A TEXT-BOOK

OF

ELEMENTARY FOUNDRY PRACTICE

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A TEXT-BOOK

OF

ELEMENTARY FOUNDRY PRACTICE

FOR THE USE OF STUDENTS IN COLLEGES
AND SECONDARY SCHOOLS

BY

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PREFACE

In offering this book to the public, the author would state that upon taking up the work of teaching foundry practice to boys in secondary schools, he was confronted with the great lack of literature on the subject, there being very little of an elementary character suitable for use as a text or a reference work.

He has therefore tried to select matter — not too difficult for high school pupils and at the same time sufficiently advanced for the college student — such as will bring out the largest number of principles used in the molder's art; and he has endeavored to make everything so plain and practical that even without the direction of an instructor the student can put the patterns into the sand and achieve good results.

The patterns chosen may be easily obtained; moreover, as each pattern brings out one or more distinct principles, a student who has completed this course ought to be able, without further instruction, to produce satisfactory results with any reasonable pattern. Several supplementary exercises should be given to test the grasp of the principles. The author is fully aware that a great deal of work found in ordinary foundries and involving many principles has been omitted, but this has been done only after due consideration of all things involved and discussion with able educators.

It is hoped that the ideas herein presented will be of as much value to others engaged in the profession as they have been to the author. He freely acknowledges his indebtedness to various books and periodicals for ideas received therefrom.

He is especially indebted to the authors of the following books: *American Foundry Practice* by West, *Foundry Practice* by Tate and Stone, *Foundry Work* by Stimpson, *General Foundry Practice* by McWilliams and Longair, *Pattern Making and Foundry Practice* by L. H. Hand, and *Pattern Making* by S. E. Ritchey.

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INTRODUCTORY

Definition. — Foundry practice consists in making sand molds and filling them with metal in a liquid form, which hardens into what are called castings.

These castings may be placed into three classes, each having distinct physical properties; such as Strength, Toughness, Durability, etc. These are, —

- Gray Iron
- Alloys
  - Brass
  - Bronze
  - Bell Metal, etc.
- Mild Steel.[1]

With special treatment in the mold or after removal therefrom, two other forms of iron castings can be obtained; namely, Chilled and Malleable.

Molding is the making of the molds and the cores used in these molds, and is divided into four branches:

1. Green-sand Work
2. Core Work
3. Dry-sand Work
4. Loam Work[1]

Green-sand Molding. — This consists in ramming moistened molding sand about a pattern in a flask, the impression of the pattern being retained in the sand when it is withdrawn. This impression is then filled with molten metal, and the casting results. Because of its cheapness and quickness, green-sand molding is the most common method of making castings.

[1] Not treated in this work.

Core Making. — This consists in shaping by means of a core box (wooden mold) a mixture of core sand and some binding material, and baking the mixture. Cores are used to form holes or cavities in castings.

Dry-sand Molding. — Dry-sand molding consists in making an impression of the pattern by packing a core-sand mixture about it in a flask, and baking the sand after removing the pattern. The baking drives off all of the moisture, leaving a hard, clean surface. It is used where rush or bulk of metal would be likely to spoil a green-sand mold.

Loam Work. — This consists in building a mold of bricks on which a facing of mortar is placed. This mortar is shaped by means of sweeps or patterns, after which the entire mold is baked. Loam work is used for very heavy classes of work, or where so few pieces are required that it would not pay to make ordinary patterns.

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CHAPTER I

MATERIALS

The materials used in the foundry for making molds are:

- Sands
  - Molding
    - Light
    - Medium
    - Heavy
  - Free sands
    - Sharp or river
    - Beach sand
- Loam
- Facings
  - Graphite
  - Charcoal
  - Sea coal
  - Talc
- Miscellaneous
  - Fire clay
  - Parting dust
    - Burnt sand
    - Charcoal
    - Manufactured preparations
    - Sand
      - River
      - Beach
  - Core binders
    - Flour
    - Rosin
    - Linseed oil
    - Glue, etc.

SANDS

Sands are the result of the breaking up of rocks by weather and the action of water. Rain water lodged in the cracks and crevices of rocks, when frozen in cold weather, will cause parts of the rock to break off. These parts are carried by the rush of rain water down the mountain sides to the rivers, where they are rolled and broken and worn away, to the size we call sand. As the current of the river grows less rapid, its carrying power becomes less. The heavier grains settle first, so that we find gravel or coarse sand, then fine sand, and next a sand and clay mixture, with the clay gradually increasing until the sand disappears and clay only is found.

Our rocks have very complex compositions. Since our sand contains nearly all of the elements of the rock, it is also quite complex.

Molding Sands

The material which is used in making the molds in the foundry must be porous enough to allow the escape of the air and the steam and gas generated by the heat of the metal poured, and yet at the same time compact enough to hold the liquid metal. It must be refractory, — that is, able to stand very high temperature, — and it must not produce any chemical action with the metal at this temperature. It must be readily removed from the casting, and leave a clean, smooth surface.

Sand most nearly fulfills these conditions, as it has no chemical action with hot iron; it allows the gases to pass off readily, and at the same time compacts hard enough to retain the molten metal and conform to the pattern.

Selection. — It is very important that a proper sand be selected for the class of work to be done, for upon this the success of the casting largely depends.

Molding sand used in making molds for cast iron is composed chiefly of silica (sand), magnesium, aluminum (clay), lime, and some metallic oxides. The proportion in which these substances vary, or, occasionally, the presence of some other substances, determines the quality and use of the sand.

There is little to aid the beginner in selecting a molding sand or in applying it to its proper use. This either must be left to some one experienced in the use of sand or must be determined by chemical analysis.

To be refractory, a sand must contain a large amount of silica; if, however, it has more than a certain per cent, the sand cracks in drying, is not impervious to the liquid metal, and is not compactable, because of the lack of cohesion. The alumina and magnesia are important factors in molding sand, as they render it plastic and cohesive. Since magnesia binds the sand very thoroughly together, the amount contained in the sand should be small, else the porosity will be lost. Alumina has a tendency to vitrify at the temperature of molten iron, therefore the amount must be small. Iron acts in the same way as alumina and is beneficial as long as the total amount of iron and alumina is small. Both metallic oxides and lime are harmful. The metallic oxides must not exceed 4 per cent nor the lime 1 per cent.

Thus it can be seen that a good sand should contain silica with a little alumina, and that a small amount of iron and magnesium does no harm when the whole is so proportioned as to fulfill the following requirements:

1st. A free passage of air, gas, and steam;

2d. Withstanding the heat of the metal without fusing;

3d. Easy separation from the cold casting, giving a smooth, clean surface;

4th. Sufficient compactness to resist the pressure of the metal.

To be serviceable a sand must answer the foregoing requirements. It is obvious, however, that one grade of sand will not do for both very light and very heavy work, because the heat is so much greater with a large casting than with a small one. Also, a large casting need not be so smooth as a small one. With the small casting, a sand of fine grain is needed, containing a little more alumina than the coarser-grained sand required for heavy castings; and since the heat is less, the sand need not be so refractory, and may therefore contain less silica and more alumina, as there is less need of venting. The reverse is true in the case of heavy castings.

Grades. — This difference in work, or in the size and weight of castings, then, gives rise to three general grades of molding sands: (1) light, (2) medium, and (3) heavy. The light sand is used on small work that has fine details, such as that found on stoves. The medium sand is used when the castings range in weight from a few pounds to one or two hundred. The heavy sand is suitable for large work, such as heavy machinery and engines. There is no hard and fast rule determining the chemical analysis and the size of the grain in these grades of sand; still, the following will serve to indicate in general the amount of silica and alumina each grade should contain.

1. Light Molding Sand:[1]

Silica	82 per cent
Alumina	10 per cent
Degree of fineness	85

2. Medium:

Silica	85 per cent
Alumina	8 per cent
Degree of fineness	66

3. Heavy:

Silica	88 per cent
Alumina	6 per cent
Degree of fineness	46

Sand for brass (very fine):

Silica	78 per cent
Alumina	8 per cent
Iron	5 per cent
Degree of fineness	95

The degree of fineness is determined as follows: "An average sample of the sand is passed over five different mesh sieves, ranging from a 20 mesh up to 100 mesh to the inch.

[1] See the complete analysis in the Appendix.

The percentage passing through each sieve is used in the determination for fineness. By adding together the amounts that passed through each different sieve and dividing this by 5, the number of sieves used, one gets the average per cent that passed through all the sieves, which number is used to designate the grade of sand," or the degree of fineness. For example, the amount of a certain sand passing through the different sieves is as follows:[1]

	Per Cent
20 mesh	96.08
40 mesh	72.60
60 mesh	26.77
80 mesh	21.05
100 mesh	15.40

231.90 ÷ 5 = 46.38 = degree of fineness.
This is a coarse or heavy sand.

Free Sands

Free sands are sands having little or no clay mixed with them. There are two kinds: sharp, or river, and beach sand. The sharp or river sand has sharp, angular grains, and the beach has round grains. Both are used in core and daubing mixtures and for parting sand. The sharp sand is better for the core and daubing mixtures, because the angular grains interlock with one another, making a strong mixture.

Core Sands. — Free sand, rock sand, and the débris of abraded rock are employed in making cores. Since a core is almost entirely surrounded by the hot metal, it must be refractory and contain no alumina, as the alumina would cause the cores to cake and be hard to remove from the casting. It should also be free from gypsum and salt.

Parting sand is used on a mold at the joint, or place where the parts of the mold are to separate, to prevent them from sticking to each other. It should have a uniform, fine grain and should be free from any substance that draws or retains moisture. Rat-

[1] *A Treatise on Molding Sand.* Trade publication of H. S. Vrooman.

tler dust (burnt sand shaken from the castings in a rattler), brick dust, and pulverized blast-furnace slag make the best partings, though charcoal is sometimes used when a very close joint is desired for brass work.

Facing sand consists of the ordinary molding sand with a per cent of coal dust or other facing material added to it, and thoroughly mixed and tempered,[1] so that the mixture has the proper cohesion to retain the form of the pattern against the washing action of the metal when the mold is being filled. For economy this sand is riddled next to the pattern and the balance of the flask filled with the old sand from the foundry floor.

Loam is a soil chiefly composed of siliceous sand, clay, and carbonate of lime, with some oxide of iron, magnesia, and various other salts, and also with decayed animal and vegetable matter. It is, next to molding sand, the most important material used in the foundry. Loam will part with its combined water at a red heat, and at the temperature of molten iron that containing carbonate of lime will fuse and become vitrified. Loam containing iron, alumina, and silica is refractory, and therefore desirable, while that containing pyrites, lime, and alkalies is objectionable. When more than 5 per cent of lime is present in the loam, it should be rejected. When flint pebbles are present, they should be picked out before the loam is ground in a mill.

Black loam is a cheap loam having strong binding properties which make it suitable for mortar for setting the brick work, in loam molding, for the first coating of round cores, which must be strong, and for sealing cracks.

FACINGS

A facing is a material incorporated with the sand, which is riddled next to the pattern or is dusted over the sand after the pattern has been removed.

[1] Method of mixing and tempering described in Chapter III.

The purposes of a facing are :

1st. To prevent the sand in the mold from being burned ;
2d. To make castings peel,— that is, to leave the sand clean ;
3d. To make the castings smooth and bright ;
4th. To reduce the expense of cleaning the castings.

These results are accomplished in two ways :

1st. By filling the pores between the grains, a smooth surface is given to the sand ;
2d. By burning slowly, owing to the heat of the metal, a thin film of gas is maintained between the iron and the sand. This film prevents the burning out of the alumina and the consequent roughness of the casting.

To accomplish these results the following precautions should be observed :

1st. The facings must be finely ground;
2d. They must not burn easily;
3d. They must adhere firmly to the face of the mold, to prevent them from being washed away by the iron.

The materials used for facings are the different forms of carbon ; such as sea coal or gas coal, graphite, charcoal, and coke. They are used because they will glow and give off gases but will not melt. The form in which the raw facing materials are obtained makes it necessary that they be ground by passing them through a series of crushers, or grinders ; the finest are then bolted.

Sea coal facing is made by grinding screenings of an ordinarily good grade of soft or gas coal, — one that is free from slate and low in sulphur.

Graphite is a soft, greasy, mineral form of carbon taken from the earth in large lumps that are much blacker than coal. Large amounts are mined in Rhode Island and other parts of North America, but the best and purest is imported from Ceylon.

Charcoal is a vegetable form of carbon made by charring or driving off the volatile constituents of wood by means of fire, in kilns or in heaps covered with dirt and sod. Either hard or soft wood charcoal is used for facings.

Coke is the carbonaceous matter left after driving off the gases from soft coal by heat, in a retort or oven. The coal must be very free from earthy materials, so that the amount of impurities introduced into the sand with the facing shall be as small as possible.

Talc is a magnesium silicate ore. It makes a good facing for some classes of work when very finely ground and shaken into the mold from a bag. It also makes a good core wash.

Blacking is a mixture of a facing, usually charcoal or graphite, and a clay wash or molasses water.[1]

MISCELLANEOUS MATERIALS

Fire clay is almost pure oxide of alumina. It comes from the same sources as sand, but is found in a lower stratum, having been washed away from the sand by water. It can be mixed with water and molded into almost any desired shape, and when exposed to the fire, it hardens into a very refractory, brick-like substance. It therefore serves very well as a lining where heat is to be resisted, and in daubing mixtures and clay washes.

Clay wash is fire clay mixed with water to such a consistency that it will leave a film of clay on an object when dipped into it. It is used as a base for blackings, wetting crossbars of flasks, gaggers, and in any place where a strong bond is required.

Core binders are materials used to stick or bind the grains of sand together in making cores, such as flour, rosin, linseed oil, etc. These materials are taken up in detail in Chapter VII.

Manufactured Preparations. — All foundry supply houses have specially manufactured or prepared parting sands, core binders, facing mixtures, daubing mixtures, and the like.

[1] See Chapter VII.

CHAPTER II

TOOLS

In performing the exercises taken up in this work only hand tools are used, and only such will here be described. They will as nearly as possible be taken up in the order in which they are required for use in the molder's hands.

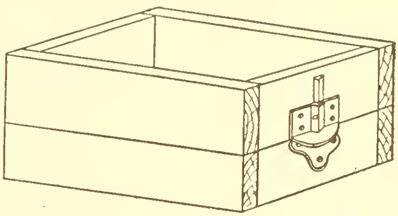


Fig. 1.

Small work is usually done on a bench or bracket projecting from the wall. Large work requires that it be done on the floor. (The author is rather partial to floor work and requires the greater portion of the work to be done on the floor, whether it is large or small.)

Flasks. — Flasks consist of two or more frames of exactly the same length and breadth, though the heights may vary. The frames are used to hold the sand while the impression of the pattern is being made.

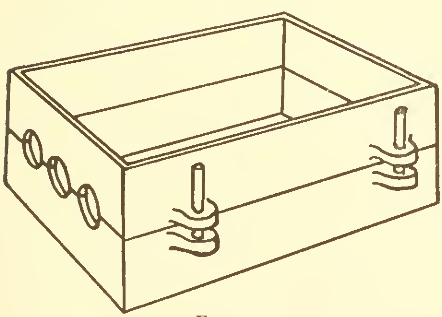


Fig. 2.

The frames are made of either wood (Fig. 1), iron (Fig. 2), or pressed steel (Fig. 3). Iron and steel flasks are much stronger and are used where a special class of work is done. Wooden flasks are used in jobbing shops, as they are much cheaper. They deteriorate very rapidly, however, and so need much care in handling.

They should be thoroughly inspected before use. The pressed steel flask (Fig. 3) is the most serviceable for school use, being light and strong and of reasonable cost.

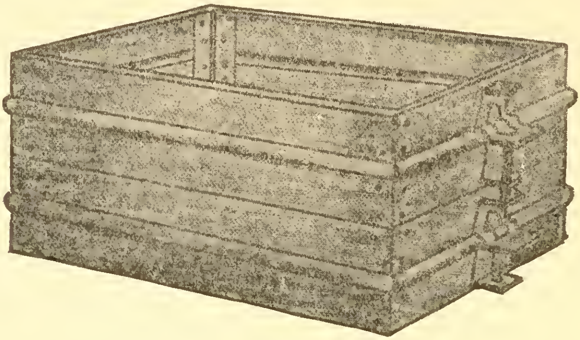


Fig. 3.

The parts are held together in the same relative position by guide pins and sockets. The pins are in the top part, called cope; the sockets are in the bottom and middle parts. The bottom part is called the nowel, or drag, and the middle part, the cheek. When a flask has but a cope and a drag, it is called a two-part flask; when it has three parts, a three-part flask; and so on.

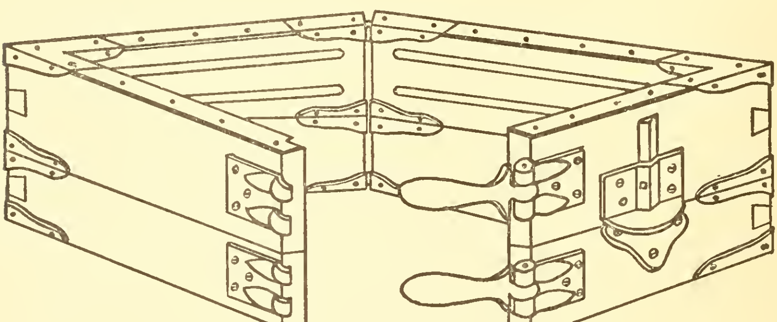


Fig. 4.

A flask may be ordinary, as shown in Fig. 1, or a snap flask; *i.e.* one having hinges on one corner and latches on the opposite corner, as shown in Fig. 4. Snap flasks are used for small work when the pressure of metal on the sides of the mold is not great. They range in size from $9'' \times 12''$ to $18'' \times 20''$. The advantage of a snap flask lies in the fact that when a mold is made up, the flask can be removed and used again immediately. The ordinary flask cannot be removed until after the metal is poured.

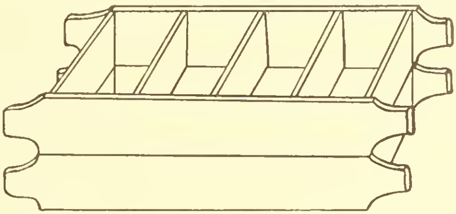


Fig. 5.

Large flasks usually have crossbars in the copes to help hold the sand while the copes are being removed. A flask with crossbars is shown in Fig. 5. The number and size of flasks that a school should have depend entirely on the quantity and size of the work done. Good results can be obtained if there is one $10'' \times 12'' \times 3''$ two-part steel flask for each student, and aside from these for general use three or four two-part snap flasks of each of the smaller sizes, and three three-part snap flasks of a suitable size for the grooved pulley, Ex. 11. Ordinary flasks, like Fig. 1, can be made in any school wood shop as a regular exercise.

Slip Case. — A slip case (Fig. 6) is a frame which is slipped around the sand, after the snap flask has been re-

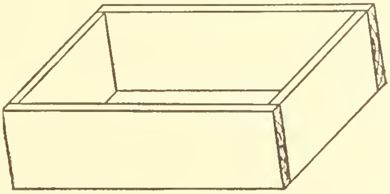


Fig. 6.

moved, to protect the mold until the metal has been poured. There should be about three cases for each snap flask.

Moldboard or follow board (Fig. 7) is a board the size of the outside dimensions of the flask, and strengthened by stiff cleats. The drag and pattern are placed upon this board in making up a mold.

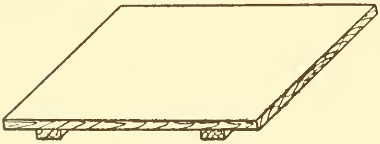


Fig. 7.

Bottom Board.—This is a board similar to the moldboard. The mold rests upon this board until poured. A school should be supplied with one moldboard and two or three bottom boards for each flask.

Riddle (Fig. 8) is used to sift the sand that comes next to the pattern. It should be 16 to 18 inches in diameter with oak rims and galvanized iron wire cloth, No. 8–12.

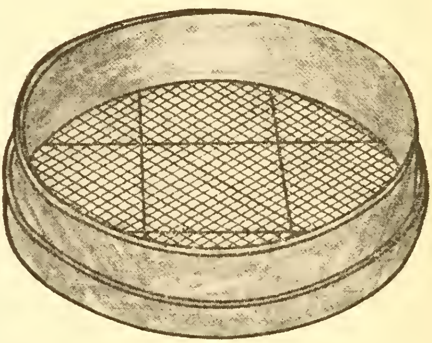


Fig. 8.

Shovel.— In the foundry the flat-bladed shovel (Fig. 9) is used for cutting, turning, and in general for handling the sand. The flat blade is best since it is often desirable to let the sand slide off from the side of the shovel when working on a bench.

Rammers (Fig. 10) are used for tamping or ramming the sand in the flasks. There are two kinds, — bench rammers and floor rammers.

The bench rammer is short and made of wood, while the floor rammer has cast iron ends on a wooden bar about three and a half feet long. In foundries where a great deal of large work is done, and where compressed air is to be had, pneumatic rammers are sometimes used. One end of the rammer is called the peen and is shaped like a dull wedge. It is used for packing the sand around the edges of the flask and in the corners of some patterns. The other end, called the butt, is a short cylinder with a flat face and is used for compacting the sand in the body of the flask.

Straightedge (Fig. 11) is a piece of metal or wood having a thin edge for leveling the sand with the top of the flask. Each student should be provided by the school with one riddle, shovel, rammer, and straightedge.

Trowels (Fig. 12) are used for cutting the sand down to the parting lines, and for shaping the large faces of the mold.

Three shapes are generally used: (*a*) The square trowel for getting into square corners; (*b*) the round-pointed finishing trowel; (*c*) the sharp-pointed finishing trowel, used for both coping out and finishing. The round-pointed trowels are the most useful. The size of the trowel is determined by the length and width of the blade.

Fig. 9.

Slicks. — Slicks are used, as their name indicates, for slicking over the parts of a mold and for patching small breaks. There are a great many varieties on the market, used for various classes of work. The shapes shown (Fig. 13) are the ones most commonly used. Slicks are designated by the shapes of their

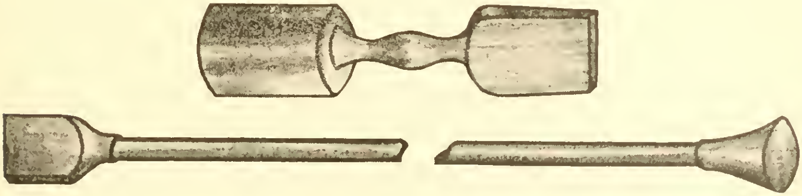


Fig. 10.

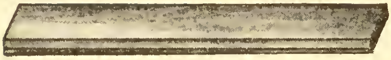


Fig. 11.

blades, and sizes by the widest part of the widest blade; they run from 1 to $1\frac{3}{4}$ inches.

The shapes are (*a*) taper and square, (*b*) heart and oval spoon, (*c*) heart and leaf, (*d*) heart and square.

Lifters. — A lifter (Fig. 14) has a long, narrow blade on one end and a short foot at right angles to the blade on the other. They are used for cleaning and finishing the deep and narrow portions of the mold.

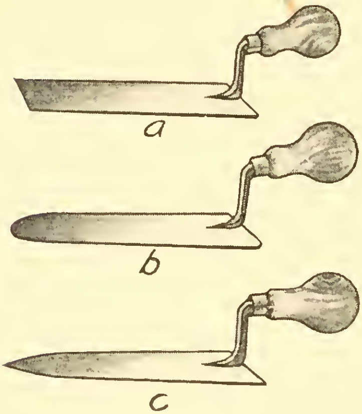


Fig. 12.

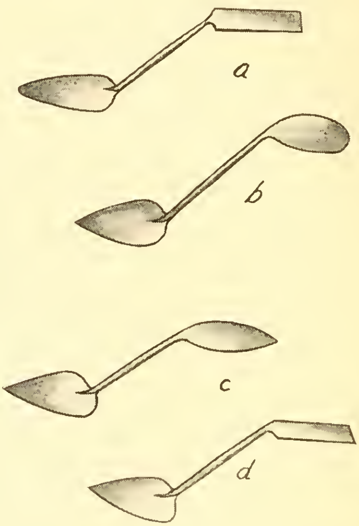


Fig. 13.

There are two styles: (*a*) bench lifters and (*b*) floor lifters. The sizes vary from $\frac{1}{8}'' \times 10''$ to $1'' \times 20''$ for floor lifters, and $\frac{3}{16}$ to $\frac{3}{4}$ inch for bench lifters. Each student should provide himself with a trowel and either a slick or a lifter. It is well for each one to get a little different style.

Bellows (Fig. 15) are used for blowing the dirt and sand from the work. There should be one for every two or three students.

A **sprue plug** (Fig. 16) is a cylindrical piece of wood, tapered. It is used for making the sprue or runner through which the metal is poured. The sizes vary with the work and the depth of the cope. The school should be supplied with a large assortment, varying from $\frac{5}{8}$ to $1\frac{1}{4}$ inches in diameter and of various lengths.

Corner slicks (Fig. 17) are used for dressing or squaring the corners. There are outside and inside corner slicks, ranging in size from 1 to 3 inches. Corner slicks are not much used on small work, but it is well for a school to have one of each style.

Fig. 14.

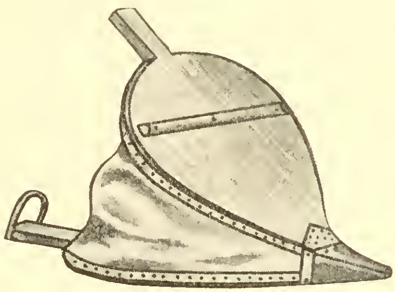


Fig. 15.

Swabs and **sponges** are used to moisten and pack the sand around the edges of the pattern before drawing. Swabs (Fig. 18) are usually made by wrapping one end of a bunch of hemp fiber, 6 or 8 inches long, with a few turns of wire. They are generally used on floor work.

