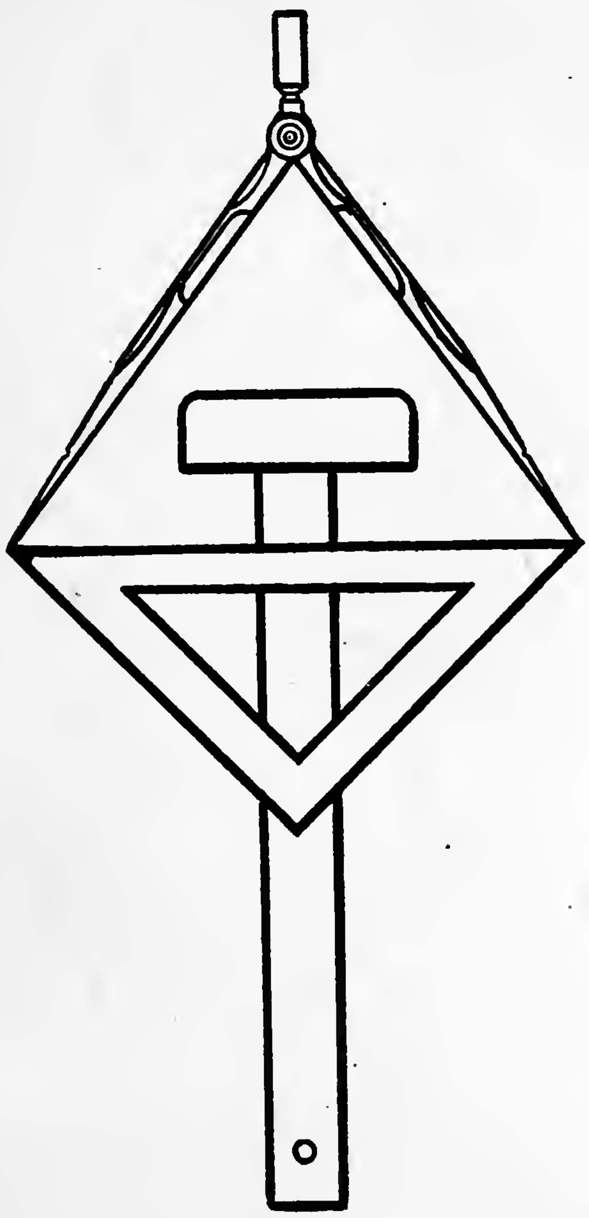
# McLain's System

OF READING
WORKING DRAWINGS OR
BLUE PRINTS

# McLain's System

## OF READING

## Working Drawings or Blue Prints



BY

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## PREFACE.

Knowing from personal experience that there exists a great need for the information contained in these lessons, and being in direct touch with good mechanics in all walks of life who are masters of their particular trade but lack the important knowledge of reading a working drawing, it has been endeavored to arrange this course of instruction in such a manner as to make it complete and intelligible. We are positive that with persistent effort on the student's part, he will be able to absorb this information both to his own personal benefit and to his employer's, thereby making himself a **stronger link** in the human chain of producers.

After glancing over the work, the student may be under the impression that the illustrations and descriptive matter as here presented are not suited to his particular trade, and therefore of no benefit to him; however, we assure you this is erroneous, as the **principle involved** in the reading of any working drawing, as explained and discussed within these pages, is identically the same for all classes of working drawings, and is applicable to all trades.

It is a well-known fact that a person may be well posted on a certain subject but lack the faculty to express himself in such a way as to impart this knowledge to others so they may understand it. We have therefore, borne this in mind and produced this work so that it will be readily understood and at the same time interesting. It should be remembered that all working drawings require more or less study, and it is practice in reading them that will make the student proficient; therefore do not become discouraged if you find some subject seemingly difficult to understand. We earnestly suggest that you **read** and **re-read** each paragraph and master each step as you proceed and we feel confident of your success.

The object of these instructions is to give you a general knowledge of how to read a working drawing, as it is **not our aim** to teach you how to become a draftsman or engineer. By following the instructions closely and referring to the illustrations you will master the information contained in these pages and will be able to read a fairly complicated working drawing.

**McLAIN'S SYSTEM, Inc.**

David McLain

## A UNIVERSAL LANGUAGE

In the mechanical world the reading of working drawings is just as important as the reading of words in a language, but a knowledge of reading drawings once acquired has a still greater value, as the interpretation of working drawings is universal.

# LESSON ONE

## IMPORTANCE OF CAREFUL STUDY.

The careful student must be impressed with the necessity of knowing things. The way to know a thing is to **study** it, just as you studied your books when learning to read. First you learned the simple words—how they look—what letters of the alphabet are used in spelling them—how the words are pronounced, etc. Anyone who is ambitious enough to study these lessons can learn to read working drawings.

To assist the student in doing this, a variety of simple working drawings has been selected for analysis. Altho they by no means cover all classes of work, those selected are especially good examples in bringing out the point in question. Carefully **study each working drawing** as well as the descriptive matter pertaining to it.

**Important**—To understand an object shown on a working drawing, the student must remember that it is necessary to refer **to more than one view of the object**—no single view will explain a drawing fully unless it is a very simple object, such as a solid cylinder having proper notations for diameter, etc.

## WHAT IS A WORKING DRAWING?

A working drawing may be defined as a drawing made to represent an object—not as it appears to the eye in perspective view—but showing the actual relation of all surfaces and points to each other, using a combination of plan, side, end or bottom views.

Blue prints are reproductions of original working drawings.

## WORKING DRAWINGS CLASSIFIED.

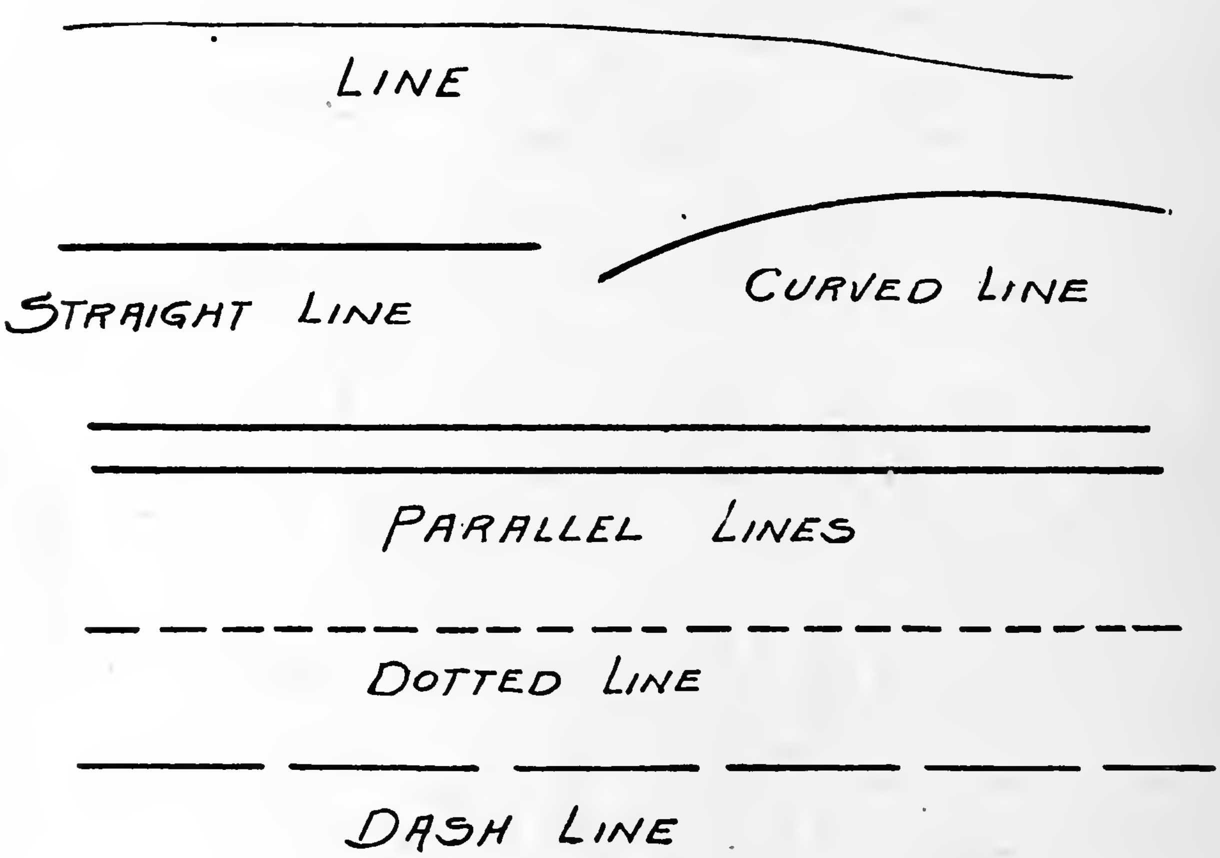
All working drawings may be divided into two classes—general or assembly drawings, and detail drawings.

**General or assembly drawings** show the relative position of the various parts in relation to one another or the general outline of the finished assembled product with its component parts. On an assembly drawing, the over-all dimensions and the more important distances between center lines are usually shown.

**Detail drawings** show the exact shape and size of each component part used to make up a finished product. A detail drawing should be made complete in every respect showing sufficient dimensions and notations to enable the workman to complete his particular operation in its production without the necessity of personal explanation.

It is the general practice to make detail working drawings with all necessary dimensions for the various operations; however, on very complicated work separate drawings are sometimes made for the pattern maker, machinist and blacksmith, giving only the dimensions which pertain to his particular trade.

## LINES.




The above represents several different styles of lines.

A **line** is a mark having length but neither breadth nor thickness.

A **straight line** is the shortest distance between any two points assuming there are no obstructions.

A **curved line** changes its direction continually.

**Parallel lines** are the same distance apart thruout their entire length.

**Dotted lines** are short portions of lines, each being separated.

**Dash lines** are long portions of lines, each being separated.

## DESCRIPTION OF LINES APPEARING ON WORKING DRAWINGS.

Working drawings are produced by a combination of straight, curved and dotted lines arranged to show the outline and details of an object. It has been found that different kinds of lines are necessary to more clearly explain the various surfaces and points of the objects under discussion. For this purpose a series of different lines has been adopted.

**Center line**—The above represents a center line which is usually drawn thru the center of the object. If the object is symmetrical, this line is drawn thru the exact center; if, however, it is not symmetrical, the line is drawn thru its established center and forms the base for the taking of dimensions.

**General line.**—This represents the style of line usually employed to indicate the outline of the object and generally is medium heavy.

**Dotted line.**—A dotted line on a drawing indicates that a certain portion of the object exists, but is hidden from view.

**Long dash line.**—This line is used to indicate the location of a cross sectional view.

It is not always the practice to use the conventional representation of lines as here noted, and any deviation will readily be detected, as for example, the center line may be represented by a line, thus

instead of

The general outline may also be represented with **very heavy** lines in place of the **medium heavy.**

In these lessons all lines mentioned as being **horizontal** are lines running from left to right, thus

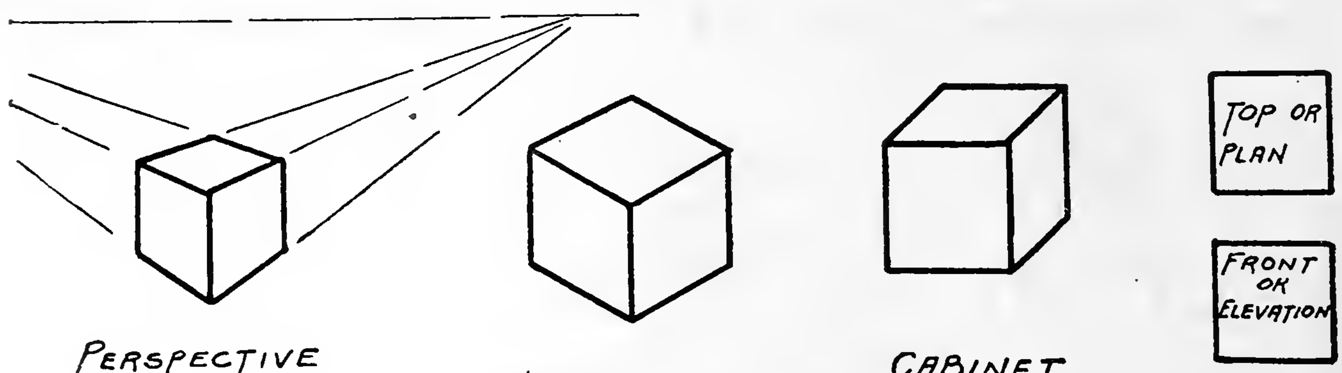
HORIZONTAL LINE

All lines mentioned as vertical lines run in the direction of top to bottom of sheet, thus

VERTICAL LINE

## KINDS OF DRAWINGS.

There are several types of drawings, namely—perspective, isometric, cabinet and orthographic.




PERSPECTIVE FIG-1 ISOMETRIC FIG-2 CABINET FIG-3 ORTHOGRAPHIC. FIG-4

Fig. 1 represents a true perspective drawing of a cube. In true perspective drawings the points or surfaces farthest from the point of observation are the smallest. The eye must be in a stationary position for all types of perspective drawings.

A condensed method of constructing the perspective of Fig. 1 is illustrated by the light lines, converging to a common point on an established vanishing line.

Fig. 2 represents an isometric drawing of a cube. This type of drawing shows the true length of each line and is a modification of the perspective drawing in Fig. 1. Generally three surfaces are shown, a top and two adjacent sides.

Fig. 3 is a cabinet projection of this cube. In this drawing one face of the cube is shown full view; the side surface is shown inclined upward and to the right. This drawing differs from the isometric drawing in so far as the side and top are not shown in full length, but approximately half.

All drawings in these lessons, shown as in Figs. 1, 2 or 3, for convenience will be classified **perspective drawings**.

Fig. 4 represents an orthographic projection of this same cube. This type of drawing will be classified as **working drawing views** in these lessons. This figure represents the projection of the top and front of cube and is the type of drawing which is used in the making of all working drawings.

Mechanical drawing is a language of lines, arranged to produce working drawing views—and the interpretation is universal.

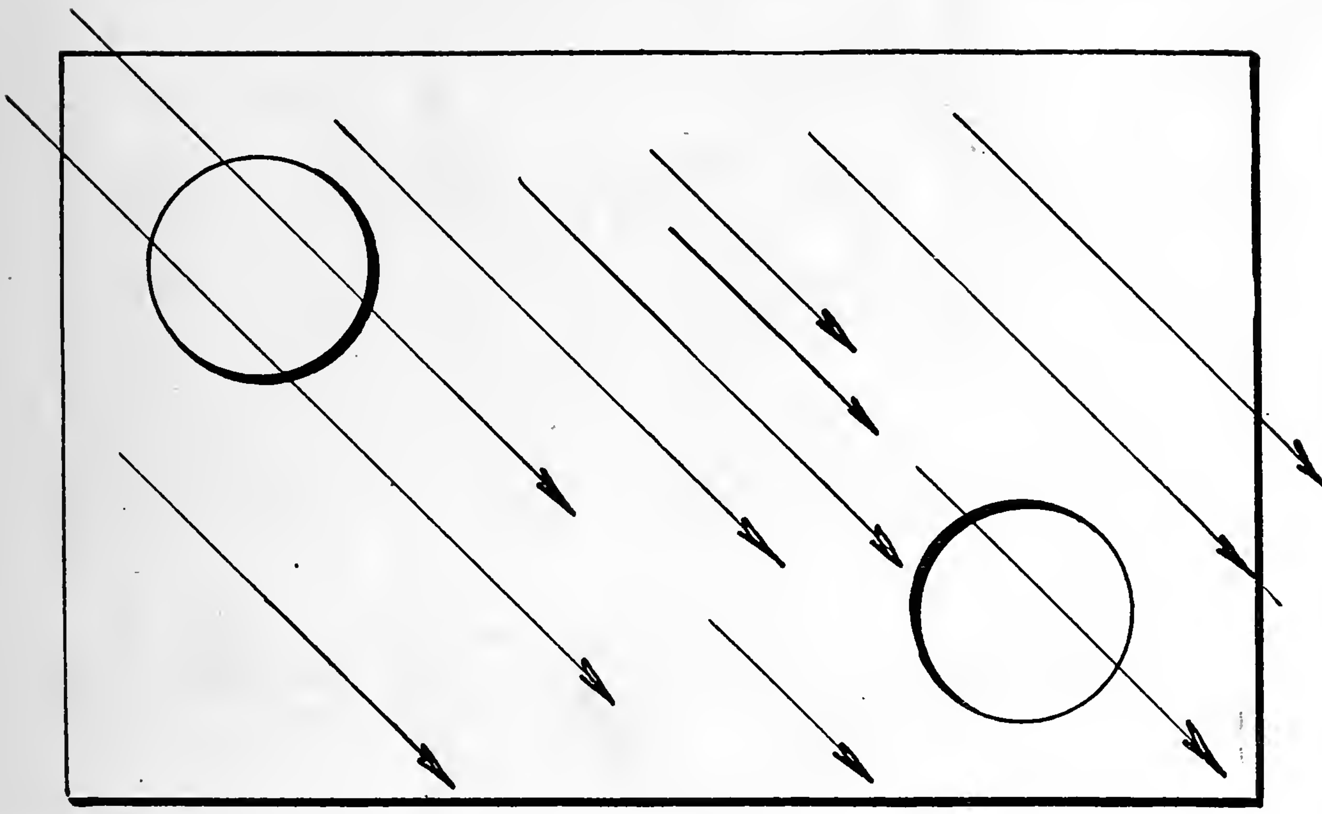


Fig. 5

Fig. 5 represents shaded lines. These are seldom used on working drawings. All patent and sometimes assembly drawings of working parts are made using shaded lines. The shaded line is used to assist in a better understanding of the character of a particular part and will show whether the surface is raised, depressed or represents a hole. For example, let us assume that Fig. 5 represents a flat board upon which a coin or similar object is placed in the upper left hand corner, while in the lower right hand corner a round hole is cut.

It is always assumed that rays of light fall from the upper left hand towards the lower **right hand corner** in the direction of the diagonal lines. In passing over the coin the light rays will throw a shadow around the lower right half of the coin, also showing at a glance that this shadow is produced by the raised surface. Likewise, we have the opposite condition when the rays pass over the hole as indicated in the lower right hand corner. The light will throw a shadow along the **upper left hand** of the cut-out portion, indicating a hole. This also applies to a depressed surface.

## LINE SHADING.

A series of lines is sometimes employed to show that a certain object is rounded, as for example Fig. 6.

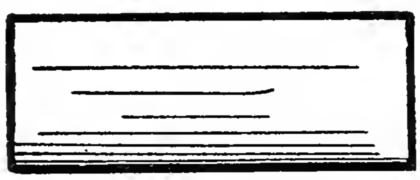
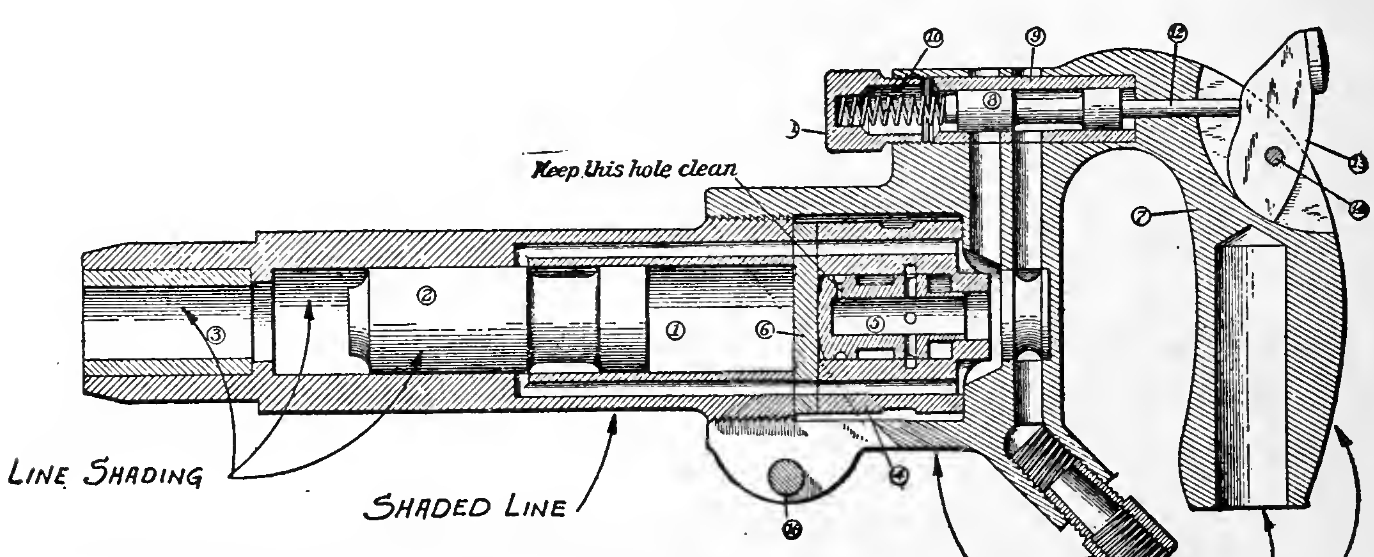


FIG-6.

FIG-7.

The above line shading aids in indicating a solid cylinder. Again, we will assume that the light comes from the top, producing a shadow along the lower surface of the cylinder. The horizontal lines are placed closer together as they near the lower edge of the cylinder indicating the magnitude of the shadow.

Fig. 7 illustrates the use of line shading on a vertical rounded surface—the lines being placed closer together as they near the edge which is farthest away from the source of light.




Sectional View of Chipping Hammer

**The sectional view of chipping hammer** illustrates the use of line shading and shaded lines, each being marked on the illustration.

Your attention is also called to the line shading of the cylinder walls, the lines being placed closer together as they near the top, which indicates it is hollow.

For depressed cylindrical surfaces the line shading is opposite of that shown in Figs. 6 and 7.

## EXAMINATION

## LESSON 1

1. What are parallel lines?

2. Are horizontal and vertical lines shown in Fig. 4?

3. What is the difference in construction between a center line and a general line?

4. Are shaded lines generally used on working drawings?

5. What is the advantage of using line shading?

# LESSON TWO

## IMAGINATION A VALUABLE ASSET.

Imagination will be found to be your best assistant in this work, and by the aid of the projections, picture a model of the object represented.

An object, or solid, of any conceivable shape may thus be resolved into its elementary parts or points. The drawing of the object, then, will consist simply of locating the positions of these points on the drawing. You may have drawings that require the location of a hundred or more of these points, depending entirely on the form or shape of the object in question, but the principles are the same in all cases.

If, after resolving an object in this imaginary way, you will carefully study or imagine the proper location of these points in their relation to the object itself, **defining their positions on the drawing, one at a time,** much that may appear complicated at first sight will resolve itself into very simple and comparatively elementary work. Complicated work is usually nothing more nor less than the aggregation of a number of simple operations that appear complicated only because they are combined.

It is in the imaginary way thus described that you are directed to picture each figure as presented for the reading of working drawings. This part of the study is almost entirely the work of the imagination, as will be noted, but it should be practiced for the sake of the assistance it will render later on.

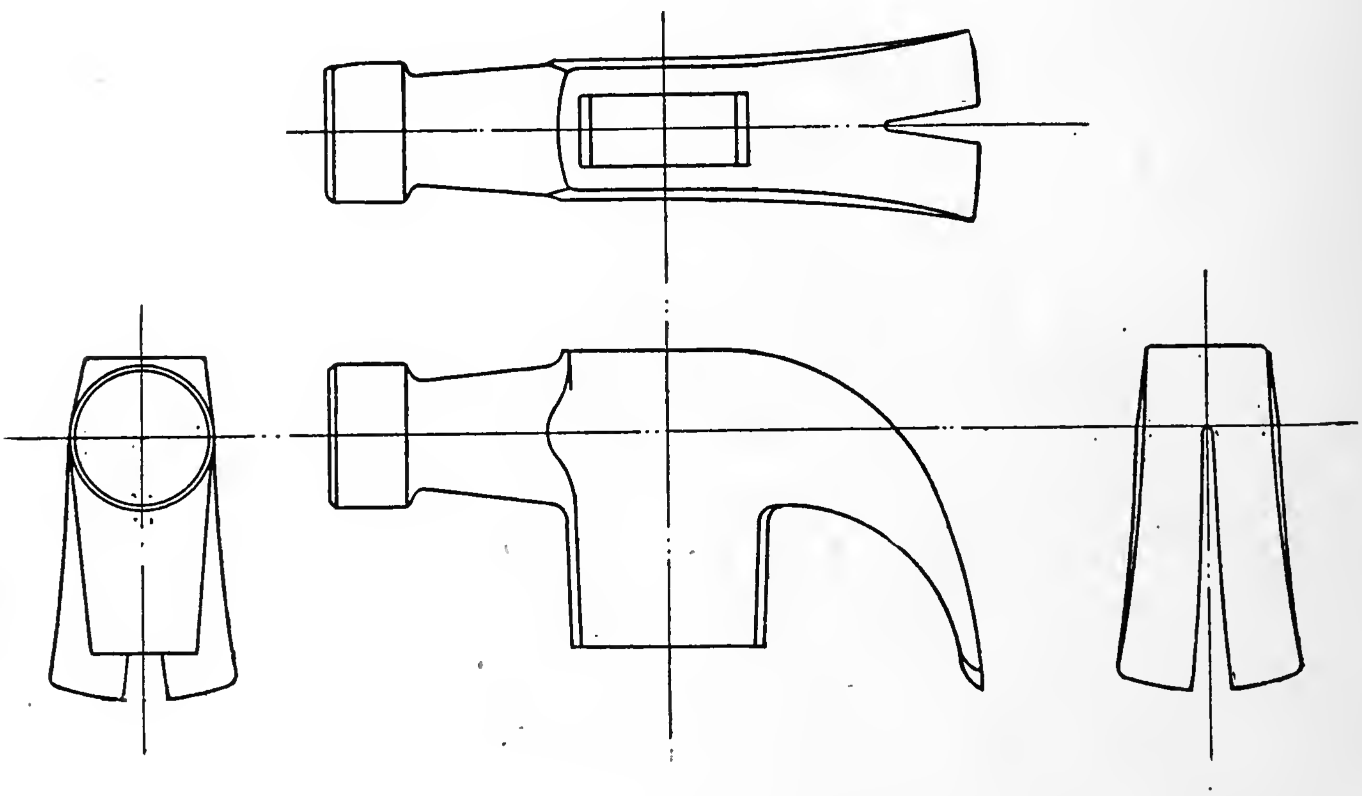
As the working drawing is produced on a flat surface, it is necessary to use your imagination to make the lines and views lift up from the paper. When a clear-cut mental picture has been formed, the dimensions should be studied until understood. Next all the lettered text should be read and considered.

In order to more readily understand a working drawing, it will be necessary to imagine or picture the object under discussion, and after a little practice you will be surprised how quickly this can be mastered.

## DEVELOPING THE IMAGINATION.

We suggest that you take some familiar object, say a hammer; close your eyes and picture the outline of it. Try several other objects. Such practice will greatly assist in a better understanding of the principle of reading working drawings.

It is also important that you learn to look at an object and see only **a view** representing a side, or a top, an end or bottom at a time. For example, take the hammer and hold it level with the eye, so that only the side can be seen; then look directly at the top, not seeing either side. This is exactly what a working drawing would show—**only one view at a time and never in perspective.** Of course, it is not always possible to take the various objects that are shown on a drawing and place yourself in a position so that only one view is visible at a time.

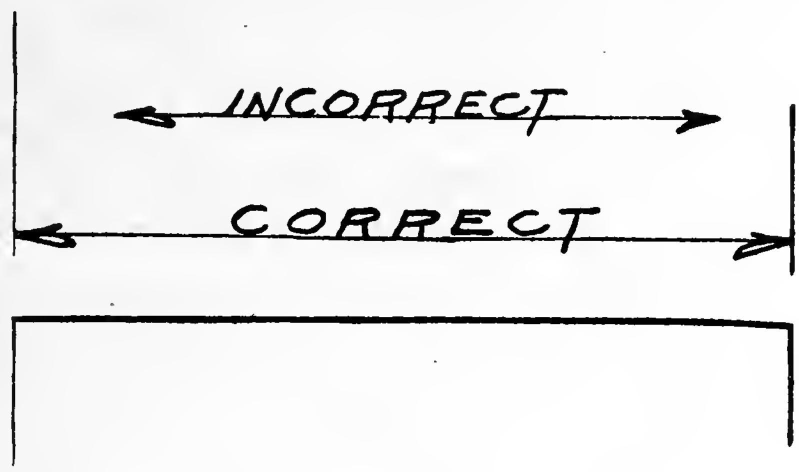


Let us assume a pattern maker is called upon to make a pattern to dimensions on a certain drawing. You will readily see that it will be absolutely necessary for him to be able to read a working drawing correctly and to form a mental picture of the finished object as he has no object to look at.

It is important that you clearly understand each topic and illustration as you proceed, as each is the stepping stone to the next, therefore if you master the subjects in their order, we feel confident that you will be able to read the final drawing of the instructions submitted without difficulty.

## CARE IN THE MAKING AND READING OF WORKING DRAWINGS.

It is important that care be exercised in the reading of a working drawing as sometimes a draftsman may become careless and not place dimension lines on a drawing correctly, which may cause much confusion. For example, the dimension lines here shown are correctly and incorrectly placed. Dimension lines with the arrows should always extend to meet the lines to which they refer.




Much confusion is also caused by carelessness on the part of the draftsman in writing his dimensions. For example, assume he wishes a certain dimension to be

$\frac{11}{16}''$ but writes it thus, $11/16''$

it may be mistaken for $1\frac{1}{16}''$, therefore it is always advisable to use the horizontal line when writing fractions, instead of the diagonal.

## POSITION OF EYE FOR WORKING DRAWING VIEWS.

Fig. 8. The object of this illustration is to show the position of the eye when making working drawing projections, and is shown in a direct horizontal line with each and every point along the entire height and width of the object.

This figure shows a tall, square, tapered chimney in perspective view, also an elevator capable of traveling a distance equal to the height of the chimney.

Disregard the elevator for the present. Looking at the chimney from the angle as here shown, the vertical line "c d" is nearest to **your** eye and therefore the longest; the lines "f e and a b" being farther away, are all shortened in accordance to one of the rules for perspective drawing which says that "all horizontal lines of an object vanish to a common point called the **vanishing point** located on a vanishing line, and sometimes called the horizon."

Perspective drawing is a study in itself and we will not attempt to discuss it in these lessons.

We have shown the outline of a man on the elevator and it is assumed that he has closed one eye and is in such a position that the line of vision of the other eye is in a direct line with the edge E of chimney, not being able to see either the right or left hand side of chimney. The horizontal line from his eye to a point on the edge E is here shown and marked "line of vision."

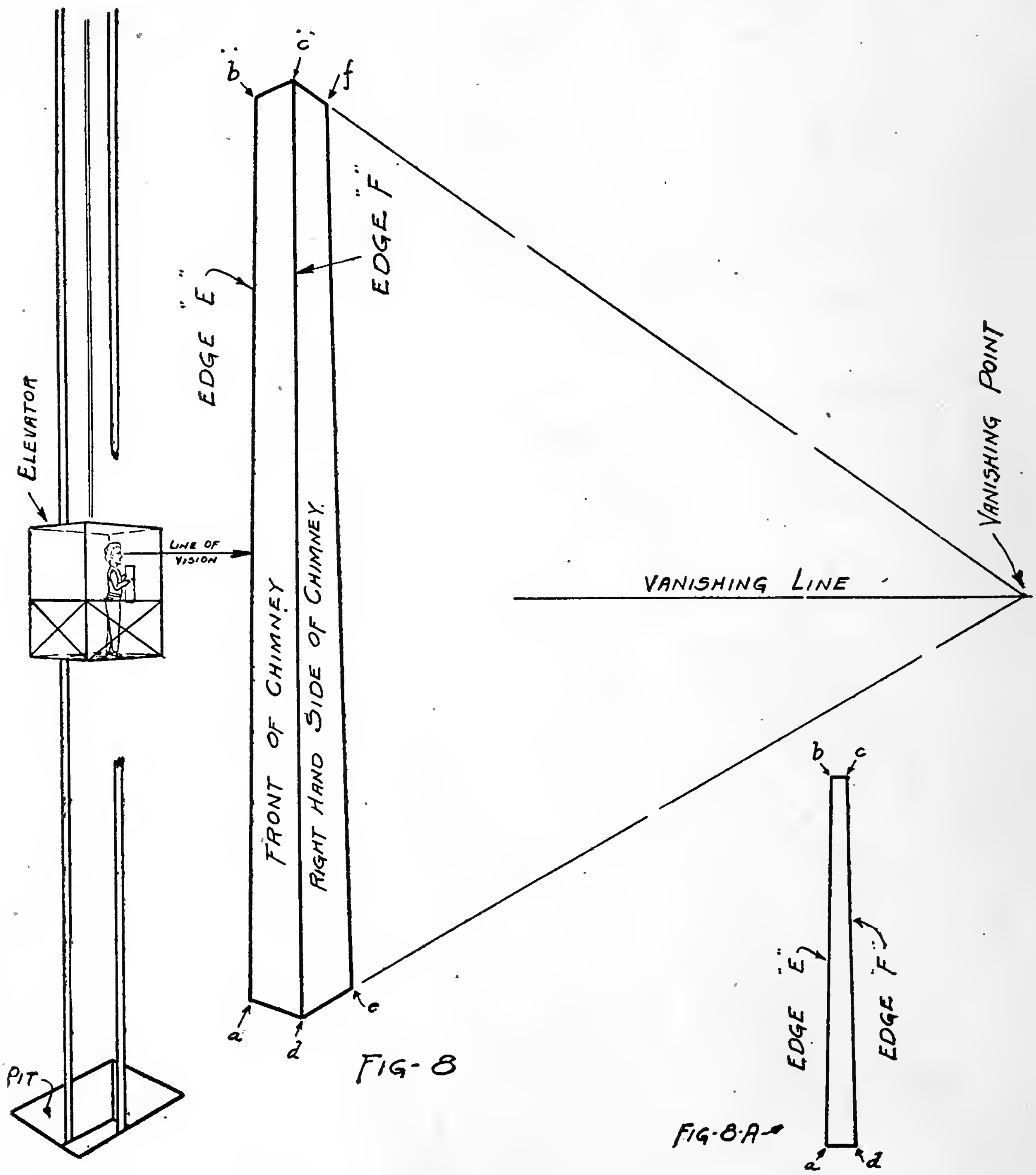



FIG-8

FIG-8-A

Imagine that the elevator had started at the bottom, the man's line of vision being at point "a". As the elevator travels up he sketches the vertical edge E on the paper; when his eye is in a horizontal line with the top point "b" he stops the elevator, walks across to the other side of it, keeping his eye in line on the edge "b c" and sketches this line. He then starts down, keeping his line of vision on the edge F, sketching each point as he moves down until he reaches the bottom point "d" where he stops and walks back to the other side of elevator, keeping his eye on the line "d a," and sketching same.

His completed sketch of the front view will be as illustrated at the right and marked "Fig. 8 A," the corresponding edges and points being marked with the same letter in both views.

This illustrates the imaginary position of the eye for all working drawing views and regardless of the height or width, the line of vision is always in a direct horizontal line when projecting any side or end of an object.

The explanation of Fig. 8 is **very important** and you should clearly understand this before proceeding further as it is absolutely essential to know the location of the imaginary position of the eye when making a working drawing view.

The horizontal position of the eye applies not only to the **outline** of the object as shown and explained, but also to any **point on the surface** of the particular face you may be sketching. This will be better understood after you have studied the illustrations and descriptive matter pertaining to Figs. 9, 10 and 11.

As mentioned, Fig. 8 A corresponds to the working drawing view of one of the exterior faces of this chimney and is designated as the front view.

Imagine that the elevator is moved around so that it is directly opposite the **right hand** side of chimney, and the elevator and man moved up and down in a similar manner as mentioned when the front view was sketched—the man sketching the outline of the right hand side or face.

A view similar to that shown in Fig. 8 A would be produced to represent the right hand side of the chimney and the letters "d e" would designate the two lower corners and "c f" the two upper corners. This view should then be placed to the right of Fig. 8 A and both views would represent the exterior working drawing views of the front and right hand side of the chimney.

The horizontal position of the eye applies to the making of front, side or end views. The position of the eye for a top view will be explained under Fig. 11.

**Important**—It should be remembered that the eye must be in a direct **horizontal** line with all points along the outline, also with all points on the surface or face of the object you are sketching when making a front, side or end view of an object.

## ILLUSTRATION EXPLAINING THE PROJECTION OF A DEPRESSED SURFACE.

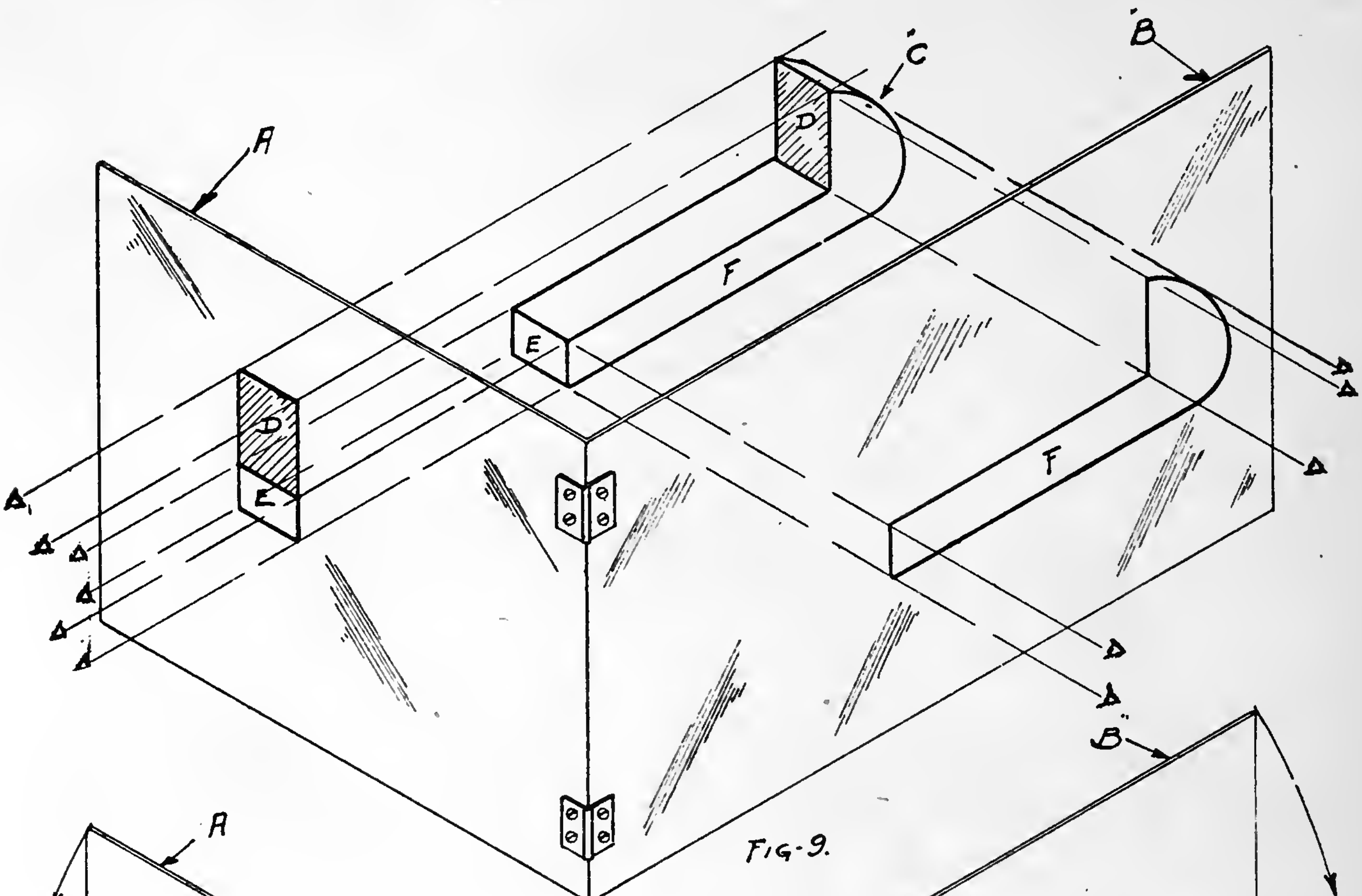



FIG-9.

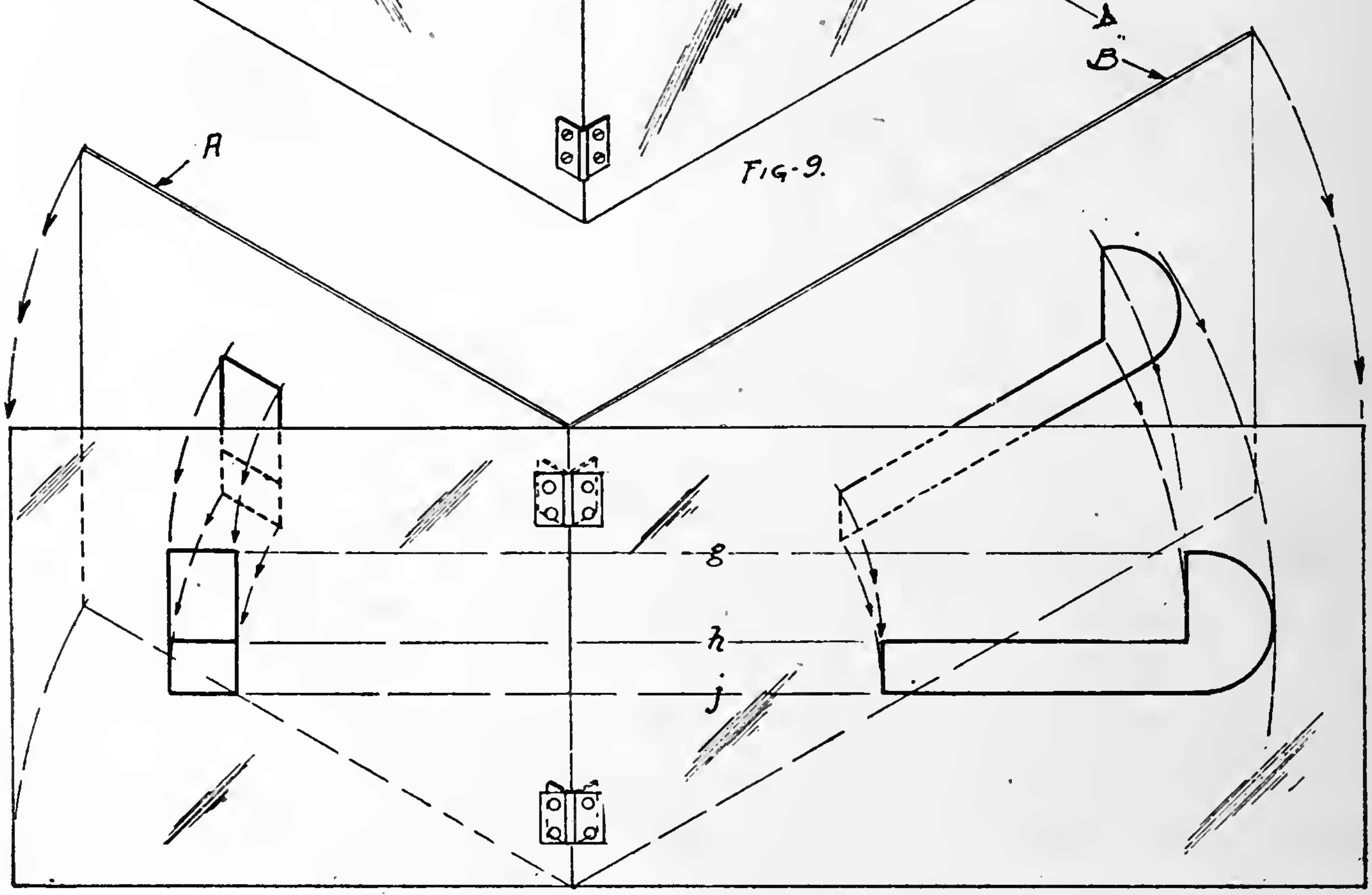



FIG-10.

Fig. 9. Suppose that A and B are glass plates placed at right angles to each other and bolted together at the corners with hinges—the object C being placed back of these glass plates as shown.

Object C represents a solid and may be made of any material cut to the shape shown. We call your attention particularly to the relative position of the surface D to E—the surface D being some distance back of E. In the projections of various surfaces of an object, all surfaces as D and E are brought to the same plane. To illustrate this, we have projected the various points of this object to the glass plate A and have indicated the correct projection on the plate.—Regardless of how far back the surface D may have been located on the object C, these surfaces are always brought to the same plane to produce working drawing views. **It is important** that you understand this as it is one of the first steps in the reading of working drawings.

Object C is here shown in perspective, or as it would actually appear when looking at it from an angle. A perspective view of an object is obtained by looking at it from an angle so that two or more views are visible at one time. Working drawings are produced by looking at an object so that a **view** representing **only one** of its sides, top, end or bottom, is visible at a time—all depressions and extensions being brought to the same plane, and the eye placed directly in line with each point on its surface or outline regardless of its length or height.

To illustrate this we have shown the position of the eye at various points along the length and height of the object at the left and right of this figure.

To make this clearer we suggest that you take a book and place it flat upon a table, and look at it from an angle so that the top, end and back can be seen. This view would be called a **perspective.** Pick up the book, hold it flat with the end towards you and at a level with the eye, close one eye and you will see the end only which would correspond with one view of a working drawing. Coming back to the illustration Fig. 9 keep in mind the experiment with the book and refer to the projection of the side surface F of object C on plate B, then you will readily understand how this projection is produced and likewise the projection of the surfaces D and E on the glass surface A.

Fig. 10. Now suppose that we have opened these plates and then imagine that the projected surfaces D, E and F have been outlined on the glass plate as shown. In opening the glass plate the arrows indicate the path of travel of the outer edges of the glass plates and also the assumed path of the outline of the object. After these plates have been completely opened the **lines** g, h and j will show the **corresponding points of the end and side views.** These final views of the surfaces D, E and F are the correct working drawing projections of the original object C in Fig. 9 and illustrate one method of producing a working drawing view.

## ANOTHER EXAMPLE ILLUSTRATING THE POSITION OF EYE FOR WORKING DRAWING VIEWS.

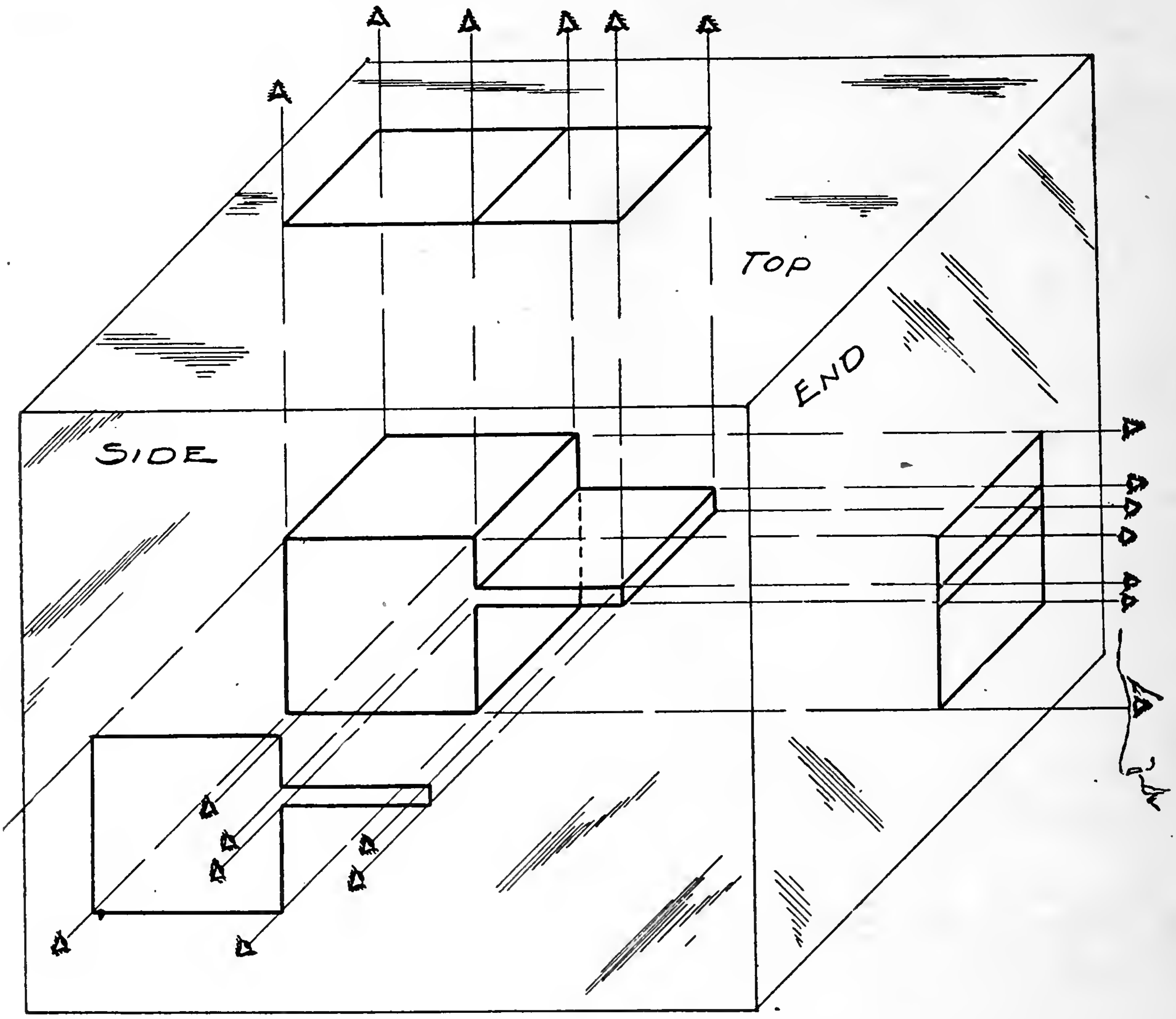



FIG-11

In the making and reading of a working drawing, it is always supposed that the eye is in direct line with each point or surface, **vertically** for a top view and **horizontally** for a side or end view—for example Fig. 11. Let us imagine that we have placed a block of iron with a shelf projection on one side into a solid cube of glass.

We will now explain the projection of the shelf surface:

It will be seen that the top surface of this shelf projection is shown some distance from the top of the iron block proper; however, when making a projection for a working drawing, all depressions and extensions are brought to the same plane, as shown on the top surface of the glass cube; likewise when looking at the end, the eye must be in a horizontal position with each point regardless of the height of the object.

Your attention is called to the various positions of the eye at the side to illustrate this point—then by projecting each point to the end surface of the glass cube, or same plane, a view is produced as shown at the end surface of cube. Likewise the side view is projected to the surface of glass cube in the same manner. The object having no depressions or extensions on its side has identically the same outline in the side view as the original iron block.

## EXAMINATION

## LESSON 2

1. Is the man in Fig. 8 supposed to see either side of chimney in making his working drawing of the front view?

2. What kind of lines are shown in the illustration of hammer on page 14.

3. Fig. 9. (a) Does the projection of the surfaces D and E on the glass plate A show how far back the surface D is in relation to E ?
   (b) If not, does this show on glass plate B ?

4. Fig. 11. (a) How many views indicate the distance shelf projects beyond the block proper?
   (b) Name them.
   (c) What type of drawing does the outline of glass cube represent?

## LESSON THREE

### PROJECTIONS.

One important subject in these lessons comes under the title of "Projections," as it is the key to the understanding of working drawings.

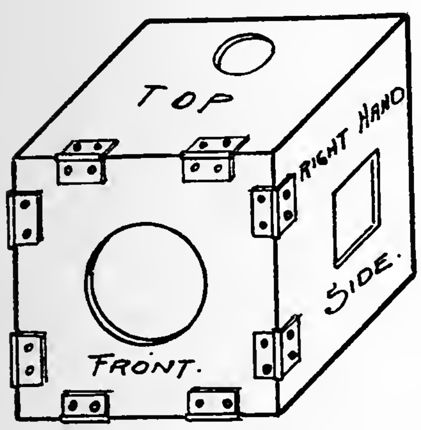



FIG-12

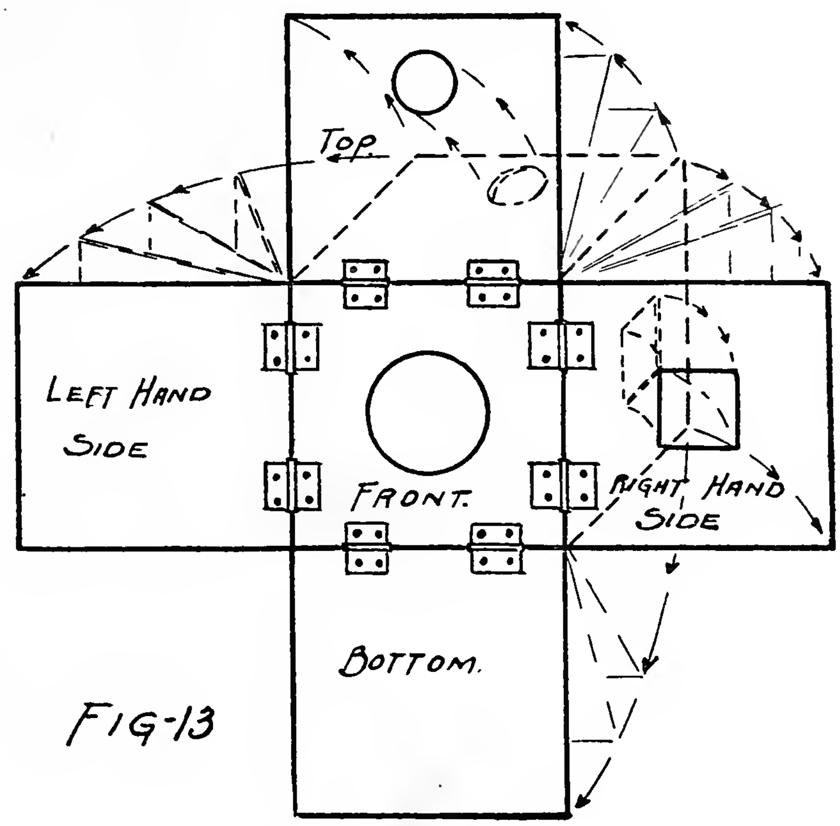



FIG-13

Fig. 12 represents a box, open at the back, and for the sake of illustration, we have placed hinges along the four edges of the front and have supposed that the sides, top and bottom can swing on these; the box has also been marked front, top and right hand side. In addition you will note the front of box has a large hole in the center, the top a smaller hole towards the rear, and the right hand side, a square hole. Left hand side and bottom have no holes.

In Figs. 12, 13 and 14 we have attempted to show only how the exterior surfaces are projected, paying no attention to the thickness of the walls.

Fig. 13 shows the same box as Fig. 12 except that the top of box is opened, both sides are spread out and the bottom is dropped; the arrows indicate the path of the outer edges. You will readily understand by looking at the front view that the large hole in center corresponds with the front in the perspective view; the top and right hand side correspond with the top and right hand side in the perspective view. Note the relative position of all the views in relation to the front—namely, that the right hand side is placed to the right side of the front, top at the top, and bottom at the bottom of front view. It is important that you clearly understand the relation of these views to the front.

In Fig. 14 we have removed the hinges and separated each view from the front of the box. The same relation of top, bottom and sides to the front view exists as in Fig. 13.

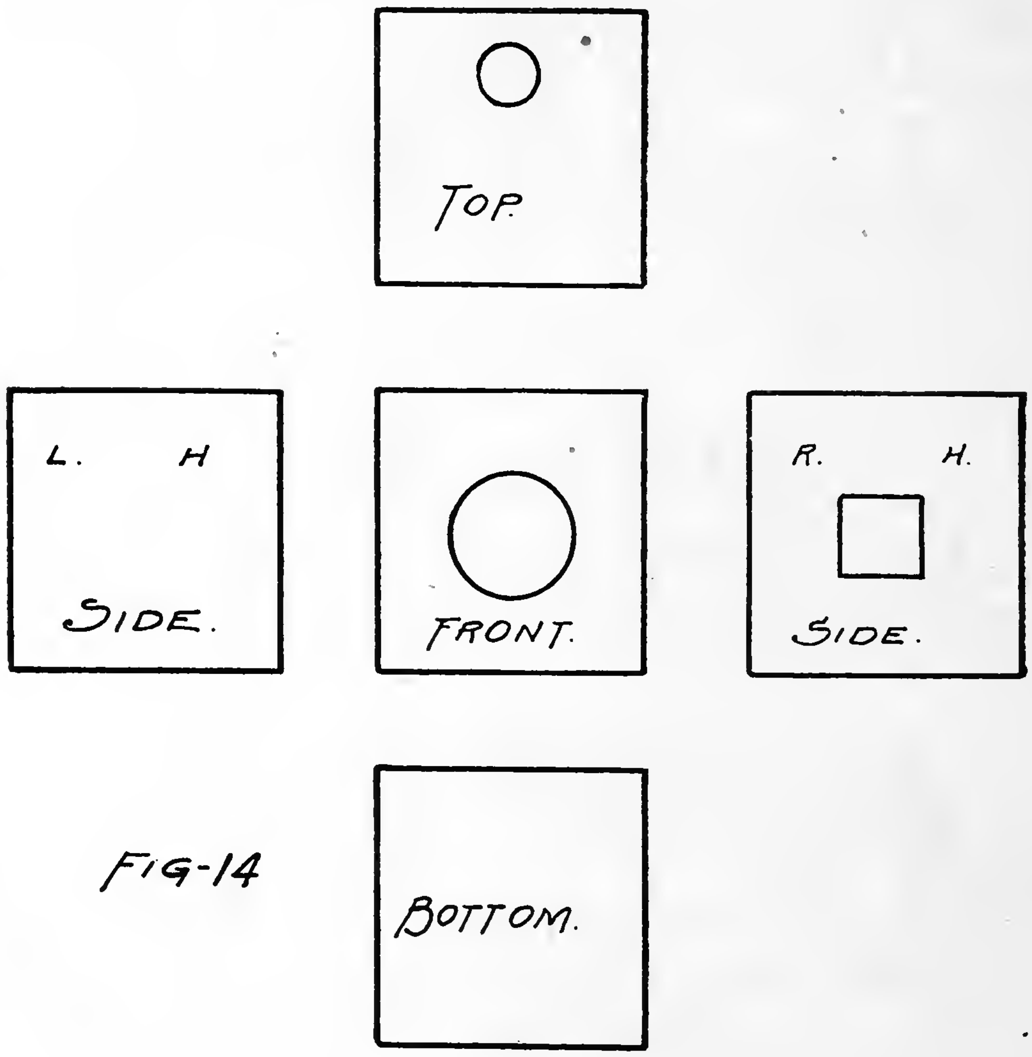



FIG-14

Again referring to Fig. 12, if you will imagine that this box is placed in such a position that when looking at the front you will not see top, sides nor bottom, you will have an outline as shown in the middle of Fig. 14, marked "front." If you will look at the side so as not to see any of the other surfaces, you will see an outline as shown at the side, and by placing yourself directly over the top so that no other surface can be seen, you will get a view as shown, and marked "top."

It is important that you train your imagination to see a view which represents the surface and outline of only **one** of its faces—either a side, an end, the top or bottom of the object at a time.

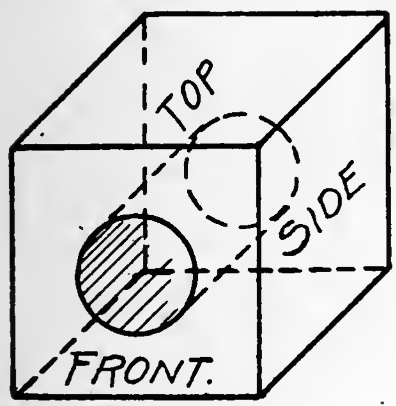



FIG-15

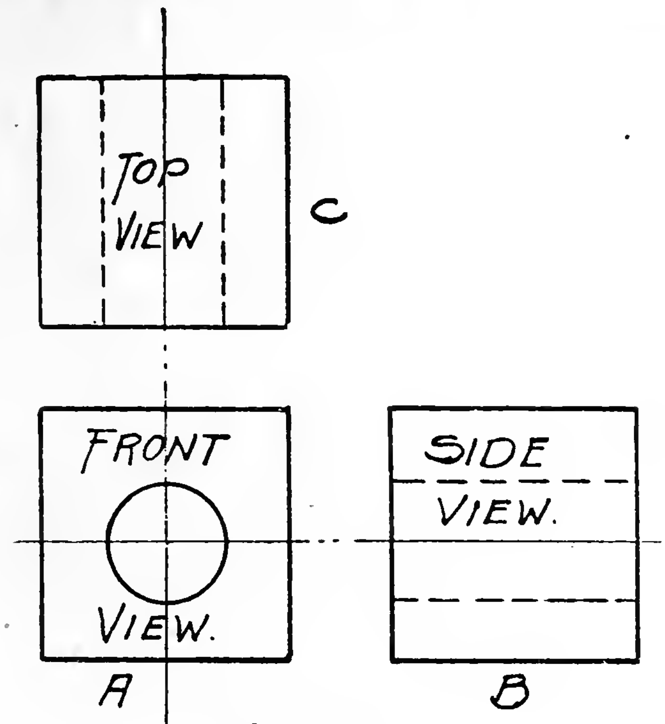



FIG-16

The illustration marked Fig. 15 represents a solid block of wood with a hole thru its full length. You will have no difficulty in understanding this view as it is what is termed a "perspective" and shows this block as it would actually appear, viewed from an angle.

Fig. 16 illustrates the fundamental principles of producing a working drawing. You will note that it does not resemble the view in Fig. 15. In order to learn to read a working drawing, it will be necessary that you place yourself squarely in front of the object so that sides, top and bottom will not be seen and you will see a view similar to that shown at A, Fig. 16, marked "front view."

Again, assume this block is placed in such a position that you will see only the side—you will then see a view as at B, Fig. 16, marked "side view."

View C, Fig. 16, is a top view and shows only the top of this block, were it placed in such a position that front, back and sides were not visible. The rear and bottom views are not necessary as rear would be the same as the front and bottom the same as the top.

You will note that the hole shown as a circle in view A is indicated on view B by two parallel dotted lines, which also show that this hole extends thru the full length of the block.

On view C the dotted parallel lines again indicate the hole.

Remember, working drawings are **never** shown in perspective, but always as in Fig. 16 and all views of working drawings are generally placed in relation to front, as shown. A top view, or perhaps a side view, is not always necessary; in this case either the side or the top would have been sufficient. Then again, in very complicated drawings all four sides and several cross sectional views may be necessary.

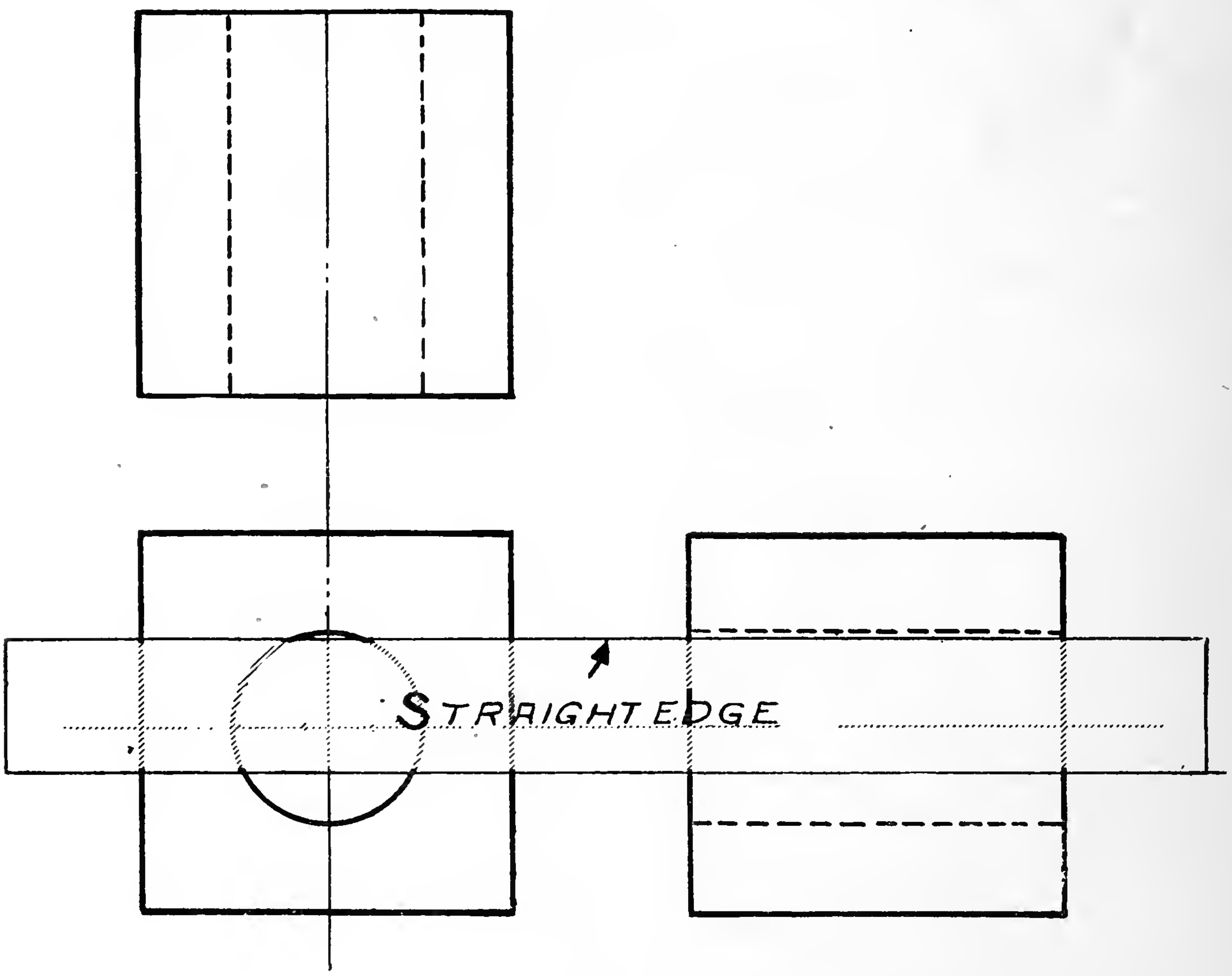



FIG-17

Fig. 17. (Also refer to Fig. 16.) In this figure we have shown how the upper edge of the hole in the front view is projected to the side view. You will note the straightedge is placed horizontally, the upper edge of this straightedge just touching the top of the circle which point, projected horizontally, corresponds to the dotted line in the side view and indicates that the dotted line is the correct projection of the upper edge of the hole and also that this hole extends thru the full length of the block.

Any point or surface may be projected in this manner, horizontally between front and side views, and vertically between top and front views.

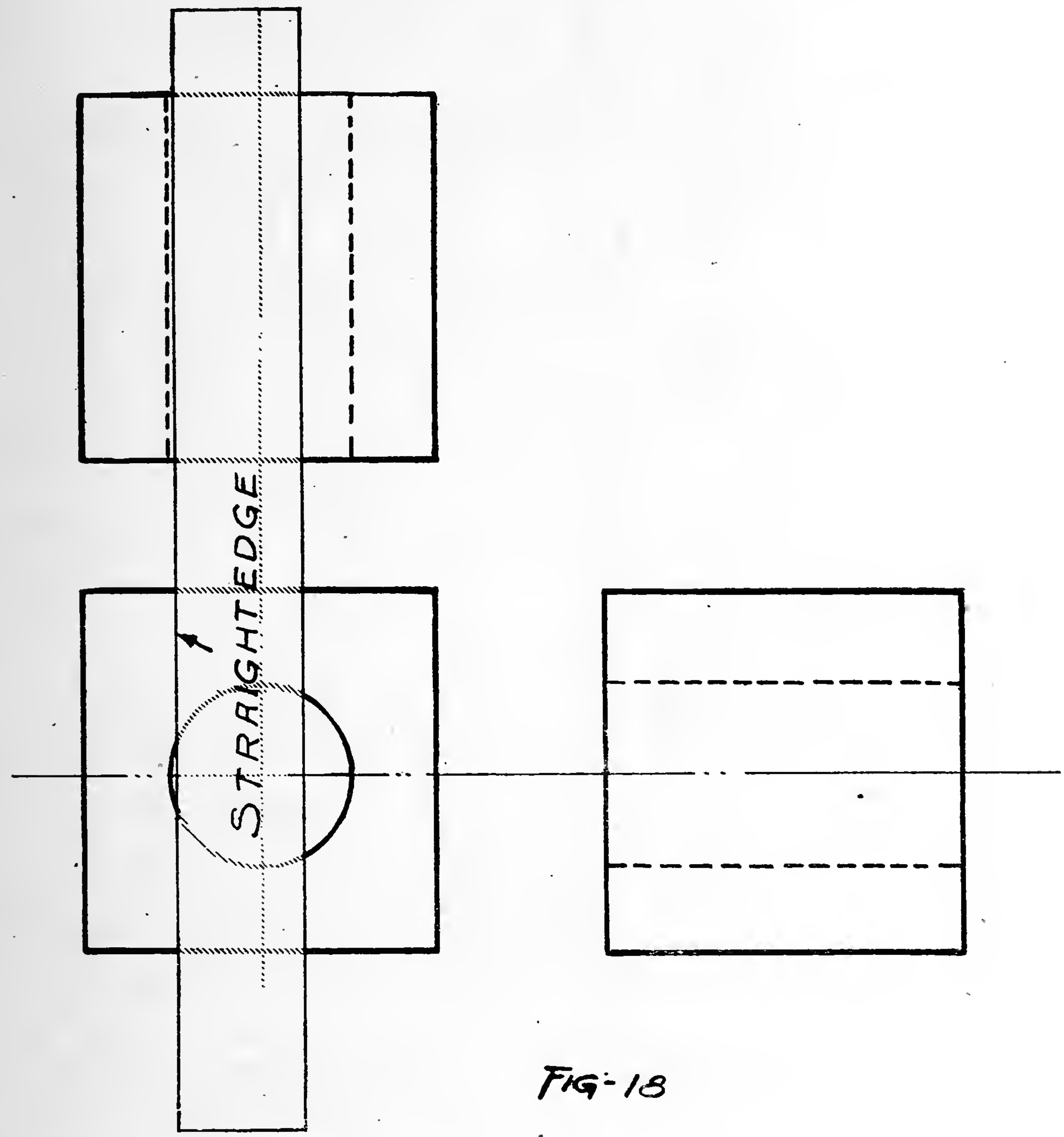



FIG-18

Fig. 18 illustrates the method of projecting this same hole from the front view to the top view. The straightedge is just touching the extreme left hand edge of the circle (see front view). This point projected to the top view is indicated by the dotted line.

The eye should be trained to do exactly what the straightedge is used for in both Figs. 17 and 18.

In views as here placed, all points, lines or surfaces are projected horizontally from front to side view and vertically from front to top view.

Next, let us take this same block and cut out a portion of the upper right hand corner as shown in the perspective view, Fig. 19.

