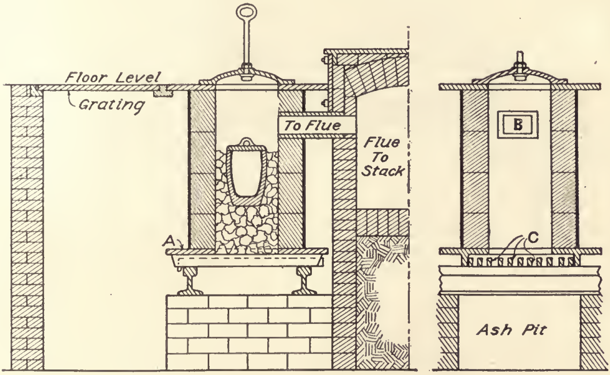


Fig. 134. Natural Draft Furnace.

as full as possible with the charge, is lowered in and the space around it filled with fuel. The crucible should be kept covered, especially for brass. In melting brass, melt down the copper first, then the scrap. When this is melted, charge the zinc and stir well before lifting the pot. Allow the mixture to come to the proper heat again, then pull the pot, skim off the dross, and stir in the lead if any is called for, just before pouring.

In bronze the same method is pursued, but both the tin and zinc are stirred in after the pot is drawn.

In mixing in the zinc in brass, care must be taken to plunge it well under the surface of the copper with long handled pick-up tongs, and to hold the piece down with the stirring bar until it has melted.

Where a large casting requires more metal than can be melted in a single crucible, several furnaces must be used and the contents of their various crucibles assembled into one large pouring ladle just before pouring.

Gas or Oil Furnace. With the development of natural gas and crude oil burners for commercial heating, several good furnaces have been designed in which a large quantity of metal can be melted at one time.

Fig. 135 shows a furnace of this character in section. This type

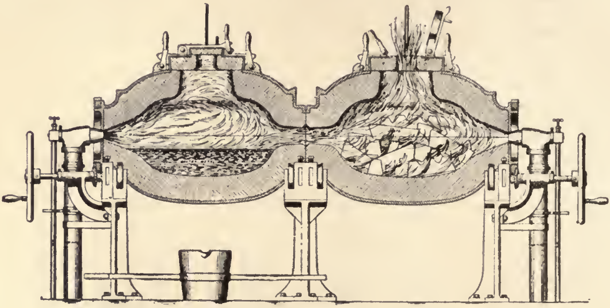


Fig. 135. Section Through Oil Furnace.

has tandem melting chambers with burners at the end, which may be used separately or both together. The waste gases from the bath of liquid metal are used to heat up a fresh charge in the other chamber.

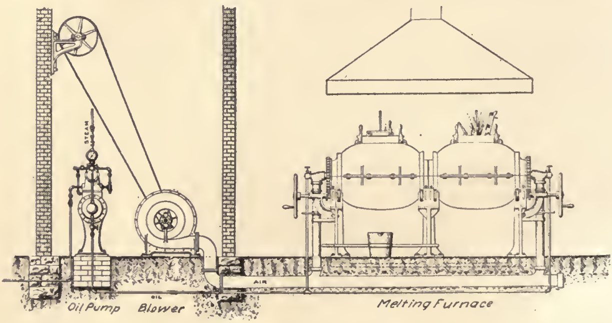


Fig. 136. Oil Furnace—General Elevation.

The metal is charged and poured from the openings at the top of the furnace. Each chamber may be revolved separately, to empty the furnace when the charge is melted. Fig. 136 shows the general arrangement of the oil feed pump, and blower for these melting furnaces.

The flame plays directly on to the metal. The oil pressure should remain constant at about 5 pounds per square inch. But the air pressure is regulated to vary the intensity of the heat as desired.

The pouring ladle must be well heated before using. This is done with a special gas burner, or when crucibles are used, they are often heated by means of a small fire in an ordinary furnace.

Different sizes of furnaces are built to melt from 250 to 2000 pounds of metal at a heat. Twelve or fourteen heats a day can be run. The saving is approximately 50 per cent in time and is also very considerable in expense, over ordinary crucible furnaces of equal capacity.

