FOUNDRY WORK

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

PART I

FOUNDRY WORK

PART I

INSTRUCTION PAPER

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PART I

Foundry work is the name applied to that branch of engineering which deals with melting metal and pouring it in liquid form into sand molds to shape it into castings of all descriptions.

In the manufacture of modern machinery three classes of castings are employed, each one having its individual physical properties, such as strength, toughness, durability, etc. These castings are made from gray iron, copper alloys, *i. e.*, brass, bronze, etc., and mild steel. By far the greatest number of castings made are of gray iron, that is, iron which may be machined directly as it comes from the mold without any further heat treatment.

The main purpose of this book is to explain the underlying principles involved in making molds for gray iron castings, and the mixing and melting of the metals for such castings.

There are two other forms of iron castings. These are chilled iron, used for rolling mill rolls, car wheels, etc., and malleable iron, used for certain lines of builders' and manufacturers' hardware. These are not dealt with in detail because they are rather specialities in the trade, whereas there are few towns of importance in this country in which therc is no gray iron foundry.

The chapters on brass founding and steel casting will emphasize only those features of the methods used which differ from iron foundry practice.

The chapter on shop management is intended to set students thinking on this subject; because the whole trend of modern shop practice is toward specialization and system in handling every department of the work, in order to increase efficiency and reduce cost.

IRON MOLDING

There are four main branches in gray iron molding: green sand work, core work, dry sand molding, and loam work.

Green sand molding is the cheapest, quickest method of making the general run of castings. Damp molding sand is rammed over the pattern. Suitable flasks are used for handling the mold. When the pattern is withdrawn the mold is finished and the metal poured while the efficiency of the mold is still retained by reason of this dampness. The mold may be poured as soon as made. In case of necessity the mold may be held over a day or more depending upon its size. If the sand dries out, the mold should not be poured.

Core making supplements molding. It deals with the construction of separate shapes in sand which form holes, cavities, or pockets in the castings. Such shapes are called cores They are held firmly in position by the sand of the mold itself. Core sand is of a different composition from molding sand. It is shaped in wooden molds called core boxes. All cores are baked in an oven before they can be used. The whole detail of their construction is so different from that of a mold, that core making is a distinct trade. A trade, however, that is generally considered a stepping stone to that of molding. Boys usually begin to serve their time in the core shop.

Dry sand is the term applied to that class of work where a flask is used, but a layer of core sand mixture is used as a facing next to pattern and joint. and the entire mold is baked before pouring. This drives off all moisture and gives hard, clean surfaces to shape the iron. It is used where heavy work having considerable detail is to be cast, or where the rush of metal or the bulk of it might injure a mold of green sand. Dry sand molds are usually made up one day, baked over night, and assembled and cast the next day.

Loam work is the term applied to molds built of bricks carried on heavy iron plates. The facing is put on the bricks in the form of mortar and shaped by sweeps or patterns depending upon the design of the piece to be cast. All parts of the mold are baked, rendering the surfaces hard and clean. After being assembled, these brick molds must be rammed up on the outside with green sand in a pit or casing to prevent them bursting out under the casting pressure. Simple molds can be made up one day, assembled, rammed up and poured the next, but it usually takes three or four days and sometimes as many weeks to turn out a casting.

Loam work is used for the heaviest class of iron castings for which, on account of the limited number wanted, or the simplicity of the shape, it would not pay to make complete patterns and use a flask.

In some cases the intricacy of the design makes a pattern necessary, and size alone excludes the use of sand and flasks.

No hard and fast rules exist for the selection of the method by which a piece will be molded. Especially with large work the question whether it shall be put up in green sand, dry sand, or loam, often depends upon local shop conditions. The point to consider is: How can the best casting for the purpose be made for the least money, considering the facilities at hand to work with?

MATERIALS

Before taking up the making of molds, let us consider briefly the materials used, where they are obtained, and what is their particular service in the mold. Also we shall describe the principal tools used by the molder in working up these materials into molds.

There are three general classes of materials for molding kept in stock in the foundry. These are:

Sands	Facings	Miscellaneous
Molding sands	Graphite	Fire clay
Light	Charcoal	Parting dust
Medium	Sea coal.	Burnt sand
Strong		Charcoal
Free sands		Partainol
Sharp or Fire		Core binders
Beach sand		

SANDS

All sands are formed by the breaking up of rocks due to the action of natural forces, such as frost, wind, rain, and the action of water.

Fragments of rocks on the mountain sides, broken off by action of frost, are washed into mountain streams by rainfall. Here they grind against each other and pieces thus chipped off are carried by the rush of the current down into the rivers. Tumbled along by the rapid current of the upper river, the sand will finally be deposited where the stream flows more gently through the low land stretches below the hills. Here the slight agitation tends to cause the finer sand and the clay to settle lower and lower down in the bed. Thus we find beds that have been formed in ages past; possibly with a top soil formed over them, so long have they been deposited. But on removing this top soil we find gravel or coarse sand on top; this merges into finer sand and this again finally into a bed of clay.

Rocks, however, are very complex in their composition, and sands contain most of the elements of the rocks of which they are fragments. For this reason molding sands in different parts of the United States vary considerably.

A good molding sand should, first of all, be refractory, that is, capable of withstanding the heat of molten metal. It should be porous to allow the escape of gases from the mold. It should have a certain amount of clay to give it "bond" or strength, and should have an even grain. All of these properties will vary according to the class of work for which the sand is used.

The two important chemical elements in such sands are silica, which is the heat-resisting element, and alumina, or clay, which gives the bond. Other elements which are found in the molding sands are oxide of iron, oxide of lime, lime carbonate, soda potash, combined water, etc. The following analyses, by W. G. Scott, will give an idea of the proportion of these elements in the different foundry sands:

Chemical Symbols		Fire Sand	Molding Sands: Iron Work			Molding Sands: Brass	Core Sand
			Light	Medium	Heavy	Light	
a. Silica	SiO_2	98.04	82.21	85.85	88.40	78.86	85.50
Alumina (clay)	Al_2O_3	1.40	9.48	8.37	6.30	7.89	2.65
Iron oxide	Fe_2O_3	.06	4.25	2.32	2.00	5.45	.85
Lime oxide	CaO	.20	....	.50	.78	.50	....
b. Lime carbonate	$CaCO_3$	....	.68	.29	....	1.46	2.65
Magnesia	MgO	.16	.32	.81	.50	1.18	4.27
Soda	Na_2O	....	.09	.10	....	.13	.04
Potash	K_2O	....	.05	.03	....	.09	.04
Combined water	H_2O	.14	2.64	1.68	1.73	3.80	2.00
Organic matter			.28	.15	.04	.64	1.00
Specific gravity		2.592	2.652	2.645	2.630	2.640	
Degree of fineness			85.	66.	46.	95.	

Silica alone is a fire-resisting element, but it has no bond. These other elements help in forming the bond. But under heat, silica combines and fuses with them, forming silicates. These silicates melt at a much lower temperature than does free silica. Therefore with sands carrying much limestone in their make up, or those containing much oxide of iron, soda potash, etc., the molten iron will "burn in" more, making it more difficult to clean the castings.

The limestone combinations also go to pieces under heat, tending to make the sand crumble, which may result in dirty castings.

The proportions given in the above table must not be considered as absolutely fixed, for no two samples of sand, even from the same bed, will analyze exactly alike. The table is instructive, however, because it shows the reason why the different sands are especially adapted to the use to which they are put in practice; as for example:

Fire Sand is used in the daubing mixture for repairing inside of cupola and ladles, and should be in the highest degree refractory, and should contain as little matter as possible that would tend to make it fuse or melt.

Light Molding Sand is used for castings such as stove plate, etc., which may have very finely carved detail on their surfaces, but are thin. The sand should be very fine to bring out this detail; it must be strong, *i. e.*, high in clay, so that the mold will retain every detail as the metal rushes in. On the other hand, the work will cool so quickly that after the initial escape of the air and steam there will be very little gas to come off through the sand.

Medium Sand is used for bench work, and light floor work, making machinery castings having from $\frac{1}{2}$ to 2-inch sections.

These will have less fine detail, so the sand may be coarser than in the previous case. The bond should still be fairly strong to preserve the shape of the mold, but the tendency of the large proportion of clay to choke the vent will be offset by the larger size of the grain. This vent must be provided for because the metal will remain hot in the mold for a longer time and will cause gases to form during the whole of its cooling period.

Heavy Sand is used for the largest iron castings. Here the sand must be high in silica and the grain coarse because the heat of the molten metal must be resisted by the sand and gases must be carried off through the sand for a very long time after pouring. The amount of bond or clay must be small or it will cause the sand to cake and choke these gases. The detail is generally so large that the lack of bond is compensated for by the use of gaggers, nails, etc. The coarse grain is rendered smooth on the mold surface by careful slicking.

(**Core Sand**, often almost entirely surrounded by metal, must be quite refractory but have very little clay bond.) This bond would make the sand cake, choking the vent, and render it difficult of removal from a cavity when cleaning the casting. Compared with medium molding sand it shows higher in silica although having less than half the proportion of alumina.

Sands having practically no clay in them are called *free sands.* Of these there are two kinds in use, *river sands* and *beach sands.*

The grains of river sand retain the sharp fractured appearance of chipped rock, and these little sharp grains help much in making a strong core because the sharp angular grains interlock one with another. River sand is used on the larger core work. Beach sand is considerably used in coast sections because it is relatively inexpensive, but its grains are all rounded smooth by the incessant action of the waves. It will pack together only as will so many minute marbles. For this reason it is used only for small cores.

FACINGS

Foundry facing is the term given to materials applied to or mixed with the sand which comes in contact with the melted metal. The object being to give a smooth surface to the casting. They accomplish this in two ways: 1st, by filling in the pores between the sand, thus giving a smooth surface to the mold face before the metal is poured; 2nd, they burn very slowly under the heat of the metal, forming a thin film of gas between sand and iron during the cooling process. This prevents the iron "burning into" the sand and causes the sand to separate from the casting when cold.

Different forms of carbon are used for this purpose because carbon will glow and give off gases, but it will not melt. The principal facings are *graphite, charcoal,* and *sea coal.*

Graphite is a mineral form of carbon. It is mined from the earth and shipped in lumps which are blacker than coal and soft and greasy like a lump of clay. The purest graphite comes from the Island of Ceylon, India. There are several beds, however, in the coal fields of North America.

Charcoal is a vegetable form of carbon. It is made by forming a shapely pile of wood, covering this over with earth and sod, with the exception of four small openings at the bottom and one at the top. The pile is set on fire and the wood smoulders for days. This burns off the gases from the wood, leaving the fibrous structure charred but not consumed. Charcoal burning is done in the lumbering districts. The charcoal for foundry facings should be made from hard wood.

Although sea coal contains a high per cent of carbon, it is less pure than the other facings and will give off much more gas. Sea coal is made from the screenings from the soft coal breakers. The coal should be carefully selected by the manufacturer and be free from slate and very low in sulphur.

All facings are manufactured by putting the raw materials through a series of crushers, tumbling mills or old-fashioned burr stone mills, and then screening them. The finest facings are bolted much as flour is.

In the shop the molder distinguishes between facings or blackings, and facing sand. The former consists of graphite or charcoal, and is applied to the finished surface of a mold or core. The latter is the name given to a mixture of new sand, old sand, and sea coal which in the heavier classes of work form the first layer of sand next the pattern.

The use of the different facings will be clearly seen from the following table:

Material	Uses	Action
Charcoal.	Good facing for light molds; dusted on from bag after pattern is drawn.	Burns at low enough temperature to be effective before thin work cools.
	Mixed with molasses water for wash for small cores and dry sand work.	
	Mixed with some graphite and clay wash for blacking for heavy dry sand and loam work; slicked over with tools.	Resists moisture; prevents sand surfaces from sticking together.
	May be used as a parting dust on joint of bench molds.	
Graphite.	Good facing for bench molds; dusted on from bag; good for medium and heavy green sand work. Applied with camel's hair brush, and slicked over with tools. For heavy blacking for dry sand and loam work. See above.	Good on heavier green sand because it is more refractory than charcoal, but still forms gas enough to keep metal from burning into sand.
Sea Coal.	Mixed with facing sand in proportions 1—6 to 1—12. See section on molding.	Helps to force vents through sand when mold is first poured, and prevents strong sand of the facing from caking, because it continues to throw off gas after casting has solidified.

MISCELLANEOUS MATERIAL

Fire Clay comes from the same source that sand does. It is almost pure oxide of alumina, which is separated out from the sand by a combination of the chemical and mechanical action of the waters of the streams. Fire clay has traces of the other impurities mentioned in the analysis of molding sands. It is found in the lowest strata of the deposit beds.

It is used to mix with fire sand in the proportion of 1 to 4 as the daubing mixture for cupola and ladles.

Clay Wash—fire clay and water. The test for mixing this is as follows: Dip the finger into the wash and then withdraw it. There should be an even film of clay deposited on the finger.

Clay wash is used as the basis of heavy blackings. It is used for wetting crossbars of flasks; breaks in sand where a repair is to be made; to wet up the dry edges of ladle linings when repairing with fresh daubing mixture; in fact, any place where a strong bond is required at some particular spot.

Parting Sands or parting dusts must contain no bond. They are used to throw on to the damp surfaces of molds which must separate one from another. They prevent these surfaces formed of high bond sands from sticking to each other.

The cheapest parting sand, and by far the most commonly used, is obtained by putting some burnt core sand, from the cleaning shed, through a fine sieve.

Beach sand is also used as a parting sand, but the rounded nature of its grain weakens the molding sands more than does burnt core sand.

Charcoal facing dusted from a bag makes an excellent parting dust on fine work.

A dust manufactured expressly for the purpose and called "Partainol" is the most perfect material for fine work. This is applied from a dust bag. It is not only useful for sand joints, but is a great help if there is a deep lift on a pattern where the sand is liable to stick; or for a troublesome box in the core room.

Core Binders. Although the materials for this purpose, flour, rosin, oil, etc., are on the purchasing list of the general foundry buyer, for the purposes of this paper they will be explained in detail in the section on Core Work.

TOOLS

Under this heading only the hand tools and equipment used by the molder in putting up his mold, will be described. The mechanical appliances for reducing labor are described in a later section.

To use sand economically for molds, sets of open frames called flasks are used. *Flasks* consist of two or more such boxes. The lower box is called the *drag* or *nowel*, the upper box is called the *cope*. If there are intermediate parts to the flask they are called *cheeks*. Flasks are fitted with pins and sockets so that they will always register.

For small castings the molds are rammed up on benches or projecting brackets. Such work is termed bench work and the flasks are usually what are known as snap flasks. They range in size from 9 x 12 inches to 18 x 20 inches. As will be seen from Fig. 1, these flasks hinge on one corner and have catches on the diagonal corner. The advantage of the snap flask is that with but one flask any number of molds may be put up, and the flask removed as each mold is completed. There are several good snap flasks to be had on the market. Many foundries, however, make up their own.

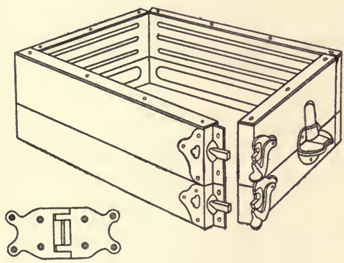

Fig. 1. Snap Flask.

Each size of flask should have at least one smooth straight board called the mold board, the size of outside dimensions of the flask. Rough boards or bottom boards of same size should be provided, one for each mold that will be put up in a day.

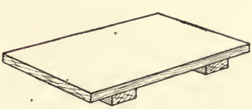

Fig. 2. Mold Board.

Boards for snap work are made from $\frac{7}{8}$ to 1 inch stuff, and should have two stiff cleats, as shown in Fig. 2, to hold them straight.

For heavier castings where the molds are made on the floor, box flasks are used made of wood or iron.

In the jobbing shop, wood flasks are more economical, as they can more readily be altered to fit a variety of patterns, while in a foundry turning out a regular line of castings, iron flasks pay because they require less repair.