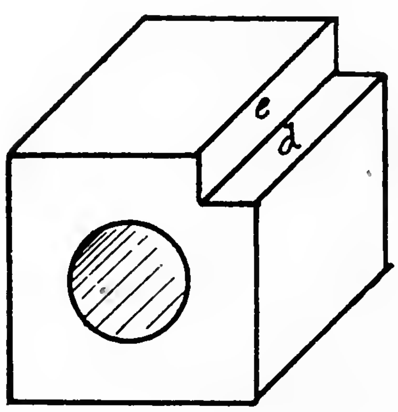


FIG-19

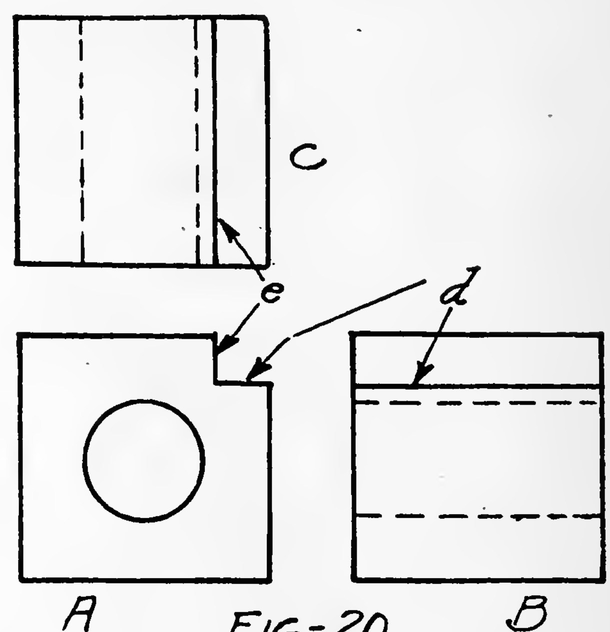


FIG-20

The **front view** of working drawing shows this cut-out portion in upper right hand corner. In the **side view** B, Fig. 20, you will note the full line marked d corresponds with line d on view A. It is shown as being a full line on view B because the line of this surface can be seen when looking at the side of block. Here again, the depressed surface is brought to the same plane (see view B) as discussed under Fig. 11. Referring to the top view C, Fig. 20, line e corresponds with line c on view A, the depressed surface d in view A having been brought to the same plane. Each line has its corresponding surface in one view or another, and you should study each line to determine just what surface or point it represents on the various views.

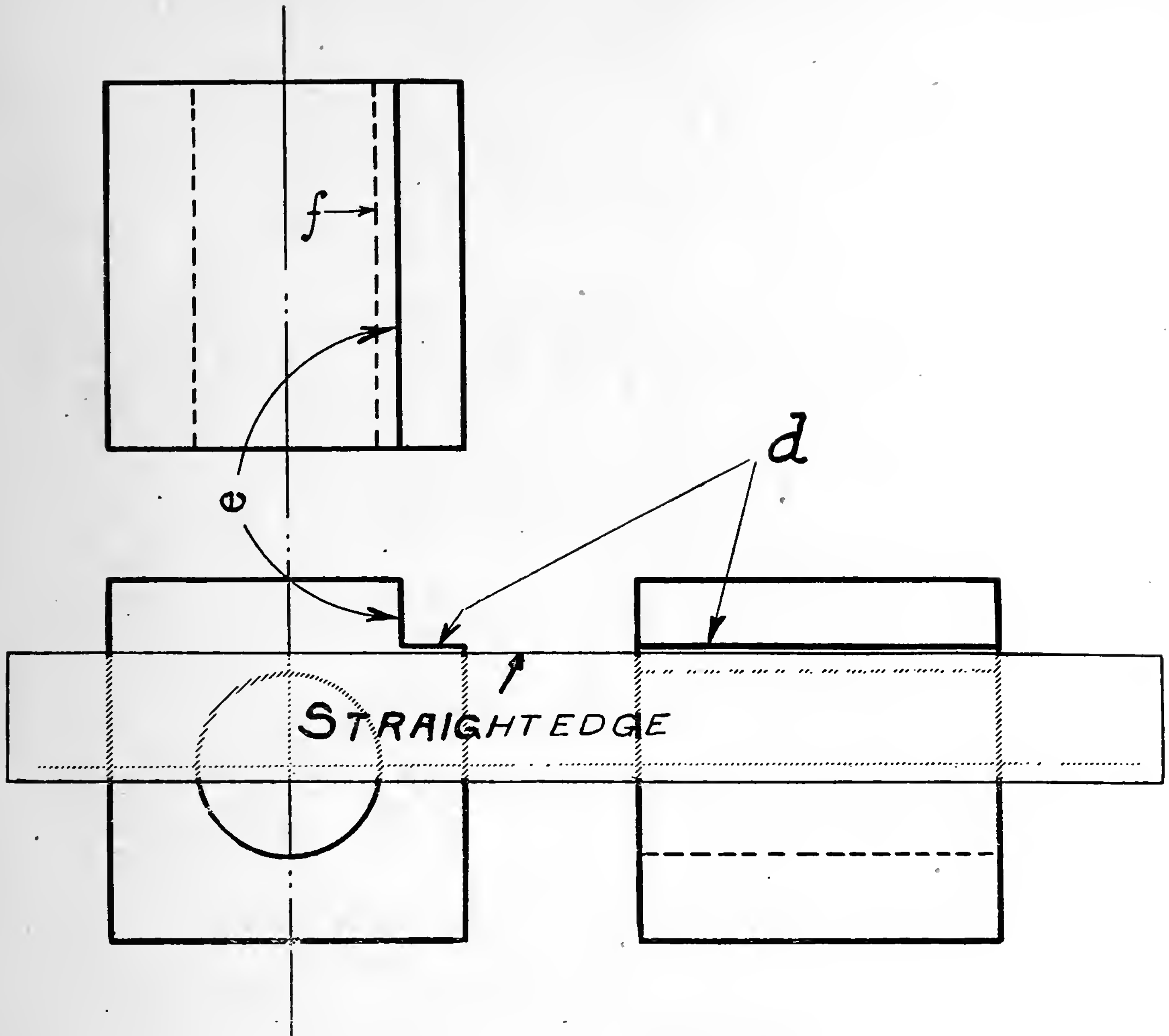



FIG-21

Fig. 21 again illustrates, with the use of a straightedge, how the surface d is projected from the front to the side view.

Fig. 22 illustrates the projection of the surface e from the front to the top view.

Your attention is called to the dotted line f directly in front of the straightedge. This line indicates the projection of the right hand edge of the hole. Note the relative location of surface e to the right hand edge of the hole in the front view.

It is good practice to note the relative positions of the various points or surfaces in one of its views as this will be a helpful guide in locating the various points on the corresponding views.

## POINTS OR SURFACES PROJECTED HORIZONTALLY.

Whenever two views are placed to either **right or left** of one another, all corresponding points or surfaces of these two views are projected **horizontally**. The straightedge, as placed in Fig. 21, illustrates a **horizontal** projection.

## POINTS OR SURFACES PROJECTED VERTICALLY.

Whenever two views are placed above or below one another, all points or surfaces are projected **vertically**. Fig. 22 illustrates this, the straightedge being placed **vertically** in projecting the surface e.

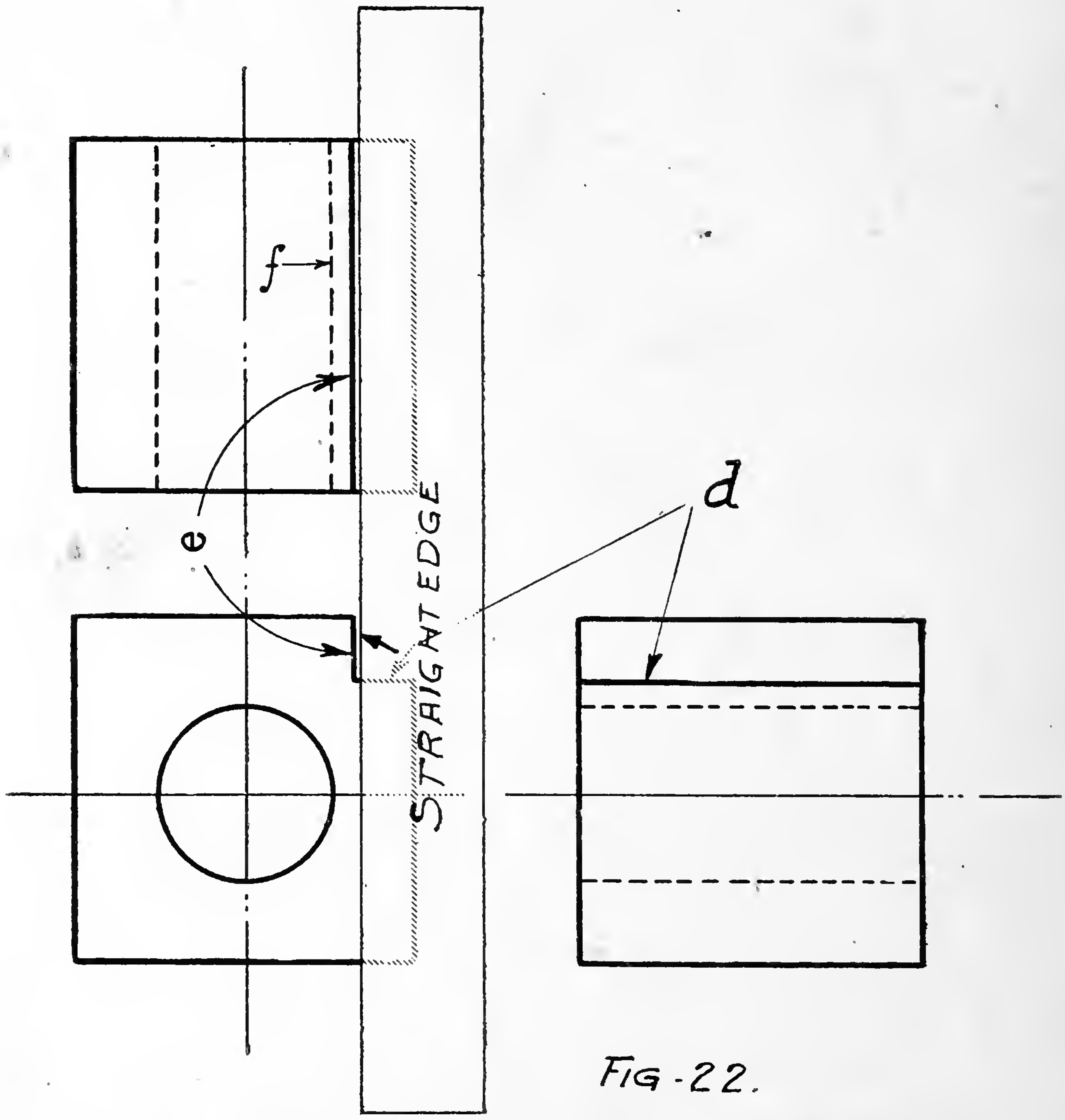



FIG-22.

Fig. 23 is similar to Fig. 19, except we have cut out another portion of this block—the lower left hand corner. Fig. 24 shows the working drawing views of this block.

The full line d again corresponds with line d on front view, and represents the length of this surface. The dotted line f on side view corresponds with line f on front view but is shown dotted on the side view because it cannot be seen when looking at the right hand side of block. It must be remembered that all lines which can be seen when looking at front, side, top or bottom of object are always indicated by full lines and those that actually exist but cannot be seen are always indicated by dotted lines.

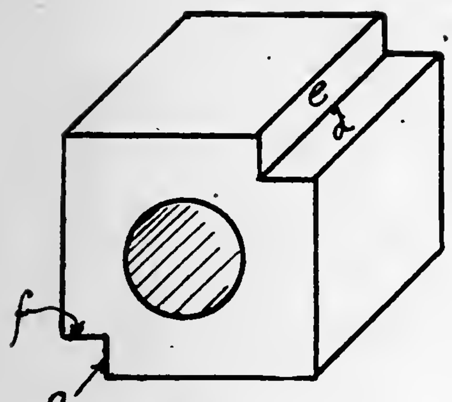



FIG-23

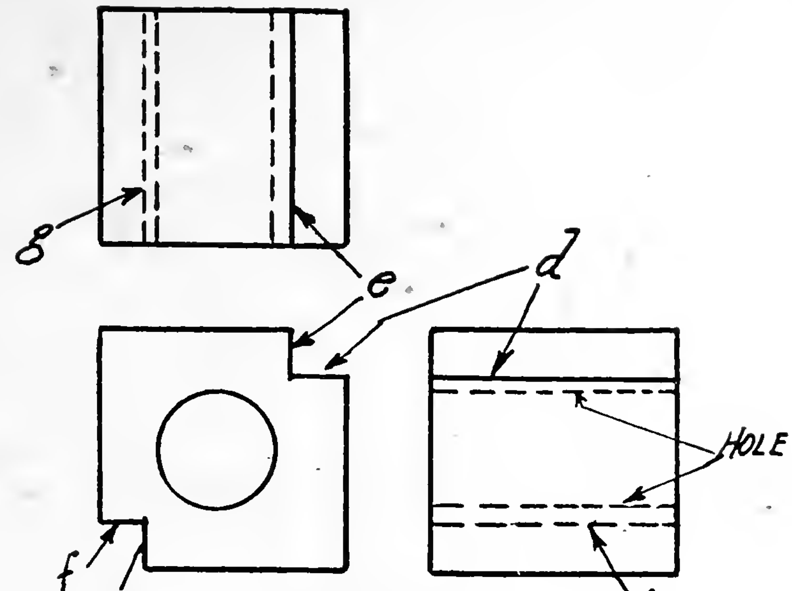



FIG-24

Had the side view been placed to the left of the front view instead of the right, line d would be shown as a dotted line and line f as a full line.

Referring to the top view—lines e and g correspond with lines e and g on the front view and represent the length of these surfaces.

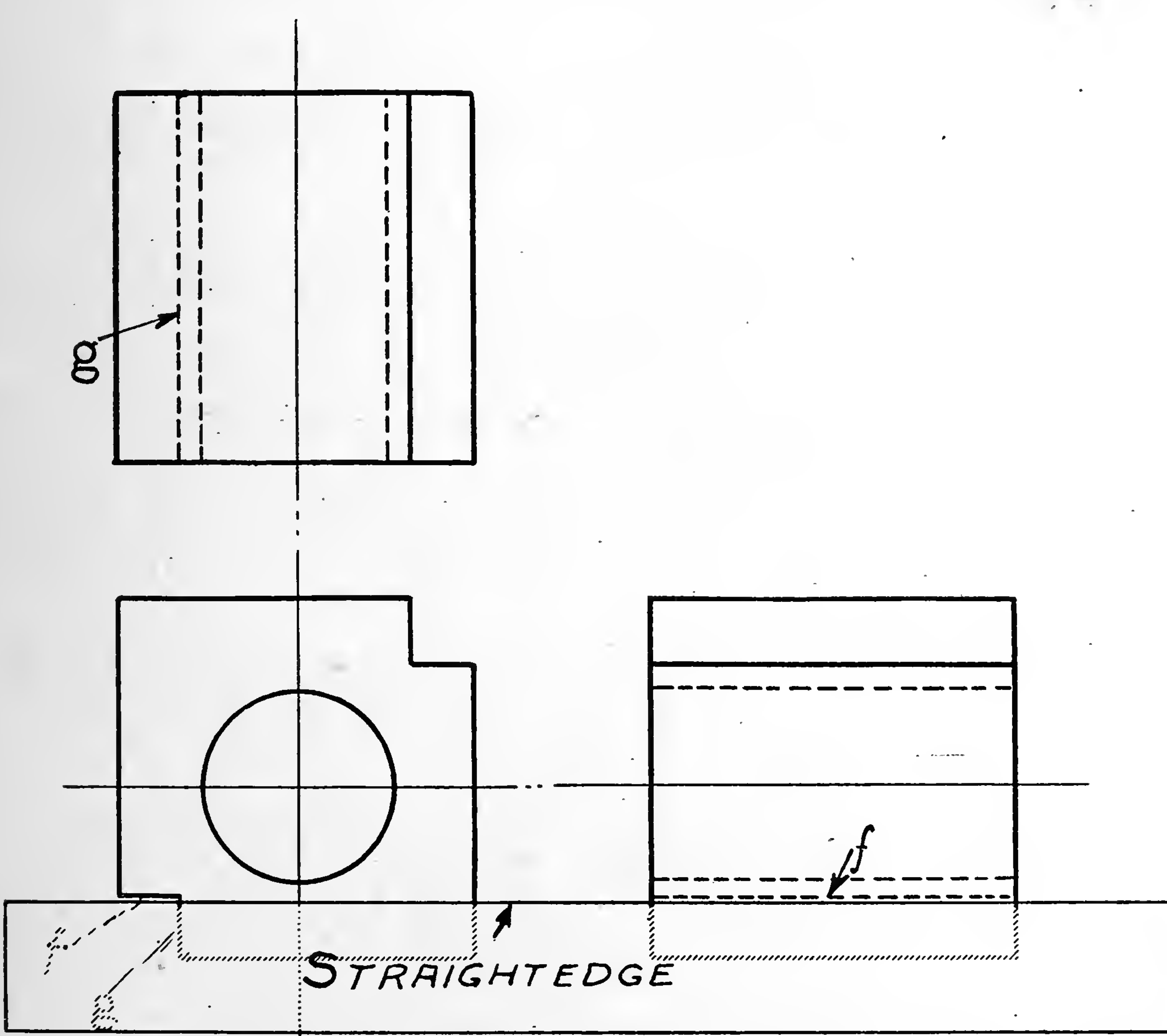



FIG-25

Fig. 25. The surface f is here shown projected from the front to the side view. It will be seen that this surface is a trifle below the bottom of the hole (see front view). Note the relative position on the side view—line f also being a trifle below the dotted line representing the hole.

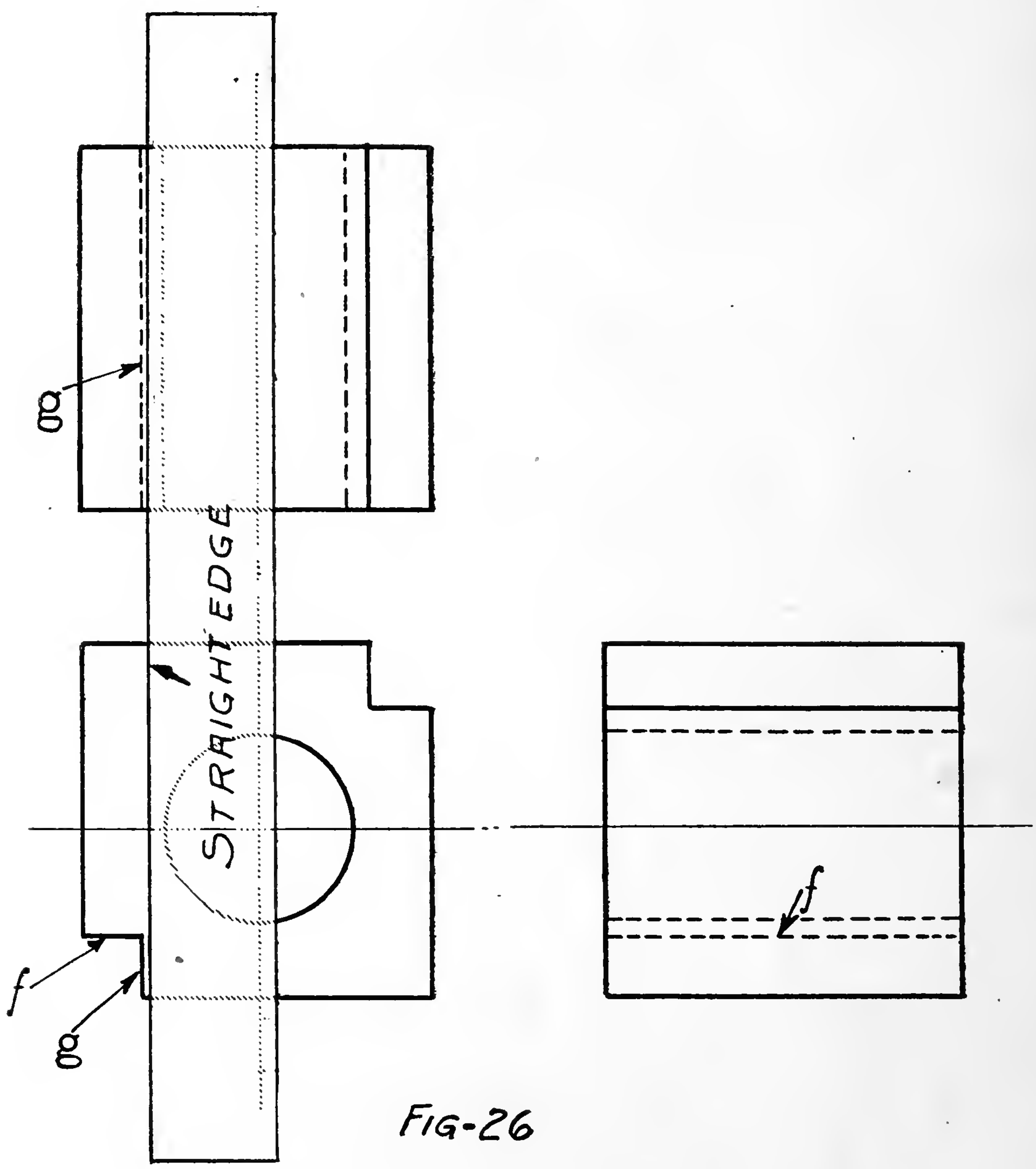



FIG-26

Fig. 26 illustrates the method of projecting the surface g from the front to the top view.

## EXAMINATION

## LESSON 3

1. Is it possible, by looking at Fig. 12, to know if the square hole shown in the right hand side is also in the left hand side?

2. Fig. 16. (a) Which views show that the hole extends thru the full length of the block?
   (b) By what kind of lines is this hole shown?
   (c) Why is this kind of line used?

3. Fig. 20. (a) Which views show the length of the surface d ?
   (b) Why is the line d in the side view B shown as a full line?

4. Fig. 21. (a) Is the vertical height of the surface e shown in the side view? (Views named as in Fig. 16.)
   (b) Is it shown in the top view?

5. Fig. 26. Why is line g dotted in the top view?

## LESSON FOUR

### CROSS SECTIONAL VIEW (HOW PRODUCED).

Let us imagine this block of wood has been cut in two as shown in Fig. 27—one part marked A and the other B. Take these two halves and set them together to represent a front view as shown in Fig. 28. Now imagine that part B is removed and by looking

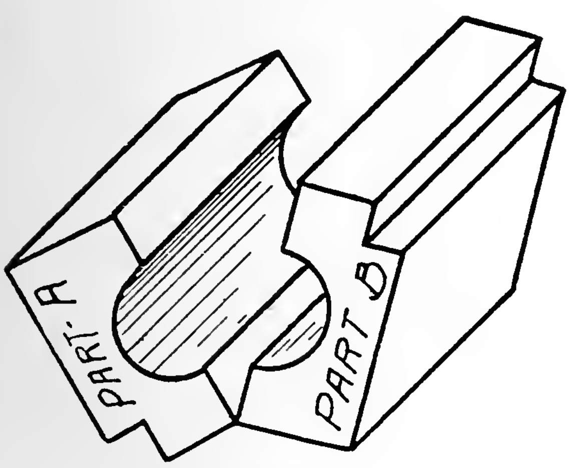



FIG-27

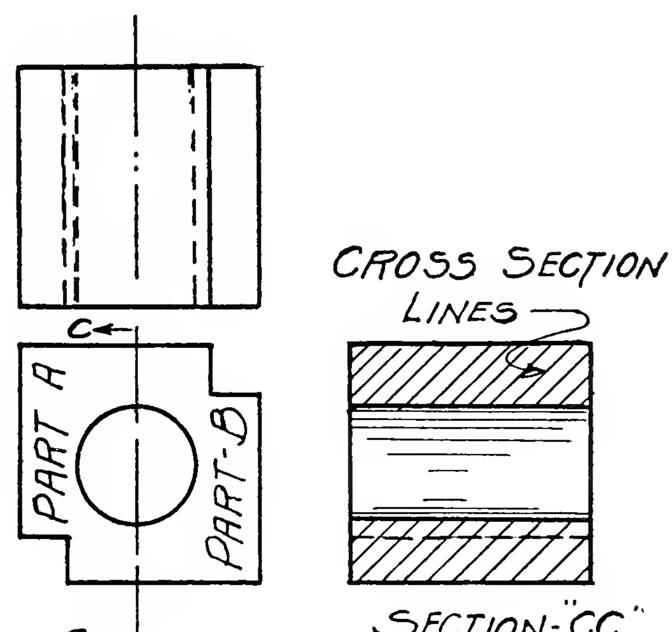



FIG-28

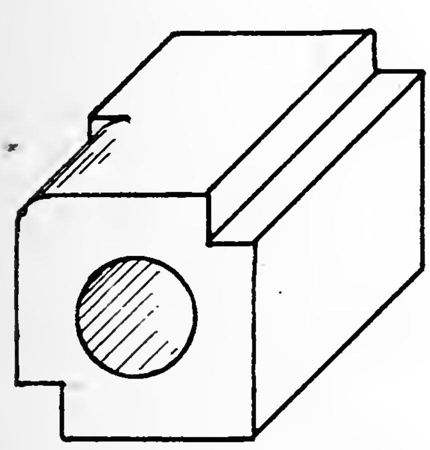


FIG-29

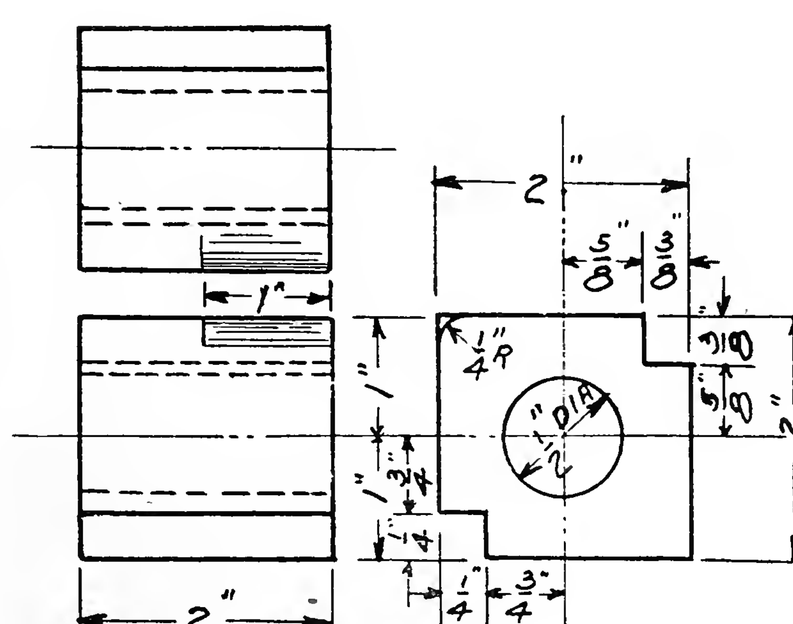



FIG-30

at the **side** of part A it will appear as shown at the right and marked "section CC." The two parallel lines representing the hole are now shown as full lines as the imaginary cut thru this block will reveal this hole. The surfaces above and below this hole, or the surfaces which have been imaginarily cut, are shown covered with diagonal lines called "crosshatching."

The notation section CC indicates that the imaginary cut has been taken along the line marked CC on the front view.

It must always be remembered when crosshatching appears on a drawing that an imaginary cut has been taken thru a certain section of the object, the surfaces cut being crosshatched.

Fig. 29 is a representation of the same block of wood (Fig. 23) except that we have shown the upper left hand corner rounded off one-half the length of the block.

In Fig. 30 we have shown the working drawing of this block.

## REARRANGEMENT OF VIEWS.

No doubt you will notice that the views in Fig. 30 have been rearranged when compared with those previously shown. It is immaterial which side view is shown—either right or left—but right hand views are shown to right of front and left hand views to left of front; likewise a top view is always shown on top and a bottom view at the bottom.

On Fig. 30 we have also shown all dimensions necessary to explain the details of this object. An explanation of the ¼″ R. and the ½″ dia. will appear later. Your attention is called to the placing of these dimensions and that wherever possible the dimensions are taken from the center lines.

## PROJECTIONS OF CIRCULAR OBJECTS.

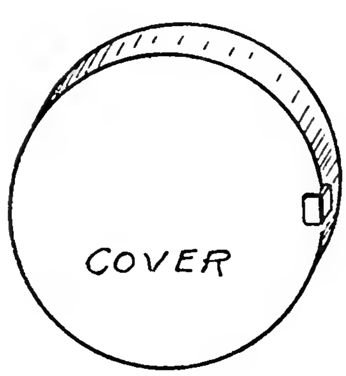



FIG-31

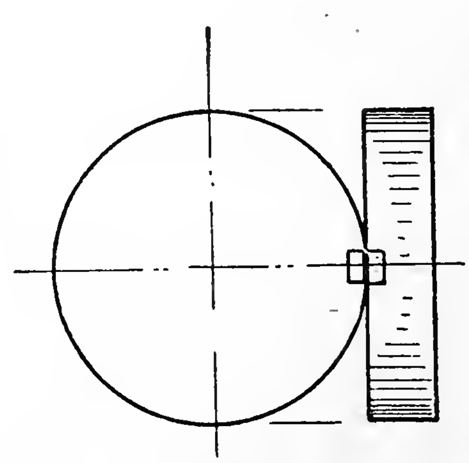


FIG-32

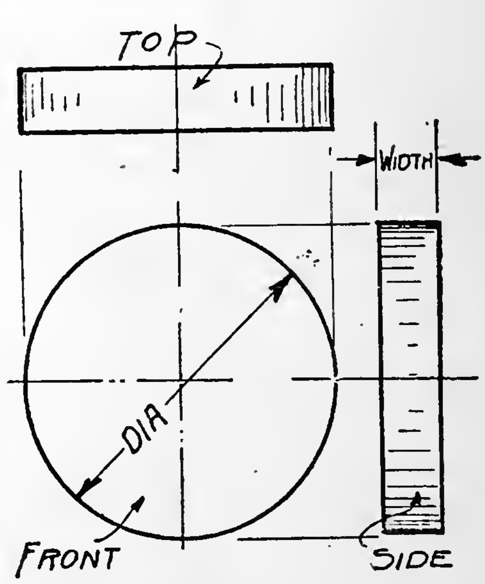



FIG-33

Fig. 31 is a representation of a round box having a hinged cover.

Fig. 32 shows this box with a flat disc or cover opened, and in opening it we have supposed that the cover has been held stationary and the box swung one-quarter way round, so that only the side is shown. This illustrates the projection of a circular object.

Fig. 33 has the hinge removed and the side view separated from the front.

The object of the illustrations shown in Figs. 31, 32 and 33 is to show the method of projecting the side view in relation to the front and by referring to Fig. 13 you will see that the method of projecting these views is exactly the same.

You will note that at the top of Fig. 33 we have shown a top view also—in appearance it is exactly the same as the side, giving no further information other than shown in the side view, and for that reason top view might have been omitted.

Fig. 33. It must be remembered that all depressed surfaces of the side of this box are brought to the same plane to produce the side view. Each point is projected horizontally.

Fig. 34 shows a round disc with a hole thru its center.

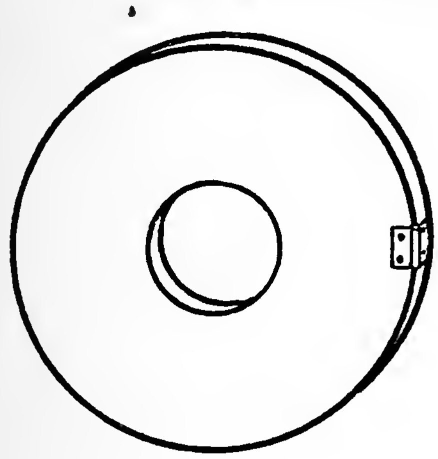


FIG-34

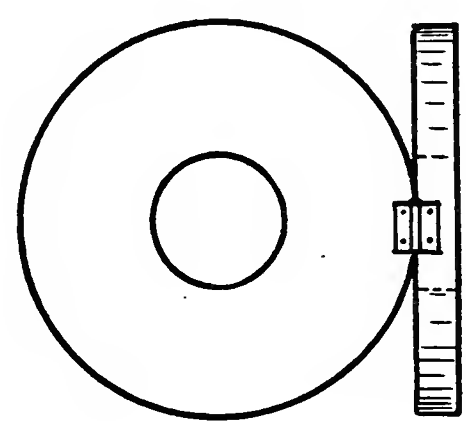


FIG-35

Fig. 35 shows this same disc in front and side views. Let us imagine we have taken a very thin slice from the face of the disc, opened and fastened it with a hinge, to the disc proper. We have shaded the upper and lower portion of this side view so as to indicate that it is round; however, this line shading seldom appears on a working drawing. A top view would be identically the same

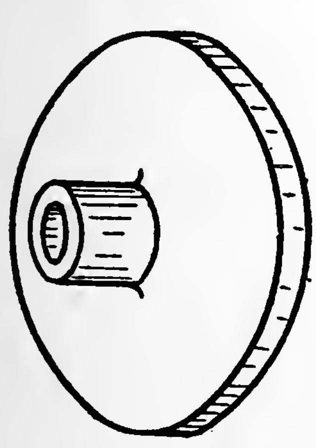


FIG-36

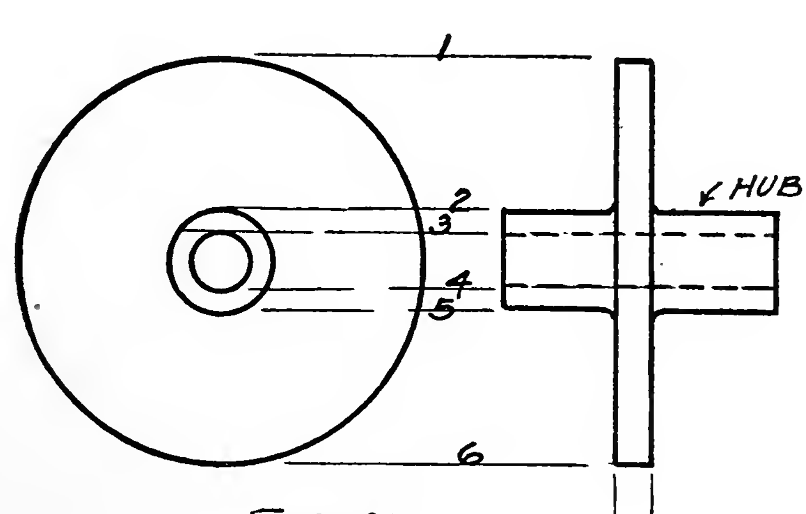



FIG-37

as the side, except that it would be placed above the front view. In this case a top view is not necessary. The removal of the hinge and separating the two views will produce working drawing views of this disc.

Fig. 36. By comparing this perspective with Fig. 34, you will see that we have a disc with an extension on each side which we will designate as a hub; a hole is also shown thru the full length of the hub.

Fig. 37 shows this disc with its proper projection. As you will note, the horizontal lines marked 1, 2, 3, 4, 5, and 6 indicate the various points which have been projected from one view to another, for example—

Lines 2 and 5 indicate the outside diameter of the hub;
Lines 3 and 4 indicate the vertical diameter of the hole;
Lines 1 and 6 indicate the outside diameter of the disc.
Again, a top view would be identically the same as side view.

(By making a systematic analysis of each point or surface from one view to another as above explained, the reading of complicated working drawings becomes simplified.) Use a straightedge as explained for Figs. 25 and 26.

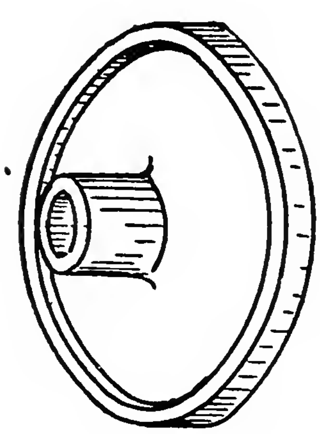


FIG-38

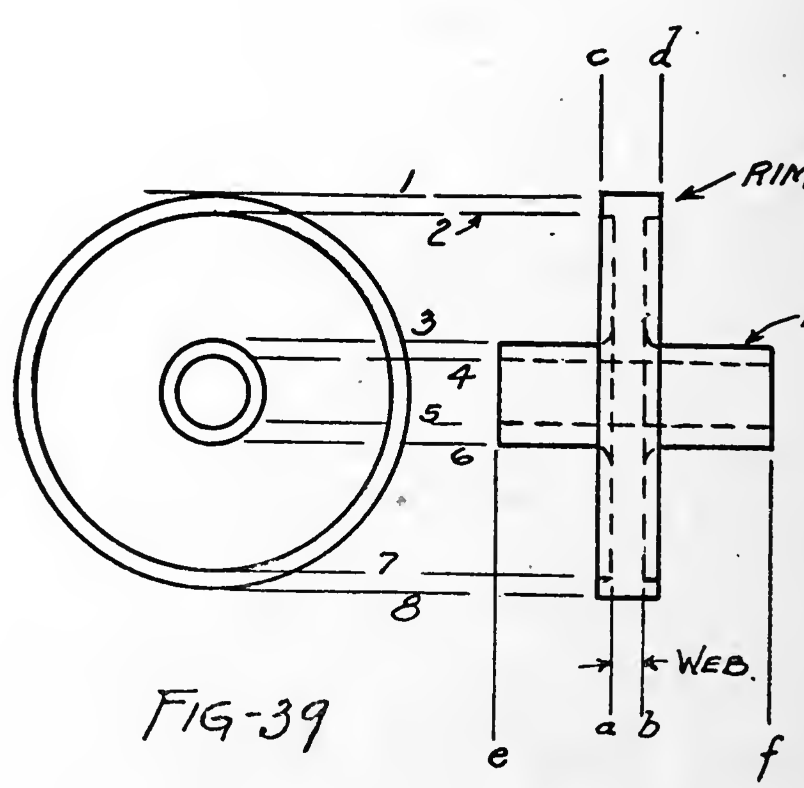
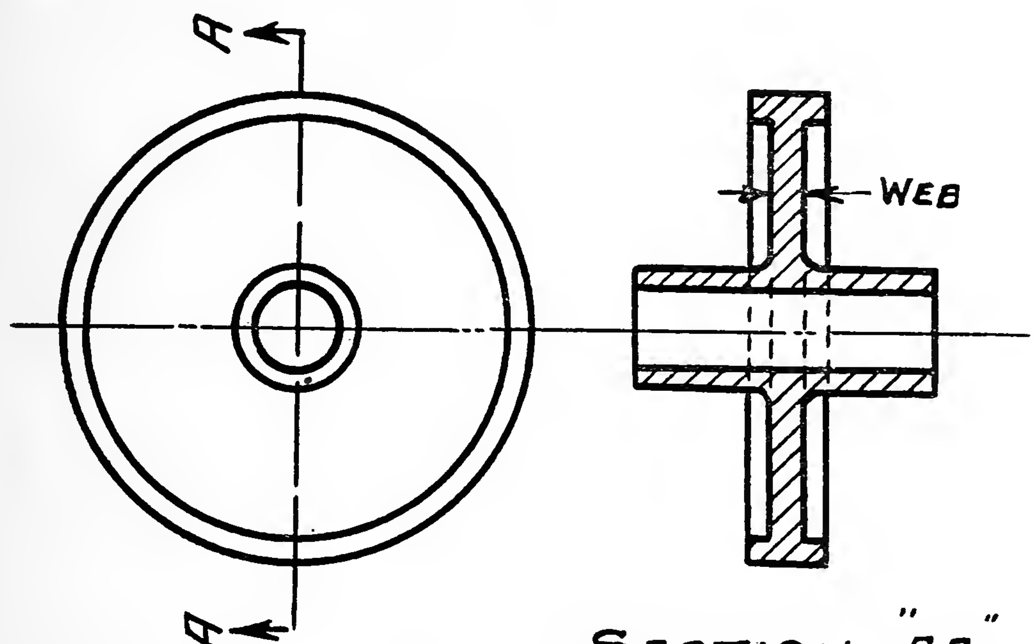



FIG-39

Fig. 38. Let us assume that to Fig. 36 we have added an extension on each side of the disc around its circumference and we will designate this as the rim.

Fig. 39. This is similar to Fig. 37. By looking at the side view, it is supposed that we are looking at the outside of the wheel. The horizontal lines 1 and 2, also 7 and 8, indicate the projection

of the thickness of the rim. We will explain the reason for the vertical dotted lines marked a and b which represent the thickness of the web.—The rim being wider than the web will cover the web completely when looking at the width of the rim. The distance between lines c and d represents the width of the rim. The vertical lines a and b are dotted the full length to represent that the web extends all around the hub. The distance between lines e and f represents the **length** of the hub.




SECTION - "AA"

FIG - 40

Fig. 40 represents a cross sectional view. By referring to Fig. 27 you will readily understand that the wheel has been imaginarily cut along the vertical line AA (see front view). By removing (imaginarily) right hand portion and by looking towards the surface of the remaining portion, you will see a view shown at the right and marked section AA, remembering that the surfaces which have been imaginarily cut are covered with diagonal lines, called crosshatching. The general outline of the rim, web and hub is now shown by full lines instead of dotted as this (imaginary cut with one-half removed) will show a full outline when looking against the surfaces cut along line AA.

**General**—The notation "section AA" or "section A, B, C, D" (or any other combination of letters) indicates that an imaginary cut has been taken thru the object and the location of this cut is found by referring to one of the views and locating the above mentioned letters.

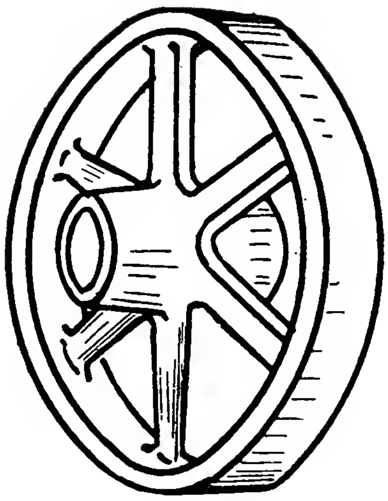


FIG-41

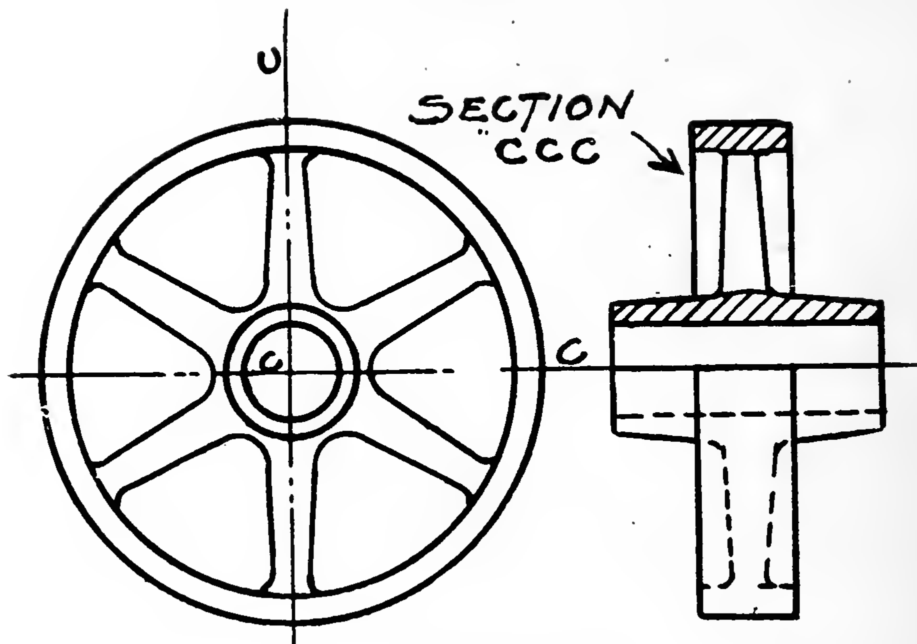



FIG-42

*Side View* *End View*

Fig. 41. Imagine that we have cut out a portion of the web shown in Fig. 38 and that sufficient of it remains to form spokes or arms—you will readily understand that Fig. 41 is a representation of a wheel having spokes, hub and rim—the spokes taking the place of the web.

Fig. 42 shows working drawing views of this wheel. The views of some drawings may be shown half in cross section; and the other half in full. In this case we have shown the upper half of end view in cross section and have assumed that the upper right hand quarter of the wheel has been removed (see side view). By looking at the end of the wheel, the upper half will have the outline of the rim, hub and arm or spoke shown in full, and the lower half will have the above mentioned shown dotted.

Note that the line CCC indicates the imaginary cut and happens to pass thru the full length of one of the spokes, but as it is customary **not to crosshatch** arms or spokes, it has not been done here, but strictly speaking, it should have been crosshatched as it has been cut by the line CCC.

## EXAMINATION

## LESSON 4

1. What does crosshatching on a drawing indicate?

2. Fig. 28. (a) Is the lower left hand cut-out portion in part A indicated on the sectional view CC?

   (b) Why is the upper right hand cut-out portion in part B not shown in the cross sectional view?

3. What do the light lines indicate in the top and side views of Fig. 33?

4. Fig. 37. (a) Which view shows the length of the hub? (Name view as in Fig. 33.)

   (b) Which view shows the thickness of the disc?

## LESSON FIVE

### WORKING DRAWING VIEWS OF TWO SEPARATE OBJECTS COMBINED.

Fig. 43. By referring to Figs. 34 and 19 you will see that there is a similarity. We have now combined two formerly separate objects and the working drawing views are shown in Fig. 44.

By employing the same manner of projecting as has been explained for an individual object, you will see that by combining these two, the horizontal lines 1, 2, 3, 4, 5, and 6 indicate the corresponding points of the side and front views, and the vertical lines 7 thru 14, indicate the corresponding points of the top and front views.

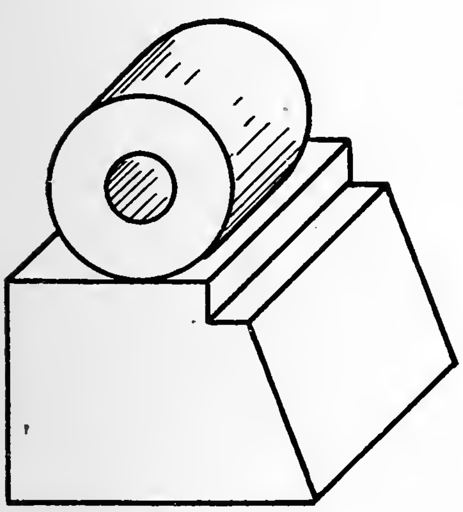


FIG-43

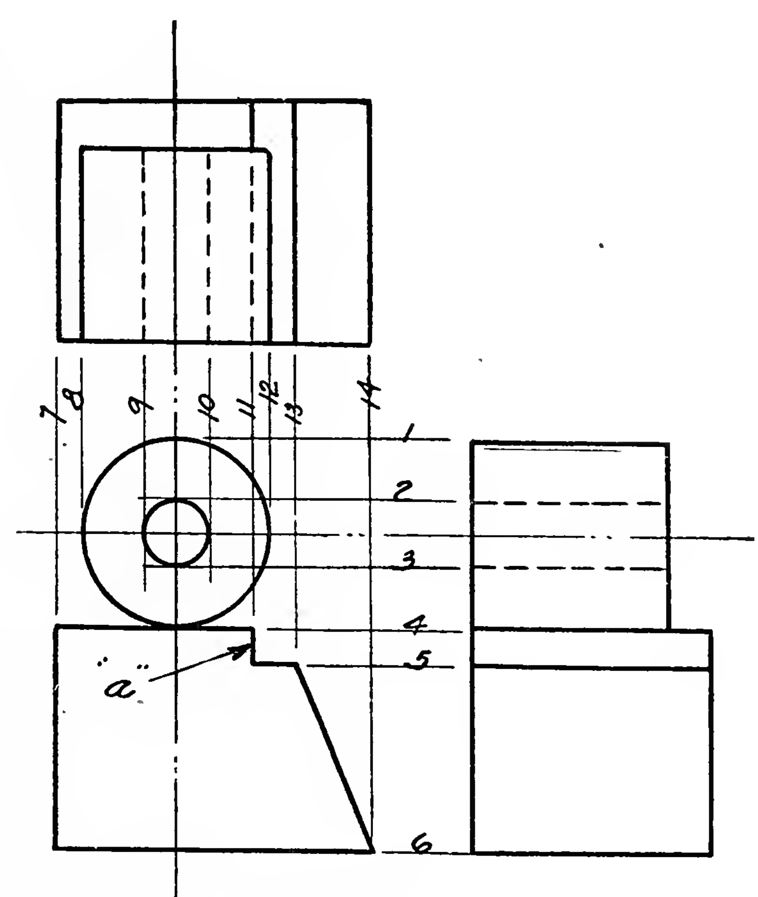



FIG-44

Line 14 shows the extreme lower right hand point of the front view, projected to the top view.

Attention is called to the projection of the surface marked a on front view, to the top view. Part of this line is shown dotted and part in full (see top view). The part of line directly under the roller is shown dotted as it is not visible, and the short distance this line extends beyond the rear of roller is shown as a full line as it can be seen when looking directly down on top of the object.

The roller does not extend the full length of the block and therefore the line representing the surface beyond roller is visible and shown as a full line.

**Note**—Take one line or surface at a time and project same (or find its corresponding line or point) on one of the other views. By taking one at a time it will enable you to readily understand the drawing.

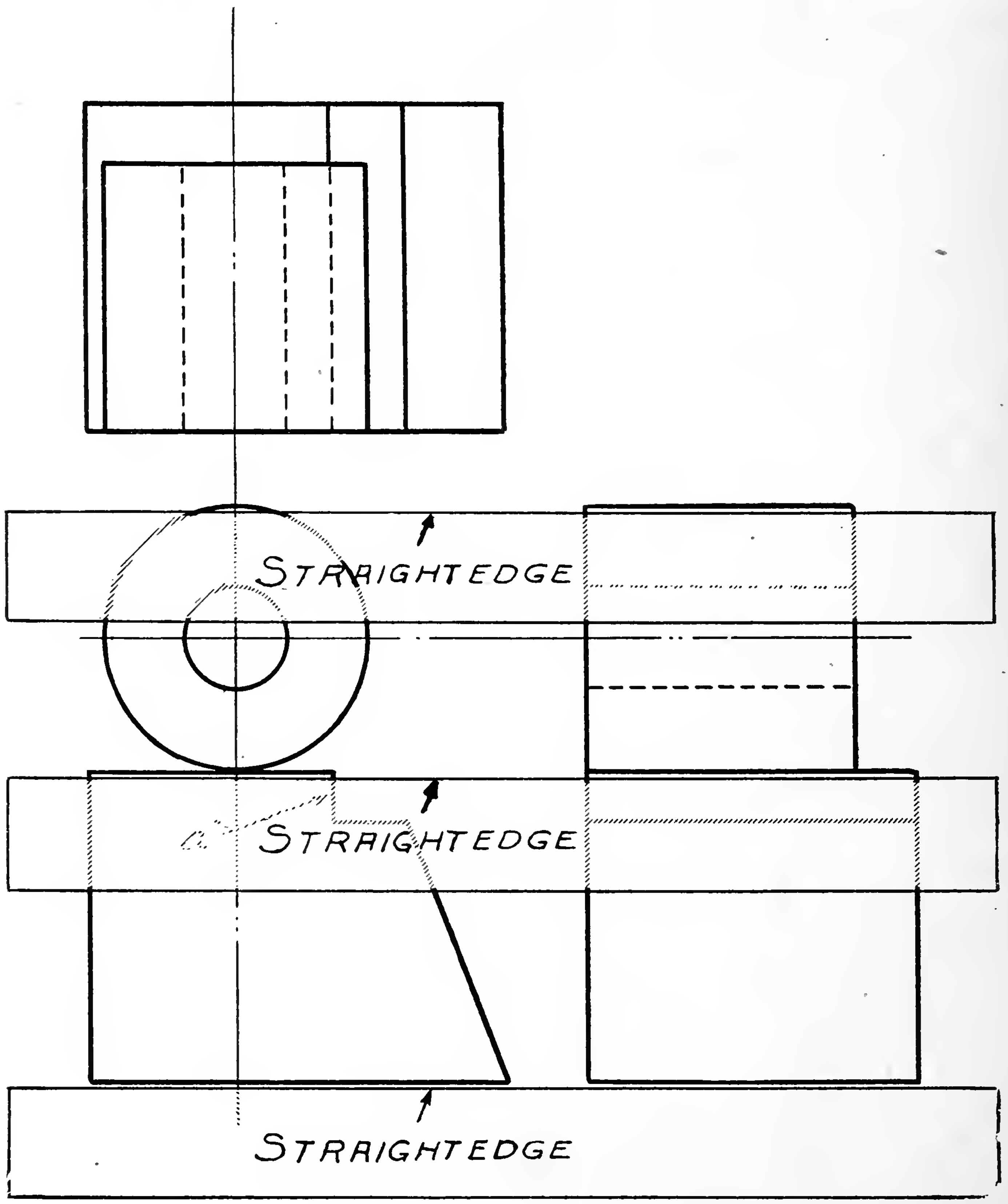



FIG 45

Fig. 45 is an exact duplicate of Fig. 44 except that we have shown the projection of several points and lines from the front to the side view by the use of a straightedge. Starting at the top each line or point should be taken separately and projected. In

Fig. 45 we have only shown three different projections by the use of a straightedge, namely the top of roller, bottom of roller which also happens to be the top of the block—the third surface projected being the bottom of the block.

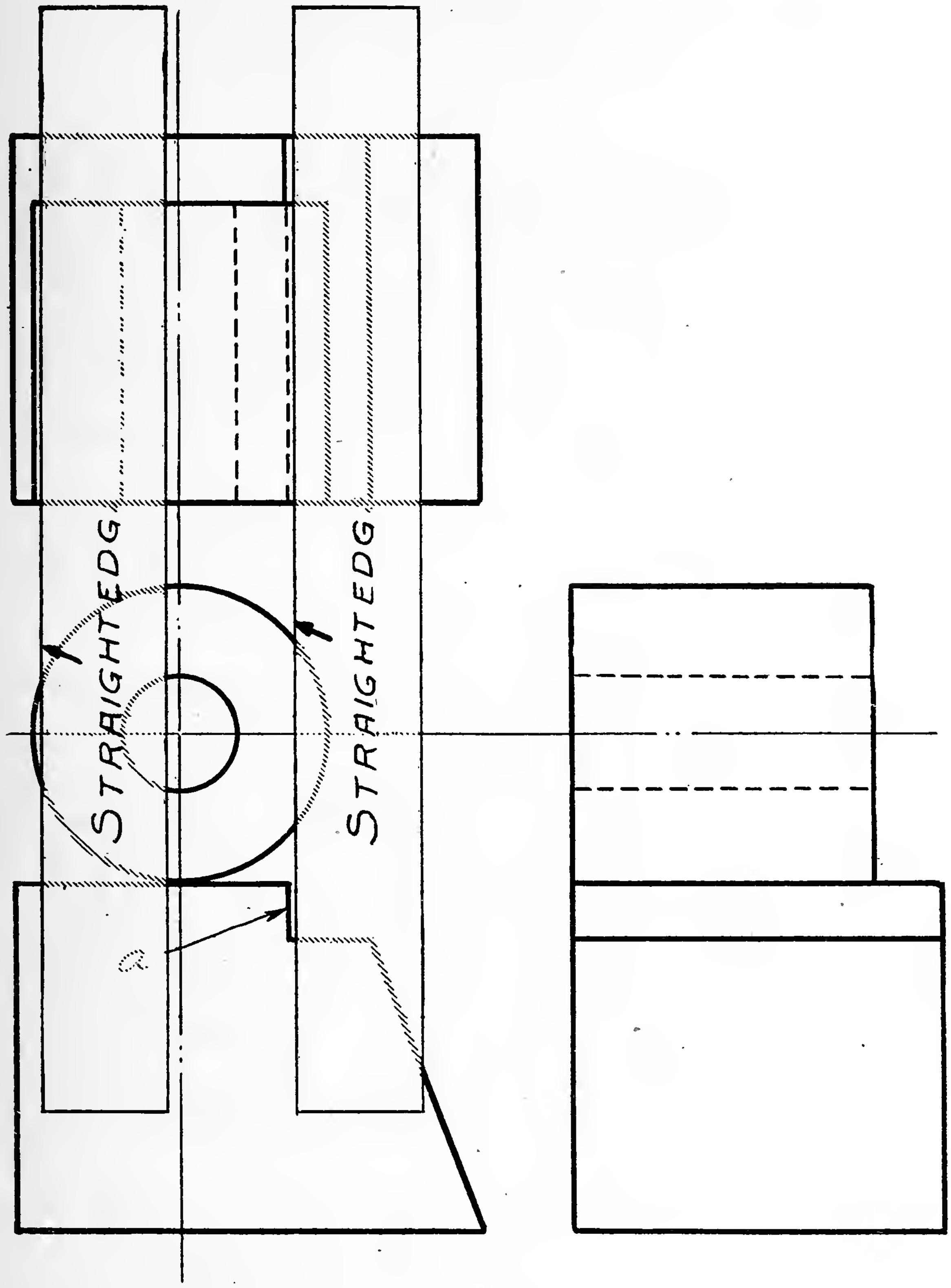



FIG - 46

Fig. 46. This figure illustrates the projection of the surface a with the use of the straightedge. The extreme left hand edge of the roller is also shown projected to the top view. Note the relative position of this edge of roller to the left hand edge of the block (front view). Look at the top view and note the relative position there.

In studying a working drawing it is good practice to note the relative position of the various lines as explained. This will also enable you to more readily locate the various points and lines without the use of a straightedge.

## PERSPECTIVE VIEWS NOT SHOWN ON WORKING DRAWINGS.

Up to this point you had a perspective drawing to look at to assist in the understanding of a working drawing. However, in actual practice, there are no perspective drawings to illustrate the object and you must form in your own mind, the perspective view from the working drawing.

For an example, a working drawing outline is shown in Fig. 47. You are requested to make a free hand sketch showing the perspective view of this object. After making your sketch turn to page 50, Figs. 48 or 49, and check its correctness.

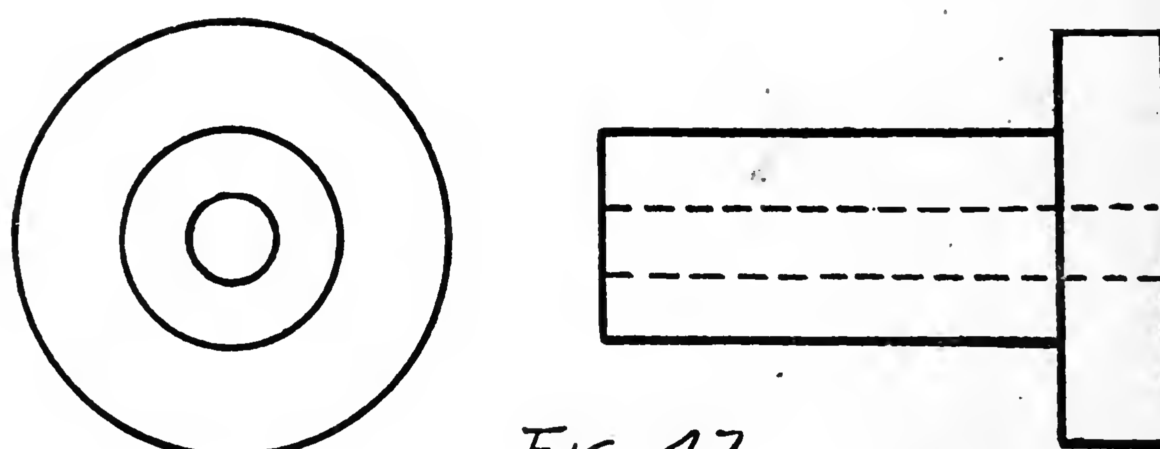


FIG-47

## DESCRIPTION OF GEOMETRICAL FIGURES AND SOLIDS.

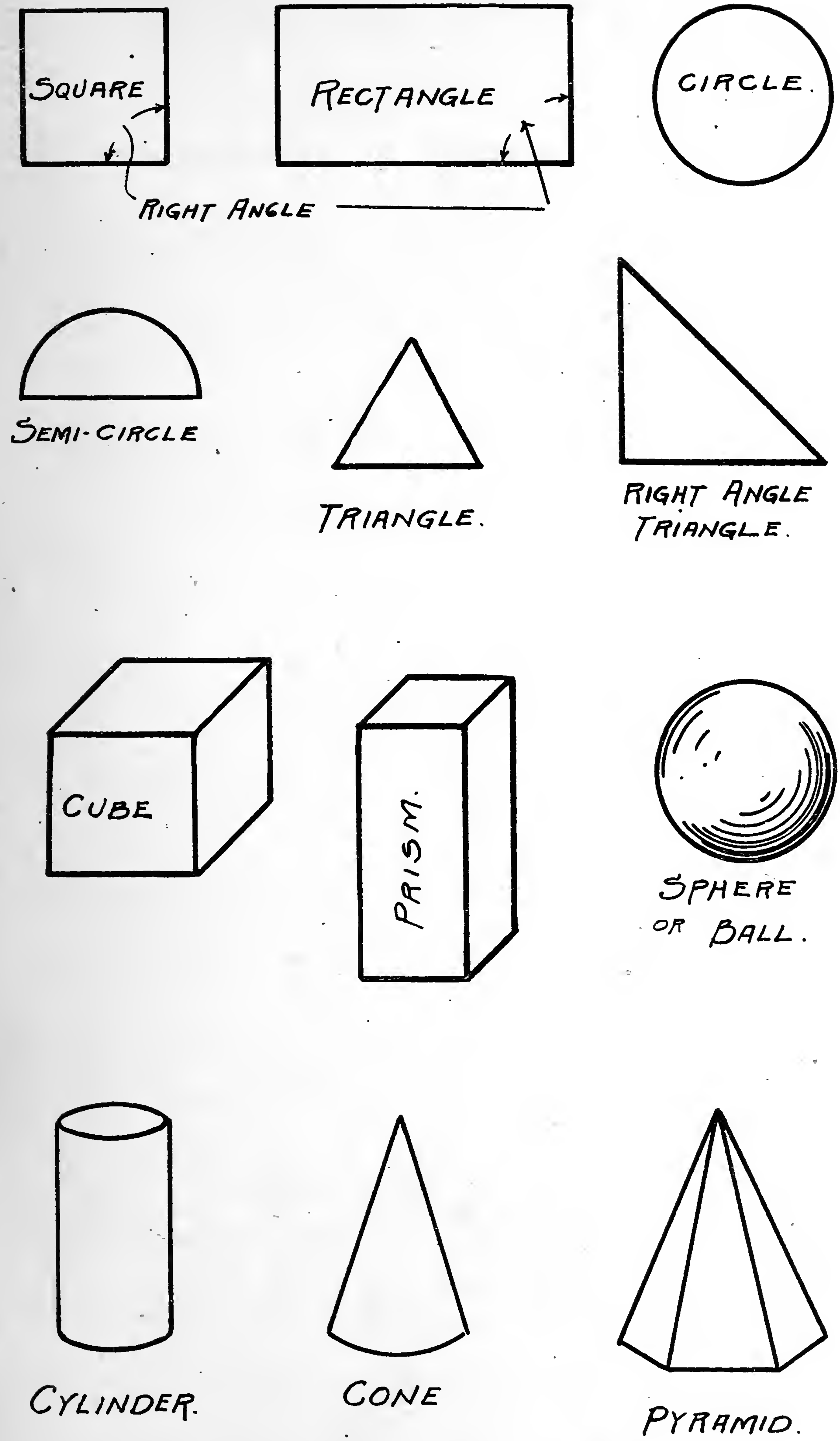
A few of the commonly used figures and solids, each being properly named, are shown on page 47. Some of the terms are used thruout the lessons.

**Parallelogram**—A flat surface enclosed by four lines, opposite lines being parallel. (Squares and rectangles are parallelograms.)

**Square**—A parallelogram having four sides of equal length and four right angles. Whenever two lines meet, so that the angle is the same on either side, they form right angles, thus —|—. An ordinary carpenter's square is a good example of a right angle.

**Rectangle**—A parallelogram having four sides, two of which are longer than the others and forming a right angle at each corner.

**Circle**—A flat surface enclosed by a line which is the same distance to all points from a common center. A circle may also mean


SQUARE
RECTANGLE
CIRCLE.
RIGHT ANGLE
SEMI-CIRCLE
TRIANGLE.
RIGHT ANGLE TRIANGLE.
CUBE
PRISM.
SPHERE OR BALL.
CYLINDER.
CONE
PYRAMID.

a curved line having neither beginning nor end and all points on the curved line being an equal distance from a common point within.

**Semi-circle**—One half of a full circle.

**Triangle**—A flat surface enclosed by three lines. When all lines are the same length it is known as an equilateral triangle.

**Right angle triangle**—A flat surface enclosed by three lines, two of which form a right angle at their junction.

**Cube**—A solid having six equal square sides.

**Prism**—A solid, the ends being alike and all sides rectangular.

**Sphere or ball**—A solid, all points of its surface being an equal distance from a point within, called the center.

**Cylinder**—A volume formed by a complete revolution of a rectangle about one of its sides as an axis.

**Cone**—A solid having a circle for its base, and its lateral surfaces uniformly tapering to a common point, called the vertex.

**Pyramid**—A solid having any number of sides for its base and the lateral surfaces triangular, the apex of each meeting at a common point called the vertex.

## DESCRIPTION OF INSTRUMENTS AND TOOLS.

Page 49 illustrates the most common tools used by a draftsman in making working drawings. They are shown to give a general knowledge of their construction, use and proper name.

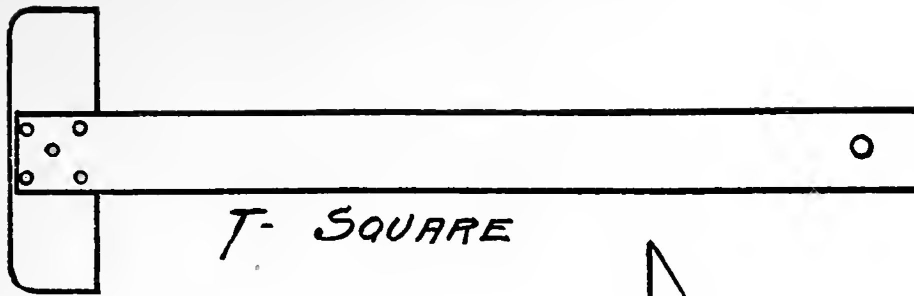
The illustration at the top is known as a T square, getting its name from its general shape. It consists of a short piece known as the head, which is fastened to the thin, straight edge, known as the blade. T squares are usually made of wood. The inner edge of the head is designed to fit the left hand edge of the drawing board. When used, it is held securely against this edge with the left hand, while the right draws the horizontal line along the upper edge of the blade. When a horizontal line is desired at any other position, the T square is moved either up or down, keeping the head firmly against the left hand edge of the board until the desired position is obtained.

## TRIANGLES.

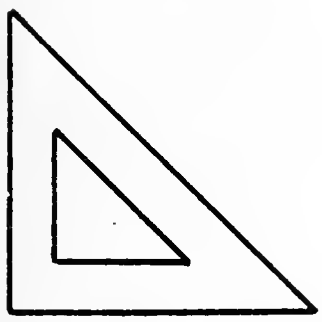
The commonly used triangles are shown and marked "45° triangle"—"30-60° triangle." They are made either of wood or celluloid.

The 45° triangle has two 45° angles and one 90° angle.

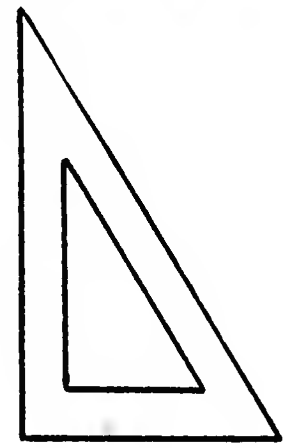
The 30-60° triangle has one angle of 30°, one of 60° and the third of 90°.



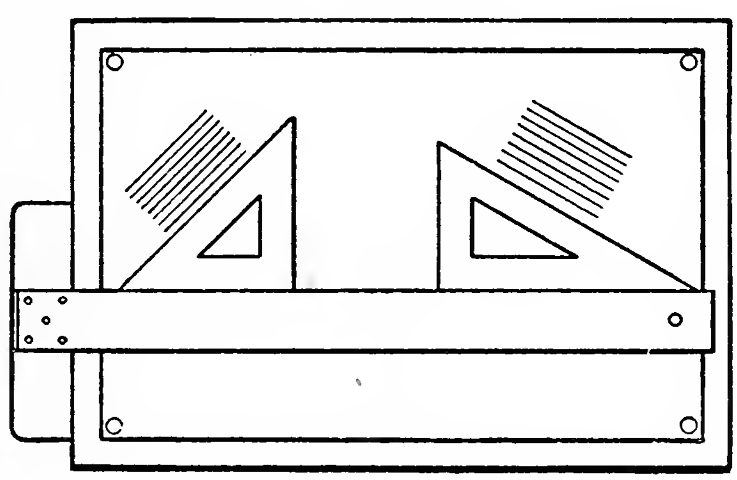
T- SQUARE

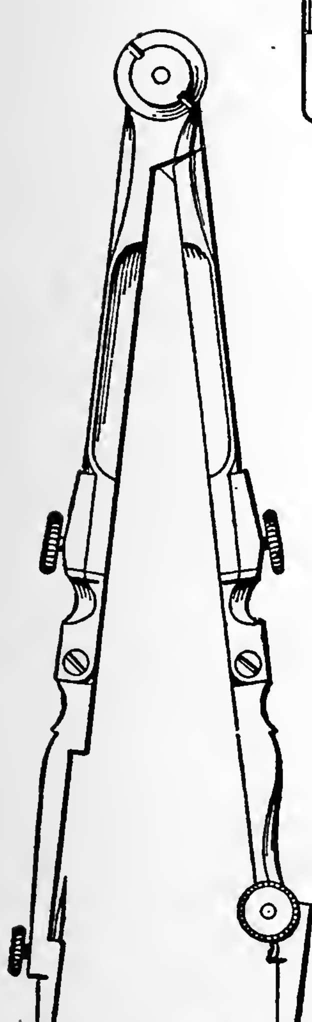


45° TRIANGLE

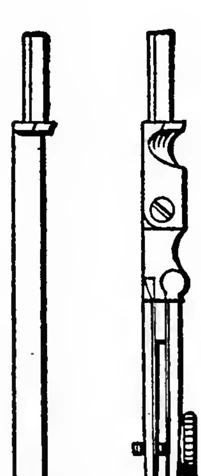


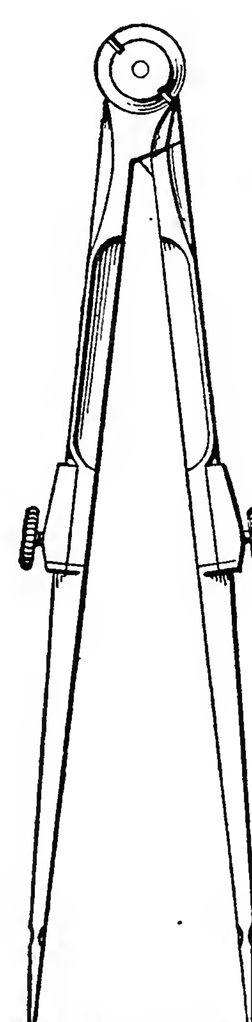
30°·60° TRIANGLE





COMPASS.





DIVIDER.

A drawing board showing the T square and triangles in position is shown in the center.

The series of diagonal lines shown above the triangles were produced by drawing a line along the diagonal edge of the triangle, then moving the triangle horizontally a short distance toward the center of the board, and drawing another line along the upper edge of the triangle.

A compass is shown in the lower left hand corner. This instrument is used to draw circles, or arcs of a circle, either with pencil or ink. The lower ends of the legs may be removed and the pen may be inserted when desired; when a very large radius is desired, the extension bar may be inserted. One end of this extension bar has a socket to accommodate either the pen or pencil. This bar is shown between the compass and pen.

A divider is similar in construction to a compass, having removable points. This instrument is used to lay off distances, either from a scale or some other part of the drawing.