SHOP MANAGEMENT

The success of a foundry depends upon the ability of its managers to promptly turn out castings which will meet the requirements demanded of them, at the lowest possible cost commensurate with the

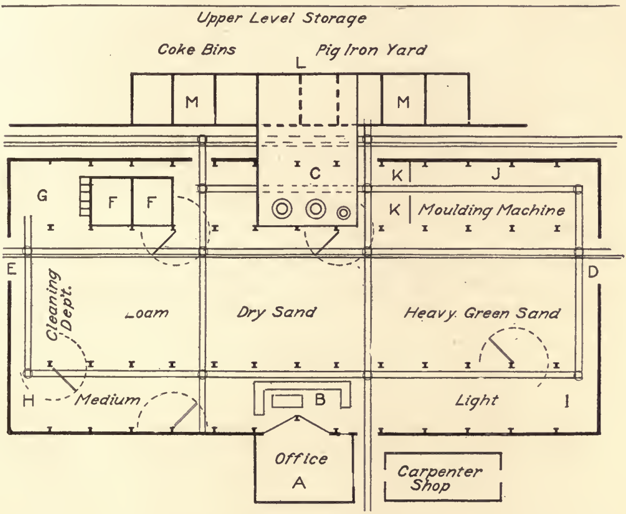


Fig. 137. Typical Plan of Foundry.

quality of the work. In this chapter we wish to direct the attention of students to some features in the way of equipment and management which aid in accomplishing these results.

The most important processes in the foundry are melting metal, making molds, and pouring them. Much of the work necessary in preparing for these processes consists of handling heavy materials such as coke, iron, sand, etc. To reduce this handling to its lowest limits, as to distances, number of re-handlings, and methods of conveyance, are problems to be considered in the plan of the shop as a whole.

To briefly illustrate some of the points to be brought out, let us consider the plan of a shop shown in Fig. 137, and its sectional elevation shown in Fig. 138.

The building is of steel construction and the columns supporting the roof trusses serve also to carry the tracks for the overhead traveling cranes.

The outer walls should be filled in with some good weather-re-

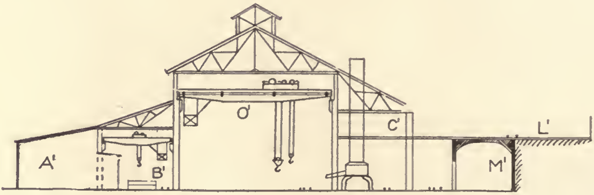


Fig. 138. Typical Elevation of Foundry.

sisting material of which there is nothing better than brick. These walls should be of good height and have a sufficient window area to supply light well in toward the middle of the shop.

The method of heating and ventilation best adapted for a foundry is the indirect fan system. One or more large fans situated generally toward the ends of the shop, draw fresh air in through a compact system of steam coils, and by means of overhead piping deliver it to all portions of the shop. The impure gases are carried off through ventilators in the clear story at the top of the roof.

The floor of the foundry should consist of molding sand, the depth of the sand floor varying with the class of work to be done. If the natural soil of the grounds is open and porous, a thickness of 3 or 4 inches of clay well rolled down should be put in underneath the sand floor. This will help greatly in keeping the molding floor in good condition, as it prevents the moisture draining out of the sand.

The foundry office should be located at such a point that the foreman can command a view of the whole shop. It should be convenient to the different departments and at the same time be protected as far as possible from dust. The office room, shown in Fig. 137 at A, is built on the outside of the main building, but has a large bay window which projects a few feet into the shop from which all corners of the foundry can be seen.

A space B having suitable low tables and shelving, is reserved near the office for the temporary storing of patterns in daily use. This brings them directly under the attention of the foreman and his assistants who can readily check the patterns as they come in and quickly find those requiring prompt attention.

At C is shown the cupolas, directly opposite the foreman's office, and so situated that all of the molding floors may be served as quickly as possible without interfering one with the other.

In large foundries there are two or more cupolas, to admit of different mixtures being melted simultaneously. Often a comparatively small cupola is installed near the floor for light work for the service of that floor alone.

The blowers should be placed near the cupolas avoiding long connecting wind pipes. The application of electric motors removes the necessity of concentrating the power at one point in the shop.