Wooden flasks of necessity receive hard usage in the shop and grow weaker each time they are used. They will burn more or less each heat; they receive rough usage when the mold is shaken out; and often the flasks must be stored where they are exposed to all kinds of weather. It is economy, therefore, to build wooden flasks heavier than would be necessary if they were always to be used in their new condition.

Fig. 3 shows construction of a typical wooden flask; the sides project to form lifting handles, the ends are gained in to the sides. Through bolts hold the sides firmly in addition to the nailing. Detail

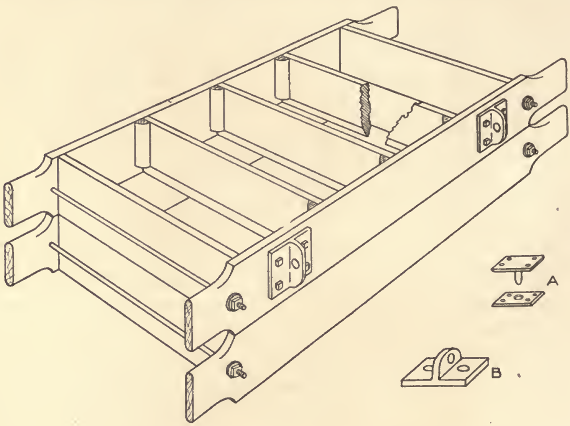

Fig. 3. Wooden Flask.

of the pin is shown at A, and at B is a cast-iron rocker useful on flasks over 4 x 5 feet, to facilitate lifting and rolling over. The cleats make it a simple matter to alter crossbars. The crossbars should be not over 8 inches on centers. For more than 3-foot spans they should have short crossbars through the middle connecting the long ones. In flasks 4 feet and over there should be one or more iron crossbars and a ½-inch through bolt with good washers to clamp the sides firmly to them.

The following table shows thickness of stuff for sides and crossbars for average sizes of jobbing flasks:

FLASK SIZES, 6 INCHES DEEP	SIDES	CROSS-BARS	SHORT CROSS-BARS	IRON CROSS-BARS
Up to 24 x 24 ins.	1½ in.	1 in.		
18 ins. to 24 ins. wide to 5 ft. long	2 ins.	1 in.		1
24 ins. to 36 ins. " " 6 " "	2½ in.	1¼ in.	1 row	2
36 ins. to 48 ins. " " 7 " "	3 ins.	1½ in.	2 rows	2

N. B.—For each additional 6-inch depth of cope or drag, add 25 per cent to the thickness given.

Example. Find thickness of sides and bars in a flask 30 x 48 inches.

Length on side over 2 ft. under 5 ft. *Thickness of side* = 2 inches.

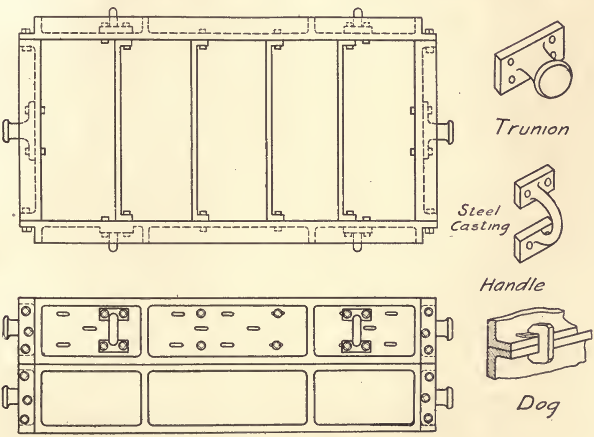

Fig. 4. Iron Flask.

Width of flask over 24 inches under 36 inches, *Thickness of crossbar* = $1\frac{1}{4}$ inches.

Fig. 4 shows the construction of a large iron flask suitable for dry sand work. The pieces of the flask are usually cast in open sand from a skeleton pattern, all holes cored in. The crossbars are cast in the same way; they have a slot in the flange instead of holes to facilitate adjusting them. Trunnions and rockers are sometimes cast on the sides in a core instead of being made separate and bolted on. Holes for pins are usually drilled through the joint flange. For pins, short iron bars are used temporarily in closing. Thickness of metal varies from $\frac{7}{8}$ to $1\frac{1}{4}$ inches according to size of flask.

Fig. 5 shows typical form of iron flask used on some molding machines. The boxes are cast in one piece. The handles serve as lugs for the closing pins. Only one pin is fixed on each box. This makes the boxes interchangeable and capable of being used for either cope or drag.

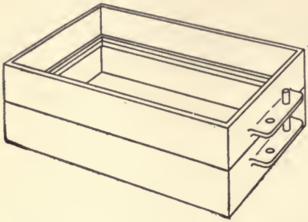

Fig. 5. Flask for Molding Machine.

For cutting and handling loose sand the molder uses a shovel with flat blade, Fig. 6, for it is often more convenient to let the sand slide off of the side of the shovel than off of the end. This is especially true when shoveling sand into bench molds or molding machine flasks.

The foundry sieve or riddle, Fig. 7, is used to break up and remove lumps, shot iron, nails, etc., from the sand placed next the pattern or joint. Sieves should have oak rims with brass or galvanized iron wire cloth. In ordering, the diameter of rim and number of meshes to the inch of the woven wire is given. Good sizes for the iron foundry are 16 inches to 18 inches diameter, No. 8 to 12 on bench work, No. 4 to 8 on floor work.

Fig. 6. Flat Blade Shovel.

Rammers are used for evenly and quickly packing the sand in the flask. One end is in the shape of a dull wedge, called the peen end, the other is round and flat, called the butt end. In Fig. 8, *a* is the type of rammer used on bench work; *b* is a floor rammer having cast heads and wooden shaft; *c* shows rammer made up in the foundry by casting the heads on the ends of an iron bar; *d* shows small peen cast

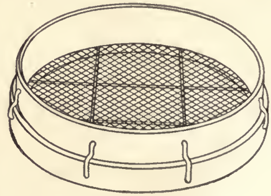

Fig. 7 Foundry Sieve.

on short rod; this is convenient for getting into corners or pockets on floor work.

In shops equipped with compressed air a pneumatic rammer is sometimes used to butt off large flasks, and for ramming loam molds in pits. See Fig. 9.

Molders' tools are designed for shaping and slicking the joint surfaces of a mold and finishing the faces of the mold itself. Except the trowels, they are forged in one piece from steel. The trowels have steel blade and short round handle which fits conveniently into the grasp of the hand. All of the tools are ground slightly crowning on the bottom. They are rocked just a little as they are worked back and forth over the sand to prevent the forward edge cutting into the surface of the mold.

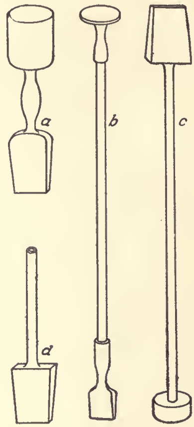

Fig. 8. Rammers.

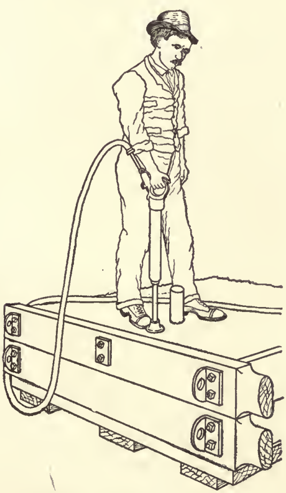

Fig. 9. Pneumatic Rammer.

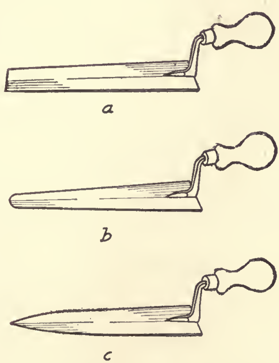

Fig. 10. Trowels.

Of the sixty or more combinations of shapes on the market, the few illustrated represent the ones most commonly used in jobbing shops.

Trowels, Fig. 10, are used for shaping and smoothing the larger surfaces of a mold. The square trowel (*a*) is convenient for working up into a square corner, and the finishing trowels (*b* and *c*) are more for coping out and finishing along the curved edges of a pattern. Trowels are measured by the width and length of blade.

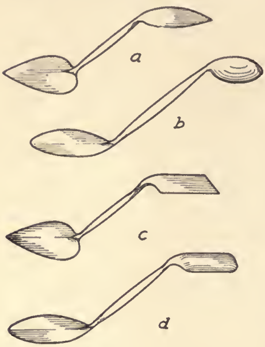

Fig. 11. Slicks.

Slicks are designated by the shape of the blade and the width of the widest blade. In Fig. 11, *a* is a heart and leaf; *b*, leaf and spoon; *c*, heart and square; and *d*, a spoon and bead. These are in sizes of 1 inch to $1\frac{3}{4}$ inches. They are used for repairing and slicking small surfaces

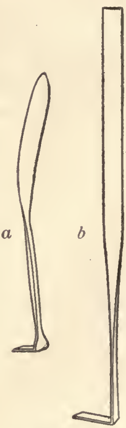

Fig. 12. Lifters.

Fig. 12 shows lifters used to clean and finish the bottom and sides of deep narrow openings; *a* is a floor lifter, made in sizes $\frac{1}{8} \times 10$ to 1×20; *b* is a bench lifter, sizes vary from $\frac{3}{16}$ inches to $\frac{3}{4}$ inch.

Fig. 13 shows at *a* and *b*, inside and outside square corner slicks, made in sizes of 1 to 3 inches. *c* is a half round corner, widths 1 inch to $2\frac{1}{2}$ inches; and *d* is a pipe slick made 1 inch to 2 inches. This style of tool is mainly used on dry sand and loam work.

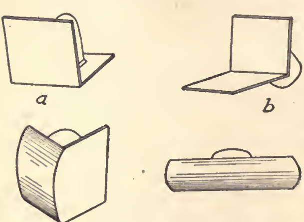

Fig. 13. Square Corner Slicks.

Swabs are used to moisten the edges of the sand about a pattern before drawing it from the mold.

This foundry swab is a dangerous though useful tool. Its danger lies in a too free use of water around the mold, which may result in blow holes. A good swab for bench work is made by fastening a piece of sponge, about double the size of an egg, to a goose quill or even a pointed hardwood stick. The point will act as a guide and the water may be made to run or simply drop from the point by varying the pressure on the sponge. Floor swabs, Fig. 14, are made from hemp fiber. They should have a good body of fiber shaped to a point, and be made about 12 inches or 14 inches long. They will take up considerable water and deliver it from the tip of the point. In heavy work the swab is trailed lightly over the sand like a long bristled brush.

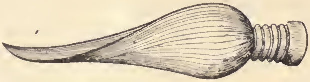
Fig. 14. Floor Swab.

Vent wires are used to pierce small holes through the sand connecting the mold cavity with the outside air. For bench work a knitting needle is the most convenient thing to use. It should have a short hardwood handle or cast ball on one end. Select a needle as small as possible, so long as it will not bend when using it.


Fig. 15. Vent Rod.

Heavy vent rods are best made of a spring steel from $\frac{3}{16}$ inches to $\frac{1}{2}$ inch with the pointed end enlarged a little to give clearance for the body of the rod when run deep into the sand. See Fig. 15.

Draw sticks are used to rap and draw patterns, from the sand. Fig. 16 shows three kinds: (*a*) is a small pointed rod $\frac{1}{4}$ inch to $\frac{3}{8}$ inch in size, which gets its hold by simply driving it into the wood of the pattern. (*b*) is a wood screw welded to an eye for convenience. (*c*) is an eye rod with machine screw-thread, which requires a metal plate let into the pattern. The plate is called a rapping plate and is made with separate holes not threaded. Into these holes a pointed rapping bar is placed when rapping the pattern. This preserves the threads used for the drawbar.

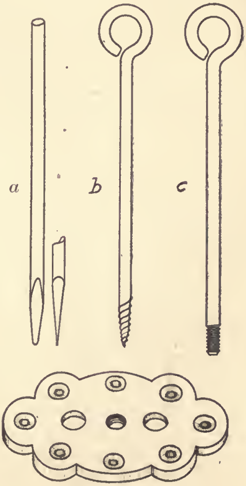

Fig. 16. Draw Sticks.

In pouring, the parts of a mold must be clamped by some method to prevent the pressure of the liquid metal from separating them, causing a run-out.

For light work a weight, shown in Fig. 17, is the most convenient. This is simply a plate of cast iron 1 inch to 1½ inches thick, with a cross-shaped opening cast in it to give considerable liberty in placing the runner in the mold. The weights are from 15 to 40 pounds, according to size of flasks.

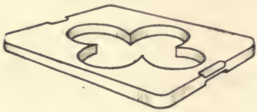

Fig. 17. Weight.

Floor flasks are fastened with clamps made of cast iron. These are tightened by prying them on to a hardwood wedge. Fig. 18 shows how wedge may first be entered and how the clamping bar is used to firmly clamp the flask. For iron flasks used in dry sand work the clamps are very short as only the flanges are clamped together. See Fig. 4. Iron wedges are used instead of wood. Often the iron bottom board is clamped on and the joint flanges bolted together before pouring.

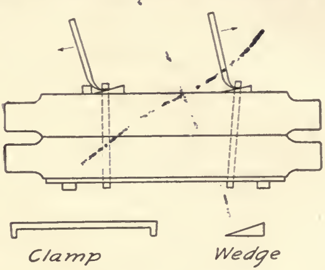

Fig. 18. Method of Clamping.

PRINCIPLES OF MOLDING

There are certain *principles* underlying iron molding which hold good in all classes of founding, and a practical understanding of these principles is necessary for good work in any line.

Aside from the fact that we generally want a mold which takes the least possible time to put up, there are three things aimed at in green sand work, these are: A *sound casting,* free from internal imperfections, such as blow holes, porous spots, shrinkage cracks, etc. A *clean casting,* free from dirt, such as slag, sand, etc. A *smooth casting,* having uniform surface free from scabs, buckles, cold shuts, or swells. The natural sands best adapted to obtain these results have already been dealt with. The methods of adding new sands vary with different classes of work. For light work the entire heap should be kept in good condition by adding a little new sand every day; for the light castings do not burn out the sand to a great extent.

On heavier work of from 50 pounds and upward, the proportion of sand next the pattern is so small compared with that used simply to fill the flask, that it does not pay to keep the entire heap strong enough for actual facing. The heap should be freshened occasionally with a cheap molding sand, but for that portion of the mold which forms the joint surface and especially that which comes in contact with the metal, a facing sand should be used.

The range of new sand in facing mixtures is

$$\left.\begin{array}{l}\text{3 to 6 New sand}\\ \text{6 to 2 Old ``}\\ \text{1 to 2 Free `}\end{array}\right\}\ \tfrac{1}{6}\text{ to }\tfrac{1}{8}\text{ Sea coal facing.}$$

These proportions, and the thickness of the layer of facing sand, vary with the weight of metal in the casting. Too much new sand tends to choke the vent and cause sand to cake; too little new sand renders facing liable to cut or scab. Too much sea coal makes sand brittle, and more difficult to work, also gives off too much gas which is liable to cause blow holes in casting. Not enough sea coal allows the sand to cake, making cleaning difficult.

To prepare foundry sand for making a mold, it must be "tempered" and "cut" through. This is now usually done by laborers.

To temper the sand, throw water over the heap in the form of a sheet by giving a peculiar backward swing to the pail as the water leaves it. Then "cut" the pile through, a shovelful at a time, letting the air through the sand and breaking up the lumps. This moistens the clay in the sand, making it adhesive and puts the pile in the best condition for working.

To test the temper, give one squeeze to a handful of sand. An excess of water will at once be detected by the soggy feeling of the sand. Now hold the egg-shaped lump between thumb and finger of each hand and break it in the middle. The edges of the break should remain firm and not crumble.

Too much moisture will make excess of steam in the mold, causing blow holes. Not enough moisture renders sand weak and apt to wash or cut.

Bearing in mind the nature of the materials we have to work with, we must now study the important *operations* involved in making a sand mold.