Other instruments used are known as bow pencil, bow pen and bow divider. They are used similarly to the compass and divider, except for smaller circles, arcs, etc. These instruments have no removable legs. The bow pen, pencil and divider are separate instruments. The distance between the points is regulated by turning a thumb nut.

A ruling pen is similar in construction to the pen shown with the compass except that it is provided with a short handle.

Ink is fed between the two blades of the pen, from a quill which projects from the under side of the cork in the ink bottle and into the ink. The thickness of line is regulated by adjusting the thumb screw near the points of the pen.

Special ink, known as India Ink, is used.

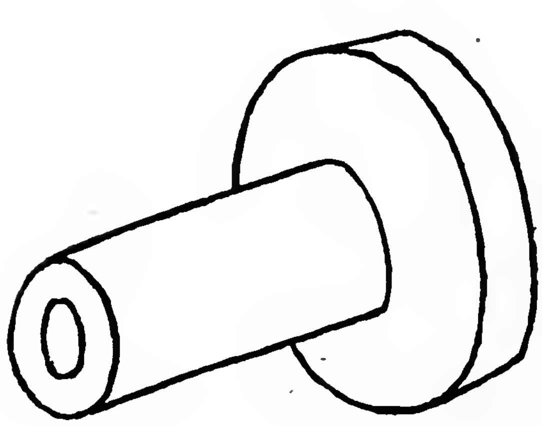


FIG-48

OR

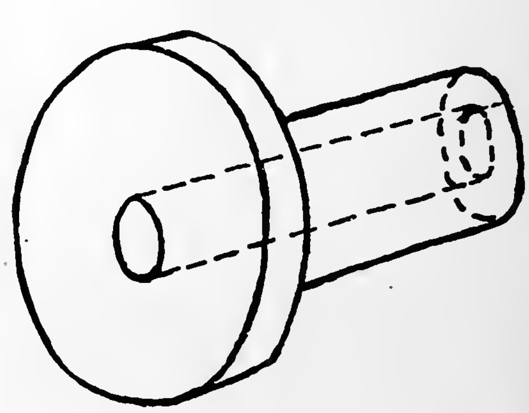


FIG-49.

## EXAMINATION

## LESSON 5

1. Are the lines representing the rear of the cylinder and also of the block shown in both side and top views in Fig. 44?

2. Make working drawing views of the prism and cylinder shown on page 47.

3. (a) Give definition of a cone.
   (b) Give definition of a sphere.
   (c) Give definition of a right angle triangle.

4. (a) Name the angles in the 45° triangle.
   (b) Name the angles in the 30-60° triangle.

5. (a) How are horizontal lines drawn when using a T square?
   (b) How are vertical lines drawn when using a T square and triangle?

# LESSON SIX

The fundamental principles of projections have been discussed and it is of utmost importance that you clearly understand the work covered. We advise you to study Lessons 1 to 5—going over the entire work several times and as you proceed with the instructions—review the previous lessons.

The following lessons cover important points which are essential to the reading of complicated working drawings.

The notations on page 54 should be carefully studied. Thruout the lessons, notations will appear and you should be able to readily interpret their meanings.

Review the following important rules which must be observed in the reading of working drawings:

1. The line of vision must be in a direct horizontal line with all points along its height, length or width for horizontal projections; and in a direct vertical line with all points along its length and width for vertical projections. (See page 20.)

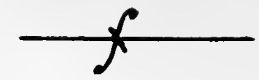
2. All depressions and extensions must be brought to the same plane. (See page 20; also illustrated in lesson 8.)

3. Each view represents that which can be seen when looking directly at the object, with a view representing only **one** of its faces—a side, an end, the top or bottom visible at a time.

4. No single view will give all the information necessary to explain the object (except very simple objects), therefore two or more views of an object must always be studied.

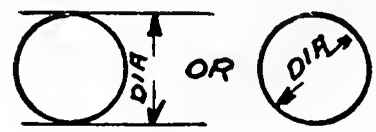
## EXPLANATION OF NOTATIONS APPEARING ON WORKING DRAWINGS.

This f sign indicates that a surface is to be finished or machined —it may also be shown thus:—F.

This sign  should be placed thus 

The short diagonal line of the sign should intersect the surface line which is to be finished or machined.

**Diameter** (dia) is the distance across a circle at its widest point and is indicated thus:




**Radius** (R or Rad) is one-half the diameter of a circle—or may be indicated in a corner connecting two lines:


**Circumference** is the distance around the outer edge of a circle.

| | |
|---|---|
| P. D. pitch diameter<br>O. D. outside diameter<br>D. P. diametrical pitch<br>C. P. circular pitch | These notations relate to dimensions for gear teeth |

**Press Fit**:—Two parts fitted or machined so as to require pressure to force one over the other and sufficiently tight so as not to move or rotate.

**Running Fit**:—Two cylindrical parts sufficiently loose so that they will be free to rotate.

**Drive Fit**:—Two cylindrical parts machined—the inner part a trifle larger so that when assembled with its component parts, they are sufficiently tight to require a driving force to bring them together.

**Shrinkage Fit**:—Two parts machined, the outer just a trifle smaller, which, when heated expands and passes over other part. In cooling, this part will shrink sufficiently to produce a very tight fit.

**Bore**:—A hole bored with a machine tool (drill press, lathe or boring bar).

**Drill**:—A hole drilled with a machine tool (drill press).

**Ream**:—Enlarging a hole with a reamer after being bored or drilled (hand, drill press or lathe).

**Cored Hole**:—A hole in a casting produced by pouring the liquid metal around a sand core placed in a mold.

**Face**:—The width of a gear or pulley; or may indicate a machine operation—that of cutting off part of the surface with a machine tool (lathe or boring mill).

**Turn**:—Taking a cut off the circumference in a lathe or other machine tool.

**Broach**:—A machine operation—that of enlarging a previously made hole to some special shape by forcing a drift thru it.

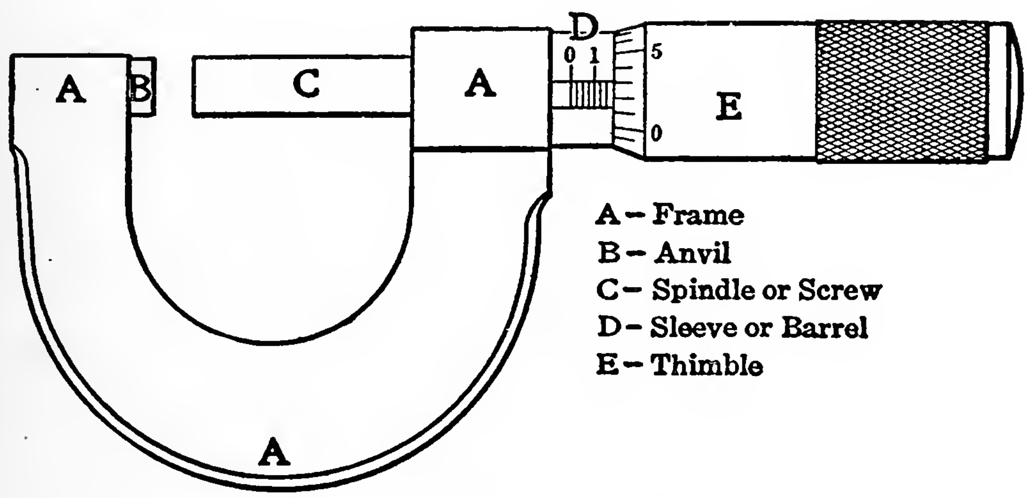
**Grind**:—The operation of grinding off a portion of the surface with an emery wheel or surface grinder.

R. H.—Right hand.

L. H.—Left hand.

±Indicates allowable variation from a decimal dimension. To illustrate their use;—if written thus, 5.000″ ± .001″, it would indicate that the finished dimension may be .001″ larger or smaller than 5.000″ and will be accepted as being machined correctly.

.001″ is read "one thousandth of an inch"—less than the thickness of a hair and is measured with an instrument known as a micrometer, which is illustrated.




—Micrometer.

| | | | |
|---|---|---|---|
| C. I. | —cast iron | Forg. | —forging |
| I. | —iron | M. S. | —machinery steel |
| St. | —steel | T. S. | —tool steel |
| C. St. | —cast steel | Ec. S. | —electric steel |
| W. I. | —wrot iron | C. Bore | —counter bore |
| Brs. | —brass | P. Tap | —pipe tap |
| Cop. | —copper | Ctrs. | —centers |
| Alu. | —aluminum | Thds. | —threads |
| C. Brs. | —brass casting | Bush. | —bushing |
| C. R. S. | —cold rolled steel | Tap | —tap |
| O. H. S. | —open hearth steel | F. A. O. | —finish all over |
| Semi-St. | —semi-steel | ℄ | —center line |

S. F.—Spot face—a machine operation (generally drill press)—that of cleaning up the rough surface of casting which will come directly under the head of a bolt or nut.

B. C.—Bolt circle.

## SCALES.

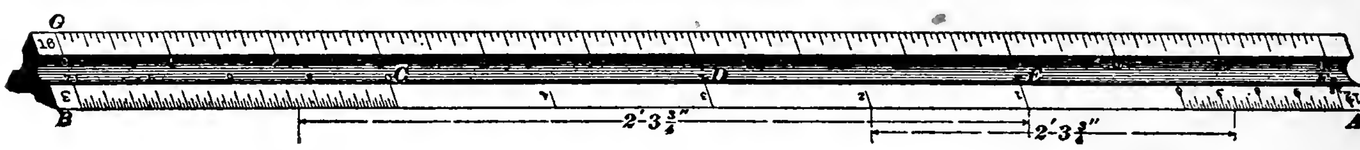


Fig. 50

All drawings cannot be made full size as space will not permit, therefore all parts are reduced proportionately by the use of a reducing scale. Fig. 50 illustrates one form of reducing scale. As you will note, it is triangular in shape and is generally about 12″ in length. It has six edges on which are marked eleven different scales. The full size scale covers one entire edge—all others are grouped in pairs, for example;—the 3″ scale at B and the $1\frac{1}{2}$″ scale at the other end marked A. The 3″ scale indicates that a length of 3″ is divided into twelve equal spaces representing inches—each in its turn subdivided into parts of an inch. It will be seen that by using this scale an object may be reduced to one-quarter its actual size as 3″ equals $\frac{1}{4}$ of 12.

The "$1\frac{1}{2}$″ equals 1 foot" scale is used when it is desired to reduce an object $\frac{1}{8}$ its actual size, as $1\frac{1}{2}$ is $\frac{1}{8}$ of 12. The scales on the edges are grouped as follows:

| At one end | At other end |
|---|---|
| $\frac{1}{2}$″=1′ | 1″=1′ |
| $\frac{1}{4}$″=1′ | $\frac{1}{8}$″=1′ |
| $\frac{3}{8}$″=1′ | $\frac{3}{4}$″=1′ |
| $\frac{3}{16}$″=1′ | $\frac{3}{32}$″=1′ |
| 3″=1′ | $1\frac{1}{2}$″=1′ |

12″=1′

Whenever drawings are made without dimensions, the scale to which the drawing is made is generally noted on the drawing. By scaling the various distances using the scale as noted, the dimensions may be determined. In some instances a dimension may be shown which, when scaled, does not check with the dimension—in such a case the dimension shown is always considered correct.

Some drawings are marked "Not to scale" or "Do not scale."—In that event only the dimensions shown should be used. Drawings with the above notations usually have some parts which are not drawn to scale or have had some changes made in the dimensions of some of the parts without changing the drawing to scale; or it is desired that the mechanic work to the dimensions given instead of determining any of the dimensions by the use of a scale.

Some scales are divided into 1/10, 1/20, 1/30, etc. parts of an inch. These are generally used by architects and civil engineers.

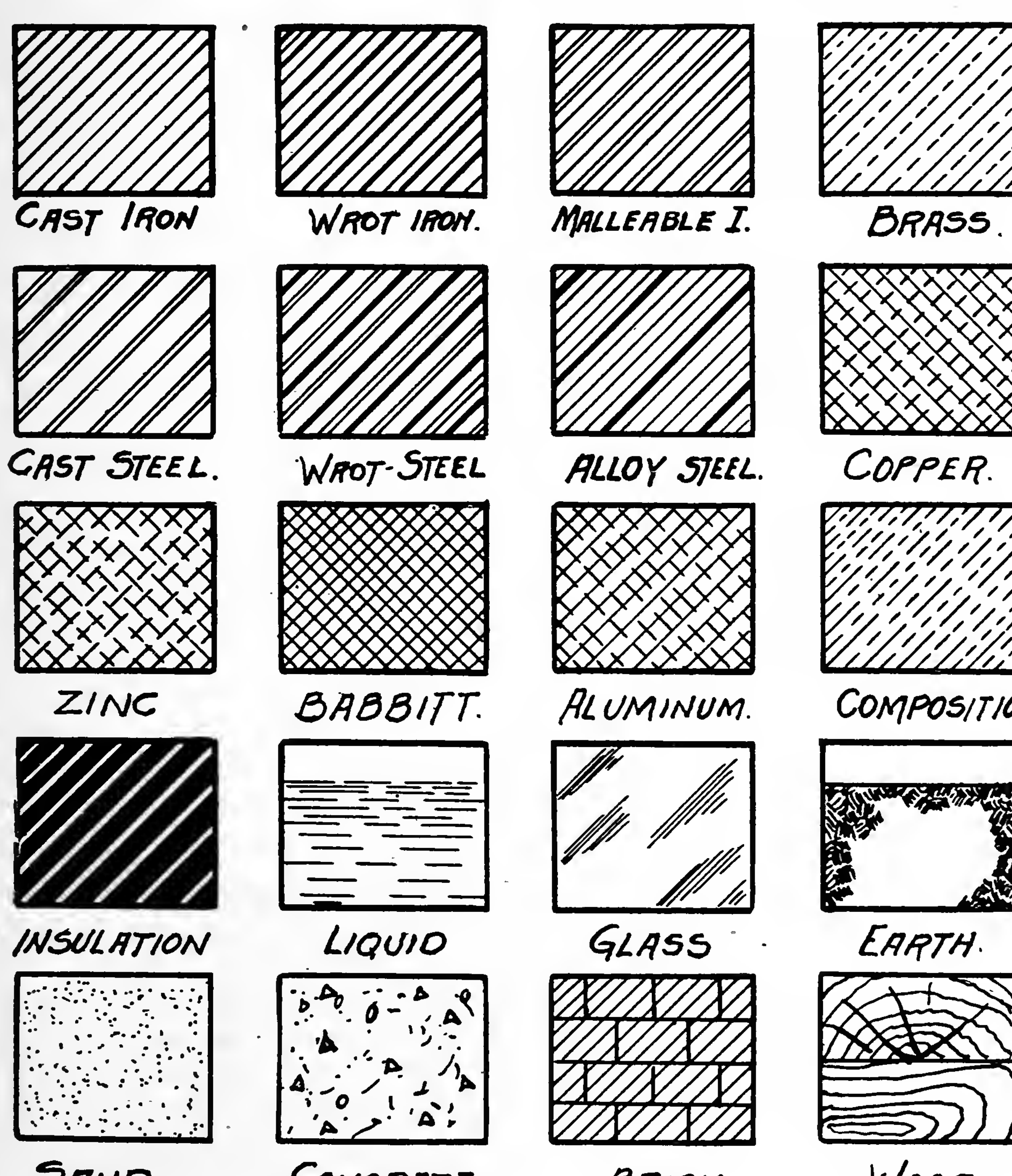
In making a drawing ½ actual size, the full size scale is used, and each dimension reduced accordingly by one-half. For example, a dimension 9¾″ long is made 4½″ plus ⅜″ equals 4⅞″ in length when made half size using the full size scale.

## CROSS SECTIONS AND CROSSHATCHING.

The surface of a cross sectional view which has been imaginarily cut is always covered with a group of lines (generally diagonal) to form symbols used to designate various materials.

The grouping of these diagonal lines is known as crosshatching and is employed to illustrate that a certain section or imaginary cut has been taken at some position in the object and the symbol indicates the material from which the object is made. The conventional forms of crosshatching as adopted are shown.

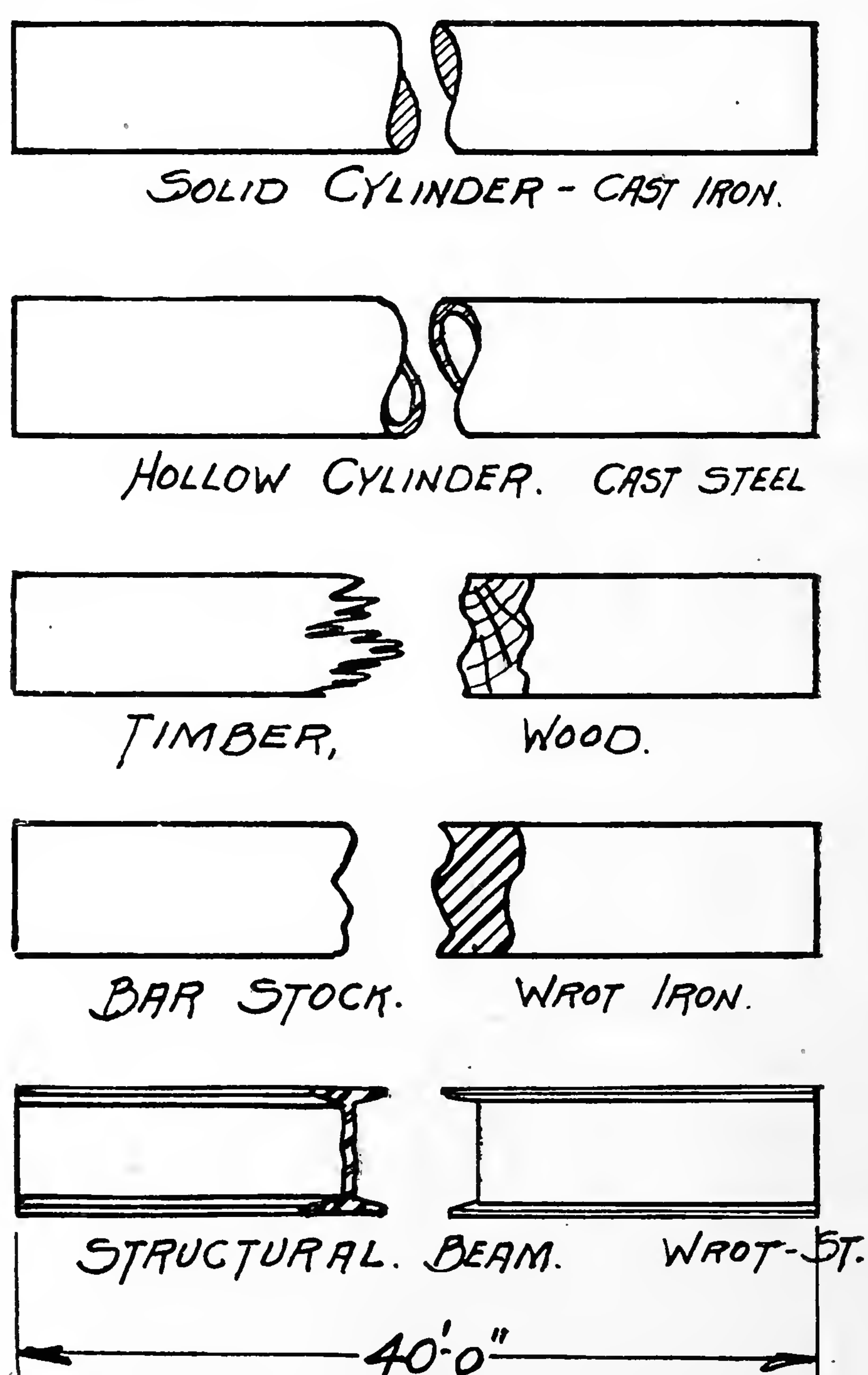
CONVENTIONAL FORMS OF CROSS SECTIONING.



However, the practice of indicating the various materials with their corresponding symbols is not always followed and a deviation from these illustrations will be met with.

In making working drawings, it is also customary that the material is noted on the drawing or on a specification and this should **always be the guide** in determining the material which is to be used. Additional symbols representing materials not shown here may be used.

CONVENTIONAL FORMS OF REPRESENTING BREAKS.



Page 58 shows the conventional forms of representing breaks and also the method of indicating the broken portion, which is shown crosshatched to correspond to the material as listed under each item, as for example solid cylinder cast iron. This has the single, evenly-spaced diagonal line covering the broken portion, indicating cast iron. Breaks are employed whenever it is impossible to conveniently show the full length or height of an object and a dimension placed from one extremity to the other indicates its total length. The 40′ 0″ dimension from one extremity to the other on the structural steel beam illustrates the above.

A piece may be shown broken and have several dimensions indicated for its length. This would show that several pieces are to be made to the various lengths.

## EXAMINATION

## LESSON 6

1. (a) What is the diameter of a circle?

   (b) What is the circumference of a circle?

   (c) What is a cored hole?

2. What do the following abbreviations represent?
   M. S.
   C. R. S.
   W. I.
   O. H. S.

3. If you wish to make a drawing $\frac{1}{16}$ of its actual size, what scale would you use?

4. In the event a part of drawing was crosshatched to represent cast iron and a notation specifies that the material is to be made of brass, which would you use?

5. Why are breaks, as shown on page 58, used?

# LESSON SEVEN

## METHOD OF INDICATING CROSS SECTIONS.

Lesson 4, Figs. 40 and 42, illustrate the method of producing a cross sectional view. Fig. 40 is a full cross section and Fig. 42 a half cross section. Fig. 51 illustrates another method of showing the form of construction thruout the length of an object, the handle (or upper portion) being round. Directly below this is a length which is square and below this it is rectangular. The long dash line passing thru the cross sections also designates the position where these cross sectional views were taken on the object.

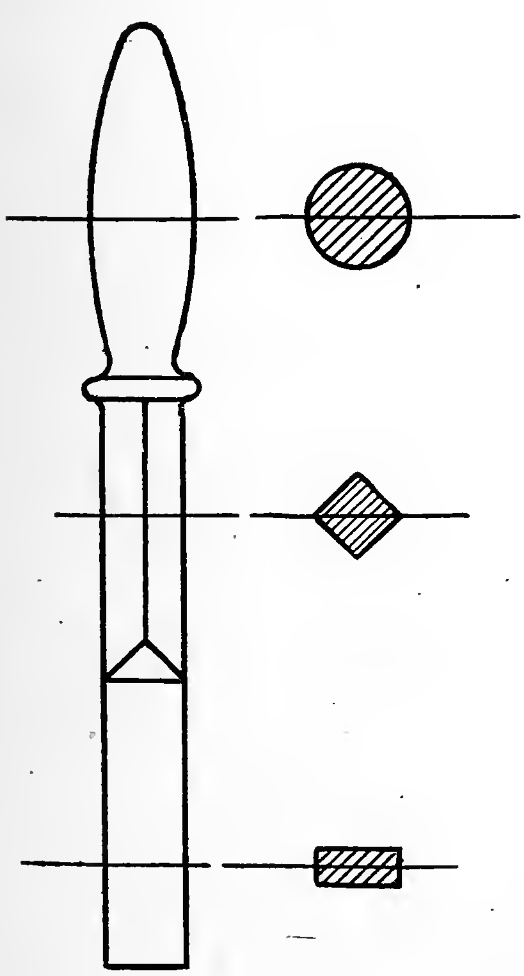


FIG-51

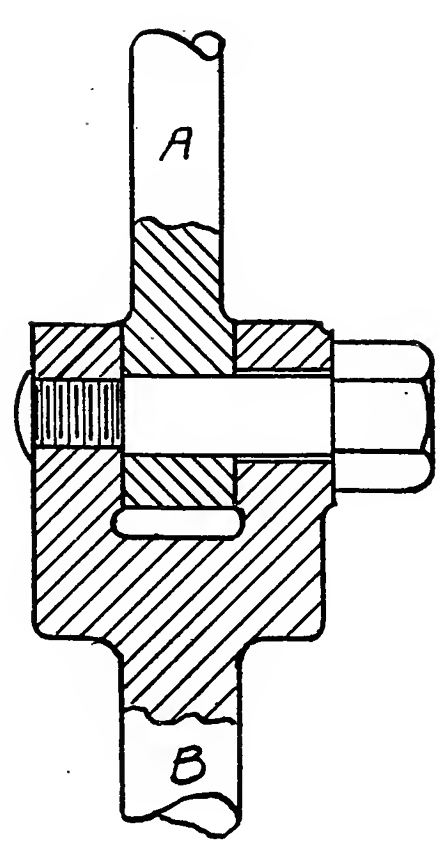



FIG-52

Fig. 72 also illustrates the foregoing.

Fig. 52. It is the usual practice when a cross section is taken thru a connection as here illustrated, to alternate the direction of the diagonal lines. The lines, where the change of direction takes place, indicate the surface of an adjacent part, also the cross hatched surfaces of the same piece have the diagonal lines in the same direction. To illustrate, part A is one piece and part B the other. Both ends of the fork part B have the diagonal lines in the same direction.

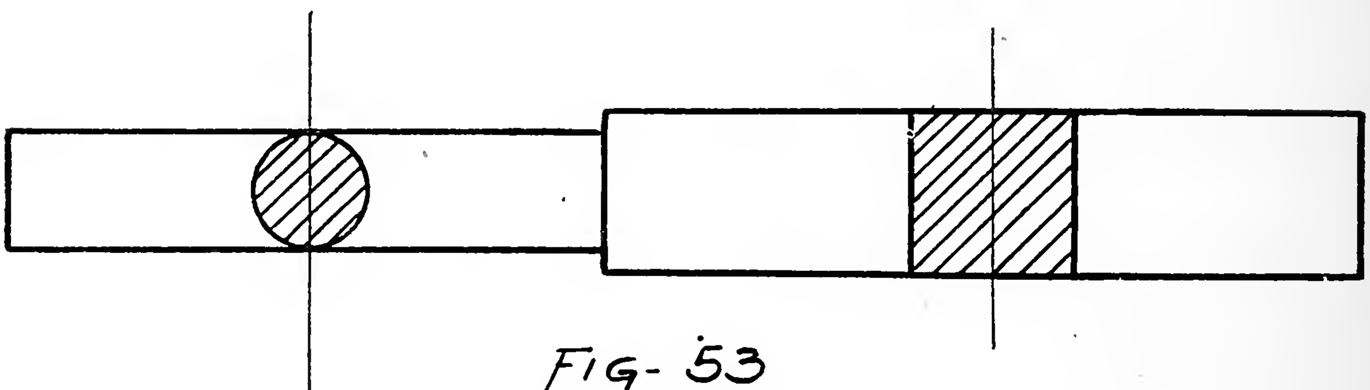


FIG-53

Another method of indicating the cross section of a certain part of an object is to place it directly within the outline of the object as illustrated in Fig. 53. This represents a bar of iron being round for about half its length and the other half square.

## ZIGZAG CROSS SECTION

By employing the zigzag line to locate cross sectional views, it is possible to show the complicated parts of an object more clearly. In Fig. 54 is shown a square block having an oblong tapered hole in the upper right hand—a round projection with a hole thru its center in the lower left hand corner—the lines A, B, C, and D, one letter appearing at each offset. In this figure only one zigzag or offset is shown. However, some drawings may have two or more, the zigzag line always indicating the imaginary cut, the cross sectional view revealing the surfaces cut and covered with crosshatching to represent the material from which it is made.

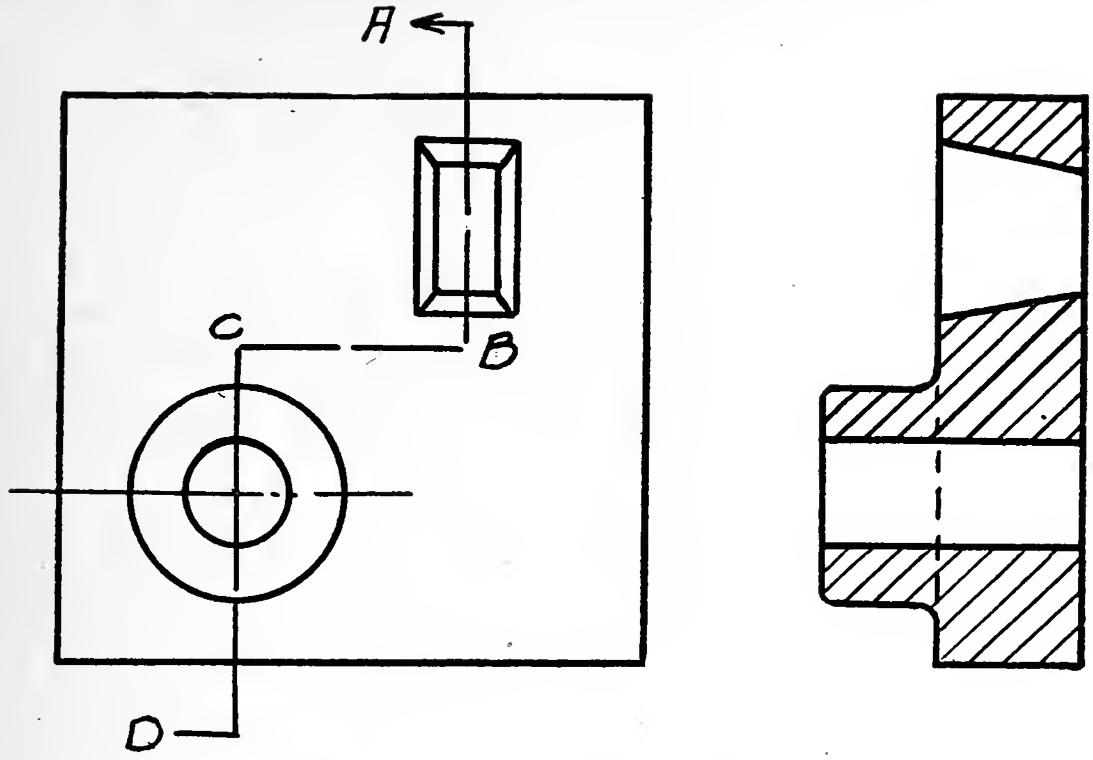



FIG-54

## HALF AND QUARTER CROSS SECTIONS.

Fig. 55 shows a perspective view of a cube, and it is assumed that we have cut out one portion and marked it c—cut out another and marked it d. The c and d portions have been removed from the cube proper and set to one side as shown.

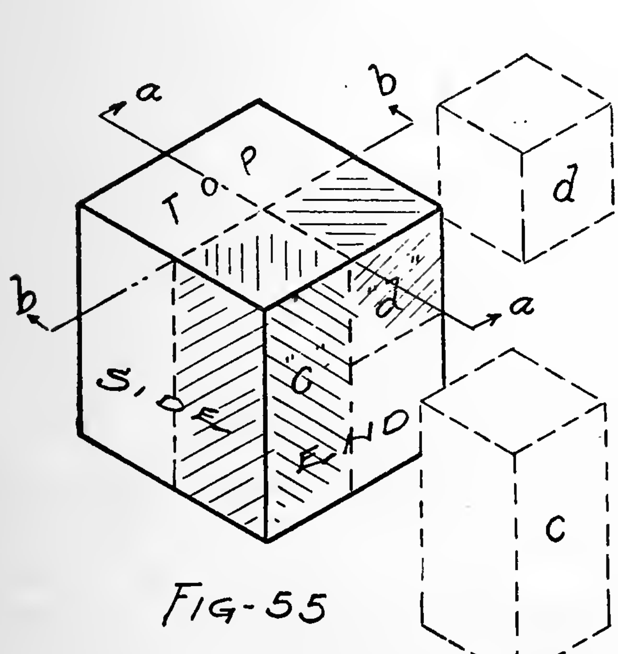
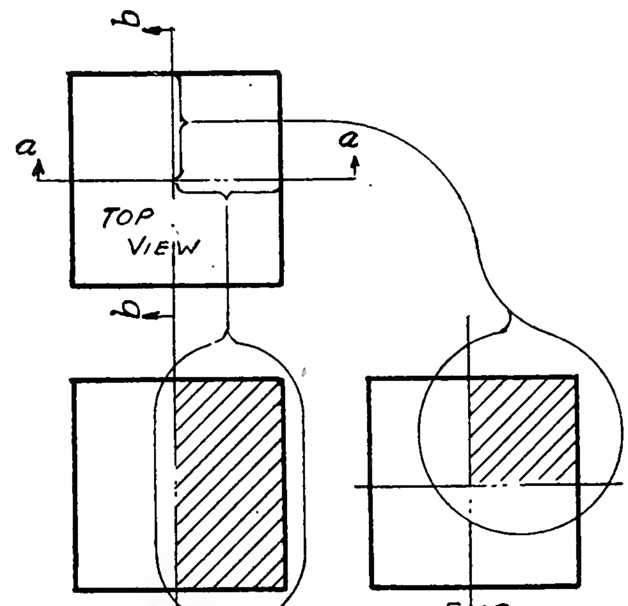



FIG-55




HALF SECTION ON LINE "a a"

ONE QUARTER SEC. ON LINE "b b"

FIG-56

By referring to the working drawing views, placed at the right and marked Fig. 56, it will be seen that the lines aa and bb indicate the corresponding center lines in both perspective and working drawing views.

Referring to Fig. 55 let us assume that we have replaced the block marked d in its proper position in the cube. By looking against the surfaces which have been imaginarily cut by the removal of block c, a side view is obtained as shown and marked "half section on line aa," (see Fig. 56) indicating that the half section is taken on line aa, the full height of the cube.

Let us assume that block c is replaced and block d removed from the cube proper on the perspective view. Then by looking at the end, a view is obtained and marked "one quarter section" on line bb. See working drawing views.

It is important to remember that these cuts are imaginary and that a cross section shown on one view has no relation to the one on another view. This was illustrated in the two working drawing views (side and end) and is the result of imaginarily replacing block c and d in the cube proper.

## BOLTS, THREADS AND TAPS.

Various methods of representing bolts, threads and taps are here illustrated. Fig. 57 shows the general method of indicating threads, being alternate light and heavy horizontal lines. Fig. 58 shows another method—it being alternate light and heavy diagonal lines sloping from the left to the right, indicating that these are right hand threads.

Fig. 60 is similar to Fig. 58 except that the diagonal lines slope from the right to the left, indicating that these are left hand threads. Fig. 59 represents a method of indicating threads generally used on tool drawings.

When threads are shown as in Fig. 57 or Fig. 59, it is always understood that they are right hand, unless otherwise marked.

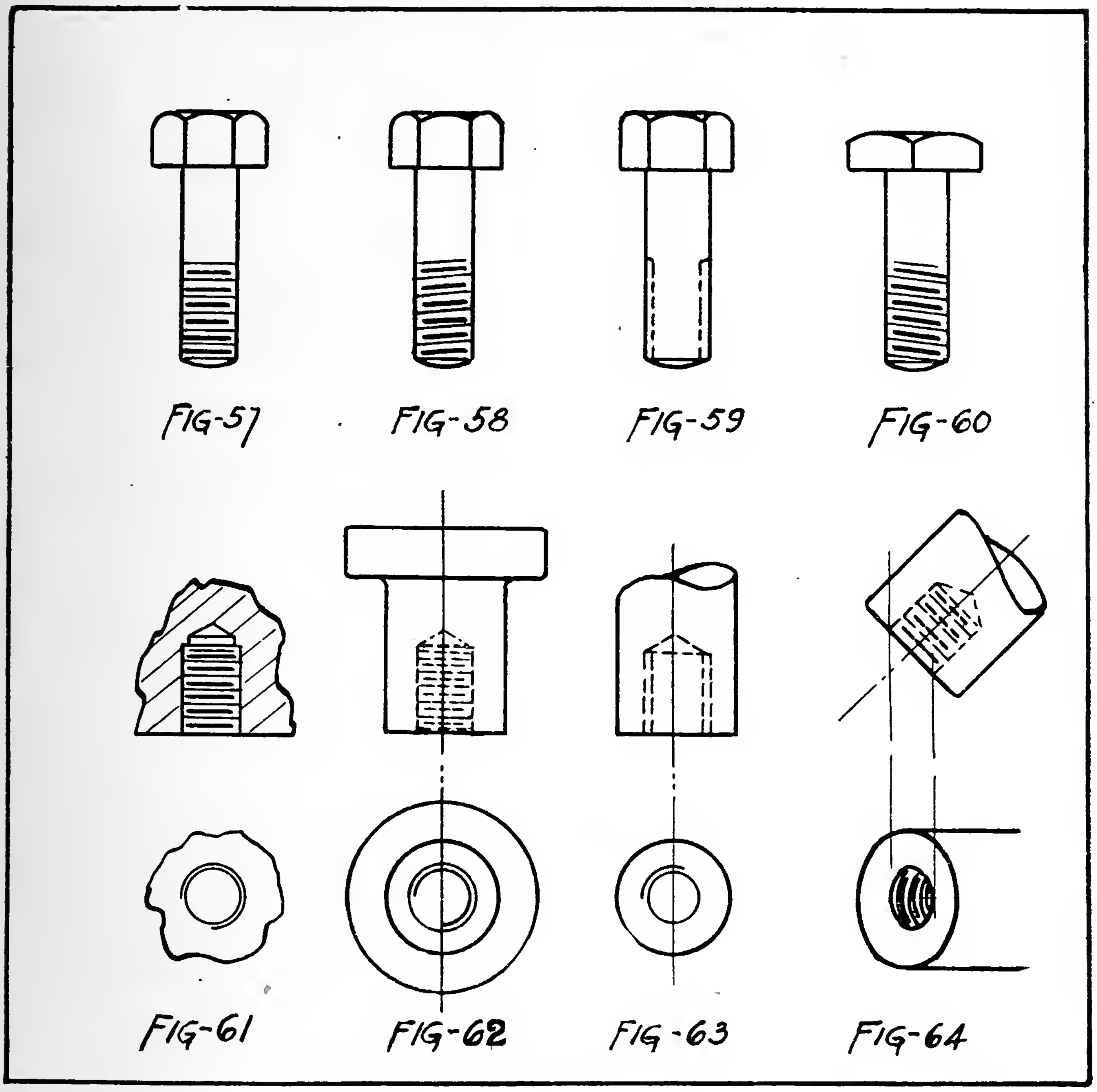
Fig. 61 shows a cross sectional view of tapped hole, the bottom of which shows the point of the drill. Attention is called to the various methods of indicating the end view of these tapped holes.

Fig. 61 shows a complete circle with a larger circle circumscribed ¾ around.

Fig. 62 shows another method of indicating the end view of a tapped hole—it being a ¾ circle inscribed in a complete circle.

Fig. 63 shows still another method of indicating the end view of a tapped hole—it being a ¼ circle circumscribed around a complete circle.

Fig. 64 shows the method of projecting tapped hole when it is projected from an angle.




## SHRINK RULE—EXPLANATION AND USE.

Shrink rules are special rules used by the pattern maker. It has been found that as castings cool after being poured, the amount of shrinkage varies when made of different materials. In order to take care of this shrinkage or contraction of the metal so that the finished product will be of the proper pre-determined size, the pattern must be made larger than the finished casting. It is evident that if it were made the same size as the finished casting, it would be smaller than desired, therefore a shrink rule which will take care of this shrinkage is employed by the pattern maker. This rule is a trifle longer than the standard—the length depending upon the shrinkage of the different materials.

Before the pattern maker starts work on his pattern he is informed as to the material of which it is to be cast, and will use the proper shrink rule to produce the required amount of shrinkage.

If casting is to be made of steel, the rule will be 1/4″ longer than the standard foot, indicating that steel in cooling will shrink 1/4″ for each foot of its length.

Brass will shrink 3/16″ for each foot of its length.

Cast iron shrinks 1/8″ per foot.

When making patterns of great length, a slight deviation from the above is resorted to.

Let us assume the pattern maker is to make a pattern—the casting made from same to be cast iron. He will use a rule which, by actual measurement, is made 12 1/8″ in length and divided into 12 equal parts, which in turn are subdivided to the various fractions of one inch. It will be seen that each inch in length will be a trifle longer than the standard inch. With this rule the pattern maker works to the dimensions given on the drawing, using the particular shrink rule for cast iron and when the casting is finished, it will shrink sufficiently to have the dimensions desired.

## THE MEASUREMENT OF ANGLES.

In the mechanical world angles are measured by degrees or subdivisions of a degree. For such measurement the circumference of a circle is supposed to be divided into 360 equal parts, and the angle formed by drawing a line from two adjacent points of the circumference to the center is an angle of one degree, and is written thus, 1°. The small circle above and to the right is the symbol for degree. Fig. 65A illustrates an angle of 1° to a slightly enlarged scale. The distance between the two lines at the circumference represents 1/360 part of the circumference.

If we were to add up ninety of these divisions and draw a line between the first and the last one to the center, the angle formed would be 90° or the 1/4 part of a complete circle. The upper half of Fig. 65B shows two angles of 90° each.

The lower half of Fig. 65B shows the half circle divided into four equal parts, each being marked 45° (or 1/2 of 90°). If the complete circle (360°) were divided into eight equal parts, each would contain 45°, as 360÷8 equals 45.

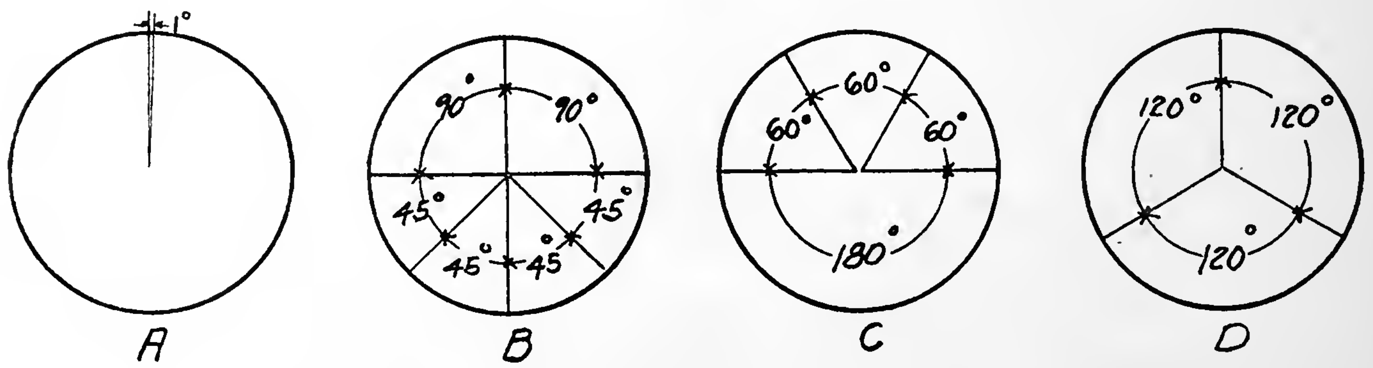



FIG. 65.

The upper half of Fig. 65C is shown divided into three equal parts, each marked 60°, as the half circle contains 180°, which, when divided into three equal parts, equals 60 (180÷3=60). Dividing one of the 60° spaces equally in two will make each angle 30°.

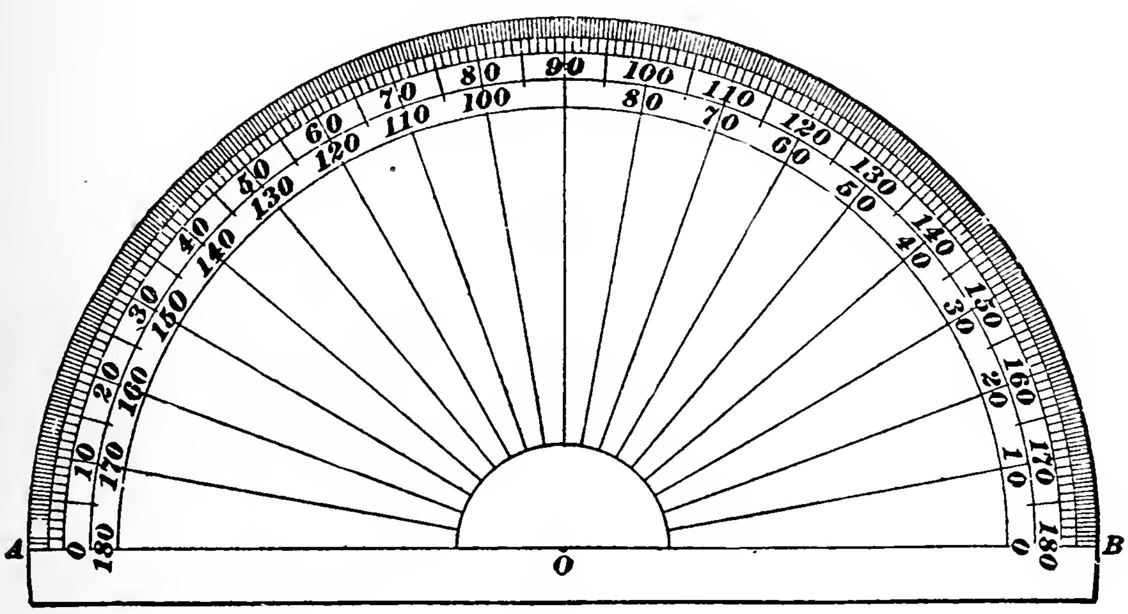
If the complete circle is divided into three equal parts, each will contain 120° (360÷3=120). See Fig. 65D.

The above divisions are the most common, altho any number of degrees or fractions of a degree may be used.

For accurate measurement a degree may be subdivided into 60 equal parts, called minutes, each of these again in turn, being subdivided into 60 equal parts, called seconds; hence the following notation on a drawing

61° — 32′ — 15″

is read "sixty-one degrees, thirty-two minutes and fifteen seconds."




Protractor

Degrees and minutes are laid out with a special instrument known as a protractor—an illustration of which is shown. However, it is not always possible to read this instrument closer than within five minutes, and it is very seldom that any tradesman except a machinist, tool-maker or pattern maker will be called upon to make layouts using other than those most common.

## CHAPLET.

Fig. 66 is a perspective view of a chaplet. A chaplet is made of a very fusible metal and used to support a core when placed in a mold. The liquid metal when poured into the mold, readily melts the chaplet.

Fig. 67 represents working drawing views of this chaplet. It will be seen that the two flat discs are shown as a large and smaller full outlined circle in the end view, and the stem is shown in this

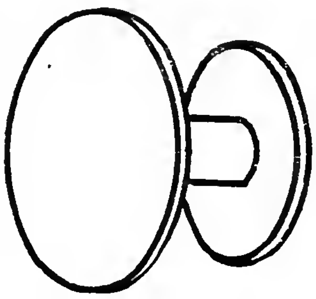


FIG-66

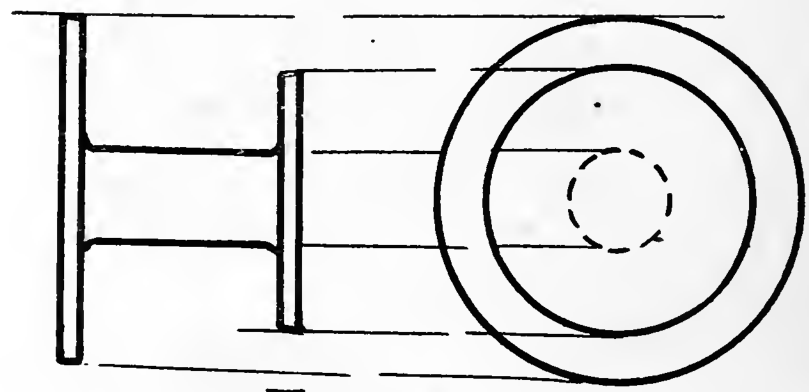


FIG-67

same view as the small dotted circle in the center. It is dotted as it exists but cannot be seen when looking directly at the end of the object.

The light lines between the two views are known as **construction lines.** These lines are **never** shown on a working drawing, but are used in this case to assist in locating the corresponding points or surfaces on the two views.

## EXAMINATION

### LESSON 7

1. What material does the crosshatching in Figs. 51 and 52 represent?

2. Do Figs. 57 and 58 indicate the same kind of thread?

3. (a) If a complete circle were divided into twelve equal parts, what is the angle between each part?

   (b) If it were divided into 90 equal parts, what is the angle between each?

4. Which view in Fig. 54 shows the thickness of the block proper?

5. Why is the inside circle dotted in Fig. 67?

# LESSON EIGHT

## ANOTHER METHOD ILLUSTRATED OF BRINGING ALL EXTENSIONS AND DEPRESSIONS TO THE SAME PLANE.

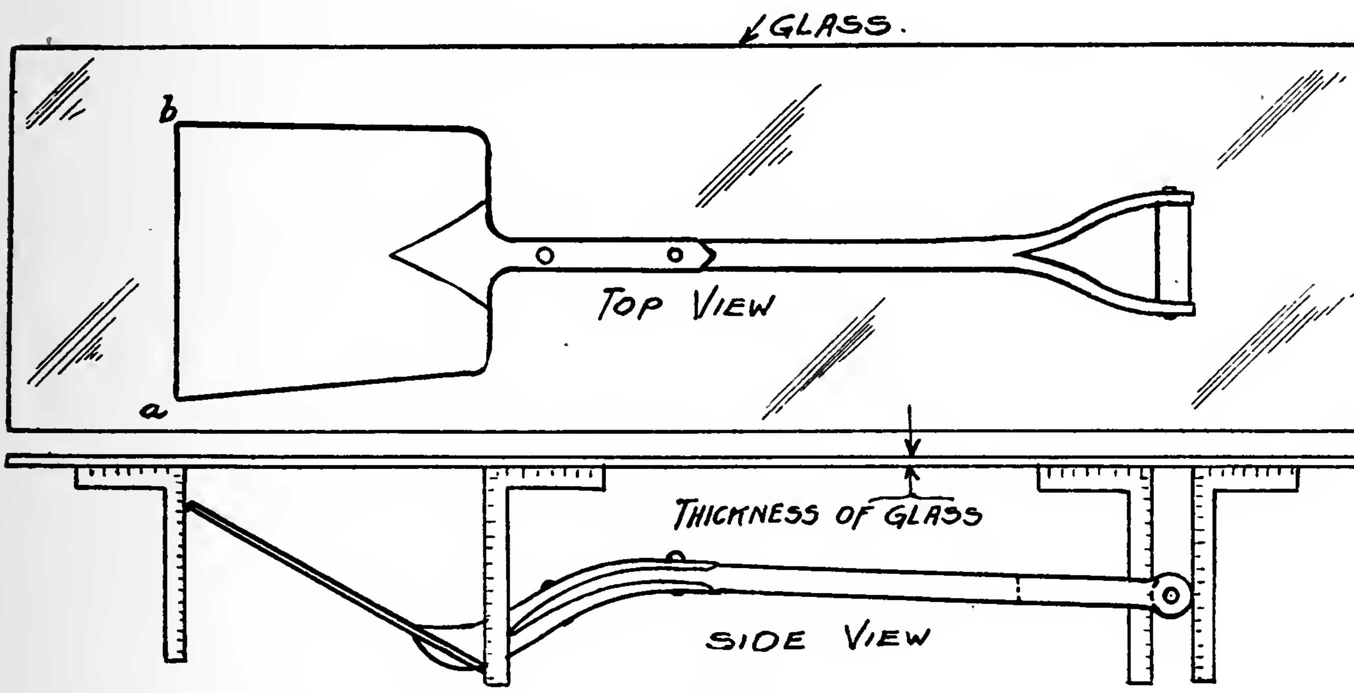



FIG-68.

Fig. 68. Let us suppose that between the top and side view we have placed a sheet of glass and that you are looking against its edge so that only the thickness will be seen.

Now let us take an ordinary carpenter's square and hold the short leg of it against the underside of the glass plate and the long leg against the extreme left hand edge of the shovel. With the square held in this position move it back and forth along this edge. If a line were drawn on the glass at the points where the longer leg of square meets it and were you to look down thru the glass, a line as shown on top view and marked a b would be produced. Now if the square, held in this position, were moved all around the shovel with the long leg just touching, and each point marked on the glass plate an outline of the shovel would be seen when looking down on the glass. This illustrates another method of bringing all depressions and extensions to the same plane, the glass plate being the plane in this case (see also Fig. 11 in Lesson Two).

The projection of the cylinder which forms the handle is shown at the right, the two parallel lines in the top view being the lines projected.

## SCREW DRIVER.

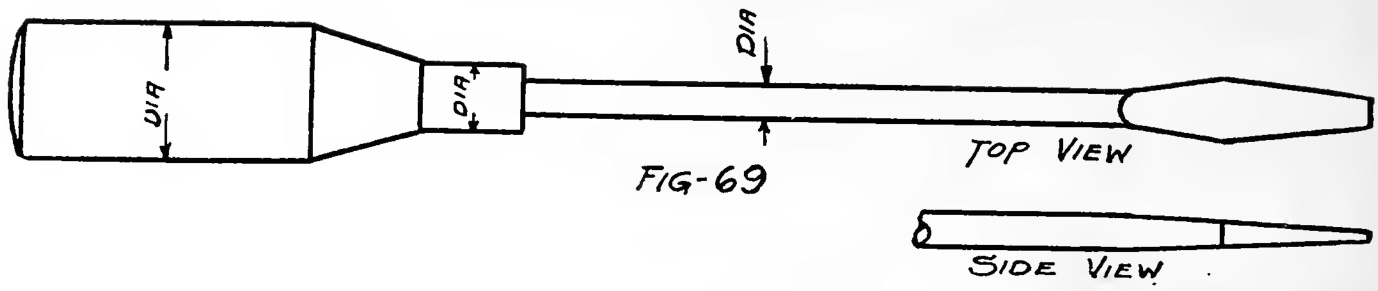



FIG-69

Fig. 69 is a working drawing view of a screw driver and no doubt you will experience no difficulty in understanding the object—the handle is cylindrical and the opposite end flattened and tapered down.

Looking directly at the screw driver with the flat surface toward you will produce a view as shown at the top; then by looking at the side so that the taper may be seen, an outline as marked "side view," will be produced.

The handle is not shown in the side view as it is not necessary—the portion of side view as shown is all that is needed to clearly explain the end of the screw driver, the notation, "DIA" as placed on the handle will explain that these parts are cylindrical.

## WRENCH.

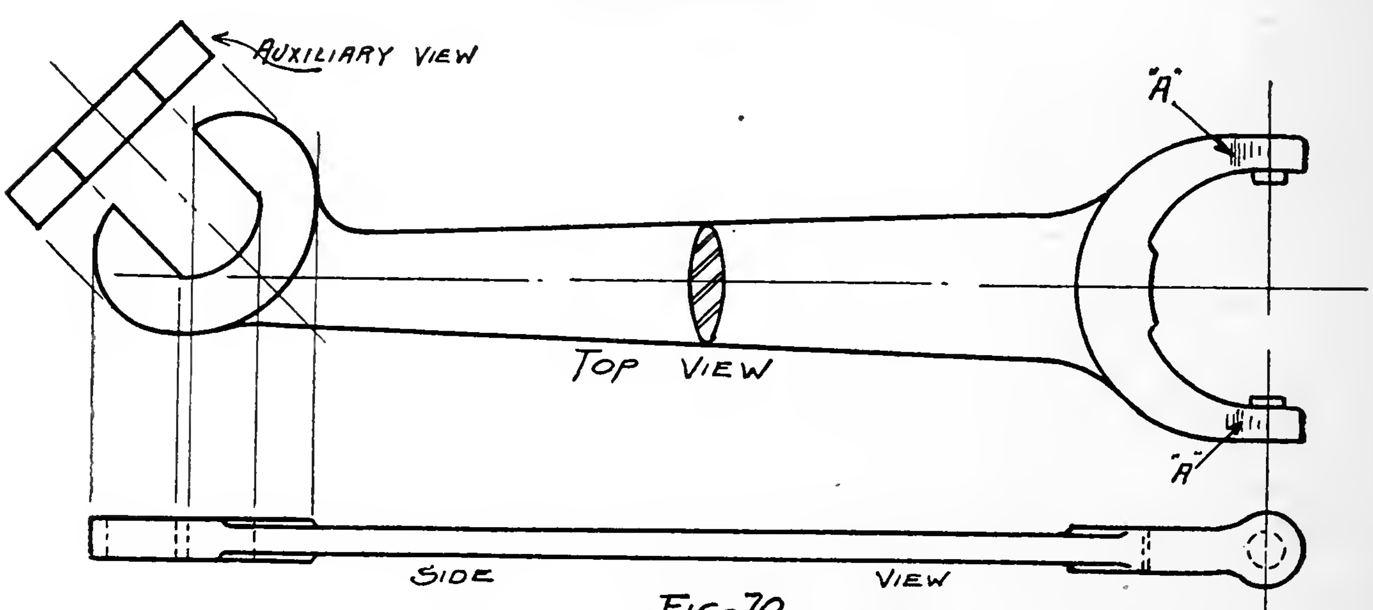



FIG-70

A special wrench is shown in Fig. 70, one end being known as an open end and the other as a spanner. This drawing illustrates the position of an angle projected view, the placing of a cross sectional view, the cast steel symbol of crosshatching, and the manner of projecting the various points from one view to the other.

The angle projected view above the open end of wrench shows the thickness and width of jaw; however, this view does not show any other part of this wrench and is therefore classified as an

**auxiliary view.** The construction lines at the left hand end and placed between the top and side views show the various points projected.

We advise you to project the points, lines or surfaces of the opposite end of the wrench in the same manner.

An illustration of line shading is shown at A which assists in showing the enlargement at the end of the wrench.

The placing of cross section view is explained on page 62.

## STANDARD ELBOW.

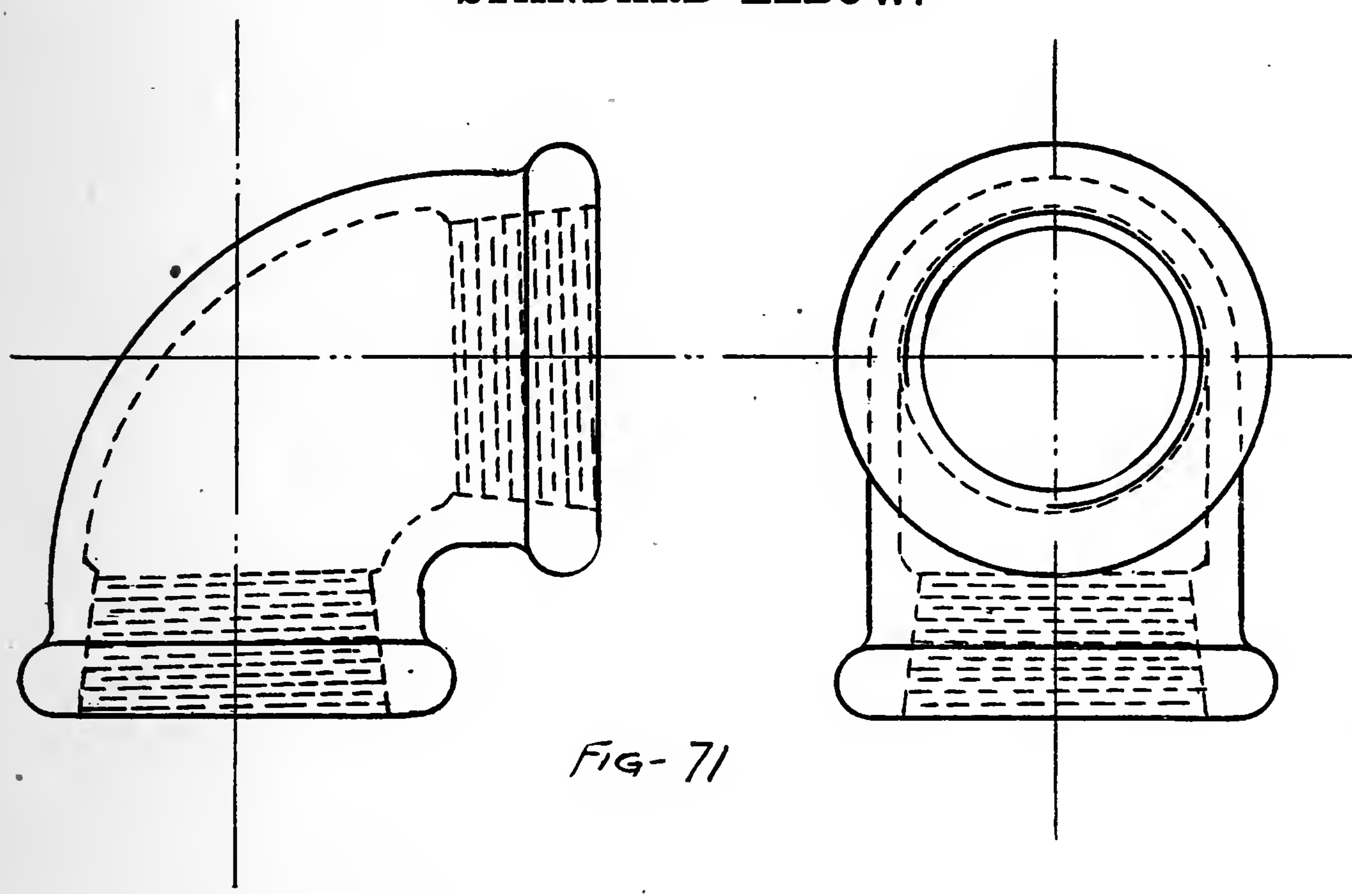


FIG- 71

Fig. 71 represents a working drawing outline of a standard pipe fitting (elbow). The method of indicating pipe threads is shown by dotted lines. It is customary to make no distinction in the thickness of lines representing the threads when dotted, however when threads are shown in full or in cross section, the alternate lines are heavy and light. See page 65.

Study the projection of the various points with the use of the straightedge as explained in Lesson 3.

If possible secure an elbow fitting and compare the actual article with this drawing—holding it in the positions here outlined; also look down at the elbow directly from the top and make a free hand sketch of the top view.—This will be very good practice.

## MALLET.

Fig. 72 represents a working drawing outline of a wood mallet. Side and top views are shown.

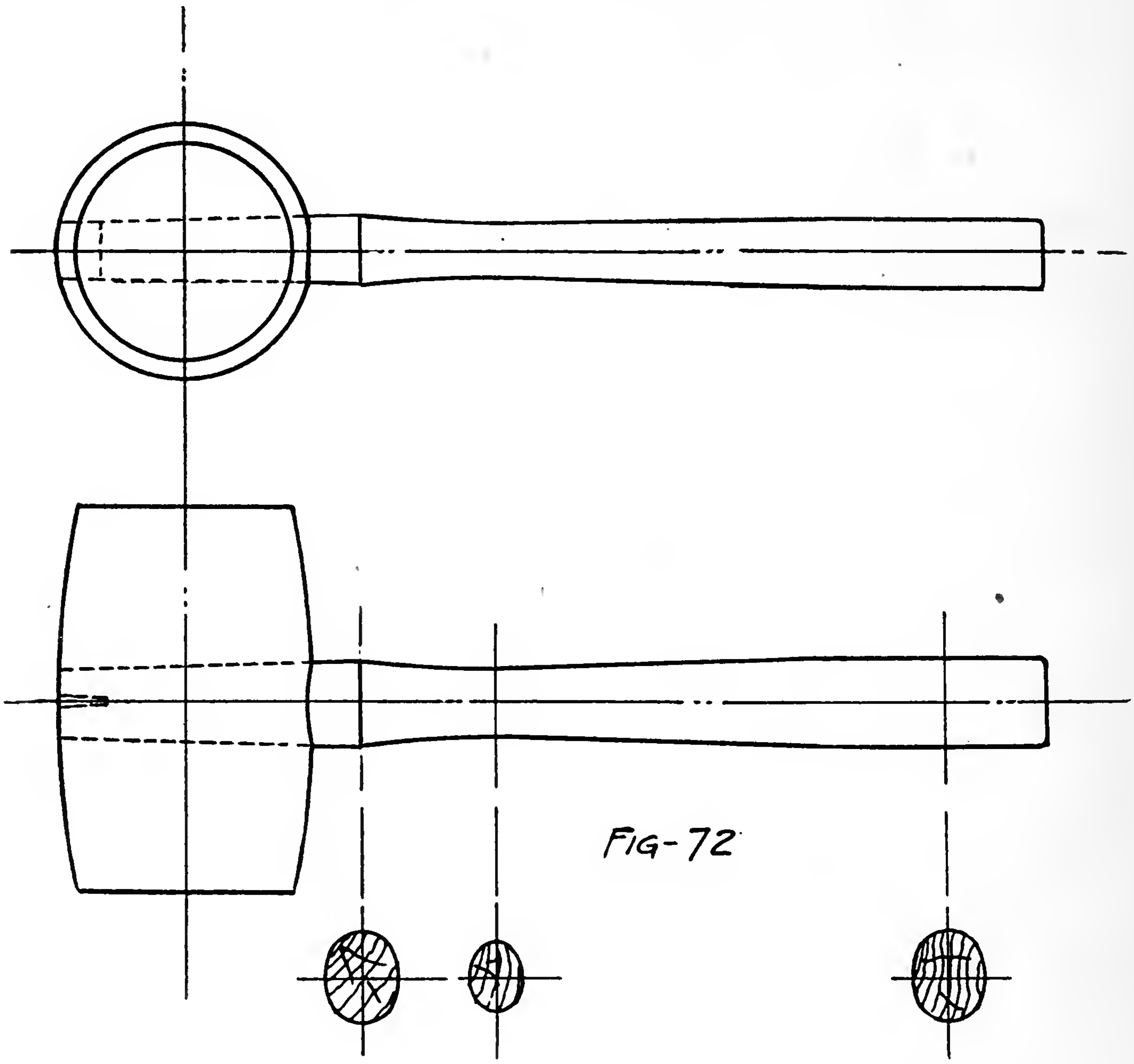


FIG-72

One method of indicating the shape of the handle is shown by the cross sectional views. The vertical lines passing thru these sections locate the positions of the various cross sections along the length of the handle. In some instances these cross sections are shown directly on the outline of the object. (See page 62, Fig. 53.)

Cross section indicates **wood.**

The two circles in top view indicate that the mallet head is larger in diameter at its center than at the top and bottom.—The inside circle represents the top of mallet (side view) and the outer circle the diameter at the center.

The dotted lines thru the mallet head indicate the hole, as well as the handle. The wedge in the end of handle is also shown dotted.

The bottom diameter of mallet head (side view) is the same as the top; if it were not the same, the top view would show another dotted circle indicating its diameter. However, none being shown, it is correct to assume that the top and bottom are the same in diameter. Furthermore, if an attempt were made to show the bottom diameter of this mallet head in the top view, a dotted circle indicating its diameter would fall directly on the full inner circle, and therefore could not be seen.

## PERSPECTIVE DRAWINGS OF MOLDERS' TOOLS.

On page 76 you will see various tools used by molders in the ramming and placing of sand in a mold—their use being common to the foundry molding trade.

We have taken the second illustration shown at the top of the page, a hand rammer, and have made a working drawing of it. Fig. 73 illustrates the working drawing of this hand rammer. It should be noticed that neither the side nor top view indicates that the right hand end of this rammer is cylindrical, therefore the end view has been added to explain this.

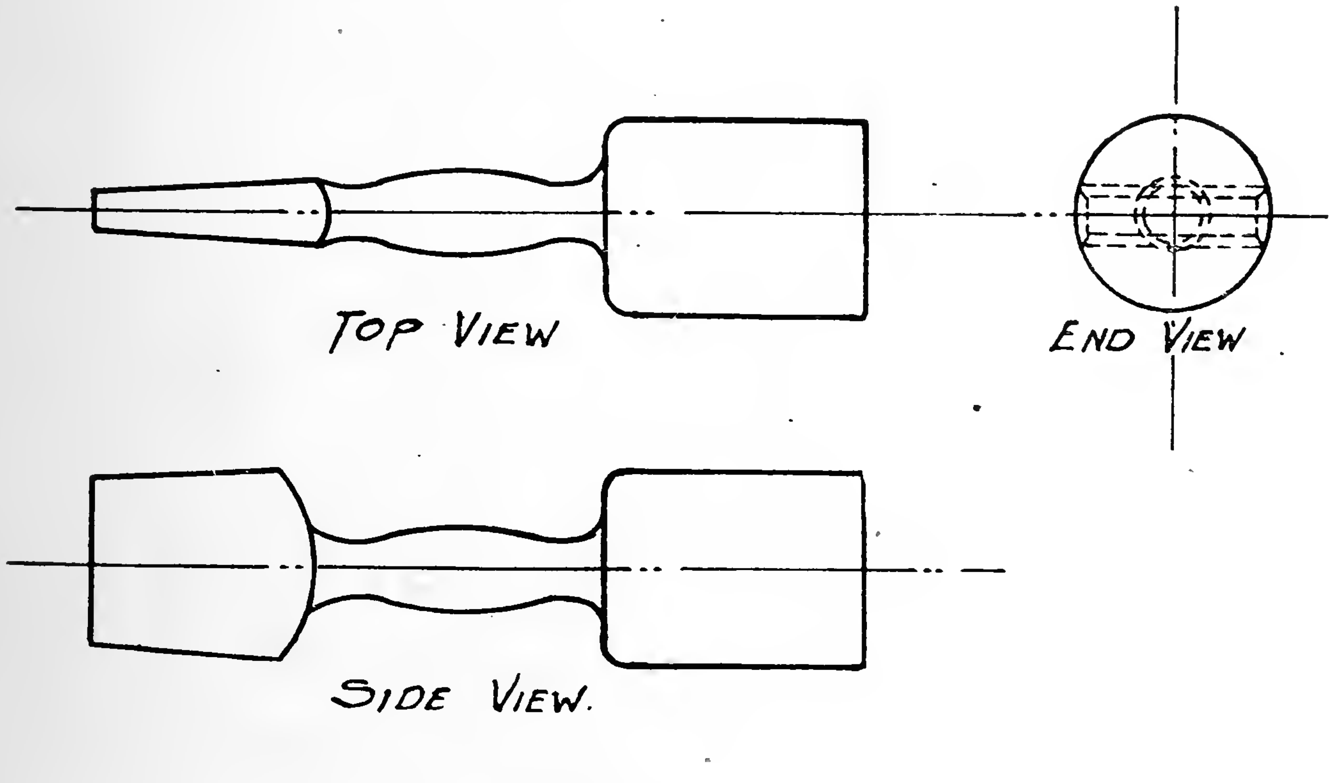
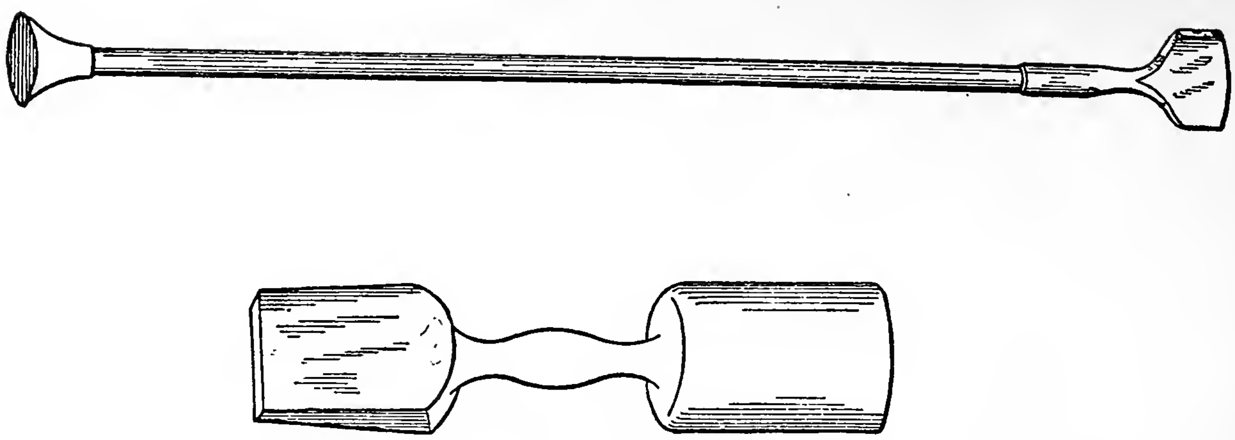


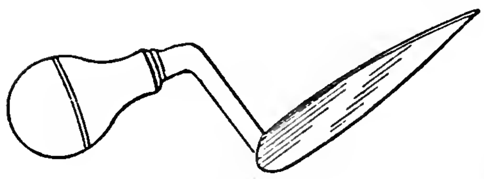

FIG - 73

Sufficient views should always be used in connection with working drawings to clearly show the outline of each and every part of the object.