By attaching a quill or small round piece of hard wood to a sponge to guide the stream of water, a very efficient instrument is made. It is well for each student to have a sponge and for the school to provide two or three swabs.

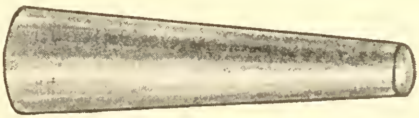


Fig. 16.

Draw spikes (Fig. 19) are used for drawing the patterns from the sand. There are various styles and sizes: some with sharp points *a* for driving into the pattern; some with a wood screw point *b*, and others

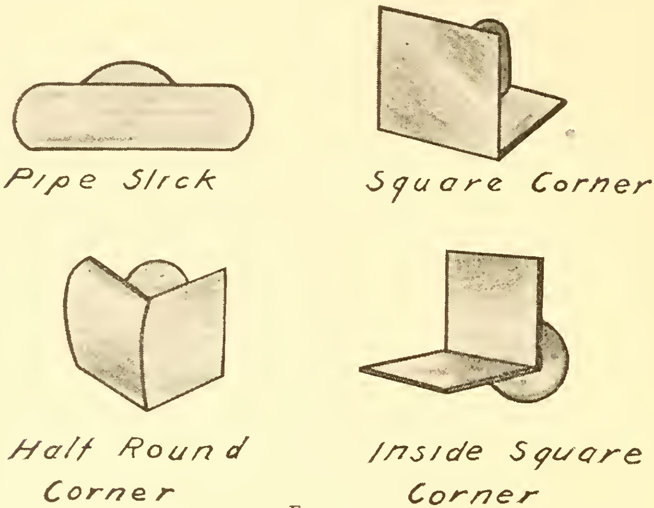


Fig. 17.

with a machine screw thread *c* which screws into a tapped hole in a metal pattern, or a metal draw plate attached to a wooden pattern. There should be one draw spike like *a* for each student, three or four like *b*, and one like *c* for $\frac{1}{4}$, $\frac{3}{8}$, and $\frac{1}{2}$ inch holes.

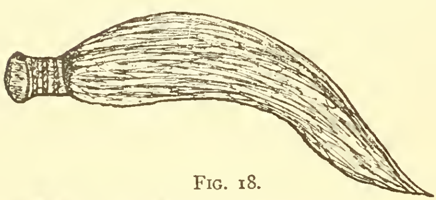


Fig. 18.

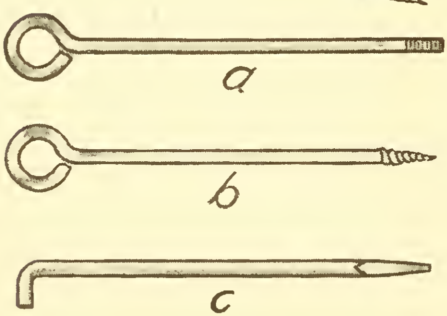


Fig. 19.

Draw plate (Fig. 20) is a metal plate with a tapped hole *a* in the center and one or more other holes *b* without threads. To lift a pattern the draw spike is screwed into *a*. The pattern is rapped loose by inserting a rod in holes *b*. By using the holes *b* for rapping the pattern the threads in *a* are not spoiled.

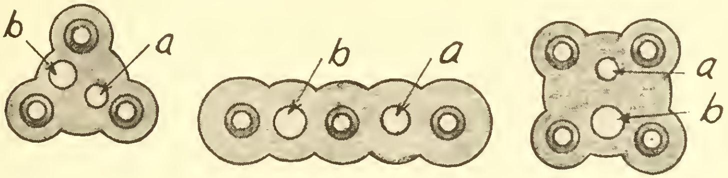


FIG. 20.

Vent rods are sharp-pointed steel rods for making passages through the mold for the escape of the gases, steam, and air. They vary in size from a small knitting needle to a $\frac{3}{16}$ or $\frac{1}{4}$ inch rod. Each student should have a knitting needle, and the school should have several vent rods. Drill rods of different sizes make excellent vent rods.

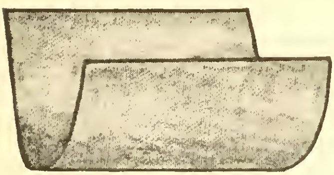


FIG. 21.

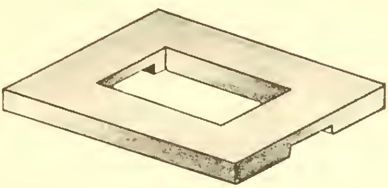


FIG. 22.

Gater, or Gate Cutter. — A gater (Fig. 21) is a small piece of tin about 3″ × 4″ bent U shape, which is used for making the gates through which the metal enters the mold. There should be one for each student.

Weights (Fig. 22) are placed on top of the mold before pouring to hold the cope down against the pressure of the metal. They should be as large as the outside measurements of the flasks and from $\frac{1}{2}$ to $1\frac{1}{2}$ inches thick. A school should have at least 12 weights.

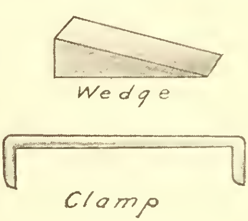


FIG. 23.

Clamps of **iron** and **wedges** of wood (Fig. 23) are used for the same purpose as the weights. Their uses can be clearly seen from the figure (Fig. 25). Two clamps are needed for each ordinary flask and in addition a large number of wedges with different angles.

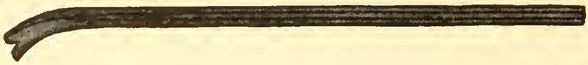


FIG. 24.

Pinch bars (Fig. 24) are used to set the clamps on the wedges. They are made of steel and are about 12 or 14 inches long. Two pinch bars will accommodate a large class.

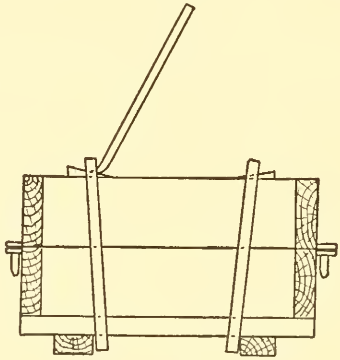


FIG. 25.

Tool box. — A small box (Fig. 26) divided into two or more compartments and arranged with a handle for carrying is very

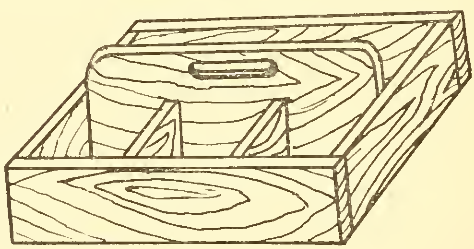


FIG. 26.

convenient for floor work. In serving as a handy receptacle for the sponge, parting sand, and small tools, it greatly lessens the loss of these articles.

CHAPTER III

PRINCIPLES OF MOLDING

To do good work in any trade or occupation it is absolutely necessary to learn the general principles, and in foundry practice there is no exception to this rule.

It is essential in commercial foundry practice to make a mold in the least possible time and at the least expense, and it must always be borne in mind that these conditions are not reached if the castings are unsound, dirty, or not smooth.

Castings are unsound when they contain imperfections; such as blowholes, porous spots, shrinkage cracks, etc.[1] They are dirty when they are covered with sand, and are not smooth when they have swells, cold shuts, etc.[1] In the first case the casting is useless and must be made over, while in the two latter cases loss of time and expense are incurred in getting them into shape.

The principles that must be followed in making a mold that answers the foregoing requirements are applicable to all classes of molding, and are:

1. Preparing the sand by:
   a. The introduction of new sand or a facing;
   b. Tempering.
2. Ramming:
   a. Drag;
   b. Cope.
3. Use of auxiliary holding devices:
   a. Crossbars;
   b. Gaggers;
   c. Soldiers;
   d. Nails.
4. Venting.

[1] See page 93.

5. Gating.
6. Placing risers.
7. Skimming gates.
8. Shrinkage heads.
9. Patching.
10. Stopping off.

1. PREPARING THE SAND

a. **The Introduction of New Sand or a Facing.** — The sand must be put in condition before a good, strong, clean casting can be made.

In light work, when the sand is not burned too much, these requirements can be met by the addition of a little new sand, every day or so, according to the amount of work done. In heavy work the amount of sand next to the pattern is small in comparison with that necessary to fill the flasks. Therefore the sand is kept in condition by strengthening the heap occasionally with a little new sand, while that which is riddled next to the pattern should be treated with a facing mixture varying with the thickness and weight of the casting.

Too much new sand causes the mold to crack — this is due to lack of venting — and not enough, causes cutting of the mold or scabbing of the casting. Too much facing mixture makes excessive gas, causes blowholes in the casting, and makes the sand brittle and hard to work; while too little facing mixture results in dirty castings.

The correct proportions are: One part of facing mixed with six, eight, or twelve parts of sand. The amount depends upon the weight and size of the casting to be poured as well as the time of pouring and the intended fluidity of the metal. This may be more definitely stated thus: Castings $\frac{1}{2}$ inch or less in thickness need no facing, as well-riddled heap sand gives better results. For castings $\frac{1}{2}$ inch to 1 inch in thickness, use one part facing to fourteen parts of sand; for those from 1 inch to 2 inches, use one part facing to from eight to ten parts sand, and when thicker than 2 inches, one part facing to from six to eight parts sand. When the sand is new, less sand should be used.

When a facing is to be added to the sand, the two must be thoroughly and evenly mixed by handling over and over; otherwise a bad casting will be obtained.

The materials should be as dry as possible. The sand should be spread out in a thin layer, and the new sand or facing material distributed over it as evenly as possible; it should then be cut over with a shovel a few times, and well riddled with a No. 6 or No. 8 riddle. It is then tramped down, wet, and tempered in the same manner as heap sand. (See *Tempering* in the following article.) After this it should be riddled through a No. 4 riddle two or three times. It is then in condition to be used.

b. **Tempering.** — The sand is tempered for use by wetting it down. Water is thrown on to it from a pail[1] or with a hose or sprinkling can, and the sand is then turned over from top to bottom with a spreading motion so as to intermix the wet portions with the dry. This must be repeated until the sand is evenly moistened and all lumps broken. It must not be wet enough to feel soggy when squeezed in the hand. When an egg-shaped ball can be held between the fingers and thumb of each hand and broken, and the edges remain firm and sharp, the sand is in good condition. If the sand is too wet, the hot metal will generate steam and cause blow holes in the castings; if it is too dry, the metal is likely to crumble.

2. RAMMING

The sand is rammed to make it stick in the flask and to give the mold strength to withstand the flow of the metal. The hardness to which the sand in a flask should be rammed depends upon several things; such as the size of the mold, the size and the

[1] The pail should be given a turning motion so as to cause the water to spread out into a sheet.

condition of the sand, and the weight of the casting. This can be learned only by experience.

When the sand is rammed too hard, blow holes are caused, since the natural vents are closed up. When not rammed hard enough, the sand will either sink under the weight of the metal, or be forced or bulged out, owing to the pressure, and a swelled casting is the result. Also, when loosely rammed, the sand may be washed from the face of the mold, and the casting will be marred by scabs and sand holes.

The bottom of the mold must stand the weight of the metal; therefore it must be rammed harder than the cope. The joint — that is, the place where the parts of the mold separate — should be rammed hard, for it is exposed to much handling. The mold should be left as soft as possible, but it must be hard enough to hold the casting in proper shape. Beyond this the risk of losing the casting increases with the hardness of the ramming.

The following general directions should be observed in ramming all molds:

a. **Ramming Drag.** — When the depth of the drag is less than 5 inches, it should be filled heaping full of sand. If it is greater, it should be filled to a depth of 5 or 6 inches. The sand is then rammed around the edge of the flask with the peen of the rammer,[1] next about the pattern, and finally the sand between the two, or the remainder of the flask. On small work the sand over the pattern should not be rammed with the peen, nor should the rammer strike nearer to the pattern than 1 inch, or a hard spot will be formed in the sand. When but little more sand is needed, the drag should be filled heaping full and rammed with either the peen or butt end of the rammer. If the mold is deep, another layer of sand 5 or 6 inches deep is added and rammed with either end of the rammer. When the mold is large, time can be saved by tramping the sand before butting.

[1] When a floor rammer is used, the rod must be grasped firmly with both hands. Never put one hand on top of the rammer.

b. **Ramming Cope when there are no Crossbars.** — If the depth of the cope is 5 inches or less, it is filled heaping full of sand and rammed with the peen, first around the edge and then over the rest of the cope. If more sand is needed, it can be added, and the cope rammed all over with the butt of the rammer. If the pattern should extend into the cope, care must be observed not to strike the pattern.

When the cope is deep, it is filled to a depth of 5 or 6 inches and rammed with the peen, first around the edge and then over the rest of the cope. More sand is then added and the ramming repeated until the cope is filled. The butt of the rammer must not be used until the cope is entirely filled or the successive layers will not stick. It should be used, however, for the final top ramming.

When the Cope has Crossbars. — When the cope has crossbars, each compartment is rammed as a separate cope. Care must be taken to have all the sand rammed with equal hardness.

3. AUXILIARY HOLDING DEVICES

To avoid excessive ramming in the cope various devices are used to hold the sand, such as (*a*) crossbars, (*b*) gaggers, (*c*) soldiers, and (*d*) nails.

a. **Crossbars and Gaggers.** — Crossbars, shown in Fig. 5 and at *a* in Fig. 27, are placed in the cope to prevent hard ramming, by dividing the sand into small bodies.

b. Gaggers (*b*, Fig. 27), L-shaped pieces of iron, usually $\frac{5}{16}$ or $\frac{1}{2}$ inch square section, are used in connection with crossbars to anchor the sand. They are held against the crossbar by the pressure of the sand on the long leg, while the short legs hold the sand above it. Therefore to have the gaggers most effective the long leg must be placed squarely against the crossbar, plumb, so that the short leg comes near the place where the sand in the cope and drag part. The long leg should extend at least two thirds of the way to the top of the crossbar, the higher the better, as long as it does not project above the top of the cleat. If it projects, the gaggers may be struck and the mold spoiled. Gaggers are shown properly set in Fig. 27, and improperly in Fig. 28.

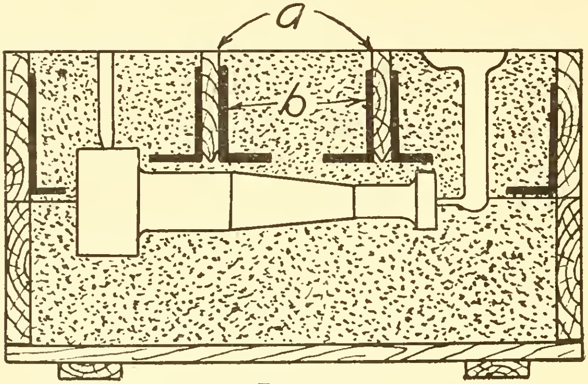


Fig. 27.

c. **Soldiers.** — Strips of wood (*a*, Fig. 29) placed in the sand to anchor the body together are called soldiers. They vary in size, shape, and length to suit the conditions of use. Soldiers have great holding power and are, therefore, much used to hold

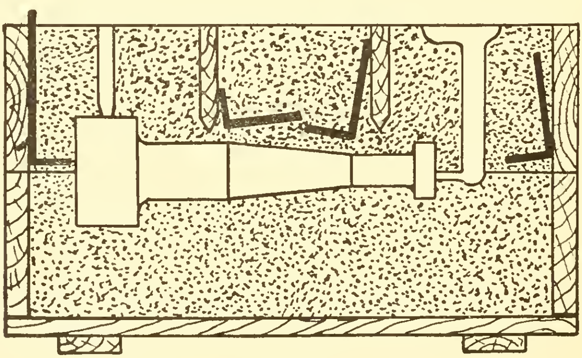


Fig. 28.

hanging bodies of sand, often eliminating the necessity for special bars when placed beside the regular crossbars. When soldiers are used, they must be wet with clay wash and then pressed into place in the sand, and the sand rammed. A thin layer of sand must always cover the soldiers, to prevent their burning as well as to separate them from the parting surface.

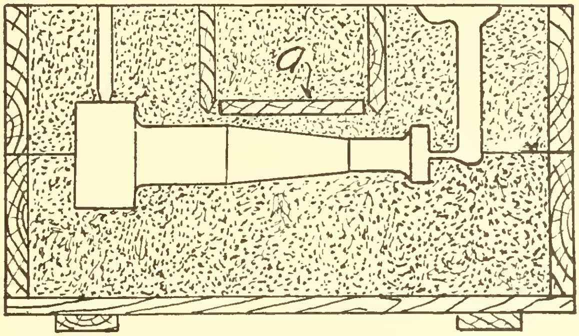


FIG. 29.

d. **Nails**. — Nails are often used to hold green cores, points, and corners of molds. They are pressed into the sand after it is rammed, in such a manner that the head will hold the sand. The nail should, however, be completely covered with sand.

4. VENTING

Venting a mold, or the making of passages for the escape of gas and air in the sand and the steam generated by the liquid iron coming in contact with the damp sand, is one of the most important details in molding. If the gas, air, and steam are not given an opportunity to escape, the casting is sure to be spoiled. Either the mold will explode and the iron be forced out of the runner, or some parts will not be filled with iron, on account of the pocketing of the gas, which prevents the iron from flowing into these parts. If it were not for the necessity of providing for the escape of the gas, air, and steam, molds could be rammed much harder, and a much better and smoother casting would result.

In venting a mold the following facts must be heeded:

New sand needs a great deal of venting, as it contains much gas; sand mixed with sea coal or coke dust needs still more.

The bottom requires much venting because it is completely covered with iron.

Copes are vented more to allow the escape of air in the mold than for the escape of gas and steam.

Copes having projections, flanges, or pockets in them require such places to be vented.

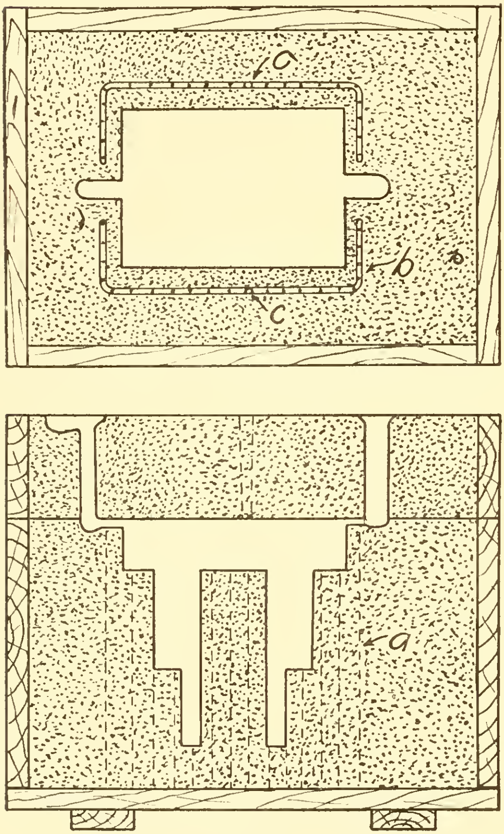


Fig. 30.

Molds to be poured very fast must be amply vented, so that the air, gas, and steam may pass off rapidly.

Less venting is required when a mold is poured with hot iron than with chilled, since the hot metal has life enough to force the air through the sand pores. In the case of cold iron, the compressed air, unless it finds ready escape, will hold back the iron so long that it will cool. This leaves the casting with smooth, flat hollows in the cope part.

In venting copes for light or heavy castings very little difference need be made as regard closeness of vents, but for light work the vents should extend to the surface of the mold, while heavy work should be vented to within 2 or 3 inches of the surface. Molds for heavy castings require venting along the sides, as shown in Fig. 30. The vents are shown at *a*. These connect with the channel *b*, through which the gases are carried to the risers at *c–c*, where they escape.

The bottom surface of the drag should be crisscrossed with a slick to form passages for the escape of the gases between the sand and the bottom board.

In pouring, the gases passing from the mold should be lighted as soon as possible because they are very poisonous.

5. Gating

Gates are openings formed in the sand through which the metal enters the mold. These openings are composed of three parts: (1) basin, (2) runner or sprue, and (3) gate. The basin, shown at *b*, Fig. 31, is a depression shaped by hand on top of the cope and connected with the runner. The runner or sprue (*c*, Fig. 31) is an opening through the cope, found by setting a plug of wood, called a sprue plug. The gate *d*, Fig. 31, is the opening that connects the runner with the mold. It is cut with a gate cutter or gater (Fig. 21).

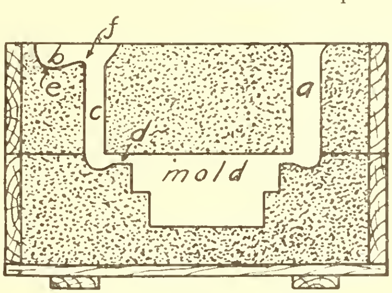


Fig. 31.

The object of gating is to fill the mold quickly with perfectly clean metal and with as little disturbance as possible.

There is nothing in the art of molding that requires more care than the making of basins, runners, and gates. Bad gates are often responsible for bad castings. The mold may be slighted and a casting comes out all right, but ignorance or carelessness in gating will almost always cause trouble. The following general rules should be observed in placing gates:

1. Section should be wide and shallow.

2. They should be located where the natural flow of the metal will fill the mold quickly.

3. They should be placed where the sprues can be easily broken or ground off.

4. There should be gates enough to allow the metal to fill all parts of the mold.

5. The runner or sprue should not be over $\frac{3}{4}$ inch in diameter on ordinary sized work.

6. The point *d*, Fig. 31, should have the smallest sectional area of any part of the gate in order that the basin and runner may be quickly flooded and kept full of metal. This will give a strong head on the mold.

7. The end *e* should be the deepest. There should be a low dam at the entrance to the runner, as shown at *f*.

Figure 42 shows a properly made gate for a rectangular casting, and the riser is made in a similar manner. Their location is shown in Fig. 41. If the casting is long, the sprue should be placed at the middle and gates made to several places along its length as shown at *a–a–a* in Fig. 32. In this case it is well to place two risers on the opposite side at the ends, as shown at *b–b*, or one riser at the middle connected by gates with the ends.

Figure 46 shows the placing of gates for a cylindrical casting. If the cylindrical casting is long, gates can be branched as shown in Fig. 32. The gates should be cut so the metal will enter the mold at the center line.

It is often necessary in order to fill a mold to have the metal enter with greater force than can be obtained due to the head in the cope. In such cases a pouring head or outside basin is used. A pouring head consists of a small frame in which sand is packed

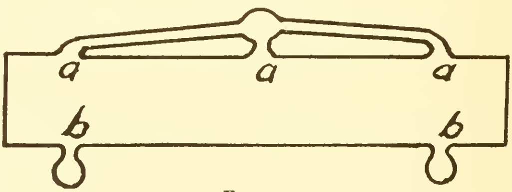


Fig. 32.

and a basin and runner formed as shown at *a*, Fig. 33. The runner *b* of the pouring head is placed directly over the runner *c* in the cope, thus giving a much higher head.

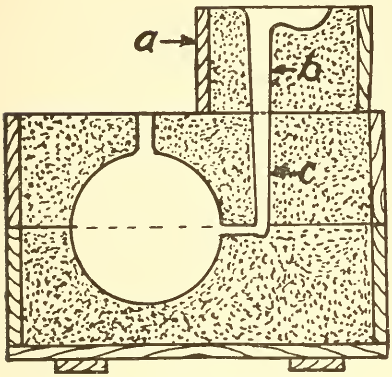


Fig. 33.

For a sphere the gate and riser should be located as shown in Fig. 33. The pouring head *a* is needed only when the height of the sand in the cope above the pattern is small.

Fig. 34.

Figure 48 shows the position in which the sprue should be placed in making a handwheel, and it should be placed in a similar way on all types of wheels, pulleys, or shieves. If the hub is to be cored, the sprue will be set to one side of the core.

Figure 51 shows the placing of a gate on a short cylindrical casting, cast on end.

It is sometimes desirable to pour a casting from the bottom. Figure 61 shows the way of doing this in a three-part flask. In a two-part flask a horn sprue is used. A horn sprue (Fig. 34) is a sprue similar in shape to a cow's horn, circular in section, and tapered from one end to the other so that it can be easily drawn from the sand.

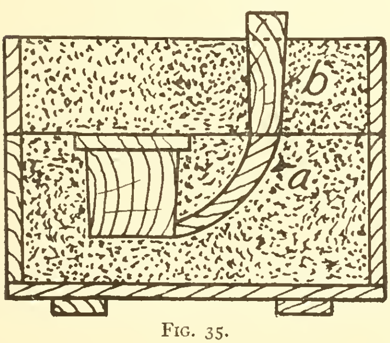


Fig. 35.

Figure 35 shows the use; *a* is the horn sprue in position. The large end is flush with the parting line and an ordinary sprue *b* is placed in the cope directly above it. The shape of the sprue makes it easily removable.

Figure 119 shows the way of making gates for thin brass work.

6. Risers

Risers, shown at *a*, Fig. 31, serve a threefold purpose: (1) as a vent; (2) as a skimming gate; (3) to supply the metal as the piece cools.

Risers are made in the same manner as the runner for a gate, but with a diameter about one third larger. In a small casting the riser should be located where it will best catch and carry off the dirt. In castings where it acts as a feeder, it should be connected as nearly as possible to the heaviest part of the casting, and must be large enough to prevent the freezing of the metal in it before the casting has set.

7. Skimming Gates

Skimming gates, shown in Fig. 36, are for removing the dirt and impurities which all melted iron contains and which rise to the surface of the metal. To insure a clean, solid casting it is of importance to have the runners and gates made in such a way as to collect the dirt before the metal enters the mold. The riser should be large and the connecting gate (Fig. 36) curved, to give the metal a whirling motion which tends to send the dirt to the top.