The sand next to the joint and over the pattern should be *sifted*. The thickness of this layer of sifted sand varies from about $\frac{3}{4}$ inch for light work, to 2 inches on very heavy work. The fineness of the sieve used depends upon the class of work. No. 16 or 12 would be used for small name plates, stove plate, etc., while No. 8 or 6 is good for general machinery work. On floor work, from 4 to 6 inches of sand back of the facing should be riddled through a No. 4 sieve to ensure more even ramming and venting.

RAMMING

The object of *ramming* is to make the sand hang into the flask and support the walls of the mold against the flow and pressure of the metal. The knack of ramming just right only comes with continued practice and comparison of results. Hard ramming closes up the

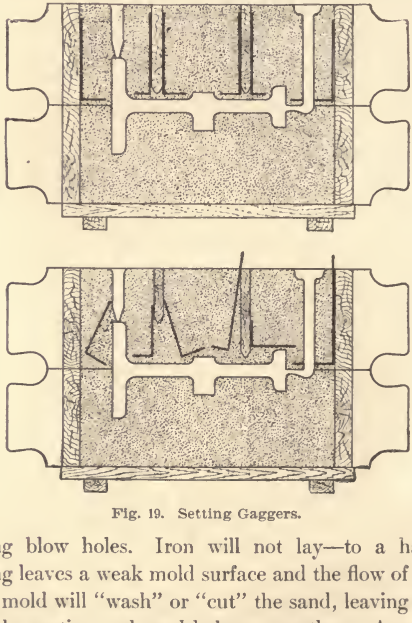

Fig. 19. Setting Gaggers.

vent, causing blow holes. Iron will not lay—to a hard surface. Soft ramming leaves a weak mold surface and the flow of the metal as it enters the mold will "wash" or "cut" the sand, leaving a "scab" on one part of the casting and sand holes on another. A mold rammed too soft will tend to "swell" under the pressure of the liquid metal, making the casting larger than the pattern or leaving an unsightly lump on the casting. The bottom parts of a mold being under greater casting pressure must be rammed somewhat harder than the upper portions.

The joint also should be packed firmly, as it is exposed to more handling than any other part.

Crossbars are put in the cope to make it possible to lift the sand with the cope without excessively hard ramming. As an additional support for the cope sand on large work *gaggers* are used. These are L-shaped pieces of iron made from wrought or cast iron of from $\frac{5}{16}$-inch to $\frac{1}{2}$-inch square section.

The force of the sand pressing against the long leg of the gagger holds it in place and the short leg supports the sand about it. Therefore the gagger will hold best when the long leg is placed tight against

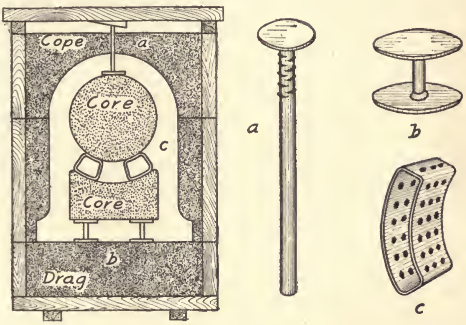

Fig. 20. Chaplets.

the crossbar and plumb. The long leg of the gagger should not project above the level of the cope, as there is much danger of striking it and breaking in the mold after the flask is closed. Fig. 19 shows the right and the wrong ways of setting gaggers.

Chaplets should be used to support parts of cores which cannot be entirely secured by their prints which are held in the sand of the mold. Fig. 20 shows the three principal forms of chaplets used, and how they are set in the mold; (*a*) is a stem chaplet; (*b*) is a double headed or stud chaplet; and (*c*) is a form of chaplet made up of strip metal.

That portion of the chaplets which will be bedded in metal is tinned to preserve it from rusting, because rusty iron will cause liquid metal to "blow." For small cores nails are often employed for this purpose, but only new ones should be used. With the stem chaplets the tails must be cut off when the casting is cleaned—the stud chaplet becomes entirely embedded in the metal. There are now manufactured and on the market many different styles of chaplets. In selecting the size and form for a given purpose the *head* of the chaplet should be large enough to support the weight of the core without crushing into the sand and thin enough to fuse into the liquid metal. The *stem* must be small enough to fuse well to the metal and stiff enough not to bend, when hot, under its load.

VENTING

In the section on sands, reference has already been made to gases which must be taken off from a mold when it is poured. There are three forms of these: *Air*, with which the mold cavity is filled before pouring; *Steam*, formed by the action of the hot metal against the damp sand during the pouring process; and *Gases*, formed while the casting is cooling, from chemical reactions within the liquid metal and from the burning of organic matter, facings, core binder, etc., in the sands of the mold. It is of the greatest importance that these gases pass off quickly and as completely as possible. If they do not find free escape through the mold they are forced back into the liquid metal, making it "boil" or "blow." This may blow the metal out through risers and runners, or simply form numerous little bubble-shaped cavities in the casting, called "blow holes." These often form just below the skin of the casting and are not discovered until the piece is partially finished.

We cannot depend entirely upon the porosity of the molding sands, but must provide channels or *vents* for the escape of these gases.

For light work a free use of the vent wire through the sand in the cope will answer all purposes.

On castings of medium weight, besides venting with the wire, risers are placed directly on the casting or just off to one side as shown in Figs. 19 and 21. These are left open when the mold is poured and provide mainly for the escape of the air from the mold.

Heavy castings that will take some time to cool, and thus keep facings burning for a long time after the mold is poured, require venting on sides and bottom as well as top. Fig. 21 shows side vents *a a* *a a* connecting with the air through the channel *b b b* cut along joint and risers *c c c* passing through the cope. At the bottom the vents connect with cross vents *d d* run from side to side between the bottom board and edge of flask. Fig. 22 shows a mold bedded in the floor; the side or down vents connect at the top, as in previous examples, and at the bottom with a cinder bed about 2 inches thick, rammed over entire bottom of pit. The gases find escape from this cinder bed through a large gas pipe.

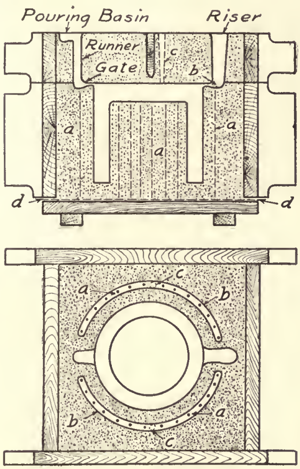

Fig. 21. Use of Risers.

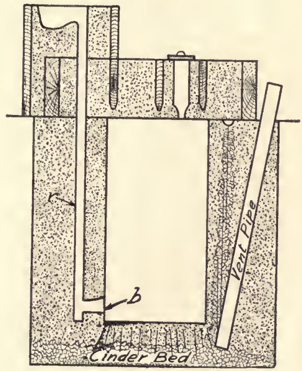

Fig. 22. Mold Bedded in Floor.

In pouring, the gas from vents should be lighted as soon as may be. The burning at the mouth of vents helps draw the gases from below and also keeps the poisonous gas out of the shop.

It is customary to keep risers closed with small cover plates when large castings are being poured so that the air in the mold will be compressed as the metal rises in the mold. This helps sustain the walls of the mold and forces the vents clear so that they will act more quickly when the mold is full. These covers are removed occasionally to watch the progress of pouring, and are entirely removed when the metal enters the risers.

GATING

Gating is the term applied to the methods of forming openings and channels in the sand by which liquid metal may enter the mold cavity. The terms *sprues* and *runners* are also used with the same meaning in some shops.

There are practically three parts to all gates—the pouring basin, the runner, and the gate. See Fig. 21. The runner is formed by a wooden gate plug made for the purpose. The pouring basin is shaped by hand on top of the cope, and the gate proper is cut along the joint surface by means of a gate cutter. In all cases the gate section should be smaller than any other part so that, when pouring, the runner and basin may be quickly flooded; also that the gate when cold will break off close to the casting and lessen the work of cleaning.

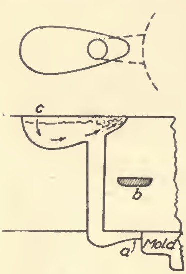

Fig. 23. Gate.

The object of gating is to fill the mold cavity with clean metal—to fill it quickly, and while filling, to create as little disturbance as possible in the metal.

The impurities in liquid metal are lighter than the metal itself, and they always rise to the top when the melted metal is at rest or nearly so. Advantage is taken of this important property to accomplish the first of the objects mentioned.

Fig. 23 shows a good type of gate to use on light work. For reasons given, the point *a* should have the smallest sectional area. This section should be wider than it is deep as shown at *b*, because the hot iron necessary for light work runs very fluid.

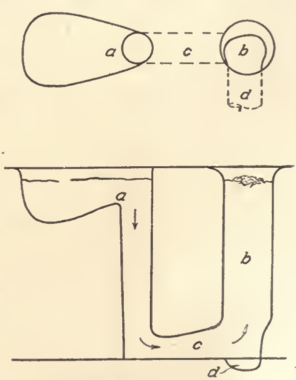

Fig. 24. Skimming Gate.

The runner should not be more than $\frac{5}{8}$ to $\frac{3}{4}$ inch in diameter. The pouring basin should be made deepest at point *c*, and slant upward crossing the runner. When pouring, the stream from the ladle should enter at *c*, flood the basin at once, and keep it in this condition. The current of the metal will then tend to hold back the slag, allowing clean metal to flow down the runner.

When particularly clean castings of medium weight are required, some form of skimming gate should be used. Fig. 24 illustrates one of several practical forms. They all depend for their efficiency upon the principle cited above. In the cut, *a* is the pouring basin and runner, *b* is a good sized riser placed about 3 or 4 inches from *a*, and *c* is a channel cut in the *cope joint,* connecting these two. The gate *d* should be cut in the drag side of the joint, just under the riser but at an angle of 90° or less with *c*. The metal rushing down the runner is checked by the small size of the gate and so washes any dirt or slag up into the large riser *b*. The level of metal in this riser must be sustained by sufficiently rapid pouring until the mold is filled.

In bench work and floor work, the greatest care must be used to have all parts of the gate absolutely free from loose sand or facing which will wash into the mold with the first flood of metal.

On heavy work special skimming gates are not used, for the capacity of the pouring basin is very much greater than that of the runners which can be quickly flooded and thus retain the slag. Besides this, large risers are set at the sides or directly upon the casting, to receive any loose sand or facing that washes up as the mold is being filled. Fig. 22 illustrates this type.

In regard to filling the mold quickly and quietly, the two are closely allied. The shape and thickness of the casting are the important factors in determining the number and position of the gates. Aside from the fact that the gate should never be heavier than the part of the casting to which it attaches, the actual size of the gate opening is something that the molder must learn from experience.

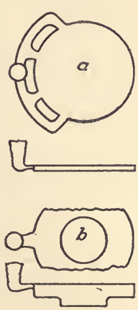

Fig. 25.
Use of Gates.

In arranging gates with regard to the shape of the pattern, the following points should be borne in mind. Place gates where the natural flow of the metal will tend to fill the mold quickly. Usually gate on lighter sections of casting. Select such points on the casting that the gates may be broken and ground off with least trouble. The greater the number of castings to be handled, the more important this point becomes. A study of the molding problems given will illustrate this point.

Provide enough gates to fill all parts of the mold with metal of uniform temperature. This depends upon the thickness of the work, as is illustrated in Fig. 25, by two molds having same shape at joints, but different thicknesses. In thin castings the metal tends to chill quickly, so it must be well distributed. In the cut, *a* is a plate ¼ inch thick, and should have several gates. A piece having the same diameter but heavier, would run better from one gate, see *b*, while if a bushing of this diameter is required, the best results would be obtained by gating near the bottom, as in Fig. 22. For running work at the bottom as shown in Fig. 22, the gate piece *b* is separate from the runner, and is picked into the mold after the pattern is drawn. The runner *r* should extend below the level of the gate to receive the force of the first fall of metal, which otherwise would tend to cut the sand of the gate.

SHRINKAGE HEADS

Melted metal shrinks as it cools, and this process begins from the moment the mold is filled. The surfaces next to the damp sand are the first to solidify, and they draw to themselves the more fluid metal from the interior. This process goes on until the whole casting has solidified. This shrinkage causes the grain in the middle to be coarse and sometimes even open or porous.

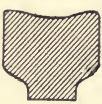

Fig. 26. Sinking of Casting.

The lower parts of a casting are under the pressure or weight of all the metal above, and so resist these shrinkage strains. The top parts, however, require the pressure of liquid metal in gates or risers to sustain them until they have hardened sufficiently to hold their shape, or they will sink as indicated by the section, Fig. 26. *Risers* mentioned in connection with securing clean metal are also required on heavy pieces to prevent this distortion and give sound metal. When used in this way they are called shrinkage heads or feeders. They should be 6 or 8 inches in diameter, so as to keep the iron liquid as long as possible, and should have a neck 2 or 3 inches in diameter, to reduce the labor required to break them from the casting in cleaning. To prevent the metal in this neck from freezing, an iron feeding rod is inserted, as in Fig. 27, and churned slowly up and down. This insures fluid metal reaching the interior. As the level in the feeder lowers, hot metal should be added from a hand ladle.

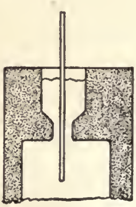

Fig. 27. Feeding Rod.

PRESSURE IN MOLDS

The subject of the pressure of liquid iron mentioned repeatedly in the foregoing pages, must be dealt with by the molder in weighting his copes, strengthening flasks, securing cores, etc., but most frequently by the first of these.

Molten iron acts in accordance with the same natural laws that govern all liquids—as for example, water (see Mechanics, Part II). Iron, however, is 7.2 times heavier than water. The two laws applicable in foundry work are these: Liquids always seek their own level: Pressure in liquids is exerted in every direction.

Applying these laws: If we have two columns of liquid iron connected at the bottom, they would just balance each other. For convenience we shall leave out of our calculations the upward pressure on the gates in the following examples, for in practical work they need seldom be taken into account.

In A, Fig. 28, suppose these columns stand 6 inches above the joint *b d*, and that column *c d*, has an area of 1 sq. in. In B, suppose the area of the right hand column *c d e f* is five times the area of column *c d*. In both cases the level with top of runner *a* will be maintained. The depth of the cavity below the joint *b d f* makes no difference in maintaining these levels. The weight of one cubic inch of iron, .26 lb., is taken as the basis of all calculations.

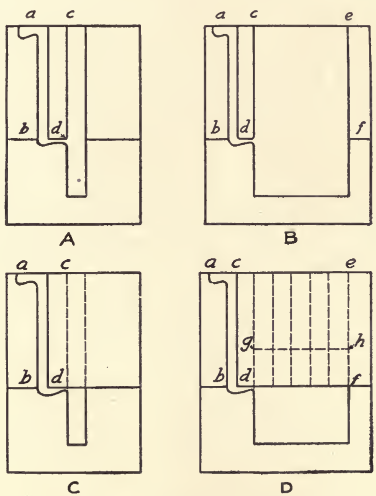

Fig. 28. Pressure of Liquids.

Now if we close the column *c d* at *d*, as in C, it is clear that it would require the actual weight of that column to balance the lifting pressure on surface *d*, or 6 inches $\times$ .26 $\times$ 1 sq. in. = 1.56 lbs. And if the larger area $d\ f$ is closed over, as in D, it takes five times this weight to resist the pressure exerted upon it by the runner, or 6 inches $\times .26 \times 5$ sq. in. $= 7.8$ lbs. If the pattern projected 2 inches into the cope the height of the runner above the surface acting against the cope would be but 4 inches, and the pressure to be overcome would be equal to the weight of $c\ d\ g\ h$, equal to 4 inches $\times$ .26 $\times$ 5 inches $=5.2$ lbs.

The important factors are, then, *height of runner*, and *area of mold which presses against the cope.* We can therefore state a rule: To calculate the upward pressure of molten iron, multiply the depth in inches by the weight of one cubic inch of iron (.26) and this product by the area in square inches upon which the pressure acts.

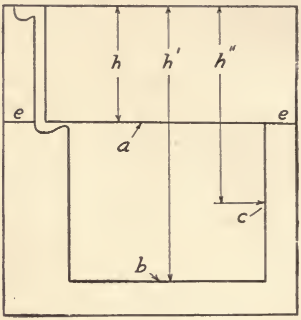

Fig. 29. Pressure of Liquids.