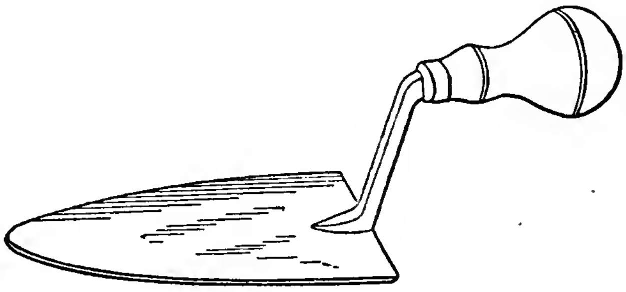
As mentioned the large full circle in the end view shows the construction of the right hand end (see top view). The two small dotted circles show the construction of the handle and the flat dotted oblong shows that the left hand end (see top view) is flat.



Floor and Hand Rammers



Finishing Trowel

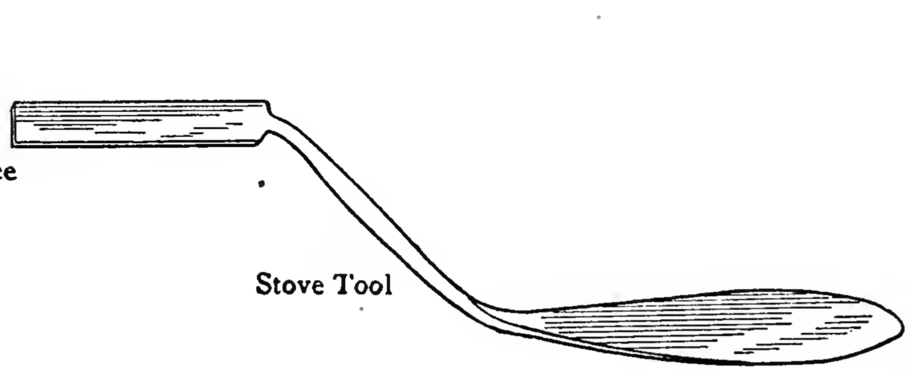


Finishing Trowel

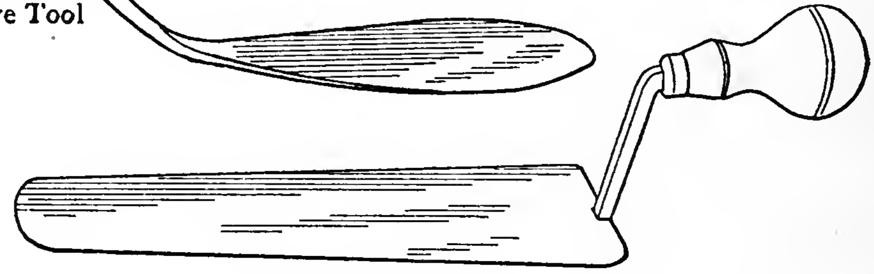
Yankee

Lifter

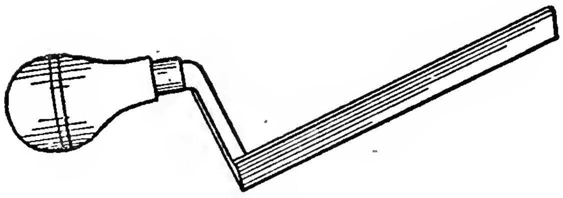
Bench Lifter



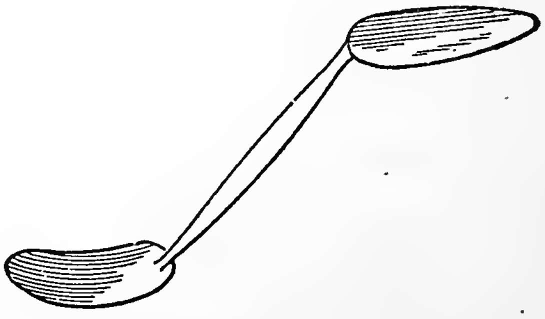
Stove Tool



Finishing Trowel



Square Trowel



Slick and Spoon

## EXAMINATION

## LESSON 8

1. What notation on Fig. 69 explains that certain parts are cylindrical?

2. What material is wrench in Fig. 70 to be made of?

3. Why are the threads shown tapered in Fig. 71?

4. Fig. 72 shows a side and top view. Would bottom view look the same as top view?

5. What do the two dotted circles indicate in the end view of Fig. 73?

# LESSON NINE

## WOOD FLASK

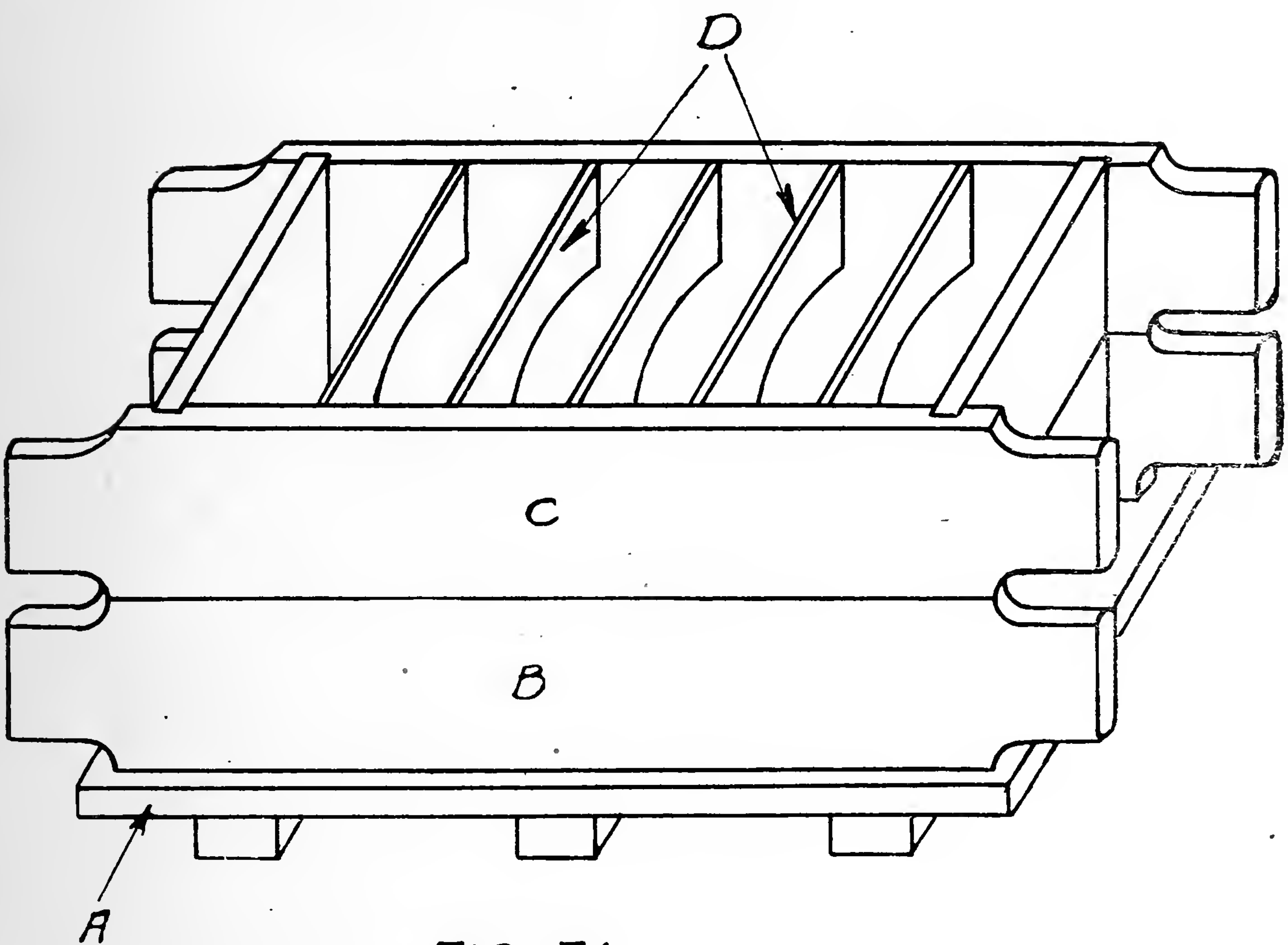



FIG-74

Fig. 74 represents the perspective of a wood flask for use in a foundry for molding purposes. It is composed of a bottom board A, drag B and cope C. Cross bars are shown at D, the object of which is to support the sand while it is being rammed into the mold. This drawing is shown to give you a general knowledge of a perspective drawing and also to familiarize you with equipment used for foundry work. The working drawing of a similar flask will be shown and explained later.

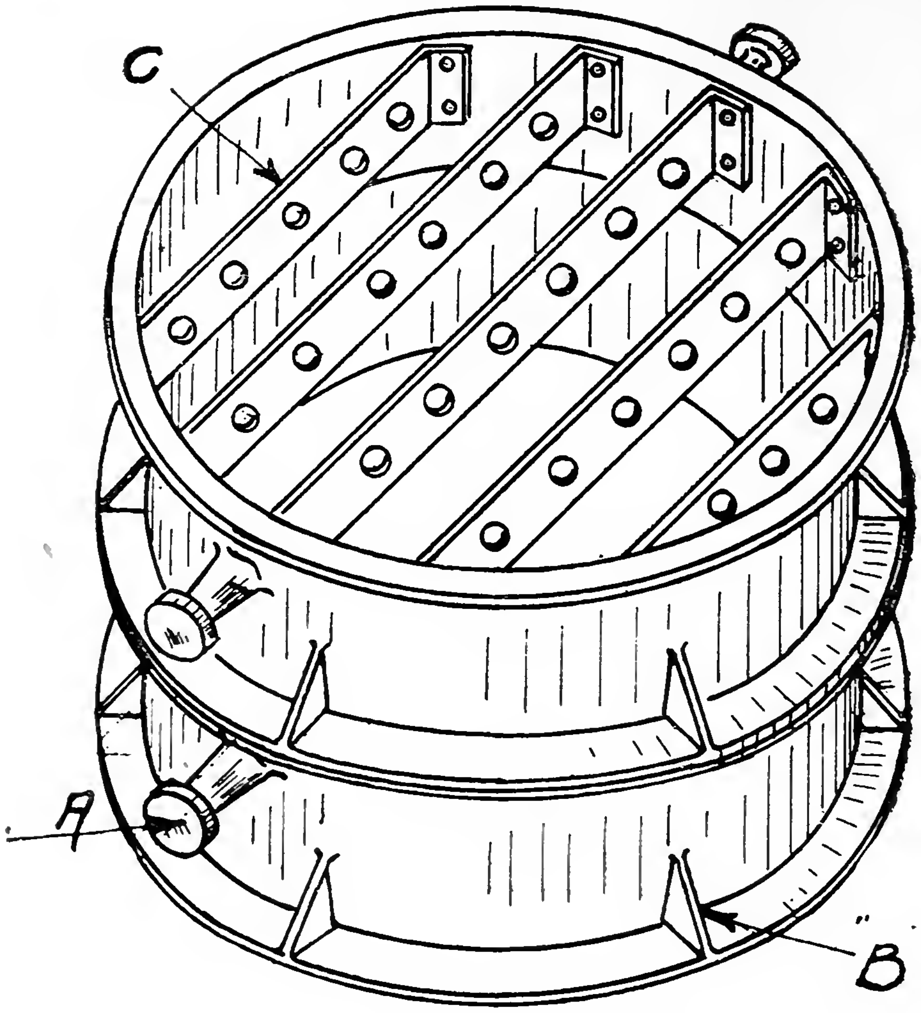



FIG-75

Fig. 75 shows a perspective drawing of a cast iron flask composed of a cope and drag. The cope and the drag are generally cast of cast iron, the trunnion A and ribs B forming part of the casting. The trunnion A forms a suitable fastening for crane hooks or chain and allows the cope or drag, as the case may be, to be rolled over when desired.

Your attention is called to the cast iron or cast steel cross bars shown at C. You will note these cross bars have numerous holes in them—the object of which is to further assist in supporting the sand after it is rammed in place.

## PERSPECTIVE AND WORKING DRAWING VIEWS OF A FOUNDRY FLASK.

Fig. 76 shows a perspective view of a foundry flask. It consists of an open box made of wood—the two long sides having the ends cut down to form handles. For the sake of an example and to illustrate the method of projecting, we have shown the rear board of this box approximately twice as thick as the front board.

Fig. 77 represents the working drawing views of Fig. 76. The lines A and B, also C and D, are shown dotted on the front view as they are hidden from actual view when looking at the front of the flask. The lines B and C, also E and F indicate the inner surfaces of this box and the corresponding surfaces are shown with the same letters on the other views. The projection

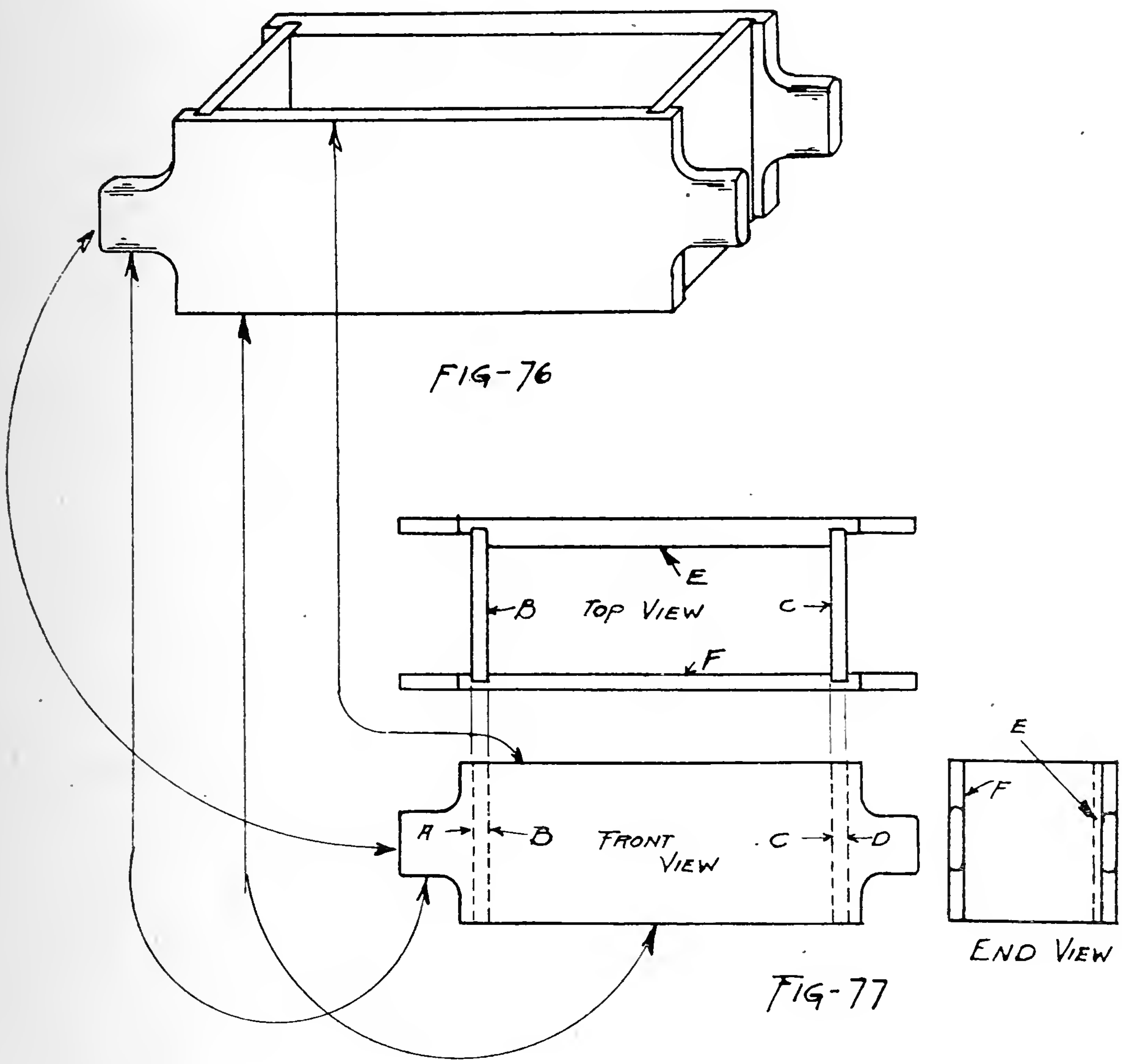



FIG-76

FIG-77

and relative position of the views are obtained in exactly the same manner as previously explained, and if you will refer to Fig. 68, bearing in mind the principle of bringing all depressions and extensions to the same plane, you will be able to readily understand this drawing. The rear board of the flask, as mentioned, is approximately twice as thick as the front board. We will explain how this thickness is shown on a working drawing:

By referring to the top view, the inside of the rear wall is indicated by the letter E and the correct projection of this surface is indicated by the dotted line E on the end view.

Attention is called to the projection of the inside surface F on the end view. This board being the same thickness thruout its length, makes it impossible to indicate the inside surface of the box on the end view, as a dotted line would fall directly on top of the full line F on end view, and is therefore omitted. However, the thickness of the front board is shown on the top view. It is important that sufficient views and cross sectional views be shown to thoroly explain an object and if a surface or point is not projected on one view, its position or outline may be seen by referring to one of the other views. The projection of the surface F illustrates this point.—The light lines at the left indicate the corresponding lines between Fig. 76 and Fig. 77.

## SHANK.

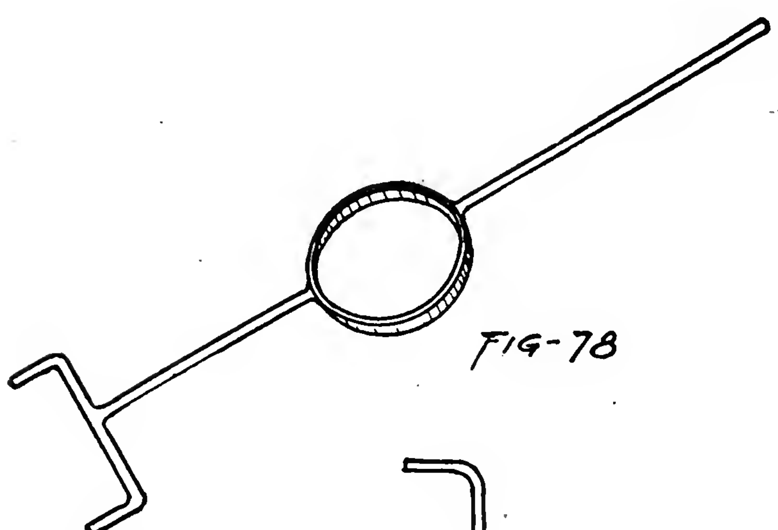


FIG-78

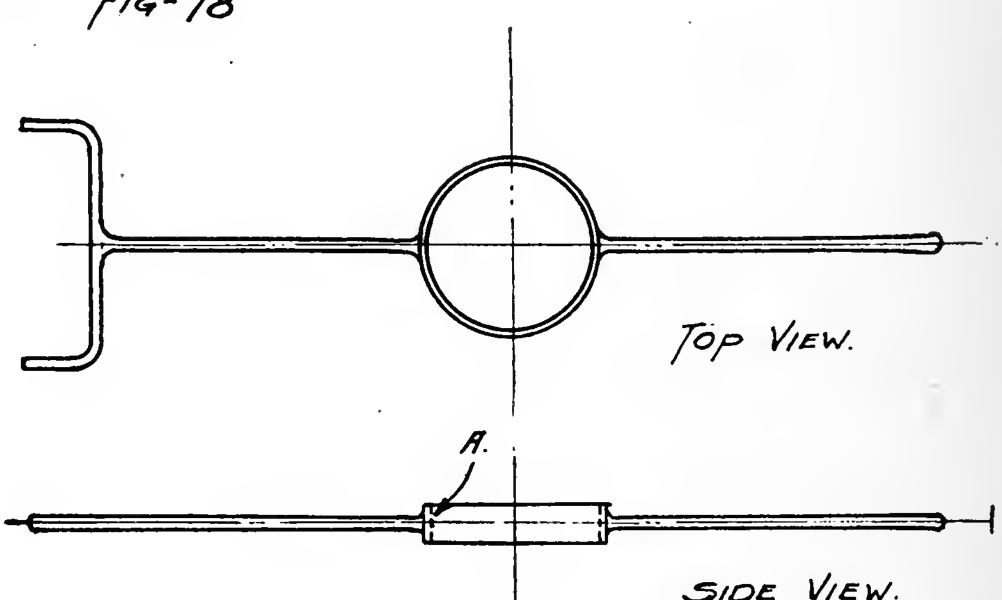



FIG-79

Fig. 78 represents a perspective view of a shank for a bull ladle. When in use, a pot or ladle is inserted into the circular band, filled with molten metal and conveyed to the molds.

The line shading is here shown on the band to illustrate its use.

Fig. 79 shows a top and side view working drawing of the shank. Attention is called to the placing of views, construction and placing of center line, and the dotted line shown at A which indicates a point on the inside diameter of the band; again, it must be remembered that when looking at the top view only a top view is seen; likewise when looking at the side, only the side is visible.

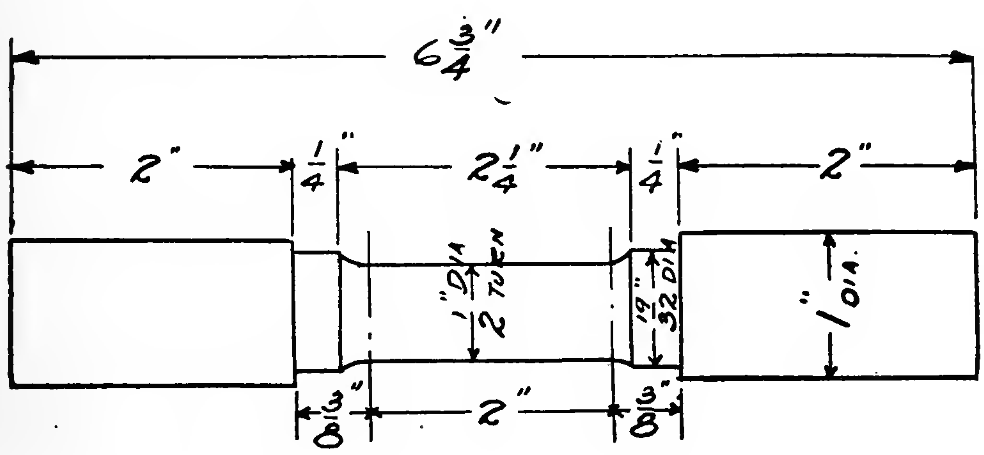
# SINGLE VIEW DRAWING.
## TENSILE TEST BARS.

Fig. 80 and Fig. 81 represent two different types of tensile test bars.

A tensile test bar is machined to the dimension as shown and made from material to be tested as to its tensile strength, reduction of area and elastic limit. This bar is then placed in a testing machine, clamped between a jaw at the top and one at the bottom; a pull is then exerted until it is ruptured, at which time a reading is taken.

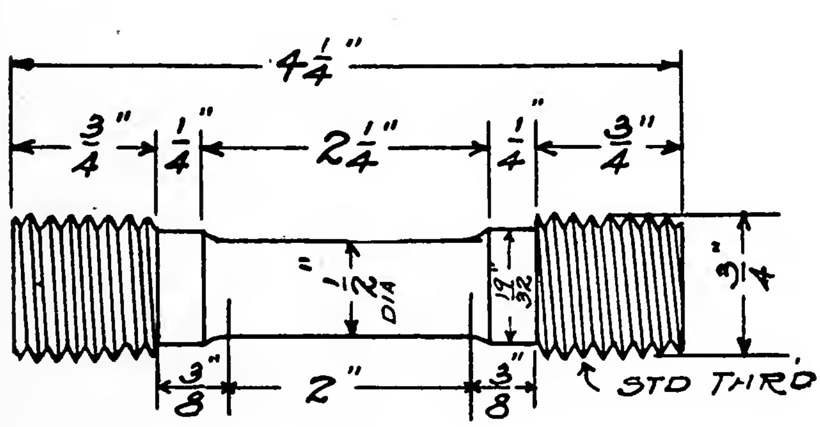
You will note that in each case only one view is shown, but that sufficient dimensions and **notations** are given to indicate that these bars are cylindrical.

The bar shown in Fig. 81 must be provided with a special jaw which screws onto the ends of the bar.




TENSILE TEST BAR

Fig. 80




TENSILE TEST BAR

Fig. 81

## NUMBER OF VIEWS NECESSARY.

Two or more views are employed to show the various details which make up the object. Whenever all the details can be clearly shown on one view, only one is necessary; this, however, applies only to very simple objects, such as solid cylinders, etc., when proper notations appear to explain more fully.

No more views should be shown than are necessary to clearly explain an object. If all details can be shown on two views, three or more would be superfluous.

In some of these pages more views are shown than necessary, but this is done to illustrate various points.

## THREE VIEW DRAWINGS.

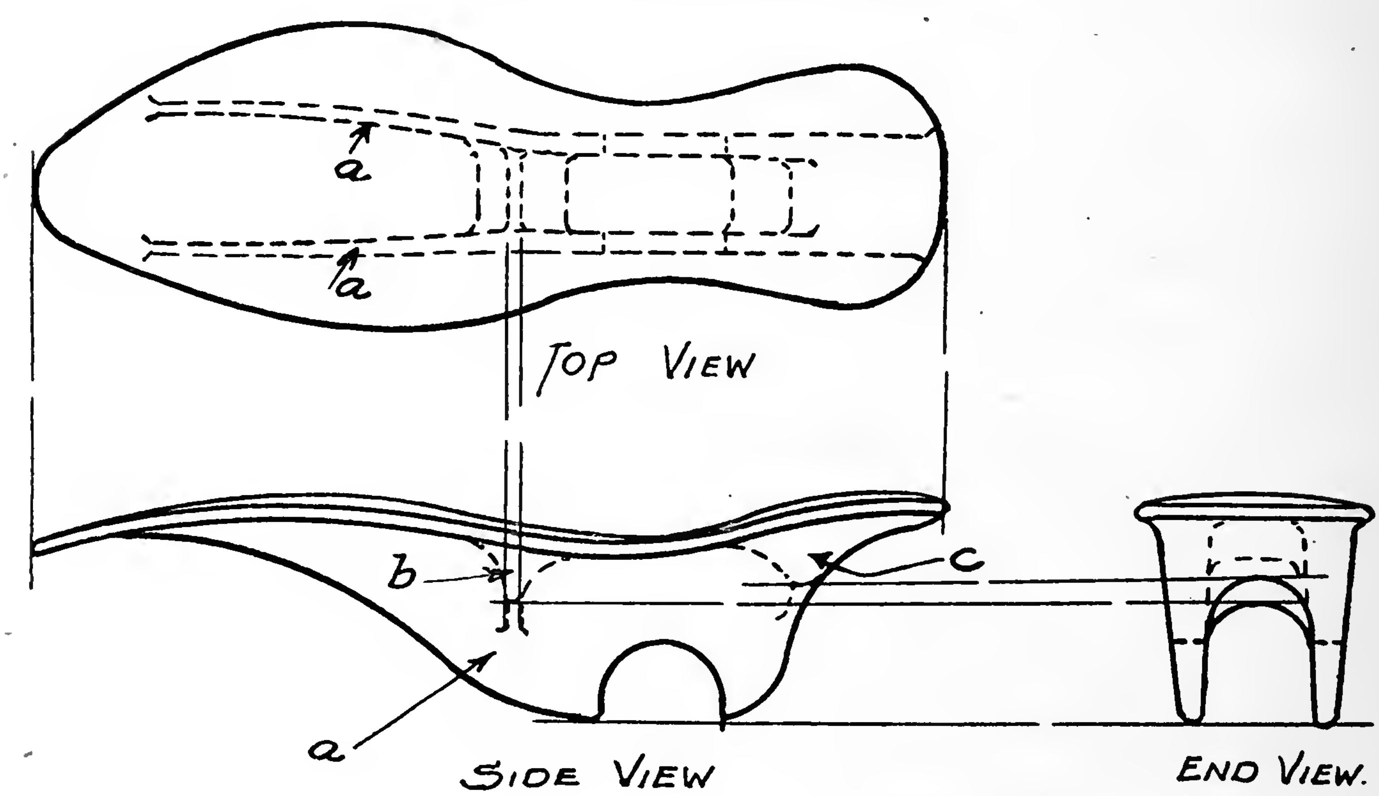



FIG-82

Fig. 82 represents the working drawing views of a shoe repair anvil. This is a good example of the necessity of having a three view drawing.

The top view shows the outline of the anvil, representing the sole of a shoe, and the position of the ribs. (Ribs shown dotted.)

The side view shows the shape of the rib a, position and shape of cross ribs b and c and general contour of the anvil.

The end view shows the tapering side of ribs a and shape at under side of ribs b and c.

In completing the working drawing for this anvil it will be necessary to show several cross sectional views. Several of the points are projected from one view to the other by the use of either horizontal or vertical lines.

Regardless of how these views are arranged, three will always be necessary. It is evident that the shape which represents the sole of the shoe (top view) cannot be shown on either of the other views and likewise the general shape of the anvil (side view) cannot be shown on either of the other views.

## EXAMINATION

## LESSON 9

1. Which views show that the rear wall of flask in Fig. 77 is thicker than the front?

2. Is there sufficient information on Fig. 81 to indicate the shape of the portion which is marked 19/32 inch?

3. In Fig. 82, which view could have been omitted?

# LESSON TEN

## CHILL ROLLS.

Chill rolls are used in rolling mills and are of various shapes, depending upon what is to be rolled.

Fig. 83 represents a chill roll for rolling flat plates. A set, consisting of two, is placed one above the other, with just sufficient space between them to allow for a thickness of the plate. The ingot which has previously been heated to almost the melting point, is then forced between these rollers. It requires several sets of rollers to reduce the plate to the desired thickness.

These rolls are usually cast solid, of a semi-steel chilling mixture and cast against a chill. This produces a very hard, close-grained surface on the outside of the roll.

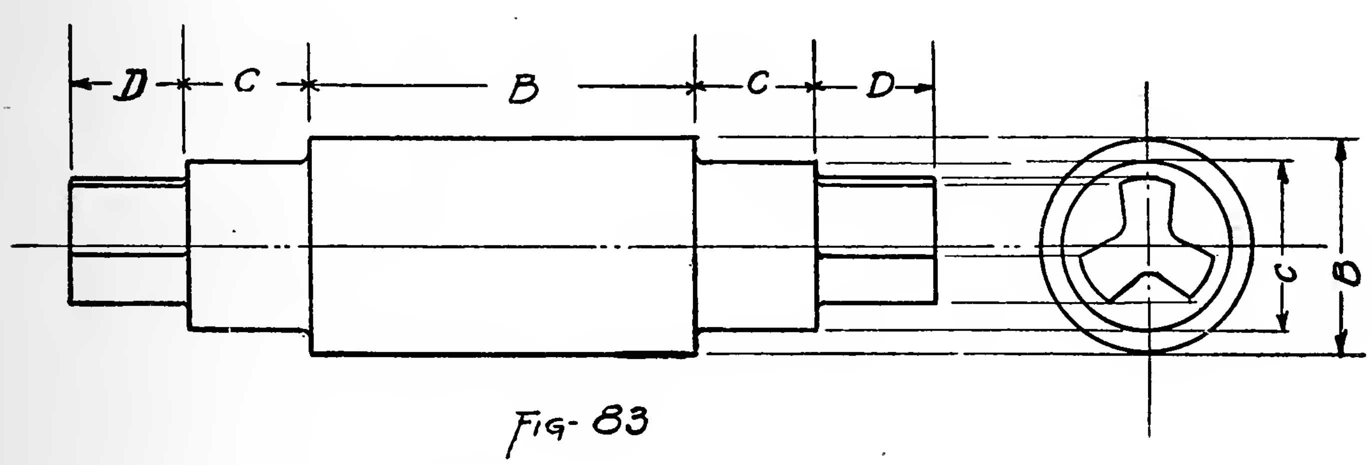



Fig-83

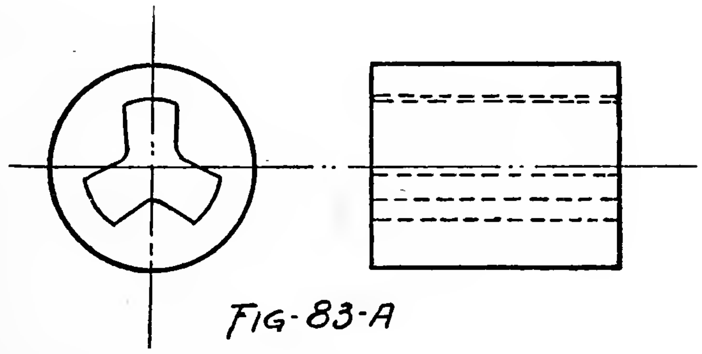


Fig-83-A

Fig. 83 shows a side and end view of a chill roll. The construction lines show the various points projected from one view to the other.

By referring to the end view, you will note the special shaped outline in the form of three legs—the length of these is indicated by D (side view). It will also be noticed that these three legs are enclosed with the circle marked C (end view) and the length of this shoulder is shown and marked C in the side view; likewise the circle marked B represents the main portion of the roller —the length is indicated by the letter B in the side view.

Fig. 83A is known as a wobbler coupling and is used to connect the ends of two rolls. It is cored out to the special shape shown and fits over the end of the roll Fig. 83. The dotted lines represent various points or surfaces of the cored hole, also that this hole extends thru the full length of coupling.

## BEARING BRACKET

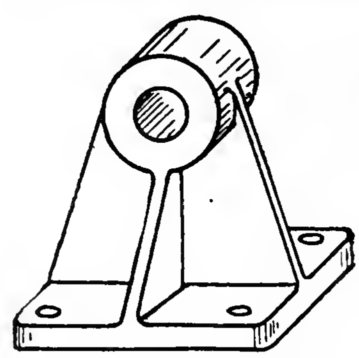


FIG-84

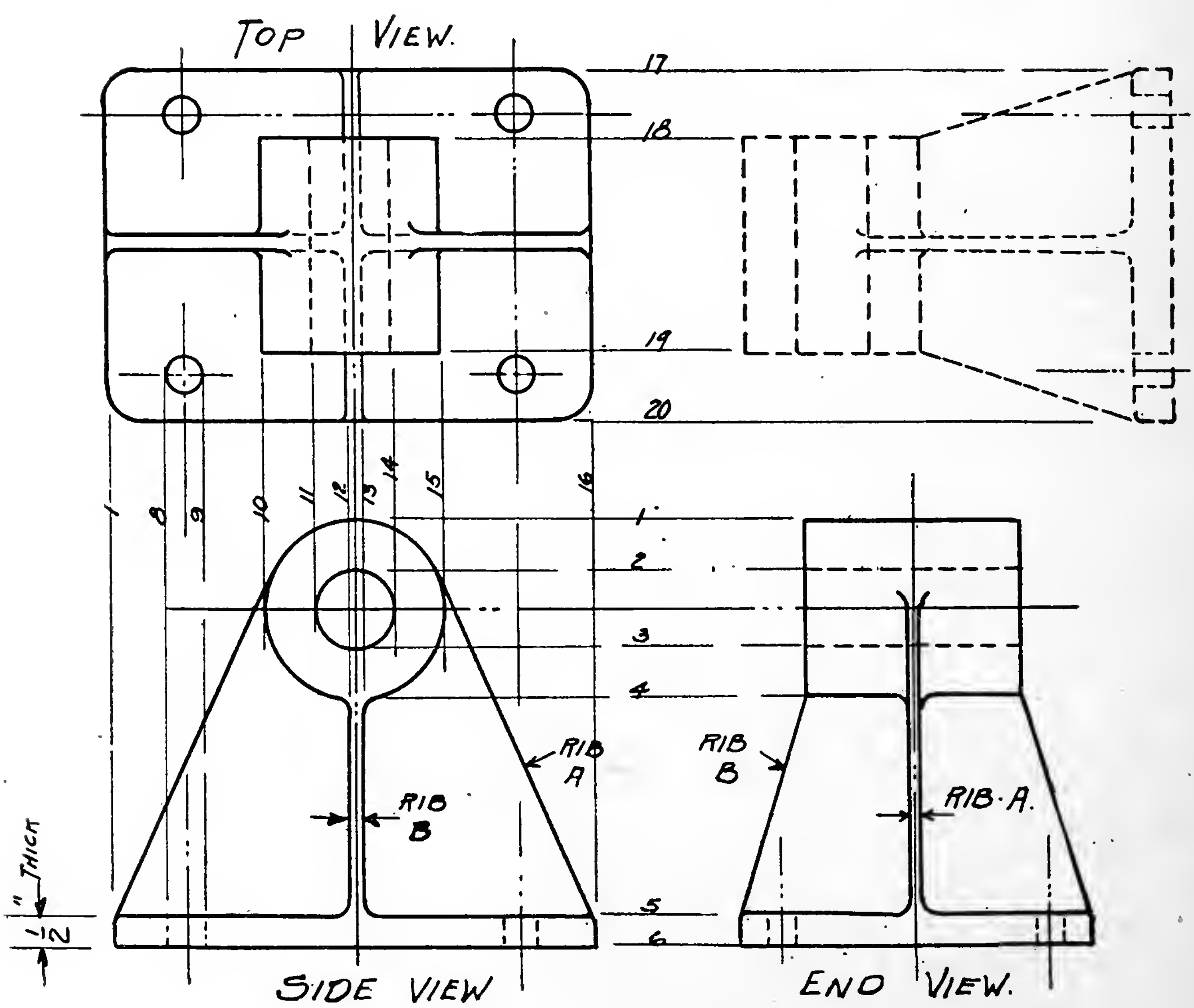



FIG-85

Fig. 84 is a perspective drawing of a bearing bracket and Fig. 85 shows this bearing bracket in working drawing views. Compare Fig. 44 with this figure and you will see that the upper portion of the side view is similar to Fig. 44, and the upper portion of the end view resembles the side view of Fig. 44. The upper portion (or bearing) is connected with the base by ribs marked Rib A and Rib B. On the end view you will again note the same designations Rib A and Rib B, which locate the ribs corresponding with those in the side view.

The base is a flat oblong surface, for convenience marked ½″ thick, having four holes—one in each corner. (See top view.) The horizontal lines between the side and end views marked 1, 2, 3, 4, 5, and 6, show the corresponding points of the side and end views, as for example:

Lines 1 and 4 show the height of the bearing, or its vertical diameter; the vertical lines between the side and top views marked 7 to 16 inclusive show the corresponding points of the side and top views. For example:

Lines 8 and 9 show the projection of one of the holes in the base.

Lines 10 and 15 show the width or horizontal diameter of the bearing.

Lines 7 and 16 show the horizontal length of the base.

The end view may be placed as indicated by the dotted outline, but it is customary to show it in the relation as here placed.—If it were placed in the dotted position, lines 17 and 20, also 18 and 19 would show corresponding points of the two views.

Lines 1 to 20 do not appear on drawings except perhaps as extension lines, but are shown here to assist in a clearer understanding of projecting one point to another view.

**Important**—From side view to end view, all corresponding points are projected horizontally; from side to top view all points are projected vertically.

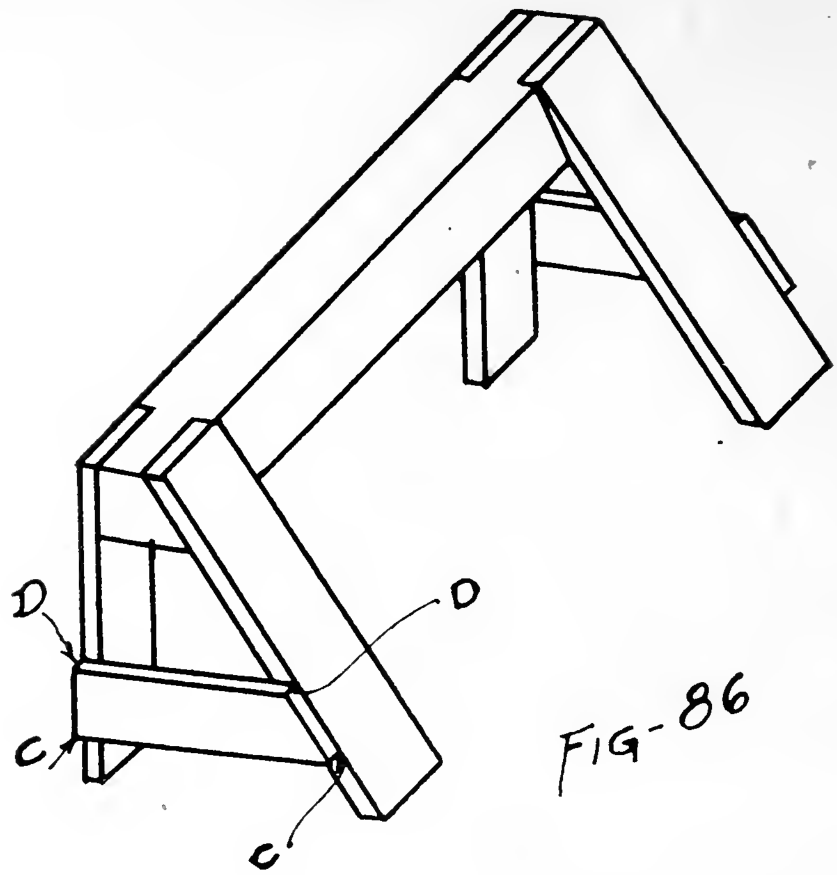



Fig. 86 shows a perspective view of a saw horse. No doubt you have seen one of these in reality in the shop and will experience no difficulty in understanding this figure.

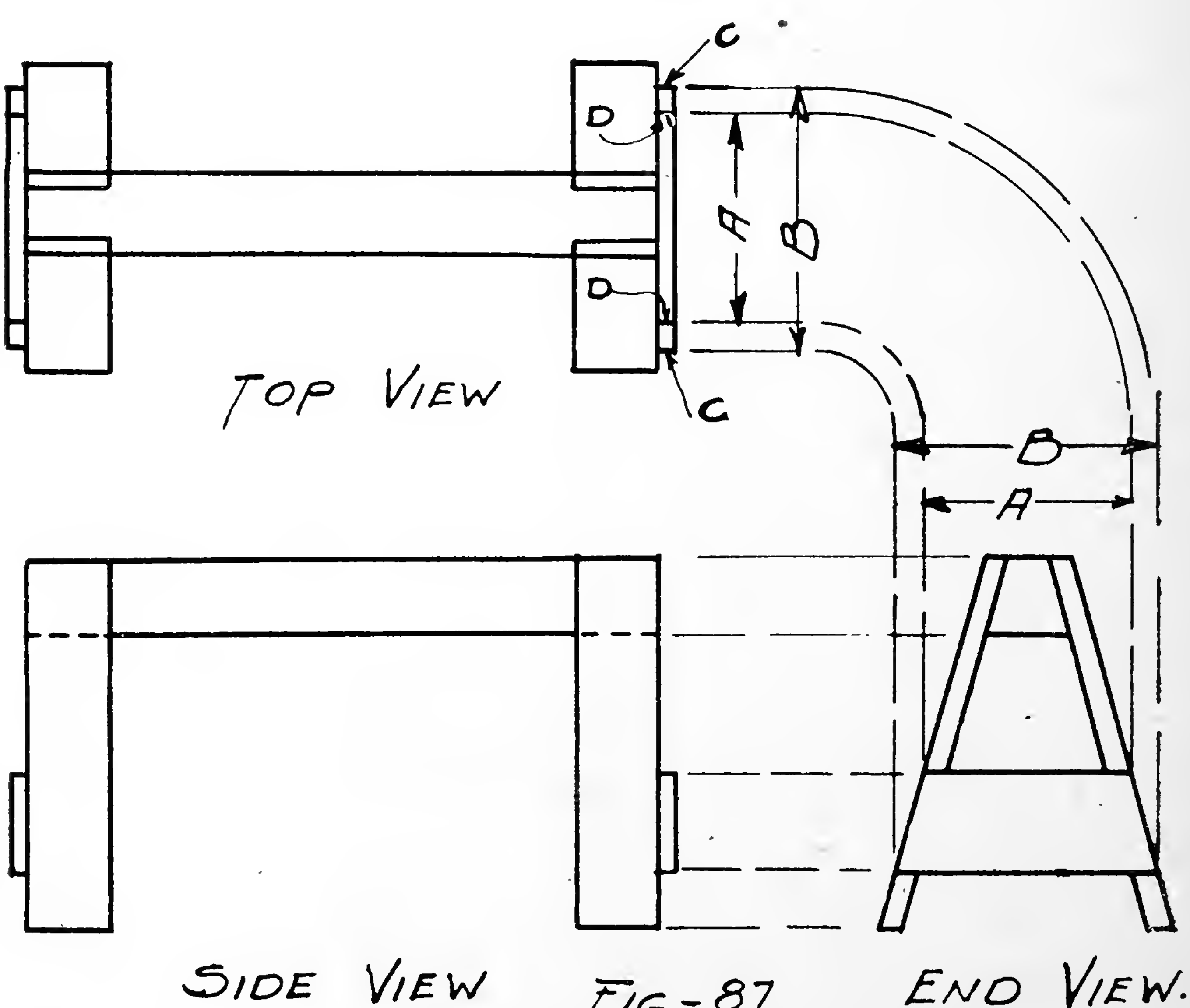


Fig. 87 shows the arrangement of several views of a working drawing of this same horse. Your attention is called to the relative position of the top, side and end views as previously explained. It is important that you understand the correct projection of each line from one view to another and it should be remembered that **every line** on a working drawing has its particular use and shows the correct projection of a surface or point from one view to another, therefore every line should be studied carefully to ascertain just what it represents.

The side braces of this horse are projected to the top view by the lines as indicated at A and B. It will be seen by looking at the end view that the cross brace is shorter along its upper edge than at its lower. This is also indicated on the top view by the lines C and D (see also Fig. 86). This is one illustration that each and every line on a view represents some particular surface or point on one of the other views.

The end view may have been placed in relation to the top view as indicated by the dotted outline in Fig. 85. Views may be rearranged, but the projecting of one view to another is always the same.

## MOLD FOR POURING BASIN.

Fig. 88 represents a cast iron mold used in making a pouring basin. A pouring basin is molded of sand and baked in an oven. It is used as a funnel for pouring the liquid metal into a mold. The drawing here shown is the cast iron mold for these pouring basins.

We advise projecting each and every point, etc., from one view to another by the use of a rule or straightedge—the projections being the same as all examples previously explained. The straightedge should be used horizontally between cross sectional and end views, and vertically between the cross sectional and top views.

**Note**—In reading this drawing, turn book so that the figure number is towards you. The cross sectional view will then be to the left of the end view.

**Remember** the general outline as well as the complete information can only be obtained by careful study of two or more working drawing views of an object.

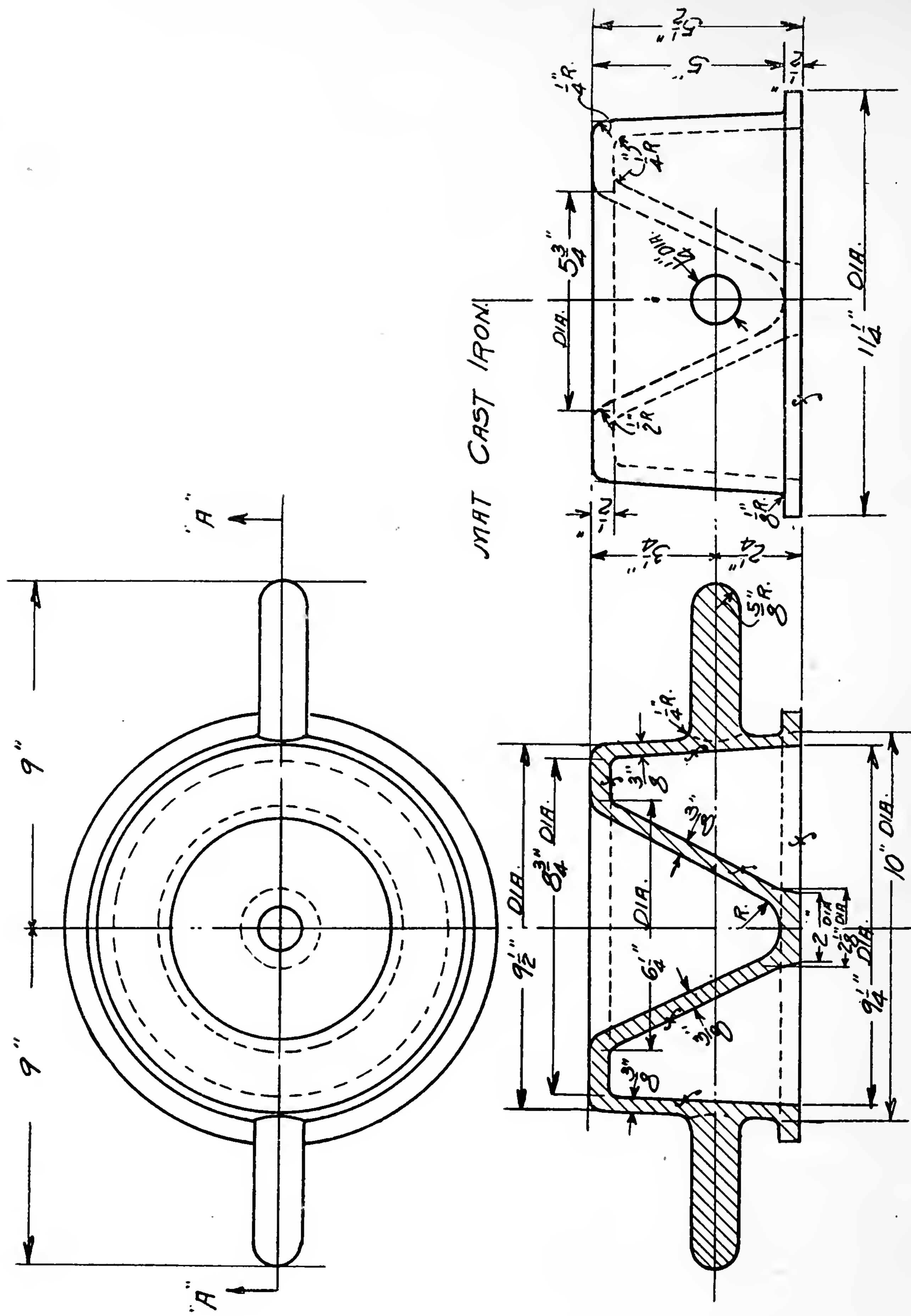



Fig. 88

The material used is cast iron—the crosshatching as well as the notation explain this.

In this working drawing the end view might have been omitted but then all dimensions now shown on it would have been placed on the cross sectional view. This may make the cross sectional view too congested with dimension lines, and therefore an end view is advisable.

Fig. 89. This drawing represents a friction disc used in the transmission of power from one wheel to another. We suggest that you make a careful study of this drawing, and try to picture or imagine the exact shape and size by comparing the dimensions given. Attention is called to the placing of the f mark and of the allowable variation dimension of 4.123″ ± .005″, the meaning of which has been previously explained. The use of the degrees is also illustrated here.

After you have carefully investigated this drawing to your entire satisfaction and are of the opinion that you thoroly understand it, we suggest that you make a perspective drawing and then turn to page 114 upon which is shown a photograph of this disc. By comparison you may readily test the power of your imagination.

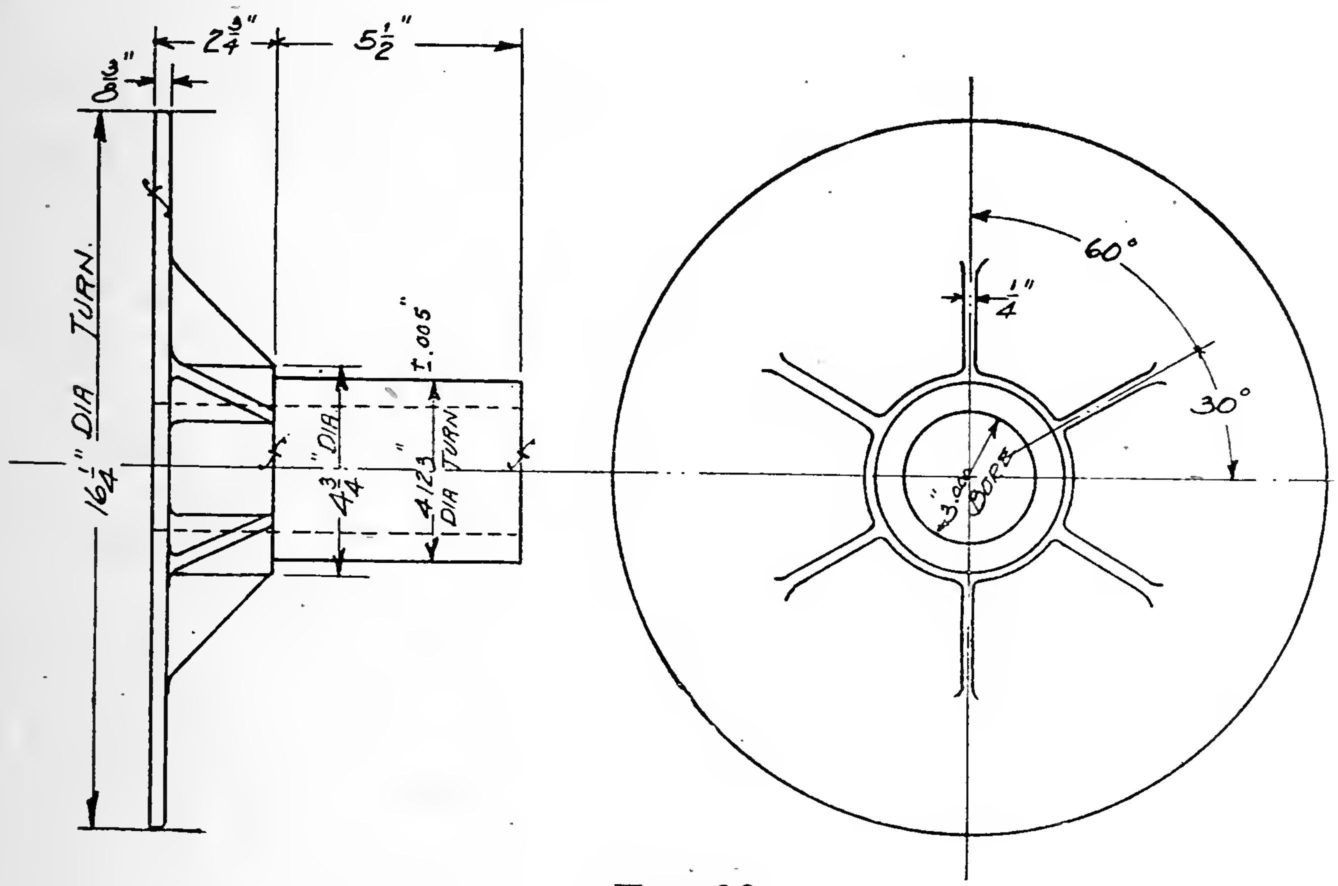



Fig. 89

This and the following drawings are shown expressly for practice in the reading of working drawings, and we earnestly recommend that you spend sufficient time on each figure to thoroly understand it, and if you have mastered the information contained in the previous pages, you will experience no difficulty in the reading of this drawing.

Free hand sketching showing working drawing views of simple objects is very good practice and you are earnestly advised to do this whenever possible. An ordinary table knife, the exterior views of an ink bottle, an empty spool, or house key, are only a few of the many simple objects which would afford excellent practice.

## EXAMINATION

## LESSON 10

1. Fig. 85. (a) How many holes are in the base of object?
   (b) Which single view shows all the holes in base?
   (c) If the top view had been omitted, would the side and end views give all the necessary information?

2. Fig. 89. (a) What is the thickness of the large circular disc?
   (b) What is the outside diameter of this disc in inches?
   (c) What is the total length of the casting?

3. Fig. 88. (a) What is the diameter of the outer circle shown in top view?
   (b) What is the vertical height of casting?

## LESSON ELEVEN

### CLAMP.

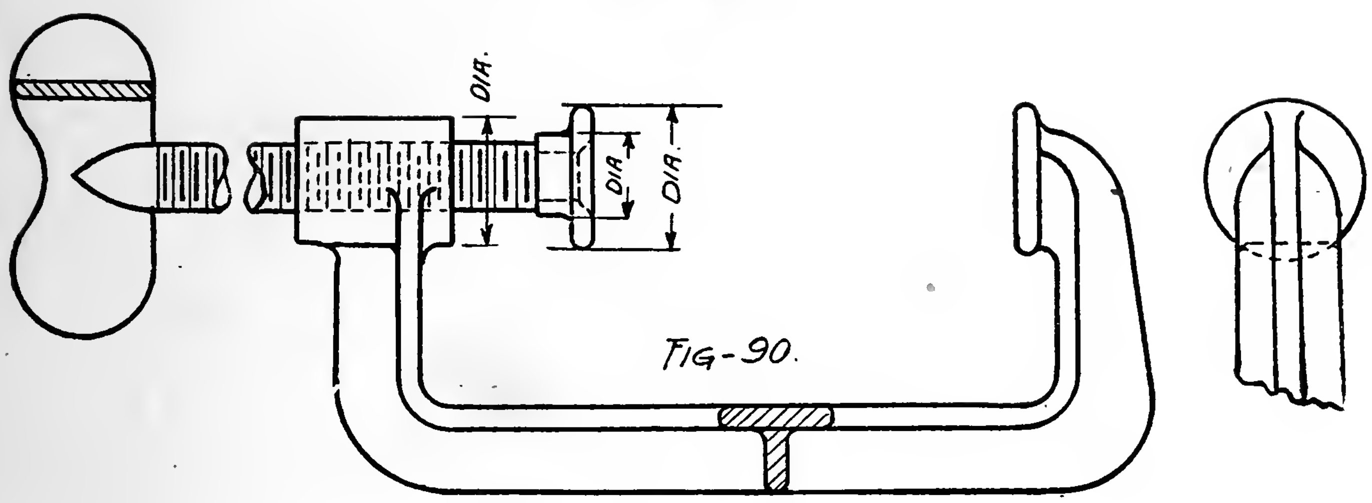



Fig. 90 represents a clamp and is shown to illustrate one method of placing a cross sectional view and the importance of a careful study of all **notations.**

There is no view on this drawing which indicates that the head (the part thru which the screw passes) is cylindrical, but the notation DIA. explains this likewise DIA. indicates that the head plate is circular, and therefore no other views are necessary.

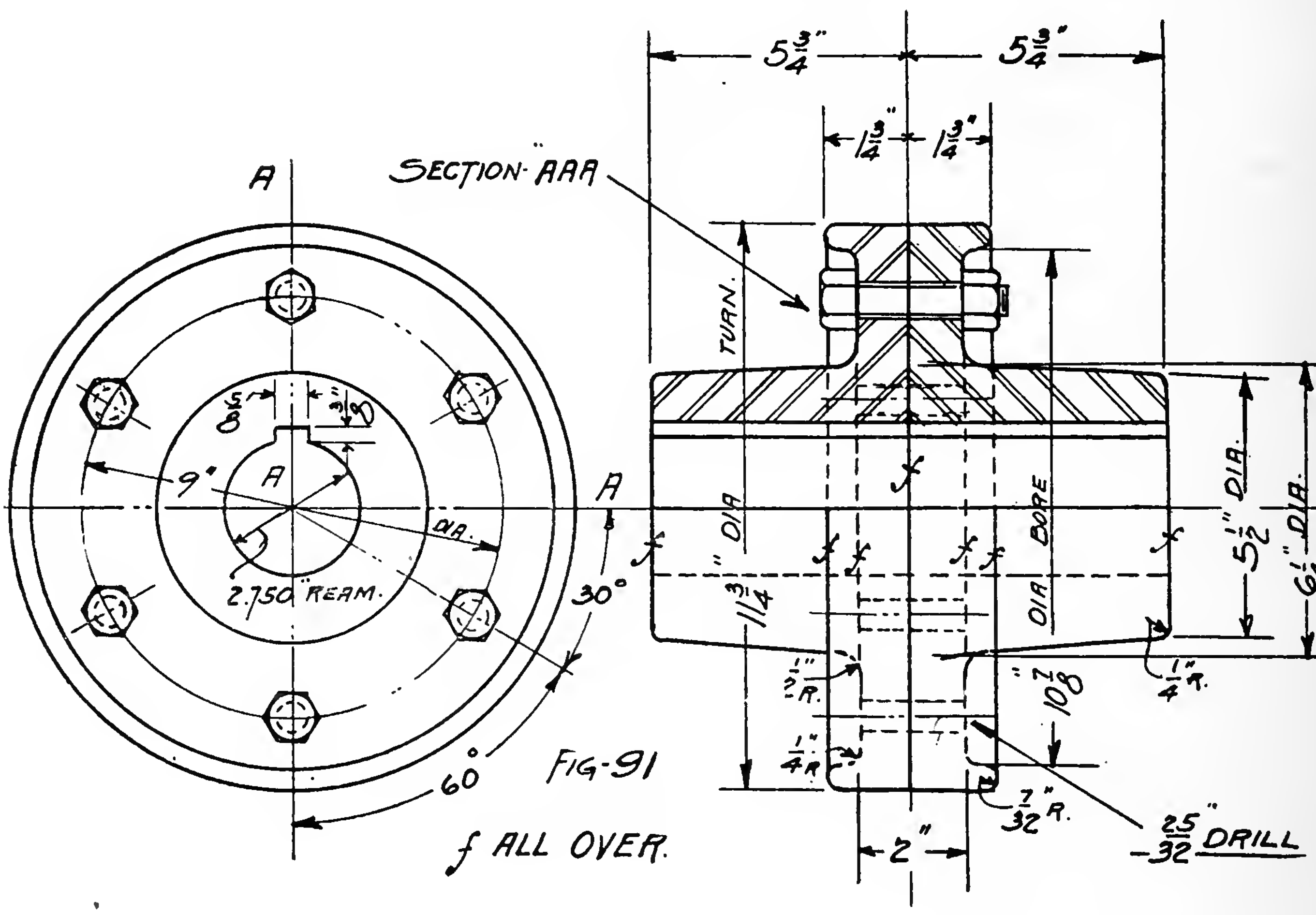
The cross section appearing on the wing of the thumb screw and frame of the clamp indicates the construction of these parts, and are practical illustrations of the text on page 62, the crosshatching indicating **cast iron.**

Two methods of representing threads are also shown—the alternate heavy and light lines represent threads of external view, and the alternate long and short dotted lines of even thickness indicate the threads in the head—shown dotted as they exist but are hidden from view.

The partial view at the right is called an **auxiliary view** as a portion only is shown to explain the construction of a certain part of the object proper.

# SHAFT COUPLING.

Fig. 91 represents the working drawing of a shaft coupling. Two views only are shown as all information necessary to fully explain this coupling is covered in these views. We suggest that you picture the general shape and outline of this coupling from drawing.




Your attention is also called to the construction of the center lines, the general outline (thickness of line), the crosshatching symbol, the use of the f mark, the section marked AAA indicating that the upper right hand portion of the front view is imaginarily removed to produce the upper half section of the side view.

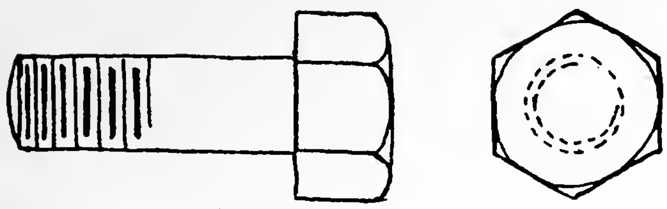
Referring to page 114 you will see a cut of this coupling and will readily be able to check your imaginative ability. Study all descriptive matter and notations. The spacing of the bolts is here shown as being 60° between each, indicating that the total number of bolts is six, as 360° divided by 60 equals 6.

The diameter of the outer circle is $11\frac{3}{4}''$; the width of the web is $2''$; the hub is tapered toward each end—each end being $5\frac{1}{2}''$ in diameter.

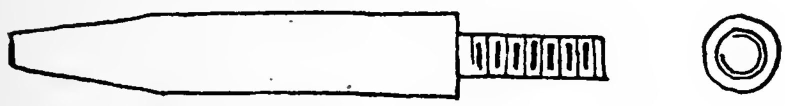
**Review**—A side view shows only that which can be seen when looking directly at the **side** of the object—the eye being in a **direct horizontal line** with each and every point of its surface and outline, with all depressions and extensions brought to the same plane. This also applies to an end view.

A top view is produced in the same manner, except that the eye, when looking at the object, is in a **direct vertical line** with each and every point of its surfare and outline.

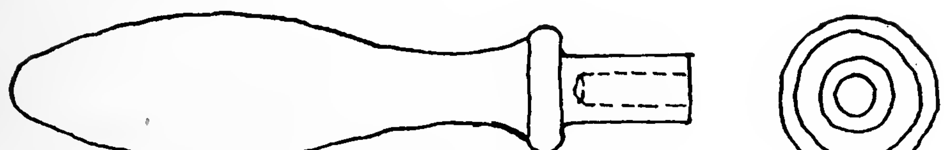
# FREE HAND SKETCHING.



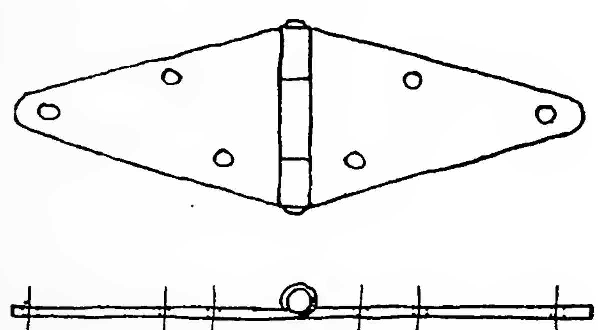
BOLT



FLASK PIN



HANDLE



HINGE

You may be called upon to explain certain operations of manufacture, details of machinery parts, placing of gates and risers, construction of cupola with suggestions for its improvement, or any other detail pertaining to the mechanical field. By being able to explain your point using an intelligently made sketch instead of motions with your hand, you will convey a much more convincing argument than would be possible otherwise; also it will add to your personal knowledge and prestige, therefore we suggest that you practice free hand sketching, taking some simple object and showing all views necessary to make the reading and understanding of the object possible.

A claw or ball hammer, pipe fittings, an ordinary wrench or any other object will afford good practice. We have shown a free hand sketch of an ordinary bolt, flask pin, handle and hinge.

# DIMENSION LETTERED DRAWINGS.

## ADJUSTABLE FLASKS.

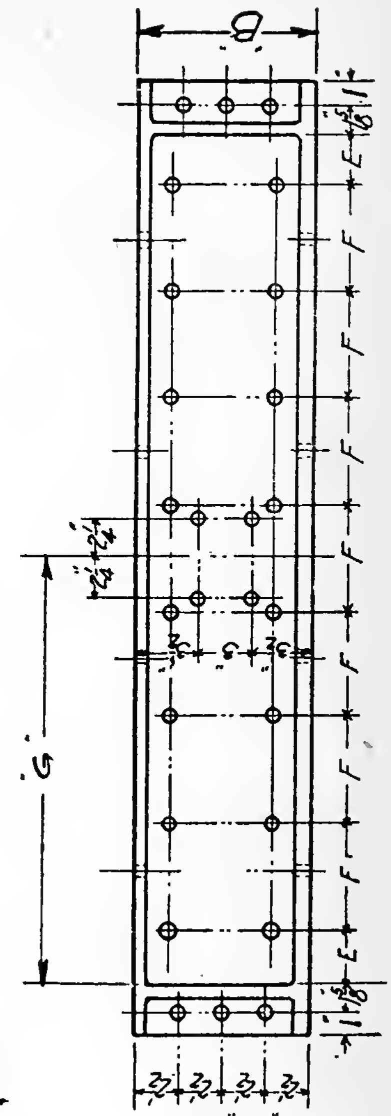
NOTE: ALL HOLES 11/16" CORE.

| A. | B. | C. | D. | E. | F. | G. |
|---|---|---|---|---|---|---|
| 48 | 10 | 6 | 12 | 3 | 6 | 24 |
| 54 | 10 | 9 | 12 | 3 | 6 | 27 |
| 60 | 10 | 6 | 12 | 3 | 6 | 30 |
| 66 | 10 | 9 | 12 | 3 | 6 | 33 |
| 72 | 10 | 6 | 12 | 3 | 6 | 36 |
| 78 | 10 | 9 | 12 | 3 | 6 | 39 |
| 84 | 10 | 6 | 12 | 3 | 6 | 42 |
| 90 | 10 | 9 | 12 | 3 | 6 | 45 |
| 96 | 10 | 6 | 12 | 3 | 6 | 48 |

AJUSTABLE FLASK.

MAT C.I.

FIG-92



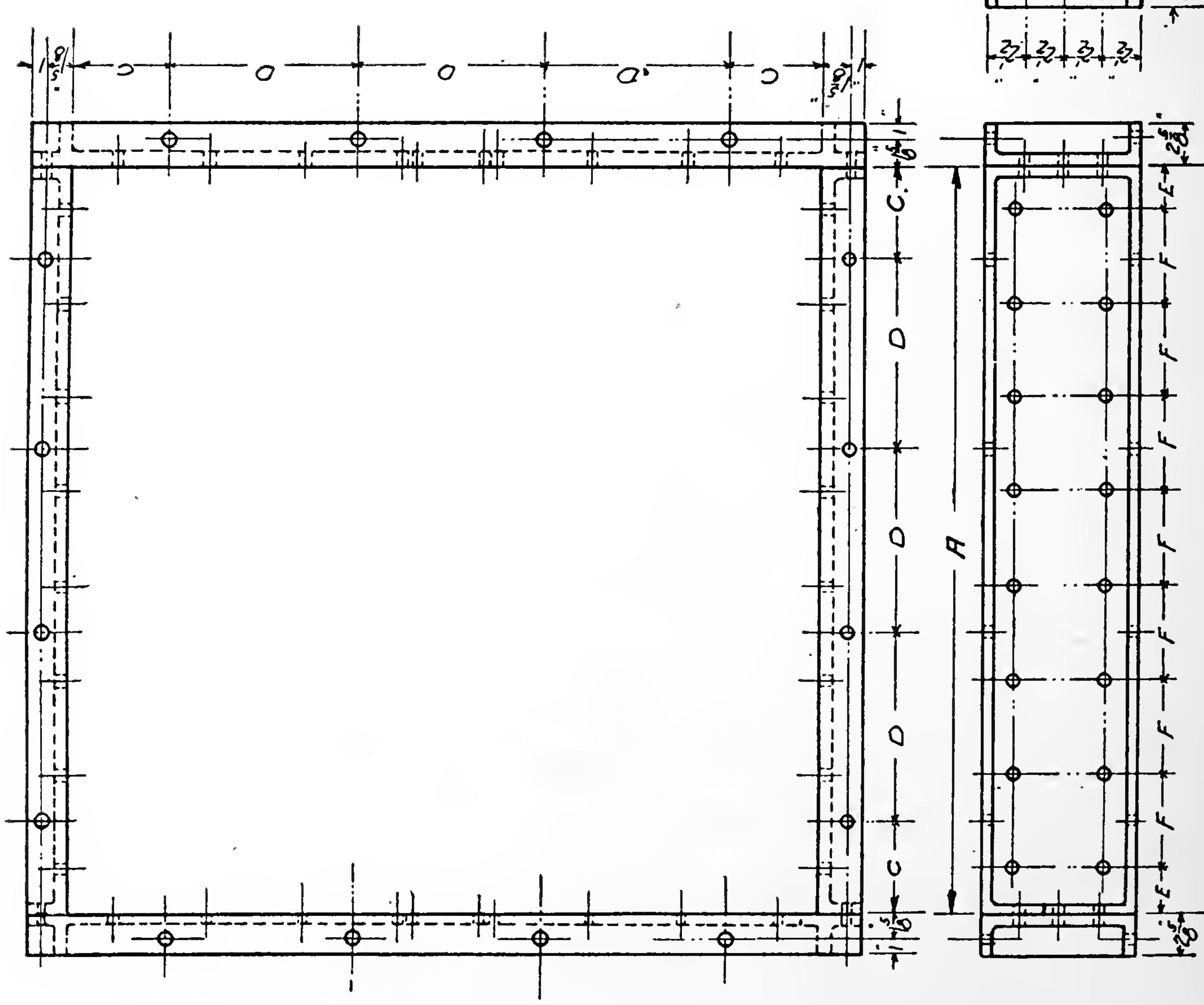



Fig. 92 is a working drawing of an adjustable iron flask used in the foundry, the various lines and points being projected from one view to another in the same manner as previously explained.