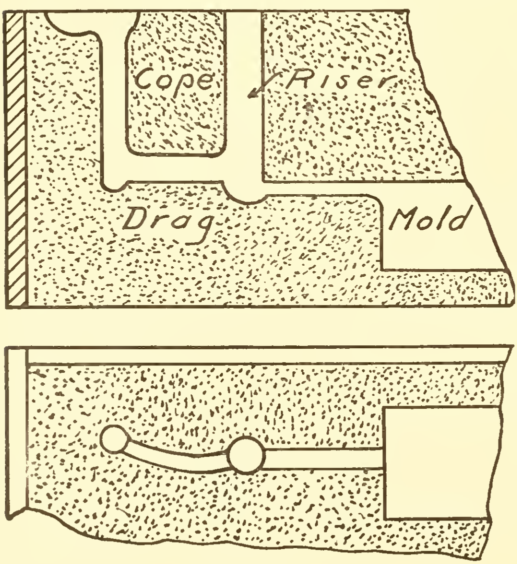


Fig. 36.

8. Shrinkage Heads

Shrinkage head, or sinking head, is a prolongation on a casting to supply metal to replace shrinkage.

The metal that comes in contact with the face of the mold solidifies rapidly and the liquid metal is drawn to these faces, leaving the interior hollow or very spongy. The lower part of the casting, having the pressure of the metal above it to draw from, resists this shrinkage, and unless the top is supplied in some manner with new metal it will become cupped, as shown in Fig. 37. In small castings the gate runners and risers supply the needed metal and pressure, but in large castings it is necessary to have a large riser (Fig. 38), called a shrinkage head, connecting directly with the casting. In order that the shrinkage head may be easily removed after the casting is cooled, the section is greatly reduced where it is attached to the casting. To prevent the metal from freezing in this reduced section, a feeding rod *b* is used to churn the metal slowly up and down.

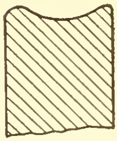


Fig. 37.

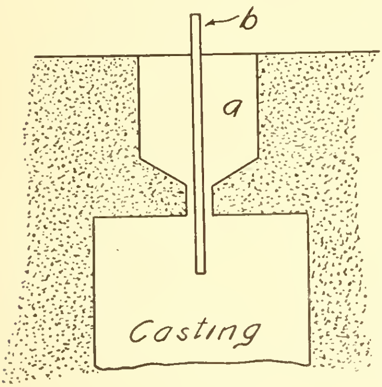


Fig. 38.

9. Patching

Many molds can be saved by patching; thus allowing the use of old or improperly made patterns. It is in patching that a molder shows his skill. Sometimes a good molder will be able to repair a mold that seems to be ruined, but one must have practice and experience to do good patching.

The beginner should carefully observe the following rules:

Dry or properly tempered sand cannot be patched without wetting, but care must be taken, however, not to get the sand too wet.

Patching should be done with the fingers wherever possible, as the castings are less likely to be scabbed.

Sand put on with the fingers can be added to; that which is slicked on cannot. Little slicking should be done as it will make hard spots on the castings.

Nails should be used to hold the sand in making large patches and should be completely covered.

Patching in a deep mold is done by lowering small balls of sand on a tool to the proper place, and pressing them on by light slicking.

A corner is patched by holding a tool with a straight face on one side and pressing the sand into the other.

All loose sand must be removed, for it will wash into the mold and cause a poor casting.

The beginner may not at first be able to save a mold that has been injured, but will, by practice and the exercise of a little patience, soon get results, and learn that a mold should not be discarded without first making an attempt to patch it.

10. Stopping off

Stopping off is filling with sand the impression left by some part of the pattern not desired in the casting; *e.g.* castings having the same section but different lengths can be made from the same pattern, if the pattern be made the length of the longest casting and the molds "stopped off" at the proper lengths for the others.

In "stopping off" a mold to make a shorter casting, a "stopping-off piece" the shape of the section is held at the proper place. The sand in the part to be "stopped off" is roughened so the new sand will take firm hold. Sand is then packed into the space not required, and after this the "stopping-off piece" is removed.

CHAPTER IV

MOLDING EXERCISES WITHOUT CORES

EACH of the first four exercises in this chapter brings out one of the four fundamental principles used in all green and dry sand molding. Hereafter not a mold will be made that does not use one or more of these principles. It is important, therefore, to get these steps well fixed in mind.

EXERCISE 1. *Rectangular Block.*

Pattern }
Casting } Rectangular block.

To make the mold: Place the pattern about centrally on the moldboard, with the widest face[1] on the board. Place the drag, with sockets down, over the pattern as shown in Fig. 39. Riddle enough well-tempered molding sand[2] into the drag to

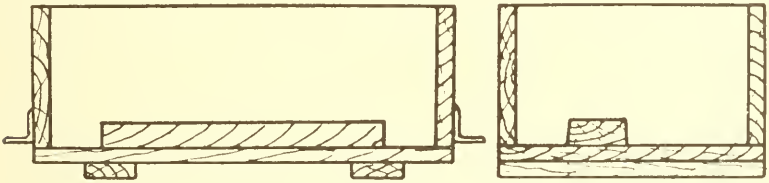


FIG. 39.

[1] **Draft.** — In order that a pattern may be drawn from the sand, it is made with a taper from the parting line (the place where the mold separates) to the opposite edge. The larger dimensions are at the parting line. Thus on the pattern used in Ex. 1, the dimensions of the face that is placed on the moldboard (the part that is at the parting line of the mold) are about $\frac{1}{8}$ inch greater than on the opposite face. The ends of the cylindrical pattern taper from the center (the parting line) to the circumference; *i.e.* the length at the center is greater than at the circumference or at any place between.

All patterns are either modifications or combinations of rectangles and cylinders, and must be made with the proper taper or draft. A study of the draft on a pattern will indicate along what line or lines of the pattern the mold should separate, and therefore how the pattern should be placed into the sand.

[2] See *Tempering Sand*, page 21.

cover the pattern. With the fingers pack the sand about the pattern. Fill the drag heaping full of sand (unriddled), taking care that no foreign matters goes in. (Ram sand as directed under *Ramming*, page 22.) With the straightedge strike off the excess sand until level with the face of the drag. Throw a handful of sand free from lumps on top of the sand (in the drag). Place the bottom board over this, as in Fig. 40, and slide it back and forth a few times to seat it well. Remove bottom board. Punch several holes to the pattern with a vent wire; then replace the board. Grasp the bottom and moldboards at the ends, holding the drag tightly between them, turn over and rest the drag on the bottom board. Remove the moldboard. Blow off any loose sand with the bellows. Smooth the face of

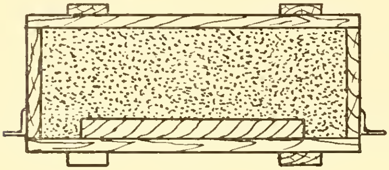


Fig. 40.

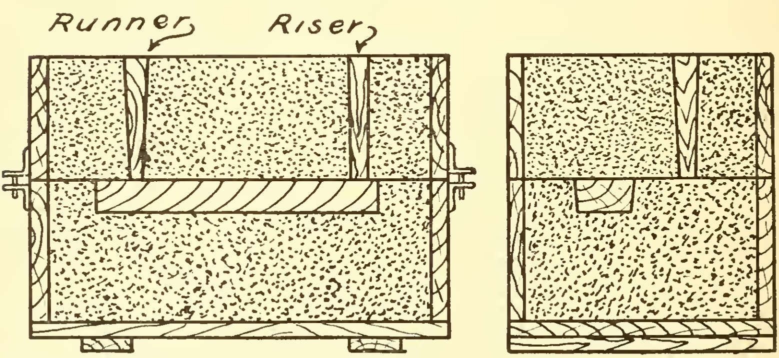


Fig. 41.

the mold about the pattern with slick or trowel. Make parting by sifting through the fingers enough parting sand to cover the joint (the place where the mold parts). Blow off excess parting sand with the bellows, being very careful that none remains on the pattern or edges of the flask. Place the cope in position and insert plugs for sprue and riser as shown in Fig. 41, about $1\frac{1}{2}$ inches from the pattern. Riddle enough sand to cover the face of the pattern, and fill and ram the cope as described under *Ramming*, page 23. With the vent wire punch several ventholes down to the pattern. Remove the sprue and riser plugs, first giving them a few turns to loosen them. Make pouring basin as shown at *b*, in Figs. 31 and 42.

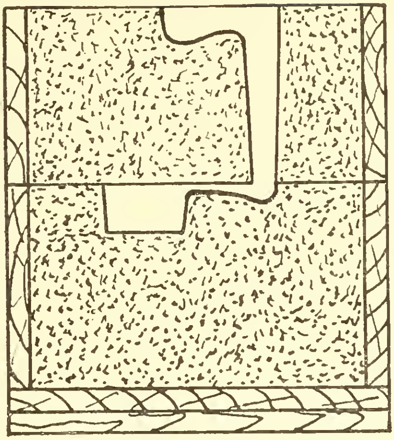


FIG. 42.

Carefully lift off the cope by raising it straight up until the pins are free. Stand the cope on edge or rest it against the moldboard, as in Fig. 43.[1] Wet very slightly around the edges of the pattern with the sponge or swab. Drive the draw spike into the pattern at the center (Fig. 44). Rap the draw spike slightly on all sides. This will loosen the pattern and pack the sand at the edges of the mold. Then lift and remove the pattern. Cut the gate as shown at *d* in Fig. 31, and connect the mold with the riser in a similar manner. Blow through sprue hole to remove any loose sand. Place the cope into position and cover with weight, or clamp it, as shown in Fig. 25.

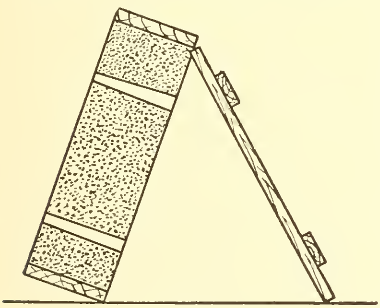


FIG. 43.

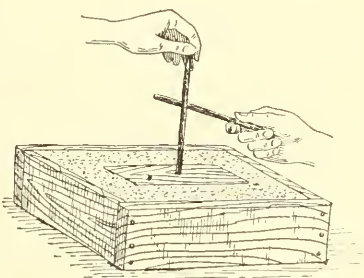


FIG. 44.

[1] The cope in small work can be laid flat on the moldboard, but the board must be placed on the cope and both the board and the cope lifted and turned at the same time.

This first exercise should be poured in iron, as no other substance shows so well whether the mold has been rammed, vented, and gated properly.[1]

EXERCISE 2. *Pattern Cylinder* (*Solid Pattern*). *Method No. 1.*

To make the mold: Place the pattern centrally on the moldboard so that the long axis of the pattern is parallel with the long edge of the board, or in a way similar to that in Fig. 39, and place the drag in position. Riddle enough well-tempered molding sand into the drag to cover the pattern. With the fingers pack the sand about the pattern. Fill the drag heaping full of sand by shoveling from the heap, picking out any foreign matter that may be in the sand. (Ram up the drag as directed under *Ramming*, page 22.) Strike off the excess sand with the straightedge. Throw a handful of sand free from lumps on top of the sand. Place the bottom board over this, as in Fig. 40, and slide it back and forth a few times to seat it. Remove the bottom board and vent the drag by punching several holes to the pattern with a vent wire; then replace

[1] **Soft Metal.** — When a school is so situated that a cupola for melting iron cannot be installed or the expense of one is too great, soft metal (metal melting at a low temperature) can be used with very satisfactory results. Lead melts very easily and runs and fills the mold very nicely. It has one fault for school work or any place where it is to be used over and over again, in that a casting made of lead alone cannot be broken easily, when it is too large to be placed in the ladle or crucible. But by mixing a small amount of block tin, bismuth, and antimony, a composition that is brittle can be made, which answers the purpose splendidly. In making a mixture, the following proportions will answer in most cases; 94 per cent lead, 2 per cent tin, 2 per cent antimony, and 2 per cent bismuth. If this mixture produces a casting too tough, add a little more antimony and bismuth.

An alloy of 95 per cent aluminum and 5 per cent zinc (alzine) melts at but little higher temperature than the above alloy and is suitable for use when small articles are to be saved.

These alloys can all be melted in the brass furnaces described under *Brass Molding*, page 103, or in a forge fire. A good substitute for a furnace for melting these soft metals is an old cast-iron depot cannon stove used for burning soft coal.

Plaster of Paris is very good for filling molds, and acts very much like cast iron. A mixture of 3 to $3\frac{1}{2}$ pounds of the plaster to a quart of water makes the best castings. It should be stirred until it sticks to the hand when dipped into it like cream. Should the plaster set too rapidly, the setting can be retarded by adding a small amount of salt or vinegar.

the board. Grasp the bottom and mold boards at the ends, holding the drag tightly between them ; turn over and rest the drag on the bottom board. Remove the moldboard. With the trowel and slick pare the sand away to the center line of the pattern all around, as shown in Fig. 45. Make as long a slope as the size of the flask will permit. Great care must be taken to cut to the exact center of the pattern. Put on parting sand by sifting through the fingers. (Have the joint well covered, but avoid having an accumulation of sand along the edge of the pattern by blowing off the excess sand with the bellows.) Place the cope in position, taking care that no sand remains on the edges of the drag, and place plugs for the sprue and riser about $1\frac{1}{2}$ inches from the pattern, as shown in Fig. 46. Note that the riser is gated from the highest part of the mold. Riddle sand till the face of the pattern is covered, and fill and ram the cope as described under *Ramming*, page 23. Make several ventholes

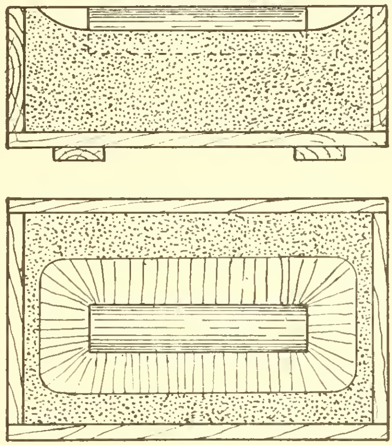


Fig. 45.

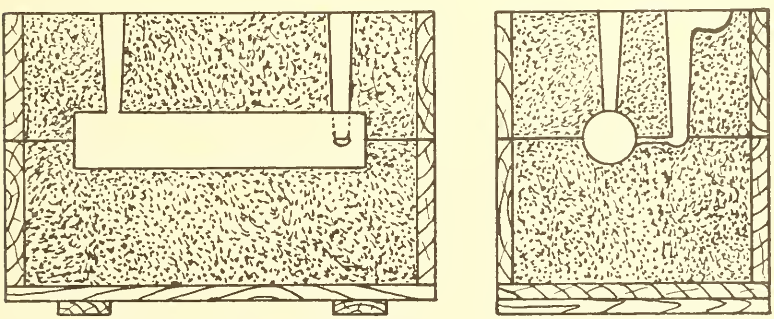


Fig. 46.

down to the pattern. Remove the sprue and riser plugs, first giving them a few turns to loosen them. Make pouring basin, as shown at *b* in Fig. 31. Carefully lift off the cope by raising it straight up until the pins are free. Stand the cope on edge or rest against the moldboard, as in Fig. 43. Wet very slightly around the edges of the pattern with the sponge or swab. Rap the draw spike slightly on all sides, to loosen the pattern. Lift and remove the pattern. Cut the gate as shown at *d*, Fig. 31, and connect the mold with the riser in a similar manner. Blow through the sprue hole to remove any loose sand. Place the cope in position and cover it with weight, or clamp it, as shown in Fig. 25.

EXERCISE 3. *Cylinder (Solid Pattern). Method No. 2.*

Pattern and casting same as in previous exercise.

To make the mold: Place the pattern on the moldboard exactly as in Ex. 2. Place the drag in position and raise it with wedges under the four corners of the drag, so that the bottom edges are exactly on a level with the parting line of the pattern, as shown in Fig. 47. To tell when the drag is at the

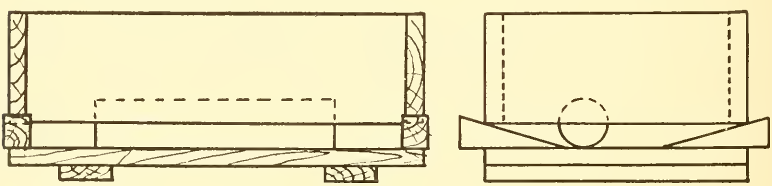


FIG. 47.

proper height, sight across the bottom edge of the drag, and see that the two edges and the parting line of the pattern are in line. Another method is to stretch a string from edge to edge of drag and then adjust wedges until the string coincides with the parting line of the pattern. Riddle on enough molding sand to cover the pattern.[1] Pack the sand around the pattern with the hand as in the preceding exercises. Fill the drag heaping full of sand from the heap, and ram as directed under *Ramming*,

[1] Some of the sand will pass out of the opening between the flask and the board, but this space will soon fill up.

page 22. Strike off the excess sand, throw a handful of sand on the drag, and seat the bottom board, as in previous exercises, by moving it backwards and forwards. Make ventholes as before. Grasp the drag between the two boards, turn it over, and rest it on the bottom board. Remove the moldboard and strike off the sand level with the top of the drag. Use care not to disturb the pattern. Smooth the surface with trowel or slick. Put on parting sand, using the same precaution as in the last exercise to blow off the excess sand and to avoid a layer along the edge of the pattern and on the drag. Place the cope in position, and set the plugs for the sprue and riser exactly as in Ex. 2, Fig. 46. Sift on enough sand to cover the pattern, pack around it with the fingers, shovel in the heap sand, and ram as directed under *Ramming*, page 23. Make ventholes. Remove the sprue and riser plugs. Make pouring basin (see *b*, Fig. 31). Lift off the cope and rest it against the moldboard, as in Fig. 43. Wet around the pattern, drive in the draw spike, and lift the pattern. Cut the gate for sprue and riser as in the last exercise. Blow the dirt out of the sprue holes. Place the cope in position, weight or clamp, and pour.

When several castings are to be made from a pattern like the one just described, two wooden strips just the height of half of the cylinder can be used in place of the wedges.

Exercise 4. *Cylinder* (*Split Pattern*).

Pattern : cylinder (split).

Casting : cylinder.

To make the mold : Place the half of the pattern which does not contain the dowel pins on the moldboard, flat face down, in a position similar to that in the last exercises. Place the drag in position similar to that in the last exercises, and riddle on sand till the pattern is covered ; then pack with the fingers. Fill the drag heaping full of heap sand free from foreign matter ; ram ; strike off level, and seat the bottom board. Replace the bottom board and turn the drag over. (All of these steps are to be performed as described under previous exercises.) Remove the moldboard and smooth the joint with slick or trowel. Put on the other half of the pattern and make the parting, sifting on the parting sand and observing the precautions noted in the last two exercises. Place plugs for sprue and riser. Riddle on sand; pack with the fingers; fill with heap sand and ram. Vent; remove plugs; make pouring basins; cut gates; weight and pour, exactly as in the last exercise.

EXERCISE 5. Application of Principles, Ex. 2 and 3.[1]

Pattern: handwheel (circular rim).

Casting: handwheel.

This pattern can be placed in the sand as directed under Ex. 2 or 3. In this case make it by paring down, as in Ex. 2.

To make the mold: Select a flask quite a little larger than the diameter of the wheel. Place the pattern on the moldboard at the center. Place the drag in position. Riddle enough sand to cover the pattern and pack with the fingers. Fill the

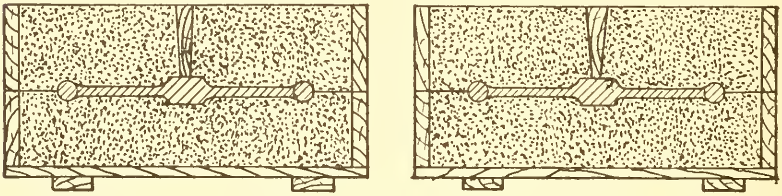


FIG. 48.

drag with heap sand; ram; level off; vent and turn as in Ex. 2. Pare the sand away to the center of the rim, making as gradual a slope as possible. With the foot of a lifter pack the sand between the arms down to their center line. Make parting; place on cope, and set the sprue plug on the hub of the wheel, as shown in Fig. 48. Riddle on enough sand to cover the pattern; pack with fingers; shovel in heap sand; ram; vent; make pouring basin, and remove sprue plug as in Ex. 2. (As the sprue plug rested on the pattern, the hole left by its removal will open directly into the mold, so no gate needs to be cut.) Weight or clamp and pour.

[1] Various other patterns of this type will suggest themselves to be tried, either by paring down to the center line or wedging up the drag.

CHAPTER V

MATCHES

A match is a mold used as a moldboard into which the pattern is inserted to its parting line (Fig. 49).

A match is often used for patterns, such as Ex. 2, 3, and 5. Matches are made of sand, oil, or plaster of Paris. A sand match is used when only a few castings are needed. When it is desirable to keep the match for any length of time, an oil match is made, and if it is to be used indefinitely, it should be made of plaster of Paris. A match is made in a shallow frame the size of the flask to be used. It should have sockets to engage the cope pins. A bottom board should be securely fastened to the frame. The oil and plaster of Paris matches, when not in use, should be stored in a place where they will not be injured, and the pattern should be left in the oil match to prevent the match from shrinking.

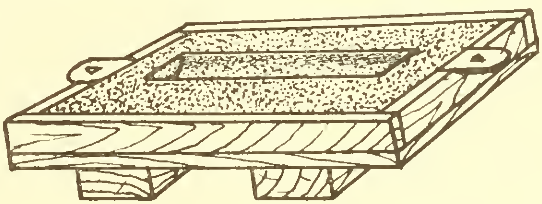


Fig. 49.

Exercise 6. *Green-sand Match.*

Pattern: solid cylinder.

To make the match: Fill the frame with riddled molding sand and pack it very solidly. Strike off the face or joint with a straight edge; flat and even with the edges of the frame. Bed the pattern in about the same relative position as shown in Fig. 37, by driving it into the sand to its exact center. Smooth the whole surface with a slick or trowel. Draw the pattern to test correctness of the work. Replace the pattern and put on the parting sand.

This match can now be used in place of the moldboard, by placing the drag on it and filling and ramming as in Ex. 2 or 3. When the drag is turned over and the match is removed, all is ready for putting on the parting sand and proceeding with the cope. A match of this kind can be used several times, thereby saving considerable time.

EXERCISE 7. *Oil Match.*

Pattern: solid cylinder.

To make oil match: Measure out enough burnt sand (or parting sand) to half fill the match frame. Thoroughly mix with the burnt sand an equal quantity of new molding sand and one fortieth litharge, and pass this mixture through a fine riddle while dry. Moisten this mixture of sand and litharge with boiled linseed oil and mix well, until the whole mass is of the consistency of well-tempered molding sand. (If too dry, it will crumble easily; if too wet, it will take a long time to dry or become hard enough for use.) Ram this tempered mixture into the frame and strike off the surface level with the frame, and smooth. Bed the pattern, in the same position as in the green-sand match, to the parting line. Lay a few brads in the sand, close to the pattern, at points where the match is likely to become injured by wear; press them into the sand with the finger and smooth the surface with slick.[1]

Draw the pattern out to test the parting, return the pattern, and set the match in a moderately warm place to dry. This will require from one to two days. When thoroughly dry, remove the pattern and apply two coats of thin shellac.

This match is used exactly as a moldboard or the green-sand match, except that no parting sand is needed as in the case of the green sand match.

EXERCISE 8. *Plaster of Paris Match.*

Pattern: solid cylinder.

To make plaster of Paris match: First make green-sand match as described in Ex. 6. Place a frame similar to the one

[1] These brads help to hold the sand firmly about the pattern.

used for the green-sand match but without bottom board,[1] bottom side up, over the match, and securely fasten. Place the pattern in position in the sand match.[2] Make a thick mixture of plaster of Paris and water, and fill the frame level full of the mixture. When the plaster has set, place the bottom board in position and securely fasten it. Remove the sand match and pattern. Remove any sand that may adhere to the plaster with a brush or wash with a little water. The match is now ready for use exactly similar to the oil match.

[1] A bottom board can be used if it is securely fastened to the frame, and a hole made through it, to pour the plaster through.

[2] The pattern should be given a coating of light machine oil to prevent the plaster adhering to it.

CHAPTER VI

MOLDING EXERCISES WITH GREEN-SAND CORES

Green-sand Core. — When a pattern is so formed that the sand of the mold is left in such a way as to form a hole or hollow in the casting, the sand so left is called a green-sand core.

EXERCISE 9. *Simple Green-sand Core.*

Pattern } Gland.
Casting }

This pattern is made with two tapers to give it draft: one on the outside with the larger dimension at the flange end, the other on the inside with the *smaller* dimension at the flange end. The outside taper allows the pattern to be removed from the sand, while the inside taper allows the inner core of sand (the green-sand core) to slip through the pattern.

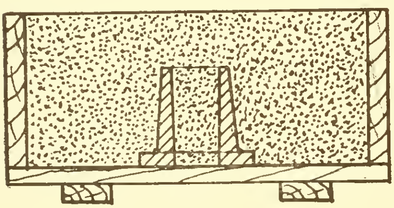


FIG. 50.

To make the mold: Place the pattern on the moldboard with flange or largest outside end on the board, as shown in Fig. 50. Place the drag in position. Riddle enough sand to cover pattern. With the fingers pack the sand about the pattern, and press it into the hole. Care must be taken that the top sand in the hole is loose enough to adhere to the sand to be added. Fill the remainder of the drag; ram and vent as in previous

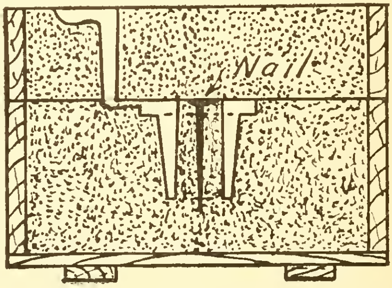


FIG. 51.

work. Care must be taken to have a good union of the sand in the hole with that in the rest of the drag. Turn the drag over; make parting; set sprue plug[1] in position shown in Fig. 51, and finish the cope as in previous exercises. Remove the cope, press a nail into the sand in the holes (Fig. 51) to strengthen the core, and anchor it to the rest of the sand in the drag. Draw the pattern (Fig. 52) and finish by cutting gate and making pouring basin; as in other exercises clamp and pour.