Applying the second law cited, the strains on sides and bottom of molds and upon cores is explained.

By the rule we first find the pressure per sq. in. at any given level by multiplying the depth by .26, and it is obvious that this pressure increases the lower in the mold a point is taken.

In Fig. 29, the pressure at a equals $h \times .26$. This also acts against the sides at $e\ e$. The pressure at b is $h' \times .26$, and is exerted sidewise and downward. The pressure at c is $h'' \times .26$. This point being half way between levels a and b, represents the average sidewise or lateral pressure on all of the sides.

If this mold then is 11 inches square, and 9 inches deep, with the pouring basin 6 inches above the joint, we have

Area of a, 121 sq. in.
Area of b, 121 sq. in.
Area of c, (one side), 99 sq. in.
Area of four sides, 396 sq. in.
Height of h = 6 in. = 1.56 lbs. per sq. in. in pressure.
Height of h' = 15 in. = 3.90 " " " " " "
Height of h'' = $10\frac{1}{2}$ in. = 2.73 " " " " " "

Multiplying these together, we have

Upward pressure on a	=	188.76
Total pressure on side c	=	270.27
Total pressure on four sides	=	1081.08
Total downward pressure on b	=	471.90

A study of these figures shows the necessity of well made flasks and bottom boards, for these must resist a greater pressure even than that required to keep the cope from lifting. They also show clearly why the lower parts of the casting will resist the pressure of the gases more and require firmer ramming than the upper portions.

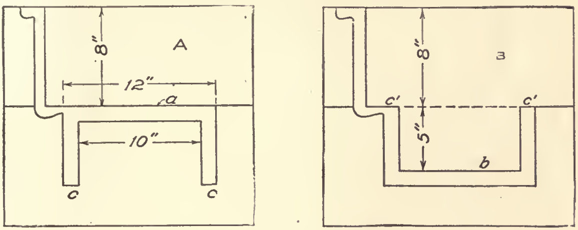

Fig. 30. Pressure of Liquids.

A difference in the way a pattern is molded may make a great difference in the weight required on the cope. Compare A and B, Fig. 30. Suppose this pattern is cylindrical in shape, we would have

Area of circle a (from table),—113.10

Area of circle b (" "),— 78.54

Area of ring c' c', equal to b subtracted from a, or 34.56.

Then:

Total lift on cope A is $8 \times .26 \times 113.10$ = 235.24 lbs.

The lift on cope B is $8 \times .26 \times 34.56$ = 71.88 lbs.

and $(8 + 5) \times .26 \times 78.54$ = 265.46

making a total of........................337.34 lbs. on B.

Fig. 31 is an example of a core 5 inches square surrounded by 1 inch of metal, with a runner 6 inches high; we have here,

Pressure per square inch on a is $7 \times .26$ or 1.82 lbs.

" " " " " b " $12 \times .26$ or 3.12 "

The difference in these pressures is 1.30 lbs. per sq. in. Then for every foot of length in the core we must balance a lifting pressure on the bottom of the core of 5 inches × 12 inches × 3.12, or 187.2 lbs. until the metal covers surface *a*, when it will exert a counteracting downward pressure, and the strain on the chaplets will be only 60 × 1.30 lbs., or 78 lbs.

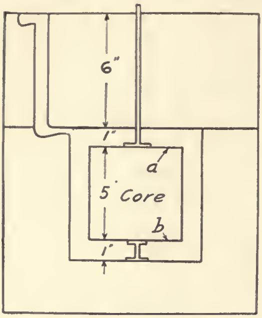

Fig. 31. Pressure of Liquids.

Some of the ordinary defects which the beginner will find on his castings are as follows:

Poured Short: The amount of metal in the ladle is misjudged with the result that the mold is not completely filled.

Blow holes come from gases becoming pocketed in the metal instead of passing off through the sand. This is due to hard ramming, wet sand, etc.

Cold Shuts form when two streams of metal chill so much before they meet, that their surfaces will not fuse when forced against each other; see Fig. 32.

Sand Holes come from loose sand or excess of facing washing into the mold cavity when pouring. They are usually bedded in the cope side of casting.


Fig. 32. Cold Shuts.

Scabs show like small warts or projections on the surface of the casting. They result from small patches of the mold face washing off. They may be caused from too much slicking, which draws the moisture to the surface of the mold, making the skin flake under the drying effect of the incoming metal.

Swells are bulged places on a casting due to soft ramming. This saves the walls of the mold too soft to withstand the pressure of the liquid metal.

Shrinkage Cracks are due to unequal cooling in the casting. They are sometimes caused by the mold being so firm that it resists the natural shrinkage of the iron, causing the metal to pull apart when only partially cold.

Warping occurs when these strains cause the casting to bend or twist, but are not sufficient to actually crack the metal.

TYPICAL MOLDING PROBLEMS

When starting to ram up a flask see that the sands to be used are well cut through and properly tempered. Select a flask large enough to hold the pattern and have at least 2 inches clear of the flask all around for bench work, and 4 to 8 inches on floor molds, depending upon the weight of the work to be cast. See that the flask is strong enough to carry the sand without racking and that the pins fit. Have the necessary tools at hand, such as sieve, rammer, slicks, etc.

Examine the pattern to be molded to see how it is drafted and note especially how the parting line runs. That part of the mold forming the surface between the parts of the flask is called the joint and where it touches the pattern this joint must be made to correspond with the parting line.

The joint of a mold will be a plane or flat surface, or it will be an irregular one. When the joint is a *flat surface* it is formed entirely by the mold board except with work bedded in the floor; there it is struck off level with a straight edge. When it is *irregular* the drag joint must be "coped out" for every mold needed; that is, shaped free hand by the molder before making up the cope; or the shape of the *cope* joint is built up *first* in a "match" frame with the cope part of the pattern bedded into it. Upon this form the drag may be packed repeatedly, receiving each time the desired joint surface without further work on the molder's part.

Our first problems in molding will illustrate these three methods of making the joint.

It is aimed to give the directions for making up molds in as concise a form as possible. The student should refer frequently to the preceding sections and familiarize himself with the reasons underlying each operation.

To make a mold having a flat joint. In the small face plate shown in Fig. 33, all of the parting line *a a a* will touch the mold board, so the joint will be flat. The draft is all in one direction from the cope side *c*, therefore all of the pattern will be in the drag. Use a snap flask for this piece.

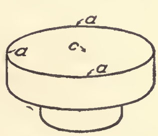

Fig. 33. Face Plate.

Place a smooth mold board upon the bench or brackets. Place drag with sockets down upon this. Set pattern a little to one side of the center to allow for runner. Sift sand over this about $1\frac{1}{2}$ inches deep. Tuck sand firmly around the pattern and edges of flask as indicated by arrows, Fig. 34, using fingers of both hands and being careful not to shift sand away from pattern at one point when tucking at another.

Fill the drag level full with well cut sand. With the peen end of the rammer slanted in the direction of the blows ram first around the sides of the flask to ensure the sand hanging in well, see Fig. 35, 1-2. Next carefully direct the rammer around the pattern, 3-4-5. Do not strike closer than 1 inch to the pattern with the end of the rammer.

Shifting the rammer to a vertical position, ram back and forth across the flask in both directions, being especially careful not to strike

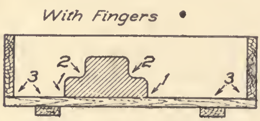

Fig. 34. Making a Mold.

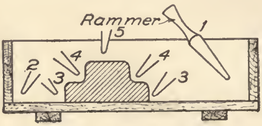

Fig. 35. Making a Mold.

the pattern nor to ram too hard immediately over it. The student must judge by feeling when this course is properly rammed. Now fill drag heaping full of sand. Use the butt end of rammer around edges of flask first, then work in toward the middle until the sand is packed smooth over the top. With a straight-edge strike off surplus sand to a level with the bottom of flask. Take a handful of sand and throw an even layer about $\frac{1}{4}$ inch deep over bottom of mold. On to this loose sand press the bottom board, rubbing it slightly back and forth to make it set well. With a hand at each end, grip the board firmly to the drag and roll it over. Remove the mold board and slick over the joint surface with the trowel. Dust parting sand over this joint (burnt core sand is good on this work), but blow it carefully off of the exposed part of the pattern. Set the wooden runner or gate plug about 2 inches from the pattern, as shown in Fig. 23.

In snap work the runner should come as near the middle as possible, to lessen the danger of breaking the sides, and to allow the weight to be placed square on top of the mold.

Set the cope on the drag and see that the hinges come at the same corner.

Sift on a layer cf sand about $1\frac{1}{2}$ inches deep. Tuck firmly with the fingers about the lower end of the runner and around the edges of the flask. Fill the cope and proceed with the ramming the same as for the drag.

Strike off the surplus sand, swinging the striking stick around the runner so as to leave a fair flat surface of sand. Drive the vent wire into the cope sand, making it strike the pattern a dozen times or more. Partially shape a pouring basin, illustrated in Fig. 23, with a gate cutter, before removing the runner. Draw the runner and finish the basin with a gate cutter and smooth it up with the fingers. Moisten the edges with a swab and blow it out clean with the bellows.

Lift the cope and repair any imperfections on the mold surface with trowel or slicks. See that the sand is firm around the lower end of the runner. Blow through the runner and all over the joint to remove all loose parting sand. Slick over the sand which will form the top surface of the gate, between the runner and the mold.

Having finished the cope, moisten the sand about the edges of the pattern with a swab. Drive a draw spike into the center of the pattern and with a mallet or light iron rod, rap the draw spike slightly front and back and crosswise. Continuing a gentle tapping of the spike, pull the pattern from the sand. If any slight break occurs, repair it with

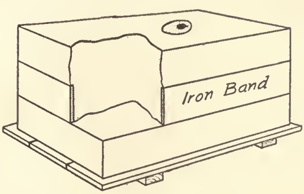

Fig. 36. Use of Iron Band.

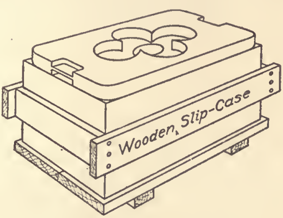

Fig. 37. Weight in Position.

bench lifter or other convenient slick. Cut the gate and smooth it down gently with the finger; blow the mold out clean with bellows. Dust on graphite facing if castings are to be cleaned in rattler. No facing is needed if they are to be picketed. The mold should now be closed and the snap flask removed.

There are two methods used to strengthen these molds against the casting pressure. One is to use an iron band which will just slip *inside* of the flask before the mold is packed. See Fig. 36. The other is to slide a wooden "slip case" over the mold after the snap flask is removed. See Fig. 37. In either case the weight, shown in position in Fig. 37, should not be placed on the mold until pouring time, lest by its continued pressure it might crush the sand.

A mold requiring to be coped out. The second type of joint surface mentioned above is illustrated by the method of molding the tail stock clamp shown in Fig. 38. This is a solid pattern and rests firmly upon the mold board on the edges *a a*, but the parting line *b b b* runs below these edges. The bulk of the pattern drafts down from this line, so will be molded in the drag while all above it will be shaped in the cope.

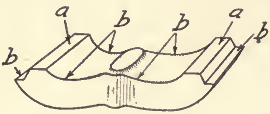

Fig. 38. Tail Stock Joint.

To mold the piece, set the pattern on the mold board planning to gate into one end. Ram the drag and roll it over as described in the last example. With the blade of the trowel turned up edgewise, scrape

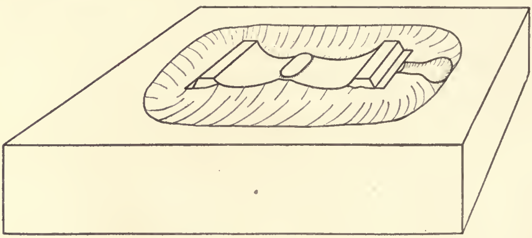
Fig. 39. Coped out Mold.

away the sand to the depth of the parting line, bringing the bevel up to the main level of the joint, about 2½ inches from the pattern, as shown at Fig. 39. Slick this surface smooth with the finishing trowel or leaf and spoon. This process is called coping out. Dust parting sand on the joint thus made. Be careful not to get too much at the bottom of the coping next the pattern. Pack cope, then lift same, and finish mold as directed.

In coping out, the molder practically shapes draft on the sand of the drag. Aim to have the lower edge of the coping parallel with main joint for a short distance, and then spring gradually up to it at about the angle shown in the section, Fig. 40, at *c*, as this is the strongest shape for the sand.

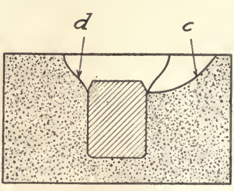

Fig. 40. Angle of Joint.

If made with an abrupt angle as in *d*, the cope sand will tend to wedge into the cut with the danger of a "drop" or break when the cope is lifted.

In many cases, more especially in floor work, an abrupt coping angle may be avoided as follows: Set wooden strips, whose thickness

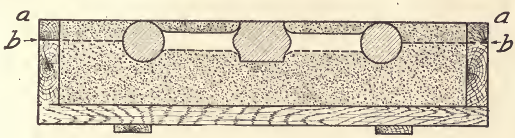

Fig. 41. Molding a Hand Wheel.

is equal to the depth of the desired coping, under the edges of the drag when ramming up the pattern. (Use, for example, the hand wheel shown in Pattern Making, page 58). When the drag is rolled over the sand will be level with the top of strips and pattern at *a a*, Fig. 41. Remove the strips and strike surplus sand off level with edges of drag, *b b*, and slick off the joint. Proceed with the cope in the usual manner. In gating this pattern, and wheels generally, place a small runner directly on the hub.

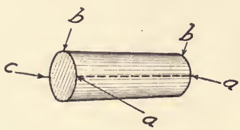

Fig. 42. Solid Bushing.

Using a sand match. The solid bushing, Fig. 42, will serve to illustrate the use of a sand match. For exercise work use only one pattern.

In practice, however, several small patterns are bedded into the same match. It is clear that in this pattern the parting line runs along

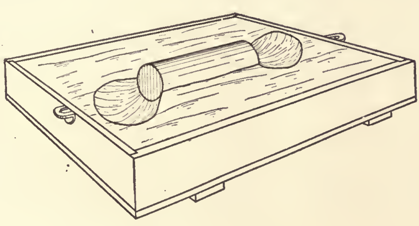

Fig. 43. Use of Sand Match.

the center of the cylinder, and to make a safe lift for the cope it should follow around the circumference of the ends from *a* to *c*, as shown by the heavy lines.

The frame for the match is shallow, and of the same size as the snap flask with which it is used. It is provided with sockets to engage the pins of the flask. The bottom board is fastened on with screws.

Fill the match with sifted sand rammed hard. Strike off a flat joint and bed in the pattern. Cope out the ends to the lower edge of the pattern, as shown in Fig. 43, flaring it well in order to make a good lift. Slick the whole surface over smooth. Rap and lift the pattern to test the correctness of the work.

Replace the pattern. Dust on parting sand and ram drag, tucking carefully in the pocket at each end. Roll the two over. Lift off the match, and set it to one side. The pattern will remain in the drag. Dust on parting sand. Set the runner and ram cope as described. When the mold is opened and the pattern drawn, it should be set back immediately into the match, ready for use again.

On account of economy of construction in the pattern shop, irregular shaped work is often made in one piece. The molder must then decide whether it is cheaper to cope out each joint or make up a sand match. Where the number of castings required is small, or where the pattern is large, it is better to cope out. But where a number of castings is required it is cheaper to make up a sand match.

For methods of making quantities of castings and use of a more permanent match, see section on Duplicating Castings.