This drawing is shown expressly to illustrate the use of **dimension letters,** for example: Take letter A and by referring to the table it will be noticed that the dimensions in column A vary from 48″ to 96″, indicating that the length of flask may be made to any of these dimensions. However, all other corresponding dimensions, as B, C, D, etc., must lie in a horizontal line with the desired length

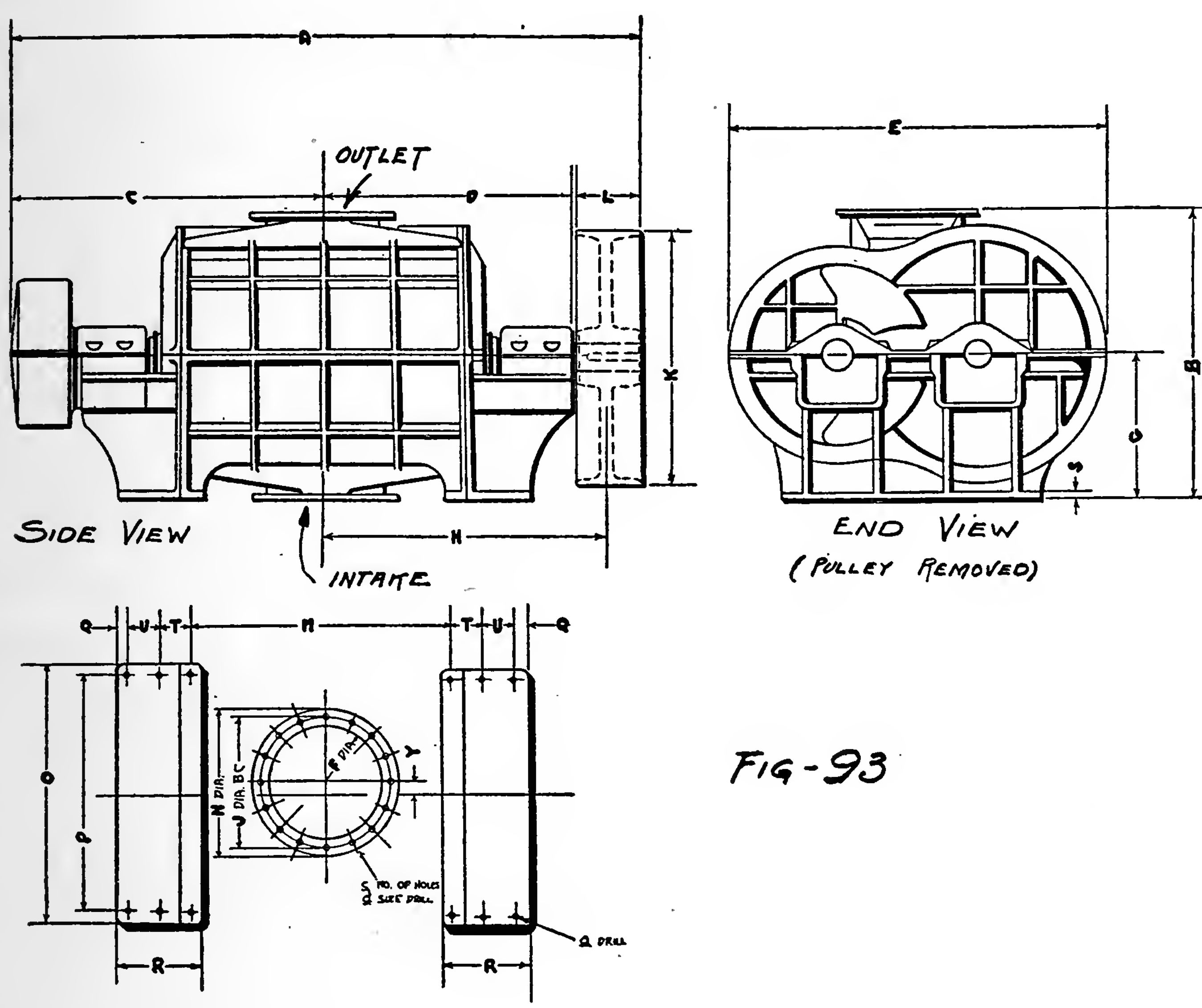



FIG-93

### TABLE OF DIMENSIONS

**All Dimensions are in Inches**

| Size No. | A | B | C | D | E | F | G | H | J | K | L | M | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | 120½ | 54½ | 59 | 47⅝ | 70¾ | 20 | 27¼ | 55¼ | 24½ | 48 | 12½ | 48¼ | 27 |
| 12 | 136⅝ | 62½ | 67 1/16 | 54 5/16 | 81½ | 24 | 31¼ | 62 5/16 | 28½ | 60 | 14½ | 55⅛ | 31 |
| 13 | 162¾ | 72 | 80 | 64⅛ | 95½ | 30 | 36 | 74½ | 35 | 66 | 16½ | 61½ | 37½ |

| Size No. | O | P | Q | R | S | T | U | Y | a | c | d | Shaft Dia. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | 47⅝ | 43⅝ | 2½ | 16 | 1⅜ | 5⅞ | 6 | | 1⅛ | 16 | ⅞ | 5 |
| 12 | 53⅝ | 49⅝ | 3 | 18¼ | 1½ | 6¾ | 7 | 2 3/16 | 1¼ | 16 | ⅞ | 6½ |
| 13 | 64 | 59½ | 3 | 23 | 2 | 7⅝ | 11 | 2½ | 1½ | 20 | 1 | 7 |

in column A. Let us assume we want to make a flask, the dimension A to be 78″—dimension B will then be 10″, C 9″, D 12″, E 3″, F 6″, and G 39″.

Fig. 93 on page 99 is another illustration showing the use of a "dimension lettered drawing," this being a Sturtevant blower used for supplying air to a cupola.

A side, end and auxiliary views are shown. At the right hand end of side view you will note a pulley is shown; by referring to the end view it will be seen that this pulley has been omitted—this is done to explain the construction of some detail back of the pulley.

The auxiliary view at the bottom is not a complete bottom view, it shows only the size and number of bolt holes in the feet and intake flange.

The over-all length of blower for a No. 13 size is 162¾″ and the over-all height is 72″.

**Note**—Refer to the drawing and locate all the letters and their dimensions.

The use of dimension lettered drawings eliminates the necessity of making a separate drawing for each size.

## WORKING DRAWING OF BEARING.

Fig. 94 represents a working drawing of a special bearing. The working drawing views of this bearing consist of a side, end and bottom view. This is the first illustration in which a bottom view is shown. As explained the bottom view is placed at the bottom of either side or end view (in this case at the bottom of the side view), and the various points have been projected vertically from the bottom to the side view.

Attention is called to the construction of the center line—it being a long dash with **one** short dash, in all previous drawings shown as a long dash with **two** short dashes. The center line is here shown thus to illustrate that a deviation from the regular practice may be met with.

Referring to the bottom and side views one method of indicating a tapped hole is here shown (also see page 65, Fig. 62).

The notations "¼″ drill for No. 5 taper pin" also "17/32″ drill, ⅝″-11 tap," appearing at the right hand of the bottom view, explain these two operations. It will be seen that the arrows are directed to one of each of these holes, however, there are two of each shown in the bottom view. In the reading of working drawings it is always understood that any notation explaining a part or operation also applies to all similar parts or operations on the object, therefore it is **not** necessary that explanatory notations appear at each.

The distance between the two horizontal dotted lines in the side view is 2.00″ ± .001″. This represents the bore.

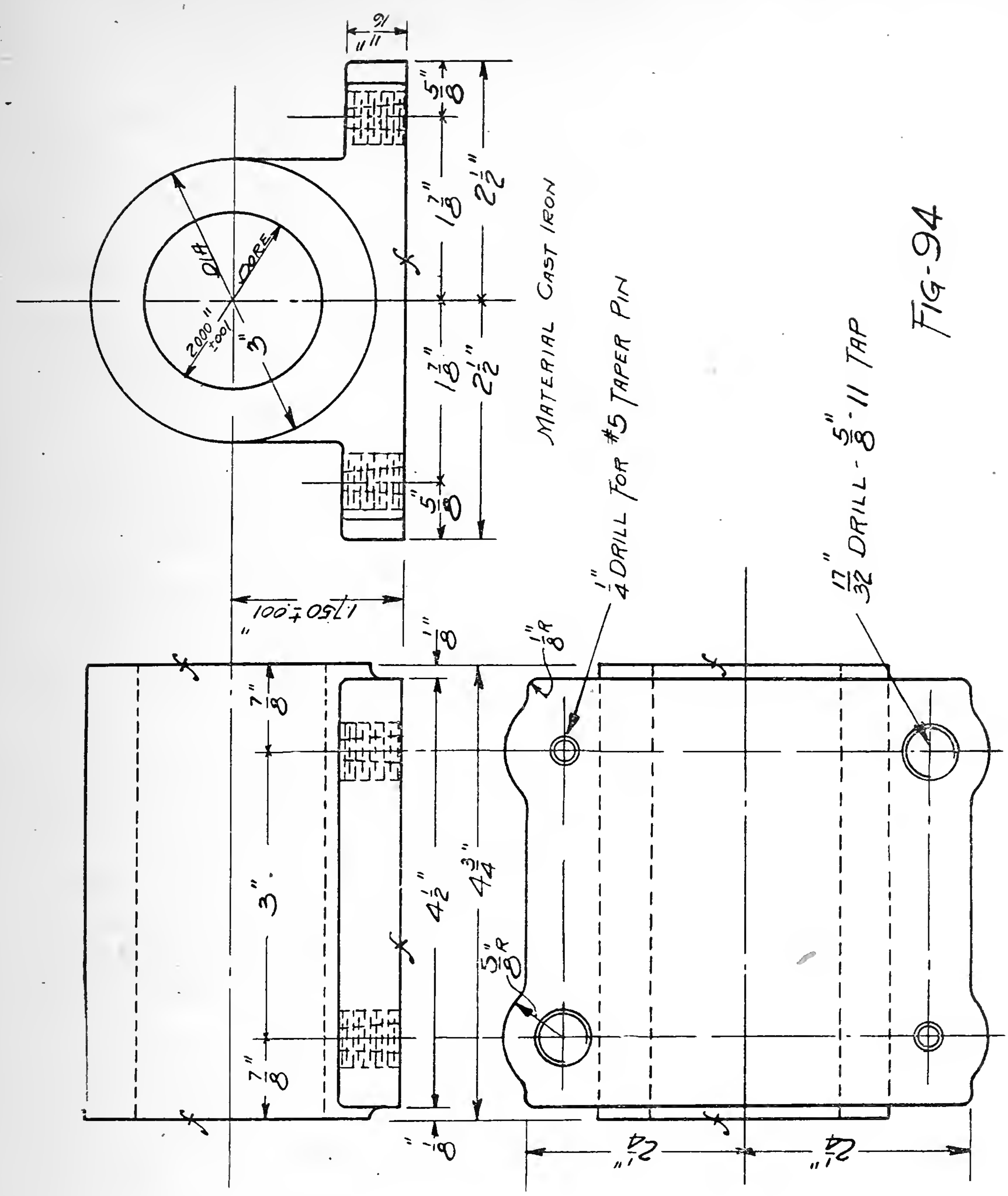



FIG-94

## SPECIFICATIONS

In some instances one sheet may have the details of several pieces shown on it.—This is done to keep the details of corresponding component parts together and to economize on materials—such as paper and tracing cloth. However, in some shops it is the usual practice to show the working drawing views of only one object on a sheet, and the drawings showing its component parts are listed on a separate sheet called a **specification.**

Specifications usually mention all the miscellaneous materials which are necessary to complete the machine, giving number required, size and material for each item separately—such as bolts, nuts, screws, washers, cotter pins, etc.

## EXAMINATION

## LESSON 11

1. Fig. 91. (a) What is the length of the coupling?
   (b) What material is coupling to be made of?
   (c) What is the diameter of bolt circle?
   (d) What is the size of hole thru which these bolts pass?

2. If it is desired to make a flask as shown in Fig. 92, 7 feet square on the inside, give all the other dimensions which would correspond with this size.

3. Fig. 93. (a) What are the over-all length, height and width for a No. 11 blower?
   (b) What is the size of holes in the intake flange for a No. 13 blower?
   (c) What is the dimension for diameter and face of pulley for a No. 11 blower?

4. Fig. 94. (a) What is the size and kind of hole shown in the upper left hand of the bottom view?
   (b) What is the length of the bored hole marked 2.00″ ± .001″ in the end view?

# LESSON TWELVE

## PRACTICE READING.

The reading of working drawings is a comparatively easy matter if you will resolve each portion of the object represented into its respective surfaces and locate the various outlines as they are shown in the different projections. If this is found a difficult task, the surfaces may be further resolved into lines and points, whose respective positions may then be located in each view shown.

Practice reading and free hand sketching of simple objects showing **working drawing views** will be of great value to you. Working drawings of practical objects with an explanation of the important points are shown in the following lessons. It will be excellent practice to make a free hand sketch representing a view not shown on the illustration. For example, if a side and end view are shown on the illustration, draw a top or cross sectional view.

It is not to be expected that the position of every surface in a complicated drawing will be seen by the beginner at a single glance—an expert seldom acquires such proficiency—but as "practice makes perfect," you may, by careful study of the various positions of the surfaces composing the solids that are projected in the following problems, easily accustom yourself to the more or less complicated projections found in the various mechanical and architectural journals, in shop drawings, or in such other projection drawings within your reach.

The work covered in these lessons is for practice in reading a working drawing, and it will be to your advantage to understand the projection of **all** parts, points and lines from one view to another. Remember all drawings require more or less study to understand them and the understanding of an object is possible only by a thoro study of **all** of its views, therefore **study these pages** very carefully.

The rules for reading working drawings should be referred to from time to time, so that you will become thoroly familiar with them.

The various examples and illustrations shown are general, and a deviation from this practice will be met with.

In this lesson is shown and explained the reading of practical working drawings and again we advise you to use the straightedge in the various projections if in doubt or if the eye has not become sufficiently trained to substitute the straightedge.

We suggest that **each and every line and point be projected** from one view to another. This practice is absolutely essential in order to acquire **accuracy** in the reading of working drawings.

Concentrate on what you are reading and do not attempt to study unless you can do so **undisturbed.**

## REVIEW.

1. The line of vision must be in a direct horizontal line with all points along its height, length or width for horizontal projections; and in a direct vertical line with all points along its length and width for vertical projections. (See page 20.)

2. All depressions and extensions must be brought to the same plane. (See page 20; also illustrated in lesson 8.)

3. Each view represents that which can be seen when looking directly at the object, with a view representing only **one** of its faces—a side, an end, the top or bottom visible at a time.

4. No single view will give all the information necessary to explain the object (except very simple objects), therefore two or more views of an object must always be studied.

## BEARING CAP.

Fig. 95 represents a complete working drawing of a bearing cap, with all the necessary dimensions for its construction properly placed. The three views shown are side, top and end—the end view being placed to the right of the top view.

As explained in Lesson 3 Figs. 21 and 22, all points or surfaces are projected **horizontally** when views are placed to either **right or left** of a corresponding view, and all points or surfaces are projected **vertically** when a view is placed either above or below a corresponding view.

Three center lines are shown between side and top views. The center one indicates the center of the cap proper and those on each side show the corresponding center of the two end projections. The method of analyzing this drawing is as follows:

Looking at the side view, it will be seen that the general outline is in the form of a half circle with a projection at each end. The top view will show that these projections are round, having a hole thru them which corresponds to the dotted lines in the side view.

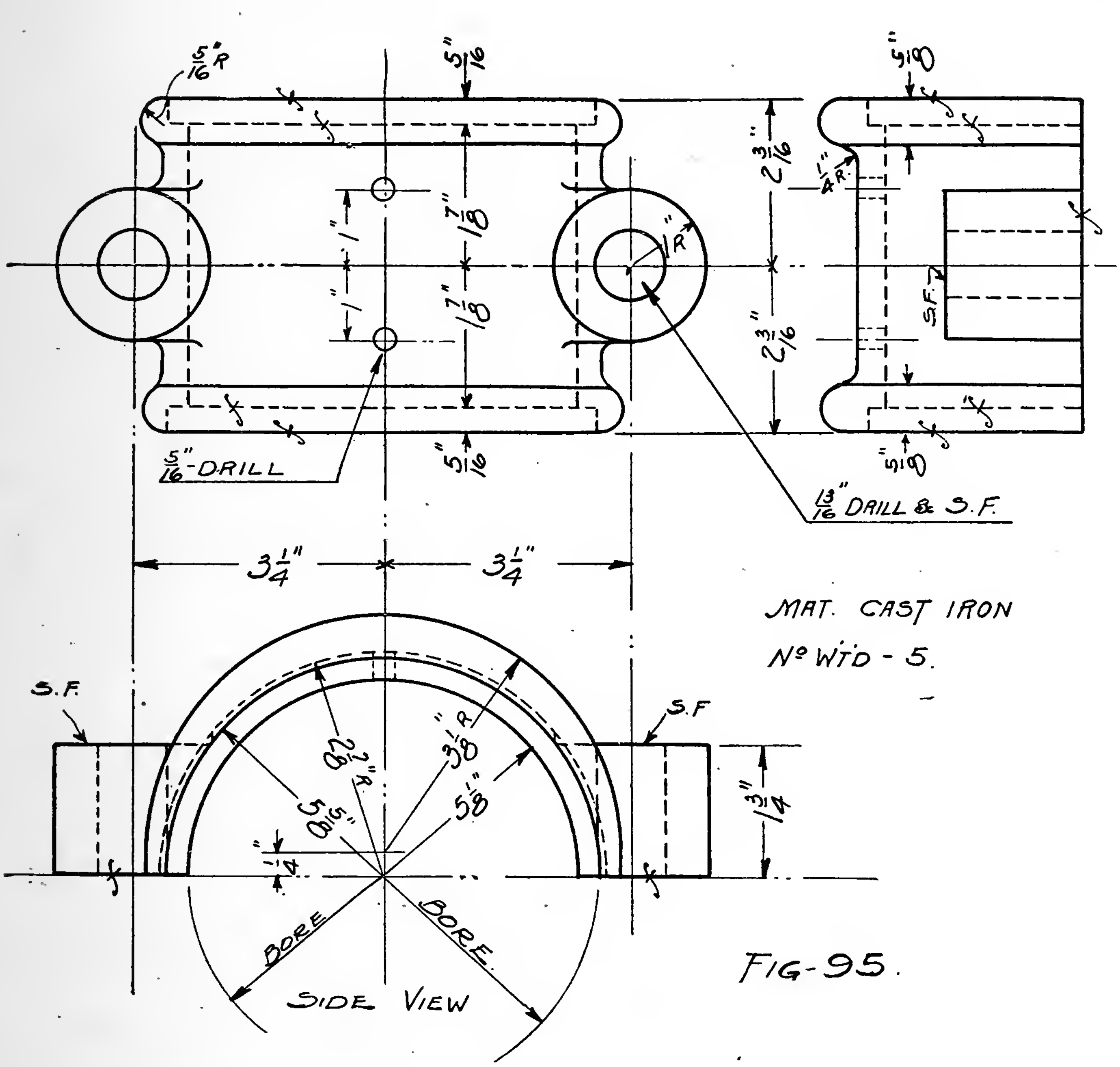
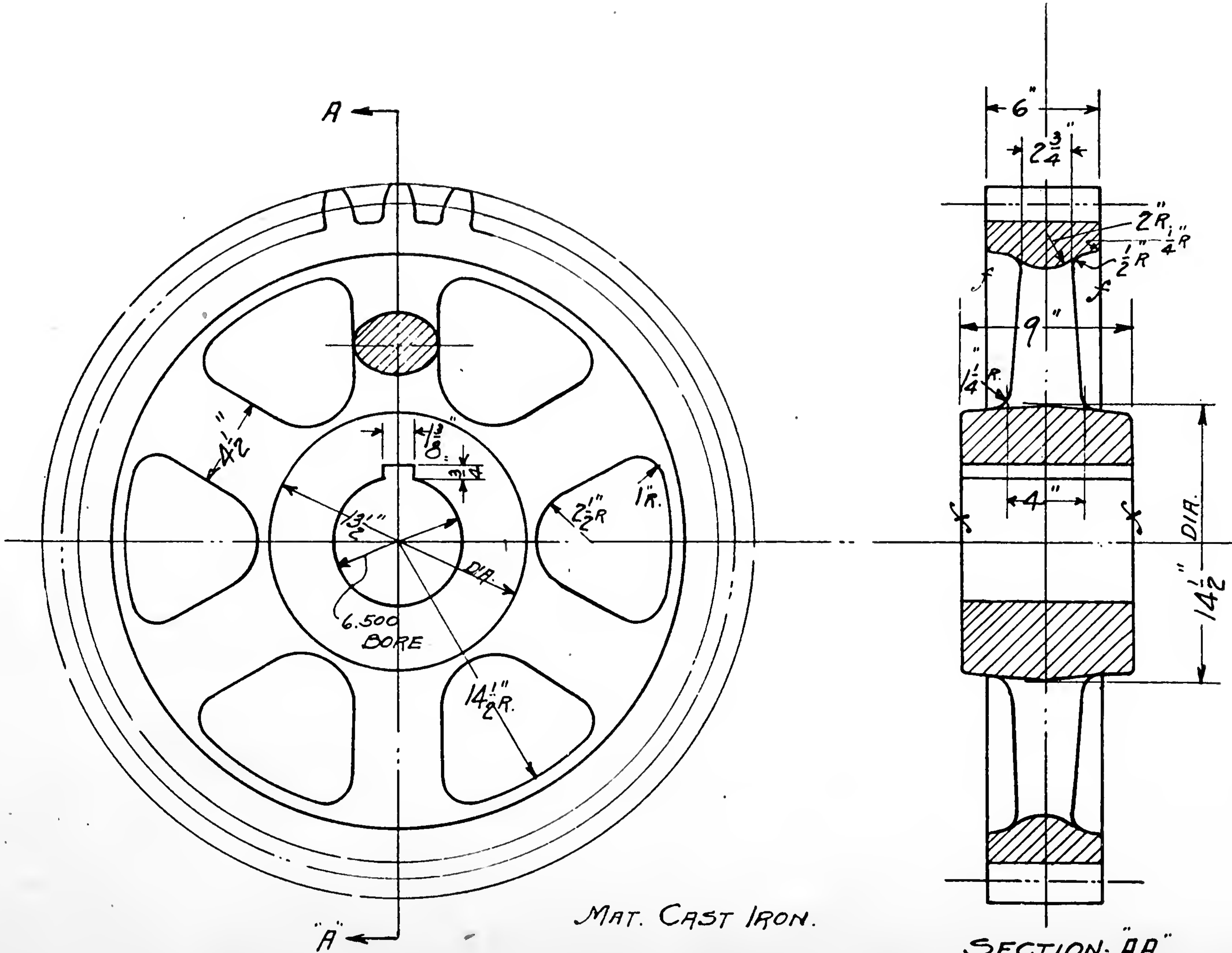



FIG-95.

The top view also shows that the half circular portion is $4\frac{3}{8}''$ wide having an enlarged projection around its outer edge—the radius of which is $3\frac{1}{8}''$ (see side view).

The end view shows these enlarged projections as being $\frac{5}{8}''$ wide.

The two $\frac{5}{16}''$ drill holes are shown dotted in the end and side views, but the holes being in line (see top view) only permit one being shown in the side view. The top and end views explain that there are two holes, placed 2″ apart (see top view).




| TOOTH DATA. | |
|---|---|
| No. OF TEETH | 37 |
| DIA. PITCH. | 1.00 |
| PITCH DIA. | 37" |
| OUT. DIA. | 39" |
| BOTTOM DIA. | 36.685" |
| CUT TEETH. | — |

FIG-96.

## GEAR WHEEL.

Fig. 96 is the working drawing for a gear wheel having six oval arms.

The cross sectional view marked section AA shows the outline of the rim, arms and hub. Your attention is again called to the fact that the arms are not shown covered with crosshatching. As previously explained, it is customary not to crosshatch arms altho the imaginary cut is taken thru them but strictly speaking, they should be crosshatched.

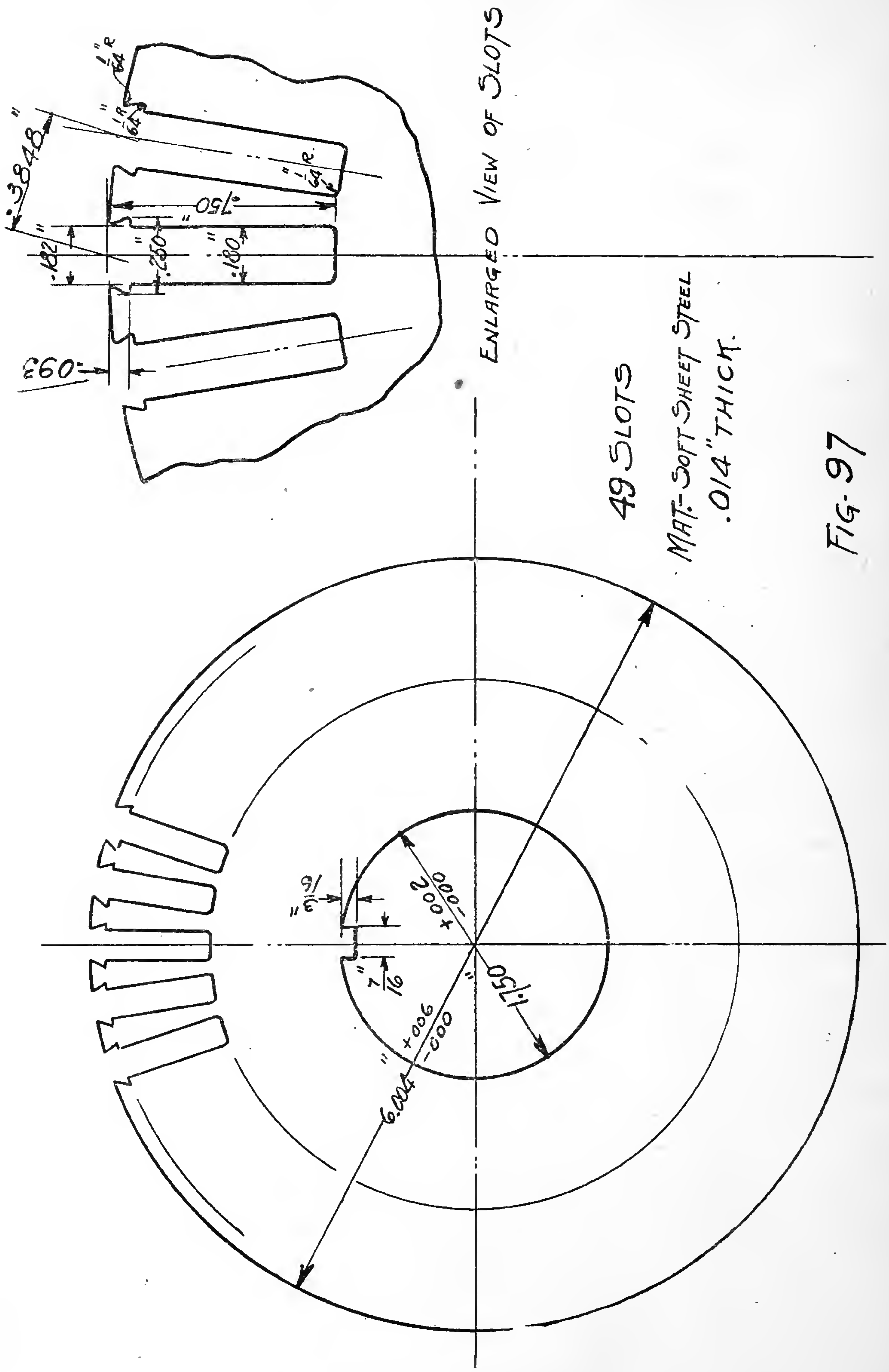
Referring to the front view, note the oval outline which is crosshatched and directly on one of the arms. This indicates the shape of the arm. In some instances the arms are made rectangular and in that case a rectangle would be shown and crosshatched, instead of the oval.

It is not necessary that the total number of teeth be shown, for instance in this case only three are indicated, and sometimes not any are shown. The tooth data or table shown at the right gives the information necessary for cutting these teeth, namely the total number of teeth, the diametrical pitch which gives the number of teeth for each inch of pitch diameter. The pitch diameter is the diameter of the circle which passes approximately midway between the outside diameter and bottom diameter of the tooth. The bottom diameter is the diameter at the bottom of two teeth, diametrically opposite.

When it is desired that the teeth be cast instead of cut, it is customary to show an enlarged view of two or more teeth, giving the necessary dimensions so that pattern maker can make the teeth accordingly.

Form a mental picture of the general outline, etc., then refer to page 114 upon which is shown a cut of this same gear.

The bore is given as 6.500″ or might have been written 6½″.



Enlarged View of Slots
.3848"
1/64" R
1/64" R
1/64" R
.750"
.182"
.250"
.180"
.093"
49 Slots
Mat- Soft Sheet Steel
.014" Thick.
3/16"
7/16"
2" +.002 -.000
1.750"
6.004" +.006 -.000


Fig. 97

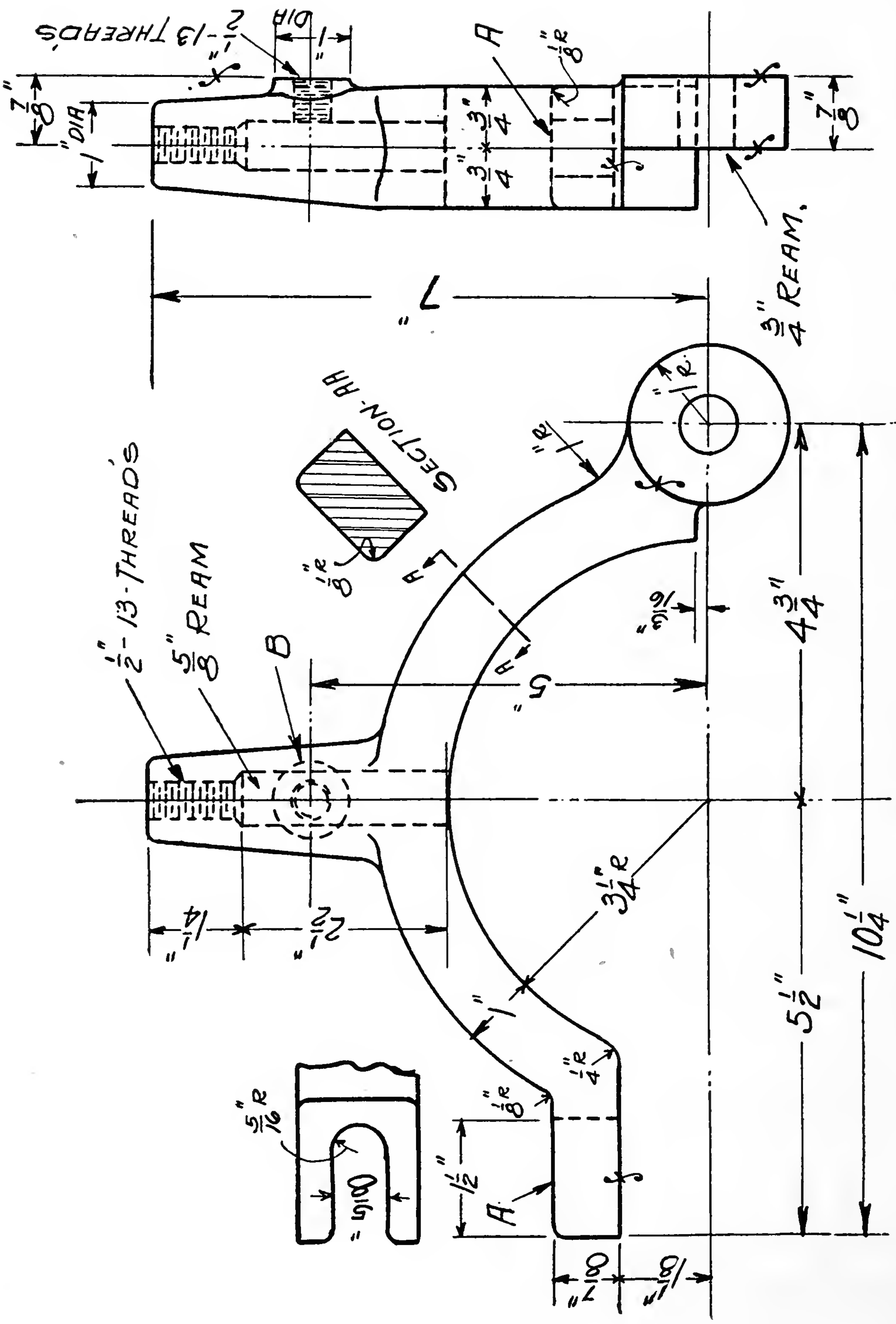
## PUNCHING.

## SINGLE VIEW DRAWINGS.

Fig. 97 represents a working drawing of a punching, such as is used for the magnetic field of small electrical motors. The copper winding is woven into the small slots having contracted openings at their outside circumference. When a certain detail on drawing becomes so small that it is impossible to clearly show the outline with its respective dimension, it is customary to show an enlarged view of that particular detail—an example of which is given by the enlarged view at the right. This view is drawn to a considerably larger scale than the punching proper which enables the mechanic to more readily see the general outline of the slot and its dimensions.

## ILLUSTRATING THE USE OF LIMIT DIMENSIONS.

It is only necessary to make one view of this punching as the thickness (.014″) is mentioned on the drawing. Attention is called to the placing of the limit dimensions as this is a good example of their use. The dimension 6.004″ being the outside diameter, is the ideal dimension; if, however, it were made .006″ larger it would still be accepted, but if it were made smaller than 6.004″, it would be rejected.




MATERIAL - SEMI STEEL

FIG-98

## CENTER REST TOP.

Fig. 98. This casting illustrates the use of dotted lines, the representation of threads and the use of the f mark. Attention is called to the boss shown at B on the side view. It is indicated by a dotted circle as it projects beyond the rear surface of object. By referring to the end view you will notice that this boss projects $\frac{7}{8}''$ from the center line of the object and is marked 1″ dia. The dotted lines thru it represent a tapped hole.

The round boss marked 1″ R. and shown at the **right hand of the side view** is not the same thickness as the casting proper and in vestigation of the end view will illustrate this and show that this thickness is $\frac{7}{8}''$.

Attention is called to the proper projection of the surface marked A on the side view, to the end view—the letter A representing the same surface in both views. By projecting horizontally each point or line on the side to the end view, you will readily understand the correct projection.

The notation $\frac{1}{2}''$—13 threads indicates that this hole is to be tapped with a $\frac{1}{2}''$ tap having 13 threads per inch. The 1″ diameter dimension at the top of the end view indicates that this projection is cylindrical. If the notation "DIA" had been omitted, it would have been necessary to show a top view as there is nothing on either view indicating the shape of this projection.

The importance of a careful study of all notations is here illustrated.

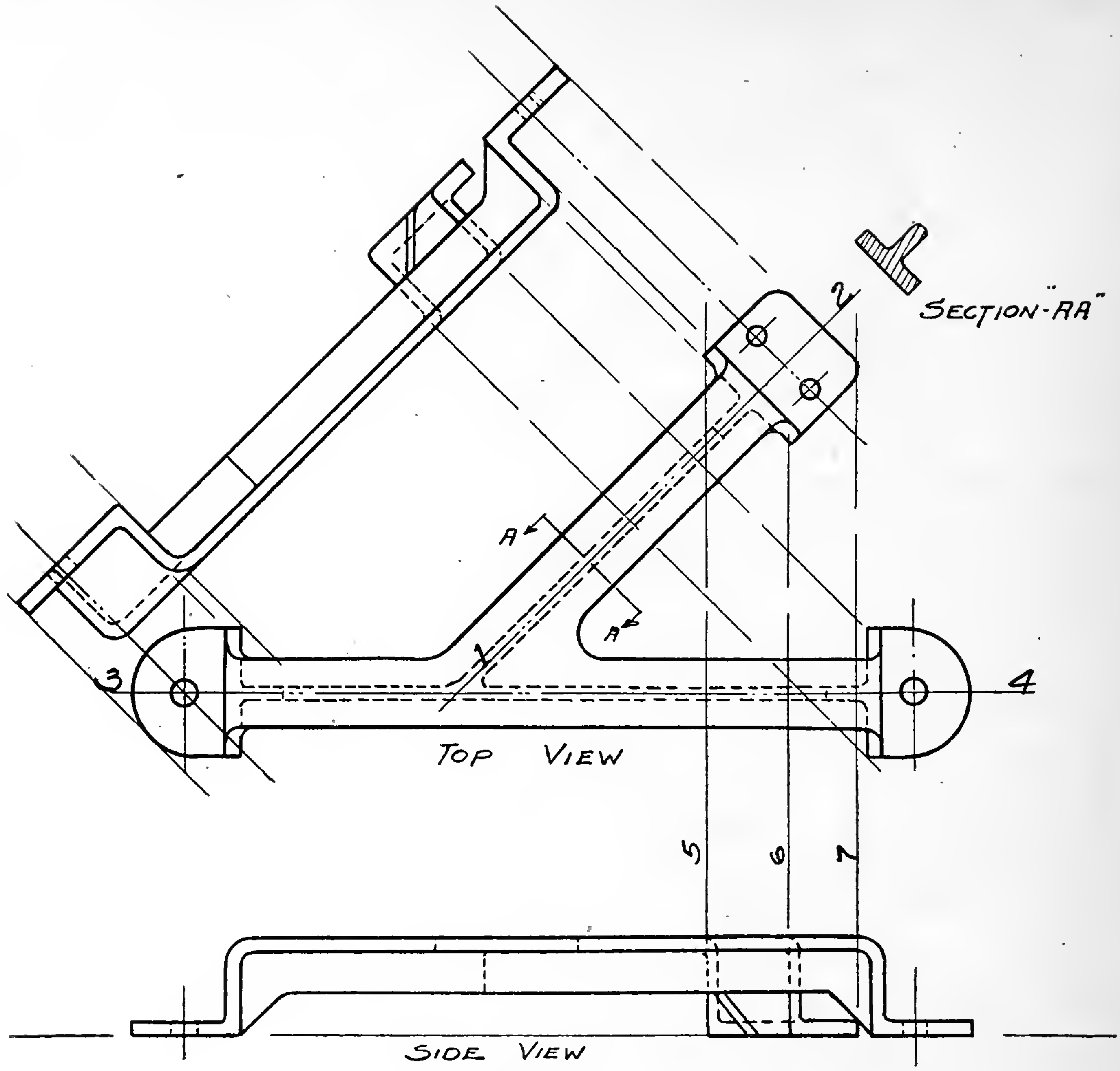


FIG-99.

## ANGULAR PROJECTIONS.

In all previous illustrations, the views were placed either horizontally or vertically in relation to one another. However, in Fig. 99 the projection of a view is illustrated on an angle with another. This is done to show the true projection of the arm 1—2.

The projection of the arm 3—4 is shown directly under it. It will be noticed that the lines 5, 6 and 7 project the various points from the arm 1—2, and it will also be seen that a true view is not obtained by this projection, therefore the angle projection of arm 1—2 is employed to show its correct construction.

The cross section marked "Section AA" shows the construction of arm proper at the point where line AA passes thru it. However, no further cross section or notation appears to indicate the shape of the arm at any other point in its length, therefore it is understood that the shape is the same thruout its length. To illustrate, the shape of arm 3—4 is the same as arm 1—2.

The diagonal lines between the angle projected view and top view indicate the corresponding points projected.

## EXAMINATION

### LESSON 12

1. Fig. 95. (a) What is the height of the end projection or lugs, which are 2 inches in diameter? (See top view.)

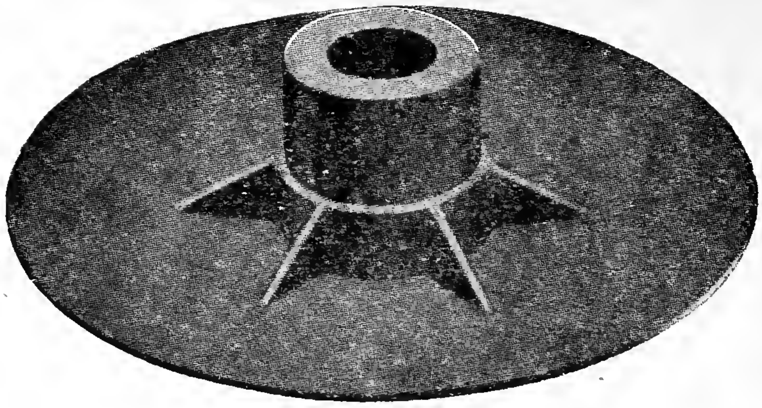
   (b) What is the thickness of metal thru which the two 5/16-inch drill holes pass?

2. Fig. 96. (a) What is the length of hub?

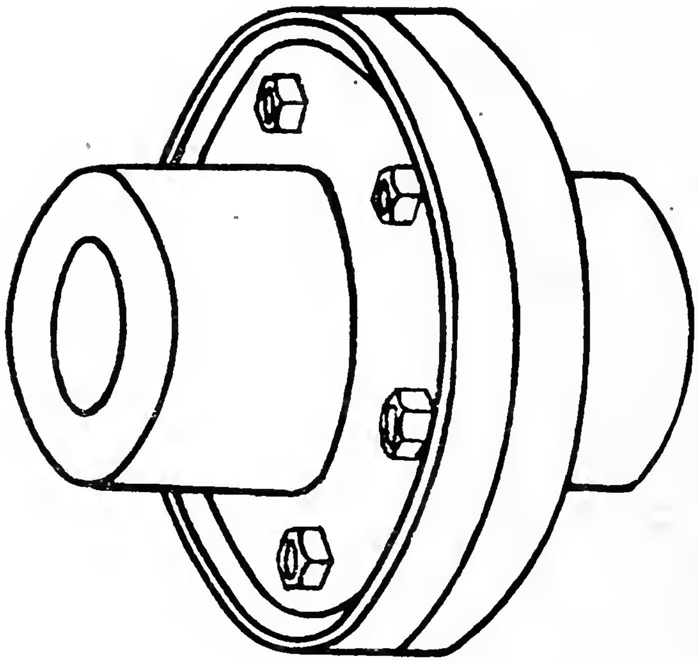
   (b) What is the size of bore in hub?

3. Fig. 98. (a) How many tapped holes are in this casting and what size are they?

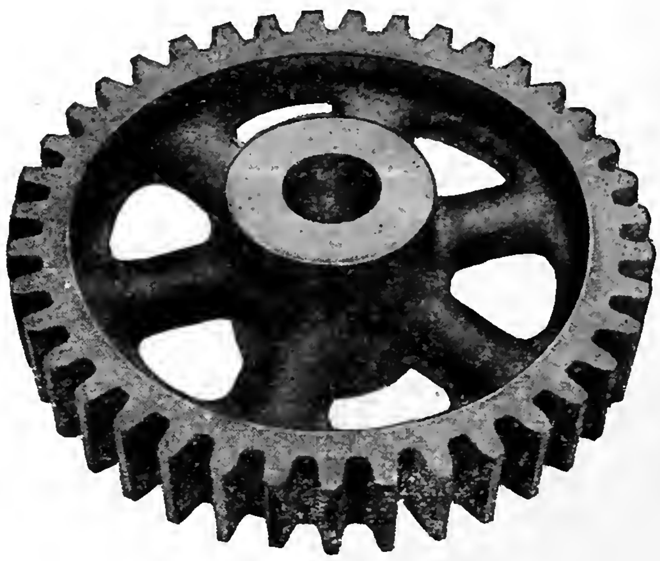
   (b) How many reamed holes and what size are they?



The working drawing of this friction disc is shown on page 93.



The working drawing of this coupling is shown on page 96.



The working drawing of this gear is shown on page 106.

# LESSON THIRTEEN

## PISTON.

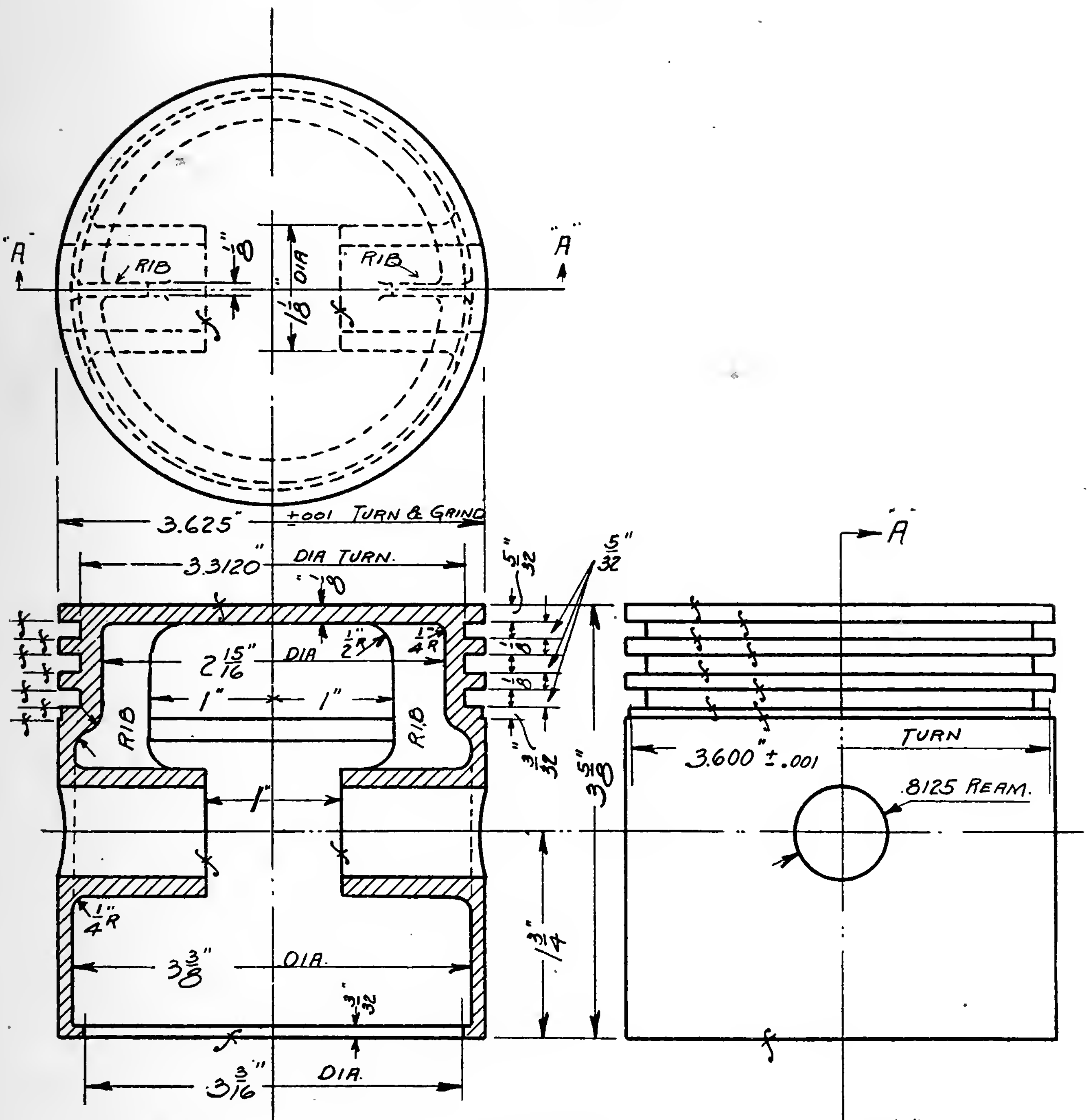



FIG-100

Fig. 100 shows the complete information of a piston for an automobile engine—top, cross sectional and end views.

The dotted lines in the top view represent the various points, lines or surfaces projected vertically from the cross sectional view.

The line AA (in top view) passes thru the center of the piston, cutting the ribs. Referring to the cross sectional view, you will note that the ribs **are not** crosshatched—which is customary, as previously explained. The end view shows an exterior view of the piston—on which view no dotted lines are shown. To outline the interior of the piston with dotted lines on this view is superfluous as the interior construction is readily shown on cross sectional and top views.

Referring to the top view, the diameter of outer circle is 3.625″±001″. Referring to the cross sectional view, the distance from the bottom to the center line of the .8125″ reamed hole is $1\frac{3}{4}$″. Thickness of each rib is $\frac{1}{8}$″.

Vertical height of these ribs is 1-3/16″. This dimension is not given on the drawing but sufficient information is given so that this may be determined as follows:

Total height of piston is $3\frac{5}{8}$″
less $1\frac{3}{4}$″

$1\frac{7}{8}$″ = the distance from top of piston to center line of the .8125″ reamed hole. Now subtract the thickness of the top wall, $\frac{1}{8}$″, and one-half of $1\frac{1}{8}$″ (the outside dia. of the shell around the .8125″ reamed hole) or

$$1/8 + 9/16 = 11/16$$

$$\begin{array}{r} 1\text{-}\ 7/8 \\ -\ \ 11/16 \\ \hline 1\text{-}3/16'' \end{array}$$ height of rib.

## SEMI-STEEL PISTONS.

A very large percentage of pistons is now being made of semi-steel. This is a metal melted in the cupola, containing from 15 to 50 per cent steel scrap, producing a very close-grained, easily machined and stronger metal compared with a straight gray iron mixture.

**McLain's System** of semi-steel mixing has been on the market since 1908 and covers the process of making castings of better quality at lower cost by the addition of steel scrap to regular cupola mixtures.

All classes of castings made of cupola metal are benefitted by the addition of steel scrap—the percentage added depending on the section of castings.

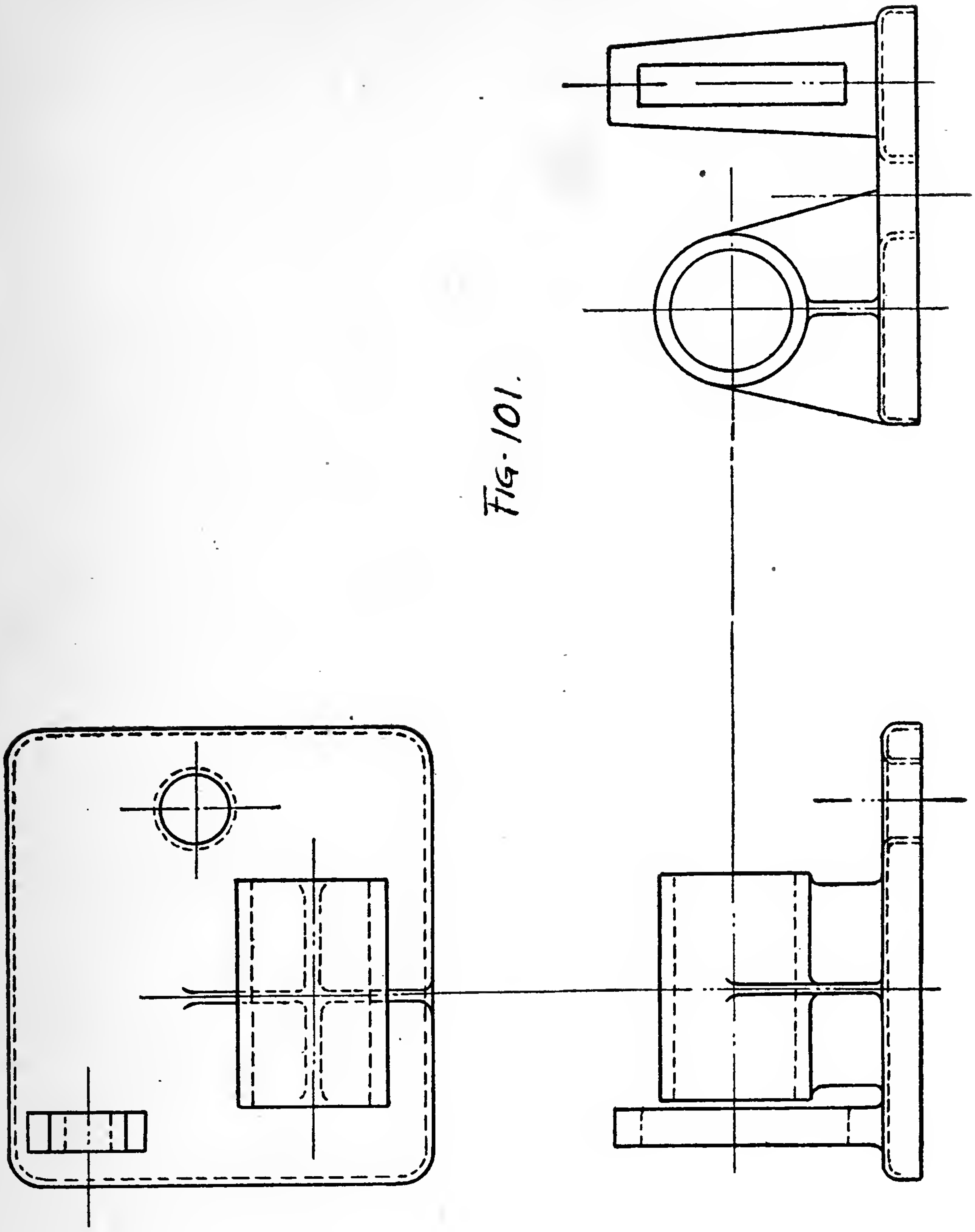


FIG. 101.

## BASE.

Fig. 101 represents the working drawing views of a special base casting. You will note that on this drawing no dimensions or lines are shown projecting from one view to another (except the center lines). This drawing will afford an excellent example for practice in the correct projection of the various points from one view to another. We advise that you locate each individual point, surface or line, drawing a pencil line to its corresponding point on each of the other views.

Study Fig. 101 and if you are in doubt, check up by referring to Fig. 102.

For example, you will note the 3¼″ bore shown at A is also shown at A on the side view. This indicates the projection of the bore on two of the views; however, the bore is shown, but not indicated on the top view. Dimensions covering all lines or points are shown on **two views** and may be referred to if you do not understand the projections of the various lines or points shown on Fig. 101.

You will note that each dimension is shown on two views on Fig. 102; however, this was done only to assist you in understanding Fig. 101, and is not done in actual practice.

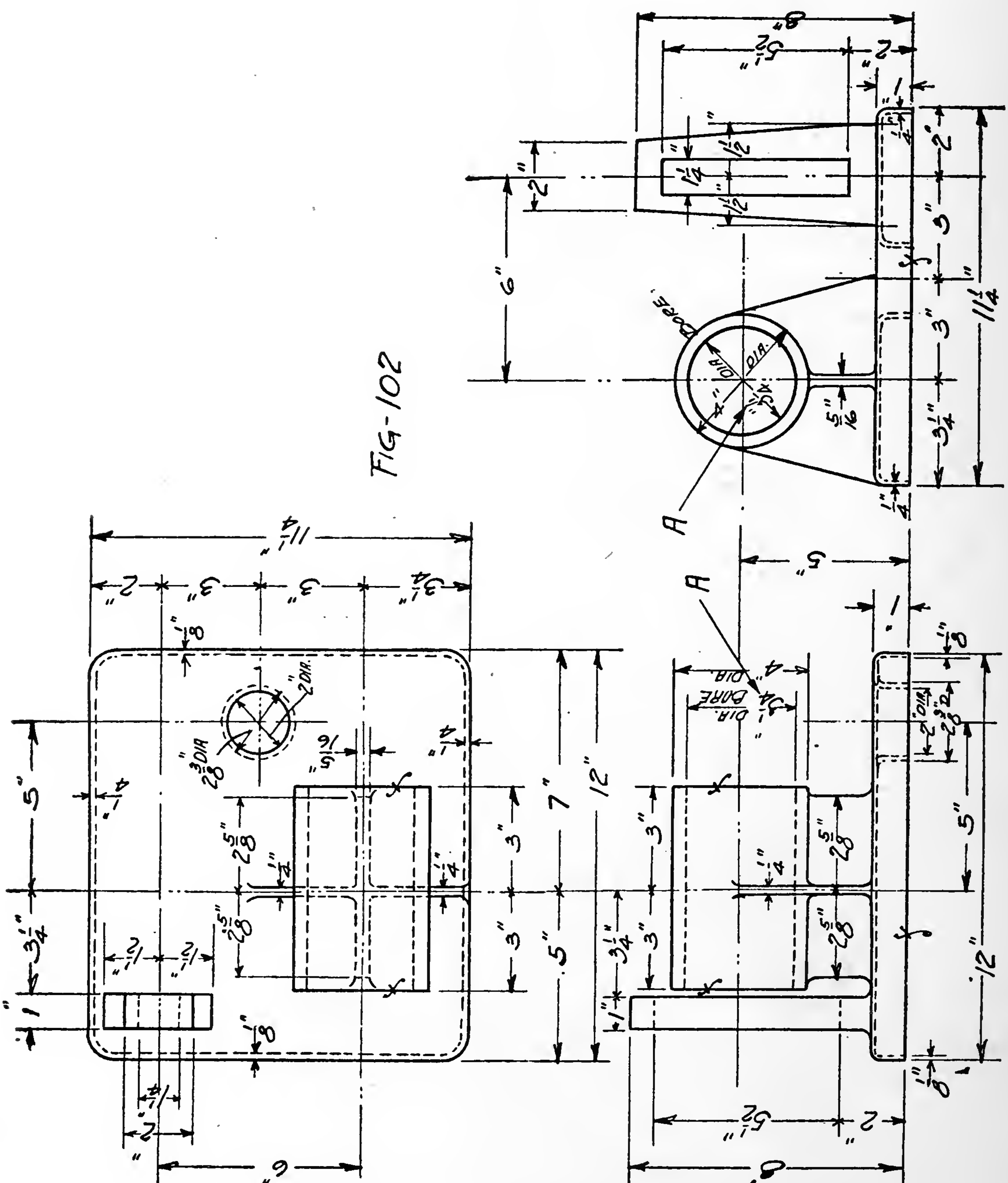


FIG-102

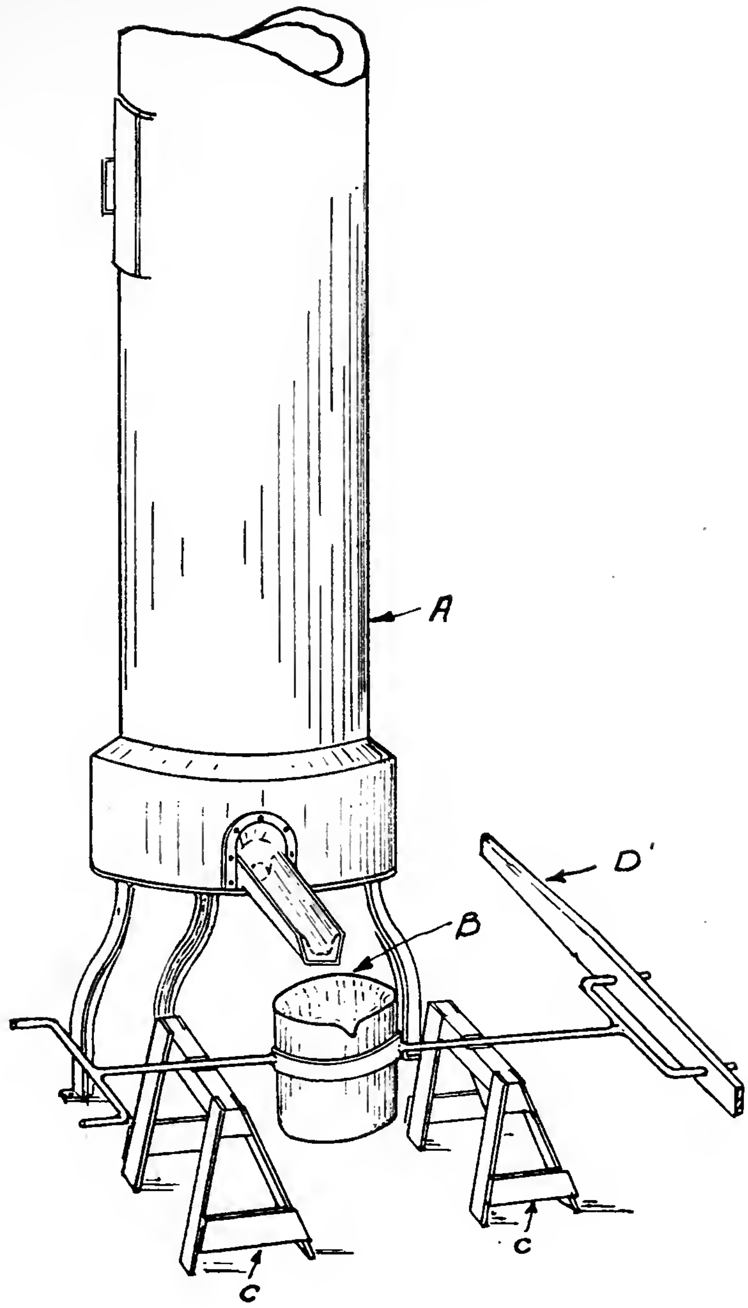



Fig. 103

Fig. 103 shows a perspective drawing of a cupola A, with a receiving ladle B which is supported on two saw horses C. A simple and practical method employed in some shops to tilt this ladle is shown.

The metal flowing from the spout empties into this receiving ladle; it is then tilted by the use of the lever handle D and the metal allowed to flow from this receiving ladle into hand ladles placed under it (hand ladles not shown).

A cross sectional view showing the interior construction of the cupola is shown in Fig. 104.

The explanation of a shank, similar to the one housing the receiving ladle, is given under Fig. 79 and the working drawing views of the saw horse are explained under Fig. 87.

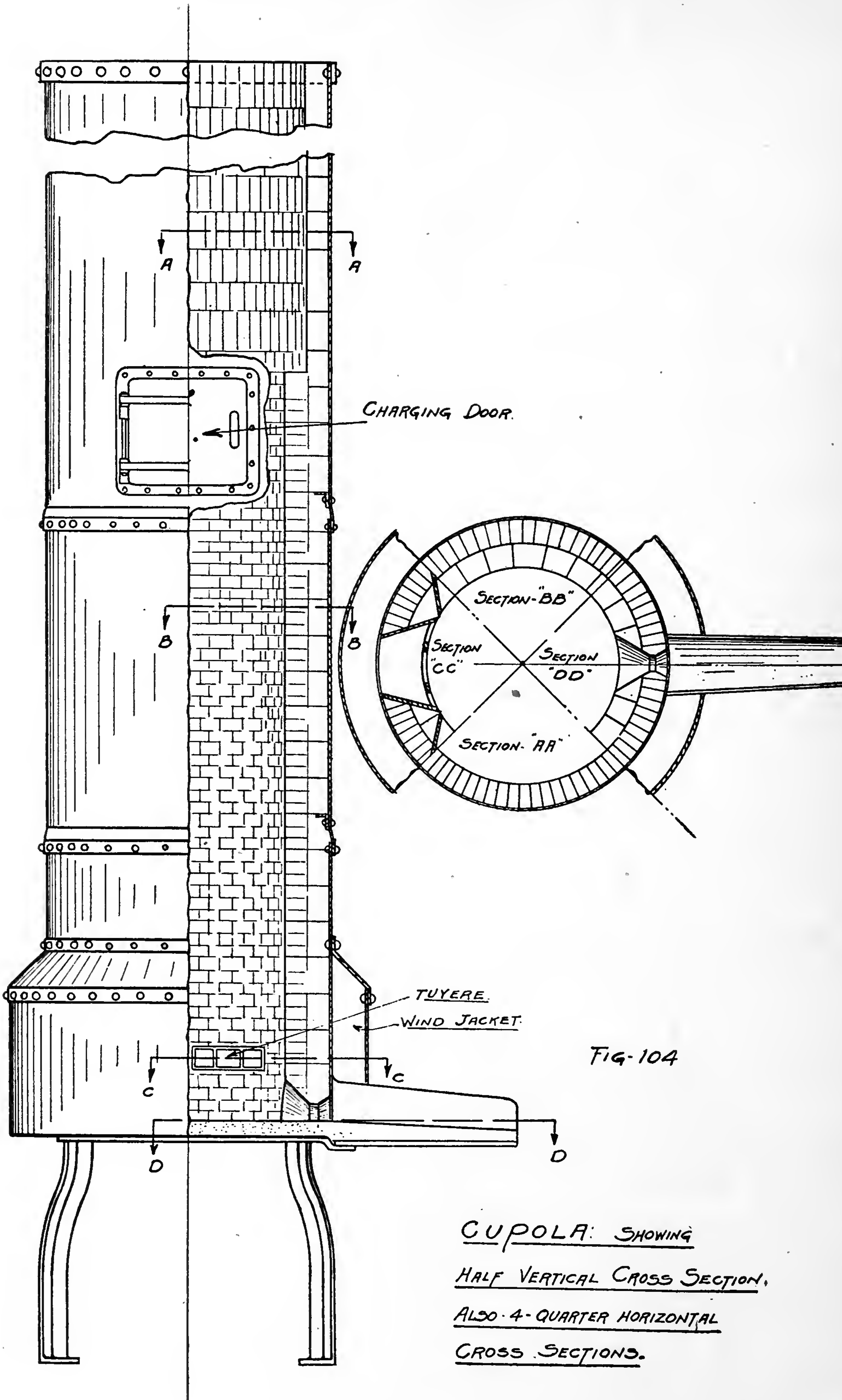



FIG-104

CUPOLA: SHOWING HALF VERTICAL CROSS SECTION. ALSO 4-QUARTER HORIZONTAL CROSS SECTIONS.

## CUPOLA.

Fig. 104 illustrates the construction of a cupola. A cupola consists of a vertical cylindrical steel shell, at the lower end of which is an outer casing known as the wind jacket. A charging door thru which material is charged into cupola is also shown. Passages connecting the wind jacket to the interior of the cupola are known as tuyeres. These permit the air to enter the cupola supplying the necessary air for the proper combustion of the fuel. The entire cylindrical shell is lined with refractory brick.

This drawing illustrates the method of showing the construction at the various heights, the sections being indicated as AA, BB, CC and DD. The arrow at each end indicates the direction the eye is supposed to be looking at the section—in this case it is down. There are five cross sectional views shown in this drawing—one vertical half section and four quarter horizontal sections.

Section AA is taken thru the brick lining above the charging door. One quarter section only is shown; however, it is understood that the entire horizontal section at this point is a continuation of that shown in the one-fourth section.

Section BB is taken thru the lining directly under the charging door.

Section CC is taken thru one of the tuyeres.

Section DD is taken thru the tap hole.

Vertically one-half of the cupola is shown in exterior and the other half in cross section.

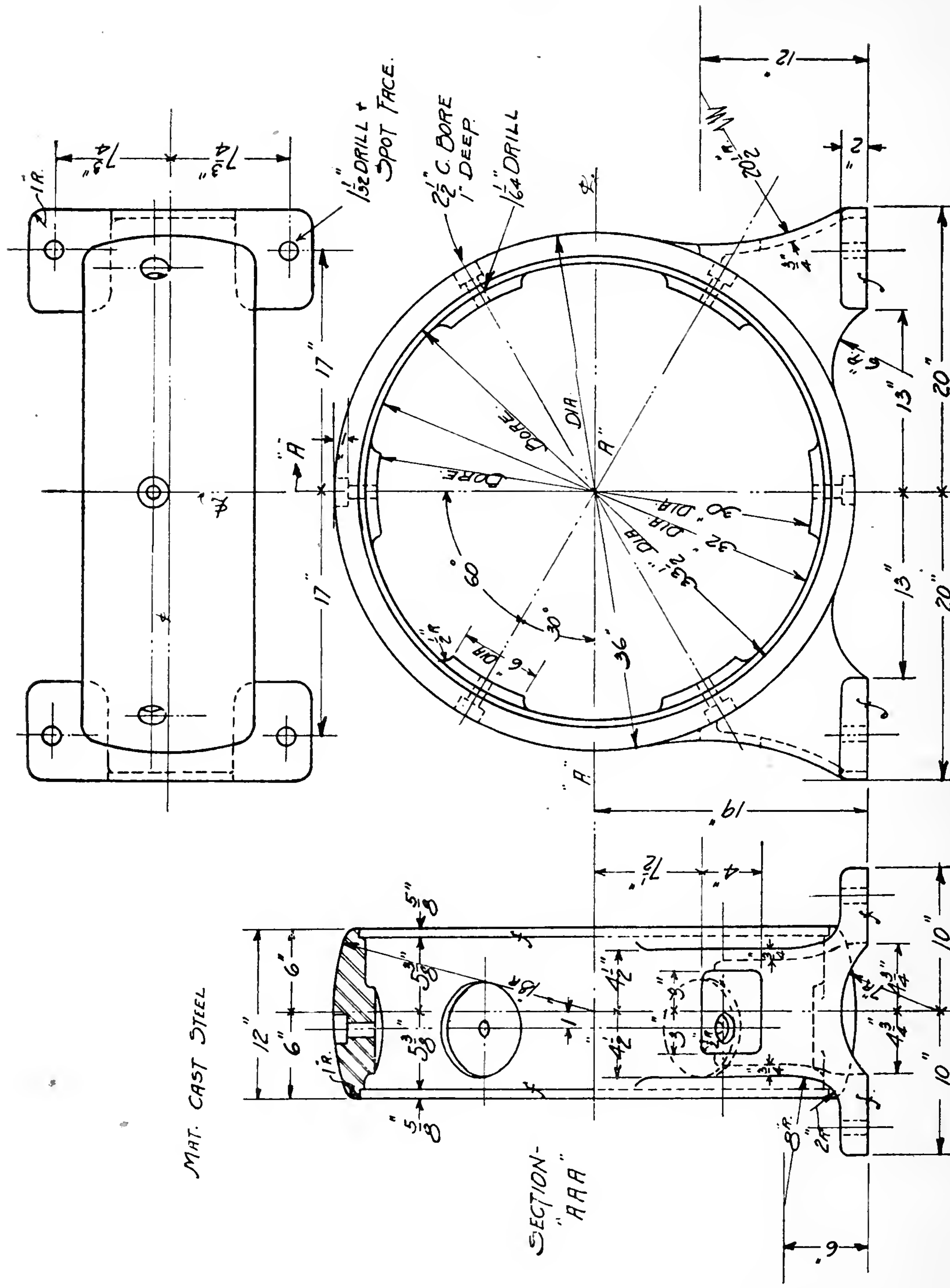



Fig. 105

Fig. 105 is the working drawing of a motor frame with all necessary dimensions. On correctly made working drawings, the dimensions between certain lines, points, or the size of holes, etc., should appear on only one view and not on any other view pertaining to the same object.

The projections are produced the same as previously explained. Bear in mind that the section AAA, or the upper left hand corner of the side view, is supposed to be removed. The upper half of the end view shows the surface imaginarily cut, covered with cross-hatching.