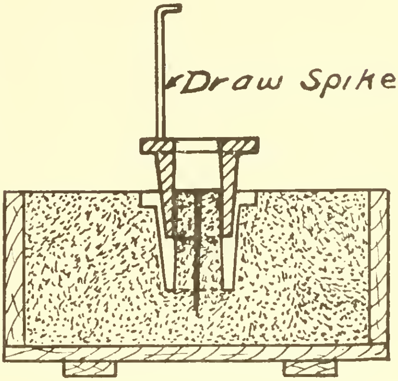


FIG. 52.

EXERCISE 10. *Grooved Pulley (Two-part Flask). One roll over.*

Pattern }
Casting } Grooved pulley.

To make the mold: Select a flask quite a little larger than the pattern. Place the female part of the pattern on the mold-board as shown in Fig. 53. Place the drag in position; insert the sprue plug as shown at *a*, Fig. 53; fill; ram and vent as in Ex. 1. (The sprue plug must not project above the drag.) Turn the drag over in the usual way. With a trowel pare the sand down to the parting line of the edge of the pulley, as shown in Fig. 54. Put on parting sand, taking care that none gets on the pattern. Place the male part of the pattern in position and build up the cheek, or green-sand core, as shown at *b* in Fig. 55. This is done by packing in riddled sand with the hands, and lightly slicking. Put parting sand on the exposed part of the

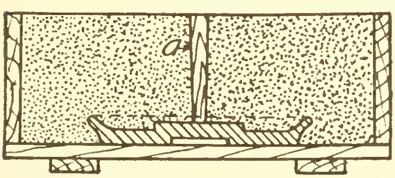


FIG. 53.

[1] Riser is not necessary in this case.

cheek. Place cope in position; fill; ram and vent as in other exercises.

To draw the pattern: Lift off the cope. The cheek and pattern will remain on the drag as in Fig. 55. The half of the pattern is now removed as in previous exercises. Should the half pattern remain in the cope, as shown in Fig. 54, it can be removed in the usual way. Figure 56 shows the drag with the pattern removed. Dust on a little facing. Replace the cope; place bottom board on top; turn the flask over, remove the sprue plug and form pouring basin. Lift off the drag. The cheek will now remain on the cope and the remainder of the pattern can be drawn from the drag. Should the pattern remain on the cheek great care must be observed in driving the draw spike not to injure the cheek. Dust on facing; replace the drag, which is now a cope; clamp, etc., as in the previous exercises. Figure 57 shows mold ready for pouring.

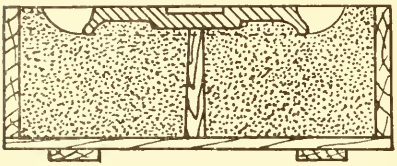


Fig. 54.

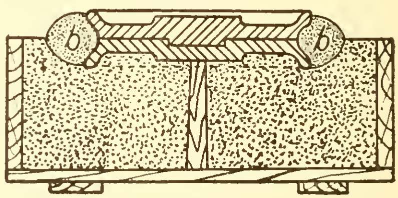


Fig. 55.

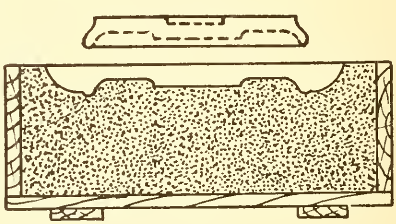


Fig. 56.

Exercise 11. *Grooved Pulley (Three-part Flask).*

Pattern: grooved pulley, same as in Ex. 10.

Casting: same as from Ex. 10.

To make the mold: Select a three-part flask in which the height of the cheek is equal to the distance between the parting lines of the pattern (Fig. 58) and considerably larger than the diameter. Place the cheek on the moldboard with the drag side up. Then place the pattern centrally in the cheek. With wedges raise the cheek so that its edges come to the parting lines of the pattern (Fig. 58). Fill with riddled sand, press well into the groove with the fingers, and then ram. Smooth the joint and make parting. Place the drag in position and ram and vent as usual. Turn the drag and cheek over. Smooth the joint and make parting. Place the cope in position. Set the sprue plug over the hub, and finish the cope in the usual manner, as shown in Fig. 59. Remove the sprue plug and form pouring basin.

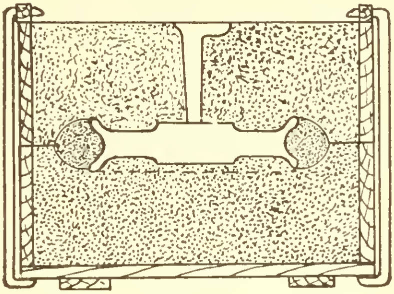


FIG. 57.

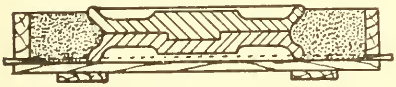


FIG. 58.

To remove the pattern: Lift off the cope and cheek without separating them. Draw the part of the pattern in the drag. Dust on facing. Replace the cope and cheek. Lift off the cope and remove the rest of the pattern. Should the pattern remain in the cheek, great care must be observed in driving in the draw spike not to injure the cheek. Dust on facing and replace the cope. Clamp and pour.[1]

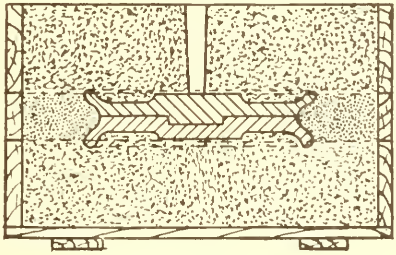


FIG. 59.

EXERCISE 12. *Column Base (Three-part Flask). Sprue in Cheek and Cope.*

Pattern } Column base.
Casting }

To make the mold: Select a three-part flask of suitable size with a cheek of the same height as the pattern. Set the pattern

[1] Other methods of making the grooved pulley should be discussed.

on the moldboard with the large face on the board. Place the cheek on the board with the drag side up. Put a sprue plug just the height of the cheek, at one side or in one corner, as shown at *a*, Fig. 60. Ram up the cheek and sift parting sand over all exposed molding sand. Place the drag in position and ram and vent it in the usual way. Turn the drag and cheek over and put parting sand on that portion of the mold between the pattern and the cheek frame. With a slick loosen up the top sand inside the pattern, so that there will be a good union when sand is added. Put on the cope, and set the sprue plug *b* about one inch from the plug *a* in the cheek (Fig. 61). Ram, vent, and finish in the usual way.

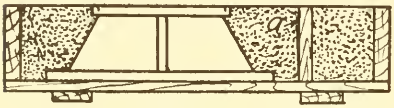


Fig. 60.

To remove the pattern: Draw the sprue plug *b*, Fig. 61, and form the pouring basin. Place on bottom board and lift off the cope, and turn over and rest on the board. This must be done with great care, as the sand inside the pattern (green-sand core) will lift with the cope. Draw the sprue plug *a* from the cheek, draw the upper part of the pattern *g*, and dust on facing. Cut gate *f* and replace the cope. Lift off the cope and cheek, draw the remainder of the pattern *c*, and dust on facing. Replace the cope and cheek; clamp and pour.[1]

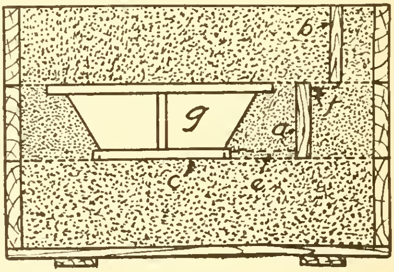


Fig. 61.

[1] If the hanging portion of the cope (the part extending into the pattern) is very deep, it may be well to roll the complete flask over and draw the pattern by first lifting the drag and cheek, drawing part *g* of pattern, replacing drag and cheek, removing the drag and part *c* of pattern, replacing the drag and rolling flask back to pouring position, or by placing the top face of the pattern on the moldboard when making the mold.

CHAPTER VII

DRY CORES

1. Dry cores consist of a mixture of a refractory sand and some binding material, molded in a core box, or swept by a sweep (Fig. 105) to the shape of a desired hole or cavity in a casting, and then baked. When placed in the mold, these cores prevent the metal from filling certain portions, and when burned by the heat of the metal, the core crumbles and leaves a hole in the casting. The cores may form recesses in, holes of any desired shape through, or they may hollow out the inside of a casting. The making of dry cores is a separate branch of the foundry business.

In core making, as in green-sand molding, the principal material is sand. In green-sand molding the grains of sand are held together by the alumina. In dry core work the grains of sand are held together by the binder which the molder introduces, the amount and kind of which he controls as best suits his use and convenience. A naturally free sand must be used as a base. A sand containing alumina would cake in baking, and also when in contact with the hot metal, thus becoming very hard to remove from the casting. To this free sand some organic material possessing binding qualities must be added. This holds the grains of sand together until the metal has formed about the core. At the same time that the metal is cooling, the binder should be burning out. The core can then be easily removed.

2. Binders. — The materials most generally used and answering the above requirements are :

Flour. The most universal material is wheat flour, which acts in the core as it acts in bread.

Rosin. A hard vegetable gum which, when finely powdered and mixed with the sand, has a strong binding action; this is due to the fact that it melts in the oven, forming a coating over the sand grains which cements them together upon cooling.

Linseed oil, when mixed with sand, acts very much like the rosin. It is also used in connection with flour when a very strong core is wanted.

Glue, when dissolved in water and used to temper the sand, makes a good binder.

Molasses water is used for wetting the sand in making small cores. It is made by mixing one cup of molasses with a pail of water.

Clay wash is used as a base for blacking. (See page 8.)

Manufactured binders, both in liquid and in dry forms, can be obtained on the market. Some claim that a better and cheaper core can be made by their use.

3. Core Materials Other than Binders.

Soft iron wire in various sizes, usually not smaller than No. 16.

Bar iron in sizes from $\frac{1}{4}$ inch to $\frac{3}{4}$ inch according to the work the foundry handles.

Gas pipes of various sizes are used for strengthening cores in some classes of work.

Wooden frames wrapped with straw or hay rope, plastered with a thick clay wash, are used on large work to strengthen cores.

Cinders are used in large cores to make venting easier, also to prevent cracking due to expansion.

Wax which will melt and run between the sand grains on baking, leaving a passage through which the gas can escape, is very often used.

Charcoal or graphite washes are applied to the cores before using, by dipping the cores or painting them.

Composition and Making of Cores. — As mentioned before cores are for forming holes or cavities in castings. In order to effect this result the core usually spans an opening in the sand.

The core must therefore be strong enough to hold its weight when supported at its ends, and also to withstand the force of the metal rushing in to fill the mold. This condition is met by properly proportioning the mixture of free sand and binder, and by the use of wires or of iron rods in the core.

The binder serves not only to keep the core in shape before baking, but to insure its strength after baking. Too much binder causes the core to sag before it is baked, and also to "blow" (give off more gas than the vent can take care of) when the metal surrounds it. When too little binder is used, the core is not strong enough to do its work. It "cuts" when the metal is poured.

As sands vary so greatly, no exact proportions can be given for all cases. The following will serve as a guide:

Composition: Small Cores

Beach sand	8 parts
Flour	1 part

Temper with molasses or beer.

Large Cores

Sharp sand	8 parts
Strong molding sand	2 parts
Flour	$1\frac{1}{2}$ parts

Temper with clay wash.

For Small Complicated Cores

1.	Beach sand	15 parts
	Fire sand	15 parts
	Rosin	2 parts
	Flour	1 part
2.	Beach sand	15 parts
	Molding sand	5 parts
	Flour	2 parts
	Linseed oil	1 part

MAKING

Tools. — The tools used in core making are the same as those used in the foundry. The small trowel, however, almost entirely replaces the slick. A small iron rod is used on small work as a rammer. A spraying can (Fig. 62) is used to spray molasses water over the cores.[1]

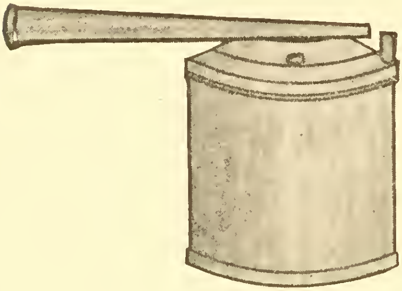


Fig. 62.

Mixing. — The proper amount and proportion of sand and other constituents should first be thoroughly mixed dry, or until the mixture becomes uniform in color, and then formed into a circular heap with a crater in the center. Into this crater is introduced water, beer, molasses water, or oil. The sides of the crater are now turned in, so the tempering liquid moistens the mixture. The mass must now be thoroughly worked until the tempering liquid is evenly distributed. Only enough liquid is to be added to cause cohesion of the sand mixture; if too wet, the core will stick to the core box. When tempered, the mixture is pressed into core boxes as explained later under the various exercises or swept into shape by means of forms and sweeps. When large quantities of cylindrical cores are used, they are made with machines. The mixture is placed in a hopper and forced from this hopper through a former as a long, cylindrical core which can be cut to the desired length. A large variation in the diameter can be obtained from each machine by changing the formers.

Baking. — As soon as a core is made it should be placed in an oven and baked. If allowed to stand for any length of time in the air, it becomes air dried and crumbles. The length of time it takes to bake a core depends on the size of the core and

[1] One or two spray cans will supply a large class.

the heat; usually from one half hour to two hours is required. A core must not be placed in the direct path of flames as they char the binder and make the core useless.

Oven. — An oven for baking cores is a necessary adjunct to every foundry. In foundries doing only light work, a small oven

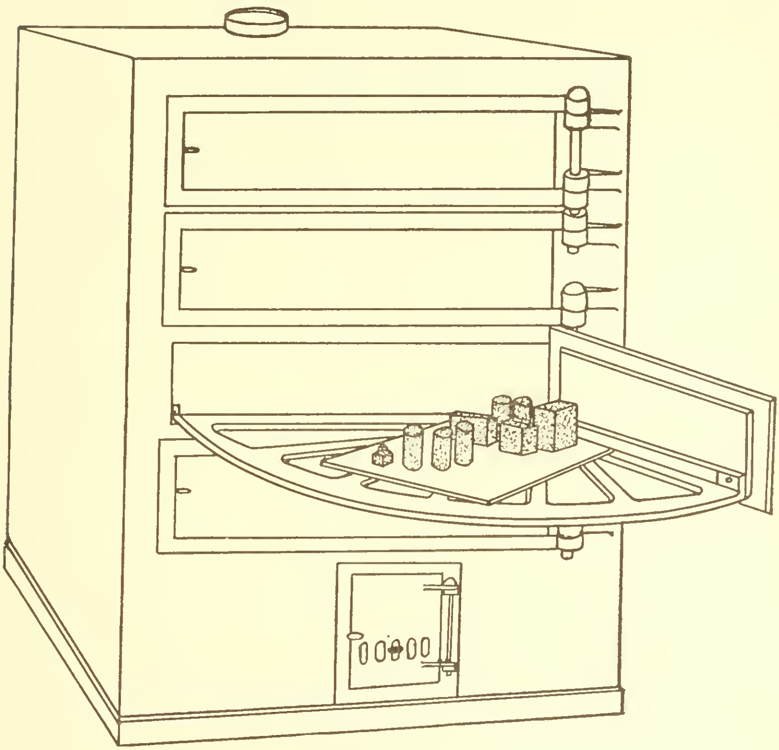


FIG. 63.

similar to the one shown in Fig. 63 is used. These ovens are made of brick or of iron. The iron ones are portable. They consist of an ash pit, a fireplace, and an oven. The front of the oven is a series of doors, to which shelves are attached. These shelves are perforated to allow the heat to pass from one to the other. On the back of the shelf is a plate the size of the door. When the door is opened and the shelf drawn out, the back plate closes the opening. In this way the loss of heat is prevented. In a foundry doing large work, an oven will be found capable of taking the largest pieces made. Very large ovens are fitted with tracks so that the pieces can be run in and out on cars. The portable oven is the most desirable for school use.

Finishing. — Before a core is used it should be given a coat of blacking. This will give the core a smoother surface and leave a smoother, better hole in the casting.

A good blacking for light cores is made as follows: Mix one cup of molasses in a pail of water; into this stir powdered charcoal until an even coating of black will be deposited on the core when dipped thereinto.

For heavy work, take one part of charcoal and two parts of graphite and mix with a thick clay wash. The light cores can be dipped into the blacking. In the case of large cores, the blacking should be put on with a brush.

CHAPTER VIII

MOLDING EXERCISES WITH DRY CORES

In the preceding chapter the composition, making, and baking of dry cores was given in a general way. In this chapter a few exercises will be taken up to bring out special ways of venting, forming, and setting some of the simpler forms.

Venting Cores. — The heat of the metal, by burning the binders and other constituents of cores, forms gas. This gas, as well as that in the sand, must be conducted out of the mold. If not properly carried off, it will force its way out at the point of least resistance. This is often through the molten metal. When it escapes thus, the casting is spoiled, becoming spongy, or full of holes; and sometimes it is even blown out of the mold.

A core must therefore be made with vents to carry the gas to a point where it can pass off through the sand of the mold. When the metal completely surrounds a core except at the prints, there must be ample passages to these prints through the core, and the sand of the mold next to the prints must be well vented. When the metal touches but one side of a core, no special venting is needed. The same is true of a small core partly surrounded with metal.

Setting Cores. — The setting of dry cores may be classed under two heads: (*A*) setting in prints where the print does the holding; (*B*) setting in prints where the print locates only and the core is held by chaplets or other means.

(*A*) **Cores held by Prints.** — The setting of a simple core when the pattern has prints is a simple matter. The core is vented by running a hole through it to the part that fits in the print. The core is placed in the print depression in the drag and the cope placed in position. This anchors the core in position, and the gases will pass off through the sand at the prints. When a core is set on end in the drag and projects into the cope, care must be taken that it enters the print recess in the cope properly or the mold will be broken.

EXERCISE 13. *Simple Straight Dry Core. Held by prints.*

Pattern: gland (split pattern with prints).

Core: straight core (made in halves).

Casting: gland.[1]

Core Box. — The core box is shown in Fig. 64, *a* being a longitudinal section through the center and *b* a transverse section along the line *e–e*.

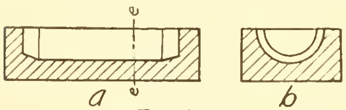


FIG. 64.

To make the core: The core for this exercise can be made in two ways: (*a*) in halves, (*b*) solid.

(*a*) Mix 8 parts of sharp sand with 1 part of flour (receipt 1, page 51) as directed in Chapter VII, page 52, and temper with molasses water,[2] care being taken not to get the mixture too wet. Fill the core box heaping full of the mixture and press it in quite hard with the fingers. (A core must be rammed harder than a mold, but not so hard as to stick to the box nor so compactly as not to vent.) Smooth the face level with the top of the box with a trowel. Invert on a sheet-iron plate heavy enough not to bend. Rap the box slightly to loosen the core, and remove the box, leaving the core on the plate. (Two of these half cores are needed, but at least four should be made to replace any that may be broken.) Spray with molasses water and place in the oven to bake. When baked, take two of these half cores, rub the flat faces together to insure perfect contact over the entire surface. Cut a groove down the center of each from

[1] The student will note that this casting and the one from Ex. 9 are similar and for the same use.

[2] To make molasses water, add 2 tablespoonfuls of molasses to 1 quart of water and stir until thoroughly mixed.

end to end. Paste the halves together with flour paste, taking care that no paste gets into the vent groove, and give a coating of blacking. (See *Blacking*, page 54.)

(*b*) Follow the directions given under (*a*) for mixture. To fill the box clamp or hold the halves tightly together, stand the box on end on a metal plate, and force the core mixture into the hole; ram it solid with a $\frac{3}{8}$-inch iron rod till full; strike off the ends smooth; run a wire through the middle of the core from end to end to form the vent passage.

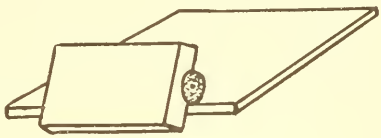


FIG. 65.

Rap the box lightly and remove one half of it. Invert the half containing the core on a plate and roll the core from the box, as shown in Fig. 65. A large core made in this way is likely to become flattened on one side because of its weight.

To make the mold: Make the mold as in Ex. 4, observing all the directions for ramming, venting, etc. Set the sprue plug as shown in Fig. 66.

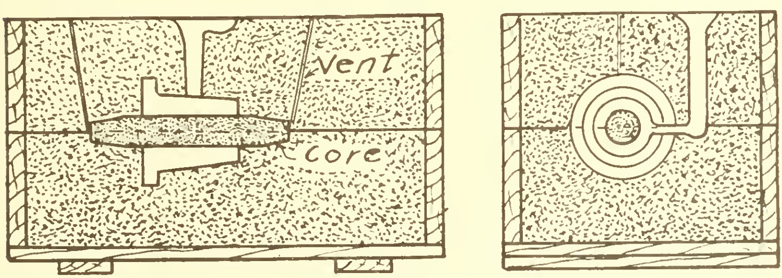


FIG. 66.

To set the core: See that the core is cool. A core must not be set into a mold hot, as this will cause sweating. Carefully place the core in the depressions in the drag left by the core prints. See that the core is a snug fit. If the core does not fit the print, make it do so by filing the core if it is too large or too long, or by filling the depression with sand if the core is too small. Vent the cope well from the ends of the core as shown

Fig. 67.

in Fig. 66. Place the cope in position, clamp, and pour.

This pattern can be made solid, in which case the mold would be made as in Ex. 2 or 3. The core for that exercise can be made in one piece, with a box, as shown in Fig. 67.

Exercise 14. *Setting Bolt Hole Core and Core below the Surface.*

Pattern: bracket.

Cores: core and filling piece combined (pocket core), *b*, Fig. 72, and short cylindrical core.

Casting: bracket with a cored hole in each part.

To make the cores: Use the same mixture as in Ex. 13. Core *a*. Hold the halves of the core box (Fig. 68) tightly together with the hands or a clamp. Ram the core mixture into the box with a $\frac{3}{8}$-inch iron rod and smooth off end. Rap the box lightly; stand it on end and separate the halves, leaving the core standing on end, as shown in Fig. 69; spray with molasses water and bake. Core *b*, core box, Fig. 70; *a* is the plan of the box and *b* the elevation of one half. It will be noticed that the box separates into halves along the line *c–d*. Hold the halves tightly together and fill with core mixture like that used for core *a*. With a $\frac{3}{8}$-inch rod ram the mixture solidly into the round portion, and with a bench rammer ram the balance of the core; run a wire or small nail into the round portion, to strengthen it, as shown in Fig. 71. Smooth off the face and end of the core even and level with the box. Invert on iron

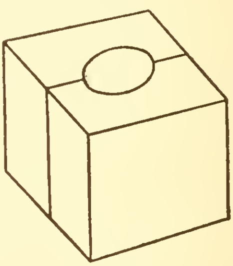


Fig. 68.

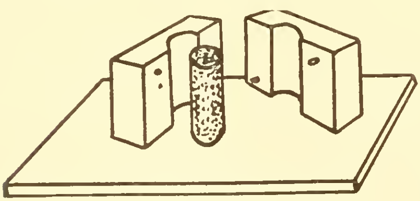


Fig. 69.

plate,[1] rap lightly, and separate the halves of the box. Spray with molasses water and bake. Give each core a coating of blacking.

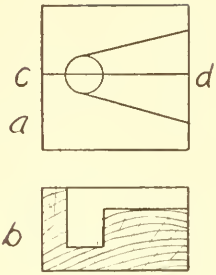


FIG. 70.

To make the mold: Place the pattern with the face *c*, Fig. 72, on the moldboard, and make the mold in a manner similar to Ex. I. Place the sprue so that the gate can be cut either in the end, as shown in Fig. 72, or to the side of the mold.

To set the cores: Core *a* is stood on end in the hole left by the print on the pattern. Core *b* is placed in the depression left by print. Care must be taken that the print holes are filled by the core. If the cores do not fit snugly, pack a little molding sand around them, and slick over to prevent the metal from flowing where it is not wanted. See that the tops of the cores come flush with the joint line. Make a vent-hole from the center of each core print before the core is set.

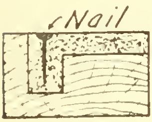


FIG. 71.

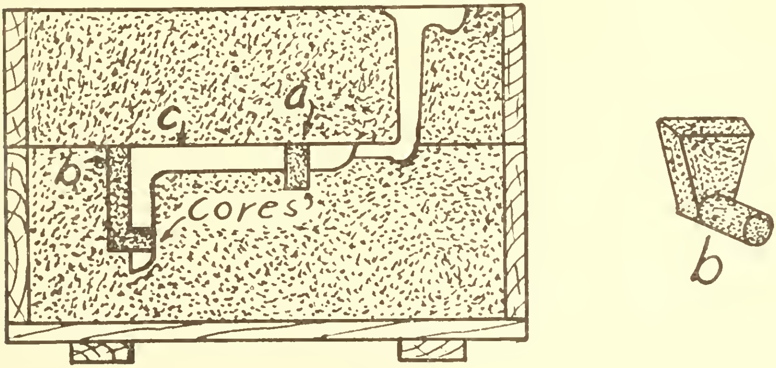


FIG. 72.

Place the cope in position. This will anchor the cores so that they will not rise when the mold is poured. Clamp and pour.

EXERCISE 15. *Balanced Core.*

A balanced core is one where the part resting in the print has

[1] All plates should be of about No. 10 iron, so they will not bend when handled.

weight enough to balance and hold in position an overhanging, unsupported end. (In Fig. 73 the hole extends into the casting, but not all the way through it. This gives the core but one support, which makes it necessary to extend it far enough back from the mold to balance the weight of the overhanging part.)

Pattern : lathe chuck for short bars.