The main bay of the foundry is devoted to the heaviest work and is served by at least two overhead cranes.

The heavy green sand castings are made at one end so that the flasks for this work may be stored in yards near by and be brought in through the door D. These molds are made up furthest from the cleaning shed because only the castings themselves need be transferred there.

The flasks and rigging for the dry sand and loam molds should be brought in through the opposite door, E. The loam work as a rule is the most bulky to handle and should be nearest the cleaning sheds so that it need not be carried across the other floors. Both dry sand and loam floors are convenient to the large ovens, F.

The core shop is situated in the side bay at G, to make it convenient to swing the large cores on to the buggies to be run into the large ovens. A jib crane near the corner of these ovens makes the men working on such cores independent of the traveling crane. The ovens for small cores are built along the side of the large ovens and utilize the same stoke hole, ash-pit and stack.

Distributed through the side bays also are the medium work floor H the light work floor I and the molding machine floor J. This ensures a supply of good light necessary to the smaller details of this class of work.

The molding machines are placed on that side of the shop near the sand storage sheds, to allow for handling the sand by means of belt

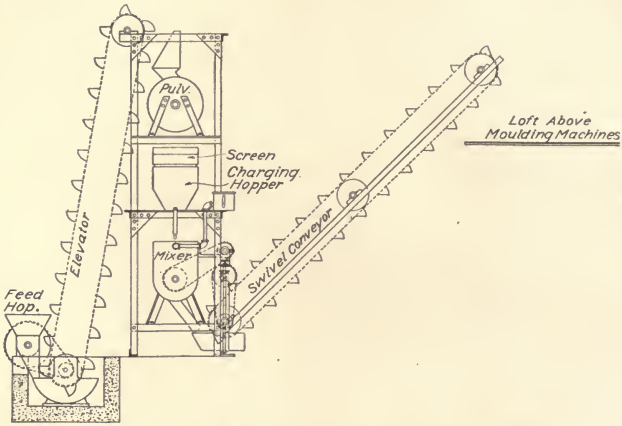


Fig. 139. Automatic Sand Mixer.

conveyors, with hoppers above the machines, an illustration of which is shown in Fig. 139.

The sand-mixing space is in the side bay near the cupolas at K, and is furnished with power from independent motors or from a jack shaft leading from the blower room. This position affords direct access to the sand bins. The raw material after being mixed and tempered is delivered by barrow or sand car direct to the various floors. The mixers might be installed in one of the storage vaults across the roadway.

The quickest means of unloading either wagon or carload lots of material is by dumping, where the material can be so handled. One of two things is necessary to accomplish this: either the storage bins must be placed in a basement underneath the roadbed, or the roadway must be run up an incline over the top of the bins. The former method is more frequently met with in the crowded condition of the large cities, but the latter is preferable because less time is consumed in running material up an incline in large quantities than will be required to hoist small quantities more frequently from a basement.

At L and L′, Figs. 137-138, is shown the storage yards for pig iron and coke; these are on a level with the charging platform of the cupola C C′, and can be loaded on cars and pushed directly to the charging door. In some modern shops these push cars are built so that their load may be dumped as a whole into the cupola.

The storage for core oven fuel, sands and clay, is shown at M M, in bins built underneath the tracks and on a level with the foundry

Fig. 140. Overhead Track and Trolley.

floor. These bins should be arranged to open on top with a shute under the track and a trap at the side so that coal or sand may either be dumped or shoveled directly into them.

In the largest shops a standard gauge track should run directly through the main foundry, also similar tracks through the roadway next the cupola bay, for convenience in removing the dump. The track over the storage bins has been mentioned.

Two methods of transferring material between departments within the shop, aside from the cranes, are the overhead trolley system, Fig.

140, and the narrow gauge industrial railway. The former is of advantage in manufacturing plants where the loads to be transferred are nearly uniform in weight and frequency of handling. This system leaves gangways smooth and free from obstructions. For general work, however, the industrial railways are more frequently installed. These serve all floors to deliver flasks, sand, or iron, and to remove castings.