**Note**:—Study the projection of each line, point or surface from one view to another; for example—the counter-bored holes thru each of the six pads. Referring to the top view it will be seen that these holes are "off center," the distance being 1″ (see end view). Also locate these holes in cross sectional view.

Study the dimensions—form a mental picture of the size and thickness of the various parts.

The oblong with the rounded corners shown in the end view, (4 x 6″), is an opening in the end of the frame (both ends).

Project the top and bottom of this oblong. Locate the dotted lines indicating the position of the hole.

Attention is called to the six pads which are shown equally spaced around the inside of the frame. You will note the 60° and the 30° notations which locate the pads around the circumference. Referring to page 66 you will readily understand that 60° plus 30° is equal to 90° or the ¼ part of a circle.

A side view shows only the surfaces and outlines visible when looking directly at the side view, with the eye in a direct horizontal line with each point. An end view shows the surfaces and outlines visible when looking directly at the end view, the eye being in a direct horizontal line with all points of the surfaces and outlines. For top view the eye must be in a direct vertical line with all points on the upper surface and with the outline.

Attention is called to the following notations which appear on Fig. 105. The crosshatching indicates that the motor frame is made of cast steel. Compare with symbol on page 57.

The following notations are shown correctly placed, and explanations will be found on page 54.

| | | |
|---|---|---|
| Bore | Rad. or R. | Spot Face |
| Dia. | Drill | C. Bore |
| ℄ Center line (note construction) | | Section AAA |

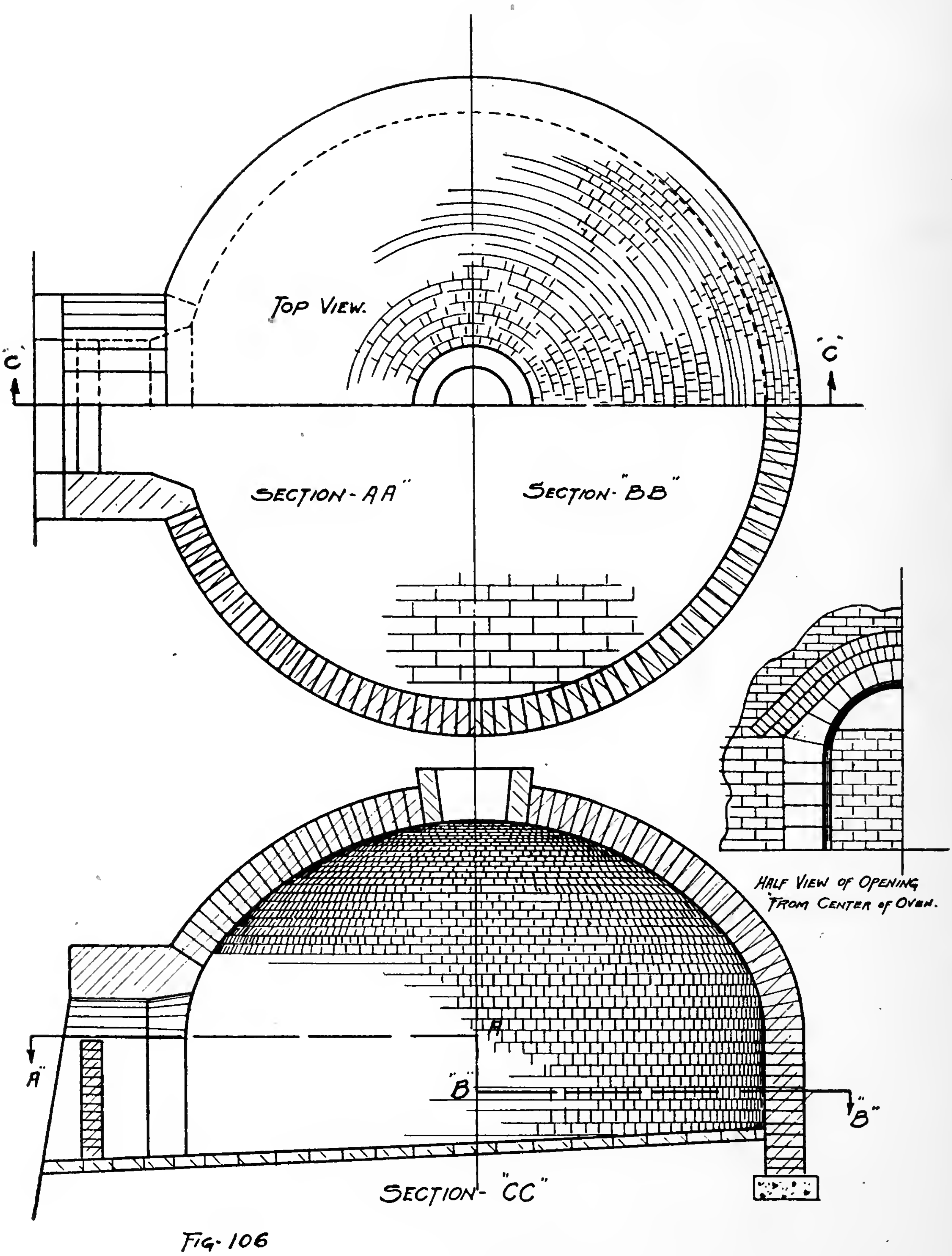

TOP VIEW.
"C"
"C"
SECTION-"AA"
SECTION-"BB"
HALF VIEW OF OPENING FROM CENTER OF OVEN.
"A"
"A"
"B"
"B"
SECTION-"CC"

FIG-106

## BEEHIVE COKE OVEN.

Fig. 106 is a working drawing of a beehive coke oven and is used for the manufacture of foundry and blast furnace coke. It is built entirely of refractory brick. The relative position of the views of this oven is exactly the same as that of any other object previously explained. A doorway is shown at the left and a circular tapered opening thru the roof. The general outline of the oven is similar to a dome.

By referring to the top view you will note that one-half of this view shows the exterior of the roof when looking directly down on top of it. The lower right hand quarter of the top view indicates a cross sectional view taken along the line BB and the lower left hand of the top view indicates the cross sectional view taken along the line AA, looking down. A longitudinal cross sectional view is shown and marked section CC, the section being taken along the line CC (see top view). A half view of the doorway looking out from the interior is shown at the right.

Cross sectional views of this oven are obtained in exactly the same manner as previously explained. It must be remembered that the surfaces which have been cut with the imaginary saw along the lines as mentioned are crosshatched. The section lines AA and BB indicate the position or location of the horizontal cut and the section lines CC on top view indicate the position or location of vertical cut thru the oven.

## OPERATION OF BEEHIVE COKE OVEN.

Beehive coke ovens are used to manufacture foundry and blast furnace coke. The dimensions are from 7 to 12 feet in diameter, vertical wall 2½ feet high and the roof almost hemispherical. These ovens are generally arranged in batteries of 20, 30 or more, being placed one alongside the other, with the doorways all on the same side.

A retaining wall is built the full length of the battery along the door side and up to the top of oven. Earth is then used to cover the entire oven, allowing only the top of the upper opening to project. A railroad track is placed about 6 or 7 feet to the right of this opening, running parallel with the ovens. On this track coal is conveyed from the screens or washery to the openings of the ovens. The largest size ovens are capable of holding a charge of about 5 ton which is introduced thru the opening at the top and is leveled off to a height of about 2½ feet.

The brickwork of the walls and roof being still red hot from the previous charge, ignites the gases. Air is admitted thru openings in the upper part of the door. When the gas is burnt off, the upper part of the door is opened and the glowing charge cooled by jets of water thrown directly upon it from a hose, and it is subsequently drawn out thru the open door. The charge breaks up into prisms or columns the length of which corresponds to the depth of the charge, and as a rule is uniform in character and free from dull black patches or ''black ends.''

The time for burning is either 48 or 72 hours. The longer the heat is continued the denser the product becomes, but the yield also diminishes, as a portion of the finished coke necessarily burns to waste when the gas is exhausted. For this reason the yield on the coal charged is usually less than that obtained in retort ovens, altho the quality is better. Coals containing at most about 35 per cent volatile matter are best suited for the beehive oven. With less than 25 per cent the gas is not sufficient to effect the coking completely, and when there is a higher percentage the coke is brittle and spongy and unsuited for blast furnace or foundry use. The spent flame from the ovens passes to a range of steam boilers before escaping by the chimney.

## EXAMINATION

### LESSON 13

1. Fig. 100. (a) How many ribs are there in the inside of this piston?

   (b) What is the outside diameter of this piston?

2. Fig. 102. What are the over-all height, length and width of this casting?

3. Fig. 105. (a) Which single view shows there are four holes in the feet?

   (b) What are the over-all length, width and thickness of one of the feet?

   (c) What is the distance from the bottom of feet to center line of frame?

# LESSON FOURTEEN

## BOTTOM POUR LADLE.

Fig. 108 is a general outline and cross sectional view of a bottom pour ladle with an adjustable stopper rod and actuating mechanism in position. The cross sectional view shows the stopper rod, sleeves and nozzle.

A bottom pour ladle is used in steel foundry practice. The molten metal is poured into this ladle and conveyed to the molds. When the nozzle (10) is directly over the gate of a mold, the lever (14) is pressed down, which in turn lifts the stopper rod off the nozzle brick seat, allowing the metal to flow into the mold.

Your attention is called to the correct projection of the adjustable slide from the front to the side view. Lever (14) is not shown in the side view.

This being only an outline drawing, it is not necessary to show the top view, however the complete detail drawing of the ladle will show a top view or the notation dia.

Fig. 109 shows the complete details of the adjusting device. On this figure the details of the several parts are shown and we advise studying each detail carefully as to projections—general outline and notations. This is a good example of assembly drawings (Fig. 108) and detail drawings (Fig. 109).

The detail drawing for the sleeves, nozzle and stopper is shown in Fig. 107.

Fig. 110 shows one type of bottom pour ladle in use.

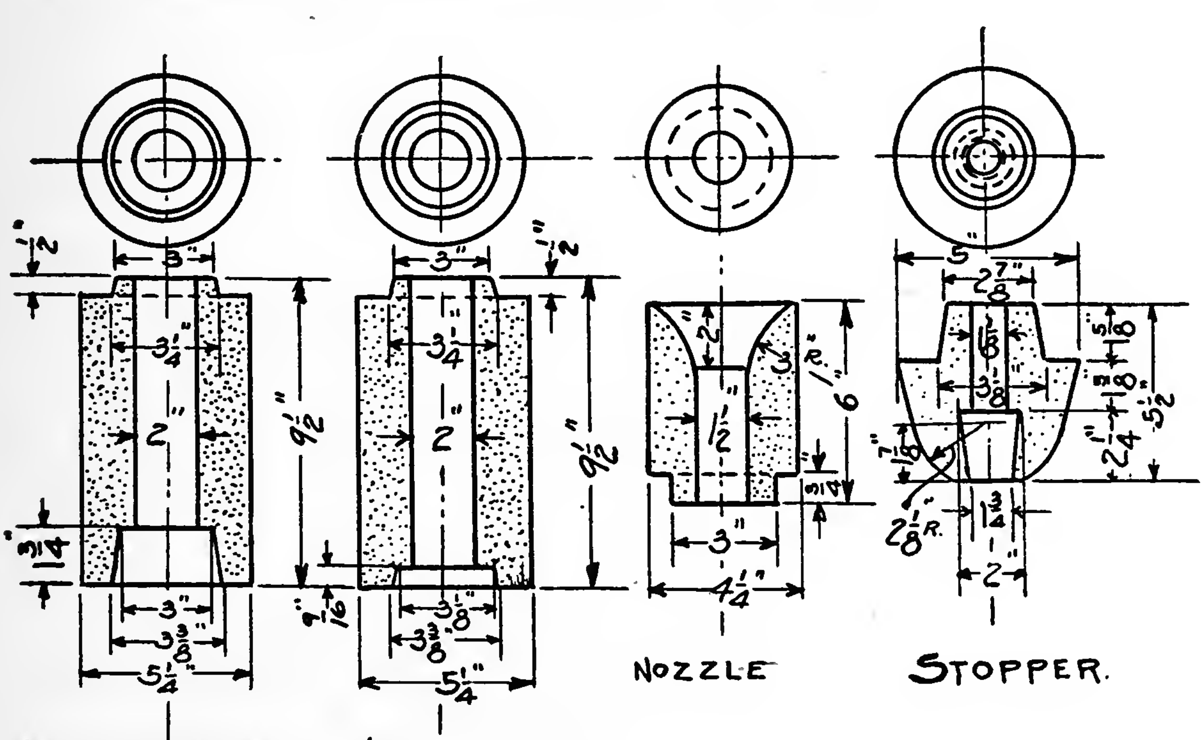



FIG. 107

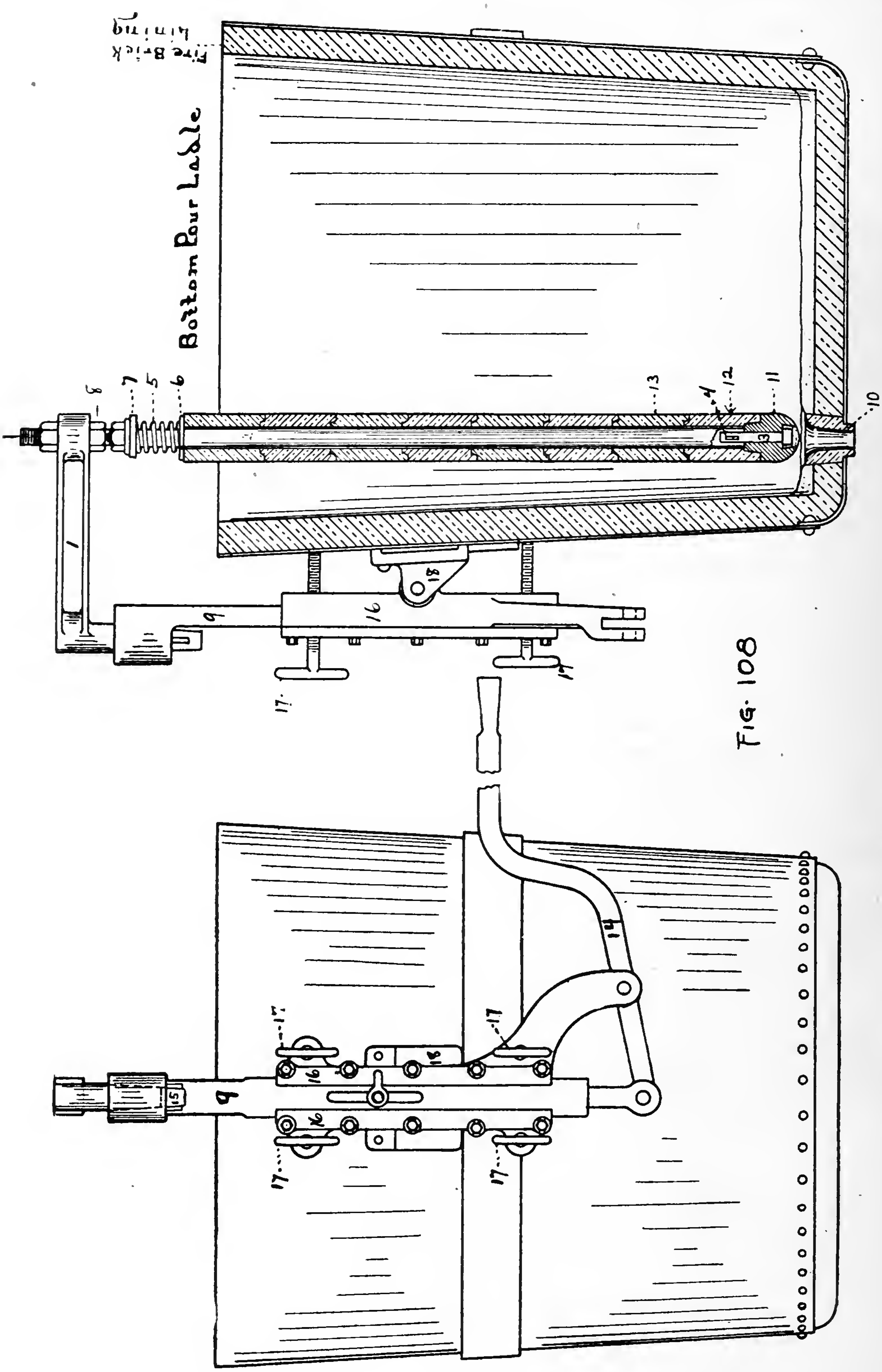


FIG. 108

## BOTTOM POUR LADLE IN USE

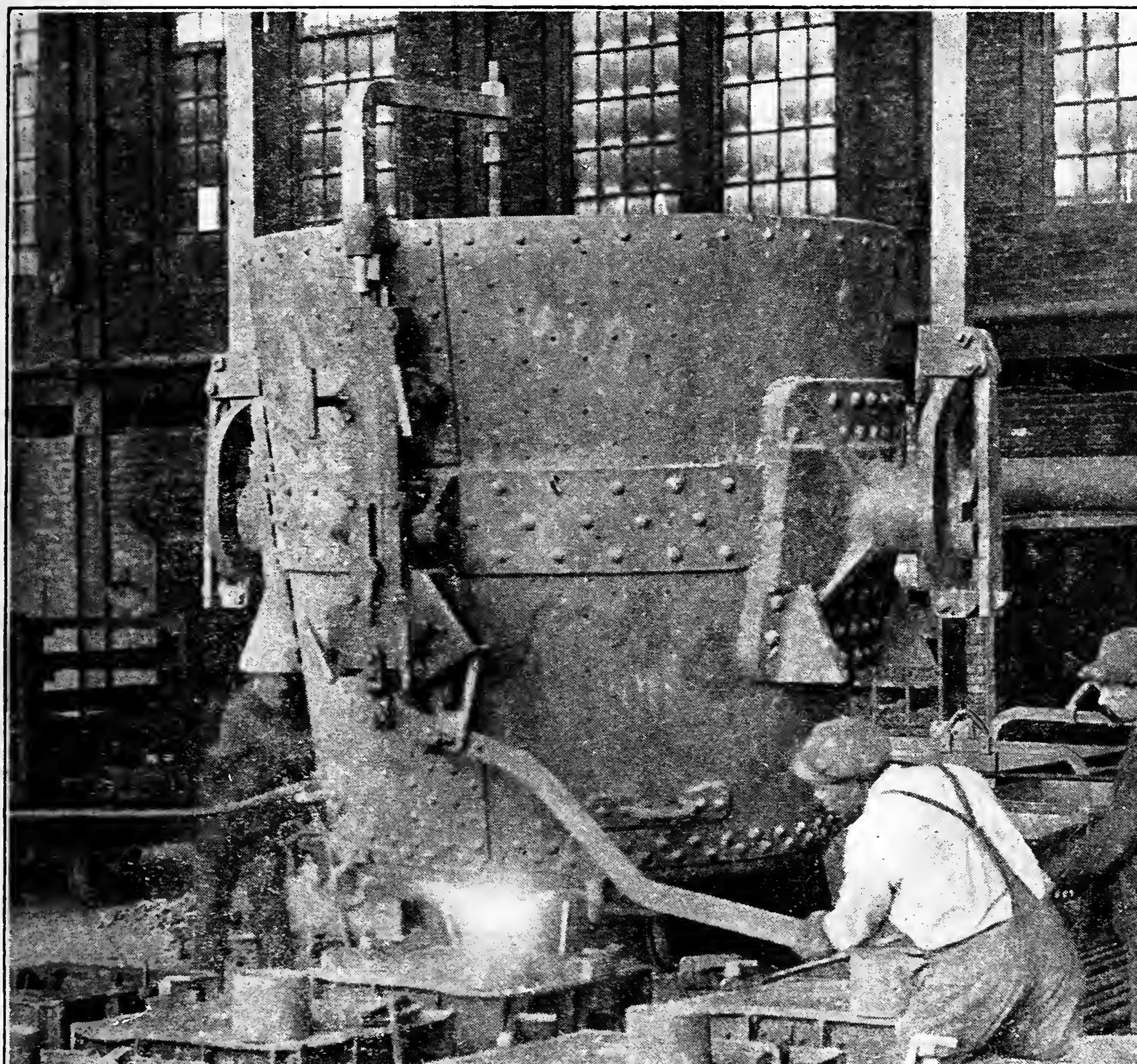
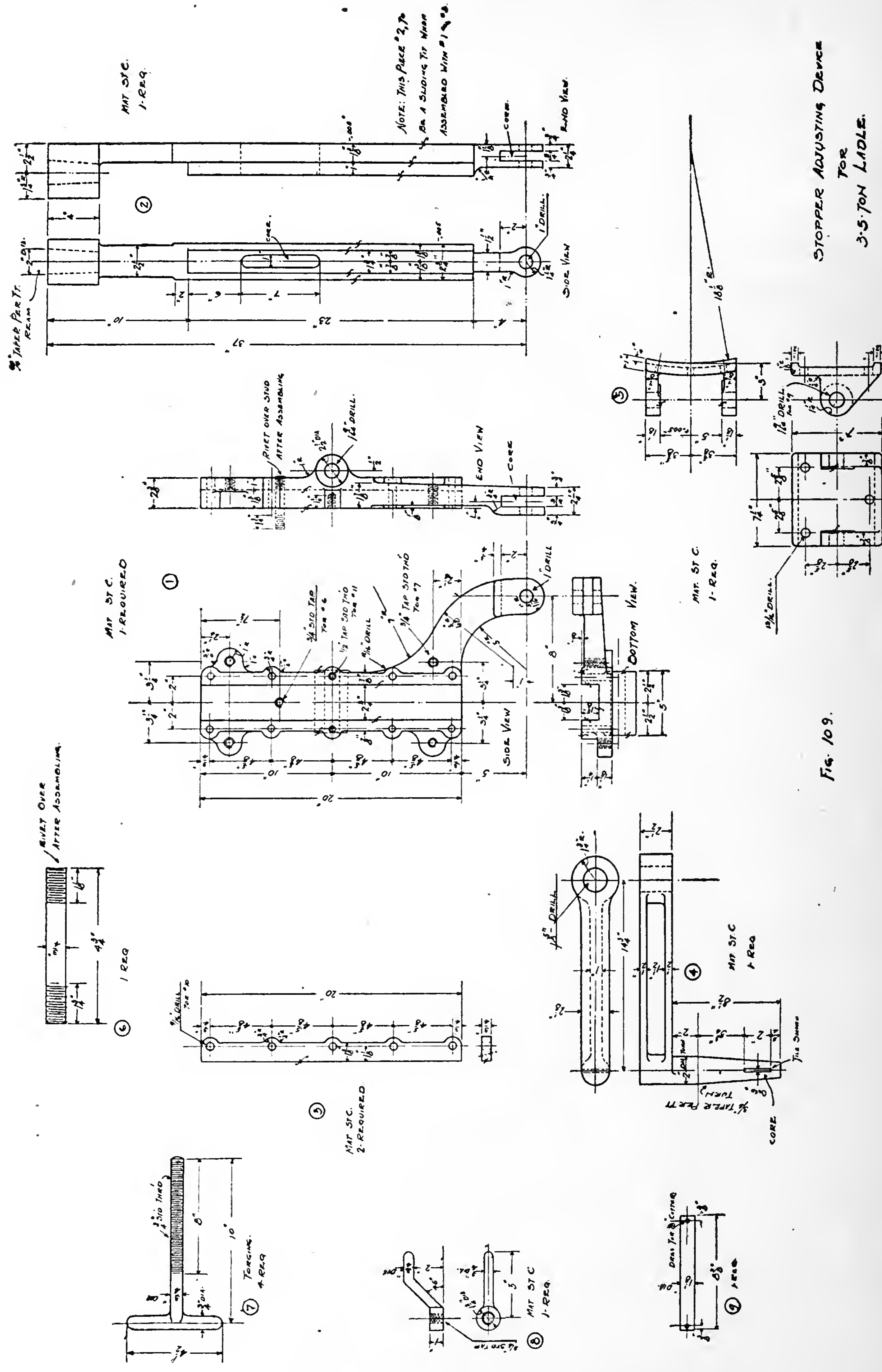


Fig 110




STOPPER ADJUSTING DEVICE FOR 3·5·TON LADLE.

FIG. 109.

## TYPICAL DETAIL DRAWING

Fig. 109 shows single, two and three view working drawings. Items 6, 7 and 9 are single view drawings; items 2, 3, 4 and 8 are two view drawings. Items 1 and 5 are three view drawings.

Referring to item 1, Fig. 109. The dimension $2\frac{3}{8}''$ shown at the top of end view indicates that the thickness of casting is $2\frac{3}{8}''$. Continue down and it will be seen that a $1\frac{3}{8}''$ dimension is given from the left hand face to the vertical dotted line—this dotted line indicates the depth of slot, which is $2\frac{3}{4}''$ wide (see side view).

The distance from the top to the center of the 1″ drilled hole in the arm is 25″ (20+5) and this hole is 8″ to the right of the vertical center line of casting proper. The width of the slot in this arm is $\frac{3}{4}''$ and is cored in the casting (see end view).

A center line is shown 10″ down from the top. There are two parallel dotted lines above and below this center line which indicate the length of the 1-9/64″ drilled hole and the vertical height of the projection marked $2\frac{1}{2}''$ dia. (end view). The length of this projection is 5″ (see bottom view).

Referring to item 2 on Fig. 109. The side view shows an oblong $1\frac{3}{4}''$ wide and 23″ long. This view does not explain if the area enclosed by these lines is depressed or raised, but by looking at the end view it will be seen that it is raised 1″. The side view shows a 1″ wide and 7″ long cored hole; the end view explains that this hole extends thru the **entire thickness.**

Make a study of each item shown on this drawing in a similar manner locating the dimensions and lines, points or surfaces they refer to.

**Note:**—A side view shows only the surfaces and outlines visible when looking directly at the side view, with the eye in a direct horizontal line with each point. An end view shows the surfaces and outlines visible when looking directly at the end view, the eye being in a direct horizontal line with all points of the surfaces and outlines. For top view the eye must be in a direct vertical line with all points on the upper surface and with the outline.

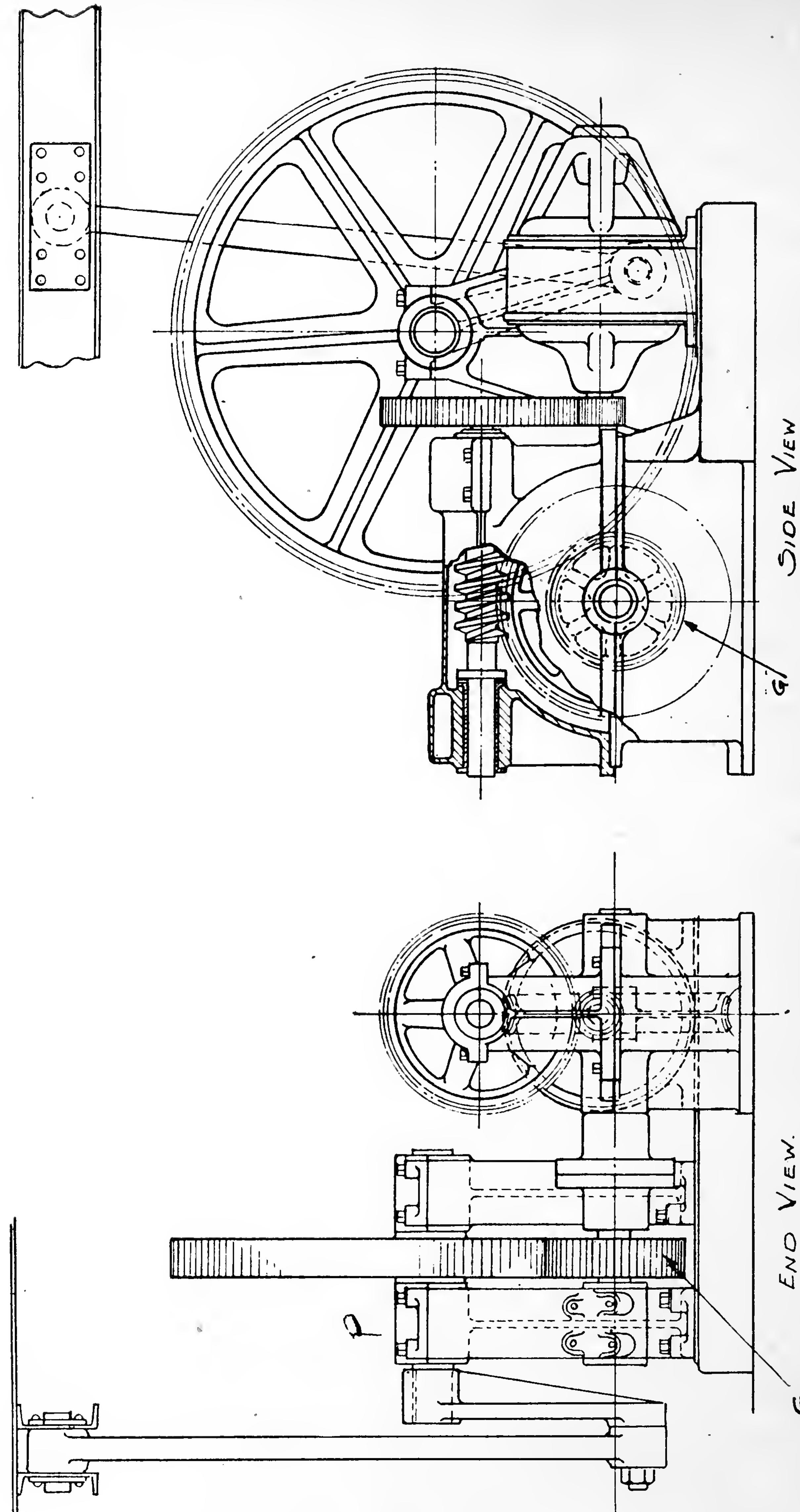



FIG. 112

## TILTING MECHANISM FOR ELECTRIC FURNACE.

Fig. 112 is a general outline or assembly drawing of the driving mechanism which is used in tilting the hearth of one type of electric furnace, thereby allowing the metal to flow from spout. The two channels shown at the top are a part of the framework on the underside of the furnace.

This drawing is shown for practice in the reading of a drawing and affords an especially good example. You are requested to study the views carefully, starting with the side view; first follow thru the method of driving by starting with the motor and continuing until you reach the final joint between the two channels, as shown near the top. The general construction consists of a base casting, motor, two pedestals, a crank, connecting rod, two pinions, two gears, one worm, and one worm wheel. The worm and worm wheel are enclosed in a casing, part of which has been broken away as will be noted on the side view. This enables a portion of the worm and worm wheel to be shown in full outline.

By projecting each line or point horizontally from one view to another (using a straightedge if necessary) you will readily understand this drawing. However, if you find it impossible to understand it, or perhaps are in doubt as to the correctness of your judgment in the projection, turn to page 136, on which is shown the same driving mechanism with each corresponding part indicated with a corresponding letter on both views; some of the construction lines also being shown.

It will benefit you to carefully study Fig. 112 making note of each point not clear and after having made these notations refer to page 136 to check up.

Referring to Fig. 112 the lower portion of bearing which carries the shaft and pinion G, is not shown on the side view as it would become too confusing. The lower half of this bearing is cast in one piece with pedestal P. By referring to Fig. 113 the mechanical terms for each part are noted.

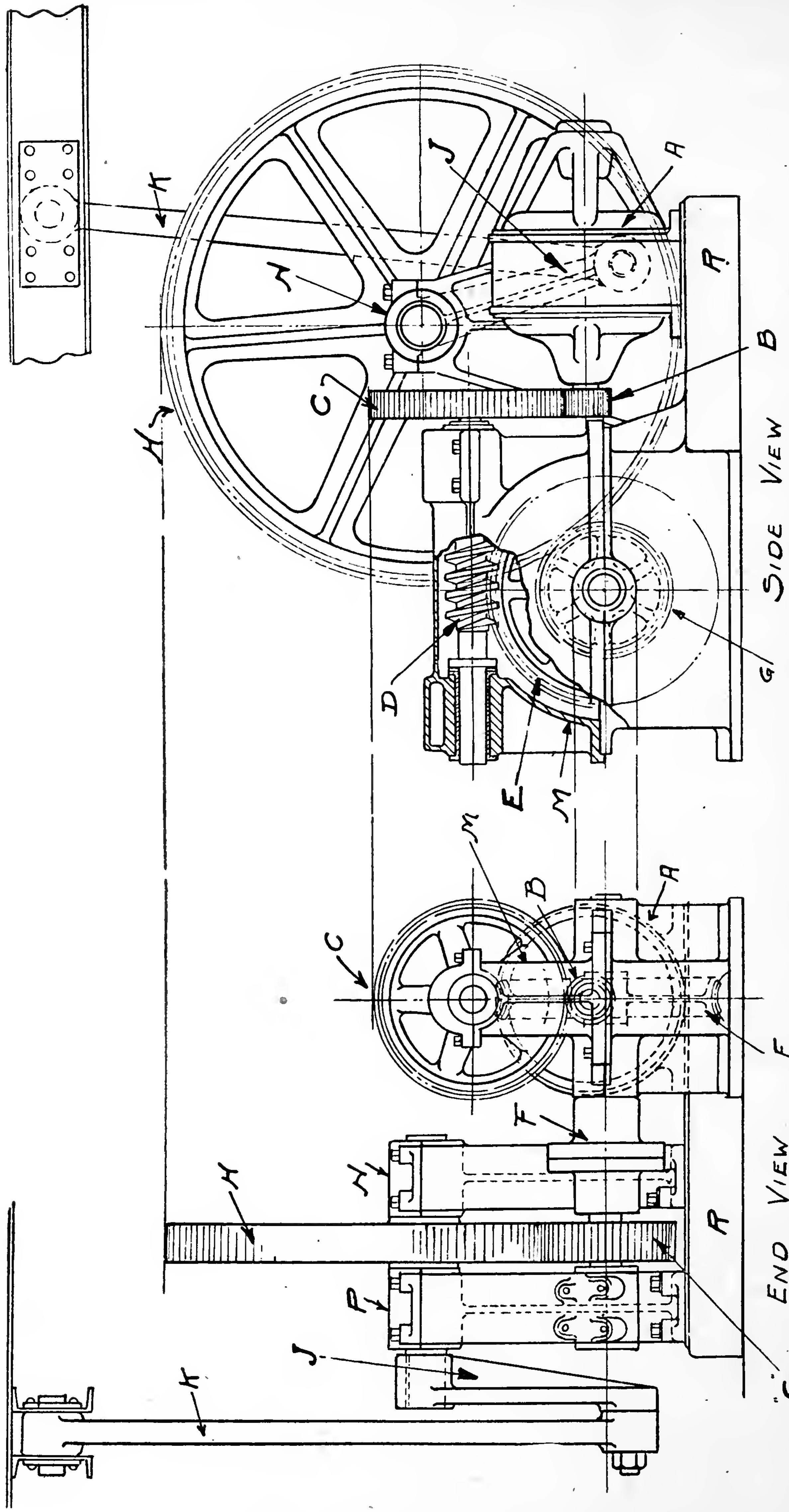



FIG-113

## NAME OF PARTS OF TILTING MECHANISM

A Electric motor
B Motor pinion
C Gear
D Worm
E Worm Wheel
F Coupling (shown in one view only)
G Pinion
H Main gear
J Crank
K Connecting rod
M Gear case
N Pedestal
P Pedestal (shown in one view only)
R Base

Detail of coupling F is shown and explained under Fig. 91.

Detail of gear C is shown and explained under Fig. 96.

A general outline drawing does not show the detail construction of each component part, but merely shows the general outline of the parts.

## EXAMINATION

## LESSON 14

1. What reference figures in Fig. 108 indicate the various parts shown on Fig. 107?

2. Fig. 109. (a) How many ¾ inch tapped holes are shown in Item 1?

   (b) What is the extreme over-all length, width and thickness of Item 3?

   (c) What is the over-all length of Item 8?

   (d) Why is only one view of Item 7 necessary?

# LESSON FIFTEEN

## GAGGER CASTING MACHINE.

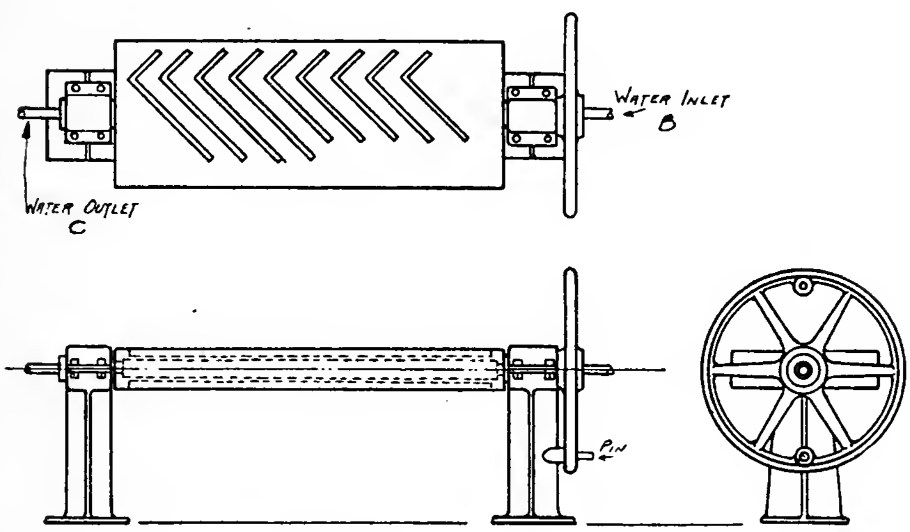



FIG-111

Fig. 111 represents a water-cooled gagger casting machine or permanent mold, consisting of a water-cooled cast iron body having gagger molds on both sides, two pedestals, a hand wheel and wheel lock, the water being supplied thru pipe B; outlet being C. It is used to cast gaggers and is admirably adapted for this purpose.

In small foundries where every penny counts, the molders are instructed to pour gaggers with excess iron instead of scattering it thruout the shop, on floors or sand heaps.

The metal is poured directly into passages forming the gaggers —no gates being necessary. The board is then turned over and the newly-made gaggers readily drop out.

As there is another set of gagger molds on the reverse side, it is now turned up and permits casting these immediately, providing it is the desired size.

This drawing is what is termed an outline drawing several parts being shown but no detail dimensions given. The projection of the various points of the hand wheel are horizontal between the end and the side view.

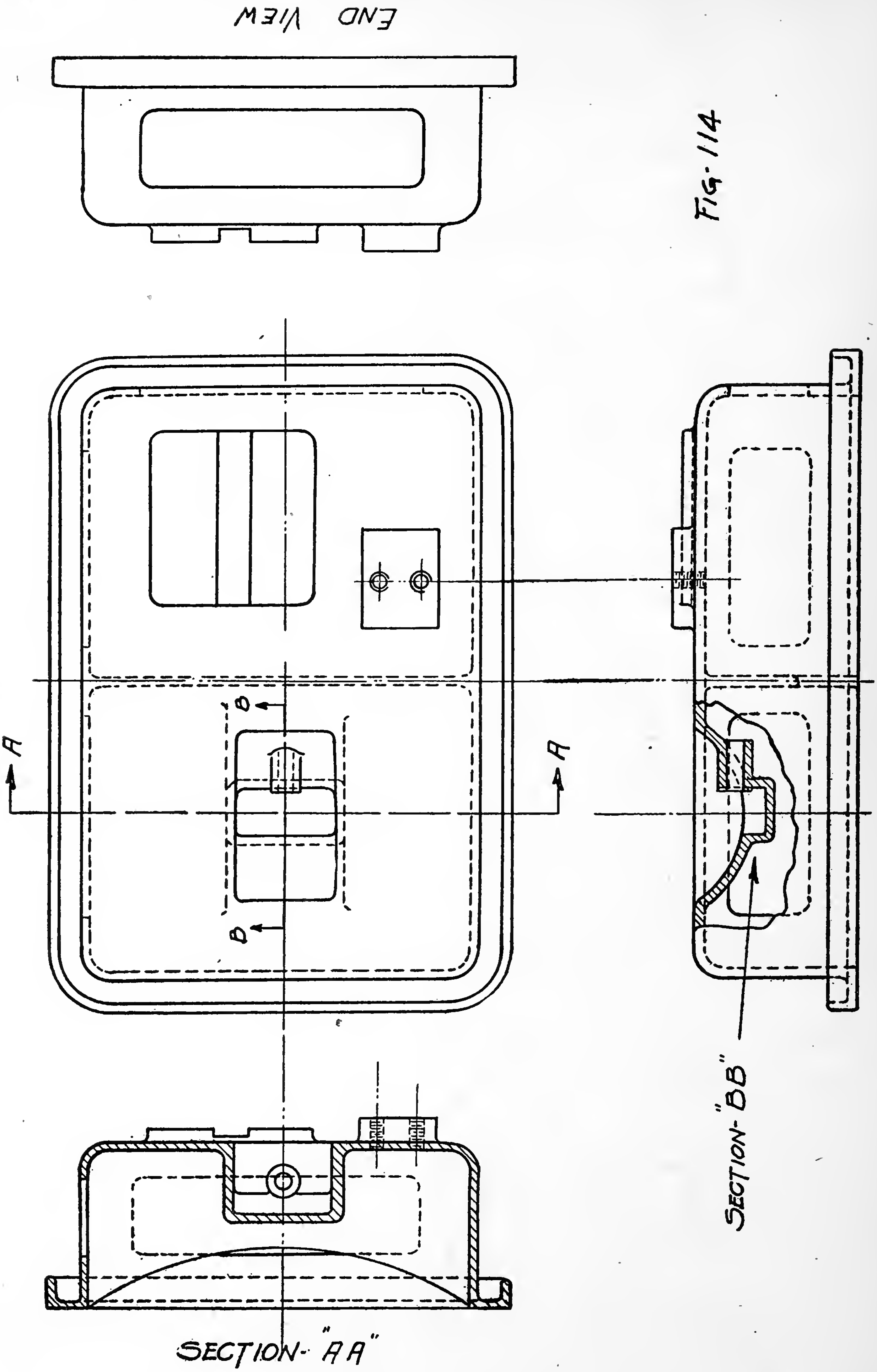



FIG. 114

**Note**:—Project the hand wheel to the top view, also bearing cap, cap bolts, foot of pedestal, and outline of mold board.

The mold board is made of cast iron and hollow, so as to allow the water to circulate and cool the molds.

The mold board of some of these machines are made solid, having sufficient metal in the mold board to provide the radiation necessary for the cooling of the mold.

## PUMP BASE.

Fig. 114 shows the working drawing views of a special pump base, giving side, top, cross sectional and end views. A portion of the side view is broken away to explain more clearly the construction of the depressed surface at point marked "Section BB" (top view). Each point, surface or line should be taken **separately** and its corresponding position located on one or more of the other views. For example: the two tapped holes in the top view are also shown on the side and cross sectional views—in this manner **each and every** line and point should be taken.

The line marked AA on the top view indicates the location of an imaginary cut. The cross sectional view at left marked "Section AA" indicates the surfaces cut.

If in doubt as to the correct projection of the various lines, etc., a rule or straightedge should be used as previously explained.

Your attention is directed to the two dotted oblongs in the side view. It should be understood from the drawing that these oblongs indicate holes cut in the side of the base, however, it should also be observed that these holes are only in **one side.** See cross sectional view AA and the top view. The short dotted lines in the top view indicate the location of three oblong holes in the vertical walls of base.

A further investigation will show that one of these holes is in one end of this base (see cross sectional view AA). The big sweep curve shows the construction of the rib which is shown on the vertical center line in top view. You will notice that the dotted oblong shown in this cross sectional view indicates that the cut-out portion of base is in the right hand end wall. This is also shown in the side view by two short dotted lines and by the outline at the right hand showing the end view.

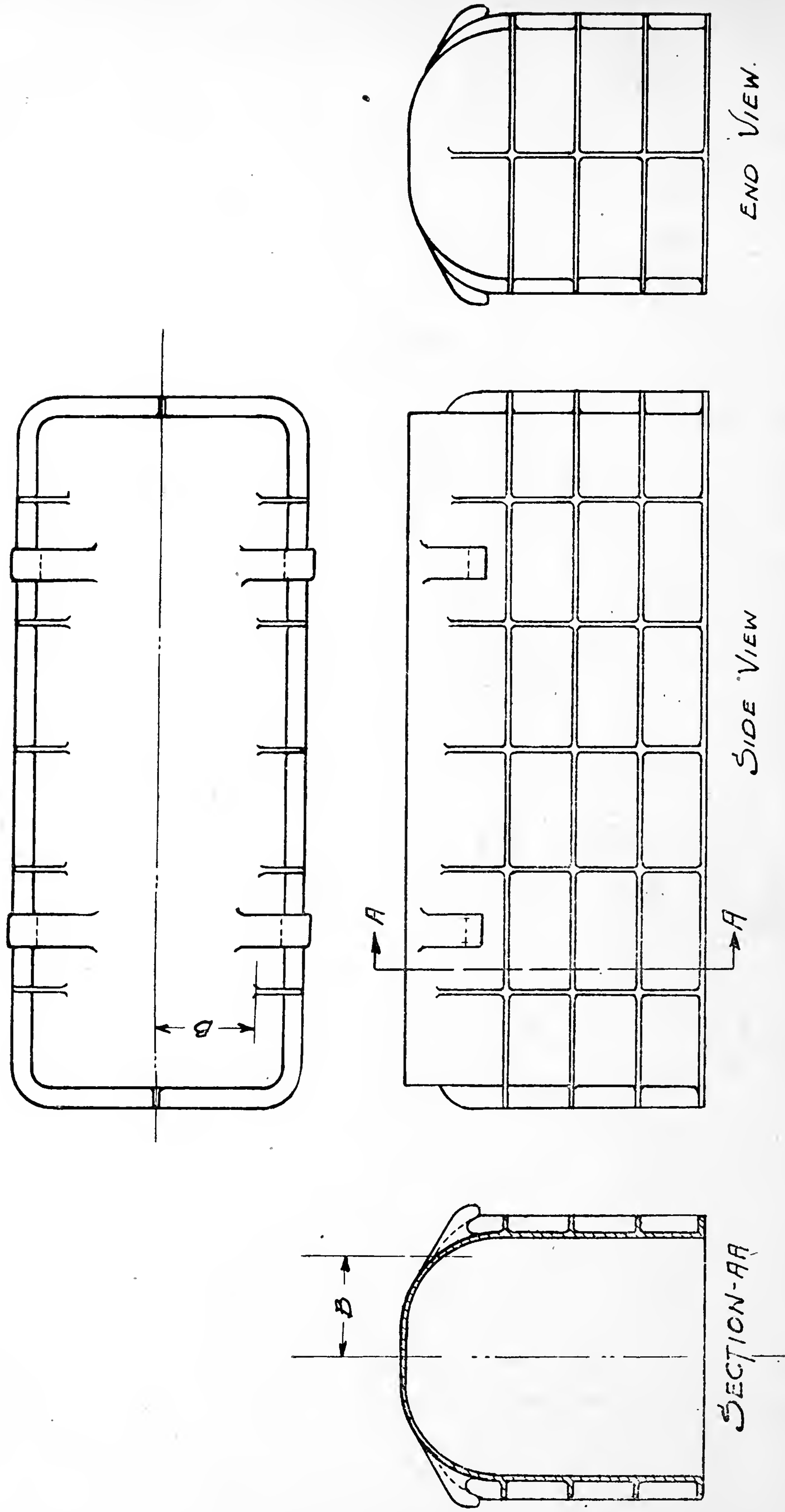



Fig-115

## ANNEALING BOXES.

Fig. 115 shows working drawing views of an annealing box—side, end and top views, also a cross sectional view at the left of side view. The entire box is surrounded by horizontal ribs with vertical ribs intersecting.

Attention is called to the various points projected. Looking at the side view you will see two hooks for lifting the entire box. These hooks are projected to the top view in the same manner as any part of its outline. The cross sectional view shows the shape of this hook as the location of the imaginary cut (line AA) will permit a full outline of the hook to be shown; however, looking at the end view, which is a full outline of the end, you will notice that the entire outline of the hook cannot be seen as one of the ribs will prevent this. Locate this rib in the side view.

The vertical ribs on each side extend part way up the rounded portion of the roof (see dotted lines in cross sectional view). The point at which these ribs stop on this curved surface is also indicated on the side and top views. Locate these points by projecting the top point of the rib in the cross sectional view, horizontally to the side view.

This point or any other may be projected from the cross sectional to the top view by measuring a distance as B from the center line to the point, and measuring this same distance from the center line in the top view to the point; in this case the point taken was the termination of the vertical rib on the roof of box. It will be noticed that the point is in vertical line with the rib in the side view.

This annealing box is used for annealing tin plate.

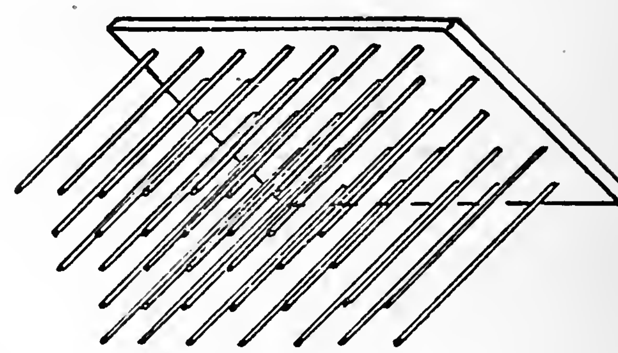


Fig-117

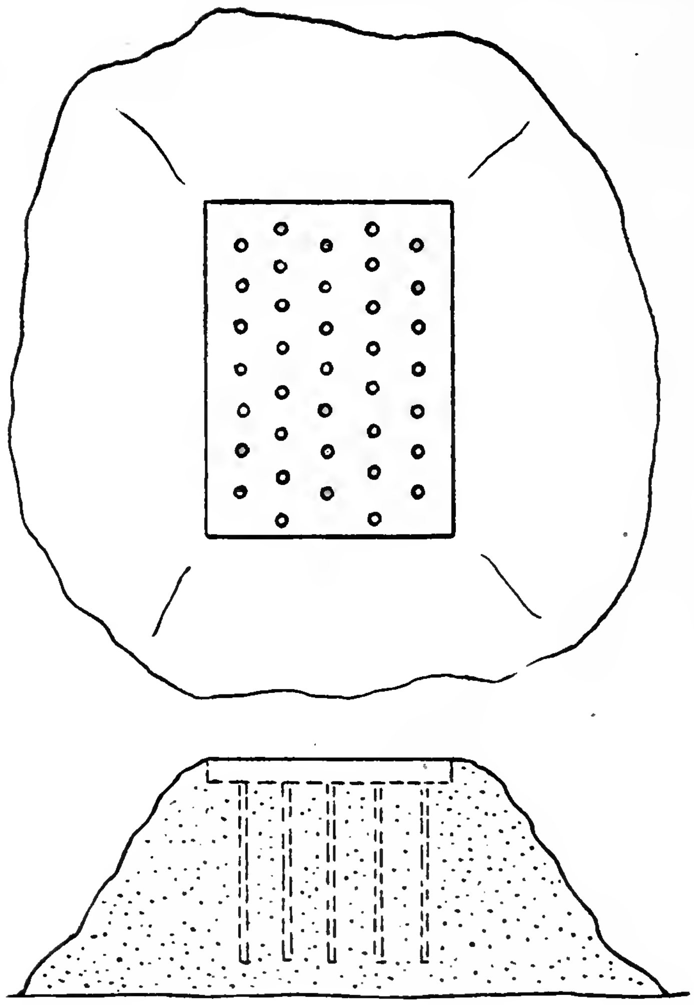


Fig-116

Fig. 116. Many old-time foundrymen made their own nails by taking a board about 12 x 18 x 1″ thick and embedding it in the top of a sand heap; it was then removed and numerous holes punched vertically into the sand with a 1/4″ vent wire. Excess iron was poured into the pouring basin formed by the 12 x 18″ board.

In some instances these 12 x 18″ boards had holes 3/8″ in diameter evenly spaced and drilled in them, the vent wire being pushed thru these holes and the board acting as a template—later being removed.

When sufficiently cool the casting was removed and it looked like the perspective drawing in Fig. 117. The long needle-like prongs were then broken into desired lengths for nailing the molds.

Fig. 116 represents working drawing views showing the above method of molding these nails, top and side views being shown. The irregular outline in the top view shows the outline of the sand heap where it meets the floor. Project the extreme width from the top to the side view; also project the width of the board and the holes in a like manner.

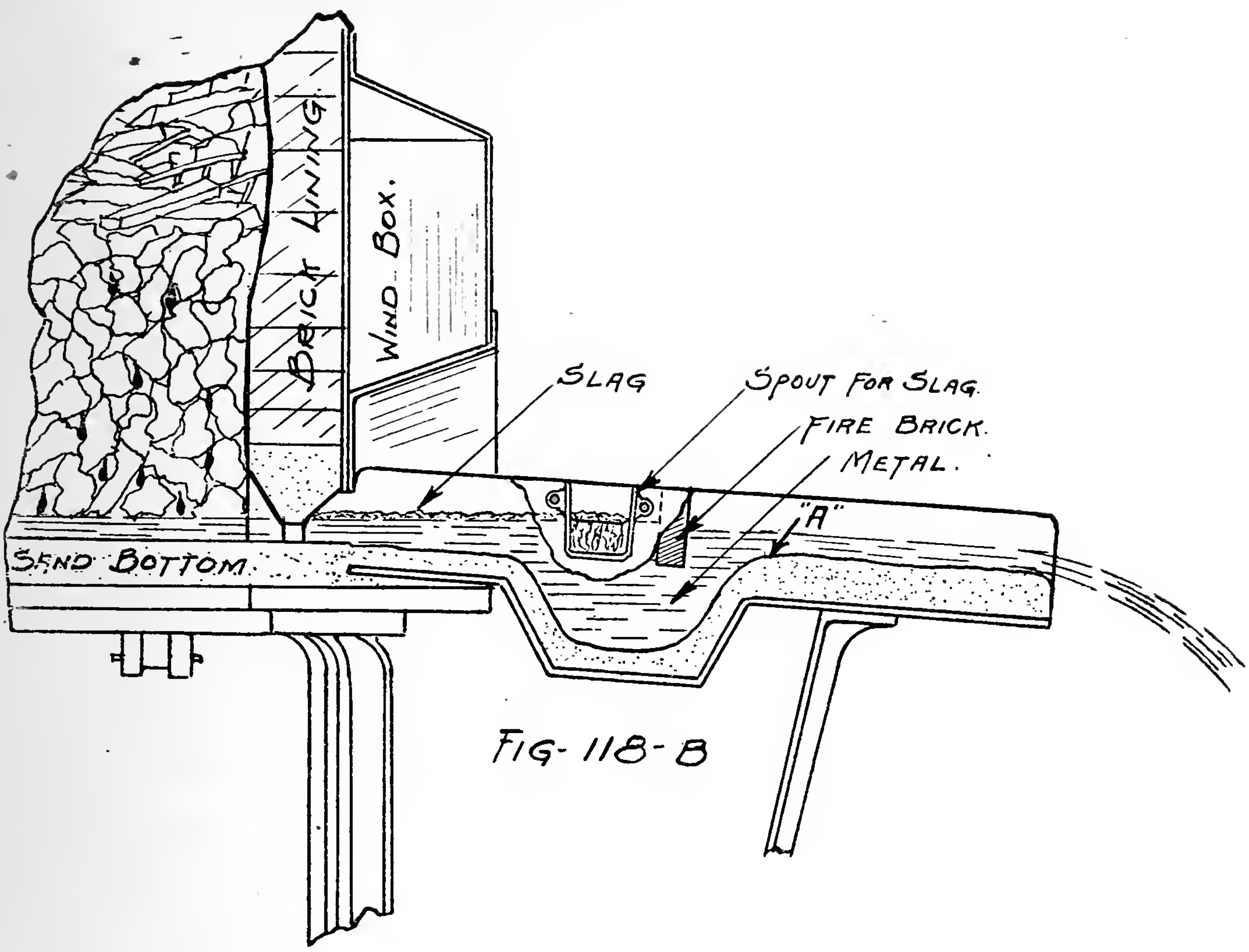



FIG-118-B

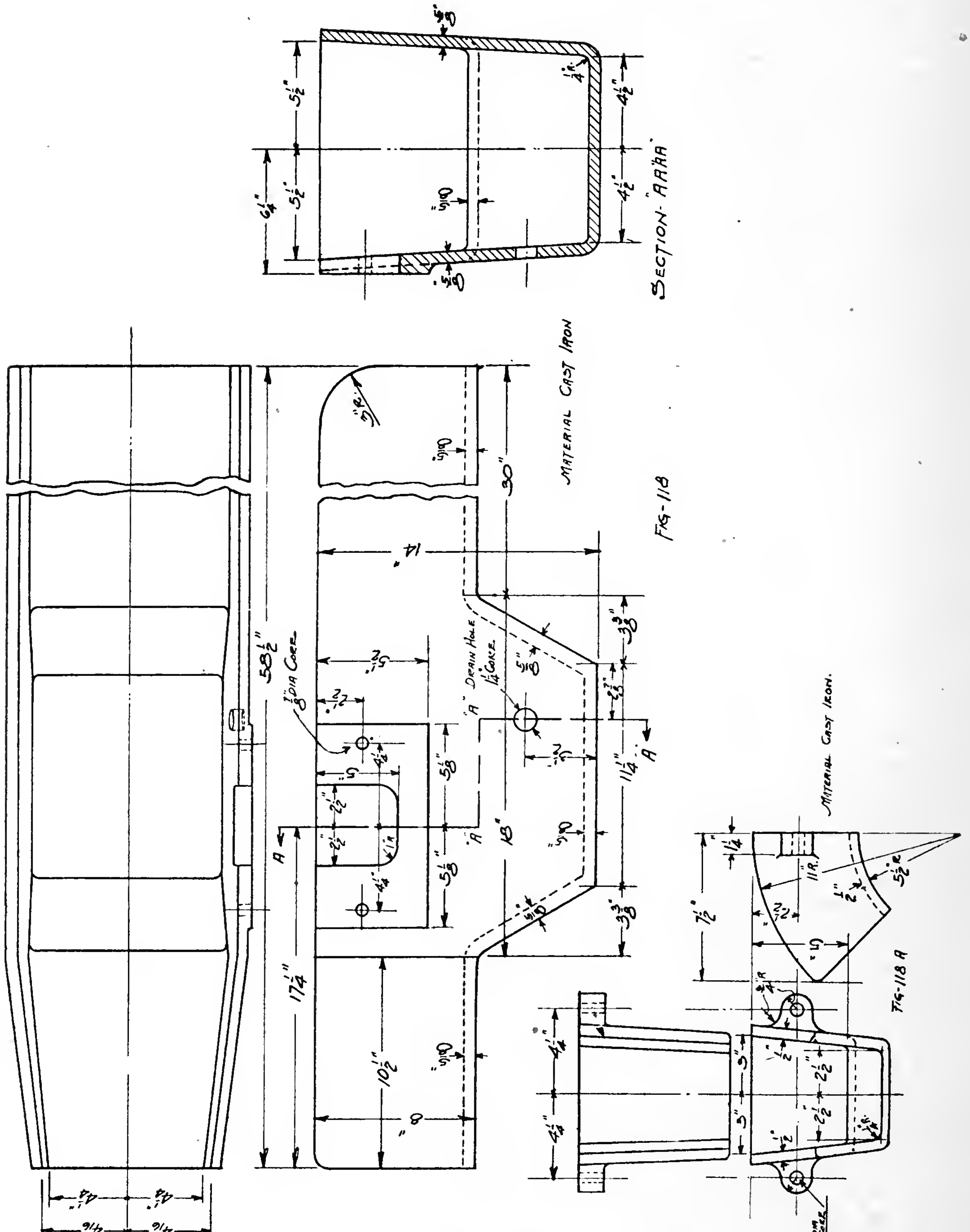
## SECTIONAL VIEW OF SLAGGING SPOUT.

A sectional view showing the slagging spout and a portion of the interior of a cupola is shown in Fig. 118 B. The fire brick and spout for slag are also shown in position.

The height of crest A is raised to suit; in some instances it is level with the upper edge of tap hole in cupola, but may also be carried a trifle higher or lower to suit conditions. This height is generally determined by experimenting.

## SLAGGING SPOUT.

Pig iron and scrap are not always absolutely clean and generally have an accumulation of sand and dirt adhering to them. This sand and dirt separates from the iron when it is changed to the liquid state and forms what is known as slag, which floats on top of the molten iron.


SECTION "AA"AA"
MATERIAL CAST IRON
FIG-118
"A" DRAIN HOLE 1¼" CORE
MATERIAL CAST IRON.
FIG-118 A

Generally cupolas are provided with an opening in the rear shell, so placed that this slag and not the iron will flow from it. However, some cupolas allow both the metal and slag to run from the tap hole and separate the slag from the iron in the spout. This is accomplished by the use of a slagging spout. When a slagging spout is used the rear hole in shell is stopped up.

This spout is lined with fire brick and a fire clay daubing mixture. Fig. 118 B. A fire brick is placed crosswise, the lower edge of which is about 3″ above the 1¼″ drain hole in the side (see side view Fig. 118). As mentioned above, the slag floats on top of the iron and when the metal flows from the cupola, the liquid iron passes under this fire brick filling the pocket gradually and rising until the lower edge of this fire brick is under the surface of the metal. The slag remains on top of the iron and cannot pass under this brick, it is therefore trapped by the obstruction caused by the fire brick, and will flow off the side thru the opening provided.

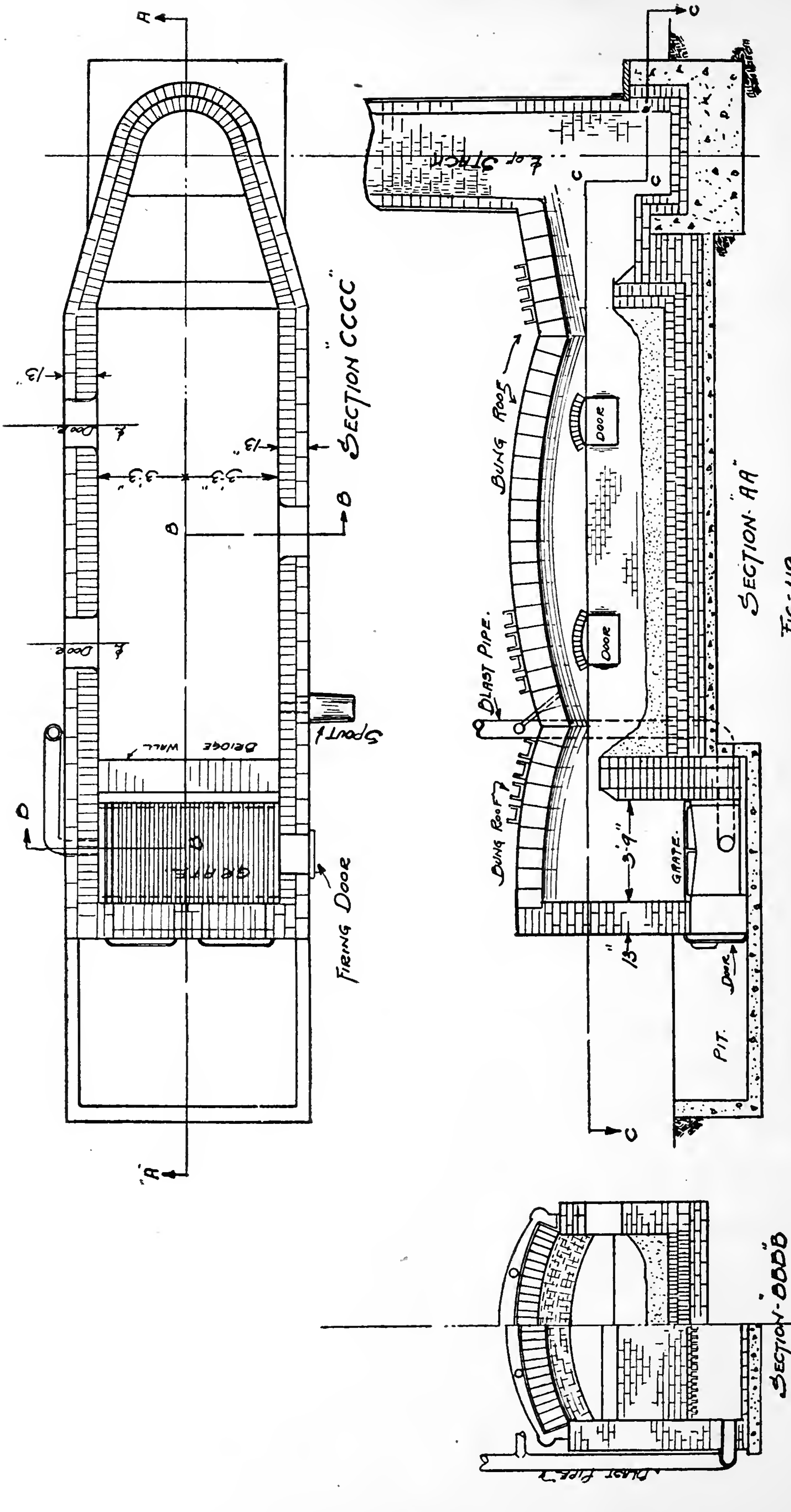
The detail drawing of one of these slagging spouts is shown in Fig. 118.

This drawing shows a zigzag cross sectional view at the right and is marked "Section AAAA." Referring to the side view, the location of this cross section may be found. A top view is placed above and shows the tapered end which fits into the recess of the cupola; this taper can only be shown on either a top or bottom view and therefore it is necessary that three views be shown of this spout.

The cross sectional view shows the vertical taper of the spout, being 11″ across the inside at the top and 9″ at the bottom. The entire length is 58½″. This dimension will be found between the side and top views.

Note that the slag hole, which is 5 x 5″, the lower corners rounded by a 1″ radius, is only shown in one side. This is indicated by the cross sectional as well as the top view.

The auxiliary spout thru which the slag flows is shown in Fig. 118 A. This spout is provided with two bolt holes for bolting it onto the main spout. These bolt holes are 8½″ apart and the lugs for these are 1¼″ thick. These holes correspond to those in the side of the main spout and are marked "⅞″ dia. core."


SECTION "CCCC"
SECTION "AA"
SECTION "BBBB"
FIG. 119
BUNG ROOF
BLAST PIPE
DOOR
GRATE
PIT
FIRING DOOR
SPOUT
BRIDGE WALL
GRATE
3'-9"
13"
3'-3"

## MALLEABLE IRON FURNACE.

Working drawing view of a furnace used in the manufacture of malleable iron is shown in Fig. 119. The views shown are longitudinal cross section, horizontal cross section (at top) and two vertical transverse half sections thru different locations in the furnace.

The longitudinal cross section is taken along the line AA (see top view) and is an imaginary vertical cut thru the furnace.

The horizontal zigzag cross section is taken along the line CCCC (see longitudinal section) and the surfaces cut by the line are shown at the top and marked section CCCC.

It is supposed that all the portion above the line CCCC is removed and that the eye is looking down in a vertical line with all points, as explained under Fig. 11.

The location of the cross sectional views at the left are indicated by the letters BBBB (see horizontal sectional view at top).

Details of the construction are as follows:

The furnace consists of a hearth, fire box and stack.

The entire furnace is covered with a removable arched roof of refractory brick which is held in place by cast iron bungs. Sections of roof are removed when charging the material—each ring being separate, allows them to be readily removed, and replaced with another when it is in need of repairs.

The heat for melting is obtained from bituminous coal which is burnt on the grate, and charged thru the door at side (see top view). The air for combustion is supplied by force draft thru the blast pipe as shown, which enters under the grate. At the upper end of this blast pipe a branch pipe runs across the top of furnace with numerous smaller pipes entering thru the roof. The additional blast at this point further assists in obtaining complete combustion and also directs the hot gases onto the charge in the hearth.

The hot gases from the combustion of the coal are deflected downward over the bridge wall by the curved construction of the roof. Assisted by the natural draft of the chimney, the gases are moved over the hearth and finally go out of the chimney.

As the scrap and pig melts, it finds its way to the tap hole, the sand bottom having been sloped in this direction, and finally the liquid metal is tapped and flows from the spout (see horizontal section).

Some malleable furnaces are arranged with a water tube boiler placed between the hearth and chimney, and utilize the waste heat which would ordinarily travel up the chimney, to generate steam in the boiler.

Three door openings are provided (see horizontal cross section).

The buck stays and tie rods which bind the entire furnace are not shown in this drawing.

## EXAMINATION

## LESSON 15

1. Fig. 115. How many vertical ribs are there around this annealing box?

2. Fig. 118. (a) What is the thickness of metal in walls of spout?

   (b) What is the distance from bottom of spout to center line of the $\frac{7}{8}$-inch diameter bored hole for bolting on the auxiliary spout?

3. Fig. 119. (a) What is the inside width of furnace?

   (b) What is the thickness of side walls?

# LESSON SIXTEEN

## MELTING FURNACES.

The manufacture of iron and steel begins with the mining of the raw material (iron ore)—approximately 85 per cent of which is mined in the Lake Superior district, about 8 per cent near Birmingham, Alabama, and the balance in New York, Pennsylvania, New Jersey, and other States.

In 1917, 75,288,000 ton of ore was mined in America and 38,621,216 ton of pig iron produced.

When it is known that approximately 2000 lbs. of coke, 1200 lbs. of limestone and 4256 lbs. of ore is required to produce one net ton of Northern pig, you can appreciate the producers' objection to the present high freight rates.

A cupola (Fig. 104) is a furnace used in the manufacture of cast iron.

A malleable furnace, sometimes called air furnace (Fig. 119) is used to manufacture malleable iron.

A converter (Figs. 121 and 122) is one type of furnace used to manufacture steel.

An open hearth furnace (Figs. 123 and 124) is another type used in the manufacture of steel.

All of these melting units use a percentage of pig iron with scrap to produce iron or steel, as the case may be. The pig iron is manufactured in a blast furnace (Fig. 120).

The electric furnace (Fig. 126) is the latest method of producing steel. This process requires electric current to generate the necessary heat.

The construction of each type of furnace is briefly outlined under its respective heading and should prove of interest to the student. Complete information on the various methods of producing steel is contained in **McLain's System** of steel foundry practice which is the result of a practical investigation of each process.