Cores : cylindrical.

To make the core : Make the core of the same composition as core *a*, Ex. 13, and in a similar manner. Vent the core the entire length except for a short distance at the end which pro-

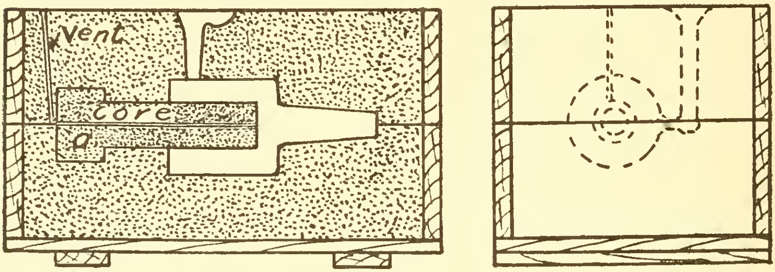


FIG. 73.

jects into the mold. (If the vent is made by running a vent wire through the core, the vent at the end that projects into the mold can be stopped up with a little fire clay.)

To make the mold : If a split pattern is used, make the mold similar to Ex. 4. If a solid pattern is used, make the mold similar to Ex. 2 or 3.

To set the core : Place the core in the print depression. Care must be taken that it is a good fit in the print and that it projects into the mold exactly the right distance.[1] See that the cope is well vented from the end of the core (Fig. 73). Close, clamp, and pour.

EXERCISE 16. *Setting Core below the Surface (by Stopping off).*

Pattern : bearing.

[1] It is well for the core to have a head like that shown at *a*, Fig, 73, as it not only adds extra weight to balance the core but locates it definitely.

Core: straight cylindrical.

Casting: bearing with cored hole.

To make the mold: Place the flat face of the pattern on the moldboard, and fill, ram, and vent both cope and drag in a manner similar to Ex. 1. Make vents from each print depression. The sprue should be placed so that the gate can be cut from the end of the mold or one side near the end.[1]

To set the core: Place the core *c* in the depressions as shown in Fig. 74. Stop off the depressions *b* above the core by holding

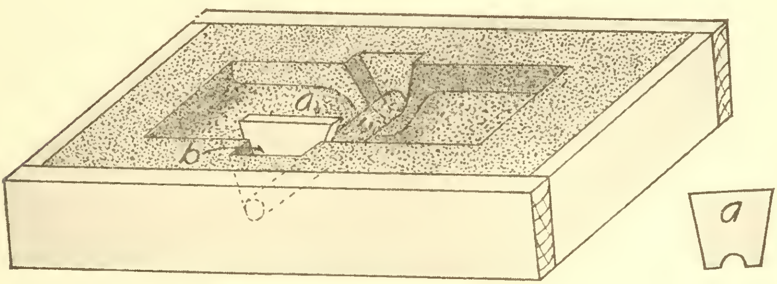


FIG. 74.

the stopping-off piece *a* over the core, and against the end face of the mold. Fill with molding sand the space *b* over the core, and slick even with the joint. Close the mold clamp; and pour.

EXERCISE 17. *Segment Core.*

Pattern: groove pulley.

Core: segment core.

Segment Core. — A segment core is one built up of segments of a circle; *a*, Fig. 75, shows one segment or one sixth of a core. Each segment is made of two halves like section *a*, Fig. 75.

To make the core:[2] To the required amount of sharp sand add linseed oil and work in thoroughly until it becomes saturated. This will be when the oil shows slightly on the finger nails when

[1] In a large casting the sprue can be placed at the side about the center and gates cut to the side near each end.

[2] This core is made with linseed oil, not because it is necessary that a segment core should be tempered this way, but to show the use of linseed oil in core work.

the hands are pressed into the sand. The oil should be introduced in the same manner as tempering water was in previous exercises, — by pouring it into a crater and then turning in the

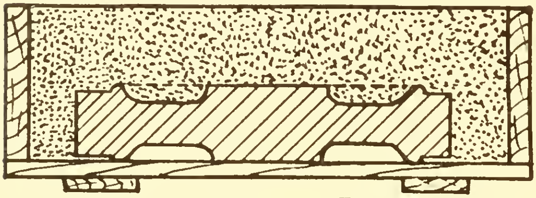
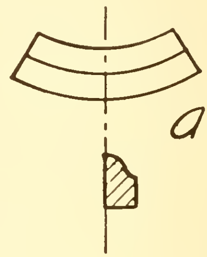


Fig. 75.



sand from the sides. The sand should then be worked with the hands and more oil added, if necessary, until properly tempered. Fill the core box in a way similar to *a*, Ex. 13. Remove to plate and bake. Twelve cores will be necessary.

To make the mold: Place the pattern on the moldboard and ram the drag as in Ex. 1. Turn the drag over and cut the sand away to the line *a*, Fig. 76. Make parting, place the cope in position, and set the sprue plug on the hub (Fig. 76). Ram in the usual way and remove the pattern.

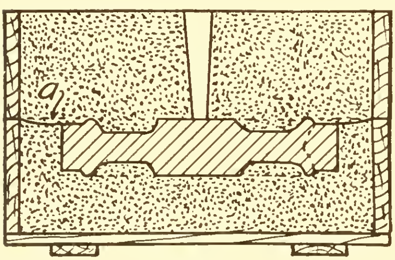


Fig. 76.

To set the core: Paste together two half cores (being sure the ends are even). Put a little paste on the ends of each pair and set them around the mold in the core print, being sure they fit snugly, and touch the mold at the back of the print. Close, clamp, and pour.

Segment cores are used on large work mostly. On small work the core is usually made in halves. Each half has the same section as the segment core, but is a complete circle.

Exercise 18. *Hollow Core.*

Pattern: cover with ornament on top.

Core: hollow core for ornament.

The projecting ornament at the top is of such a shape that it will not draw out of the sand in the position the cover must be molded. In order that the casting may be made with this ornament, the pattern has a core print at the place where the ornament is to be. A core is used whose outside shape and dimensions are the same as the print, and whose inside is hollowed to the shape of the ornament. Figure 77 shows a cross section of the box, which makes half the core.

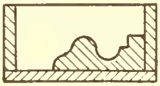


FIG. 77.

To make the core: Measure out enough sand and flour (in correct proportion) to make about three half cores; add to this a small handful of finely powdered rosin. Mix thoroughly until all is of a uniform color and then temper, as before, with molasses water. Fill the box by ramming in the core mixture as before. Invert on plate, rap the box lightly to loosen the core, and remove it. When baked, give the inside a coating of blacking and paste the halves together.

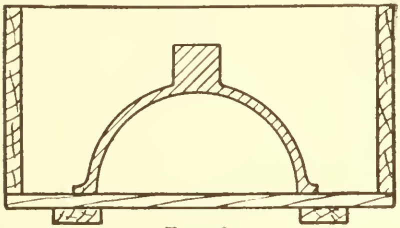


FIG. 78.

To make the mold: Place on the moldboard as shown in Fig. 78. Ram the drag in the usual manner. This pattern is easily broken, so it must be handled carefully. Turn the drag over. Put on the cope and parting sand. Set plugs for riser *a*, and runner *b*, Fig. 79, and ram in usual manner. Lift the cope and remove the pattern. Set core in print depression. The core must fit tightly in the depression, come flush with the bottom of the mold, and all openings between core and mold filled with molding sand. Replace cope; clamp and pour.

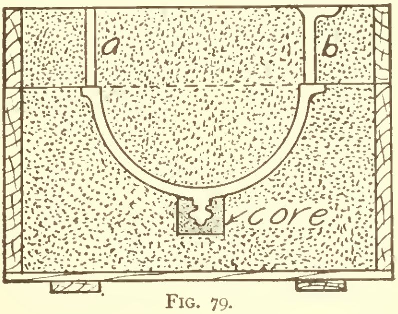


FIG. 79.

NOTE. — A large pattern of this shape would require a special cope with crossbars and gaggers to support the sand that extends into the pattern.

(*B*) **Cores located by Prints and held by Chaplets or Other Means.** — The cores just taken up are held in position by prints. There are many cases, however, where the prints are merely for locating the core. It then becomes necessary to use some device to hold the core in place while the metal is being poured. Some small cores are held by placing nails slantingly into the sand, the heads bearing against the core to hold it. Cores resting in the drag are held by chaplets as shown at *f*, *g*, and *h* in Fig. 81. Other cores have prints in the cope for locating them, but have none in the drag for support. In this case they are hung by wires (Fig. 80). The wire holds the weight of the core till the metal is poured. The metal then forces and holds the core into the print.

Chaplets are iron supports used to hold cores in position, when prints cannot be used. Chaplets are made in an almost endless variety of shapes and sizes. However, there are two general types, — single headed and double headed. A single-headed chaplet is shown at *a* and a doubled-headed at *b* in Fig. 80. The stems are burred so that the metal will grip the chaplets firmly. The stem of a single-headed chaplet may be either blunt or pointed. Stems shown at *c* to which heads of any size or shape may have been riveted make most useful chaplets. The chaplet and stand at *d* are also very useful. They allow great flexibility, since any variety of heads may be placed in the stand. *e* is a double square head chaplet of gray iron. These chaplets fuse well into the hot iron; consequently they do not cause blowholes and leave very little blotch on the surface. *g*, *h*, *i*, *j*, and *k* show the "Peerless Perforated Chaplet," used on all classes of castings requiring small cores. They are made of perforated, tin-plated sheet metal, insuring perfect ventilation of the chaplet, eliminating all possibilities of blowholes, air pockets, chills, etc., forming a perfect union with the molten metal, thereby giving

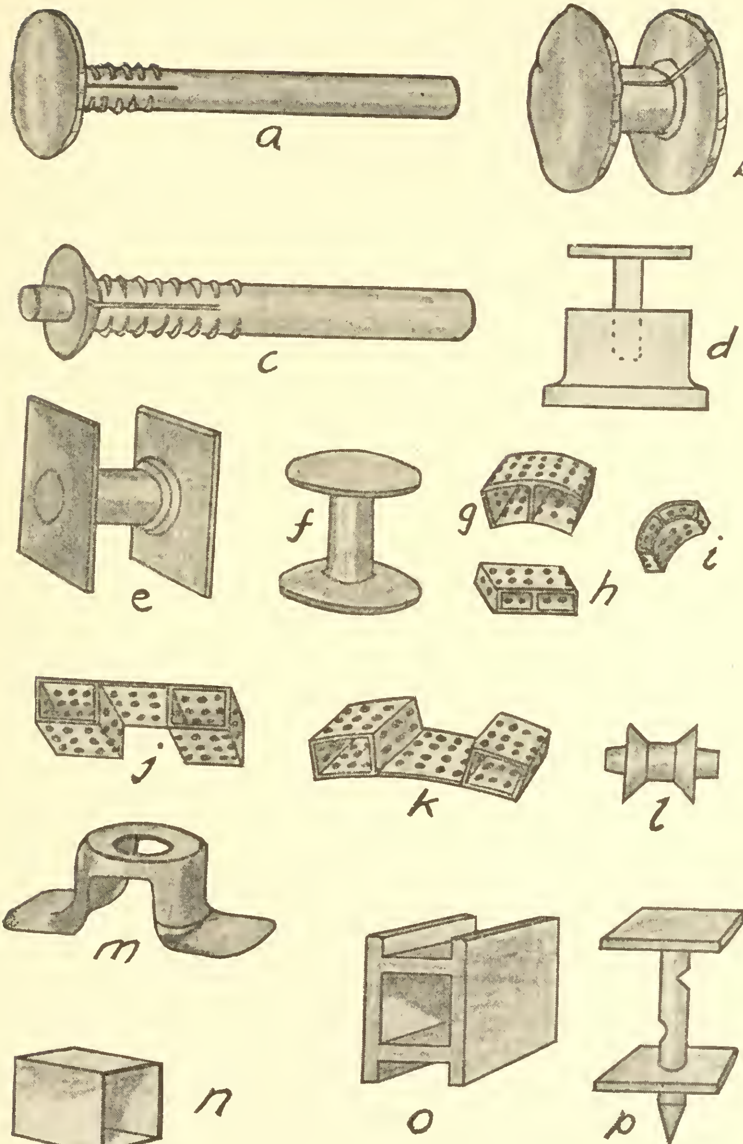


Fig. 80.

a pressure tight joint. *g* and *i* are used for cast pipe; *h* for flat straight work; *j* for flat round or straight work. They can be bent with the fingers, as in *k*, to fit the mold; *l* is a stem for a double-head chaplet; *m* and *n* are pressed tin shell chaplets. They form a perfect amalgamation and union with the cast metal. *o* is a special cast-iron shape and *p* is a double square-headed chaplet with point.

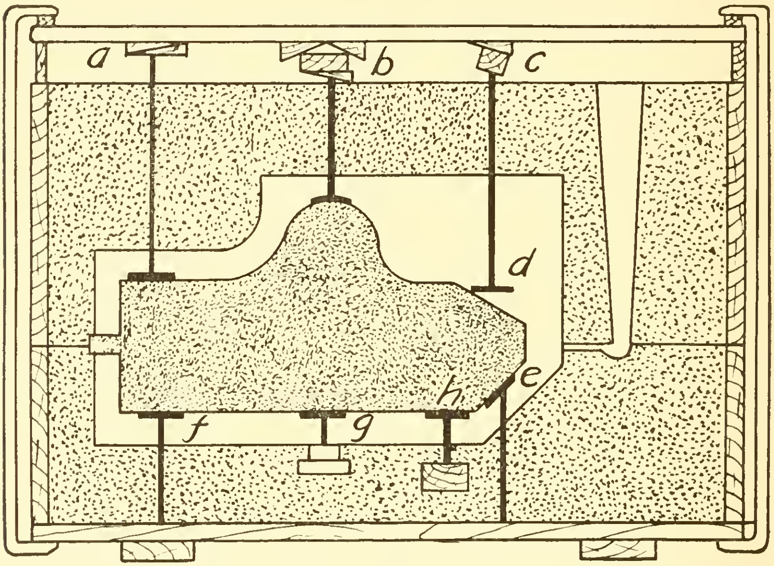


FIG. 81.

Chaplets weaken a casting, and therefore their use should be avoided as far as possible. When they must be used, care should be taken to place them where this effect will be reduced to a minimum.

Chaplets weaken a casting in three ways:

(1) By the introduction of a foreign metal;

(2) By the formation of porous spots about the chaplet, and

(3) By not fusing with the metal.

The first cannot be avoided, but can be reduced by proper design. The second can be prevented by using a tinned chaplet or placing red lead on the chaplet, and by keeping it free from moisture. The third can be avoided by roughing or notching the stem so the metal will take a close hold.

Setting Chaplets. — It is important that a chaplet be set correctly or its efficiency will be reduced. It must be wedged so as to give a solid bearing of the wedge on the stem of the chaplet, and of the chaplet on the core. The head should be bent to conform to the shape of the core as at *c*. When a bottom board is used, a drag chaplet may have a pointed stem long enough to drive into the board, as at *f* and *e*. A block of wood is sometimes rammed into the sand and the chaplet driven into it, as at *h*. At *g* are shown the uses of a chaplet and stand.

Venting and setting of different cores will be taken up under the various exercises following.

Exercise 19. *Nailed Core.*

Pattern: small rectangular block.

Core: T-section.

Casting: block with T-slot across bottom.

To make the core: Make the core of the usual sand-and-flour mixture; fill the box; remove from the box on iron plate, and bake.

To make the mold: Make the mold exactly as in Ex. 1.

To set the core: Set the core on the bottom of the mold; see that it fits tightly against the ends of the mold. (This core should be made a little long so that the ends can be filed off to insure a fit.) Press nails slantingly into the sand so that their heads will project slightly over the core, as shown in Fig. 82. The heads of the nails prevent the core from floating out of position as the mold is poured. No special venting is necessary. Close, clamp, and pour.

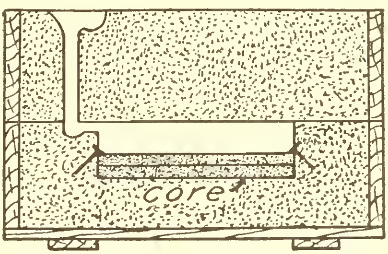


Fig. 82.

EXERCISE 20. *Nailing Core to Bottom Board.*

Pattern: rectangular block with print on one side.

Core: square core.

Casting: rectangular block with square hole partly through it.

To make the core: Make the core out of the ordinary mixture. Ram in the core box, strike off level. Make a hole completely through the core a little larger than the nail or chaplet to be used. (The hole can be enlarged by moving the nail backwards and forwards and around in a circle a few times.) Remove the nail from the core and the core from the box, and bake.

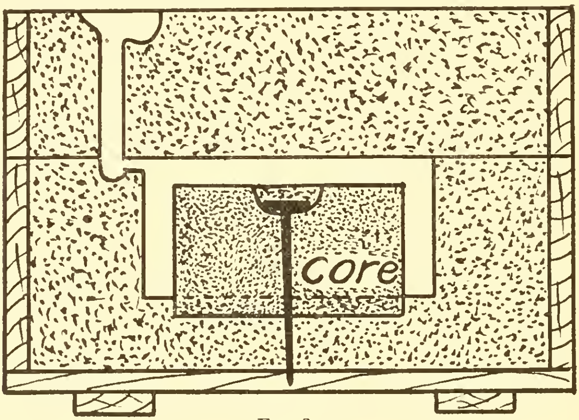


FIG. 83.

To make the mold: Make the mold as in Ex. 1, placing the pattern on the board with the core print up. Vent well the sand in the drag around the core print.

To set the core: Place the core in the depression. Press a nail or chaplet with pointed stem through the hole in the core and into the bottom board (Fig. 83). Fill in the opening in the core above the nail with a little molding sand. Close the mold; clamp and pour.

EXERCISE 21. *Hanging Core.*

Pattern: same as Ex. 20 except that the draft is in the opposite direction.

Core: square core, made in same box as Ex. 22.

Casting: same as Ex. 20.

To make the core: Make the core, using linseed oil for binder as in Ex. 17. Fill the core box about half full. Take a piece of No. 18 wire about twice as long as the core is high, bend it in the middle so as to leave a small loop, twist the wire a length equal to the height of the core box yet to be filled, and bend the remainder of the wire at right angles to the twisted portions. If there is too much wire, the ends can be cut off or coiled up. Place wire in the core box, resting the bent or coiled ends on the sand already in the box and so the loop will be in the center of the print and projecting a little above, then finish filling the box. Remove the core, and bake.

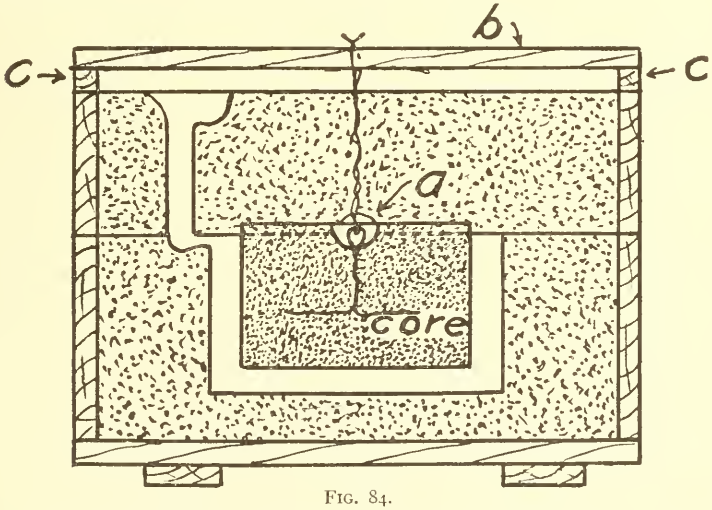


FIG. 84.

To make the mold: Make the mold the same as Ex. 1, placing the core print on the moldboard. Vent the cope above the core.

To set the core: With a vent wire make a small hole in the cope at the center of the print depression, slightly enlarging at *a*, Fig. 84. Attach a wire to the loop in the core, and twist it for a length about equal to the depth of the cope. Pass this wire through the hole. Place a bar *b* across the cope and attach the wire. With wedges between the bar *b* and the edges of the cope draw the core up tightly into the print. Close the mold; clamp and pour.

NOTE. — The use of this core prevents a deep lift of the cope.

EXERCISE 22. *Anchoring Core with Chaplets.*

Pattern : rectangular block.

Core : T-shaped, made in two parts.

Casting : rectangular block with T-slots on sides.

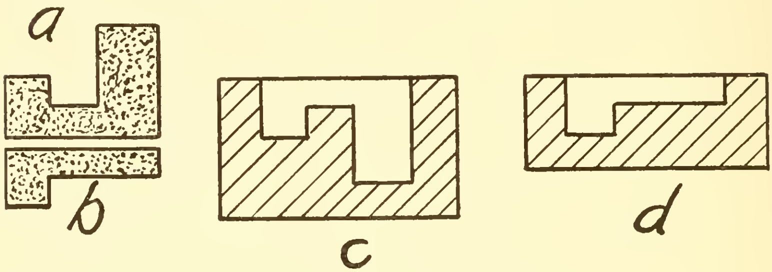


FIG. 85.

To make the core: This core is made up of two parts, as shown at *a* and *b*, Fig. 85, in boxes of which *c* and *d* show sections. Make up a core mixture using rosin, and make and bake

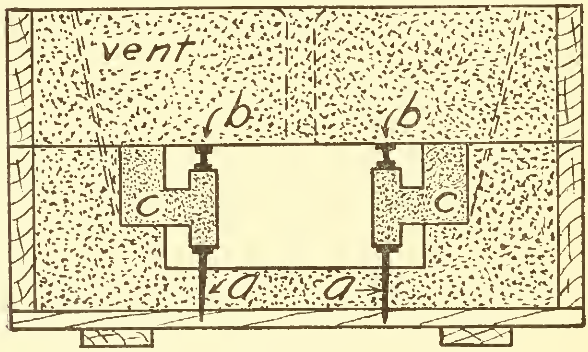


FIG. 86.

two cores from each box. Rub the flat faces of each part together, to make a good joint, and paste the parts together.

To make the mold: Make the mold exactly like Ex. 1.

To set the cores: Drive pointed chaplets *a–a*, Fig. 86, into the bottom board, letting them extend up to such a height that the cores *c–c*, when resting on their heads, are in the proper position. Put the cores in the print depressions and on chaplets *a–a*. Place double-headed chaplets on upper side of core as at *b*. The chaplets must be just long enough to come to the joint line of the flask. (By means of the chaplets and the part of the core in the print, the cope sand prevents the metal from floating the core.) Close the mold; clamp and pour.

Exercise 23.

Repeat Ex. 22, using chaplets that come up through the cope and requiring wedging, as shown at *a* in Fig. 81, page 66.

CHAPTER IX

MISCELLANEOUS EXERCISES

THERE are a few exercises involving important principles that either do not fall directly under the headings so far discussed or else were too difficult to make with the practice had when the general class under which they fall was discussed.

GATED PATTERNS

When a great many small castings of one kind are wanted, time and labor can be saved by the use of a gated pattern. A gated pattern is one composed of several similar patterns connected in such a way as to form a single pattern. The connecting pieces leave impressions in the sand, which form the gates for the individual patterns. A gated pattern is usually made of metal to make it more durable.

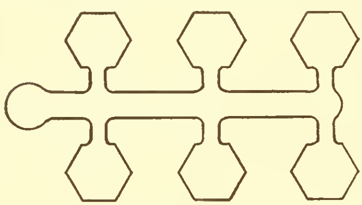


FIG. 87.

A tapped hole for the insertion of the draw screw is made in the center of the patterns. Two steady pins are usually placed on the drag side to steady the pattern as it is lifted from the mold. A gated pattern with flat joint should have a perfectly flat moldboard. When it has an irregular joint, a match should be used.

EXERCISE 24. *Gated Pattern (Plain Moldboard).*

Pattern: Fig. 87.

Castings: hexagon nuts.

To make the mold: Place the pattern in the sand as in Ex. 1. Care must be taken, however, to have a perfectly level moldboard, to avoid springing the pattern.

EXERCISE 25. *Gated Pattern (molded with Match Board).*

Pattern: Fig. 88.

Casting: bushings.

To make the mold: Make oil match as described in Ex. 7. Use this match in place of a moldboard and make mold as in previous exercises.

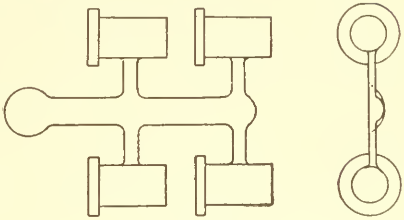


FIG. 88.

IRREGULAR PARTING

Often a pattern having some projecting part can be molded by making the parting surface an irregular surface.

EXERCISE 26. *Mold with Irregular Parting.*

Pattern / Casting } Cup-shaped cap with round projecting handles.

To make the mold: Place the pattern on the moldboard and support it with blocks, *a–a*, Fig. 89. Wedge up the drag so that the edges are in line with the point *b* of the pattern. Fill and ram the drag in the usual way. Turn the drag over and strike off the sand even with the edges. Build a mound with riddled sand about the handles, to the parting line *a*, Fig. 90, giving as gradual a slope as possible. Slick the joint well and make parting. Place the cope; set the plugs for the sprue and riser, and finish in the usual manner. Remove the plugs and lift off the cope. (The sand will part along the line *c-a-b-a-c.*) Draw the pattern; replace the cope; clamp and pour.

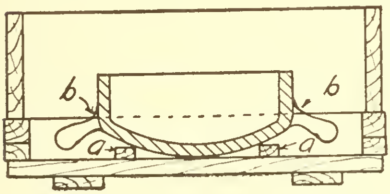


FIG. 89.

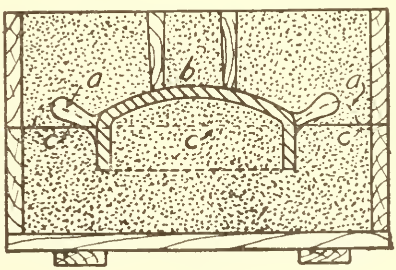


FIG. 90.