Of the many styles of overhead traveling cranes that are on the market those using electricity as the motive power are undoubtedly the most serviceable. The cranes in the main foundry indicated at O′, Fig. 138, should have two hoisting drums on the carriage; one for such light work as handling flasks, rigging and patterns, the other for the heavy work on the large ladles and castings.

Small jib cranes furnished with a 2- to 4-ton air or electric hoist placed on the side of a man's floor make it possible for the molder and helper to handle work of considerable size by themselves, and prevent loss of time waiting on the overhead crane.

The method of distributing the melted metal varies with the class of work made. In shops doing general jobbing work, the ladles for pouring the largest work are carried from the cupola direct by the overhead cranes.

For serving the floors in the bays one of the systems mentioned above is generally used. The metal is conveyed to the floor in a large ladle and from this smaller ones are filled and carried by hand or by a small crane to the molds.

The cleaning department should be situated at one end of the shop near E, Fig. 137, or in a shed extension to the foundry proper. It requires space to pile the castings as they are brought from the floors with sufficient room for the men to begin work on these piles. As a rule the smaller castings are first collected and put through the tumbling barrels, then the medium work is cleaned by hand or sand blast; this leaves room for work around the largest pieces. As soon as castings are cleaned they are weighed and shipped to the customer, store house, or to the department which does the next operation upon them.

DIVISION OF LABOR

The division of labor in a foundry is briefly as follows:

The superintendent is responsible for the operation of the foundry as a whole. He hires the men and oversees the purchase of materials and supplies, having under him clerks who keep track of the details of this work. Some of the things to which he gives personal attention are:

In consultation with his foreman he gives personal attention to the receipt of the most important patterns; decides how they shall be molded; on what floor and what mixture shall be used to pour them. He devises ways and means of increasing the productiveness of his shop.

The foreman or his assistants must be in the shop a sufficient time before work begins for the day to see that each molder has work laid out for him, and must keep the men supplied with work through the day. He estimates the amount of the charge for the day and directs the melter as to mixtures.

It is the duty of the foreman and his assistants to give directions to the apprentice boys and to see that these directions are carried out to the best of the boys' ability.

The molders should give their entire time to making up molds. On floor work they are usually given a helper who totes flasks, cores, chaplets, etc., and does the heavier work when handling the sand. When the molds are poured and his flasks stripped off the molder is through for the day.

Most modern shops employ a night gang of laborers to put the shop in proper shape for the molders to start their special work immediately when the whistle blows in the morning. These men remove the castings from the sand and transfer them to the cleaning shed. They pick out all bars and gaggers used in the molds and stow them in place. They temper and cut the sand and dig any pits necessary for bedding in work.

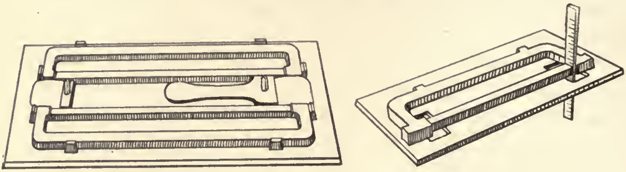
CHECKING RESULTS

The methods of mixing iron by analysis have been dealt with in an earlier chapter, but these mixtures must be checked by physical tests on the resulting castings.

Two systems are now in more or less general use throughout the United States.

Mr. W. J. Keep, of Detroit, Michigan, who has had long experience in this subject, has invented a very complete system of regulating mixtures which he terms "Mechanical Analysis." Fig. 141 A shows a follow board arranged with patterns and yokes. The test bars are ½ inch square and 12 inches long. They are cast in green sand with their ends chilled against the faces of the cast iron yokes, shown in the cut. Three molds should be cast each heat, and the test bars allowed to cool in the molds.

Mechanical Analysis is based on the fact that silicon is the most



A B

Fig. 141. (A) Keep's Test-Bar Pattern.—(B) Measuring Shrinkage.

important variable chemical element in cast iron, and that shrinkage in castings is directly proportionate to the silicon in the mixture.

The first test is to replace each bar in the same yoke in which it was cast and by means of a specially graduated taper scale ascertain accurately the amount of shrinkage. See Fig. 141, B.