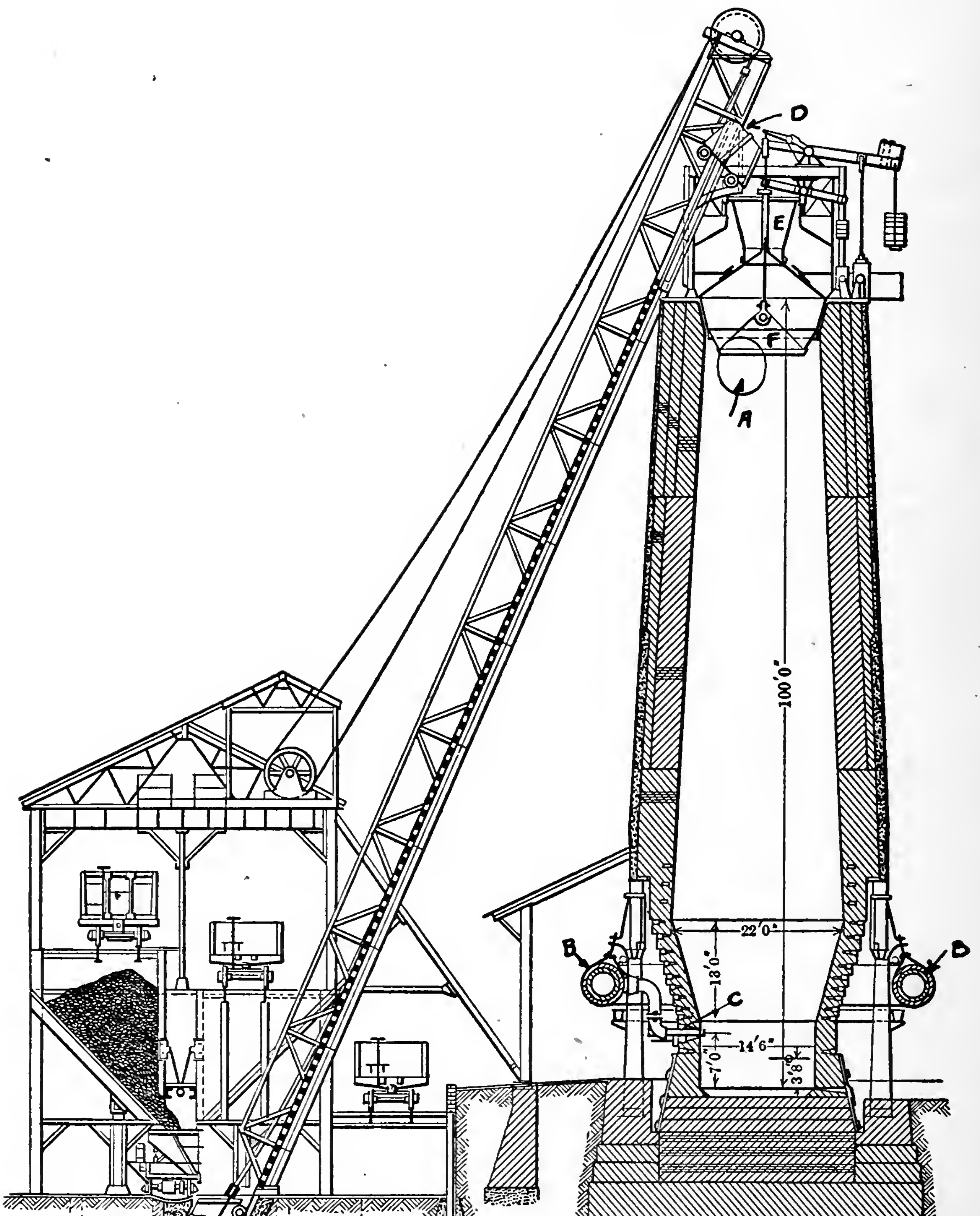



FIG-120

## BLAST FURNACE.

A blast furnace is used to manufacture pig iron from iron ore.

A cross sectional view of a blast furnace, skip hoist and hopper house is shown in Fig. 120. It is to be remembered that this drawing merely shows one view and is not a complete working drawing. However, it is shown to familiarize you with its construction and operation.

The furnace consists of a tall cylindrical shell provided with tuyeres at the bottom and a special bell hopper at the top.

Ore, coke and limestone are the materials necessary to manufacture pig iron.

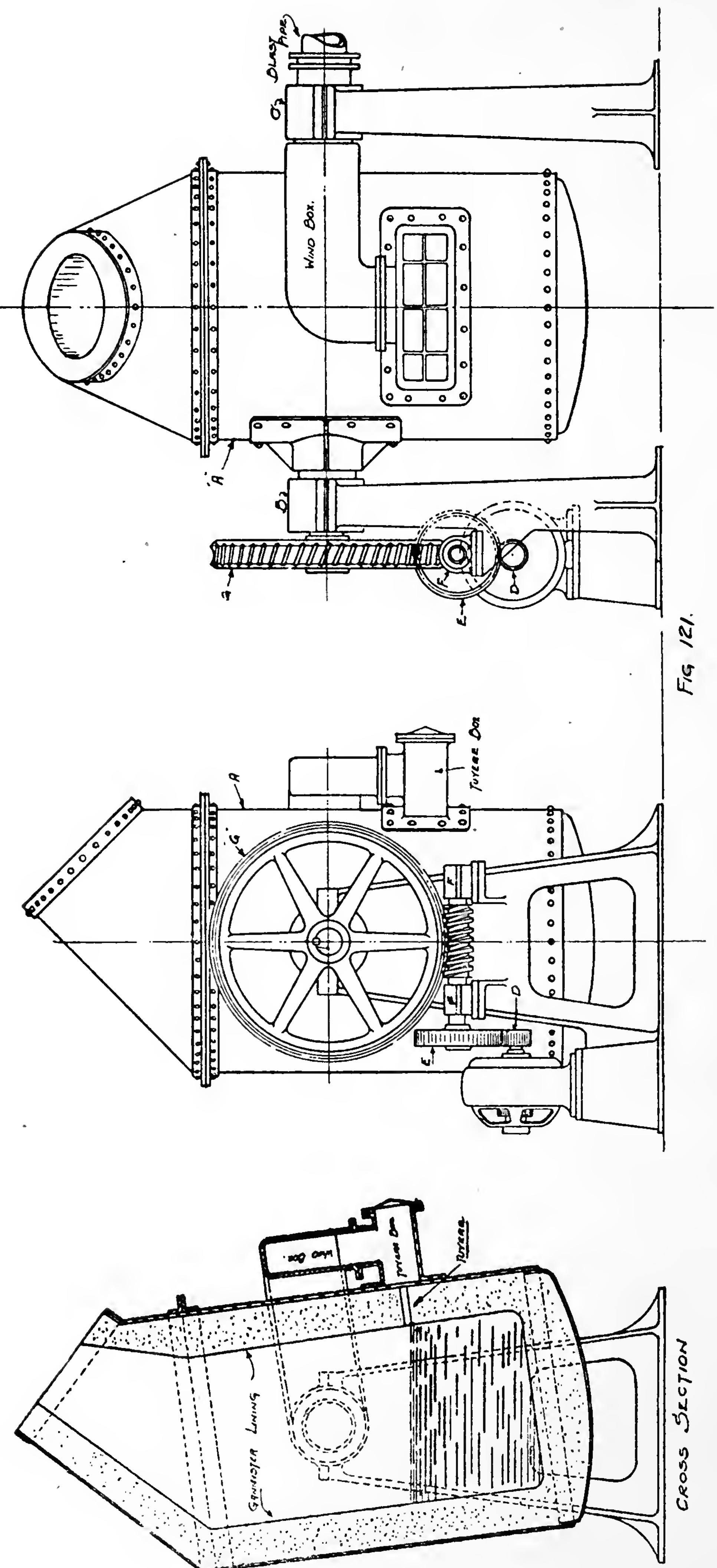
Iron ore, the raw material of the blast furnaces, is an oxide of iron usually more or less contaminated by various impurities, and it is the function of the blast furnace to remove the oxygen from the iron and to slag off the impurities. Carbon in the form of coke is the usual deoxidizing agent and its combustion also furnishes the heat necessary to melt the resulting iron and slag. Limestone is added as a flux to render the slag more easily fusible.

The ore, coke and limestone are elevated to the top by cars D which are operated by cables. The contents of these cars are automatically dumped into the receiving hopper E, . which is sealed with a bell valve F and is operated when a charge is to enter the furnace chamber.

The bell valve F also prevents the gases from making their escape thru the top, forcing them out of the opening A.

The blast furnace is provided with a spout and also a slag hole. The metal flowing from the spout is run directly into a trough and from there into the pig molds.

Air is introduced into the furnace to assist in the proper uniting of the carbon and oxygen. This air is furnished by powerful blowing engines, which pump it into a large main. From here it is piped into hot blast stoves. (Not shown.)


Blast Pipe
Wind Box.
Tuyere Box
Tuyere
Ganister Lining
Cross Section
Fig 121.

## DESCRIPTION OF HOT BLAST STOVES.

These stoves are large, vertical cylinders, lined with refractory brick and have numerous chambers and flues—some of which are filled with loose bricks set apart and on edge, each layer setting crosswise on the other. This brick work is known as **checkers.**

The gases exit thru the opening A near the top (see Fig. 120) and are piped thru downcomers into the bottom of these stoves from where they rise and heat the checker brick and finally pass out of the chimney. By regulating a valve system, the gas is then shut off and piped into one of the other stoves, three or four stoves being used in connection with each blast furnace—the air from the blowing engines is then pumped into the stove and thru the various passages between the checker brick, which have been previously heated. The air from the engines absorbs this heat and it is then piped into the bustle pipe B which surrounds the blast furnace. From here the air is delivered thru numerous smaller pipes into and thru the tuyeres C and finally into the furnace.

## SIDE-BLOW CONVERTER.

Fig. 121 is a general outline—side, end and cross section of a side-blow converter.

A converter consists of a cylindrical steel shell A, lined with refractory material. This cylinder is suspended between two trunnions which allow the cylinder to revolve.

The right hand trunnion C is designed to allow the blast pipe to extend thru it and make connection with the wind box, which in turn connects with the tuyere box (see cross sectional view) and finally with the tuyeres.

Blast is supplied by a positive blower (see Fig. 93). This blast is forced thru the tuyeres and over the bath of molten iron oxidizing the mixture and thereby eliminating the silicon, manganese and carbon of the molten iron which has previously been reduced to the molten state in a cupola.

After the blast is forced over this metal for about 10 to 12 minutes, it has reduced the above mentioned elements considerably and then the desired amount of silicon, manganese and carbon in the castings is added in the form of ferro-silicon, ferro-manganese and spiegeleisen.

**McLain's System** of steel foundry practice gives a complete detailed description of the manufacture of steel by the converter process.

The cylindrical shell is capable of being tilted back and forth. This is done to keep the liquid metal at about the same level with the tuyeres during the blow. (See cross sectional view.)

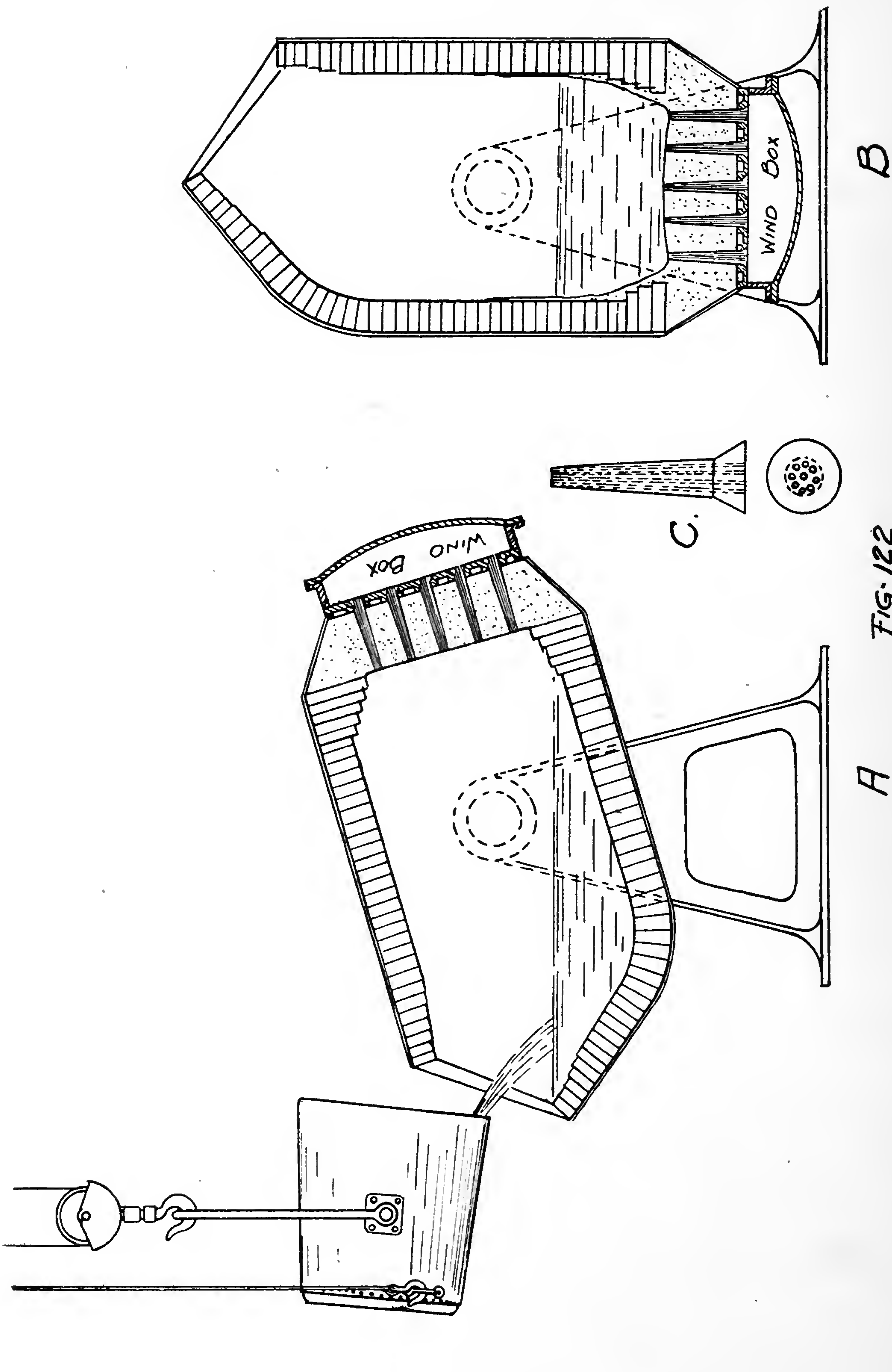


FIG. 122

This tilting is accomplished by the use of an electric motor which has a pinion D on the end of its shaft. This pinion engages with a spur gear E and this gear is supported by a worm shaft which is held in place by two bearings F. This worm engages with a worm wheel G which is keyed to the main trunnion casting extending thru the bearing B.

The projections of all points between the side and end view are horizontal and a careful study should be made of each point, line and surface projected.

Starting with the motor, project all points from the side view to the end view, taking note why some lines are dotted and others full; remember the rules for making projections and refer to these occasionally.

The opening at the top is shown as being oval in the side view and is a good example of an angular projection. The actual opening is round in the end view.

## BESSEMER CONVERTER.

The Bessemer converter is a furnace used in the manufacture of steel. Its construction is similar to the side-blow converter (the explanation of which is given under Fig. 121), except in the arrangement of the tuyeres.

Fig. 122 shows two cross sectional views of a Bessemer converter. The one at the left shows it tilted down in position for receiving a charge of molten iron which has been previously melted in the cupola. It will be noticed that the liquid metal in the converter does not interfere with the tuyere openings at the bottom.

The air which is supplied by blowing engines at 18 to 25 lbs. pressure is piped to the trunnion thru it and connects into the wind box at the bottom (instead of side as in Fig. 121).

The converter is then tilted in a vertical position, while at the same time the air is being forced thru the tuyeres—an enlarged view of a tuyere being shown at C.

When the vessel is in a vertical position, as at B, the air passing thru the liquid metal causes considerable agitation, oxidizes the carbon, silicon and manganese (acid process), the chemical reaction generating intense heat. When these elements have been reduced to a minimum, the quantity desired in the castings is then added in the form of alloys known as spiegeleisen, ferro-manganese and ferro-silicon.

After these additions have been made the vessel is again turned down, the liquid steel allowed to drain out into a ladle placed under it, and finally conveyed to the mold where it is poured—forming castings.

By comparing Fig. 122 with Fig. 121 you should experience no difficulty in forming the mental picture of the exterior views.

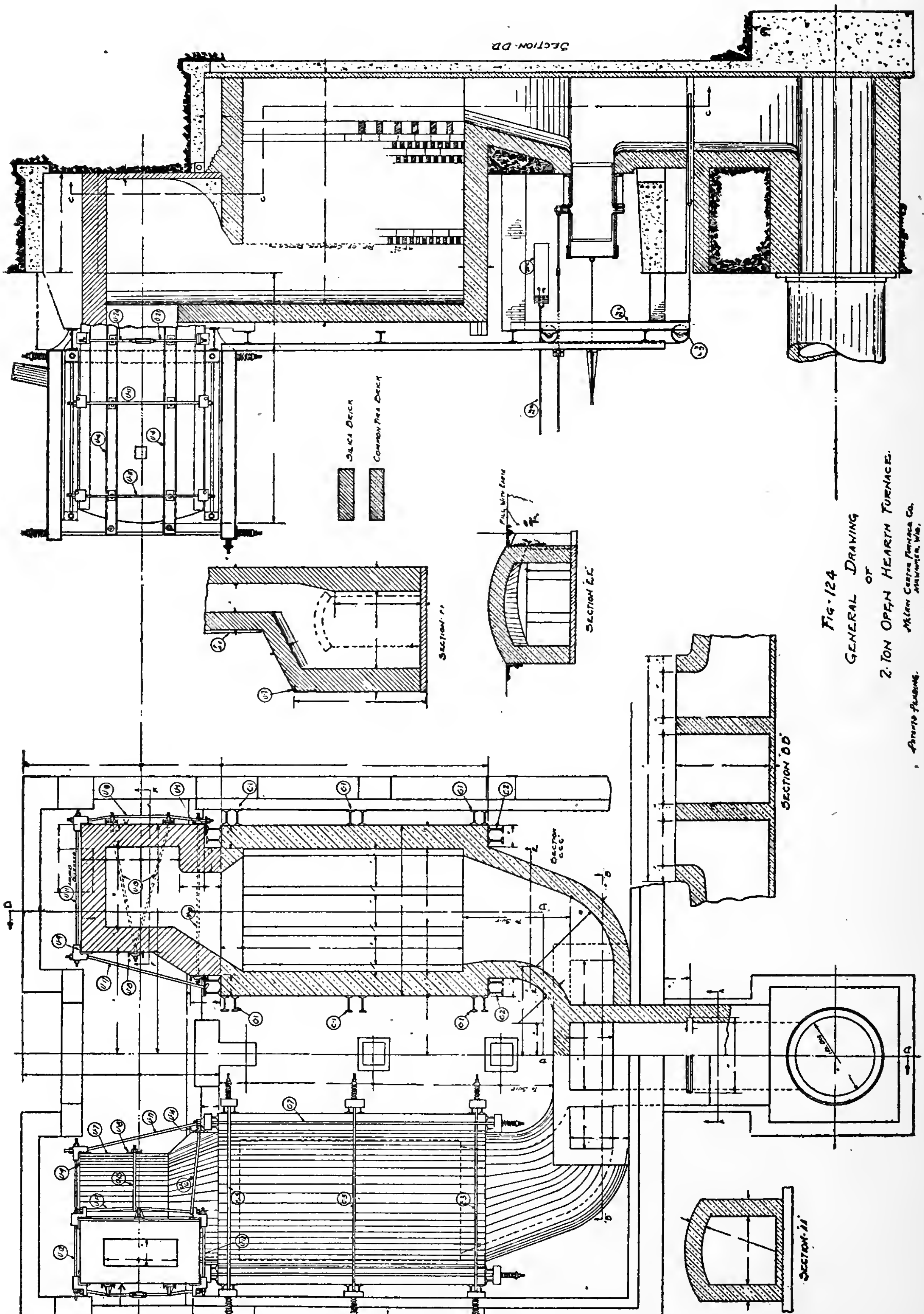



Fig. 124 General Drawing of 2-Ton Open Hearth Furnace.

## OPEN HEARTH FURNACE.

There are four types of furnaces for making steel—crucible, converter, electric and open hearth.

The open hearth furnace consists of a hearth, a set of regenerators (sometimes called checker chambers), a reversing valve, a stack to furnish draft, and a charging platform. The principle of operation is as follows:

Refer to Fig. 123. The scrap and pig iron are charged thru the doors onto the hearth. When charging is completed the fuel (in this case oil) is blown thru the burner A under high pressure, 50 to 60 lbs., over this scrap and pig iron. In order to increase the temperature of this flame sufficiently to melt the scrap and pig iron, additional air, which has been preheated, is allowed to mix with the flame of the oil, increasing the temperature.

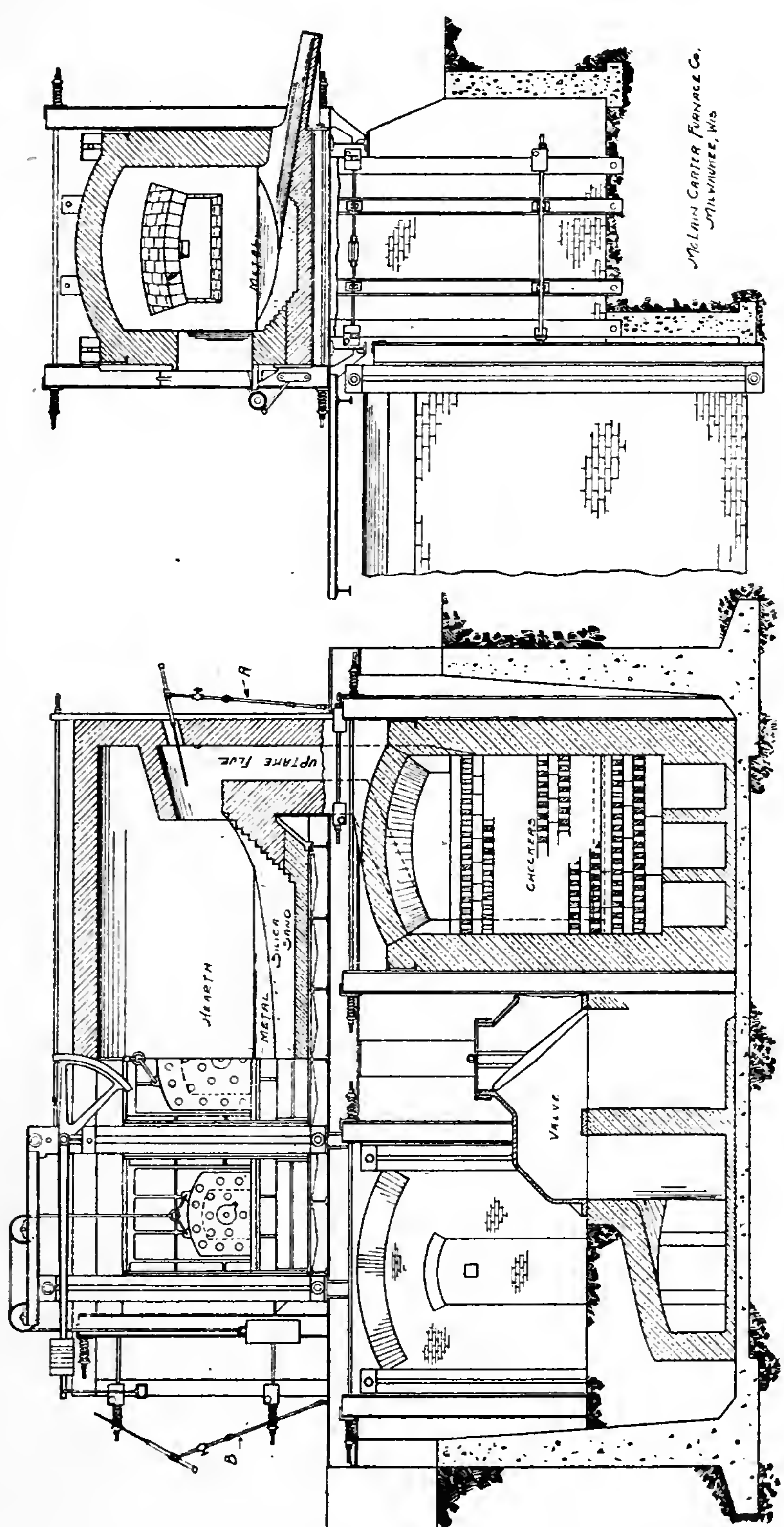



Fig. 123

After pasing over the metal, the gases still contain considerable heat, and in order to utilize this, it is passed down thru the uptake flue and into one of the regenerator chambers where these gases pass thru a series of checker brick work, which are so arranged that the gases in passing over them will give up their excess heat to the checker brick. The gases, after passing thru this regenerator, pass thru the flues, under the reversing valve and finally out of the stack.

After the gases have passed thru this circuit for about 15 or 20 minutes, the opposite oil burner B is introduced and burner A withdrawn. The reversing valve is then thrown over, allowing the air which enters at the top to pass thru the checker brick which has just been heated by the waste gases as explained. This air, in passing thru these bricks, absorbs the heat from them, then passes up the uptake flue, mixes with the fuel oil at end of burner, B, passes over the metal and down the opposite uptake flue into the opposite checker chamber and finally out of the stack.

Figs. 123 and 124 show the general arrangement and the entire construction of the complete open hearth.

Fig. 123. One-half of the hearth is shown in exterior view and the other half in cross section, showing the liquid metal and uptake flue, the burner A being in position for melting. The left hand checker chamber is shown in exterior view and the right hand in cross sectional view. The reversing valve and flue under it are shown in cross section.

Fig. 125

Fig. 124 shows a plan view of the uptake flue, a top and horizontal cross sectional view of the checker chamber, the flues connecting the checker chamber with the flues under reversing valve and the flue connection to the stack.

The longitudinal cross sectional view, section DD shows the uptake flue, regenerator chamber, reversing valve and stack in cross section.

The entire checker chamber and hearth are securely held in place by structural steel buck stays.

A photographic cut of the hearth, showing the charging doors, and counter balanced sector for raising the center door is shown in Fig. 125. The drawing and perspective photo cut shows the original 2—3 ton **McLain-Carter** furnace. This furnace is capable of melting a 3-ton heat, ready to tap out of the spout, in 1 hour 30 minutes—truly a wonderful record! This is possible, due to the shallow bath and exceedingly large regenerator which makes it very economical.

The **McLain-Carter** furnaces are now built in all sizes up to 30-ton capacity.

## ACID AND BASIC MELTING.

There are two distinct processes in the manufacture of steel in the converter as well as in the open hearth and electric furnaces. They are the acid and basic. The difference in the melting units is in the composition of its lining; the general construction and arrangement of their mechanical features are the same in both.

When the furnace is lined with a basic lining, it is capable of oxidizing not only the carbon, silicon and manganese but also the phosphorus and sulphur, providing, however, the slag is basic.

In the acid process, the lining is acid, that is a lining rich in silicic acid, such as quartz and clay. By the acid process only the carbon, silicon and manganese can be oxidized. The sulphur and phosphorus must be controlled by the amount charged.

## EXAMINATION

## LESSON 16

1. Fig. 121 cross sectional view. Which pedestal is shown in this view, B or C?

2. Fig. 124. By what section letters is the view marked which shows the construction of the flue from the stack to rear wall of pit?

# LESSON SEVENTEEN

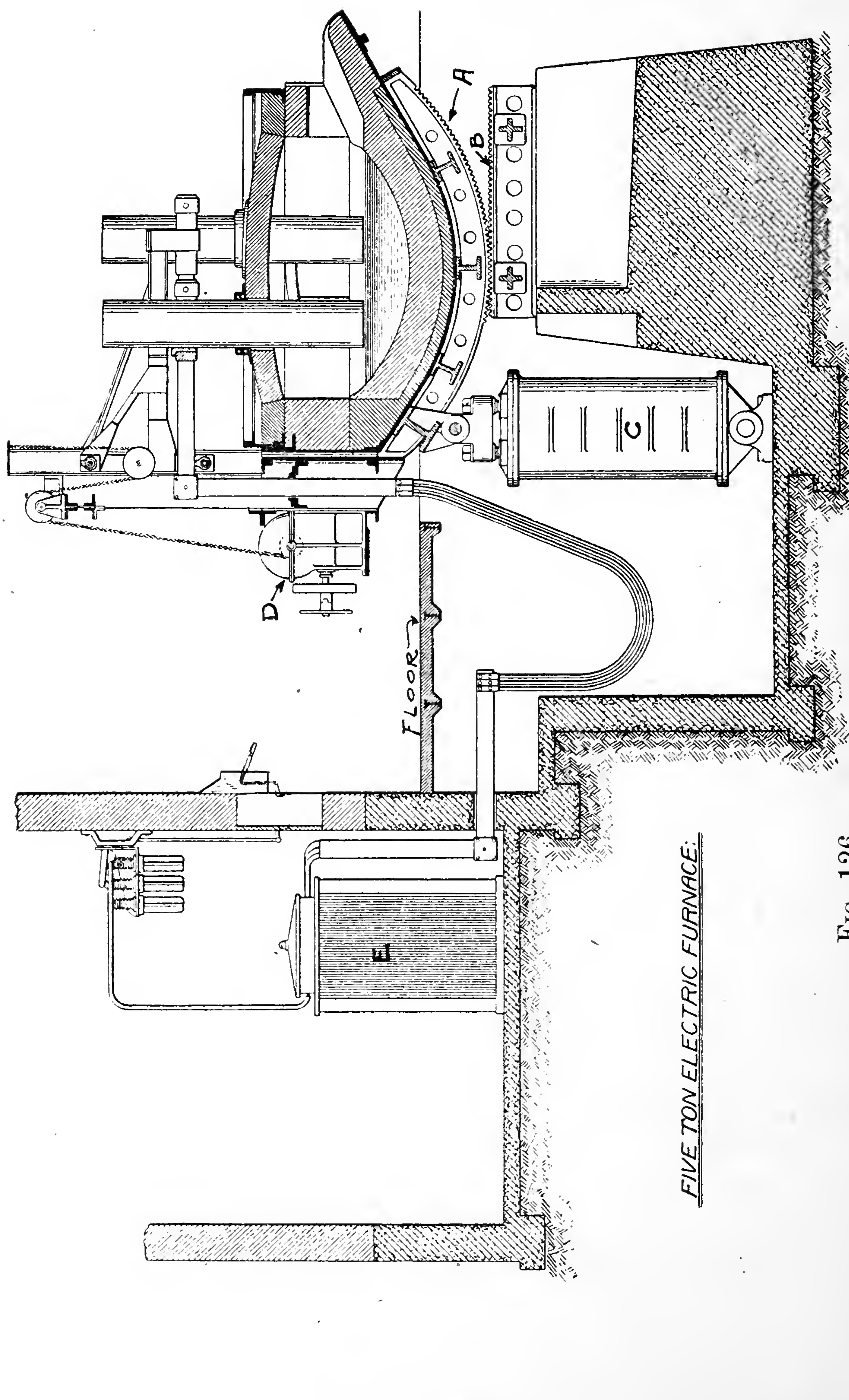
## PROCESS OF MAKING A BLUE PRINT.

It may interest you to know how a blue print is made. A draftsman draws his designs or outlines of the various objects on Manila paper. A tracing is then made of the outlines by placing either a transparent paper or cloth over the outlines on the Manila paper and tracing them with a special pen and India ink on this transparent paper or cloth.

When this is completed we have what may be compared with a negative in the photographic work—it being the outline of the object on the transparent paper or cloth, as the case may be. It is then laid face down on a sheet of clear glass, and a sensitized paper (known as blue print paper) is laid on the negative with the sensitive side against it. It is then clamped in place and exposed to the sunlight or some other strong light. In printing the light does not penetrate the inked outline of the drawing. After a short exposure the clamps are removed and the sensitized paper thoroly washed in clear water. The parts upon which the strong light has shone turn blue and the parts or lines directly under the inked outlines are not affected by the rays of the light, hence show up white.

There are blue print machines on the market, and instead of exposing the sensitized paper to the sun light as mentioned above, it is exposed to a strong electric light—the sensitized paper is fed past these strong electric lights and directly into a tray where it is washed. After this it is passed thru a dryer. The complete operation is automatic.

After a tracing has once been made, an unlimited number of blue prints can be made from it, involving very little cost.




The Héroult Furnace.

FIG. 126

## ELECTRIC FURNACE.

There are many types of electric furnaces on the market today—the majority of them being used in the manufacture of steel. Ferro-alloys are also manufactured in the electric furnace. A more recent field in which the electric furnace is gaining prominence is that of melting brass, gray iron and semi-steel.

These furnaces are generally operated on three-phase circuits, the furnaces being equipped with three electrodes entering thru the roof. Heat is generated by the arc which jumps the gap between the end of one of the electrodes and into the molten bath, making its exit thru the other two electrodes the current reversing at the rate of 60 times per second. In other types a bottom connection is provided, the current passing down thru the bath and out of the lower connection.

Fig. 126 shows a cross sectional view of a Heroult electric furnace the construction of which is as follows:

The furnace shell is of steel plates riveted together, forming in plan a circle 13′6″ diameter, flattened at the front and back. To this shell is fastened a toothed segment A, which gears into a stationary rack B, fixed to a concrete bed 5′ above the ground level. The segment has an arc of 10′ radius, and gives a maximum tilting angle of 29° to the furnace. To the back of the furnace is attached a hydraulic plunger 18″ diameter by 4′ stroke, which works at a pressure of 500 lbs. per square inch.

The furnace is lined with one 4½″ course of magnesite brick on the bottom with vertical side walls of magnesite, 18″ thick. The bottom is composed of dead burnt magnesite, 12″ deep at the center, sloping upward towards the edges to the form of the surface of a sphere, 7′ 2″ radius. The removable roof is composed of silica brick, 12″ thick. There are 5 doors, 2 on each side and 1 in the front over the pouring spout. The side doors are of cast iron lined with fire brick, and are operated by steam pressure.

The furnace works on 3-phase current and the 3 electrodes form in plan the apexes of an equilateral triangle of 5′ 2″ side. The electrode holders, which are arranged to carry 24″ electrodes (or the equivalent in electrodes built up of smaller sections), are constructed of copper castings, bolted to the busbars. They are regulated by an automatic device D, by hand, or by controllers, as desired.

For this particular furnace the power is generated at 2200 volts, 3 phase, 25 cycles, and stepped down at the furnace by means of three 750 kilowatt transformers E, which may be adjusted to give secondary voltages of 80, 90, 100 or 110 as desired. Ordinarily 90 volts is used.

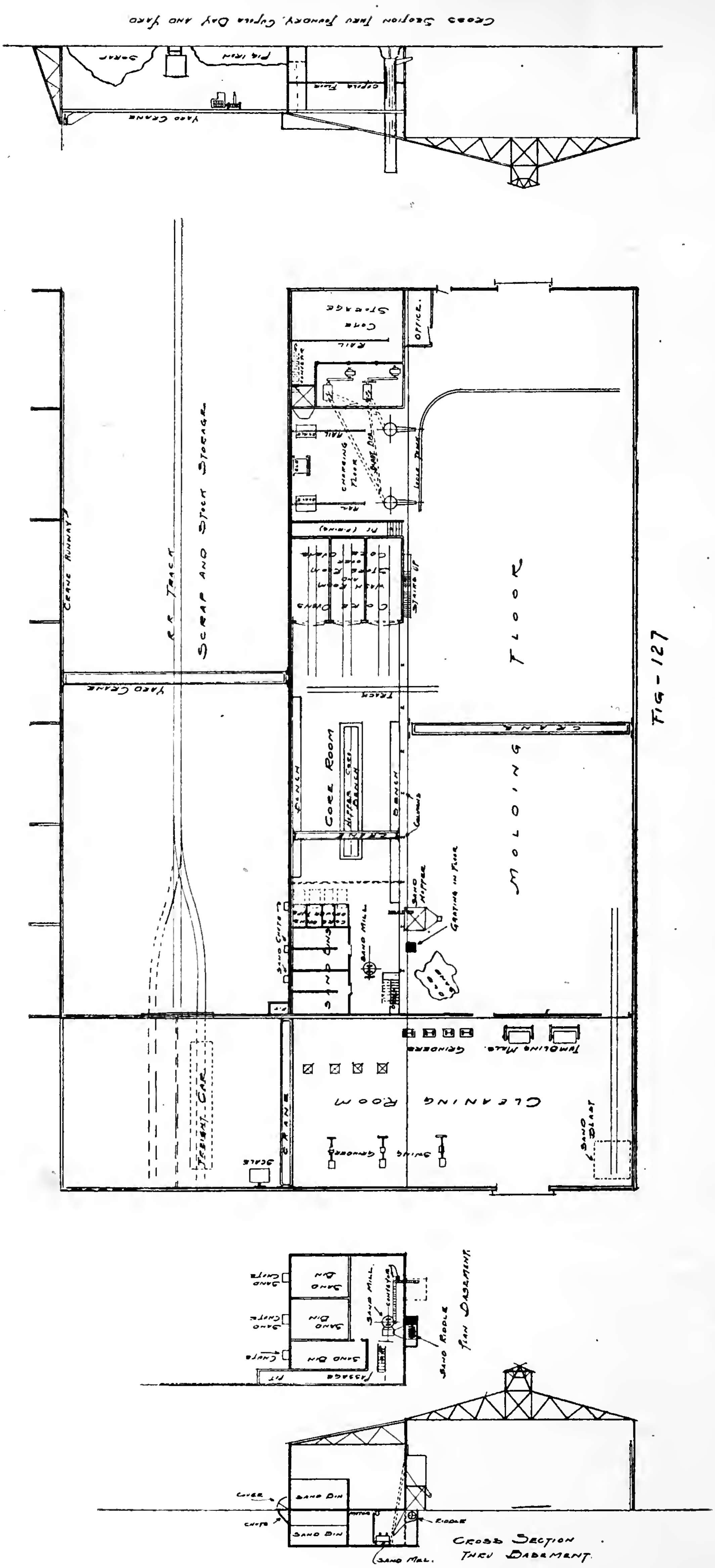

Cross Section thru Foundry, Cupola Day and Yard
Scrap
Pig Iron
Yard Crane
Crane Runway
R R Track
Scrap and Stock Storage
Yard Crane
Freight Car
Scale
Core Storage
Office
Rail
Charging Floor
Core Room
Bench
Sand Mill
Sand Hopper
Grating in Floor
Sand Bins
Sand Chute
Molding Floor
Crane
Grinders
Tumbling Mills
Cleaning Room
Sand Blast
Plan Basement
Sand Bin
Chute
Sand Riddle
Passage
Pit
Cover
Riddle
Sand Mill
Cross Section thru Basement

FIG-127

## PLANT LAYOUT DRAWINGS.

When contemplating a new plant, an addition or a rearrangement of the equipment in an existing plant, it is customary that a consultation is held and the suggestions of the superintendent, manager and foreman are invited. Frequently a layout is prepared by the Engineering Department and a consultation is held.

It is very much desired that all concerned possess a clear understanding of the general arrangement, etc. To enable you to become better acquainted with this type of drawing we have shown the layout of a foundry.

Attention is called to the practice employed in indicating the location of building columns, door ways, stairs, railroad tracks, etc., also various pieces of equipment, namely an outline showing the approximate floor space occupied by each piece of individual equipment. When making this type of drawing it is also customary that the north is shown at the top, south at the bottom, east to the right hand, and west to the left. Whenever deviating from this practice the points of the compass are always indicated.

Some plant layout drawings also show a cross sectional view of the buildings. Fig. 127 shows this type of drawing. The cross sectional view at the right shows the relative position of the yard crane and other equipment. A little study of this drawing should enable you to readily understand it. Each student should not merely glance at these drawings but study them and picture the general outline, etc. as they would exist.

Layouts of machine shops show the location of each machine. As it is always desirable to have each operation in the manufacture of an article performed with as little manual labor as possible in transferring it from one machine to another, it is always desirable to so locate them as to make this possible and in some instances mechanical means for conveying parts are installed. All this may be shown on plant layout drawings, the detail of the various appliances being worked out later and shown on detail drawings.

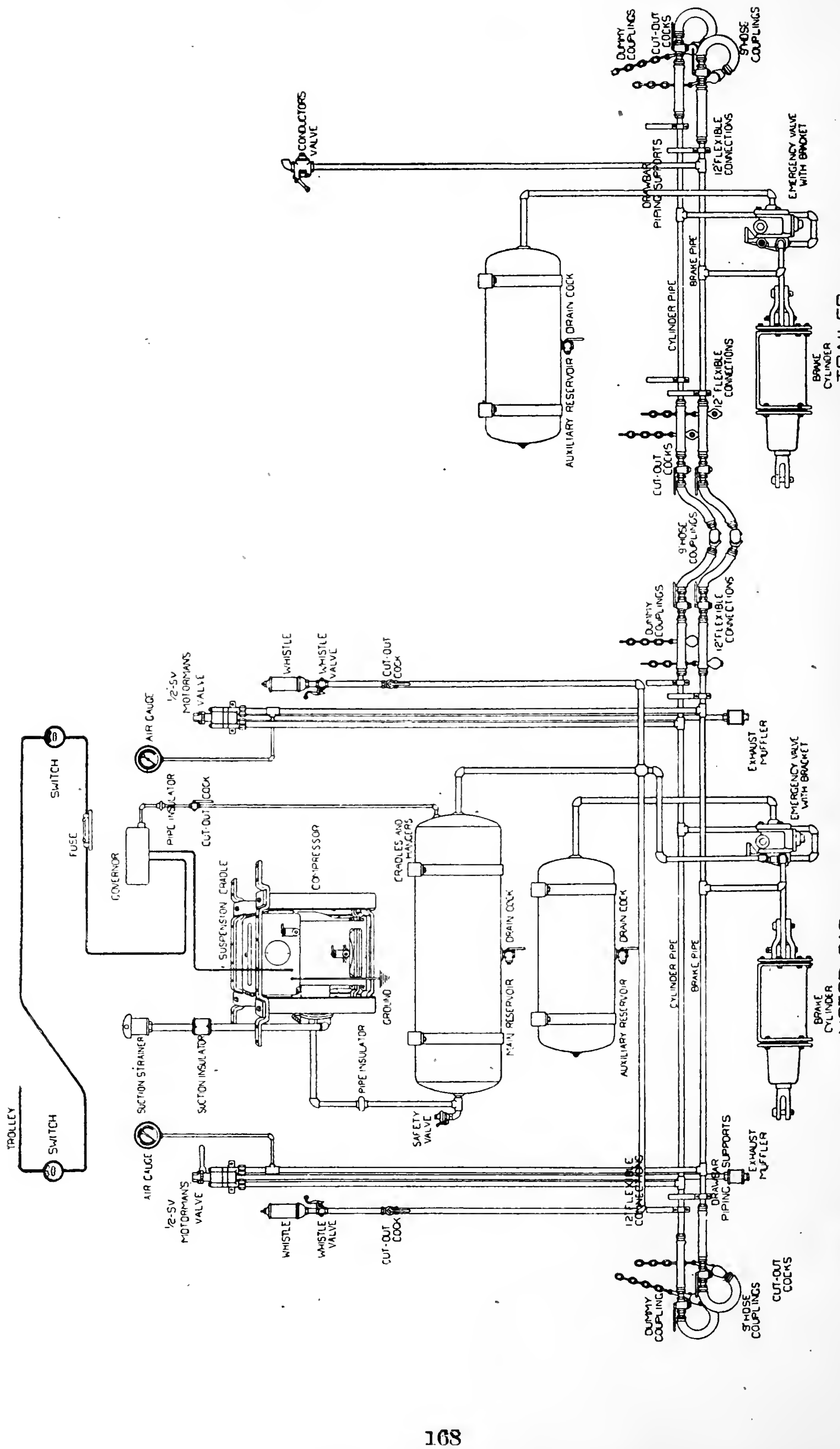
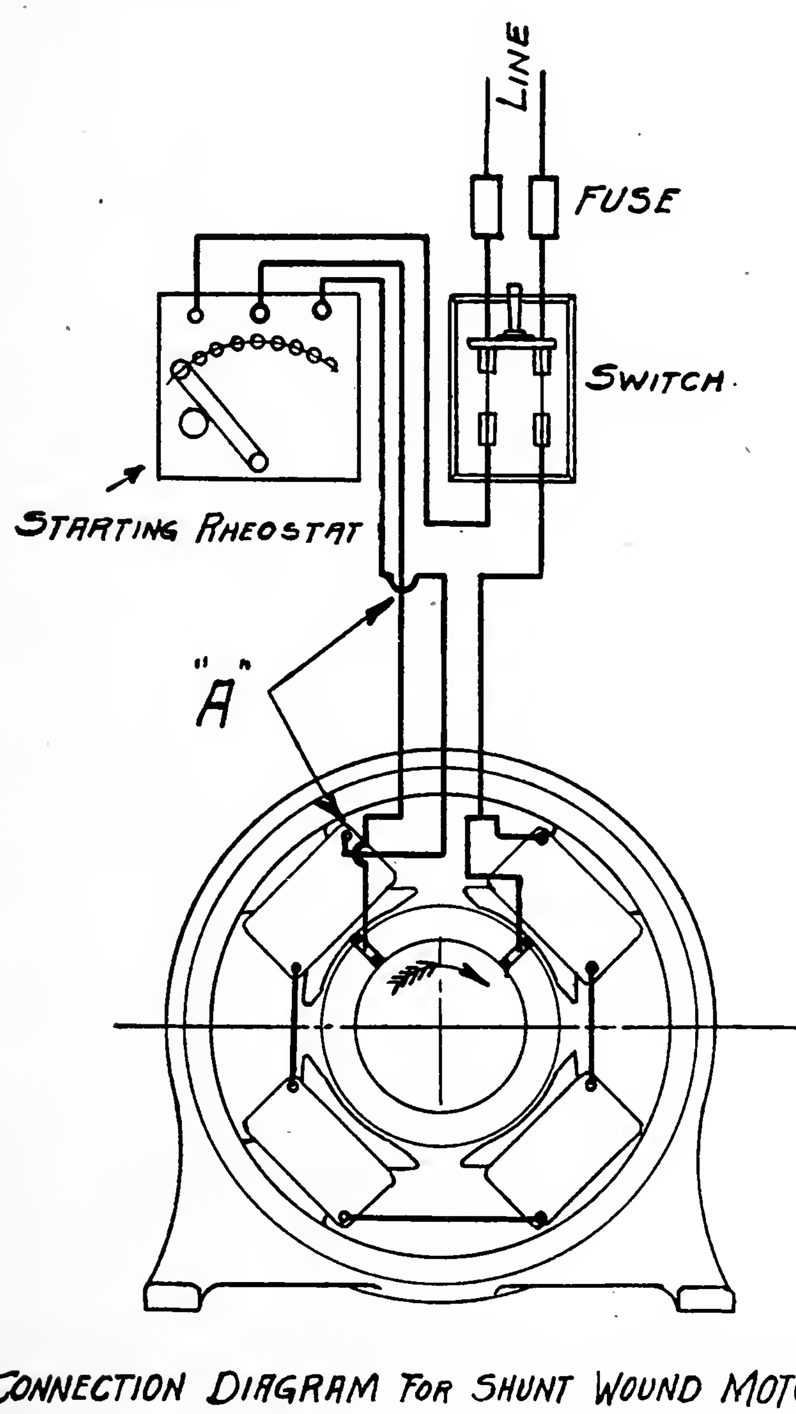

TROLLEY
SWITCH
FUSE
SWITCH
GOVERNOR
PIPE INSULATOR
CUT-OUT COCK
COMPRESSOR
SUSPENSION CRADLE
GROUND
SUCTION STRAINER
SUCTION INSULATOR
PIPE INSULATOR
AIR GAUGE
1/2-SV MOTORMAN'S VALVE
WHISTLE
WHISTLE VALVE
CUT-OUT COCK
AIR GAUGE
1/2-SV MOTORMANS VALVE
WHISTLE
WHISTLE VALVE
CUT-OUT COCK
CRADLES AND HANGERS
DRAIN COCK
MAIN RESERVOIR
SAFETY VALVE
AUXILIARY RESERVOIR
DRAIN COCK
CYLINDER PIPE
BRAKE PIPE
EMERGENCY VALVE WITH BRACKET
EXHAUST MUFFLER
BRAKE CYLINDER
MOTOR CAR
12" FLEXIBLE CONNECTIONS
DRAWBAR PIPING SUPPORTS
EXHAUST MUFFLER
DUMMY COUPLING
9" HOSE COUPLINGS
CUT-OUT COCKS
DUMMY COUPLINGS
12" FLEXIBLE CONNECTIONS
9" HOSE COUPLINGS
CUT-OUT COCKS
12" FLEXIBLE CONNECTIONS
AUXILIARY RESERVOIR
DRAIN COCK
CYLINDER PIPE
BRAKE PIPE
BRAKE CYLINDER
TRAILER
EMERGENCY VALVE WITH BRACKET
DRAWBAR PIPING SUPPORTS
12" FLEXIBLE CONNECTIONS
CONDUCTORS VALVE
DUMMY COUPLINGS
CUT-OUT COCKS
9" HOSE COUPLINGS
C.O.B.

Fig-128.

## DIAGRAMMATIC DRAWINGS.

Diagrammatic drawings show the outline of several pieces of equipment, also the various connections between them. However, the equipment and the connections are not shown in the relative location as they would actually be placed when installed, but merely show the ultimate connections between the several pieces of equipment.

Fig. 128 shows a diagrammatic drawing of a complete air-brake equipment used on a street car. The various pipe lines diagrammatically shown indicate the connection between the several pieces of equipment. The electric wire connection from trolley to compressor motor is also shown diagrammatically. When actually installed the relative positions of the equipment, etc. are entirely changed, but the ultimate connections between the several pieces of equipment must conform to the diagram.




CONNECTION DIAGRAM FOR SHUNT WOUND MOTOR.

FIG-129

## DIAGRAMMATIC WIRING DRAWING.

Fig. 129. This type of drawing is known as a wiring diagram and indicates the proper connections of the copper-leads (or wires) from the switch and rheostat to the motor. Attention is called to the method of indicating that one lead crosses another as shown at A.

In making the actual connections however, the leads are not placed in the relative position to one another as shown on this drawing, but are run in a manner best suited to the local conditions. Ultimately each lead must make its proper corresponding connection, with switch, rheostat or motor, as the case may be, regardless of the direction of the leads.

## REPAIR PART DRAWINGS.

Manufacturers of articles which are more or less complicated furnish the purchasers with a **Repair Part List,** which generally has a cut showing all the working parts. Fig. 130 is a repair part list and drawing of a special valve.

From the cross sectional view here shown it is not possible to form a picture of its general outline, etc. As has been previously mentioned, it is always necessary to refer to more than one view to clearly understand a drawing. However, this drawing was **not made** for the purpose of showing the detail of each component part but that each and every part of valve proper could be recognized when compared with the drawing and by referring to the reference figure and descriptive matter at the bottom, the name and its piece number are given. Both should always be used when it is found necessary to order a duplicate part.

Attention is called to the crosshatching (refer to page 57). Parts 1 and 17 are crosshatched to represent cast iron and parts 2 thru 8 represent cast brass.

Attention is also directed to the method of showing screw threads (14). Note the head of screw is not shown with crosshatching. Note method of showing a cross sectional view of spring (9 and 10).

The tapered thread at each end indicates a pipe tap.

When purchasing equipment which is more or less complicated it is advisable to insist on getting a repair part list and sketch showing the several parts.

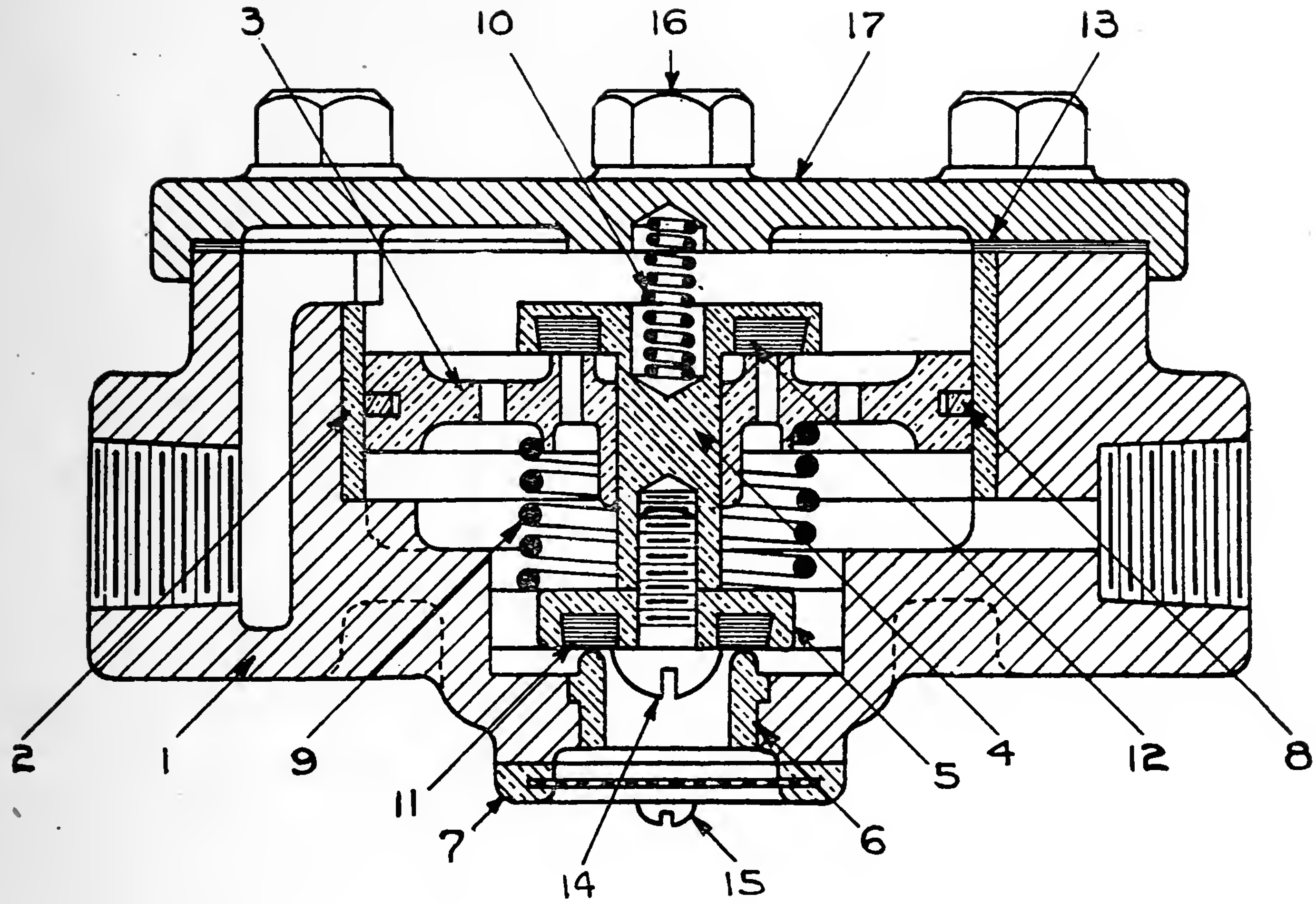
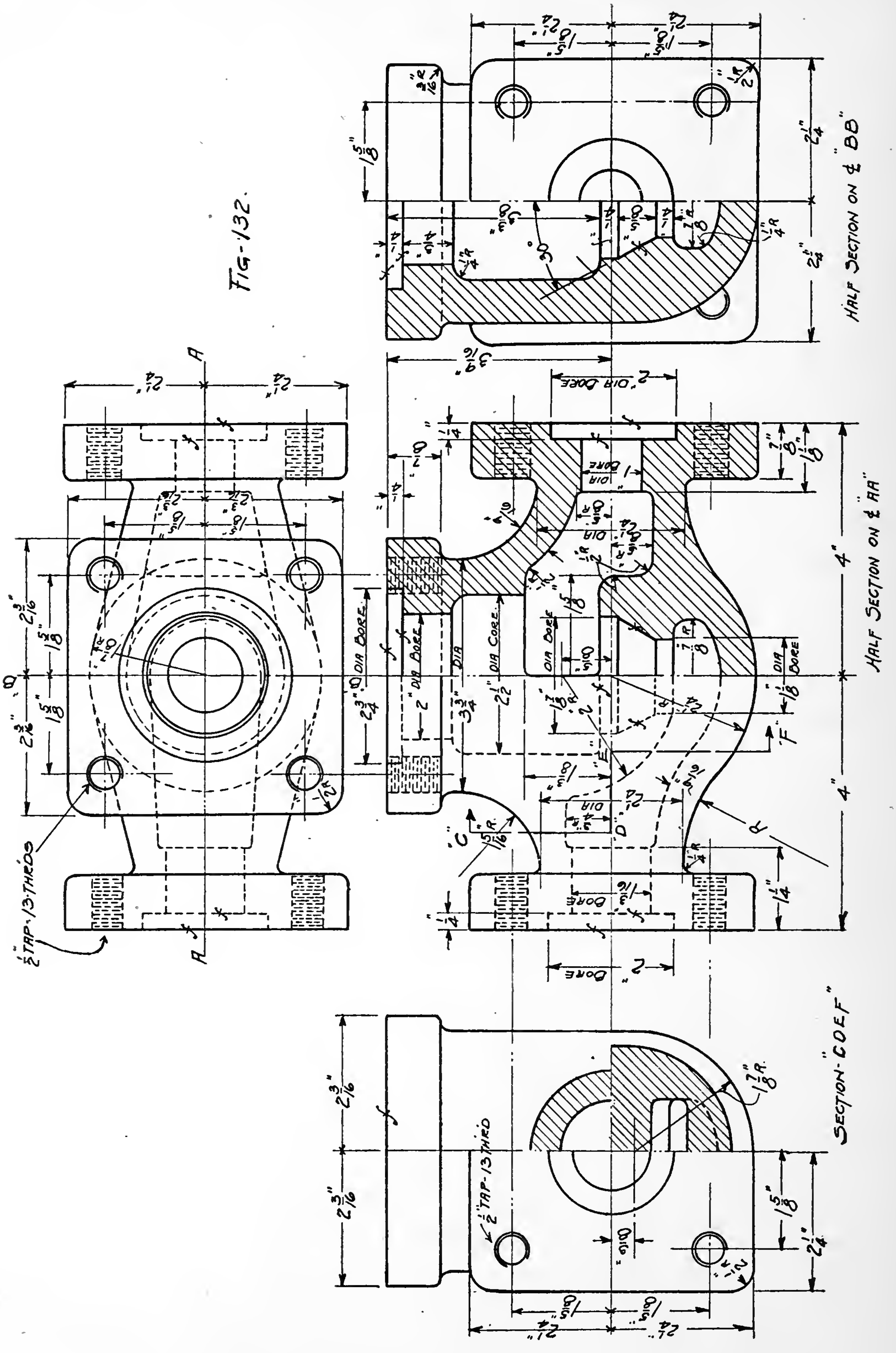



*Fig-130*

# National Release Valve

| Code Word | Ref. No. | Piece No. | Name of Part | |
|---|---|---|---|---|
| Bazzicargo | .... | 8300 | Valve body with bushing, including 8301–8302. | ........ |
| Bazzicater | 1 | 8301 | Valve body.............................. | ........ |
| Bazzicaul | 2 | 8302 | Bushing.................................. | ........ |
| Bazzicavil | 3 | 8116 | Piston.................................... | ........ |
| Bazzichoir | 4 | 8117 | Valve stem............................... | ........ |
| Beachtarn | 5 | 8118 | Piston.................................... | ........ |
| Beackoran | 6 | 8119 | Exhaust valve bushing.................... | ........ |
| Beaconless | 7 | 8120 | Strainer frame and screen................ | ........ |
| Beaconrise | 8 | 8121 | Packing ring.............................. | ........ |
| Beadlebeak | 9 | 8122 | Spring.................................... | ........ |
| Beadleglim | 10 | 8123 | Spring.................................... | ........ |
| Beambox | 11 | 8124 | Gasket.................................... | ........ |
| Beamcable | 12 | 8125 | Gasket.................................... | ........ |
| Beamcase | 13 | 8303 | Gasket.................................... | ........ |
| Beamtread | 14 | 8126 | R. H. M. screw, per 100................. | ........ |
| Beancrop | 15 | 6149 | R. H. M. screw, per 100................. | ........ |
| Beardless | 16 | 8304 | Hex. hd. cap screw, per dozen............ | ........ |
| Bearskin | 17 | 8305 | Cover..................................... | ........ |



HALF SECTION ON ℄ "BB"
HALF SECTION ON ℄ "AA"
SECTION "CDEF"
1/2" TAP-13 THRDS


FIG-132.

## VALVE BODY

Ammonia valve castings are made to withstand a working pressure of 3000 lbs. per square inch. It had been found impossible to make these with an ordinary gray iron mixture—however, by the addition of 30 to 50 per cent **steel scrap** the grain was closed, sections reduced and a more easily machined casting produced. **McLain's System** of mixing by analysis and cupola practice made this possible.

Fig. 132 represents a working drawing of an ammonia valve seat. The views shown are side (half external and half section), top, right hand (half external and half section), and left hand (half external and zigzag cross section).

At first glance this drawing may appear to be a trifle complicated but by taking each line, surface or point separately—**one at a time**—and projecting it to the other views in the same manner as on all previous drawings, it will soon resolve itself into a comparatively easily understood working drawing.

It is advisable to project the lines and surfaces of the **general outline** first—projecting all points between side and top views **vertically** and between view to either right or left of side view **horizontally**.

The half sectional view of the side view shows the construction of the interior in full lines—the imaginary cut being taken along line AA (top view) will disclose these. The surfaces cut are covered with crosshatching. The left half of side view shows exterior view—the construction of the interior being shown by the use of dotted lines.

The right hand end view also shows a half cross sectional and half exterior view. By referring to the top view it is supposed that the lower right hand quarter is imaginarily removed to produce the cross sections shown in the side and right hand end views.

The left hand end view shows two one-quarter sectional views at different locations in the valve proper. See lines C, D, E and F in side view. The upper right hand quarter section is produced by the imaginary cut being taken on line CD.

The lower right hand quarter section is produced by the imaginary cut being taken on line EF.

The top flange is $4\frac{3}{8}''$ square and the corners are rounded with a $\frac{1}{2}''$ radius. Thickness of flange is $\frac{7}{8}''$. The right and left hand flanges are $4\frac{1}{2}''$ square, have a $\frac{1}{2}''$ radius in each corner and are $\frac{7}{8}''$ thick. The extreme height of the valve is 5-13/16″; the extreme length is 8″.

There are twelve $\frac{1}{2}''$ tapped holes in the three flanges. The depth of the counter bored holes, which are marked 2″ dia. in the end flanges and $2\frac{3}{4}''$ dia. in the top flange, are $\frac{1}{4}''$.

The diameter of the neck of the valve where it meets the end flanges is $2\frac{1}{4}''$ diameter.

**Note**:—Locate the above mentioned details and dimensions.

## PATENT OFFICE DRAWINGS.

Patent office drawings are made on special paper, known as Bristol board. The outside dimensions of sheets are 10 x 15″, and the border line 8 x 13″—no part of drawing to be closer than $1\frac{1}{4}''$ from the upper border line. The title of drawing must be written on the back sheet with pencil.

In the lower left hand corner space is reserved for the witnesses' signatures and in the lower right hand corner, space is reserved for the inventor's and his attorney's signatures. All signatures must be written with black ink.

These drawings are made using shaded lines and line shading. Accompanying these drawings is a descriptive text of the apparatus in detail, explaining the operation of the mechanism by the use of reference letters which appear on the drawing.

Fig. 131 is an illustration of a patent drawing.

No. 820,591. PATENTED MAY 15, 1906.

D. McLAIN.

MOLDING FLASK OR BOX.

APPLICATION FILED AUG. 17, 1900.

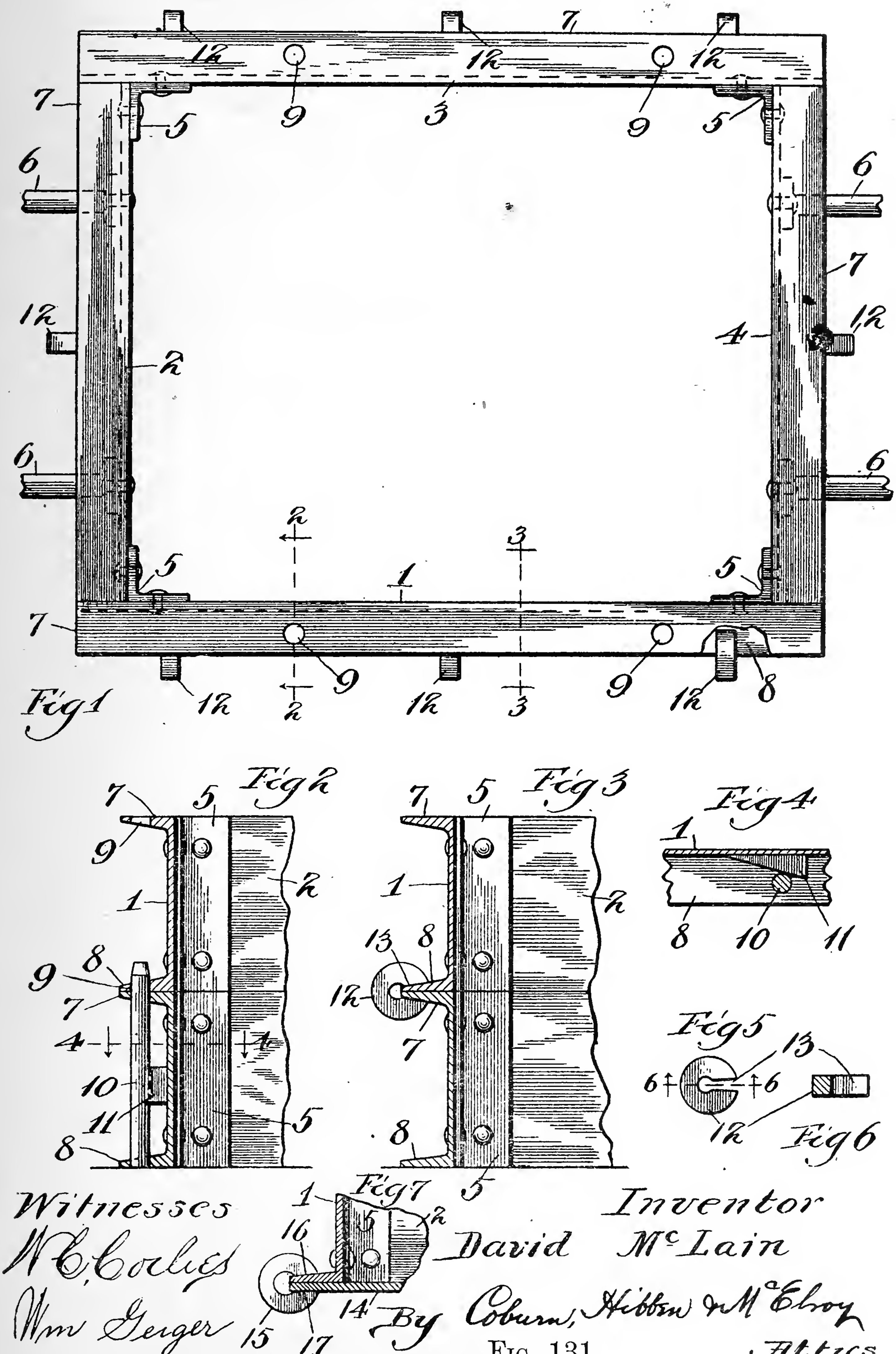



Fig. 131

## UNITED STATES PATENT OFFICE.

David McLain, of Milwaukee, Wisconsin, Assignor of One-Half to Niels Anton Christensen, of Milwaukee, Wisconsin.

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## MOLDING FLASK OR BOX.

No. 820,591. Specification of Letters Patent. Patented May 15, 1906.
Application filed August 17, 1900. Serial No. 27,117.

**To all whom it may concern:**

Be it known that I, David McLain, a resident of Milwaukee, in the county of Milwaukee and state of Wisconsin, have invented certain new and useful improvements in molding flasks or boxes, of which the following is a specification.

My invention pertains to molding flasks or boxes; and the object thereof is to improve the construction of such flasks, making them, preferably, of structural iron-work, such as I-beams or channel-bars, and also provide for interchangeability of the boxes.

My invention also contemplates a novel and advantageous clamp for the flasks.

In the drawings, Figure 1 is a plan view of one of my boxes or flasks; Figures 2 and 3, sections on lines 2 2 and 3 3, respectively, of Figure 1; Figure 4, a section on line 4 4 of Figure 2; Figure 5, an elevation of the clamp; Figure 6, a section on line 6 6 of Figure 5, and Figure 7, a fragmentary view of a modified form.

## EXAMINATION

### LESSON 17

1. Fig. 132. (a) Are all flanges the same thickness?

(b) On how many views is it indicated that the top flange is to be finished?

(c) Is the distance between centers of tapped holes in all flanges the same?

(d) What is the distance from center line to the top face of upper flange?

(e) Are all flanges the same size?

# LESSON EIGHTEEN

The following lessons contain tables and useful information which have been selected with care as we believe they will meet the requirements and prove useful to those tradesmen who follow this course of instruction.

The information contained in these tables has been selected from various handbooks, trade papers and publications.

The formulas on pages 201 to 205 inclusive, covering the areas and volumes of the various shaped surfaces and objects, have been condensed to their simplest form and the explanation given on page 197 gives a thoro understanding of the formulas.

The explanation and example on page 211, showing how to estimate the weight of a casting, illustrates the method which must be followed when estimating the weight of any casting; namely, that each and every part of the object must be taken separately, resolved into some familiar geometrically-shaped object, and the cubic inches (volume) calculated, using the formulas on pages 203 to 205. The total number of cubic inches in each component part is added and the sum multiplied by the weight of 1 cubic inch of the material from which it is made.

The weights per cubic inch of various materials are listed on pages 219 to 221.

# WEIGHTS AND MEASURES

## Measures of Length

1 mile = 1760 yards = 5280 feet.
1 yard = 3 feet = 36 inches.
1 foot = 12 inches.

The following measures of length are also used occasionally:
1 mil = 0.001 inch. 1 fathom = 2 yards = 6 feet.
1 rod = 5.5 yards = 16.5 feet. 1 hand = 4 inches. 1 span = 9 inches.

## Surveyor's Measure

1 mile = 8 furlongs = 80 chains.
1 furlong = 10 chains = 220 yards.
1 chain = 4 rods = 22 yards = 66 feet = 100 links.
1 link = 7.92 inches.

## Nautical Measure

1 league = 3 nautical miles.
1 nautical mile (knot) = 6080.26 feet = 1.1516 statute mile.

One degree at the equator = 60 nautical miles = 69.168 statute miles. 360 degrees = 21,600 nautical miles = 24,874.5 statute miles = circumference of earth at the equator.

## Square Measure

1 square mile = 640 acres = 6400 square chains.
1 acre = 10 square chains = 4840 square yards = 43,560 square feet.
1 square chain = 16 square rods = 484 square yards = 4356 square feet.
1 square rod = 30.25 square yards = 272.25 square feet = 625 square links.
1 square yard = 9 square feet.
1 square foot = 144 square inches.

An acre is equal to a square, the side of which is 208.7 feet.

## Measure used for Diameters and Areas of Electric Wires

1 circular inch = area of circle 1 inch in diameter = 0.7854 square inch.
1 circular inch = 1,000,000 circular mils.
1 square inch = 1.2732 circular inch = 1,273,239 circular mils.

A circular mil is the area of a circle 0.001 inch in diameter.

## Cubic Measure

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

The following measures are also used for wood and masonry:
1 cord of wood = $4 \times 4 \times 8$ feet = 128 cubic feet.
1 perch of masonry = $16\frac{1}{2} \times 1\frac{1}{2} \times 1$ foot = $24\frac{3}{4}$ cubic feet.

## Shipping Measure

For measuring entire internal capacity of a vessel:
1 register ton = 100 cubic feet.

For measurement of cargo:
1 U. S. shipping ton = 40 cubic feet = 32.143 U. S. bushels = 31.16 Imperial bushels.
1 British shipping ton = 42 cubic feet = 33.75 U. S. bushels = 32.72 Imperial bushels.

# WEIGHTS AND MEASURES

### Dry Measure

1 bushel (U. S. or Winchester struck bushel) = 1.2445 cubic foot = 2150.42 cubic inches.
1 bushel = 4 pecks = 32 quarts = 64 pints.
1 peck = 8 quarts = 16 pints.
1 quart = 2 pints.
1 heaped bushel = $1\frac{1}{4}$ struck bushel.
1 cubic foot = 0.8036 struck bushel.
1 British Imperial bushel = 8 Imperial gallons = 1.2837 cubic foot = 2218.19 cubic inches.

### Liquid Measure

1 U. S. gallon = 0.1337 cubic foot = 231 cubic inches = 4 quarts = 8 pints.
1 quart = 2 pints = 8 gills.
1 pint = 4 gills.
1 British Imperial gallon = 1.2003 U S. gallon = 277.27 cubic inches.
1 cubic foot = 7.48 U. S. gallons.