PATTERN WITH REMOVABLE PARTS

Often some overhanging part makes it impossible to draw the ordinary form of pattern from the sand. These parts are made detachable, and while ramming up, are fastened, or skewered, to the pattern proper with skewer pins or other fastenings which can easily be pulled out after the pattern has been rammed up, and thus the withdrawal of the pattern proper is possible. The loose pieces can then be drawn, leaving a properly formed mold of green sand.

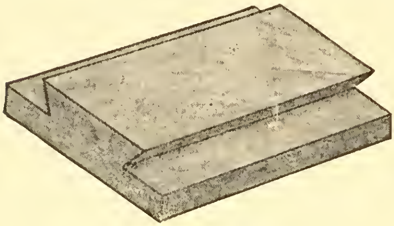


Fig. 91.

Loose-piece Pattern.—A loose-piece pattern is one having one or more parts held in place by pins in such a manner that the pieces can be withdrawn, the main part of the pattern lifted from the mold, and the loose pieces then taken out.

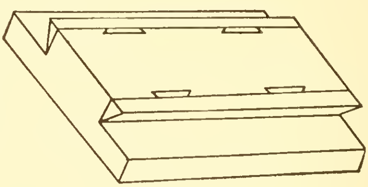


Fig. 92.

Exercise 27. *Loose-piece Pattern.*

Pattern: rectangular block with gibbed ways (Fig. 92).

Casting: rectangular block with gibbed ways (Fig. 91).

A pattern made like the casting (Fig. 91) will not draw from the sand. So the part shown in Fig. 93, which will lift, is made, and the overhanging part made separately. They are held to the main pattern with dovetails, as shown in Fig. 92.

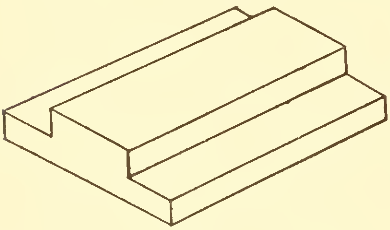


Fig. 93.

To make the mold: Place on the moldboard and make the mold, as in Ex. 1.

To remove the pattern: Lift the part shown in Fig. 93.

This will leave the mold with the loose pieces *a* still in the sand (Fig. 94). Now slip the pieces *a* out from under the sand and lift them out of the mold. Close the mold; clamp and pour.

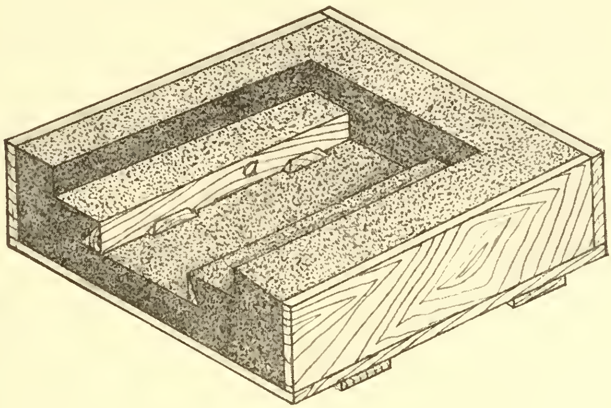


FIG. 94.

EXERCISE 28. *Removable Boss.*

Pattern: circular pattern with removable boss on one side and loose flange on one face (Fig. 95).

Casting: turbine case.

To make the mold: Select a three-part flask with cheek the height of *a*, Fig. 95. Lay the pattern on the moldboard with the flange side to the board but with the flange removed, and with the boss held in place with a skewer pin. Place the cheek in position with the cope side to the board. Fill and ram the cheek. Strike off and make the joint level with the drag edge of the cope and make parting on sand outside of the pattern. Place the drag in position; roughen the sand inside the pattern a little so that it will join to the sand in the drag. Fill and ram the drag. Turn

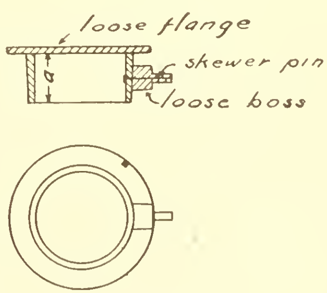


FIG. 95.

over the cheek and drag. Put on the flange piece of the pattern. Place the cope in position; set plugs for sprue and riser, and ram. Remove plug and cut pouring basin.

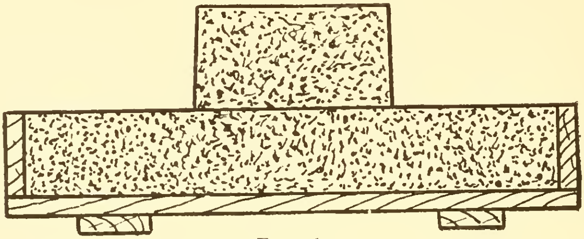


Fig. 96.

To remove the pattern: Lift off the cope and take out the flange part of the pattern and cut the gate. Place a bottom board on top of the cheek and lift the board and cheek. Turn both over and rest on the bottom board, as shown in Fig. 97. The green-sand core of the center of the pattern will remain on the drag (Fig. 96); pull the skewer pin *a*, Fig. 97, from the boss. Lift out the

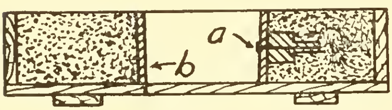


Fig. 97.

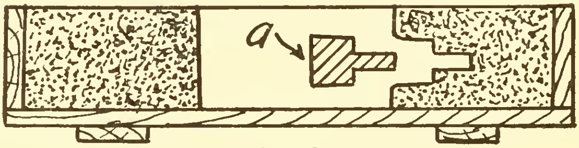


Fig. 98.

main part of the pattern *b*, Fig. 97. Draw out the boss pattern *a*, Fig. 98; place the core in print *b*, Fig. 99. Replace cheek and cope; clamp and pour.

Note. — This casting can be made in a two-part flask, if the pattern is made with a print for the boss, as shown in Fig. 100, in which is placed a hollow core.

DRAW-RIM PULLEY

A pulley having a face of any desired width can be made from a single face pattern called "draw-rim pattern." The pattern is a ring of the desired diameter, and a height, not greater than the narrowest faced pulley desired. The hub and

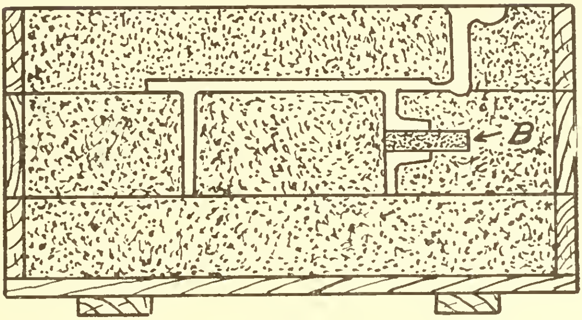


Fig. 99.

arms are made with a hollow core, or with a regular arm and hub pattern. In the latter case a special plate (lifting plate) is used to lift the sand inside the rim.

Exercise 29. *Draw-rim Pulley with Hollow Core for Arms.*

Pattern : draw rim.

Core : hollow core, one sixth of the pulley inside the rim.

Casting : pulley with face width as assigned.

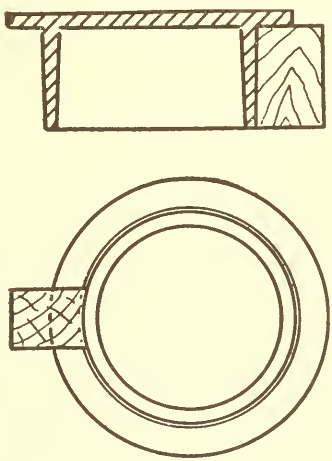


Fig. 100.

To make the core : Place the drag right side up on the bottom board. Bed in sand to such a height that its distance below the top of the drag is slightly greater than the desired width of face. Riddle in sand and bed the ring down to such depth that its bottom edge is the width of the desired face below the top of the drag, as in Fig. 101. Ram sand nearly to the top of the ring. Direct the rammer slightly away from the pattern. Vent well and draw up the ring. Take care that it is brought up evenly all around, by placing a straight edge across the edge of the drag and measuring down to the ring at several places. Continue filling and ramming, and drawing the ring, to a point equal in distance from the top of the drag to one half the width of the pulley face plus one half the thickness of the arm core.

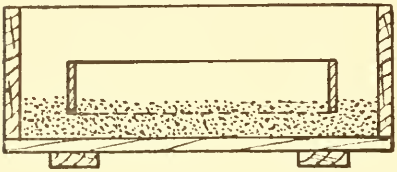


Fig. 101.

Setting the core: Set in the core segments, cutting or bedding down for the hub part of the core. Set sprue plug and continue the mold by filling, ramming, and venting as before the core was set, until the rim is drawn flush with the drag edge. Put on parting sand; set a riser over the rim, and ram the cope in the usual way, venting well. Remove plugs; draw pattern; clamp and pour. Figure 102 shows mold complete.

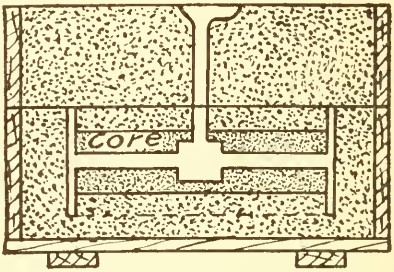


Fig. 102.

Exercise 30. *Draw-rim Pulley (Lifting Ring or Anchor).*

Pattern: rim same as in Ex. 27; hub and arms.

Casting: pulley (with face as assigned).

To make the mold: Proceed as in Ex. 27 and ram and draw the rim to a distance equal to half the width of the face called for, using all the precautions of venting as before. Bed in the arm pattern so that its center is exactly in line with the center of the pulley face. If the sand does not come up to the parting line of the arms, add sand, and ram until it does. Make parting inside the rim. Add riddled sand till the arm pattern is covered; ram lightly; add enough sand to again cover the

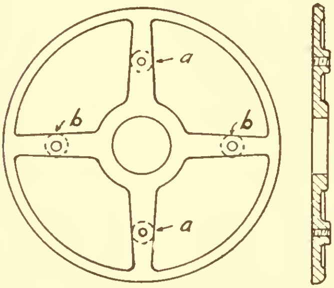


Fig. 103.

arm, and place the anchor or lifting plate (Fig. 103) in position (*a–a*, Fig. 104). The anchor, as shown at *a* in Fig. 103, has places tapped for draw spikes. The draw spikes must be left in the anchor until the cheek (the part above the anchor inside the rim) is rammed. Press into the sand, deeply enough to make firm, three small pins to guide the anchor to position after removing it from the mold. (These may be short cones or square pyramids.) Set a sprue plug on the hub just long enough to reach to the top of drag. Place a few nails around the edges of the anchor, so that they will extend nearly to the pattern. Fill and ram both inside and outside the ring, as before, until the ring has been drawn flush with the drag edge, remove the draw spikes, and cover the holes with a little heavy paper. Make parting over entire surface; place the cope in position; set another sprue plug, and ram the cope in the usual way.

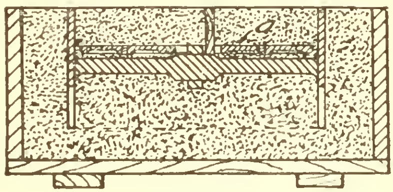


Fig. 104.

To draw the pattern: Remove sprue plug; make pouring basin and lift off cope. Remove the sprue plug from the cheek and cut a gate to connect the two sprues.[1] Screw the draw spikes into the anchor plate again and lift out the cheek. Draw the arm pattern; replace the cheek; remove the draw spikes; close the holes with a little sand; draw the rim pattern; close the mold; clamp and pour.

SWEEPING OR STRIKING A CORE

The expense of making a large core or even a small one when only a few castings are wanted can be greatly reduced by making a skeleton core box, and striking or sweeping the core to the desired shape. Figure 105 shows the plan and elevation of a skeleton box and *a* is the strike.

[1] If one sprue plug is set directly over the other, no gate is necessary.

EXERCISE 31. *Strike Core.*

Pattern: 90° pipe bend.

Core: skeleton core.

Casting: 90° ell or pipe bend.

To make the core: Mix up an ordinary core mixture and fill in the skeleton core box; press with the hand to approximately the desired shape of the core, filling the box higher than the end pieces. Strike the sand off smoothly to the profile of the strike used. Remove from the box, and bake. Make two half cores and paste together as in previous exercises.

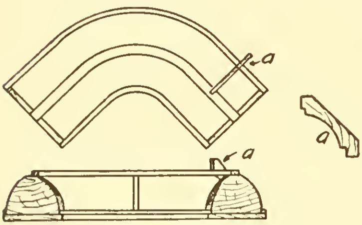


FIG. 105.

To make the mold: Make the mold as in Ex. 4.

To set the core: Place a chaplet in the mold at the middle, and in the middle of the bend, to support the core at its center. Place the core in the prints and on the chaplet. Close the mold; clamp and pour.

CHAPTER X

OPEN MOLDING, SWEEP AND STRIKE WORK

OPEN MOLDING

MOLDS having no cope are called open molds. They must be perfectly level to insure uniform thickness of metal. The casting must have one flat face.

EXERCISE 32. *Open Mold.*

Pattern: rectangular block with rectangular hole in center.

Casting: pouring weight.

To make mold: Spread out and slightly pack some molding sand on the floor. Drive into the floor four stakes, as shown at *a*,

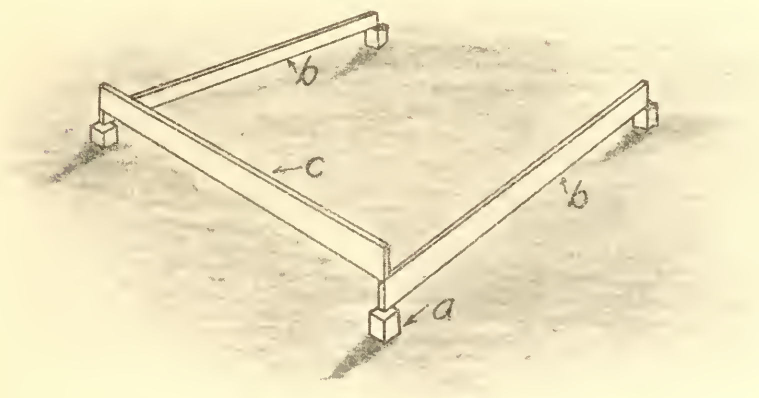


FIG. 106.

Fig. 106, about one foot farther apart than the dimensions of the pattern. Nail guideboards *b* to the posts and level. Make both the same height with straightedge *c* and a level. Fill in between the board *b* with riddled molding sand to about ½ inch above their tops. Tamp this sand down level with the guides with the face of a board, and strike it off level by drawing the straight edge *c* along the guides. This bed must not be so solid as for other molding. It must vent freely or the metal

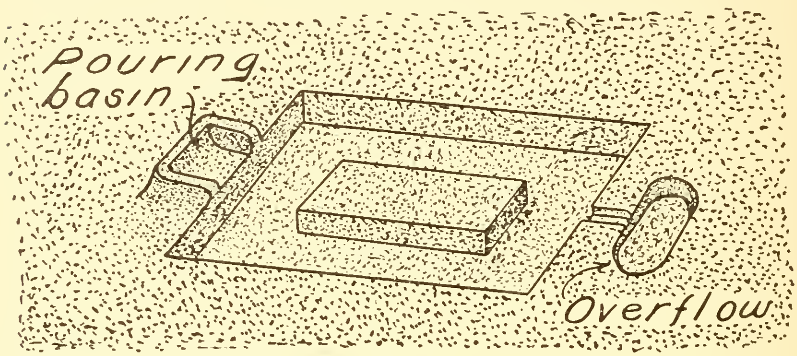


FIG. 107.

will boil. Place the pattern on this bed and build up the sand around its edges. Strike the sand off level with top of the pattern with the straight edge, using block under the ends to raise it to the proper height. Build a pouring and an overflow basin, as shown in Fig. 107, and remove the pattern.

SWEEP WORK

In sweep work the mold is made by sweeping out or shaping the sand, by revolving a board having the profile of the desired mold. Sweep work can be used only for circular forms. It is used when only a few castings are desired, and where the expense of making the pattern would far outweigh the extra expense of making the mold with a sweep. The sweeps are boards cut to the desired form, arranged to revolve around a stake driven in the floor.

EXERCISE 33. *Sweep Mold.*

Pattern : two sweeps, one the shape of the outside of the casting, and the other the shape of the inside.

Casting : kettle.

To sweep the mold: Level off the floor with a little molding sand and drive the stake solidly into the floor, leaving enough above to operate the sweep. Put sweep *a*, Fig. 108, on stake. Pack the sand about the stake and revolve the sweep until a hill is formed the shape of the sweep or outside of the desired casting. (The sweep is made with a beveled edge so as to push and pack the sand.) Remove the sweep and put on parting sand. Place the cope in position;

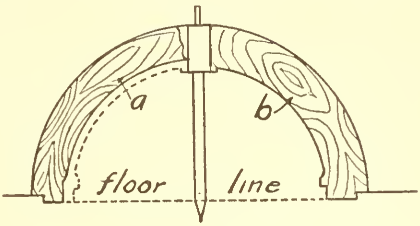


FIG. 108.

set sprue plug, and ram up cope in the usual way, taking care not to ram so hard as to spoil the shape of the hill. Remove the cope; put on sweep *b* and sweep the hill to its shape. Remove the sweep and stake; pack sand in the hole left by the stake; close the mold; weight and pour.

STRIKE WORK

Strike Work. — Strike work is similar to sweep work, in that it saves the cost of making patterns. But instead of revolving

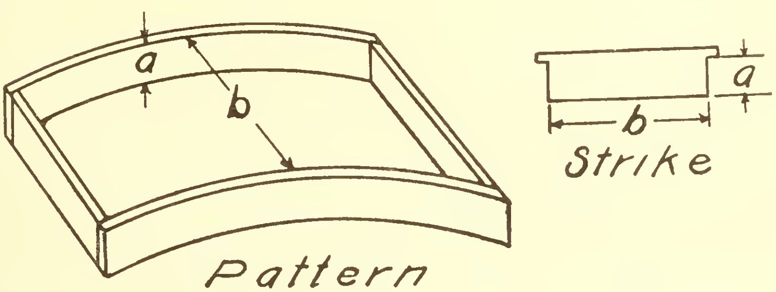


FIG. 109.

an arm about a central stake, a straight edge or "strike" is drawn horizontally across a guide. The distance *a*, Fig. 109, is equal to the depth to which the sand is to be removed. Ribs or grooves can be "struck" on by having projections on or grooves in the "strike." Cores and bosses can also be set at any desired place after "striking."

Exercise 34. *Strike Work.*

Pattern: see Fig. 109.

Casting: curved plate.

To make the mold: Place the pattern on the moldboard with the convex side to the board. Place blocks or wedges under it to prevent rocking, and ram up the drag in the usual way. Turn over; make parting, and ram up the cope. (This leaves an impression in the cope which matches the top of the desired casting.) Remove the cope, and with the "strike" brush out the sand inside the pattern. Remove the pattern and slick the surfaces. Close; clamp and pour.

CHAPTER XI

DRY-SAND MOLDING

Dry-sand molding is similar to green-sand molding, except that a core sand mixture is used next to the pattern, and this is backed off by molding sand. The mold is then placed in an oven and dried. After the mold has been dried, it is given a coating of blacking. A dry-sand mold is used when a very smooth casting is desired, or where the pressure is great. A dry-sand mold should be made in an iron flask to permit its being placed in the oven.

Dry-sand facing, or the mixture used next to the pattern, must be open-grained enough to allow the escape of the gases. The sand used, therefore, must not contain too much clay. The clay will make a strong mold, but will not let the gas escape. A facing mixture for ordinary work should be about as follows:

1 part new molding sand, 1 part old molding sand.

2 parts fire sand. Add 1 part each of flour and sea coal to 30 parts sand.

The proportions of fire sand and molding sand must be varied somewhat, according to the nature of the sands, so as not to get too close a mixture.

Ramming. — As the dry-sand facing is more open-grained, and since the moisture is driven off by drying, a dry-sand mold may be rammed much harder than a green-sand mold. As with green sand, the mold must be rammed evenly; otherwise hard spots or scabs will be formed on the casting.

Venting. — Although there is no moisture to pass off in dry-sand work the mold must be carefully vented, as the hot metal against the facing generates much gas. This gas must be carried away to insure a sound casting. In a mold with less than six inches of sand between the casting and the flask, the sand must be well filled with ventholes. Above six inches little venting is necessary.

Finishing. — After the pattern has been removed, the mold is finished to give it a smooth face from which the casting will peel. This is done by dampening the mold face with a spray of molasses water and carefully slicking. When the mold has been dried, it is given a coating of blacking to close the pores.

EXERCISE 35. *Dry-sand Mold.*

Pattern : tie rod sleeve.

Core : straight core.

To make the core : Make the core in the usual way.

To make the mold : Use an iron flask. Use the facing-sand mixture given above, or the mixture for large cores on page 51. Give the pattern a coating of linseed oil and place on the mold-board. Pack around the pattern with the dry-sand facing mixture, to a depth of about two inches, and finish the drag by "backing off" with ordinary molding sand. Vent in the usual way. Turn the drag over and make a parting by first brushing some oil over the joint, and then putting on the parting sand. Place the cope in position. Set in the plugs for the runner and riser as in green-sand work. Ram up the cope, using first the dry-sand facing mixture and then the molding-sand backing, as in the drag. Remove the cope and draw the pattern ; slick the face of the mold and dry. When dry, give a coating of blacking. When the glisten of the blacking has disappeared, slick the blacking to produce a smooth coating. Do not slick enough to bring the moisture back to the surface.

To set the core : Set the core by resting it in the print depressions. Be sure the core vents have outlets through the sand in the flask. Close the mold ; clamp and pour.

CHAPTER XII

CUPOLA PRACTICE OR MELTING

Cupola. — In the foundry, iron is melted in a cupola in direct contact with the fuel. The cupola (Fig. 110) consists of a circular shell *a* of boiler plate, lined with a fire-brick lining *b*. The shell and lining rest on a bedplate *c*. In the bedplate is a central circular opening that comes flush with the inside of the lining. The cupola is supported on four legs *d* which curve outward so that the doors *e* can swing between them. The hinges of the doors are attached to the bedplate near the outside so that when the doors are dropped, they will not interfere with the free fall of the contents of the cupola. When the doors are closed, they are held in position by a gaspipe column, placed centrally under them. Well up on one side of the cupola is a door *f* for charging. About three feet below the bottom of the door is the charging platform. In front, and at the bottom level, is an opening *g* called the breast opening, in which the tap hole for drawing off the metal is found; a spout *h* projects from this breast. A wind box *i* surrounds the cupola near the base, from which air from the blower passes into the cupola through circular or rectangular openings *j* called tuyers. The area of these tuyers should be about one-ninth of the area of the cupola. An air-tight sliding gate is placed opposite each tuyer, arranged with a peephole, so the working of the cupola can be observed. Large cupolas have a second row of tuyers *k* about ten inches above the first which are used in long heats, as the lower ones become partially closed by slag. An opening *l* is provided in the shell of the cupola directly back of the breast opening, but about two inches below the bottom of the lower set of tuyers, and fitted with a spout *m* for

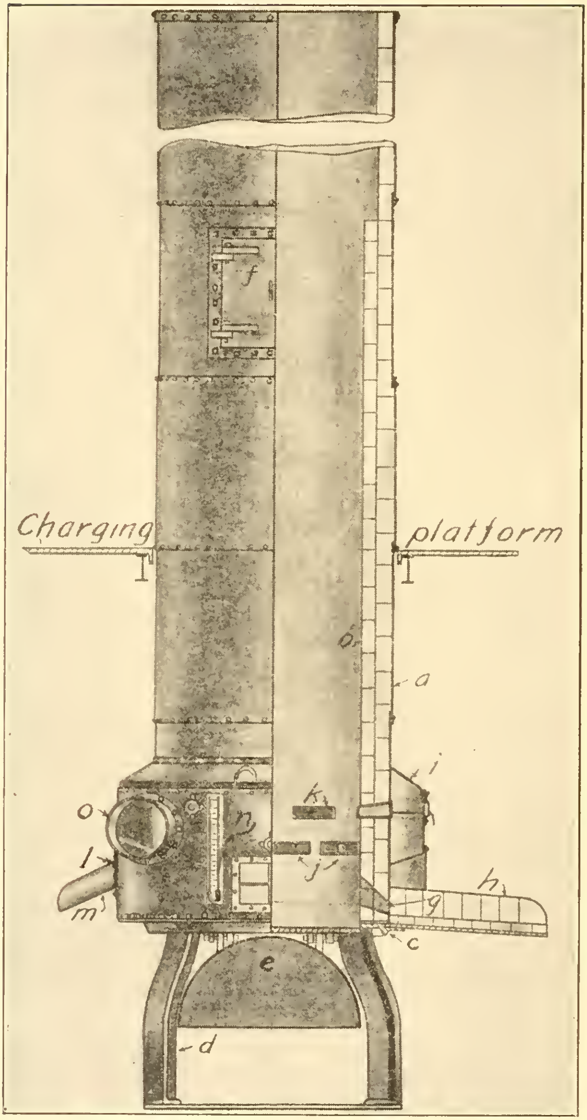


FIG. 110.

drawing off the slag. The blast is furnished by either a fan or a pressure blower through opening *o* into the wind box. A water gauge *n* is usually attached to the wind box to show the pressure of the air.

LADLES AND CUPOLA TOOLS

Ladles (Fig. 111) are used to catch the molten metal and to pour it into the molds. They vary in size from 25-pound capacity hand ladles to 20-ton capacity crane ladles. The sizes are designated by the weight of the metal they will hold, and their names, hand ladles and bull ladles, come from methods of handling them.