The shrinkage of the bars when the castings prove satisfactory should be considered the standard for that class of work for that shop. If at any time the shrinkage is greater than the standard, increase the silicon by using more soft pig; if it is less, decrease silicon by using more scrap or cheaper iron.

The depth of chill on the castings is measured after chipping off a piece from the end of the bar.

The third test is to obtain the transverse strength of each bar. This is done on a special testing machine which gives a graphical record of the deflection and ultimate breaking load. These dead loads will vary with different mixtures approximately from 340 to 500 pounds.

Quoting from Mr. Keep's circular:

"With high shrinkage and high strength of a ½-inch square test bar, heavy castings will be strong but small castings may be brittle.

"With low shrinkage and high strength large castings will be weak and small castings will be strong.

"With uniform shrinkage an increase in the strength of a ½-inch square test bar will increase the strength of all castings proportionately."

The other form of tests was devised by a committee of the American Foundrymen's Association, and is recommended in the Proposed Standard Specifications for Gray Iron Castings by the American Society for Testing Materials. A partial summary of these specifications is as follows:

"Unless furnace iron is specified, all gray castings are understood to be made by the cupola process.

"Light castings are those having any section less than ½ inch.

"Heavy castings have no section less than 2 inches.

"Medium castings are those not included in the above."

The test bar is 1¼ inches in diameter and 15 inches long, and is known as the "Arbitration Bar." The tensile test is not recommended but if called for a special threaded test piece is turned down from the "Arbitration Bar," and has a test section .8 inch in diameter and 1 inch between shoulders.

The transverse test is made with supports 12 inches apart.

Fig. 142 shows a sketch of the patterns for these bars. Two bars are rammed in a flask and poured on end. The small prints on the two bar patterns project into the cope and are connected by one pouring basin. A special green sand mixture is specified for making these molds; the molds are to be baked before pouring, and the bars allowed to remain in the sand until cold.

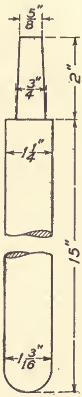


Fig. 142. Pattern for Arbitration Bar.

The following table shows the specified requirements:

TESTS ON "ARBITRATION BAR"

Grade of Castings	Chemical Properties	Physical Properties	
	Sulphur Content Not Over	Transverse Test* Minimum Breaking Strength	Tensile Strength Not Less Than
Light castings	0.08 per cent	2500 lbs.	18,000 lbs. per sq. in.
Medium castings	0.10 per cent	2900 lbs.	21,000 lbs. per sq. in.
Heavy castings	0.12 per cent	3300 lbs.	24,000 lbs. per sq in

*In no case shall the deflection be under .10 of an inch.

RULES AND TABLES

MENSURATION

Circumference of a circle	= diameter × 3.1416
Area of a square or rectangle	= base side × height
Area of a triangle	= base × perpendicular height
Area of a circle	= diameter squared × .7854
Convex surface of a cylinder	= circumference × height
Convex surface of a sphere	= circumference × diameter
Contents of a rectangular solid	= area of base × height
Contents of a cylinder	= area of base circle × height
Contents of a sphere	= cube of diameter × .5623
One side of square having same area as given circle	= diameter × .8862 or circumference × .2821