In the foregoing the main use of the match was to save time. It frequently happens that a pattern is so irregular in shape that it will not lie flat on the board in any position. In this case a match is absolutely necessary before the drag can be packed. For large patterns of this kind, the cope box of the flask is used to bed the pattern into instead of a separate frame. After the drag has been packed upon it this first cope is dumped, and the box repacked with the necessary gaggers, vents, runners, etc., required for casting. The first cope is then termed, not a match, but a *false cope.*

For very light wooden patterns which may or may not have irregular parting lines, the pattern maker builds up wooden forms to support the thin wood while the drag is being packed and to give the proper joint surface to the sand. This board serves exactly the same purpose as the sand match and false cope, but it is termed a *follow board.* See Pattern Making, page 137.

So far the patterns used have been made in one piece, but a flat joint is the most economical for the molder, when many castings are required. Generally such pieces as bushings, pipe connections and symmetrical machine parts are made in halves; one piece of the pattern remaining in each part of the flask when the mold is separated. There are many cases, too, where, to make a flat joint for the mold, the pattern maker can separate one or more projections so as to have the main part of the pattern in the drag and let these loose parts lift off in the cope.

The small punch frame and the gas engine piston, shown in Fig. 44, are examples of these two classes of patterns. At A, the section through the patterns shows the methods of matching them together.

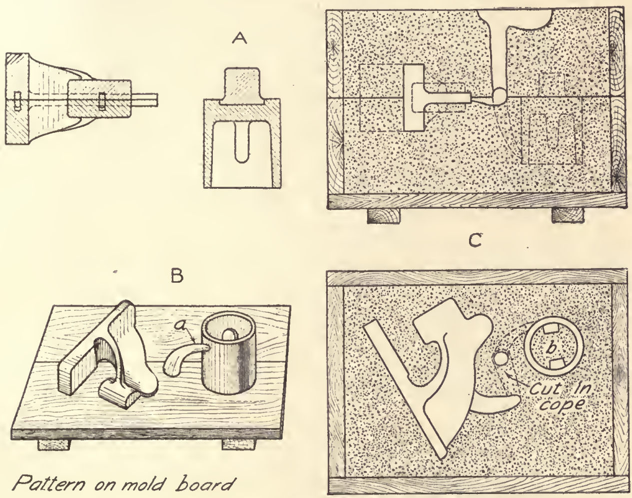

Fig. 44. Split and Loose-Piece Patterns.

B shows the drag parts of the patterns in position for molding. At C is the section through the mold and the plan of the drag showing how the gates are connected. Attention is directed to the use of the *horn sprue*—the sprue pattern is shown at *a*—by which the metal enters the mold at the bottom. If the gate were cut at the joint surface there would be danger of "cutting the sand" on top of the green sand core *b* as the metal flowed in upon it.

Some work has projections on it which lie above or below the parting line in such a way that it cannot be molded by either of the foregoing methods.

Examining the patterns for some of this work we find two entire parting lines with the pattern made to separate between the two. Such patterns require between the drag and cope an intermediate body of sand, from the top and bottom of which the two parts of the pattern may be drawn.

In small work, as illustrated by the groove pulley, this intermediate form is held in place by the sand joint of the cope and drag, and is termed a *green sand core.* A good description of the method of

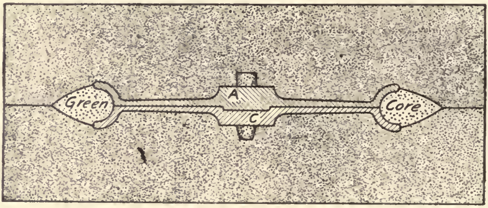

Fig. 45. Section of Mold.

molding such a piece is given in Pattern Making Part I, page 60. To provide for pouring the casting a runner should be placed on the hub of the first part packed, C. Fig. 45 shows a section of the mold before either part of the pattern has been removed. Now, when the flask is rolled over to remove the final part C of the pattern, the runner is on top ready for pouring.

Another method used does away with rolling the entire flask. A core lifting ring is first cast slightly larger in diameter than the flange of the sheave, and having a section shown in *a*, Fig. 46. The ring is set in position in the middle of the inverted *drag*, the pattern is held central inside of the ring by the recess in the mold board. Pack the drag, roll over, and remove the mold board. Tuck the green core all around and slick off the top joint of the core. Pack the cope in the usual way, lift it off, and draw the cope pattern. Now, by means of lugs cast on this lifting ring, the green core may be lifted off

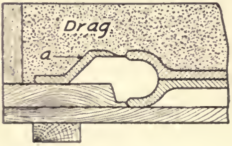

Fig. 46.

of the drag pattern, allowing it to be removed. Replace the ring, close the cope, and the mold is complete. See half-section, Fig. 47.

In larger work, where the parting planes are farther apart, this

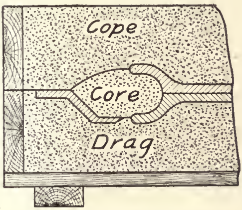

Fig. 47.

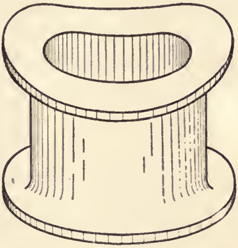

Fig. 48.

intermediate body of sand is carried in a "cheek" part to the flask, and we speak of it as three-part work.

Fig. 48 shows a casting for a 10-inch nozzle, the mold for which illustrates this class of work. Here the pattern is separated just above the fillet of the curved flange. Fig. 49 gives a view of the mold, showing the way the joint is formed.

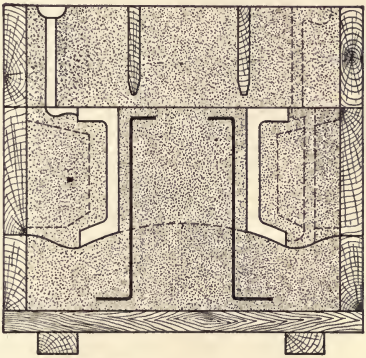

Fig. 49. Casting a Nozzle.

This casting should be made on the floor. Select a square flask 4 inches on a side, larger than the diameter of the flanges. The cheek should be as high as that part of the pattern which is molded in it. There should be two projecting bars on opposite sides of the cheek to support the sand, and crossbars in both drag and cope. These should be well wet with clay wash before using the boxes.

Set the pattern centrally inside the cheek, and place a runner stick just the height of the pattern in one corner of this box.

On account of the depth of the cheek the sand must be rammed in two courses. Sift enough facing sand into the box to cover the joint and 5 inches up around the pattern to a depth of about $1\frac{1}{4}$ inches, tucking about the pattern with the fingers. Fill in about 5 inches of loose sand and before ramming tuck around the ends of the side bars, compressing the sand between the finger tips, having a hand on each side of the bar, as illustrated in Fig. 50. Now use the peen end of the floor rammer in the same general way as the hand rammer is used in bench molding. Guide the rammer around the sides of flask and bars first, then direct it toward the bottom edges of pattern. As the sand gradually feels properly packed at this level, direct the blows higher and higher up. Proceed in this way to within about 1 inch of the drag joint. Make this joint by ramming in sifted facing sand, being careful to tuck it firmly underneath the flange. Cope this joint to the shape of the curved flange.

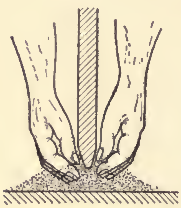

Fig. 50.

Dust on parting sand. Place the drag in position and ram it up in the usual way, only using facing sand next the joint and pattern. Place six long gaggers to strengthen the sand which forms the inside of the casting. Clamp drag to cheek and roll them over. Test, repair and sand the joint. Try the cope. The bars should clear the pattern and joint by about 1 inch. Set the cope runner about 2 inches to one side of the cheek runner and set the riser in the corner opposite. Sift on facing sand and tuck well with the fingers under the crossbars. Shovel in well-cut sand and finish packing the cope. Form a pouring basin, and vent well. Lift the cope. Draw the pattern from the cheek. Join the runners on the cope joint and connect the mold with the riser.

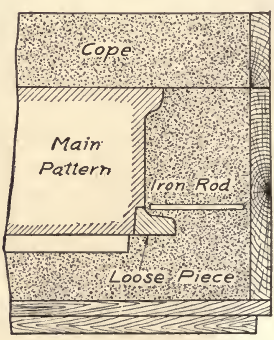

Fig. 51.

Lift the cheek and repair it. Draw the drag pattern. All of the mold surfaces should have black lead facing brushed over them with a camel's hair brush, and this facing slicked over with convenient tools. Cut a gate on the drag joint. Close the cheek on the drag Close the cope on the cheek and the mold is ready for clamping.

It often happens that bosses or projections are required on a casting at right angles to the main draft lines of the pattern and below the joint surface. Examples of such cases are shown in Pattern Mak-

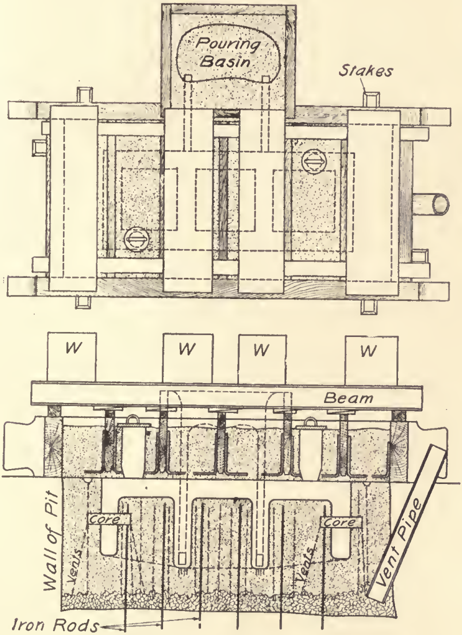

Fig. 52. Casting a Flask Section.

ing, pages 61–116. In molding such work, care must be taken that the overhanging portion of sand shall be strong enough to support itself. Where the projection is deep, the mold should be strengthened by nails or rods as shown in Fig. 51. These should be wet with clay wash and set into the sand, when the mold is rammed.

Owing to the development of the electric crane, much large work is now rammed in iron flasks and rolled over, which was formerly always bedded in the floor. This method is still much used in jobbing shops to avoid making a complete large flask.

The mold shown in Fig. 52 will illustrate the principal operations involved. The casting is a flask section for a special steel ingot mold, and in design is simply a heavy plate braced on one side by flanges and ribs of equal thickness.

For convenience in ramming between the flanges, portions of the top plate of the pattern are left loose. See Fig. 53.

Dig the pit for the mold 10 inches larger on each side than the pattern, and about 6 inches deeper. Having screened some hard cinders through a No. 2 riddle, cover the bottom of the pit with them to a depth of 3 inches. Ram these over with a butt rammer, and at one end set a piece of large gas pipe. Put a piece of waste in the top of this to prevent its getting choked with sand. Ram a 3-inch course of sand over the cinder bed and strike it off level at the depth of the pattern from the floor line. Sift facing sand over this where the pattern will rest. Set the pattern, and with a sledge, seat it on this bed until it rests level. Remove the pattern and with the fingers test the firmness of packing all over its impression.

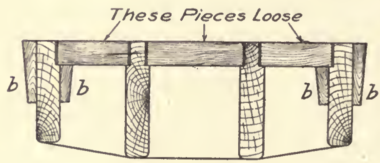

Fig. 53. Bedded-in Work.

Vent these faces through to the cinder bed, and cover the vent holes with a $\frac{1}{2}$-inch course of facing sand. Now replace the pattern, and bed it home by a few more blows of the sledge. The top of the pattern should now be level and flush with the floor line. Seat the runner sticks, and to prevent the sand on the bottom of the runners from cutting, drive 10-penny nails about $\frac{3}{4}$ inch apart into this surface until the heads are flush. Ram the outside of the mold the same as if in a flask, and strike a joint on top. Ram green sand between the inside webs of pat-

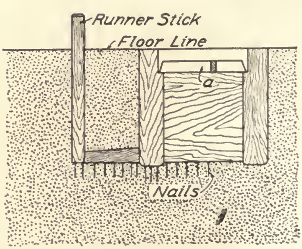

Fig. 54.

tern, and strike off at the proper height with a short stick *a*, Fig. 54. Drive long rods 3 inches apart into these piers to pass through to solid sand below the cinder bed.

Vent all around the pattern, outside and inside, through to the cinder bed. On top of the inside piers cover these vent holes with facing sand, ram and slick to finish; then cover with the loose pieces of the pattern.

Try the cope and stake it in place; set the risers and vent the plugs. Ram the cope, slicking off level for about 2 inches around the top of the risers, to receive a small iron cover.

Lift the cope, repair, and face with graphite. Draw the pattern with the crane and finish the mold. Connect the outer vent holes by a channel with the vent plug. From the end of each core print *a a a a* vent through to the cinder bed and set cores. Close the cope. Set the runner box against the side of the cope and build a pouring basin with its bottom level with the top of the risers.

In weighting, great care must be exercised not to strain the cope.

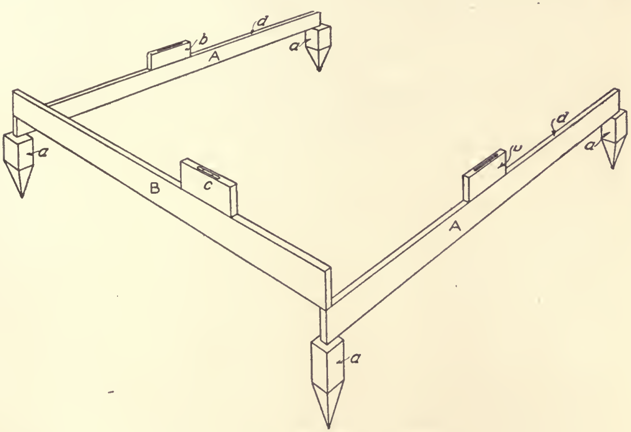

Fig. 55. Leveling a Bed for Open Sand Work.

Place blocking upon the top ends of cope. Across these lay iron beams which will be stiff enough to support the load, and pile weights on these. Now wedge under the beams to the crossbars of the cope at necessary points.

There is a large class of foundry rigging, such as loam plates, crossbars and sides to iron flasks, which may be cast in open molds. As there is no "head of metal" the beds must be rammed only hard enough to support the actual weight of the metal, or it will "boil." To insure uniform thickness in the casting, the bed must be absolutely level.

Drive four stakes, *a a a a*, and rest the guide boards A A on the top of these, as shown in Fig. 55. By using a spirit level *b b*, make these level and bring them to the same height by testing with the straight edge B.

The space between the guide boards A A should be filled with

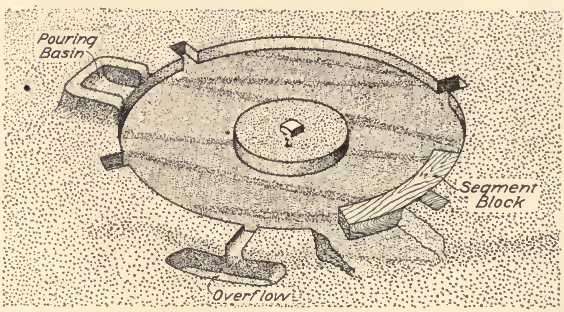

Fig. 56. Open Sand Mold.

well-cut sand even with their tops *d d*. Sift sand over the entire surface. Strike this sand off ⅜ inch higher than the guides, by placing a gagger under each end of the straight edge, as it is drawn over them. Tamp this extra sand to a level with the guides by rapping it down with the edge of the cross straight edge, and the bed will be as shown in Fig. 56. We can now proceed to build up to a segment of pattern, or with a sledge drive a pattern into this surface.

The pouring basin should drain itself at the level of the top of mold, and an overflow may be cut on one edge to drain the casting to any desired thickness.

CORE MAKING

Reference has been made in the first part of this book to the general difference between core making and green sand work.

This, and the section on sands, the reader should review carefully.

Here, as in green sand molding, the principal material used is a refractory sand. In molding sand, however, the alumina or clay forms a natural bond in the sand. To meet the necessary requirements of cores we must use a naturally free sand as a base, and give it bond by adding some form of organic matter as a binder and then bake the core.

The most common binders are as follows:

Flour: Ordinary wheat flour is an almost universal material for this purpose. Every one is familiar with the action of this material when moistened and baked.

Rosin is a hard vegetable gum—a by-product of the manufacture of turpentine. For use as a core binder it should be reduced to a powder. It melts under the heat of the oven and flows between the grains of sand and upon cooling binds them firmly together.