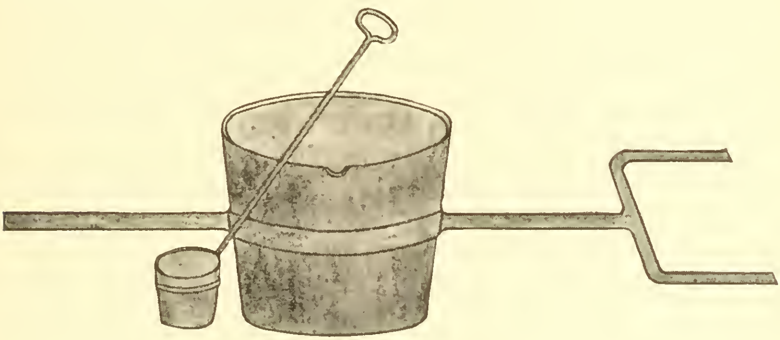


FIG. 111.

The hand ladles are usually made of pressed steel, the large ones being built up of boiler plate or are cast iron. All ladles up to $\frac{1}{2}$-ton capacity have a lining of cupola daubing mixture, varying in thickness with the size and condition of the ladles. The lining is plastered on by hand after giving the ladle a coating of thick clay wash, and should be, for the sides, from $\frac{5}{8}$ to $\frac{3}{4}$ inch thick for hand ladles and 1 to $1\frac{1}{2}$ inches thick for bull ladles. The bottom lining should be about one half thicker. The very large sizes are lined with fire brick over which a daubing mixture is plastered. The linings must be well dried and then given a coat of blacking before use. The small ladle linings can be dried in a core oven, but the large ones have a fire built inside of them. The linings are made to last by patching small breaks after each time they are used.

The cupola tools (Fig. 112) are a bott stick, used for forcing the bott ball into the tap hole in order to close it; tapping bar, a round bar of $\frac{3}{4}$-inch iron with a sharp tapering point of square

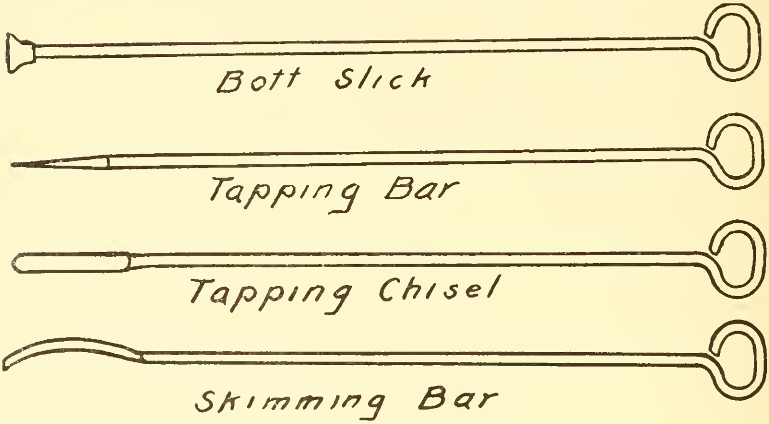


FIG. 112.

section, used for tapping; tapping chisel, a bar of $\frac{3}{4}$-inch round iron, made spoon-shape at one end, for trimming the sides of the tap hole when it gets clogged; a skimming rod, to hold back the slag when pouring.

BOTT CLAY

Mixing. — Mix thoroughly beach or sharp sand, 4 parts with 1 part of flour and about $\frac{1}{8}$ part sawdust, and temper a little more wet than a core-sand mixture.

PREPARING AND OPERATING THE CUPOLA

In preparing a cupola to take off a heat, the following steps must be taken in the order given:

1. Clear away the slag and coke dumped at the close of the former heat. All the good coke should be picked out and used to fire the core ovens.

2. Chip off all of the lumps of slag which have accumulated in the lower part of the cupola or melting zone. If the slag has formed a thin smooth coating over the lining, it should not be chipped away as it forms the best kind of coating.

3. Daub up the chipped portion with a daubing mixture composed of one-third or one-fourth parts of fire clay and fire sand, after wetting with a thick clay wash. The plastering can best be done with the hands, and must be rubbed in well, and should slightly overhang the tuyers to prevent the slag from entering and closing them up. Give the daubed portion a coat of blacking.

4. Close the bottom doors and support them with gas pipe column.

5. Lay the bottom by covering the doors with a layer of isle sand and fine cinders about 1 inch thick, and tramp it down well. Next, place another layer of about the same thickness of burned molding sand; this last layer should be given a slope of about 1 inch to the foot toward the front and center for small cupolas and $\frac{1}{2}$ inch to the foot for large ones. Too much pitch will cause too much pressure on the bott, and too little will not let the iron run well and cause it to chill at the tap hole. The bottom must be tramped evenly all over, and the sides particularly solidly. The bottom must be able to vent itself and must not be wetter than well-tempered molding sand. It must be strong enough to hold the heat, but not so solid that it will not break and let the load fall through when the bottom doors are dropped. A little daubing mixture should be worked into the bottom for a few inches in front and to the sides of the breast to strengthen the bottom at this point. On this daubing mixture, projecting well into the cupola, lay a piece of 1-inch gas pipe, and then fill up the hole at the breast with daubing mixture or ordinary clay. Withdraw the pipe and recess the hole so that the tap hole will be as short as possible, or it will give trouble by slagging.

6. Lay the fire by placing shavings on the bottom, then small kindling, next enough large kindling to light the coke, then the

amount of coke determined upon for the bed charge. This bed should be level.

7. Lighting up. From ¾ to 1 hour before the time to pour, light the shavings and let the wood and coke burn under natural draft by leaving the peephole slides and tap hole open, and the charging door closed. When the wood is burnt out and the coke is well on fire, throw in as evenly as possible the bed charge of iron. If all is ready to pour, the peephole slides are closed, the blower started, and the blast turned on, but not too strong at first. The clay bott is made into a ball and shaped, as shown in Fig. 113, on the bott stick. Two or three botts and bott sticks should always be ready when operating, for use in case one does not stick. The hands should be raised rather high in forcing the bott home so as to give a downward pressure on the bott in the tap hole, as shown in Fig. 113.

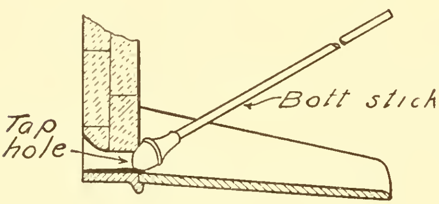


Fig. 113.

The tap hole is left open until about 10 pounds of iron has run out. It is then closed until enough iron has accumulated for the first pouring. When the bott is broken, the iron is caught in a bull ladle suspended on trunnions. After sufficient iron has run into the ladle, the tap hole is again botted up. This operation is repeated as long as there is iron to pour. The iron and fuel to supply the cupola is charged in alternate layers of coke and iron after the blast is started. Should it be desirable to delay turning on the blast after the bed is lighted, this can be done without injury if the charging door is opened. In any case the iron should be charged as soon as the coke is well lighted.

8. Dropping the bottom. When all the iron has been melted and drawn off, the bottom must be dropped. This is done by pulling out the bottom support. Throw water on the coke to quench the fire and deaden the heat.

POURING

In pouring small castings, the iron can be caught directly in the hand ladles. The slag, which floats on top, must be skimmed off. The skimming is done by means of a rod, as shown at Fig. 114, by placing the blade across the ladle at the lip. When filling small ladles from the bull ladle, the skimming is done in the bull ladle in a similar manner. There is no small degree of skill needed in pouring a mold and the work to be done must be known in order to judge whether the mold should be poured fast or slow. Light, thin work should be poured very fast, while heavy work should be poured slowly. A steady stream should be kept up. The pouring should be into the

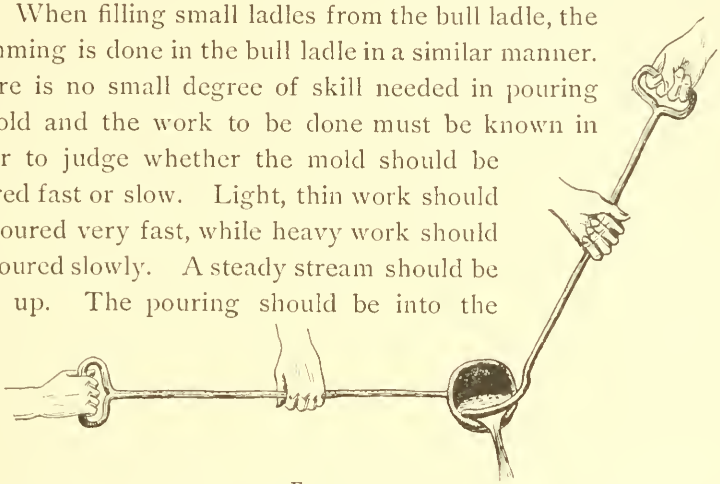


Fig. 114.

basin away from the runner, which will prevent spilling into the mold. The basin, runner, and gate must be kept full. The remainder of the metal in the ladle should be poured out as soon as a mold is poured either into a pig or back into the bull ladle, for if it is allowed to freeze in the ladle, its removal will spoil the lining.

The more common defects which the pupil will find in castings as a result of bad molds, bad or cold iron, are:

Poured Short. — When the amount of metal in the ladle is not enough completely to fill the mold, it is said to be poured short.

Blowholes. — When the gases are pocketed in the metal instead of passing off through the sand, a hole called a blowhole is left in the casting. The cause of this is hard ramming, wet sand, and lack of venting.

Cold Shuts. — When two streams of metal cool so much before meeting that they will not fuse together, the casting is said to be cold shut.

Scabs. — When small patches of the mold face wash or fall off, projections like warts are left on the surface of the casting which are called scabs. The cause is moisture brought to the surface by too much slicking. This moisture, drying out by the heat of the metal, allows the skin to flake.

Sand Holes. — When loose sand or excess facing washes into the mold while pouring, it replaces some of the metal and leaves a hole called a sand hole.

Swells. — When the sand is not rammed hard enough, the metal will cause the mold to bulge, leaving the casting thicker in places than it should be.

Shrinkage Cracks. — When there is unequal cooling in a casting, cracks are sometimes formed called shrinkage cracks. When the mold is so firm as to resist the natural shrinkage of the casting, it will sometimes cause shrinkage cracks.

Warping. — When shrinkage strains cause a casting to bend or twist, the casting is said to be warped.

FUEL

Either hard coal or foundry coke can be used as a cupola fuel. Coal will carry a heavier load than coke. It requires a stronger blast, melts more slowly, but gives a hotter iron, and can be used to better advantage in running off long heats. When coke is used, it should be what is known as 72-hour beehive coke, and as free from ash and sulphur as possible.

The proportion of fuel to iron, both bed and charges, varies greatly, and in a strange cupola must be tried out. Usually, however, if the fuel is brought up to 24 inches above the tuyers for the bed charge, the amount will be about right, and if the iron runs too cold, a little more should be used the next time, if too hot, a little less. About 3 pounds of iron to each pound of coke makes a good bed charge. The intermediate charges of coke should be just sufficient to keep up the bed, or to make a layer about 6 inches thick. The iron charge should be from 8 to 10 pounds for each pound of coke. In using hard coal, usually a little less weight can be used.

CHAPTER XIII

CLEANING CASTINGS

As soon as the metal has hardened, the flask should be removed. The casting should be left in the sand until it is cool. To remove the sand from the flask, pick up the mold and drop it on the sand heap. This will loosen the sand so that it will fall out when the flask is picked up. On snap-flask work, remove the slip case. Pile flasks; slip cases and bottom boards in their proper places.

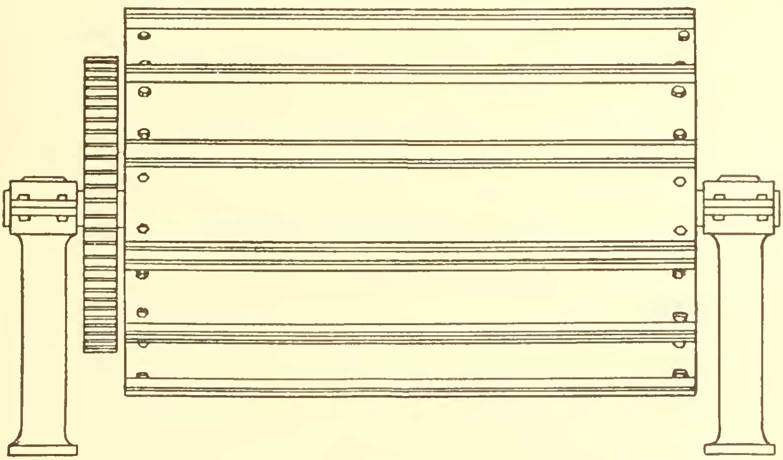


Fig. 115.

As soon as the castings are cool, lay them in the aisle. Break off the sprues and throw them into the scrap pile. Then take the castings to the cleaning room.

Rattler. — Small castings are generally cleaned in a rattler, Fig. 115. It consists of a barrel with cast-iron ends and a body made of steel channels. There is a small space between the channels for the escape of dust. One channel is removable to charge or empty the rattler. The barrel revolves on trunnions, which are attached to the ends. A dust-tight box is usually built around the barrel; the dust is caught in a drawer at the bottom. The barrel is revolved by either spur or friction gears, and should run from 30 to 50 revolutions per minute. The rattler should be packed quite full of castings; a few sprues and shot iron should also be introduced. It takes about half an hour to clean a charge. The cleaning is done by the rubbing of the castings and sprues over each other. This leaves a clean, smooth surface of gray color. When castings of 50 or 100 pounds are cleaned, they must not have thin parts, because these parts are likely to break off.

After the castings have been rattled, the gates and any slight projections are ground off on an emery wheel.

Pickling. — When castings are to be machined, they are cleaned by pickling. The castings are placed on a platform, the bottom of which slopes from each side to the center. Sulphuric acid diluted with 8 to 10 parts of water is thrown on the castings, which are kept wet from 10 to 12 hours. They are then washed with hot water. The acid runs from the platform to a tank and is used over several times. The water should be so hot that the castings will dry quickly and not rust.

The action of the acid is to eat the layer of iron oxide which forms on the outside of the castings; when this is done, clean iron is left exposed. Heavy castings are cleaned by pickling or by the sand blast.

Hand Cleaning. — In hand cleaning, the worst of the sand is removed by wrapping with a hammer. The casting is then rubbed with a wire brush, a piece of an old emery wheel, or scraped with an old file.

Sand Blast. — To clean with a sand blast, the sand is blown against the casting with great force. This is a very effective means of cleaning.

The fins and projections are cut off either with a hand or pneumatic chisel.

CHAPTER XIV

CHILLED AND MALLEABLE CASTINGS

CHILLED CASTING

THE uses to which many castings are put require that some parts be very hard and others soft and tough. Thus, the rim and flange of a car wheel must be very hard to stand the wear on the rails, while the rest must be tough to resist breaking. These conditions are obtained by chilling the surface required to be hard. The chilling is effected by placing a chill in the mold, at the point which is to be chilled. The other parts of the mold are left as in ordinary work. The chill for small work is a block of iron of the proper size and shape. For large work it is usually made hollow. This permits the passing of steam through it to warm it before pouring, and of water for cooling after pouring.

Action. — The carbon in cast iron is in two forms: combined and uncombined. When it is combined with the iron, it makes a very hard white casting. When it is uncombined, the iron is soft and gray. The action of the chill is to cause the iron to cool so rapidly that the carbon is held in the combined form. The slow cooling of the other parts of the casting allows the carbon to change to the uncombined or graphitic form.

Placing Chill. — The mold is made as in ordinary work, and the chill added as a core would be. In some cases the chill takes the place of a cheek in three-part work. In order to prevent the gathering of moisture on the chill it must be heated to about 200° F. before it is placed in the mold. Moisture causes blowing and thus prevents the metal from coming in contact with the chill.

Coating Chills. — To prevent the iron from sticking to the chill, it must be given a coating after it has been heated. Blacking wet with molasses water makes a good coating. Shellac and varnish, coated when nearly dry with plumbago, are good in some classes of work. Light oil makes a good coating when put on in a very thin layer. A heavy layer would cause gas, which would hold the metal away from the chill.

Gates. — The pouring gates must be so arranged that the metal will rise on the chill. It must never fall or lie horizontally on it. The gates must be large and arranged so that the metal will quickly cover the chill, and prevent bad spots on the surface of the casting. The iron from which a chill is made should be of the best grade. It should have very little contraction.

The thickness of a chill is regulated by the depth to which the casting is to be chilled. It must be large enough to carry away the heat of the molten metal, and not to rise above the solidification temperatures.

Depth. — The depth to which the iron is chilled is regulated by the rapidity with which the iron is cooled and by its composition. The depth to which castings are chilled varies from $\frac{1}{2}$ to 1 inch.

Mixture. — To gain the proper mixture or composition, chemical analysis is used. (For composition see Appendix.) Before pouring a chilled casting, the iron is tested for depth of chill; a bar 2 inches square and 6 inches long is cast so that one side will be against a chill. This test piece is cooled and broken and the depth of chill observed. If of sufficient depth, the chill mold is poured; if not, the metal is poured into other castings. The iron for chilled castings is usually melted in an air or reverberatory furnace.

MALLEABLE CAST IRON.

Malleable Cast Iron. — Cast iron annealed by a thermochemical process loses its brittleness and is made tough, producing what is called malleable cast iron. It can be bent and hammered considerably without breaking. Its strength is also greatly increased.

Process.— The malleableizing process by means of heat produces a chemical change in the composition of the iron. The content of carbon is reduced, and that remaining is changed from the combined or hardening form to the graphitic. The silica, manganese, and other constituents are also changed. This makes the outer part much like wrought iron.

Iron to be made malleable must have its carbon in the combined form. The silica must be low. Phosphorus to 0.15 per cent is an advantage, but sulphur is detrimental. Manganese should be rather high, as it has a beneficial effect and reduces the time of the process.

To make castings malleable, the castings are packed in iron boxes with a substance rich in oxygen. The boxes are sealed and placed in a direct-fired furnace, where they are kept at a temperature of 1800° to 1900° F. for from eight hours to several days, the length of time depending on the size of the casting. The heat must be uniformly distributed and maintained constant. The oven and its contents should be heated slowly, and after the process is completed, cooled slowly. Sudden change of temperature will spoil the castings. It is important that the castings should not touch each other in the box. The materials rich in oxygen that are generally used are red hematite, mill scale, and rusted steel turnings from a machine shop.

The chemical action which takes place is the uniting of the oxygen of the reagents with the carbon, which takes place at high temperature. This forms carbon-monoxide gas, which passes off.

The patterns from which castings that are to be malleableized are made should be given particular care in their making. Sharp corners should be avoided. Changes from light to heavy sections should be gradual, and heavy sections avoided whenever possible.

The hard iron used when malleable castings are to be made shrinks greatly and cools rapidly. Therefore the gates must be made with the greatest care to prevent the chilling of the iron in them.

CHAPTER XV

BRASS MOLDING

Difference between Brass and Iron Molding. — Brass molding differs but little from iron molding. Usually a finer sand is used, and the work, as a rule, is much smaller. The joints are made much smoother by the use of fine parting dust and careful slicking. This leaves the casting without fins. The molds are rammed about as hard as for iron.

There are three reasons why molds for brass differ from molds for iron:

1. Brass melts at a much lower temperature.

2. It is not so fluid as iron.

3. It has about double the shrinkage of iron. For all of these reasons the sand may be much less porous, and yet vent, risers being used for the escape of air. On small work a vent wire is not used.

Runners should be larger than for iron, to supply shrinkage. The gate should be less shallow.

The molds should be poured on end so as to give more head, and to overcome the sluggishness of the metal. Skimming gates should be used.

Materials. — A very fine natural molding sand is used, because most brass work has very fine details. Hence the sand must have a larger per cent of alumina to retain the sharp details. This is possible as the colder metal requires less venting.

On light work, the sand is kept in condition by frequently adding new sand. On large work a facing is used as in iron.

Rattler dust, burned sand, and powdered charcoal are used for parting materials, as they are fine and make a clean joint.

The same tools are used as in iron molding.

Flask. — A special iron flask (Fig. 2) is generally used, the pins of which fit very accurately. There are holes in one end: one through which the mold is poured and one or more for risers. Small snap flasks may be used, but they must register very accurately.

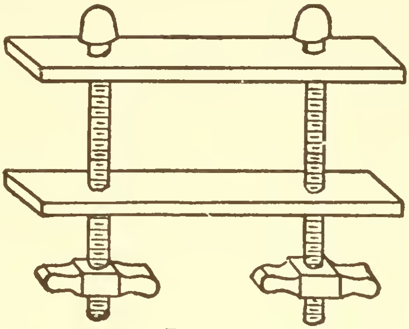


Fig. 116.

Clamps. — A clamp (Fig. 116) is used to hold the halves together when the mold is standing on end to be poured.

Spill Trough. — A spill trough, Fig. 117, is used to set the mold in while pouring, in order to catch any metal that may be spilled. A layer of sand about an inch thick should be spread over the bottom of the trough.

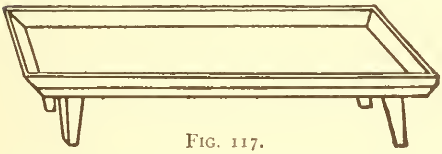


Fig. 117.

Drying. — On thin work, the surface of the mold should be dried to prevent the wet sand from cooling the metal. This is done in two ways: (1) with a blow torch; (2) a drying stove.

A drying stove (Fig. 118) is a sheet-metal stove with a projecting ledge at the bottom. The halves of the finished mold are carefully sprayed with mo-

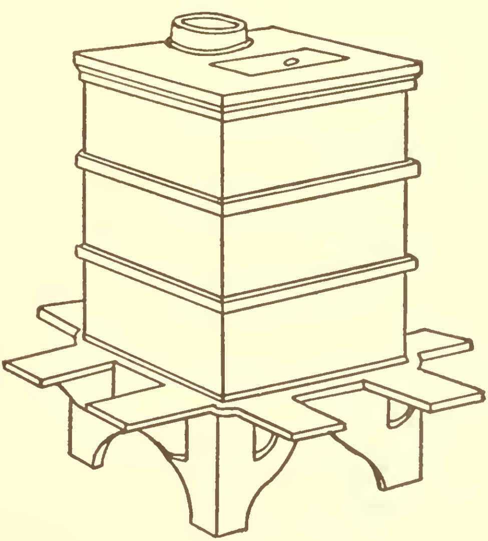


Fig. 118.

lasses water and the flask set on edge on the ledge, with the faces next to the stove. When sufficiently dry, the molds are closed, clamped, and poured. They should be poured soon after the drying or the faces will absorb moisture from the rest of the sand in the mold.

EXERCISE 36. *Ornamental Work* (*Plaque*).

Pattern : a figure consisting of a thin, flat plate.

Place pattern face down on the moldboard, a little below the center of the flask. Sift on fine sand until the pattern is completely covered. Pack the sand about the pattern rather firmly with the fingers. Fill the balance of the drag with sand and ram as in previous exercises. Turn over and smooth the joint. Dust on fine parting dust. Place cope in position ; riddle on sand and ram up as in Ex. 1, but merely hard enough to stand handling. Separate the flask ; spray with molasses water, and dust on fine pumice stone from a bag. Place on more parting dust. Replace cope, and re-ram to required hardness. Separate and draw pattern. Cut the runners, risers, and gates as shown in Fig. 119.

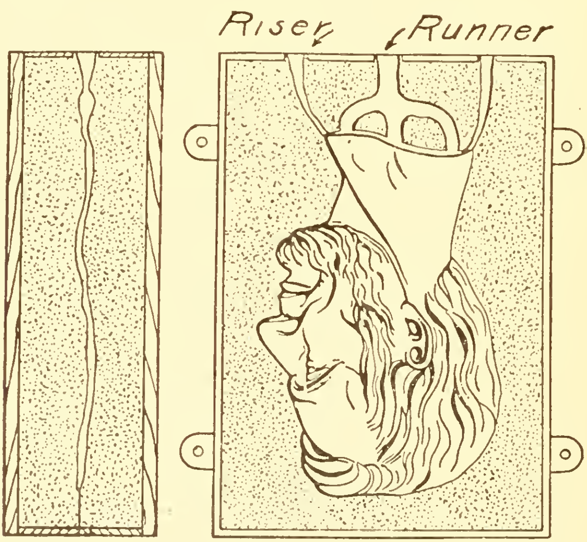


FIG. 119.

The runners should be large and round in section. This insures a heavy head of good, clean metal filling every detail of the thin mold before it has time to cool. Skin dry the faces of the mold with stove or blow torch. Close, clamp, place on end, and pour. If the mold is not skin dried, flour can be dusted over the face, allowed to stand for a short time, and then blown off. This dries the mold and makes a good facing.

EXERCISE 37. *Core Work for Brass.*

Pattern : candlestick.

Core : straight-balanced core.

To make the mold : Put in the sand in a manner similar to a like pattern for iron, and surface dry mold.

To make the core : Proceed as described for iron, but mix in about one third molding sand to the regular stock mixture. This will leave a smoother surface.

To set the core : The core is set as a balanced core for iron work.

Cleaning. — Rap the casting to free it from sand and drop it into water. This will soften the casting, free it from sand, and cause the core to blow out. Brass castings are also cleaned by placing them in a stone basket and dipping them once in a mixture of two parts of commercial nitric and one part of sulphuric acid. They are then washed thoroughly and dried in sawdust.

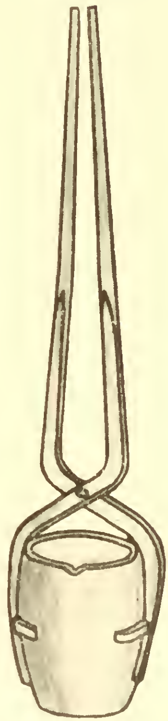


FIG. 120.