AREAS OF CIRCLES AND THEIR CIRCUMFERENCES

Diameter	Area	Circumference	Diameter	Area	Circumference	Diameter	Area	Circumference	Diameter	Area	Circumference
⅛	0.0123	.3926	10	78.54	31.41	30	706.86	94.24	65	3318.3	204.2
¼	0.0491	.7854	½	86.59	32.98	31	754.76	97.38	66	3421.2	207.3
⅜	0.1104	1.178	11	95.03	34.55	32	804.24	100.5	67	3525.6	210.4
½	0.1963	1.570	½	103.86	36.12	33	855.30	103.6	68	3631.6	213.6
⅝	0.3067	1.963	12	113.09	37.69	34	907.92	106.8	69	3739.2	216.7
¾	0.4417	2.356	½	122.71	39.27	35	962.11	109.9	70	3848.4	219.9
⅞	0.6013	2.748	13	132.73	40.85	36	1017.8	113.0	71	3959.2	223.0
1	0.7854	3.141	½	143.13	42.41	37	1075.2	116.2	72	4071.5	226.1
⅛	0.9940	3.534	14	153.93	43.98	38	1134.1	119.3	73	4185.3	229.3
¼	1.227	3.927	½	165.13	45.55	39	1194.5	122.5	74	4300.8	232.4
⅜	1.484	4.319	15	176.71	47.12	40	1256.6	125.6	75	4417.8	235.6
½	1.767	4.713	½	188.69	48.69	41	1320.2	128.8	76	4536.4	238.7
⅝	2.078	5.105	16	201.06	50.26	42	1385.4	131.9	77	4656.0	241.9
¾	2.405	5.497	½	213.82	51.83	43	1452.2	135.0	78	4778.3	245.0
⅞	2.761	5.890	17	226.98	53.40	44	1520.5	138.2	79	4901.6	248.1
2	3.141	6.283	½	240.52	54.97	45	1590.4	141.3	80	5026.5	251.3
¼	3.976	7.068	18	254.46	56.54	46	1661.9	144.5	81	5153.0	254.4
½	4.908	7.854	½	268.80	58.11	47	1734.9	147.6	82	5281.0	257.6
¾	5.939	8.639	19	283.52	59.69	48	1809.5	150.7	83	5410.6	260.7
3	7.068	9.424	½	298.64	61.26	49	1885.7	153.9	84	5541.7	263.8
¼	8.295	10.21	20	314.16	62.83	50	1963.5	157.0	85	5674.5	267.0
½	9.621	10.99	½	330.06	64.40	51	2042.8	160.2	86	5808.8	270.1
¾	11.044	11.78	21	346.36	65.97	52	2123.7	163.3	87	5944.6	273.3
4	12.566	12.56	½	363.05	67.54	53	2206.1	166.5	88	6082.1	276.4
½	15.904	14.13	22	380.13	69.11	54	2290.2	169.6	89	6221.1	270.6
5	19.635	15.70	½	397.60	70.68	55	2375.8	172.7	90	6361.7	282.7
½	23.758	17.27	23	415.47	72.25	56	2463.0	175.9	91	6503.8	285.8
6	28.274	18.84	½	433.73	73.82	57	2551.7	179.0	92	6647.6	289.0
½	33.183	20.42	24	452.39	75.39	58	2642.0	182.2	93	6792.9	292.1
7	38.484	21.99	½	471.43	76.96	59	2733.9	185.3	94	6939.7	295.3
½	44.178	23.56	25	490.87	78.54	60	2827.4	188.4	95	7088.2	298.4
8	50.265	25.13	26	530.93	81.68	61	2922.4	191.6	96	7238.2	301.5
½	56.745	26.70	27	572.55	84.82	62	3019.0	194.7	97	7389.8	304.7
9	63.617	28.27	28	615.75	87.96	63	3117.2	197.9	98	7542.9	307.8
½	70.882	29.84	29	660.52	91.10	64	3216.9	201.0	99	7697.7	311.0

RULES FOR USING PERCENTAGE

To find the *percentage* of any number when the *rate per cent is given*:—Multiply the number by the rate per cent and set the decimal point two places to the left.

Example: Find 7.5 per cent of 35. 35 × 7.5 = 262.5, decimal point moved two places to the left gives Ans. 2.625.

To find what *rate per cent one number is of another*. Add two ciphers to the percentage and divide by the number on which the percentage is reckoned.

Example: What per cent of 75 tons is 9 tons? 900 ÷ 75 = 12 Ans. 12 per cent.

To find a number when the rate per cent and the percentage is known.—Add two ciphers to the percentage and divide by the rate per cent.

Example: If 68 pounds is 15 per cent of the entire charge, how many pounds in the total charge? Ans. 6800 ÷ 15 = 453.33 pounds.

To find what number is a certain per cent *more* or *less* than a given number.

When the given number is *more* than the required number add two ciphers to the number and divide by 100 plus the rate per cent.

Example: 465 is 35 per cent more than what number? 46500 ÷ (100 + 35) 135 = 344.4. Ans.

When the given number is *less* than the required number add two ciphers to the number and divide by 100 minus the rate per cent.

Example: 526 is 23 per cent less than what number? 52600 ÷ (100 − 23) 77 = 683.116. Ans.