Linseed Oil is made from flax seed. It acts in a way similar to rosin; a small proportion of oil together with some flour makes a very strong core.

Glue, obtained from animal hoofs, and from fish stock, is also used to some extent as a core binder. It should be dissolved in water before mixing with the sand.

A weak *molasses water* is used for tempering the sand for small cores, and *clay wash* serves the same purpose on the larger work.

There are many patent combinations of the above or similar materials put on the market as core compounds. There are two classes of these: dry and liquid compounds. The advantages claimed for them is that they are more economical, (1) because a smaller proportion of the compounds is sufficient to obtain the desired results; (2) because a large proportion of the sand may be used over and over again.

Other necessary core room supplies are:

Annealed Iron Wire, No. 6 to No. 16, and round bar iron in sizes of $\frac{1}{4}$ inch, $\frac{3}{8}$ inch, $\frac{1}{2}$ inch, $\frac{5}{8}$ inch, $\frac{3}{4}$ inch. This material is cut to length as needed, and bedded in the core sand to strengthen the core, as will be demonstrated later.

A supply of clean *cinders* must be available for venting larger cores. Small wax tapers make good vents for crooked cores. There is also a patented wax vent for sale on the market.

As before stated, charcoal with some graphite is the principal *facing* material used on cores. It is always applied in liquid form by dipping the core or by using a flat brush having extra long bristles.

The general tools of the core room are similar to those already mentioned. A piece of iron rod very often replaces the regular rammer on account of the small size of the opening into which sand must be packed.

The trowel is the most com-

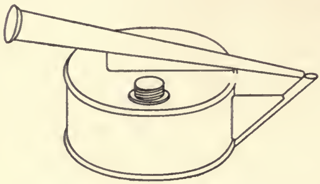

Fig. 57. Spraying Can.

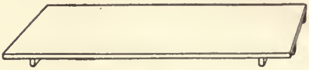

Fig. 58.

mon slick, because most of the surfaces which require slicking are flat ones formed by "striking off" after packing the box. Except in the largest work the entire face of the core is not slicked over, so a variety of small slicks is not needed.

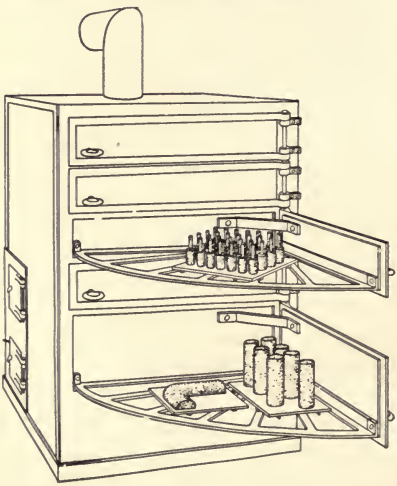

Fig. 59. Small Core Oven.

A spraying can, shown in Fig. 57, is used for spraying molasses water over small cores. Fill the can two-thirds full and blow into the mouthpiece.

Small cores are made up on a flat bench, the sand being in a small pile at the back. Larger boxes are rammed up on horses or on the floor, as is most convenient.

After being made up, cores are baked on core plates. The smaller plates are cast perfectly flat. Plates over 18 inches long are strengthened by ribs cast about 1 inch from the edge. See Fig. 58. This keeps the plate from warping and admits of its being picked up readily from a flat bench top or shelf.

Ovens are built with reference to the size of the cores to be baked. A good type of small oven is illustrated in Fig. 59. It can be run very economically with either coal or coke, and will bake cores up to 2

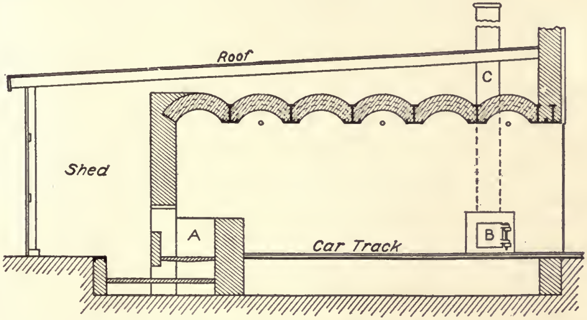

Fig. 60. Core Oven for Large Work.

inches in diameter inside of half an hour. Each shelf is fastened to its own door and when open, for receiving or removing cores, a door at the back of the shelf closes the opening. This prevents a waste of heat.

Fig. 60 shows the section through an oven suitable for the largest work, including dry sand and loam molds. The fire box A is situated in one corner at the back; its whole top opens into the oven. At the

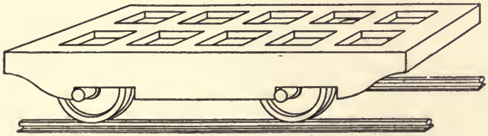
Fig. 61. Cast Iron Car.

floor level diagonally opposite is the flue B for conducting the waste heat to the stack C. The entire front of the oven may be opened by raising the sheet steel door. Two tracks side by side accommodate cars upon which heavy work is run into the oven. Fig. 61 shows a good form of cast-iron car. The wheels are designed on the roller principle to make it easier to start the car when heavily loaded.

For medium work smaller ovens of this type are used. Racks similar to the one shown in Fig. 62 may be bolted on the sides, arranged to hold the ends of the core plates; and the car may carry a line of double racks to increase the capacity of the oven.

As mentioned before, cores form those parts of a mold which will be nearly or entirely surrounded by metal. In other words, such parts as would be in danger of breaking or require too much work to construct in green sand. The object then in making cores is to make a better casting and reduce costs.

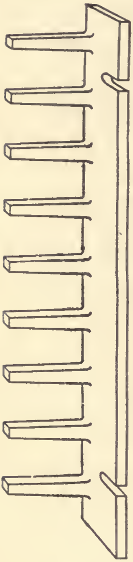

Fig. 62. Rack.

Cores are held in position by means of core prints (See Pattern Making, page 56). The main weight of the core is supported by these prints and through them all vent must be taken off and all sand removed in cleaning. Therefore cores must be stronger than green sand because whether large or small, they must stand handling while being set and must not cut or break during pouring. They require greater porosity than green sand because their vent area is limited and their composition contains more gas forming material. Furthermore, cores must lose all their bond by the time the casting is cold, so that the sand may be easily removed no matter how small the available opening.

These conditions are obtained by using a coarse free sand and a binder. To give additional strength when necessary, iron wire, or rods, or cast-iron core arbors are bedded in the core. These serve the same purpose in a core that the flask does in green sand work.

The action of the binder enables the sand to retain its shape when the box is removed, and renders the core hard and strong when baked. In the mold the intense heat of the metal gradually burns out the organic matter or "binder," leaving the core without bond. In this condition the sand may readily be removed.

Too much binder tends to make the core sag out of shape before baking, and "blow" when metal strikes it, that is, give off more gas than the vents can carry away. With too little binder the sand will not bake hard, and will "cut" when the mold is poured.

No universal mixture for core sand can be given, as sands vary so much in different localities. The following mixtures illustrate approximate proportions:

For small cores:

Beach sand	10
Flour	1

Temper with molasses water.

For large cores:

Sharp fire sand	8
Strong loamy sand	2
Flour	1½

Temper with clay wash.

For intricate smaller cores:

Beach sand	15	Beach sand	15
Fire sand	15	Molding sand	5
Rosin	2	Flour	2
Flour	1	Oil	1

Temper with molasses water.

Blacking for Light Work. One cup of molasses to a pail of water. Into this work powdered charcoal until an even black coating is deposited upon the finger when dipped into the blacking and out again.

Heavy Blacking. Use about 2 parts charcoal and 1 graphite, and mix into thick clay wash.

The effectiveness of all binders, especially flour, depends upon their thorough mixing with the sand. The especial value of rosin and oil lies in the fact that by melting under the oven heat they form a more perfect bond with the sand.

Many intricate cores are now made with an oil mixture, without using rods or wires, which formerly were considered absolutely necessary for strength.

Such cores must be well supported when green, must be thoroughly baked, and handled with much care until they are cold.

In preparing core sand the different ingredients should be measured out, thoroughly mixed and while dry, sifted. Temper the mixture a little damper than molding sand. Too much moisture will make the sand stick to the box. Not enough will make it hard to work and give a crumbly surface if dried.

In finishing small cores they should be sprayed with weak molasses water while green, then well baked and removed from the oven. When cool enough to handle, they are dipped into the blacking; then put back in the oven until this facing has dried. For large cores the blacking is applied with a brush before baking.

All cores should be baked as soon as made, for air-drying causes the surface to crumble.

Cores must not be set in a mold while they are hot, or the mold will "sweat," that is, beads of moisture will form on the inside faces. This would make the mold "blow" when poured.

A core should be rammed evenly and somewhat harder than a mold. Too hard ramming will make the sand stick in the box, besides giving trouble in casting. Too light ramming makes a weak core.

From the very nature of cores, the matter of venting them is very important and often calls for much ingenuity on the part of the core maker.

For simple straight work a good sized vent wire is run through before the box is removed. Half cores have their vents cut in each half before pasting together. Cinders are rammed in the center of large cores connecting through the prints, with the mold vents. For crooked cores, wax vents are rammed in the center—the wax melts away into the sand when the cores are baked, leaving smooth even

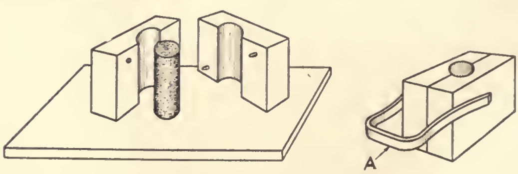

Fig. 63. Short Bolt-Hole Cores.

holes. This will be illustrated in one of the following examples.

The examples here given will serve to illustrate the principal methods used in making cores.

The simplest form of core is one which can be rammed up and baked as made by simply removing the box. Short bolt-hole cores, etc., are made in this way, as shown in Fig. 63.

Set the box on a flat bench top. Hold the two halves together by the clamp A. Ram the hole full of core sand by use of a small rod.

Slick off the top; run a good size vent wire through the middle of the core. Remove the clamp. Set the box onto the core plate, rap the sides, and carefully draw them back from the core.

Larger cylindrical cores, up to about $1\frac{1}{2}$ inches diameter, are rammed in a complete box also, only rolled out on their sides. See Fig. 64. This, however, tends to make a flat place on the side, from the weight of the sand supported on this narrow surface.

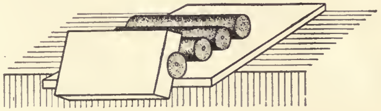

Fig. 64. Large Cylindrical Cores.

For this reason cylindrical cores of large diameter, and many symmetrical shapes, are made in half boxes. See Pattern Making, Figs. 111, 189, 194, and 200. Such boxes are rammed from the open side. Wires are bedded when necessary about in the middle of the half core. The fingers and handle of trowel are often used to ram the sand and with the blade of the trowel the sand is struck off and slicked to the level of the top of the box.

When baked, two half cores are held with their flat sides together, and any slight unevenness in the joint removed by a gentle rubbing motion. A vent channel is then scraped centrally on each half. Paste, made of flour and water, is applied around the edges and the two halves pressed firmly together; care is taken to see that they register all around. The core should then be placed in the oven to dry out the paste. When pasting cores of 6 inch diameter and over, it is well to bind the halves at each end with a single wrap of small wire.

Wherever possible, core boxes should be made with their widest opening exposed for packing the core, and designed so that the core may rest, while being baked, on the flat surface formed by striking off at this opening.

Core plates will sometimes become warped. When a core would be spoiled by resting it directly upon such a plate, the unevenness is overcome by sifting upon the plate a thin bed of molding sand and seating the core on this.

All cores cannot be made with a flat surface for baking, as illustrated by a port core, the box for which is shown in Pattern Making, Fig. 216.

This core must be rolled over on a bed of sand. Using an oil mixture, ram the core carefully, bedding into it several wax vents. These should start near the end which will touch the main cylinder core and lead out of the end which will enter the chest core. To get this crooked core on a plate for baking, a wooden frame is roughly nailed together, which is large enough to slip over the core box when the loose pieces have been drawn off of the core. See A, Fig. 65.

The space on top of the core is now filled with molding sand, rammed just enough to support the weight of the core. The edges of the frame project above the highest points of the core and form guides

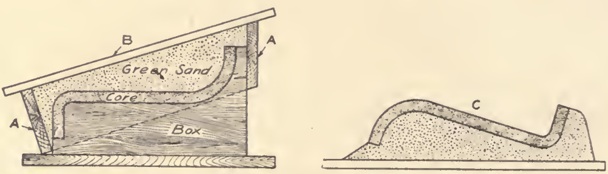

Fig. 65. Bedding a Crooked Core.

for striking off this sand and seating a core plate, as at B. Box, frame, and plate are now firmly clamped and rolled over, and the frame and box removed, leaving the core well bedded on the plate ready for the oven, as at C.

In manufacturing plants quantities of cores are often required which cannot be baked on a flat plate. To save the time and material necessary to roll each core onto a bed of sand, metal boxes are made, see Pattern Making, Figs. 227 and 228, and the core is baked in one part of the box. Only one casting is required of the larger portion of the box. The smaller part is duplicated for every core required for the day's molds.

Mention has been made of the use of wires for strengthening small cores. In making larger ones, there is a greater weight of sand to cause strain in handling the core, and proportionately greater casting strain. To resist these, a systematic network of rods is bedded in the core while being rammed, as shown in the sectional view, Fig. 66. Heavy bars *a a b b* extend the length of the core to give the main stiffness. Smaller cross rods rest on these at the bottom and top, and with the small vertical rods tie the whole core together.

At even distances from each end lifting hooks *c* are placed.

Cross rods through the lower eyes of these hooks bring all the strain of the lift on the long heavy core rods. The holes in the top of the cores where the lifting hooks are exposed, are stopped off when the core is in the mold, by moistening the sides of holes with oil and filling up with green sand.

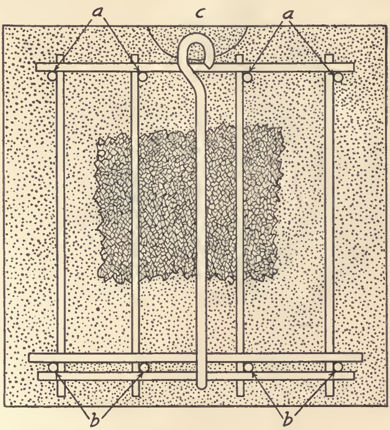

Fig. 66. Network of Rods in Core.

Cinders are packed in the middles of such cores. They aid in drying the core. They furnish good vent, and they allow the sand to give when the casting shrinks, thus relieving the strain on the metal itself.

For the largest class of cores for green sand work, cast-iron "core arbors" are used. A very satisfactory type of arbor is shown in Fig. 67. This consists of a series of light rings A carried on a cast-iron beam B. The rings are of about ½-inch metal cast in open sand and set about 8 inches on centers, and may be wedged to the beam. The beam has a hole at each end for lifting the core.

This skeleton is made up and tried in the box before the work of ramming the core is begun. It is then removed and given a coat of thick clay wash. A layer of core sand is first lightly rammed over the inside of the box, and the core arbor seated into this. The full thickness of core sand facing is then firmly rammed, and the entire center filled with well packed cinders. Vents through the facing at both ends provide for the escape of gases from these cinders.

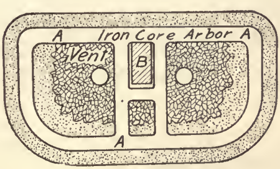

Fig. 67. Arbor.

Often, when but one or two large cores are wanted, the cost of making a box is saved by sweeping up the core. This is illustrated in the pipe core shown in Fig. 68.

The pattern maker gets out two core boards and one sweep. The boards are made by simply nailing together three thicknesses of $\frac{7}{8}$ inch stuff, with the grain of the middle piece crossing that of the others to prevent warping. The outer edges of the boards have the exact curve of the outside of the pipe pattern, and at the ends is tacked a half section of the core, shown at *a a*. One sweep does for both boards. The curve is cut the exact half section of the core The edge *b* equals the thickness of metal in the casting, and the stop *c* acts as a guide along the outer edge of the board.