Melting. — The alloy metals will burn in air when exposed to sufficient heat to melt them. To prevent burning, the draft is kept down so that no free oxygen will reach the metal. A brass furnace should therefore be a natural draft furnace, but should be supplied with a blast to make it independent of atmospheric conditions. The metal must not come in direct contact with the fuel. It is therefore melted in graphite crucibles. These crucibles are bedded in the fire. Coke is the usual fuel. The crucibles are lifted from the fire with tongs (Fig. 120).

Brass Furnace.—A section of a brass furnace is shown in Fig. 121.

The top is on, or slightly above, the level of the floor of the molding room. On a cast-iron bottom plate *a* with a circular opening rests a shell of boiler plate, lined with firebrick. A top

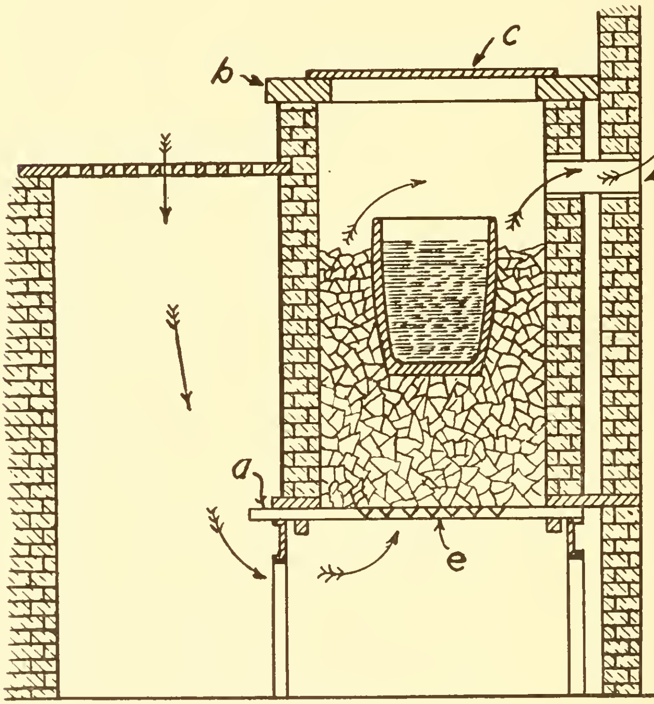


Fig. 121.

plate *b*, with an opening similar to the bottom, binds the whole together. The opening is closed with a cover plate *c*. At one side, about 6 or 8 inches from the top, is an opening *d* connecting with the smoke flue. The bottom plate rests on steel beams and these on a foundation of brick or steel columns. A grate *e* fits in the circular opening in the bottom plate. Ashes are removed by dumping the grate into the ash pit. The coke is charged through the opening in the top plate.

Operation. — A bed of freshly lighted coke 6 or 8 inches thick is laid on the grate. The crucible is placed on this and the coke is packed around the crucible, filling the space. The crucible should be packed as full of metal as possible, and covered. When the metal is melted, the crucible is lifted out and poured.

Gas Furnace. — Figure 122 shows a gas-fired furnace for melting brass or soft metals. It consists of a steel shell *a*, mounted on legs *c* by trunnions, so that it can be tilted, by turning the wheel *d*, to pour the metal. The shell is lined with a refractory brick *b*, so shaped that a crucible will fit it snugly at several points. Thus the crucible is held in place while the furnace is tilted, yet space is left for the circulation of the gases.

The gas and air enter under pressure at *e*, where they are ignited and burned in the combustion chamber *f*; the burning gases circulate about the crucible, and the products of combustion pass out the top at *g*.

These furnaces melt rapidly and are convenient to handle, but are noisy.

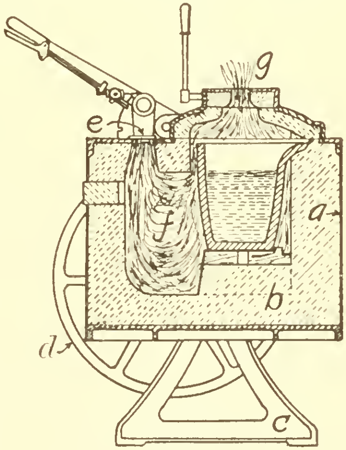


Fig. 122.

Brass and Bronze. — These are alloys of copper, and zinc or tin. The alloy is usually called brass when it is composed of copper and zinc, and bronze when composed of copper and tin. The alloys of copper and aluminum, copper and manganese, and copper and phosphorus, are called aluminum bronze, manganese bronze, and phosphor bronze.

To make a brass of a certain composition: The required amount of copper which has the highest melting point of the metals used is first melted. The zinc is then added and thoroughly stirred until it is melted. Allow the mixture to come to the proper temperature. Pull the pot; skim and pour.

With bronze, the same method is followed, except that both the zinc and tin are stirred in after the pot is drawn.

In mixing zinc, care must be exercised to plunge the zinc well under the surface of the copper, and hold it there with tongs until it is melted.

Some typical compositions of brass and bronze will be found in the Appendix.

GLOSSARY

Air dried. When a core is left in the air so long that it becomes dry before baking, it is said to be air dried.

Alloy. A combination of two or more metals, as copper and tin to form bronze.

Anchor. An appliance to hold the parts of a mold together.

Bars. See *Cleats.*

Bed charge. The first charge of coke and iron used in a cupola. (See *Operation of Cupola*, Chapter XII.)

Bedding in. Sinking the pattern in the sand to the position in which it is to be cast.

Bellows. See Chapter II, *Tools.*

Binders. Materials used in loam, core sand, and facing, to bind the sand together.

Blacking. See Chapter I, *Materials.*

Black lead. A form of carbon having a soft, greasy appearance. Also called *graphite.*

Blast. A current of air from a blower or fan into the cupola.

Blast gage. An instrument for determining the blast pressure in the wind box of the cupola. Its usual form is that of a glass tube bent U-shaped.

Blast pipe. The pipe through which the blast passes to the cupola.

Blower. A machine which forces air into the cupola.

Blowholes. Holes in castings, due to air or gas in the metal or mold.

Bottom board. See Chapter II, *Tools.*

Bott stick. See Chapter XII, *Cupola Tools.*

Breast. The fire-clay front filling the opening over the spout, in which the tap hole is located.

Bull ladle. A ladle for carrying molten metal, fitted into a shank with two handles. See Fig. III.

Burnt sand. Sand which has been in contact with molten metal.

Butting or butt ramming. Ramming the sand with the flat end of the rammer.

Casting. That which is obtained by pouring molten metal into a mold.

Chaplet block. A block of wood into which a chaplet stem is driven.

Chaplet nail. A chaplet resembling a nail, in that it has a flat head on one end and a sharp point on the other.

Chaplets. Iron supports to hold cores in position. See Fig. 80.

Cheek. The middle part of a flask or mold, when it has more than two parts.

Chill. Iron placed in a mold in such a position as to chill a portion of the casting, thereby producing a "chilled casting."

Chilled casting. A casting, a portion of which is hardened by rapid cooling induced by contact with a chill.

Cinder bed. A layer of cinders underneath a pit mold to which the gases are led and through which they escape by means of a vent pipe.

Clay wash. Fire clay mixed with water. See p. 8, Chapter I.

Coke bed. Used like cinder bed.

Cold shots. Small particles of metal, formed by the splattering of the metal on the damp surface of the mold, which harden rapidly and adhere to the casting.

Cold shuts. When two streams of metal become so cool that they do not fuse upon meeting, they form cold shuts.

Contraction. Shrinking of metal during cooling after casting.

Cope. The upper part of a flask or mold.

Core. A body of sand in the mold used to form holes or openings of a desired shape in the casting.

Core barrel. A pipe on which a cylindrical core is formed.

Core board. A board having the profile of a section of the core.

Core box. The mold in which the core is formed.

Core irons. Bars of iron embedded in a core to strengthen it.

Core mixture. See p. 51, Chapter VII.

Core oven. An oven in which to bake cores.

Core plate. A piece of heavy sheet iron on which cores are placed for baking.

Core print. A projection on the pattern which forms an impression in the mold into which the core is laid.

Core sand. Sand free from alumina (clay).

Core wash. See *Blacking.*

Crushing. A crumbling of the mold due to too great a strain in clamping or weighting it.

Cupola. See Chapter XII.

Cutting over. A turning over of the sand to obtain uniform mixture and temper.

Daubing. Plastering over the inside of the cupola with a daubing mixture.

Daubing mixture. Chapter XII.

Dowels. Pins used to hold the various parts of the patterns in their relative positions.

Draft. The taper made on the pattern to insure its easy withdrawal from the sand.

Drag. The bottom part of the mold when the latter is in position for pouring.

Drawing. Removing the pattern from the mold.

Draw plate. A plate attached to a pattern to facilitate drawing. See Chapter II, Fig. 20.

Draw spike. A tool for drawing patterns. Chapter II, Fig. 19.

Drop out. The falling out of sand from the cope while handling.

Drying. Evaporation of moisture from the mold.

Dry sand. A mixture of sand and binder which, after drying, produces a strong mold.

Dull iron. Iron too cold for successful pouring.

Facing. See Chapter I.

Facing sand. That sand which forms the face of a mold.

Fan. See *Blower.*

Feeder head. See *Shrinkage head,* Chapter III, p. 31.

Feeding. Forcing the metal into the mold from the feeder head with a feeding rod.

Feeding rod. A metal rod used in feeding.

Fin. A projection on the casting due to an imperfect joint.

Fire clay. A clay which will stand very great heat.

Flask. See Chapter II, Figs. 1, 2, and 3.

Flow-off gate. A passage through which the metal overflows from an open mold.

Flux. A material used in the cupola to make the slag more liquid.

Follow board. A board which conforms to the form of the pattern and forms the parting surface.

Foundation plate. A cast iron placed on the bottom of the mold to support the sweep stake.

Founding. The making of metal castings.

Fusing. The melting of the sand due to the heat of the metal and formation of a hard coating which adheres to the casting.

Gaggers. See Chapter III, p. 23.

Gangway. A passage between the molding floors leading from the cupola.

Gate. See Chapter III, p. 27.

Gatecutter. See Chapter II, *Tools.*

Gated pattern. See Chapter IX.

Gate stick. See *Sprue plug.*

Graphite. See *Black lead.*

Green sand. Properly tempered molding sand.

Gutters. Shallow channels at the joint which receive the gases from the vents and conduct them to the relief vent.

Hand ladle. A small vessel for carrying molten metal that is handled by one man.

Hard ramming. Packing the sand until hard.

Hatching up. The roughening of the surface of the mold to enable new sand better to adhere.

Hay rope. Hay twisted to form a rope. It is wound around the core barrel and covered with loam or core sand to form the core.

Hot metal. Metal in its most fluid state.

Ladle. An iron vessel lined with fire clay, in which the metal is handled. See *Bull ladle* and *Hand ladle,* Fig. 111.

Leveling. Making a level bed of sand.

Leveling guides. Parallel strips used in leveling.

Lifter. See *Tools,* Chapter II.

Lifting screw. See Chapter II, *Tools.*

Loam. The mixture of sand and clay and venting material used in loam molding.

Loam board. See *Strike.*

Loam mold. See *Loam Work* in Introduction.

Loam plate. An iron plate upon which a loam mold is built.

Loose piece. A portion of the pattern which is removable.

Melting zone. That portion of the cupola above the tuyers where melting takes place.

Mold. The impression left in the sand by the pattern.

Mold board. Board upon which pattern is placed to make the mold. See Chapter II, *Tools.*

Molding. The making of the mold.

Molding machines. A machine by which molding is performed.

Molding sand. See Introduction.

Nowel. See *Drag.*

Old sand. Used sand that is burned from contact with the metal.

Parting sand. See Introduction.

Patching. Repairing broken portions of the mold.

Pattern. The model from which the mold is formed.

Peeling. When the casting separates easily from the sand, it is said to peel.

Pit molding. Making a mold in a pit in the foundry floor.

Plumbago. See *Black lead.*

Pouring. Filling the molds with molten metal.

Pouring basin. That portion of a gate into which the metal is first poured. See Chapter III, p. 27.

Rammer. See Chapter II, *Tools.*

Rapping. Knocking the pattern to loosen it.

Rapping bar. Bar driven or screwed into a pattern which is struck to loosen the pattern.

Rapping hole. Hole in pattern or rapping plate into which the rapping bar is placed.

Rapping plate. A metal plate attached to a pattern in which the rapping hole is located.

Riddle. See Chapter II, *Tools.*

Riser. See Chapter III, p. 27.

Runner. See Chapter III, p. 27.

Scabbed castings. Castings having rough or uneven surfaces.

Scrap. That which has no use as it is.

Sea coal. Soft coal.

Shrinkage. Sea *Contraction.*

Shrink hole. A depression in the casting due to shrinkage.

Sinking head. See *Feeder head.*

Skim gate. See Chapter III, p. 28.

Skimmer. A spoon-shaped bar of iron used to hold back slag while pouring the mold.

Skimming. Holding back the slag with the skimmer.
Skin drying. Drying the face of the mold.
Slag. The residue in the cupola from the impurities in the fuel and metal.
Slag hole. An opening in the cupola through which the slag is removed.
Slick. See Chapter II, *Tools.*
Slicking. Finishing the surface of the mold with a slick or trowel.
Snap flask. See Chapter II, *Tools.*
Soldiers. See Chapter III, p. 24.
Spongy casting. A casting full of blowholes.
Spout. The trough through which the molten metal passes from the tap hole to the ladle.
Spray can. A can from which molasses water is forced in the form of spray by blowing through a pipe.
Sprue. The metal which solidifies in the gate.
Sprue plug. Plug of wood which forms runner of gate.
Stopping off. Filling up an unnecessary portion of a mold.
Stopping-off piece. Template used in stopping off. *a*, Fig. 74.
Straining. Sinking of the sand because of the weight of the metal.
Strike. A stick used in striking out portions of sand from a mold.
Stripping plate. The plate which holds the sand in place while the pattern is being drawn.
Strong sand. Molding sand containing much clay.
Swab. A small quantity of hemp bound together at one end, used to dampen the sand around the pattern.
Swabbing. Dampening the sand around the edge of the pattern.
Sweep. A board having the profile of the desired mold, which, when revolved around a stake, produces that mold.
Sweep work. Making a mold by means of a sweep.
Tap hole. Hole in the breast of the cupola through which the metal flows.
Tapping. Opening the tap hole.
Tapping bar. Iron bar for tapping.
Tempering sand. See *Cutting over.*
Trowel. See Chapter II, *Tools.*
Turning over. Rolling over the parts of the mold.
Turnover board. See *Moldboard.*
Tuyers. Openings through which air is admitted into the cupola.
Vent gutter. See *Gutters.*
Venting. Making vents.
Vents. Passages provided for the escape of gases, air, and steam from the mold.
Vent strings. Strings placed in crooked cores to make vent passages.
Vent wire. Wire for forming vents.
Weak sand. Sand containing little clay.
Wedges. See Chapter II, *Tools.*
Wet blacking. See Chapter I, *Materials.*
Wind box. See in Chapter XII, *Description of cupola.*

APPENDIX

MELTING POINT, WEIGHT, TENSILE STRENGTH, AND SPECIFIC GRAVITY OF METALS

Name	Melting Pt. Degree F.	Wt. Cu. Ft in Lb.	Wt. Cu. Inch in Lb.	Tensile Strength Lb. per Sq. In.	Specific Gravity
Aluminum	1300	162	0.089	23,000	2.6
Aluminum Bronze (10%)	1700	485	0.028	80,000	7.56
Antimony	790	418	0.244	1,000	8.710
Brass (common)	1500–1900	539	0.312	Cast 20,000 Wire 49,000	8.3
Bronze	1850	545	0.315	Cast 32,000 Wire 65,000	8.4
Bismuth	518	616	0.355	3,200	9.9
Copper	1850	550	0.318	Cast 22,500	8.6
Copper wire		555	0.32	60,000	8.8
Glass	1600–2300	180	0.180		3.0
Gun Metal (9 Cu., 1 tin)	1850	545	0.315	Cast 32,000 Wire 90,000	8.4
Iron, Cast	2700	450		16,000–23,500	6.21
Iron, Pig	2200–3000			1st melt. 18,000 2d melt. 20,000 3d melt. 52,000	
Iron, Wrought	3800	480	0.28	Bar 58,000 Wire 95,000	7.698
Lead	620	712	0.410	Cast 1,800 Pipe 2,100	11.33
Manganese Bronze	1800	525	0.300	Cast 57,000 Rolled 105,000	8.40
Nickel	2900	1342	0.299		8.10
Phosphor Bronze	1850	550	0.320	Cast 38,500 Wire 96,000	8.5
Platinum	4500	1342	0.761	Wire 53,000	21.842
Steel, Cast	2550	490	0.286	Plates 60,000 Wire 120,000	7.919
Tin	512	459	0.264	Cast 4,600 Wire 7,000	7.3
Zinc	775	424	0.248	Cast 2,900 Wire 20,000	6.86

SHRINKAGE OF CASTINGS

For Loam castings	$\frac{1}{12}$ in. per foot.
Green-sand castings	$\frac{1}{10}$ in. per foot.
Dry-sand castings	$\frac{1}{10}$ in. per foot.
Brass castings	$\frac{3}{16}$ in. per foot.
Copper castings	$\frac{3}{16}$ in. per foot.
Tin castings	$\frac{1}{4}$ in. per foot.
Bismuth	$\frac{5}{32}$ in. per foot.
Zinc	$\frac{5}{16}$ in. per foot.
Lead	$\frac{5}{16}$ in. per foot.

CUBIC FEET OF EARTH TO A TON

Sand, river (loaded in wagon)	21 cu. ft.
Sand, pit (loaded in wagon)	22 cu. ft.
Gravel, coarse (loaded in wagon)	23 cu. ft.
Marl (loaded in wagon)	28 cu. ft.
Clay, stiff (loaded in wagon)	28 cu. ft.
Chalk, lump (loaded in wagon)	29 cu. ft.
Earth mold (loaded in wagon)	33 cu. ft.

One cubic yard of sand weighs about 3000 lb.

TO TEST THE QUALITY OF IRON

If fracture gives long silky fibers of leaden gray hue, fibers cohering and twisting together before breaking, it may be considered a tough, soft iron. A medium, even grain mixed with fibers a good sign; a short, blackish fiber indicating badly refined iron. A very fine grain denotes a hard, steady iron, apt to be cold short, hard to work with a file. Coarse grain, with a brilliant crystallized fracture, yellow or brown spots, denotes a brittle iron, cold short, working easily when heated, welds easily. Cracks on the edge of bars, sign of hot short iron. Good iron is readily heated, soft under the hammer, and throws out but few sparks. All iron contains more or less carbon, the harder the most. The heaviest steel contains the least carbon.

PROPORTION OF ALLOYS

(By weight)

Bell metal: copper 30 lb., zinc 5.6 lb., tin 10.1 lb., lead 4.3. lb.

Brass, yellow: zinc 10 lb., lead 4 oz., copper 24 lb.

Bronze metal: antimony 1 lb., tin 100 lb., copper 2 lb.

Pewter: tin 4 lb., lead 1 lb.

Platinum, mock: copper 4 lb., zinc 18 lb.

Queen's metal: tin 9 lb., antimony 1 lb., lead 1 lb., bismuth 1 lb.

Rivet metal: tin 5 lb., zinc 2 lb., copper 10 lb.

Silver (colored metal): tin 50 lb., bismuth 1 lb., antimony 3 lb., copper 3 lb.

Silver (imitation): copper 4 lb., zinc 4 oz.

Solder, hard: copper 1 lb., zinc 8 oz.

Solder, plumbers: tin 2 lb., lead 5 lb.

Solder, yellow: copper and zinc, equal parts.

Type metal: lead 9 lb., antimony 2 lb., bismuth 2 lb.

White metal: copper 5 lb., zinc 3 lb., lead 1 lb., tin 1 lb.

ANALYSIS OF SANDS[1]

	FIRE SAND	MOLDING SAND				CORE SAND
		IRON			BRASS	
		Light	Medium	Heavy	Light	
Silica	98.04	82.21	85.85	88.40	78.86	85.50
Alumina	1.40	9.48	8.37	6.30	7.89	2 65
Iron Oxide	0.06	4.25	2.32	2.00	5.45	0.85
Calcium Oxide	0.02	——	0.50	0.78	0.50	——
Calcium Carbonate	——	0.68	0.29	——	1.46	2.65
Magnesia	16.00	0.32	0.81	0.50	1.18	4.27
Sodium	——	0.09	0.10	——	0.13	0.04
Potash	——	0.05	0.03	——	0.09	0.04
Combined Water	0.14	2.64	1.68	1.73	3.80	2.00
Organic Matter	——	0.28	0.15	0.04	0.64	1.00
Specific Gravity	2.592	2.652	2.645	2.630	2.640	——
Degree of fineness	——	85.00	66.00	46.00	95.00	——

[1] Analysis by W. G. Scott.

PROPORTIONS OF VARIOUS ALLOYS IN COMMON USE

(In 100 parts)

Babbitt metal: tin 89, copper 3.7, antimony 7.3.

Fine yellow brass: copper 66, zinc 34.

Gun metal: copper 90, tin 10.

White brass: copper 10, zinc 80, tin 10.

German silver: copper 33.3, zinc 33.4, nickel 33.3.

Machinery bearing: copper 87.5, tin 12.5.

Sheathing metal: copper 56, zinc 44.

FUEL

1 lb. of coal will evaporate from 7 to 10 lb. of water.

1 lb. of dry pine wood will evaporate 4 to 5 lb. of water.

1 ton of anthracite coal requires a space of 42 cu. ft.

1 ton of bituminous coal requires a space of 44 cu. ft.

1 ton of coke requires a space of 80 cu. ft.

150.35 cu. ft. of air are required for the combustion of 1 lb. of coal.

RECEIPTS

Burns: Keep moist with a saturated solution of picric acid.

Coppering Irons: Melt a layer of cryolite and phosphoric acid over the iron, heat to temperature of melted copper, and dip in melted copper.

Hardening Copper: Take 2 lb. of alum, 8 oz. of arsenic, for every 40 lb. of copper. Mix alum and arsenic. Melt the copper in a crucible and stir in the alum and arsenic mixture. Stir for five minutes and pour. (H. D. Chapman, *Am. Mach.*)

Rust Joint: Wet fine iron borings with sal ammoniac and water or hydrochloric acid, and pack into joint.

Rusting: To prevent iron from, warm it and rub with white wax, hold to fire till wax pervades the entire surface. Tools can be immersed in linseed oil and the oil allowed to dry on them.

Silvering Metals Mixture: Dissolve 2 oz. of silver in 3 gr. of corrosive sublimate. Add 8 qt. salt, 4 lb. tartaric acid.

Tinning Acid for Brass and Copper: Muriatic acid 1 lb., dissolve in acid all the zinc it will take, add 4 oz. sal ammoniac, 1 pt. of water.

HINTS CONCERNING THE CUPOLA[1]

When iron runs cold, draw all the melted iron off at once. This will prevent the newly melted iron dropping into the dull iron in the bottom of the cupola, and being chilled also.

When slag flows from the tap hole, with a stream of iron, when the iron is drawn off close, it is due to too much pitch in the sand bottom.

The formation of slag in a spout is due to use of poor material in lining the spout.

The cutting away of the spout lining by the stream of molten iron is due to the lack of cohesive properties in the lining material.

When a tap hole closes up with slag and cannot be kept open, the slag is generally produced by the melting of the materials used in making up the front and tap hole. Slag made in the cupola flows from the tap hole without clogging it.

A little sand or clay wash added to the front and spout material will generally remedy difficulties.

Make the spout narrow so the metal will not take a new channel at each tapping.

If the sand bottom does not drop readily when the bottom is dropped, there is too much clay in the bottom material. Mix a little sand and cinder riddled from the dump with it, or some well-burnt molding sand.

A hard-rammed bottom causes iron to boil in the cupola.

A bottom should not be rammed harder than a mold.

Wet sand not only causes the metal to boil but hardens it. Have the sand no wetter than for a mold.

Do not use new sand for a bottom. Old sand from the gangway is the best.

A bad light-up makes a bad heat. The bed must burn evenly or it will not melt evenly.

Never use green wood in lighting up. Use only enough to ignite the coke.

Don't burn up the bed before charging the iron.

A long heat is more economical than a short one, for as a rule 3 to 1 is charged on the bed and 10 to 1 on the charges, and the greater number of charges melted the less per cent of fuel used.

[1] Trade catalogue, Hill, Griffith and Co.

Sparks that fly from the stream of iron as it flows from the cupola are oxide of iron and burn very little.

Sparks from a wet tap hole or spout are molten iron and burn wherever they strike.

CHEMICAL COMPOSITION OF PIG IRON FOR VARIOUS KINDS OF CASTINGS

Ordinary machine castings (*gray iron*):

Sulphur not more than 0.05 per cent.
Phosphorus not more than 0.05 per cent.
Manganese not more than 0.80 per cent.
Silicon from 1.75 per cent to 2.75 per cent as specified.

Malleable cast (*white iron*):

Sulphur not more than 0.04 per cent.
Phosphorus not more than 0.225 per cent.
Manganese not more than 0.60 per cent.
Silicon from .75 per cent to 1.50 per cent as specified.

Chilled iron:

As for malleable.

Since the relative proportions of combined and free carbon are largely controlled by the silicon, it is not necessary to specify except as above.

THE EFFECT OF COMBINED AND GRAPHITIC CARBON

Combined Carbon causes	Graphitic Carbon causes	Converting CC. into GC. causes
Hardness	Softness	Softness
Brittleness	Decrease of brittleness	Decrease of brittleness
Decrease of tensile strength	Decrease of tensile strength	Increase of tensile strength
Increase of compressive strength	Decrease of compressive strength	Decrease of compressive strength
Decrease of ductility	Decrease of ductility	Increase of ductility
Decrease of tensile resilience	Decrease of tensile resilience	Increase of tensile resilience
Decrease of compressive resilience	Decrease of compressive resilience	Decrease of compressive resilience
	Decrease of shrinkage	Decrease of shrinkage

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