CONVENIENT DATA FOR STORAGE CALCULATIONS

Cubic Measure

1728 cubic inches = 1 cubic foot.
27 cubic feet = 1 cubic yard.

Square Box Measure

A box	24 × 16	inches and	28	inches	deep	contains	1 barrel
" "	16 × 16$\frac{4}{5}$	" "	8	"	"	"	1 bushel
" "	8$\frac{1}{4}$ × 8$\frac{1}{4}$	" "	4	"	"	"	1 gallon
" "	4 × 4$\frac{1}{4}$	" "	4	"	"	"	1 quart

21	cubic feet of	river sand	will weigh	1 ton
22	" " "	pit	" " "	1 "
28	" " "	stiff clay	" "	1 "

USEFUL FACTORS

Inches	×	0.08333	= feet
Square inches	×	0.00695	= sq. feet
Cubic inches	×	0.00058	= cu. feet
Cubic inches	×	0.004329	= U. S. gallons
U. S. gallons of water	×	8.33	= pounds
U. S. " " "	×	231.00	= cu. inches
Pounds " "	×	27.72	= cu. inches
Ounces " "	×	1.735	= cu. inches

WEIGHT CALCULATIONS

Weight of round iron per foot	= Square of diameter in quarter inches multiplied by .1666
Weight of flat iron per foot	= Width × thickness × 10.3
Weight of plates per sq. ft.	= 5 pounds for each ⅛ inch in thickness.
Weight of chain	= Diameter squared × 10.7 (approximate).
Safe load (in pounds) for chain	= Square of quarter inches in diameter of bar.

To compute weight of metal from weight of pattern; no allowance for cores or runners.

	Pattern of White Pine	Pattern of Mahogany
For Cast iron	× 16.7	× 10.7
" Brass	× 18.	× 12.2
" Lead	× 23.	× 15.
" Tin	× 15.	× 9.
" Zinc	× 16.	× 10.4

Weight of brass pattern × .9 = weight of iron casting approximately.

TABLE OF SPECIFIC GRAVITIES AND WEIGHTS OF METALS

Material	Specific Gravity	Weight per Cubic Inch (Pounds)
Water at 39.1 deg. F.	1.	.036
Aluminum	2.6	.094
Antimony, cast 6.64 to 6.74	6.7	.237
Bismuth	9.74	.352
Brass, cast 7.8 to 8.4	8.1	.30
Bronze 8.4 to 8.6	8.5	.305
Copper, cast 8.6 to 8.8	8.7	.32
Gold, pure, 24 carat	19.25	.70
Iron, cast 6.9 to 7.4	7.21	.263
Iron, wrought 7.6 to 7.9	7.77	.281
Lead	11.4	.41
Mercury at 60 deg. F.	13.58	.49
Platinum 21. to 22.	21.5	.775
Silver	10.5	.386
Steel, average	7.8	.283
Spelter or Zinc 6.8 to 7.2	7.	.26
Tin, cast 7.2 to 7.5	7.35	.262

PRESSURE IN MOLDS

For depths below pouring basin varying from 1 inch to 12 feet.

Depth Ft.	Depth In.	Pressure Per Sq. In.	Depth Ft.	Depth In.	Pressure Per Sq. In.	Depth Ft.	Depth In.	Pressure Per Sq. In.
	1	.26		19	4.94	3	6	10.92
	2	.52		20	5.20	4		12.48
	3	.78		21	5.46	4	6	14.04
	4	1.04		22	5.72	5		15.60
	5	1.30		23	5.98	5	6	17.16
	6	1.56	2	00	6.24	6		18.72
	7	1.82		25	6.50	6	6	20.28
	8	2.08		26	6.76	7		21.84
	9	2.34		27	7.02	7	6	23.40
	10	2.60		28	7.28	8		24.96
	11	2.86		29	7.54	8	6	26.52
1	00	3.12	2	6	7.80	9		28.08
	13	3.38		31	8 06	9	6	29.64
	14	3.64		32	8.32	10		31.20
	15	3.90		33	8.58	10	6	32.76
	16	4.16		34	8.84	11		34.32
	17	4.42		35	9.10	11	6	35.88
1	6	4.68	3	00	9.36	12		37.44

To find total lifting pressure on cope multiply pressure per square inch at given depth below pouring basin by area (in sq. inches) of the surface acted against. The result will be in pounds.