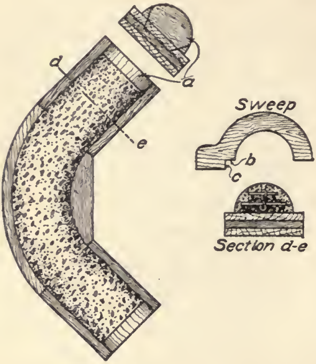

Fig. 68. Pipe Core,

In making up this core a thin layer of core sand is spread on the

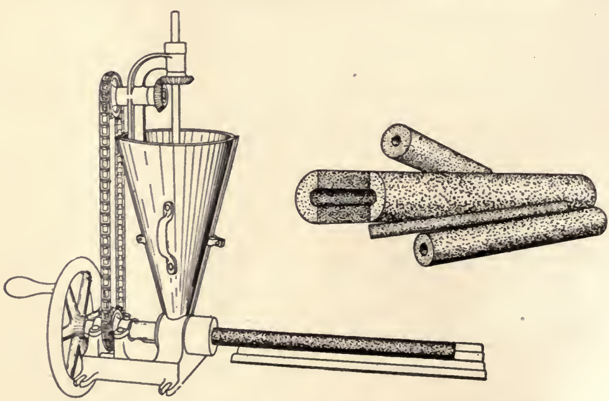

Fig. 69. Core Machine.

board and the outline of the core swept. On this the rods with their lifting hooks are bedded, and the vent cinders carefully laid along the middle. The whole general shape is then rammed up in core sand larger than required, and by using the sweep it is brought to exact size. The core is then slicked off, blackened and baked while still on the board. When both halves are dried, they are pasted together, the same as with smaller work. To prevent breaking the lower half when turning it over to paste, it is rolled over on a pile of heap sand.

For making "stock" cores, round or square, several styles of core machines have been put on the market within the last few years, of which the accompanying cut, Fig. 69, is a good representative. This is arranged to be driven by hand or by power. The core sand is placed in the hopper and by means of a horizontal worm at the bottom, it is forced through a nozzle under just the right pressure to pack the core firmly. A clean cut vent hole is left in the middle of each core. As the core is forced from the nozzle it is received on a corrugated sheet steel plate, which is moved along to the next groove when the core has run to the full length of the plate.

The advantage of the machine is that with it an apprentice boy can produce a true, smooth, perfectly vented core, in very much less time than could possibly be done by hand ramming.

SETTING CORES

The following examples show typical ways of setting and securing cores in molds and of connecting vents.

A bolt hole core, shown at A, Fig. 70, illustrates the simplest form of core to set. Only a drag print is necessary; the flat top of the core

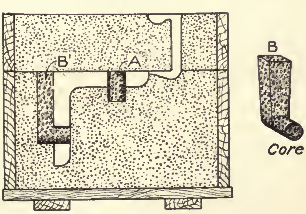

Fig. 70. Bolt-Hole Core.

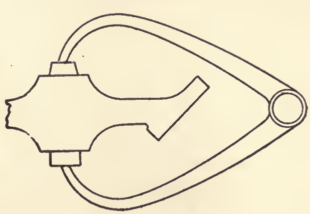

Fig. 71. Calipers.

should just touch the cope surface of the mold. The level may be tested by a straight stick or by sighting across the joint. If the core is too long, one end may be filed off a little; if too short, a little sand may be filled into the bottom of the print. For longer cores, especially hub cores, a taper print is placed on the cope side of the pattern, and the same taper is given to the end of the core; this guides it to the exact center when the mold is closed. Numerous examples are shown in Pattern Making, pages 103 to 107. The exact length of the core should be obtained from the pattern with a pair of calipers, as shown in Fig. 71. One point of the calipers should then be placed on the taper end of the core, and the print filled in or the core shortened in case of variation from the right length.

It is well to make a vent hole from the center of each print before setting the core.

With pattern and core boxes properly made, little difficulty should be experienced in setting small horizontal cores for hollow bushings, pipe connections, etc. (See Pattern Making, Figs. 111, 186 and 191.) The core must fit the print or a poor casting will result. The sand

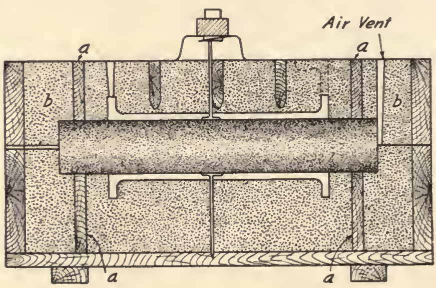

Fig. 72. Body Core, Supported.

supporting the prints must be tucked firmly enough to withstand the lifting pressure on the core. A scratch with the point of the trowel along the joint surface from the end of the print to the edge of the flask, will usually take care of the vent.

For larger cores of this character, crossbars are nailed in both drag and cope made to fit snug against the core print. See *a a a a*, Fig. 72. These hold the core absolutely firm. The spaces *b b* in the cope, are not packed until the core is set, when it is a simple matter to ram these spaces and take off an air vent directly from the center of the core.

In setting chaplets, the height of the lower one may be tested with a rule, with a straight edge rested on the prints, or by a guage similar to that shown in Fig. 73. A small boss is usually formed by pressing the trowel handle into the mold where the chaplet is to go.

The cope chaplet is not fastened until the mold is closed, then the stem can be properly wedged down under a bar clamped across the top of the mold.

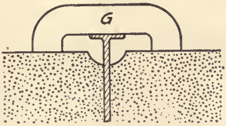

Fig. 73.

There are two methods of coring holes below the level of the joint. One is shown clearly in Fig. 74. A "stock" core is set in the bottom of the prints; a wooden template, shown at *b* and *b′*, is set over the core, and the print *a* is then packed with molding sand or "stopped off," as it is termed.

The other method is shown at B and B′, Fig. 70. Here that part of the core which will shape the hole through the casting, is formed

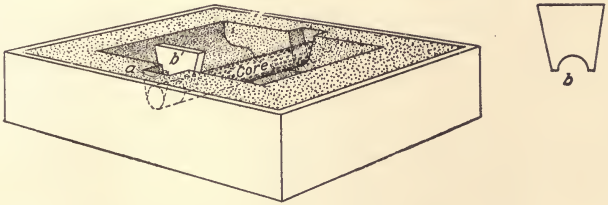

Fig. 74. Setting Core Below Surface.

on the end of a core which exactly fills the print. A single operation sets the core and stops off the print. For this reason this method is used where a large number of such holes are to be cored.

In work where a hole must project well into the casting but not all the way through it, a balanced core is often used. Such a case is illustrated by the rammer head, Fig. 75. When making this core, let the vent extend through the entire length, then stop up the vent at the small end with a bit of clay after the core is baked.

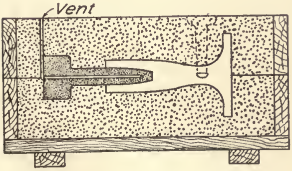

Fig. 75. Small Balanced Core.

It is not always practicable to enlarge the print as shown here, but when possible, it reduces the length of print necessary to balance the projecting end and ensures accurate depth to the hole.

Heavy projecting cores must be supported by chaplets, as illustrated in Fig. 76. Vents may be taken off through a channel and air riser as explained in the section on venting. Fig. 77 shows the shape of the print on the pattern for this mold at *a*, the pockets formed by the core are shown at *b b*, and *c* indicates the position of the gate.

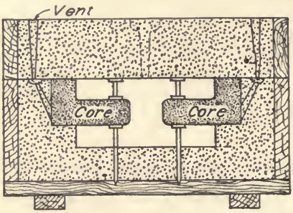

Fig. 76. Large Balanced Core.

A core is frequently used to avoid a deep lift for the cope. Suitable wire hangers, shown at *a*, Fig. 78, are bedded in the core when it is made. In setting the core small annealed wire about No. 20 or No. 24 gauge, is looped through the hangers, passed through small holes made in the cope, and fastened with a granny twist over an iron bar on top. This bar should bear on the sides of the cope and the core be brought up snug in its print by wedging under its ends. The "rigging" need only be strong enough to support the weight of the core, for the pressure of metal will force this core firmly into its print with little danger of shifting it. For heavy cores a lifting eye, as previously illustrated in Fig. 66, takes the place of the wire hanger, and the core is hung by means of a hooked rod with a nut on the end. As shown in Fig. 79, this rod passes through a long washer which bears on a pair of rails, or similar stiff rigging.

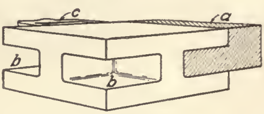

Fig. 77.

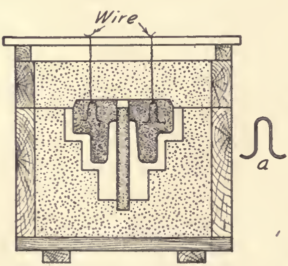

Fig. 78.

Where possible, the placing of cores in the bottom of molds should be avoided, for in this position, being much lighter than molten iron, they must be secured against a pressure tending to float or lift them.

This pressure is proportionate to their depth below the pouring basin. But the metal at the bottom of a mold is cleaner and more sound than that at the top. Therefore, planer beds, large face plates and pieces of this character, are usually cast face downward, making it necessary to anchor the T-slot cores in the bottom of the mold.

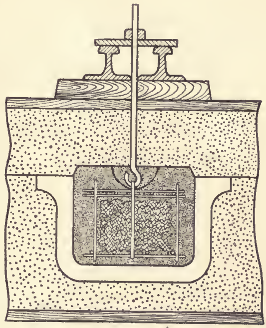

Fig. 79.

In some cases such cores may be held down by driving nails so that their heads project somewhat over the ends of the core, as shown in Fig. 80. If this method is not strong enough, pointed anchors, with a foot on one end, are run through a hole in the core, and are carefully driven into the bottom board. See Fig. 81. Where the work is bedded into the floor a plank must be set to receive these

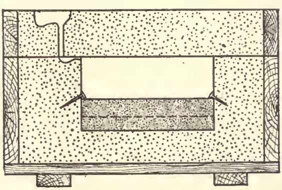

Fig. 80.

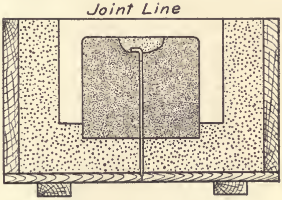

Fig. 81.

anchors just below the cinder bed. As in the case of lifting eyes, the holes in the core, into which the foot on the anchor is driven, are smeared with oil and stopped off with green sand.

DUPLICATING CASTINGS

Devising methods for increasing production and decreasing its cost is one of the important problems of modern engineering in the foundry as well as elsewhere. In the jobbing foundry where there is a great variety, not only in the patterns themselves, but in the number of castings called for from each pattern, the molder makes up a sand match as already described.

On this match he arranges such an assortment of patterns as will fill his flask and beds them into place. From a well-made sand match two or three hundred molds may be made up. When the desired number of castings is made from one pattern on the match, that one is removed and another one which will fit in its place is substituted.

For manufacturing purposes thousands of the same casting may be required calling for more durable patterns and match. Metal patterns are made and as many as can be cast in a flask are soldered to a smoothly finished metal gate pattern. With a draw screw inserted in this gate, all of the patterns may be drawn at once. Two steady-pins should be screwed and sweated into the drag side of the gate pattern. These should be of small round brass rod and project below the deepest point of the patterns. They guide the pattern as it is being drawn and prevent it from swaying and breaking the edges just as it leaves the sand. Patterns so arranged are termed "gated patterns."

When such patterns have a flat joint, a special mold board should be provided and the patterns stored on the same board. When the joint is irregular, a permanent oil match should be made. Make a strong hardwood frame the size of the flask and about 1 inch deep, with the bottom board arranged to screw on to the back. Nails should be driven into the inner sides hanging parallel to the bottom board. Measure the quantity of sand needed to fill this match. Mix thoroughly and put through a fine sieve, while dry, one-half this quantity of burnt sand, one-half new molding sand, and about one-fortieth litharge. Temper the same as molding sand, using boiled linseed oil. Ram up drag and joint the mold very carefully. Put on the match frame and ram up with the above mixture; strike off, and screw on bottom board. Remove drag and allow the match to dry for a day with the patterns left in it. A coat of shellac when dry will improve the surface. Fig. 82 shows a set of gated patterns bedded in a hard match.

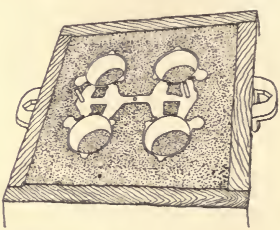
Fig. 82. Oil Match.

MOLDING MACHINES

Although there are many styles of molding machines on the market, there are practically but three separate types: Those designed to simply draw the pattern; those which only ram the flask; and those where the mechanism is arranged to perform both of these operations.

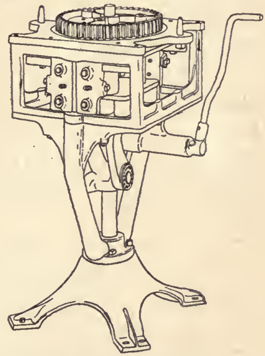

Fig. 83. Molding Machine.

Machines are used to make it possible to turn out larger quantities of small work or to simplify the production of difficult castings. The kind of machine used will vary according to the line of casting to be made. Iron flasks are used with these machines for medium weight casting, while for light work the snap flask is almost universally employed.

In Fig. 83 is shown a molding machine of the first type spoken of above. The pedestal base of the machine has a flat top. The stripping plate is supported above this by a rigid open framework. Working in guides carried on the sides of this framework is the drawing

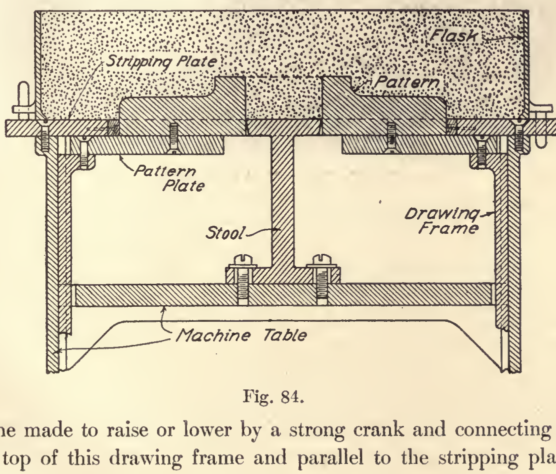

Fig. 84.

frame made to raise or lower by a strong crank and connecting rod. On top of this drawing frame and parallel to the stripping plate is screwed the plate to which the pattern is fastened. The stripping plate is cast with an opening which leaves about 1 inch clear all around the pattern. When both pattern and stripping plate are properly set in place, this space is filled with babbitt metal; this being an easy way to secure a nice fit.

In many cases there will be an interior body of sand to be supported when the pattern is drawn. To accomplish this *stools* are used. A leg screwed into the stool plate supports the stool at the exact level of the stripping plate. The *stool plate* is fastened to the flat top of the machine inside of the box-like framework which supports the stripping plate. See Fig. 84.

The gear wheel mounted in Fig. 83, would be a difficult pattern to duplicate by simple hand drawing; the machine insures a perfectly clean draw. A box is inverted on the machine, rammed, vented and

Fig. 85. Pulley Molding Machine.

struck off. A movement of the crank lever at the side draws the pattern. The mold is removed and set on a level sand floor, thus doing away with bottom boards. A second stripping plate and pattern is used for ramming the cope boxes.

Pulleys are manufactured on molding machines of this type, as shown by the equipment illustrated in Fig. 85. The rim patterns have the form of long hollow cylinders and can readily be set for any desired width of face. The hub carrying the core print separates from the spokes, lifts off in the mold and is drawn by hand. The arm patterns are so flat and smoothly rounded that the mold is easily lifted off of them with little fear of breaking the sand. Cope and drag molds are both alike for a pulley mold.