TEMPERATURES

From Late Scientific Investigations.

		Degrees Fahrenheit
Core ovens—approximate		250 to 450
Bright iron becomes	Yellow	435
	Purple	500
	Indigo	550
	Gray	750
Tin melts		445
Mercury boils		660
Lead melts		612
Zinc melts		775
Silver melts		1,775
Copper melts		1,885
Gold melts		1,900
Iron bar red in	a dark room just visible	950
	ordinary office	1,075
	daylight open air	1,450
Cast iron melts	white	2,075
	gray	2,230
Steel melts		2,750
Annealing malleable iron		1,600 to 1,750

EXAMINATION PAPER

FOUNDRY WORK.

PART II.

Read carefully: Place your name and full address at the head of the paper. Any cheap, light paper like the sample previously sent you may be used. Do not crowd your work, but arrange it neatly and legibly. *Do not copy the answers from the Instruction Paper; use your own words, so that we may be sure that you understand the subject.*

1. What is meant by the sand bottom of a cupola? How is it formed?

2. How many thicknesses of fire brick is usually placed inside of the shell of a cupola?

3. In the design of a cupola, what bearing should the class of work to be poured have on the height at which the tuyères should be placed above the bed?

4. What are some of the precautions necessary in pouring a mold in order to obtain the best results?

5. Describe the operations in making a simple loam mold.

6. Having 65 per cent of a mixture settled upon, with a silicon content of 1.66 per cent, in what proportions could No. 1 and No. 3 irons be added, with silicon 2.65 – 1.75 per cent respectively, so that the castings should contain 2.25 per cent silicon? Deduct 20 per cent silicon for loss in cupola.

7. State the successive steps necessary in operating a cupola furnace.

8. How should the bed charge for a new cupola be determined?

9. What regulates the amount of fuel to be put between the charges of iron in a cupola?

10. What is the difference between the shrinkage of steel castings and that of iron?

11. What are some of the methods used to produce sound steel castings?

12. How is steel poured? What precautions are taken to prevent a mold for steel being "cut" by the rush of the metal?

13. What precautions are taken to prevent fracture at interior corners on steel castings?

14. How does the riser on a steel casting differ from one for iron?

15. What kinds of flasks are generally used for steel molds? Why?

16. What process are the larger steel castings put through to relieve internal shrinkage strains?

17. What are some of the properties of brass molding sand?

18. In what order are the metals for bronze melted?

19. What care must be used in melting and mixing brass?

20. What is the highest percentage of tin that may be mixed with copper and form a serviceable alloy?

21. What are the usual proportions of copper and zinc in yellow brass?

22. How is a common brass furnace constructed?

23. Why must copper alloys be melted without access of oxygen?

24. What is the best modern method of heating and ventilating a foundry?

25. What is the basis of Keeps tests; and what size bar is used for them?

26. What is the size of the test bar or "Arbitration Bar" so called, recommended by the American Foundrymens' Association; and how is it poured?

27. What is the advantage of overhead traveling cranes over jib cranes?

28. Where should the blower be placed in relation to the cupola?

29. What is the advantage of having the coke and iron storage on a level with the charging platform of the cupola?

30. How are floors for light work supplied with iron when at a distance from the cupola?

31. Where should the sand mixers be placed relative to the sand storage bins?

32. What points should be considered in locating the foreman's office?

33. In an 8 ton heat the first metal came down at 2:30 o'clock, the bottom was dropped at 4:15 o'clock. What was the rate of melting for that heat? (Divide tons by time in hours).

34. How are gear patterns gated in a mold for steel?

35. What is used as facing on brass molds?

36. Why are small brass molds poured on end?

37. Why is lead added to bronze mixtures?

38. What is the basis of the composition used in making crucibles?

39. What blast pressure is usually carried on cupolas?

40. What is the average height of the melting zone above the tuyères?

After completing the work, add and sign the following statement:
I hereby certify that the above work is entirely my own.

(Signed)