Fig. 86 shows a type of machine which only packs the sand. Here the *patterns* are carried on *two sides of a plate* set between the cope and drag. Both boxes are filled with sifted sand and set on the machine. The boards are made to slide inside of the flask. The molder's weight on the lever compresses the sand.

The sprue is cut by a thin hollow steel tube called a *sprue-cutter,* which is pressed through the cope sand by the molder before separating the flask. In separating the mold the cope is first lifted from the drag

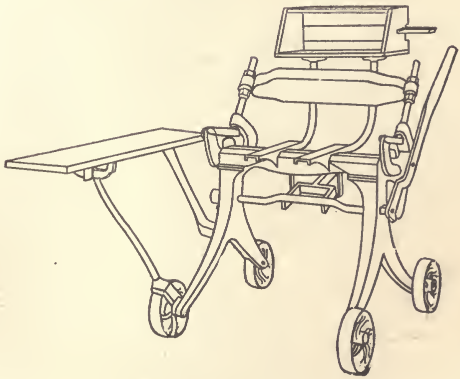

Fig. 86. Molding Machine, or Squeezer.

and the plate is gently rapped and lifted from the drag. To make a clean lift when parts of the patterns project in the cope, a second molder raps with an iron bar between the battens of the bottom board while the cope is being drawn off.

Such machines are used chiefly on thin work which will vent and solidify very rapidly—for the outer surfaces of the drag and cope are apt to be rammed so hard that they might choke the vent on heavier castings.

Fig. 87 shows the operation of the lever mechanism by which one movement draws the presser head over into place and then pulls it down to compress the sand.

With the third class of machine both hand and power are employed for the operating. A hand machine, built on the same lines as the previous example, is shown in Fig. 88. With this machine *gated patterns* are mounted on a *wooden board or hard match.* Snap flasks are used and when the size of the work will permit, both cope and drag parts are set up side by side on the same machine.

The amount of sand to be compressed is regulated by the depth of the *sand frame* which is set on top of the boxes. To avoid ramming the higher portions of the pattern too hard a thick block is fastened to the *presser head.* This block is hollowed out to conform with the shape of the patterns, as shown in the small cut. This excess is struck off before the patterns are drawn. A movement of the lift lever raises the lift table. This in turn raises four pins which pass through the corners of the pattern board, engage the edges of the flask and lift it perfectly straight off of the patterns. The end of a rapping bar may be seen under the pattern board of the cope box. With this the board is rapped while the lift is being made.

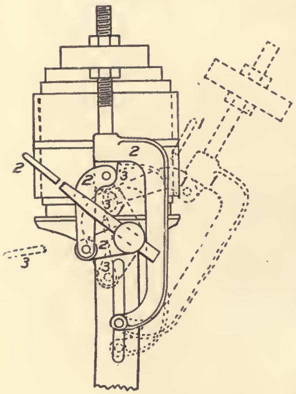

Fig. 87. Lever Mechanism.

Compressed air, steam, and in some styles, power transmitted by belting, are used for operating many molding machines. Compressed air is, however, more frequently met with. Fig. 89 shows a modern machine. The sizes range from 14 x 20 inches to 40 x 90 inches.

In operation the facing sand is tucked by hand, and the flask and sand frame filled. The presser head is swung forward but remains stationary, and the whole machine table, bearing patterns and flask are forced upward against it, by means of a cylinder underneath the center of the machine. Two or three blows are given as if by a steam hammer.

Either a stripping plate, pattern board, or pattern plate is used. As a substitute for rapping the patterns a small pair of cylinders is attached to the frame which carries them. These cylinders contain a small piston which is driven back and forth very rapidly, giving a trembling motion to the patterns. This attachment is called a pneumatic vibrator.

A rubber tube with a nozzle is conveniently attached to the compressed air pipe and provides a ready means for the molder to blow his mold clean. The force of this air is regulated by a spring valve attached to the nozzle.

On the large machines all operations, even to the swinging of the

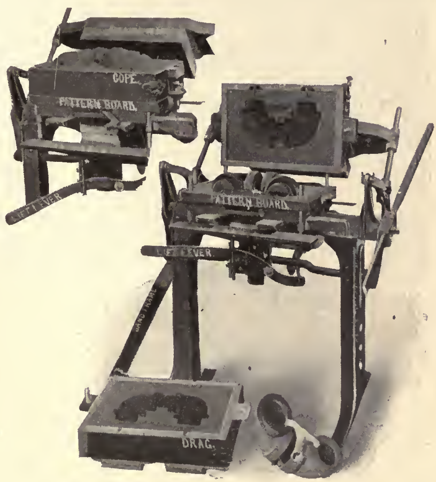

Fig. 88. Squeezer, with Device for Drawing Patterns.

presser head, are accomplished by compressed air, controlled by a few conveniently placed levers.

The advantage of molding machines lies in the fact that they can be operated with practically unskilled labor, because there is no skill required in drawing the pattern, in repairing the mold, or in gating, and in many, none required in packing the flask. All of these are points which ordinarily call for sound judgment and a high degree of skill on the part of the molder. The limitation of the simple squeezer due to hard surface ramming, has been mentioned.

The tendency of molding machine practice in the jobbing shops is toward a hand-rammed, stripping-plate machine, because the jobs may be changed quickly and the more intricate patterns can be rammed just right. The great expense of metal patterns and stripping plate

Fig. 89. Molding Machine. (Rams by Power and Draws Patterns Automatically.)

is being overcome by the use of ordinary wooden patterns and a stripping plate made of well-seasoned oak, which has been boiled in paraffin to prevent it from warping.

DRY SAND WORK

This branch of molding becomes a separate trade in shops where the work is done continually. The dry sand molder must use the same precautions as the green sand molder in setting gates, risers, and fastening his sand with crossbars and gagers. At the same time he works with a core sand mixture next his patterns and backs this with a coarse molding sand. So that he must combine the skill and judgment of both green sand molder and core maker. The venting of dry sand work must be ample as in the case of cores, but it is simpler than in core work, because the core mixture surrounds the casting so that vents may be taken off in all directions.

Iron flasks are used, generally provided with trunnions to facilitate turning. The facing mixture is the same as that used for making large cores. See Core Making. The remainder of the flask is packed with the same sand after it has been used. The patterns are made and used the same as with green sand, only they should be brushed over with linseed, crude-oil or other heavy oil before ramming. In some shops oil is brushed over the joint before parting sand is thrown on. After the pattern is drawn, the mold is finished by applying a heavy coat of good black wash. When the sand has absorbed the moisture so that all glisten has disappeared, this blacking is slicked over. Great care must be exercised in this operation, for too much slicking will draw the moisture to the surface again and result in scabs on the casting.

Engine cylinders are a representative line of work for dry sand. Consider the simple type of cylinder shown in Pattern Making, page

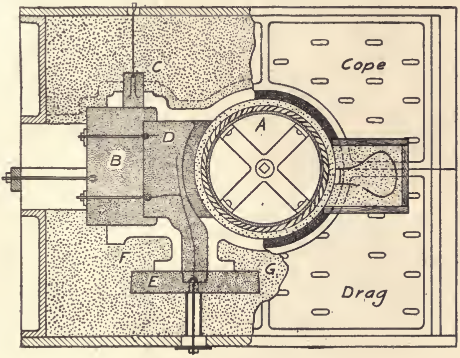

Fig. 90. Molding a Cylinder.

115, to have a bore of from 16 to 26 inches with the exhaust-outlet flange placed above the center of the cylinder. To facilitate setting the cores the pattern will be split through the steam chest. The flange just mentioned will be molded in the drag; it should be made loose and draw in the opposite direction from the main pattern. The cylinder core will be made on a "barrel" (explained later on page 67) and the mold poured on end to insure sound metal and to reduce the casting strain on the port cores. The flask is made with a round opening in one end to allow the core to project through it. This opening is larger than the diameter of the core to allow for gates and risers. There must be another opening at the side of the flask opposite the steam chest core to provide for fastening these cores. Iron plates serve for flask boards and there should be a hole in the drag plate opposite the exhaust core to allow for venting and fastening its end.

One half of Fig. 90 shows the end view of the flask. The other half shows a section through the middle of the completed mold. Here A is the hollow cylinder core, B is the chest core, C the live steam core hung in the cope, D the exhaust core. The flask is packed in a manner similar to green sand. The method of molding the exhaust flange, however, has not previously been explained. To do this, proceed

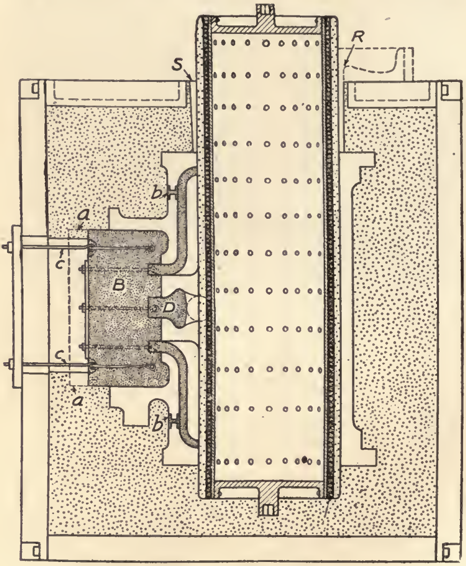

Fig. 91. Plan on Drag.

packing the drag until the pattern is covered. Tuck the facing carefully underneath the flange, setting in rods as in core work, to strengthen the overhanging portions. Make a flat joint, F G, at the level of the top of the flange, then carefully fit over the print of the flange the cover core, E, and fix its position with nails driven into the joint at its corners. Now remove the cover core, draw the flange and finish that part of the mold with black wash and slicking. When this is accomplished, replace the cover core, place a short piece of pipe over its central vent, and finish ramming the drag. This method may be used in many cases, both in dry sand and green sand work where a small detail of the casting requires a separate joint surface.

A sectional plan looking down on the drag is shown in Fig. 91. When the mold has been properly finished and baked, the drag is brought from the oven and set on a pair of stout horses. The cylinder core is first set in place, then the exhaust core is set in its drag print and held close to the cylinder core, while the port and chest cores, previously pasted and fastened, are lowered into the chest print. The chest print is cut a little long at *a a*, to allow its core to be drawn back slightly while the exhaust core is entered into its place between the port cores. Then all of the cores are set forward into position, the chaplets *b b* set, the space *a a* tightly packed again, and the anchor bolts *c c* placed in position and made fast. The drag print of the exhaust core is made fast from underneath the drag plate. When all the cores have been firmly fastened, the cope is closed on, the two boxes clamped at the flanges, and set up on end. The runner R and the riser S were cut and finished before baking; the basins must be built in green sand after the mold is closed.

MAKING A BARREL CORE

Loam is used here for the outer shell of the core. It is probably the simplest job in which a loam mixture is employed, and is made by a core maker more frequently than by the higher paid loam molder. Barrel cores are used where the core is long and can best be supported at the ends only; for example, in gas and water pipes and cylinder work.

Loam is a facing mixture, of the consistency of mortar, applied to the face of the core or mold. It contains fire sand with a bond of strong porous molding sand moistened with a thick clay wash. A small proportion of organic matter in the shape of horse manure is put in to aid the bond and to leave the crust of loam more fragile by burning out as the casting cools. Proportions of the mixture will vary according to locality, but the principles already cited hold here as with other molding compounds. With too much bond the loam works easier but tends to choke the vents when casting. With not enough it will be weak and liable to break, cut or crumble under strain. A typical mixture is as follows:

	Mixed by Hand	Mixed by Mill
Fire sand	10 parts	10 parts
Strong coarse molding sand	4 "	3 "
Horse manure	1½ "	2 "

Wet with thick clay wash.

The advantages of loam cores are that they are lighter, cheaper to make, and carry off the gases faster than do dry sand cores.

The method of making barrel cores is as follows: A piece of pipe about three inches smaller than the outside diameter of the core is selected to form the center. The pipe is perforated with a large number of holes. If the pipe is more than three or four inches in diameter, centers or trunnions are riveted in the ends to serve as bearings. The pipe is arranged to revolve freely on a pair of iron horses, as shown in Fig. 92. A crank handle is attached by which the pipe may be turned. A couple of wraps of hay rope are first given around one end of the pipe and the loose end pinned flat by a nail run under these strands. Tight wrapping is then continued to the other end of the pipe where the rope is fastened in a similar manner and cut off. Hay rope should be made of long wisps tightly twisted. Sizes vary from ¾ to 1 inch. Where only a small amount of hay rope is used, it is bought ready made. Foundries using large quantities are equipped with one or more machines built especially for making this rope.

The first coat of loam is rubbed on with the hands, then well pressed in with the flat side of a board as the barrel is slowly revolved. When this has set, the core board, A, is placed in position, and the roughing coat worked on to the core to within about ¼ inch of finished size. The core is now dried in the oven. Placing the core again on the standards, the finishing coat of "slip" is applied with the core board while the core is still hot. The diameter is tested with calipers and brought to required size by slight adjustment of sweep board A. When the core has been built to size, move the loam back from the edge of board A, then withdraw the board while the "barrel" is still in motion.

Slip or *skinning loam* is made by thinning regular loam as it is rubbed through a No. 8 sieve. The heat of the core is usually sufficient to dry this slip coat enough so that black wash may be brushed on and slicked, as in dry sand work, before running the core into the oven again for its final baking.

The service of the hay rope on a barrel core is twofold. It furnishes a surface over the smooth metal of the barrel to which loam

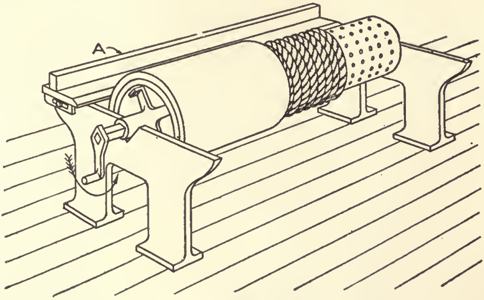

Fig. 92. Making Loam Core for Cylinder.

will adhere; and it is elastic enough to give as the casting shrinks around the core. The hay slowly burns out after the casting has set, and this frees the barrel so that it can easily be withdrawn and used again.

EXAMINATION PAPER.

FOUNDRY WORK.

PART I.

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 you understand the subject.*

1. Why is facing used on a mold?
2. What is the practical way to test the temper of molding sand?
3. What are chaplets?
4. What three forms of gases must be carried off by venting?
5. What is a skimming gate?
6. What are the properties of a good molding sand?
7. When making a large core what provision is made for handling it after baking?
8. How should a deep mold of heavy section be gated?
9. How are molds for pulleys usually gated?
10. What are risers?
11. What is the effect on the casting of ramming the mold too hard?
12. Name two means used to support the sand in the cope of a mold?
13. What are the common forms of chaplets?
14. How are the sides of deep molds vented when a flask is used?
15. What is the upward pressure on a cope where the exposed surface is 2 feet square and the depth 19 inches?
16. Why is blacking used on a core?
17. How are molds secured before pouring?
18. What are gaggers?
19. What precautions are taken in venting the sides and bottom of work which is bedded in the floor?
20. Name three important objects sought in venting a mold.

21. What size of runner is good on bench work?

22. What is the object in using a sand match?

23. Where are gaggers most commonly used?

24. What precaution is taken with sand coming next the pattern?

25. What is the danger resulting from too soft ramming?

26. How are bench molds vented?

27. How does a skimming gate act in keeping impurities out of a mold?

28. How should thin work be gated?

29. What is the object in feeding castings?

30. Why is hay rope used on loam or barrel cores.

31. How are small patterns arranged when quantities of the same piece must be put up by hand?

32. What operations are done on the three ordinary classes of molding machines?

33. How are molding machine patterns drawn?

34. How is the vent taken from the ends of long cores?

35. How are the cores for pockets or deep recesses in a casting supported in a mold?

36. Give two methods of coring holes through a casting at a level below the joint line.

37. How are cores hung in the cope?

38. How may a warped core plate be used for baking a flat core?

39. What are the advantages of using a machine to make stock cores?

40. How are irregular shaped cores like port cores baked?

After completing the work, add and sign the following statement.

I hereby certify that the above work is entirely my own.

(Signed)