### Old Liquid Measure

1 tun = 2 pipes = 3 puncheons.
1 pipe or butt = 2 hogsheads = 4 barrels = 126 gallons.
1 puncheon = 2 tierces = 84 gallons.
1 hogshead = 2 barrels = 63 gallons.
1 tierce = 42 gallons.
1 barrel = $31\frac{1}{2}$ gallons.

### Apothecaries' Fluid Measure

1 U. S. fluid ounce = 8 drachms = 1.805 cubic inch = 1/128 U. S. gallon.
1 fluid drachm = 60 minims.
1 British fluid ounce = 1.732 cubic inch.

## Measures of Weight

### Avoirdupois or Commercial Weight

1 gross or long ton = 2240 pounds.
1 net or short ton = 2000 pounds.
1 pound = 16 ounces = 7000 grains.
1 ounce = 16 drachms = 437.5 grains.

The following measures for weight are now seldom used in the United States:
1 hundred-weight = 4 quarters = 112 pounds (1 gross or long ton = 20 hundred-weights); 1 quarter = 28 pounds; 1 stone = 14 pounds; 1 quintal = 100 pounds.

### Troy Weight, used for Weighing Gold and Silver

1 pound = 12 ounces = 5760 grains.
1 ounce = 20 pennyweights = 480 grains.
1 pennyweight = 24 grains.
1 carat (used in weighing diamonds) = 3.168 grains.
1 grain Troy = 1 grain avoirdupois = 1 grain apothecaries' weight.

# FRACTIONS OF AN INCH AND EQUIVALENT DECIMALS

| Fractions of an Inch | | Decimals of an Inch | Fractions of an Inch | | Decimals of an Inch |
|---|---|---|---|---|---|
| 1/64 | = | .015625 | 33/64 | = | .515625 |
| 1/32 | = | .03125 | 17/32 | = | .53125 |
| 3/64 | = | .046875 | 35/64 | = | .546875 |
| 1/16 | = | 0625 | 9/16 | = | .5625 |
| 5/64 | = | 078125 | 37/64 | = | .578125 |
| 3/32 | = | .09375 | 19/32 | = | .59375 |
| 7/64 | = | 109375 | 39/64 | = | .609375 |
| ⅛ | = | .125 | ⅝ | = | .625 |
| 9/64 | = | .140625 | 41/64 | = | .640625 |
| 5/32 | = | 15625 | 21/32 | = | .65625 |
| 11/64 | = | .171875 | 43/64 | = | .671875 |
| 3/16 | = | .1875 | 11/16 | = | .6875 |
| 13/64 | = | .203125 | 45/64 | = | .703125 |
| 7/32 | = | .21875 | 23/32 | = | .71875 |
| 15/64 | = | .234375 | 47/64 | = | .734375 |
| ¼ | = | .25 | ¾ | = | .75 |
| 17/64 | = | .265625 | 49/64 | = | .765625 |
| 9/32 | = | .28125 | 25/32 | = | .78125 |
| 19/64 | = | .296875 | 51/64 | = | .796875 |
| 5/16 | = | .3125 | 13/16 | = | .8125 |
| 21/64 | = | .328125 | 53/64 | = | .828125 |
| 11/32 | = | .34375 | 27/32 | = | .84375 |
| 23/64 | = | .359375 | 55/64 | = | .859375 |
| ⅜ | = | .375 | ⅞ | = | .875 |
| 25/64 | = | .390625 | 57/64 | = | .890625 |
| 13/32 | = | .40625 | 29/32 | = | .90625 |
| 27/64 | = | .421875 | 59/64 | = | .921875 |
| 7/16 | = | .4375 | 15/16 | = | .9375 |
| 29/64 | = | .453125 | 61/64 | = | .953125 |
| 15/32 | = | .46875 | 31/32 | = | .96875 |
| 31/64 | = | .484375 | 63/64 | = | .984375 |
| ½ | = | .5 | 1 in. | = | 1.000000 |

## HOW TO USE DECIMALS.

Let us assume that an inch in length represents one dollar in money. Then:

½ dollar equals 50 cents or $.50
½ inch equals .50 inches in a decimal
¼ dollar equals 25 cents or $.25
¼ inch equals .25 inches in a decimal
¾ dollar equals 75 cents or $.75
¾ inch equals .75 inches in a decimal.

As mentioned, ½ equals .50—the small dot before the 5 is called a "decimal point." Each figure to the right of this point is called a **decimal place**; example, in .509 there are three decimal places (the 0 also counts as a place). In 20.96207 there are two places to the left of the decimal point; however these are not decimal places but whole numbers. The five places to the right of the decimal point are decimal places.

| | | |
|---|---|---|
| 1/10 | (One tenth) | is written .1 |
| 5/10 | (Five tenths) | is written .5 |
| 5/100 | (Five hundredths) | is written .05 |
| 55/100 | (Fifty five hundredths) | is written .55 |
| 5/1000 | (Five thousandths) | is written .005 |
| 55/1000 | (Fifty-five thousandths) | is written .055 |
| 555/1000 | (Five hundred fifty-five thousandths) | is written .555 |
| 5/10000 | (Five ten-thousandths) | is written .0005 |

Referring to the decimal, you will note that the value becomes less the farther it is moved to the right of the decimal point.

## ADDITION OF DECIMALS.

If you know how to add different sums of money, you will readily understand how to handle decimals. For instance:

You know that 50 cents is half a dollar, therefore it is 50 parts of the hundred cents or **fifty one-hundredths,** and is written .50. One dollar and seventy-five cents is one and three-quarters dollars, and is written $1.75, or one and **seventy-five hundredths.** $2.25 is read two dollars and a quarter, or two and twenty-five hundredths. In adding decimals, you do the same as in adding money.

It is important to keep the decimal points directly under one another and add as in the ordinary way.

$$\begin{array}{r} .50 \\ 1.75 \\ 2.25 \\ \hline 4.50 \end{array}$$

## SUBTRACTION OF DECIMALS.

It is again important that the decimal points be placed directly under one another and subtracted in the same manner as whole numbers. Examples:

$$\begin{array}{r} 3.25 \\ -1.75 \\ \hline 1.50 \end{array} \qquad \begin{array}{r} .5625 \\ -.4375 \\ \hline .1250 \end{array}$$

## MULTIPLICATION OF DECIMALS.

The decimal equivalent table will be found very convenient in multiplying fractions. For example: Let us suppose we wish to multiply $3/8$ x $5/8''$.

$$
\begin{array}{rl}
3/8'' = .375 & \text{(Multiplicand)} \\
5/8'' = .625 & \text{(Multiplier)} \\
\hline
1875 & \\
750\phantom{0} & \\
2250\phantom{00} & \\
\hline
.234375 & \text{Answer (Product)}
\end{array}
$$

The decimal point before the 2 in the answer must be used with care. In order to know where to place the decimal point in the answer, add the number of decimal places to the right of the dot in the .375, and those to the right of the dot in the .625, which equals six. Start at the right hand figure in the answer and count six figures to the left, and set this dot before the sixth figure. In this case it is the 2.

**Important.** Remember, you only count the number of decimal places to the **right** of the dot in the multiplicand and multiplier and do not pay any attention to those to the left, if there are any, as these are whole numbers. For example:

$$
\begin{array}{lrl}
\text{Multiply } 2\tfrac{7}{8} \text{ x } 30\tfrac{1}{8} & 2.875 & (7/8 = .875, \text{ see decimal equiva-} \\
 & \text{x}30.125 & (1/8 = .125, \text{ lent table.} \\
\hline
 & 14375 & \\
 & 5750\phantom{0} & \\
 & 2875\phantom{00} & \\
 & 86250\phantom{000} & \\
\hline
 & 86.609375 &
\end{array}
$$

Note :—Be sure to count the total number of decimal places to the right of the dot, regardless of how many there may be.

The decimal equivalent table will also be found useful in multiplying the thickness of a casting by its length and width; especially when the thickness is less than 1 inch, or a fraction over 1 inch. For example:

$\frac{9}{16}''$ thick = .5625

$1\frac{9}{16}''$ thick = 1.5625

$5\frac{9}{16}''$ thick = 5.5625

(If the casting is $10''$ x $15''$ x $1\frac{9}{16}$ =
10 x 15 x 1.5625 = 234.3750 cubic inches)

## DIVISION OF DECIMALS.

You will note there are three terms used in division; namely, **divisor—dividend—quotient,** or answer.

Example:

$$\begin{array}{rl} & \text{Quotient} \\ \text{Divisor} & \overline{)\ \text{Dividend}} \end{array}$$

This form should be used when dividing.

The placing of the decimal point in the quotient is one of the important things to watch in the division of decimals.

**Rule:**—If the number of decimal places in the dividend is less than the number in the divisor, annex ciphers to the dividend until there are as many or more decimal places as in the divisor. Divide as in whole numbers, and point off as many decimal places in the quotient as there are **more** decimal places in the dividend than in the divisor.

It is a simple operation to divide a large number by a smaller one, thus:

$$\begin{array}{rl} & 5 \\ 2 & \overline{)10} \end{array}$$

But when dividing a small number by a larger one, it is more confusing. Let us assume we wish to divide 2 by 10.

$$10\ \overline{)\ 2}$$

We know that 10 is not contained in 2, so we place a decimal point after the 2 and add 0, thus:

$$10\ \overline{)\ 2.0}$$

Now divide as in whole numbers and point off one place in the quotient.

$$\begin{array}{rr} & .2 \\ 10 & \overline{)\ 2.0} \\ & \underline{20} \end{array}$$

According to the rule there is one more **decimal** place in the dividend than in the divisor, therefore one place is pointed off in the quotient.

In pointing off decimal places in the quotient, start counting from the right to the **left.**

If it is desired to divide .2 by 10, the operation is done in exactly the same way:

$$\begin{array}{r} .02 \\ 10\,\big)\overline{.20} \\ 20 \\ \hline \end{array}$$

One 0 has been added after the 2 in the dividend and the 10 is now contained in 20. Divide as in whole numbers and point off two places in the quotient as there are two decimal places more in the dividend than in the divisor.

Now let us divide .02 by 10.

$$\begin{array}{r} .002 \\ 10\,\big)\overline{.020} \\ 20 \\ \hline \end{array}$$

Again a 0 has been added after the 2 in the dividend and the division made as tho they were whole numbers, pointing off three places in the quotient.

A more complicated problem presents itself when we wish to divide 2 by .10

$.10\,\big)\overline{2}$ The first thing to do is to place a decimal point after the 2 and **add as many 0's as there are places to the right of the decimal point in the divisor,** thus,

$.10\,\big)\overline{2.00}$ Then divide as tho you were dividing whole numbers, paying no attention to the decimal, thus:

$$\begin{array}{r} 20 \\ .10\,\big)\overline{2.00} \end{array}$$ The answer will be 20.

There being as many decimal places in the dividend as in the divisor, will make the answer a whole number.

Let us divide .005 by .0006.

$.0006\,\big)\overline{.005}$ Here we have 4 decimal places in the divisor and only 3 in the dividend (0's count as places) therefore we add one 0 after the 5 thus: $.0006\,\big)\overline{.0050,}$ making the number of decimal places the same in both dividend and divisor, and then divide as in whole numbers.

```
           8.33
.0006 ) .005000
          48
          --
           20
           18
           --
            20
            18
            --
```

Point off two places in the quotient as there are four in the divisor, which subtracted from the six in the dividend leaves two.

## PROOF OF DIVISION.

Division may be proved by multiplying the quotient by the divisor which should equal the dividend.

## EXAMINATION

## LESSON 18

1. What is the decimal equivalent of 49/64, 7/32, 27/32? See table of decimal equivalents.
2. How many yards in a mile?
3. How many cubic feet in a cubic yard?
4. How many pounds in a long ton?
5. Write 27-23/32 inches in a decimal.

## LESSON NINETEEN

### AREAS OF SQUARES AND CIRCLES.

In Fig. 139 we have shown a square surface 2 x 2″—the area of this square will be 4 sq. in. Now let us make each side of this square twice as large, or 4 x 4″ (Fig. 140)—the area will then be 16 sq. in. As you will see, we have made the side of the original square twice as large, but the area has been increased four times (16 is 4 times as much as 4). This also applies to circles.

Referring to Fig. 141 we will try to explain that a 1″ diameter circle has only about ¾ the area of a 1″ square. By referring to the figure you will readily see that by cutting away the corners of the square, we will have an outline of a circle—the area of which will be approximately ¾ of that of the original square, or to be exact, .7854

We found the area of the square by multiplying the length of one side by the length of the other. If we substitute the letter d for the length of one side, the area of the square may be written d x d; and the area of the circle being approximately ¾ of that of the square its area is then written d x d x .7854.

Fig. 142 is a circle 2″ in diameter. Let us double this diameter to 4″ (Fig. 143) and the area of the 4″ circle will be **four** times as much as the 2″ circle, altho the larger circle is only twice the diameter of the smaller one.

Let us write this out in figures: The area of the 2″ circle equals 2 x 2 x .7854 = 3.1416 sq. in.; the area of the 4″ circle is 4 x 4 x .7854 = 12.5664 sq. in. It will be seen that the area of this 4″ circle is **four** times that of the 2″ circle.

Examples covered in Fig. 139 to 143 inclusive cover **surface area only,** and we will now show a few examples covering **volume.**

### VOLUME OF CUBES.

Fig. 144 is a cube 2 x 2 x 2″ and will contain 8 cu. in. In Fig. 145 we have made the side of the cube 4″, or doubled the length, width and depth of the cube in Fig. 144. The cubic inches in Fig. 145 will be 4 x 4 x 4″ = 64 cu. in.; or the 4″ cube has eight times as much volume as the 2″ cube and for this reason will also weigh eight times as much, if made of the same material.

## AREAS

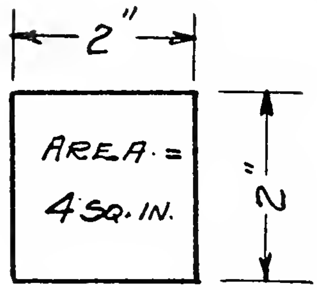



FIG-139

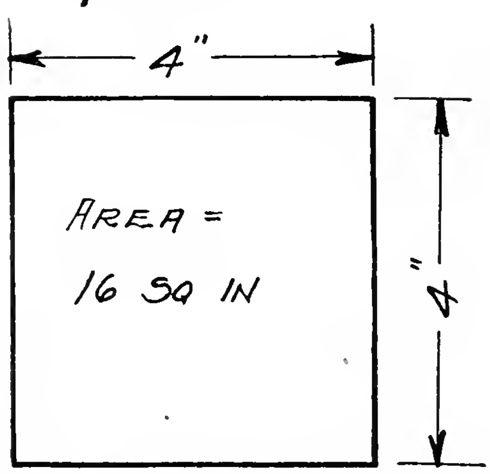



FIG-140

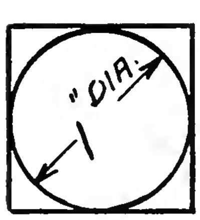



FIG-141

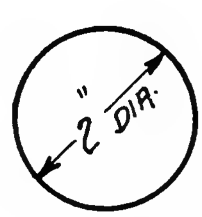



FIG-142

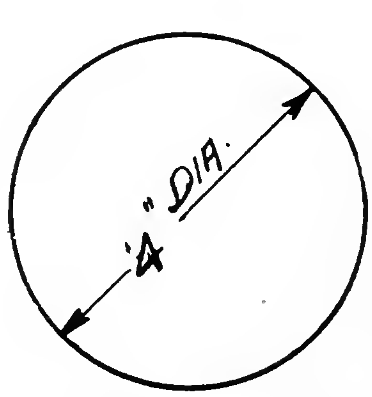



FIG-143.

## VOLUMES.

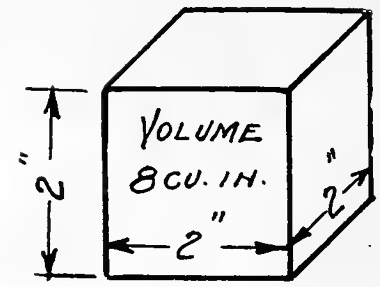



FIG-144

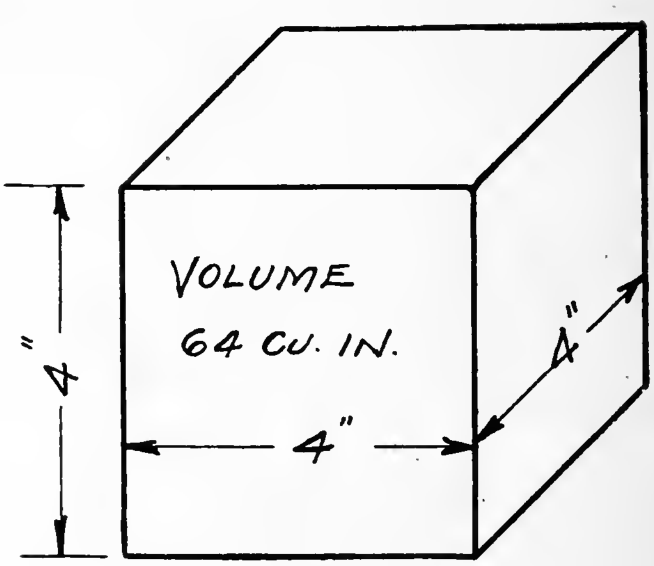



FIG-145

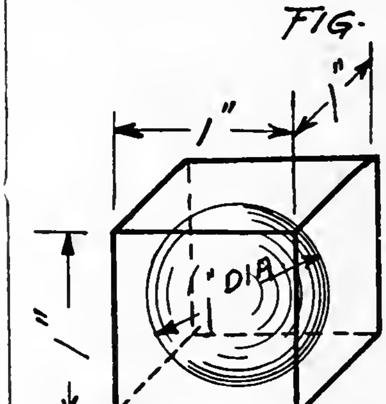



FIG-146


FIG-147

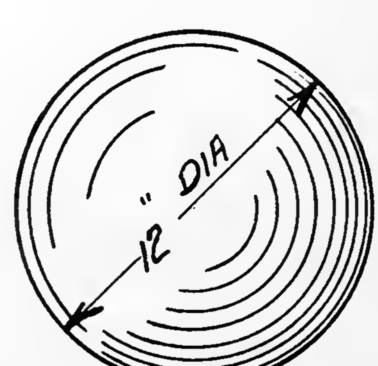



FIG-148


FIG-149.

## VOLUME OF SPHERES.

We have explained that the volume of a cube is equal to the length multiplied by the width, multiplied by the depth. In Fig. 146 we have shown a sphere placed inside of a cube and have assumed that the length of a side of this cube is 1″ and that the diameter of the sphere is also 1″. If this block were made of wood and we were to cut away the 8 corners making a 1″ diameter sphere, we would **only have about ½ of the original volume of the cube** left in the sphere, the exact figure being .5236.

As we explain that .7854 is the area of a 1″ circle and is used as a base on which to figure the area of circles of any diameter—and .5236, being the volume in cubic inches of a 1″ ball or sphere, it is used as a base on which to figure the volume of balls or spheres of any diameter. In other words, to find the volume of a sphere or ball is the same as figuring the volume of a cube (length of side equal to diameter of sphere) **less the 8 corners,** the figure .5236 making the allowance for the volume in cubic inches of the 1″ sphere or ball.

If we insert the letter d in place of the 1″ dimension for the side of the cube, the volume of the cube will be written d x d x d and the volume of the sphere will be written d x d x d x .5236.

Fig. 147 is a ball 6″ in diameter and the volume is equal to 6 x 6 x 6 x .5236, which equals 113.10 cu. in. Fig. 148 is a 12″ ball—the volume is equal to 12 x 12 x 12 x .5236 = 904.78 cu. in.

A 12″ ball (Fig. 148) weighs 8 times as much as a 6″ ball (Fig. 147) (not twice as much), altho the 12″ ball is twice the diameter of the 6″ ball; and an 8″ ball (Fig. 149) weighs about 2.4 times as much as a 6″ ball—or almost 2½ times.

## WEIGHT OF BALLS.

The weights of the 6, 8, and 12-inch balls will be in the same ratio as the volumes if made of the same material.

## CIRCUMFERENCES AND AREAS OF CIRCLES FOR DIFFERENT DIAMETERS.

On pages 192 to 196 you will find tables giving the areas and circumferences of circles for various diameters. This table may be used to advantage in finding the areas of pipes, surfaces, flues, etc. Attention is called to the column headed "Circumferences." The circumference of a circle is the distance around its outer edge and is equal to the diameter multiplied by 3.1416.

The area of a circle is found by multiplying the diameter by the diameter by .7854, or may be written $d^2 \times .7854$—($d^2$ indicating that the diameter is multiplied by itself). It should be remembered that **area** represents only flat surface with no thickness.

| Diam. | Circum. | Area | Diam. | Circum. | Area |
|---|---|---|---|---|---|
| 1/64 | .04909 | .000192 | 4 | 12.5664 | 12.5664 |
| 1/32 | .09818 | .000767 | 4 1/8 | 12.9591 | 13.3641 |
| 1/16 | .19635 | .003068 | 4 1/4 | 13.3518 | 14.1863 |
| 1/8 | .3927 | .012272 | 4 3/8 | 13.7445 | 15.033 |
| 3/16 | .589 | .027612 | 4 1/2 | 14.1372 | 15.9043 |
| 1/4 | .7854 | .049087 | 4 5/8 | 14.5299 | 16.8002 |
| 5/16 | .98175 | .076699 | 4 3/4 | 14.9226 | 17 7206 |
| 3/8 | 1.1781 | .110447 | 4 7/8 | 15.3153 | 18 6555 |
| 7/16 | 1.37445 | .15033 | | | |
| 1/2 | 1.5708 | .19635 | 5 | 15.708 | 19.635 |
| 9/16 | 1.76715 | .248505 | 5 1/8 | 16.1007 | 20.629 |
| 5/8 | 1.9635 | .306796 | 5 1/4 | 16.4934 | 21.6476 |
| 11/16 | 2.15985 | .371224 | 5 3/8 | 16.8861 | 22.6907 |
| 3/4 | 2.3562 | .441787 | 5 1/2 | 17.2788 | 23.7583 |
| 13/16 | 2.55255 | .518487 | 5 5/8 | 17.6715 | 24.8505 |
| 7/8 | 2.7489 | .601322 | 5 3/4 | 18.0642 | 25.9673 |
| 15/16 | 2.94525 | .690292 | 5 7/8 | 18.4569 | 27.1086 |
| 1 | 3.1416 | .7854 | 6 | 18.8496 | 28.2744 |
| 1 1/8 | 3.5343 | .99402 | 6 1/8 | 19.2423 | 29.4648 |
| 1 1/4 | 3.927 | 1.2272 | 6 1/4 | 19.635 | 30.6797 |
| 1 3/8 | 4.3197 | 1.4849 | 6 3/8 | 20.0277 | 31.9191 |
| 1 1/2 | 4.7124 | 1.7671 | 6 1/2 | 20.4204 | 33.1831 |
| 1 5/8 | 5.1051 | 2.0739 | 6 5/8 | 20.8131 | 34.4717 |
| 1 3/4 | 5.4978 | 2:4053 | 6 3/4 | 21.2058 | 35.7848 |
| 1 7/8 | 5.8905 | 2.7612 | 6 7/8 | 21.5985 | 37 1224 |
| 2 | 6.2832 | 3.1416 | 7 | 21.9912 | 38.4846 |
| 2 1/8 | 6.6759 | 3.5466 | 7 1/8 | 22.3839 | 39.8713 |
| 2 1/4 | 7.0686 | 3.9761 | 7 1/4 | 22.7766 | 41.2826 |
| 2 3/8 | 7.4613 | 4.4301 | 7 3/8 | 23.1693 | 42.7184 |
| 2 1/2 | 7.854 | 4.9087 | 7 1/2 | 23.562 | 44.1787 |
| 2 5/8 | 8.2467 | 5.4119 | 7 5/8 | 23.9547 | 45.6636 |
| 2 3/4 | 8.6394 | 5.9396 | 7 3/4 | 24.3474 | 47.1731 |
| 2 7/8 | 9.0321 | 6.4918 | 7 7/8 | 24.7401 | 48.7071 |
| 3 | 9.4248 | 7.0686 | 8 | 25.1328 | 50.2656 |
| 3 1/8 | 9.8175 | 7.6699 | 8 1/8 | 25.5255 | 51.8487 |
| 3 1/4 | 10.2102 | 8.2958 | 8 1/4 | 25.9182 | 53.4563 |
| 3 3/8 | 10.6029 | 8.9462 | 8 3/8 | 26.3109 | 55.0884 |
| 3 1/2 | 10.9956 | 9.6211 | 8 1/2 | 26.7036 | 56.7451 |
| 3 5/8 | 11.3883 | 10.3206 | 8 5/8 | 27.0963 | 58.4264 |
| 3 3/4 | 11.781 | 11.0447 | 8 3/4 | 27.489 | 60.1322 |
| 3 7/8 | 12.1737 | 11.7933 | 8 7/8 | 27.8817 | 61.8625 |

## Circumferences and Areas of Circles
### continued

| Diam. | Circum. | Area | Diam. | Circum. | Area |
|---|---|---|---|---|---|
| 9 | 28.2744 | 63.6174 | 15 | 47.124 | 176.715 |
| 9⅛ | 28.6671 | 65.3968 | 15⅛ | 47.5167 | 179.673 |
| 9¼ | 29.0598 | 67.2008 | 15¼ | 47.9094 | 182.655 |
| 9⅜ | 29.4525 | 69.0293 | 15⅜ | 48.3021 | 185.661 |
| 9½ | 29.8452 | 70.8823 | 15½ | 48.6948 | 188.692 |
| 9⅝ | 30.2379 | 72.7599 | 15⅝ | 49.0875 | 191.748 |
| 9¾ | 30.6306 | 74.6621 | 15¾ | 49.4802 | 194.828 |
| 9⅞ | 31.0233 | 76.5888 | 15⅞ | 49.8729 | 197.933 |
| 10 | 31.416 | 78.54 | 16 | 50.2656 | 201.062 |
| 10⅛ | 31.8087 | 80.5158 | 16⅛ | 50.6583 | 204.216 |
| 10¼ | 32.2014 | 82.5161 | 16¼ | 51.051 | 207.395 |
| 10⅜ | 32.5941 | 84.5409 | 16⅜ | 51.4437 | 210.598 |
| 10½ | 32.9868 | 86.5903 | 16½ | 51.8364 | 213.825 |
| 10⅝ | 33.3795 | 88.6643 | 16⅝ | 52.2291 | 217.077 |
| 10¾ | 33.7722 | 90.7628 | 16¾ | 52.6218 | 220.354 |
| 10⅞ | 34.1649 | 92.8858 | 16⅞ | 53.0145 | 223.655 |
| 11 | 34.5576 | 95.0334 | 17 | 53.4072 | 226.981 |
| 11⅛ | 34.9503 | 97.2055 | 17⅛ | 53.7999 | 230.331 |
| 11¼ | 35.343 | 99.4022 | 17¼ | 54.1926 | 233.906 |
| 11⅜ | 35.7357 | 101.6234 | 17⅜ | 54.5853 | 237.105 |
| 11½ | 36.1284 | 103.8691 | 17½ | 54.978 | 240.529 |
| 11⅝ | 36.5211 | 106.1394 | 17⅝ | 55.3707 | 243.977 |
| 11¾ | 36.9138 | 108.4343 | 17¾ | 55.7634 | 247.45 |
| 11⅞ | 37.3065 | 110.7537 | 17⅞ | 56.1561 | 250.948 |
| 12 | 37.6992 | 113.098 | 18 | 56.5488 | 254.47 |
| 12⅛ | 38.0919 | 115.466 | 18⅛ | 56.9415 | 258.016 |
| 12¼ | 38.4846 | 117.859 | 18¼ | 57.3342 | 261.587 |
| 12⅜ | 38.8773 | 120.277 | 18⅜ | 57.7269 | 265.183 |
| 12½ | 39.27 | 122.719 | 18½ | 58.1196 | 268.803 |
| 12⅝ | 39.6627 | 125.185 | 18⅝ | 58.5123 | 272.448 |
| 12¾ | 40.0554 | 127.677 | 18¾ | 58.905 | 276.117 |
| 12⅞ | 40.4481 | 130.192 | 18⅞ | 59.2977 | 279.811 |
| 13 | 40.8408 | 132.733 | 19 | 59.6904 | 283.529 |
| 13⅛ | 41.2335 | 135.297 | 19⅛ | 60.0831 | 287.272 |
| 13¼ | 41.6262 | 137.887 | 19¼ | 60.4758 | 291.04 |
| 13⅜ | 42.0189 | 140.501 | 19⅜ | 60.8685 | 294.832 |
| 13½ | 42.4116 | 143.139 | 19½ | 61.2612 | 298.648 |
| 13⅝ | 42.8043 | 145.802 | 19⅝ | 61.6539 | 302.489 |
| 13¾ | 43.197 | 148.49 | 19¾ | 62.0466 | 306.355 |
| 13⅞ | 43.5897 | 151.202 | 19⅞ | 62.4393 | 310.245 |
| 14 | 43.9824 | 153.938 | 20 | 62.832 | 314.16 |
| 14⅛ | 44.3751 | 156.7 | 20⅛ | 63.2247 | 318.099 |
| 14¼ | 44.7678 | 159.485 | 20¼ | 63.6174 | 322.063 |
| 14⅜ | 45.1605 | 162.296 | 20⅜ | 64.0101 | 326.051 |
| 14½ | 45.5532 | 165.13 | 20½ | 64.4028 | 330.064 |
| 14⅝ | 45.9459 | 167.99 | 20⅝ | 64.7955 | 334.102 |
| 14¾ | 46.3386 | 170.874 | 20¾ | 65.1882 | 338.164 |
| 14⅞ | 46.7313 | 173.782 | 20⅞ | 65.5809 | 342.25 |

# CIRCUMFERENCES AND AREAS OF CIRCLES
## CONTINUED

| Diam. | Circum. | Area | Diam. | Circum. | Area |
|---|---|---|---|---|---|
| 21 | 65.9736 | 346.361 | 27 | 84.8232 | 572.557 |
| 21⅛ | 66.3663 | 350.497 | 27⅛ | 85.2159 | 577.87 |
| 21¼ | 66.759 | 354.657 | 27¼ | 85.6086 | 583.209 |
| 21⅜ | 67.1517 | 358.842 | 27⅜ | 86.0013 | 588.571 |
| 21½ | 67.5444 | 363.051 | 27½ | 86.394 | 593.959 |
| 21⅝ | 67.9379 | 367.285 | 27⅝ | 86.7867 | 599.371 |
| 21¾ | 68.3298 | 371.543 | 27¾ | 87.1794 | 604.807 |
| 21⅞ | 68.7225 | 375.826 | 27⅞ | 87.5729 | 610.268 |
| 22 | 69.1152 | 380.134 | 28 | 87.9648 | 615.754 |
| 22⅛ | 69.5079 | 384.466 | 28⅛ | 88.3575 | 621.264 |
| 22¼ | 69.9006 | 388.822 | 28¼ | 88.7502 | 626.798 |
| 22⅜ | 70.2933 | 393.203 | 28⅜ | 89.1429 | 632.357 |
| 22½ | 70.686 | 397.609 | 28½ | 89.5356 | 637.941 |
| 22⅝ | 71.0787 | 402.038 | 28⅝ | 89.9283 | 643.549 |
| 22¾ | 71.4714 | 406.494 | 28¾ | 90.321 | 649.182 |
| 22⅞ | 71.8641 | 410.973 | 28⅞ | 90.7137 | 654.84 |
| 23 | 72.2568 | 415.477 | 29 | 91.1064 | 660.521 |
| 23⅛ | 72.6495 | 420.004 | 29⅛ | 91.4991 | 666.228 |
| 23¼ | 73.0422 | 424.558 | 29¼ | 91.8918 | 671.959 |
| 23⅜ | 73.4349 | 429.135 | 29⅜ | 92.2845 | 677.714 |
| 23½ | 73.8276 | 433.737 | 29½ | 92.6772 | 683.494 |
| 23⅝ | 74.2203 | 438.364 | 29⅝ | 93.0699 | 689.299 |
| 23¾ | 74.613 | 443.015 | 29¾ | 93.4626 | 695.128 |
| 23⅞ | 75.0057 | 447.69 | 29⅞ | 93.8553 | 700.982 |
| 24 | 75.3984 | 452.39 | 30 | 94.248 | 706.86 |
| 24⅛ | 75.7911 | 457.115 | 30⅛ | 94.6407 | 712.763 |
| 24¼ | 76.1838 | 461.864 | 30¼ | 95.0334 | 718.69 |
| 24⅜ | 76.5765 | 466.638 | 30⅜ | 95.4261 | 724.642 |
| 24½ | 76.9692 | 471.436 | 30½ | 95.8188 | 730.618 |
| 24⅝ | 77.3619 | 476.259 | 30⅝ | 96.2115 | 736.619 |
| 24¾ | 77.7546 | 481.107 | 30¾ | 96.6042 | 742.645 |
| 24⅞ | 78.1473 | 485.979 | 30⅞ | 96.9969 | 748.695 |
| 25 | 78.54 | 490.875 | 31 | 97.3896 | 754.769 |
| 25⅛ | 78.9327 | 495.796 | 31⅛ | 97.7823 | 760.869 |
| 25¼ | 79.9254 | 500.742 | 31¼ | 98.175 | 766.992 |
| 25⅜ | 79.7181 | 505.712 | 31⅜ | 98.5677 | 773.14 |
| 25½ | 80.1108 | 510.706 | 31½ | 98.9604 | 779.313 |
| 25⅝ | 80.5035 | 515.726 | 31⅝ | 99.3531 | 785.51 |
| 25¾ | 80.8962 | 520.769 | 31¾ | 99.7458 | 791.732 |
| 25⅞ | 81.4889 | 525.838 | 31⅞ | 100.1385 | 797.979 |
| 26 | 81.6816 | 530.93 | 32 | 100.5312 | 804.25 |
| 26⅛ | 82.0743 | 536.048 | 32⅛ | 100.9239 | 810.545 |
| 26¼ | 82.476 | 541.19 | 32¼ | 101.3166 | 816.865 |
| 26⅜ | 82.8597 | 546.356 | 32⅜ | 101.7093 | 823.21 |
| 26½ | 83.2524 | 551.547 | 32½ | 102.102 | 829.579 |
| 26⅝ | 83.6451 | 556.763 | 32⅝ | 102.4947 | 835.972 |
| 26¾ | 84.0378 | 562.003 | 32¾ | 102.8874 | 842.391 |
| 26⅞ | 84.4305 | 567.267 | 32⅞ | 103.2801 | 848.833 |

# Circumferences and Areas of Circles

CONTINUED

| Diam. | Circum. | Area | Diam. | Circum. | Area |
|---|---|---|---|---|---|
| 33 | 103.673 | 855.301 | 39 | 122.522 | 1194.593 |
| 33⅛ | 104.065 | 861.792 | 39⅛ | 122.915 | 1202.263 |
| 33¼ | 104.458 | 868.309 | 39¼ | 123.308 | 1209.958 |
| 33⅜ | 104.851 | 874.85 | 39⅜ | 123.7 | 1217.677 |
| 33½ | 105.344 | 881.415 | 39½ | 124.093 | 1225.42 |
| 33⅝ | 105.636 | 888.005 | 39⅝ | 124.486 | 1233.188 |
| 33¾ | 106.029 | 894.62 | 39¾ | 124.879 | 1240.981 |
| 33⅞ | 106.422 | 901.259 | 39⅞ | 125.271 | 1248.798 |
| 34 | 106.814 | 907.922 | 40 | 125.664 | 1256.64 |
| 34⅛ | 107.207 | 914.611 | 40⅛ | 126.057 | 1264.51 |
| 34¼ | 107.6 | 921.323 | 40¼ | 126.449 | 1272.4 |
| 34⅜ | 107.992 | 928.061 | 40⅜ | 126.842 | 1280.31 |
| 34½ | 108.385 | 934.822 | 40½ | 127.235 | 1288.25 |
| 34⅝ | 108.778 | 941.609 | 40⅝ | 127.627 | 1296.22 |
| 34¾ | 109.171 | 948.42 | 40¾ | 128.02 | 1304.21 |
| 34⅞ | 109.563 | 955.255 | 40⅞ | 128.413 | 1312.22 |
| 35 | 109.956 | 962.115 | 41 | 128.806 | 1320.26 |
| 35⅛ | 110.349 | 969. | 41⅛ | 129.198 | 1328.32 |
| 35¼ | 110.741 | 975.909 | 41¼ | 129.591 | 1336.41 |
| 35⅜ | 111.134 | 982.842 | 41⅜ | 129.984 | 1344.52 |
| 35½ | 111.527 | 989.8 | 41½ | 130.376 | 1352.66 |
| 35⅝ | 111.919 | 996.783 | 41⅝ | 130.769 | 1360.82 |
| 35¾ | 112.312 | 1003.79 | 41¾ | 131.162 | 1369. |
| 35⅞ | 112.705 | 1010.822 | 41⅞ | 131.554 | 1377.21 |
| 36 | 113.098 | 1017.878 | 42 | 131.947 | 1385.45 |
| 36⅛ | 113.49 | 1024.96 | 42⅛ | 132.34 | 1393.7 |
| 36¼ | 113.883 | 1032.065 | 42¼ | 132.733 | 1401.99 |
| 36⅜ | 114.276 | 1039.195 | 42⅜ | 133.125 | 1410.3 |
| 36½ | 114.668 | 1046.349 | 42½ | 133.518 | 1418.63 |
| 36⅝ | 115.061 | 1053.528 | 42⅝ | 133.911 | 1426.99 |
| 36¾ | 115.454 | 1060.732 | 42¾ | 134.303 | 1435.37 |
| 36⅞ | 115.846 | 1067.96 | 42⅞ | 134.696 | 1443.77 |
| 37 | 116.239 | 1075.213 | 43 | 135.089 | 1452.2 |
| 37⅛ | 116.632 | 1082.49 | 43⅛ | 135.481 | 1460.66 |
| 37¼ | 117.025 | 1089.792 | 43¼ | 135.874 | 1469.14 |
| 37⅜ | 117.417 | 1097.118 | 43⅜ | 136.267 | 1477.64 |
| 37½ | 117.81 | 1104.469 | 43½ | 136.66 | 1486.17 |
| 37⅝ | 118.203 | 1111.844 | 43⅝ | 137.052 | 1494.73 |
| 37¾ | 118.595 | 1119.244 | 43¾ | 137.445 | 1503.3 |
| 37⅞ | 118.988 | 1126.669 | 43⅞ | 137.838 | 1511.91 |
| 38 | 119.381 | 1134.118 | 44 | 138.23 | 1520.53 |
| 38⅛ | 119.773 | 1141.591 | 44⅛ | 138.623 | 1529.19 |
| 38¼ | 120.166 | 1149.089 | 44¼ | 139.016 | 1537.86 |
| 38⅜ | 120.559 | 1156.612 | 44⅜ | 139.408 | 1546.56 |
| 38½ | 120.952 | 1164.159 | 44½ | 139.801 | 1555.29 |
| 38⅝ | 121.344 | 1171.731 | 44⅝ | 140.194 | 1564.04 |
| 38¾ | 121.737 | 1179.327 | 44¾ | 140.587 | 1572.81 |
| 38⅞ | 122.13 | 1186.948 | 44⅞ | 140.979 | 1581.61 |

# Circumferences and Areas of Circles

CONTINUED

| Diam. | Circum. | Area | Diam. | Circum. | Area |
|---|---|---|---|---|---|
| 45 | 141.372 | 1590.43 | 51 | 160.22 | 2042.82 |
| 45⅛ | 141.765 | 1599.28 | 52 | 163.36 | 2123.71 |
| 45¼ | 142.157 | 1608.16 | 53 | 166.50 | 2206.18 |
| 45⅜ | 142.55 | 1617.05 | 54 | 169.65 | 2290.21 |
| 45½ | 142.943 | 1625.97 | 55 | 172.79 | 2375.82 |
| 45⅝ | 143.335 | 1634.92 | 56 | 175.93 | 2463.01 |
| 45¾ | 143.728 | 1643.89 | 57 | 179.07 | 2551.75 |
| 45⅞ | 144.121 | 1652.89 | 58 | 182.21 | 2642.08 |
| | | | 59 | 185.35 | 2733.97 |
| | | | 60 | 188.50 | 2827.43 |
| 46 | 144.514 | 1661.91 | 61 | 191.64 | 2922.46 |
| 46⅛ | 144.906 | 1670.95 | 62 | 194.78 | 3019.07 |
| 46¼ | 145.299 | 1680.02 | 63 | 197.92 | 3117.24 |
| 46⅜ | 145.692 | 1689.11 | 64 | 201.06 | 3216.99 |
| 46½ | 146.084 | 1698.23 | 65 | 204.20 | 3318.30 |
| 46⅝ | 146.477 | 1707.37 | 66 | 207.35 | 3421.18 |
| 46¾ | 146.87 | 1716.54 | 67 | 210.49 | 3525.65 |
| 46⅞ | 147.262 | 1725.73 | 68 | 213.63 | 3631.68 |
| | | | 69 | 216.77 | 3739.28 |
| | | | 70 | 219.91 | 3848.45 |
| 47 | 147.655 | 1734.95 | 71 | 223.05 | 3959.19 |
| 47⅛ | 148.048 | 1744.19 | 72 | 226.19 | 4071.50 |
| 47¼ | 148.441 | 1753.45 | 73 | 229.34 | 4185.38 |
| 47⅜ | 148.833 | 1762.74 | 74 | 232.48 | 4300.84 |
| 47½ | 149.226 | 1772.06 | 75 | 235.62 | 4417.86 |
| 47⅝ | 149.619 | 1781.4 | 76 | 238.76 | 4536.45 |
| 47¾ | 150.011 | 1790.76 | 77 | 241.90 | 4656.62 |
| 47⅞ | 150.404 | 1800.15 | 78 | 245.04 | 4778.36 |
| | | | 79 | 248.19 | 4901.66 |
| | | | 80 | 251.33 | 5026.54 |
| 48 | 150.797 | 1809.56 | 81 | 254.47 | 5153.00 |
| 48⅛ | 151.189 | 1819. | 82 | 257.61 | 5281.01 |
| 48¼ | 151.582 | 1828.46 | 83 | 260.75 | 5410.59 |
| 48⅜ | 151.975 | 1837.95 | 84 | 263.89 | 5541.77 |
| 48½ | 152.368 | 1847.46 | 85 | 267.04 | 5674.50 |
| 48⅝ | 152.76 | 1856.99 | 86 | 270.18 | 5808.80 |
| 48¾ | 153.153 | 1866.55 | 87 | 273.32 | 5944.67 |
| 48⅞ | 153.546 | 1876.14 | 88 | 276.46 | 6082.11 |
| | | | 89 | 279.60 | 6221.13 |
| | | | 90 | 282.74 | 6361.72 |
| 49 | 153.938 | 1885.75 | 91 | 285.88 | 6503.87 |
| 49⅛ | 154.331 | 1895.38 | 92 | 289.03 | 6647.61 |
| 49¼ | 154.724 | 1905.04 | 93 | 292.17 | 6792.90 |
| 49⅜ | 155.116 | 1914.72 | 94 | 295.31 | 6939.78 |
| 49½ | 155.509 | 1924.43 | 95 | 298.45 | 7088.21 |
| 49⅝ | 155.902 | 1934.16 | 96 | 301.59 | 7238.23 |
| 49¾ | 156.295 | 1943.91 | 97 | 304.73 | 7389.81 |
| 49⅞ | 156.687 | 1953.69 | 98 | 307.88 | 7542.96 |
| | | | 99 | 311.02 | 7697.68 |
| 50 | 157.08 | 1963.5 | 100 | 314.16 | 7853.97 |

# FORMULAS.

In mathematics formulas are used to define rules by the use of symbols instead of words.

When this symbol + is placed between two figures, 9 + 2, it indicates that 2 is to be added to 9.

When this symbol — is placed between two figures, 9 — 2, it indicates that 2 is to be subtracted from 9.

When this symbol x is placed between two figures, 9 x 2, it indicates that 9 is to be multiplied by 2.

When this symbol ÷ is placed between two figures, 9 ÷ 2, it indicates that 9 is to be divided by 2. If written with a figure above and below, $\frac{9}{2}$ it also indicates that 9 is to be divided by 2.

We advise you to work out several of the above formulas, substituting any figures you may decide upon.

Let us assume we write the rule for finding the volume of a cube:

Length multiplied by width multiplied by height.

The above expressed by the use of a formula in which symbols and letters are used may be expressed as V = b x c x h (see page 203 Fig. 165), in which V = volume, b = length, c = width, h = height.

It is not always the practice to use x when it is desired to multiply two dimensions, and the above formula may be written—V = b c h—it being **understood that b is multiplied by c and this product by h,** when the letters are grouped without a symbol between them.

Example illustrating the use of a formula:

Take the formula for finding the volume of a cone (see page 204 Fig. 169).

$$V = d^2 \times .7854 \times \frac{h}{3}$$

Let us assume the diameter (d) of the cone at its base is 9″ and that the height (h) is 12″; using these figures in place of the letters in the formula, it is written

$$V = 9^2 \times .7854 \times \frac{12}{3}$$

The small letter placed above and to the right of the 9 indicates that 9 is to be multiplied by itself ($9 \times 9 = 81$). The formula may again be written as follows:

$$V = 81 \times .7854 \times 4$$

which, when multiplied out, is

$$\begin{array}{r} 81 \\ \times .7854 \\ \hline 324 \\ 405\phantom{0} \\ 648\phantom{00} \\ 567\phantom{000} \\ \hline 63.6174 \\ \times 4 \\ \hline 254.4696 \end{array} \text{ cubic inches.}$$

$V = 254.4696$ cubic inches.

Assume we have a formula which reads "$a = \frac{b}{c}$." This is known as an equation.

**Rule.** It should be remembered that the factor below the line, multiplied by the one on the other side of the equation sign (=) must equal the factor above the line. Regardless of how you rearrange this formula, this must hold true.

**Example:**

Values: $a = 10$ $\quad b = a \times c$ or substituting the values $20 = 10 \times 2$

$b = 20$ $\quad c = \frac{b}{a}$ or substituting the values $2 = \frac{20}{10}$

$c = 2$ $\quad a = \frac{b}{c}$ or substituting the values $10 = \frac{20}{2}$

Let us work out a practical problem to illustrate the above: Assume we have a fan which is belt driven to a motor and we want to determine the size pulley on fan shaft to give a certain fan speed; the rule is

Speed of fan x dia. pulley = speed of motor x dia. pulley.

This is an equation similar to the above and we will substitute the following values in the equation:

a = speed of fan, 900 R. P. M. (revolution per minute)
c = diameter of fan pulley, 8″
b = speed of motor, 1200 R. P. M.
d = dia. of motor pulley, 6″

$$\underset{(a)}{900} \times \underset{(c)}{\text{dia. of fan pulley}} = \underset{(b)}{1200} \times \underset{(d)}{6}$$

$$\underset{(c)}{\text{dia. of fan pulley}} = \frac{\overset{(b)}{1200} \times \overset{(d)}{6}}{\underset{(a)}{900}} = 8''$$

$$b = \frac{c \times a}{d} \text{ or } b = \frac{8 \times 900}{6} = 1200$$

$$a = \frac{b \times d}{c} \text{ or } a = \frac{1200 \times 6}{8} = 900$$

$$d = \frac{a \times c}{b} \text{ or } d = \frac{900 \times 8}{1200} = 6''$$

## EXAMINATION

## LESSON 19

1. What are the area and circumference of a 13-7/8 inch diameter circle? See table.

2. What are the area and curcumference of a 49-3/8 inch diameter circle?

3. What is the volume of a cone if the diameter of its base is 15 inches and its height 24 inches.

4. When no symbol is placed between two letters in a formula, what operation is understood to be performed?

# LESSON TWENTY

## AREAS AND VOLUMES OF VARIOUS SHAPED FIGURES.

A = Area
d or D = Diameter
V = Volume, cubical contents.

### SQUARE

a is 10″, find the area.

A = 10 x 10″ = 100 sq. in.

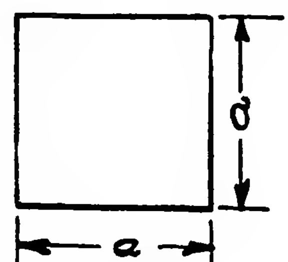



Fig-150

$A = a \times a$

or $A = a^2$.

### RECTANGLE

a is 10″ and b 15″, find the area.

A = 10 x 15″ = 150 sq. in.

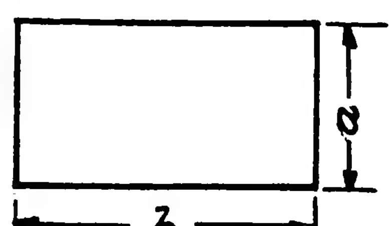



Fig-151

$A = a \times b.$

### PARALLELOGRAM

a is 10″ and b 15″, find the area.

A = 10 x 15″ = 150 sq. in.

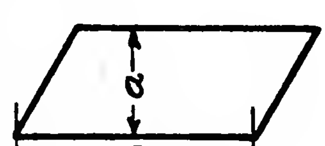



Fig-152

$A = a \times b.$

### TRAPEZOID

a is 10″, b 15″ and h 8″, find the area.

$$A = \frac{(10 + 15) \times 8}{2} = \frac{25 \times 8}{2} = 100 \text{ sq. in.}$$

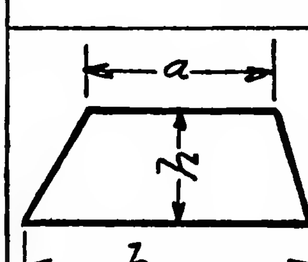



Fig-153

$$A = \frac{(a + b)\,h}{2}$$

### TRIANGLE

b is 10″ and h 8″, find the area.

$$A = \frac{10 \times 8}{2} = 40 \text{ sq. in.}$$

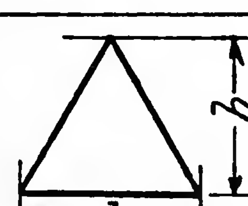



Fig-154

$$A = \frac{b\,h}{2}$$

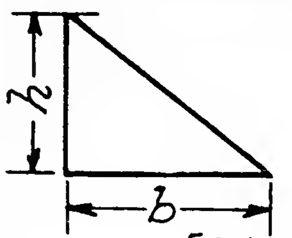



FIG-155

$$A = \frac{b\ h}{2}$$

**RIGHT ANGLE TRIANGLE**

b is 10″ and h 8″, find the area.

$$A = \frac{10 \times 8}{2} = 40 \text{ sq. in.}$$

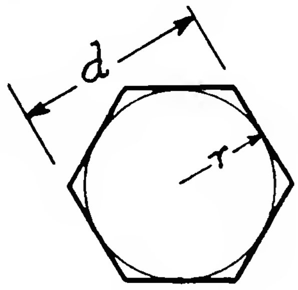



FIG-156

$A = 3.464 \times r \times r$

or $3.464 \times r^2$.

**HEXAGON**

r is 10″, find the area.

$A = 3.464 \times 10 \times 10'' = 346.4$ sq. in.

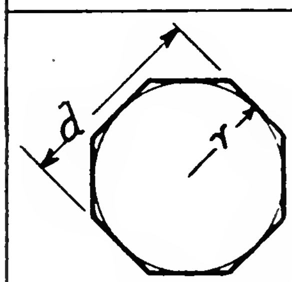



FIG-157

$A = 3.314 \times r \times r$

or $3.314 \times r^2$.

**OCTAGON**

r is 10″, find the area.

$A = 3.314 \times 10 \times 10'' = 331.4$ sq. in.

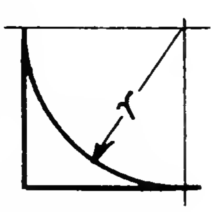



FIG-158

$A = .215 \times r \times r$

or $.215 \times r^2$.

**FILLET**

r is 10″, find the area.

$A = .215 \times 10 \times 10'' = 21.5$ sq. in.

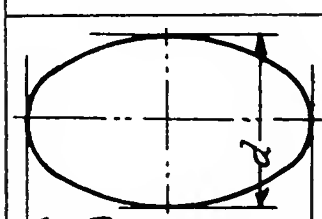



FIG-159

$A = .7854 \times D \times d$.

**ELLIPSE**

D is 15″ and d 10″, find the area.

$A = .7854 \times 15 \times 10'' = 117.81$ sq. in.

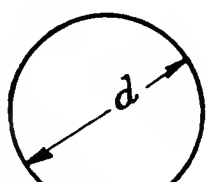



FIG-160

$A = d^2 \times .7854$

**CIRCLE**

d is 10″, find the area.

$A = 10 \times 10 \times .7854 = 78.54$ sq. in.

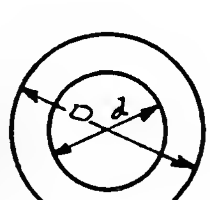



FIG-161

$A = .7854\ (D + d)(D - d)$.

**CIRCULAR RING**

D is 20″ and d 10″, find the area.

$A = .7854\ (20 + 10)\ (20 - 10) =$

$.7854\ (30)\ (10) = .7854 \times 300 =$

235.62 sq. in.

### SEGMENT

r is 20″, l 31.4″, h 5.8″ and c 28″, find the area.

$A = \frac{1}{2}\,[20 \times 31.4 - 28\,(20 - 5.8)] =$

$\frac{1}{2}\,[628 - 28\,(14.2)] =$

$\frac{1}{2}\,[628 - 398.6] = \frac{230.4}{2} = 115.2$ sq. in.

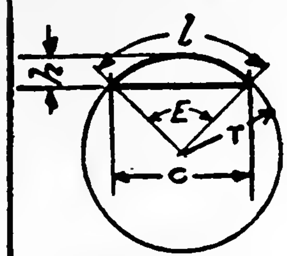



FIG-162

$A = \frac{1}{2}\,[r\,l - c\,(r - h)]$.

### CIRCULAR SECTOR

r is 10″ and l 20″, find the area.

$A = \frac{10 \times 20}{2} = 100$ sq. in.

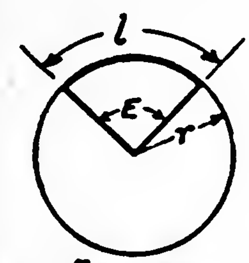



FIG-163

$A = \frac{1}{2} \times r \times l$.

Divide the area into equal spaces and find the sum of the partial areas. If the figure is very irregular, the approximate area may be found as follows:

Divide the figure by parallel lines, b, c, d, etc. The lengths of these lines being measured, then, calling a the first and i the last length, and y the width of strips.

$$A = y\left(\frac{a + i}{2} + b + c + d + e + f + g + h\right)$$

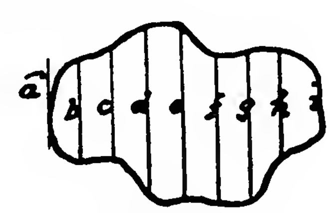



FIG-164

### IRREGULAR AREA

a is 3″, b 7″, c 8″, d 10″, e 10″, f 9″, g 9″, h 5″, i 5″, y 3″, find the area.

$$A = 3\left(\frac{3 + 5}{2} + 7 + 8 + 10 + 10 + 9 + 9\right) = 3 \times 57 = 171 \text{ sq. in.}$$

### CUBE

b is 8″, c 8″ and h 8″, find the volume.

$V = 8 \times 8 \times 8 = 512$ cu. in.

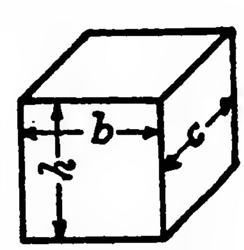



FIG-165

$V = b \times c \times h$.

### PRISM

b is 8″, c 8″ and h 20″, find the volume.

$V = 8 \times 8 \times 20 = 1280$ cu. in.

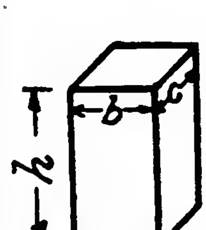



FIG-166

$V = b \times c \times h$.

### PYRAMID

b is 12″, c 12″ and h 20″, find the volume.

$V = \frac{12 \times 12 \times 20}{3} = 960$ cu. in.

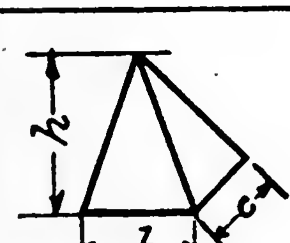



FIG. 167

$V = \frac{b \times c \times h}{3}$

## REGULAR PYRAMID

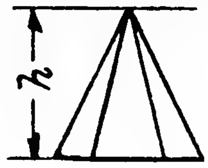



FIG. 168

$$V = \text{area of base} \times \frac{h}{3}$$

Area of base 150 sq. in., height 20″, find the volume.

$$V = \frac{150 \times 20}{3} = 1000 \text{ cu. in.}$$

## CONE

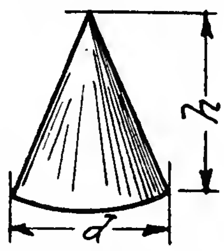



FIG. 169

$$V = d^2 \times .7854 \times \frac{h}{3}$$

d is 10″ and h 24″, find the volume.

$$V = 10 \times 10 \times .7854 \times \frac{24}{3} = 628.32 \text{ cu. in.}$$

## FRUSTUM OF CONE

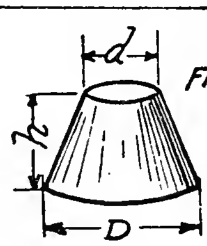



FIG. 170

$$V = .2618\ h \times (D^2 + D\ d + d^2).$$

D is 12″, d 10″ and h 8″, find the volume.

$V = .2618 \times 8 \times (144 + 12 \times 10 + 100) =$

$2.0944 \times 364 = 762.3616$ cu. in.

## WEDGE

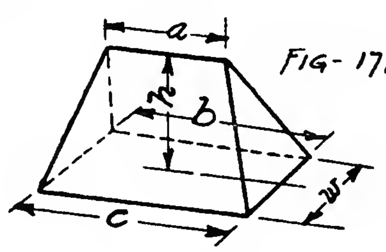



FIG. 171

$$V = \frac{1}{6}\ w\ h\ (a + b + c).$$

w is 10″, h 24″, a 12″, b 28″ and c 30″, find the volume.

$$V = \frac{1}{6} \times 10 \times 24\ (12 + 28 + 30) = 2800 \text{ cu. in.}$$

## SPHERE OR BALL

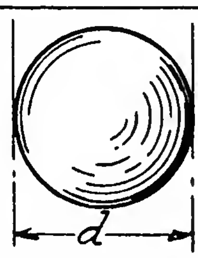



FIG. 172

$V = .5236 \times d \times d \times d$

or $.5236 \times d^3$

d is 9″, find the volume.

$V = .5236 \times 9 \times 9 \times 9 = 381.7044$ cu. in.

## RING

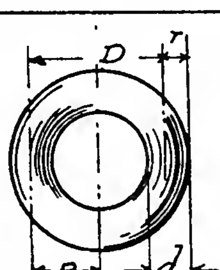



FIG. 173

$$V = 2.4674\ D \times d^2.$$

D is 10″ and d 2″, find the volume.

$V = 2.4674 \times 10 \times 2 \times 2 = 98.6960$ cu. in.

## PORTION OF CYLINDER

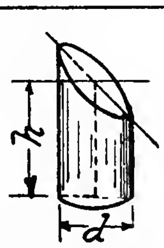



FIG. 174

$$V = d^2 \times .7854 \times h$$

d is 4″ and h 8″, find the volume.

$V = 4 \times 4 \times .7854 \times 8 = 100.5312$ cu. in.

**CYLINDER**

d is 4″ and h 10″, find the volume.

V = .7854 x 16 x 10 = 125.664 cu. in.

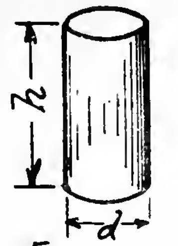



FIG-175

$V = .7854 \times d^2 h.$

**HOLLOW CYLINDER**

D is 20″, d 8″ and h 30″, find the volume.

V = (400 — 64) x .7854 x 30 =7916.83 cu. in.

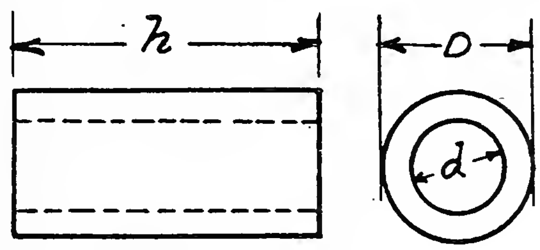



FIG-176

$V = (D^2 - d^2) \times .7854 \times h$

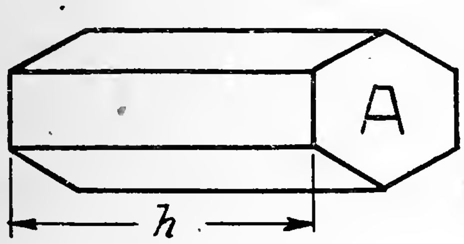



FIG-177

V = Area of one end x h.

The area A of the end surface is found by the formulas for areas of plane figures on the preceding pages. Distance h must be measured perpendicular to end surface.

## HOW TO ESTIMATE THE WEIGHTS OF VARIOUS SHAPED OBJECTS WHEN MADE OF DIFFERENT MATERIALS.

It will be of value to you to know how to estimate the weight of any object and following is the simple rule which must be followed when estimating weights:

Find the cubical contents of the object and multiply this by the weight of 1 cubic inch of the material from which it is made. (**Cubical contents** means the number of cubic inches contained in an object.)

When multiplying a length by a width, or a length by a height, square inches or square feet are obtained as the case may be; but when multiplying either of the above by a third dimension (depth), the result is cubic inches or cubic feet, indicating the cubical contents of the object. Let us explain this by an example:

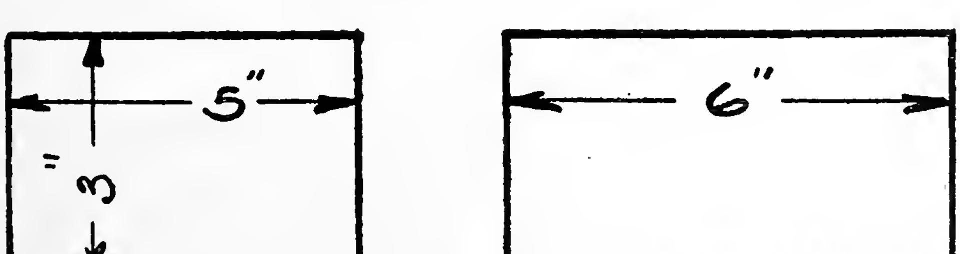



**Fig. 178**

## SQUARE INCH AREA.

Fig. 178 represents a block which has been marked 6″ long, 5″ wide and 3″ high. The area of one side will be 6 x 3 = 18 sq. in.— or the length multiplied by the height, gives square inches.

## CUBIC INCH.

By multiplying this square inch area by the depth, 5″, we obtain cubic inches, and the total operation may be written 6 x 3 x 5″ = 90 cu. in.

We will now proceed to explain how the weight of this block is obtained. Referring to page 219 you will note the column headed "Weight per Cubic Inch." In this column the weights for one cubic inch of the various materials mentioned in the left hand column are given.

We will assume the block, Fig. 178, is to be made of cast iron and by referring to the column headed "Weight per Cubic Inch," we see that .26, or approximately ¼ lb., is the weight given for each cubic inch of iron. We previously found that this block contained 90 cu. in. and as each cubic inch of iron weighs .26 lbs. we multiply the 90 by .26 which equals 23.40 lbs.

Now let us assume that this block, Fig. 178, were to be made of lead. By referring to the table, page 219 you will note that the weight of 1 cu. in. of lead is given as .410 and the total weight of this block made of lead would be 90 x .41 = 36.90 lbs.

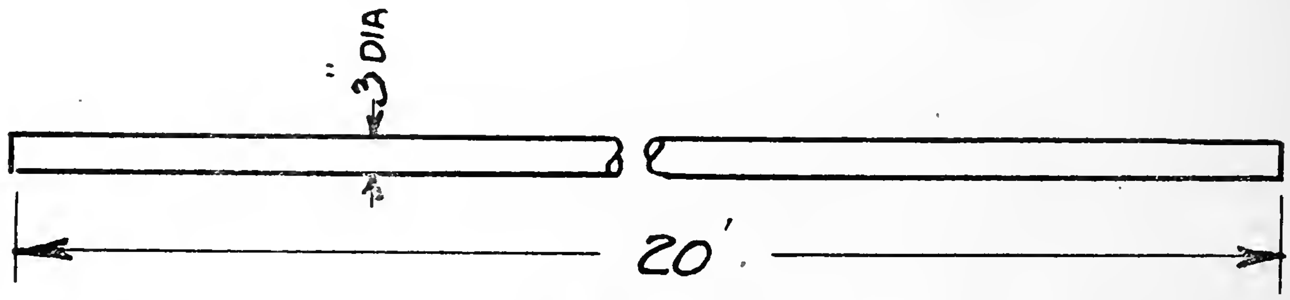



**Fig. 179**

Fig. 179 represents a cylinder or rod—3″ in diameter by 20′ in length. In order to find the cubical contents of this figure, we will proceed in exactly the same manner as in the case of the block and multiply the square inch area of one end by the total length, 20 ft.

It will be seen that the end not being square or oblong, a length cannot be multiplied by a width in order to get the square inch area, therefore formulas or fixed rules have been calculated to assist us in these problems. These formulas have been worked out by the use of higher mathematics and the final condensed result is written $d^2$ x .7854 = A, as explained on page 189. The letter d represents the diameter, which may be given in inches, yards, etc. The letter A represents the area.

The table given on page 192 shows the areas of circles for different diameters, and by referring to the table it will be seen that the area of a 3″ circle is 7.0686—this result having been obtained by multiplying 3 x 3 x .7854. In order to obtain the cubical contents of this rod we must multiply the area of one end by its length; however, the area obtained is given in square inches, therefore we must multiply this by its length in **inches.** Reduce the 20′ to inches (20 x 12 = 240″), and the total operation for finding the cubical contents of this rod may be stated in the following condensed form:

$$3 \times 3 \times .7854 \times 240 = 1696.46 \text{ cu. in.}$$

The rules for finding the square inch area and the circumference of a circle, also the area of a triangle should be memorized as these are the most common—the others for various shaped surfaces may be referred to when needed.

The method of finding the weight of the rod, Fig. 179, is exactly the same as that for the block—the cubical contents multiplied by the weight of 1 cu. in. of the material from which it is made. Assume this rod were to be made of aluminum, by referring to the table you will note that 1 cu. in. of aluminum weighs .092 lbs. which, when multiplied by the total number of cubic inches in the rod (1696.46 cu. in.), is equal to 156 lbs. and the total operation may be stated

$$1696.46 \times .092 = 156 \text{ lbs.}$$

## HOLLOW CYLINDER.

### (Cubic Inches in Walls)

Let us figure the cubic inches in the walls of a hollow cylinder or pipe using the formula shown in Fig. 176 page 205, which reads $V = (D^2 - d^2) \times .7854 \times h$. Assume that the outside diameter is 12″, inside diameter 9″ and the length 8′. Feet and inches cannot be multiplied together so we must change the 8′ to inches, by multiplying it by 12, which equals 96. The formula may be written:

$$V = (12^2 - 9^2) \times .7854 \times 96, \text{ which reduced equals}$$

$$V = (144 - 81) \times .7854 \times 96. \text{ This is then written}$$

$$\begin{array}{r} 144 \\ -81 \\ \hline 63 \end{array}$$

$$V = (63) \times .7854 \times 96, \text{ and equals}$$

$$\begin{array}{r} 63 \\ \times\ .7854 \\ \hline 252 \\ 315\phantom{0} \\ 504\phantom{00} \\ 441\phantom{000} \\ \hline 49.4802 \\ \times 96 \\ \hline 2968812 \\ 4453218\phantom{0} \\ \hline 4750.0992 \end{array}$$

4750.0992 cu. in. of metal in pipe = V.

## ESTIMATING WEIGHT OF CASTING FROM PATTERN.

The approximate weight of a casting may be obtained by multiplying the weight of the pattern by the figure given in the table which corresponds to the material from which the pattern is made, and the material poured in the casting. Example:

If a pattern is made of white pine, weight 10 lbs., and casting is to be made of cast iron, then multiply 10 x 14.7, (see table) which equals 147 lbs.—weight of casting.

Allowance should be made for any metal in the pattern.

| Pattern weighing one pound | Weight when cast in— | | | |
|---|---|---|---|---|
| | Cast Iron Pounds. | Yellow Brass Pounds. | Gun Metal Pounds. | Aluminum Pounds. |
| Bay wood | 8.8 | 9.9 | 10.3 | 3.2 |
| Beech | 8.5 | 9.5 | 10.0 | 3.1 |
| Cedar | 16.1 | 18.0 | 18.9 | 5.8 |
| Cherry | 10.7 | 12.0 | 12.6 | 3.9 |
| Linden | 12.0 | 13.5 | 14.1 | 4.3 |
| Mahogany | 8.5 | 9.5 | 10.0 | 3.1 |
| Maple | 9.2 | 10.3 | 10.8 | 3.2 |
| Oak | 9.4 | 10.5 | 11.0 | 3.4 |
| Pear | 10.9 | 12.2 | 12.8 | 3.9 |
| Pine, white | 14.7 | 16.5 | 17.3 | 5.3 |
| Pine, yellow | 13.1 | 14.7 | 15.4 | 4.7 |
| Whitewood | 16.4 | 18.4 | 19.3 | 5.9 |

If pattern has cores, the approximate weight of casting may be determined as follows:

Fill the core boxes with dry sand—weigh the sand and multiply by one of the following factors:

4.0 if cast in iron,

4.65 if cast in brass or gun metal,

1.39 if cast in aluminum.

Then subtract this product from the weight obtained when the solid pattern was multiplied by the factor corresponding to the material in which it was cast. Example:

Assume the total weight of casting when estimated from solid pattern, was 147 lbs., as mentioned; the sand which filled the core boxes weighed 12 lbs; casting being made of cast iron—12 lbs. x 4 (factor for cast iron) equals 48 lbs.

$$\begin{array}{r} 147 \\ -48 \\ \hline 99 \end{array}$$ lbs. net weight of casting.

## EXAMINATION

## LESSON 20

1. Fig. 154. If $b = 8$ and $h = 10$, what is the area of this figure?

2. Fig. 158. If $r = 12$, what is the area of this figure?

3. Fig. 174. If $d = 6$ and $h = 14$, what is the volume of this figure?

# LESSON TWENTY-ONE

## METHOD OF ESTIMATING THE WEIGHT OF A CASTING FROM DRAWING.

Fig. 180. When it is desired to estimate the weight of a casting, it is customary to resolve the object into several distinct geometrical figures and in this case we have

(1) A cone 4″ diameter at its base and 2″ high,

(2) A cylinder 4″ outside diameter, 3″ inside diameter and 5½″ long,

(3) A flat plate or base 6 x 6 x ½″ thick with a 3″ hole thru its center,

(4) 4 triangular ribs 1 x 1 x ¼″ thick.

We will now explain how to find the cubical contents of each part:

**The Cone**:—By referring to page 204 we see that the formula for finding the cubical contents (or volume) is

$$V = d^2 \times .7854 \times \frac{h}{3}$$

Inserting the figures representing the diameter and height of the cone, we have

$$V = 4^2 \times .7854 \times \frac{2}{3} \qquad V = 16 \times .7854 \times \frac{2}{3}$$

$$\begin{array}{r} 16 \\ .7854 \\ \hline 64 \\ 80\phantom{0} \\ 128\phantom{00} \\ 112\phantom{000} \\ \hline 12.5664 \end{array} \times \frac{2}{3} = \frac{25.1328}{3} = 8.3776 \text{ cu. in.}$$

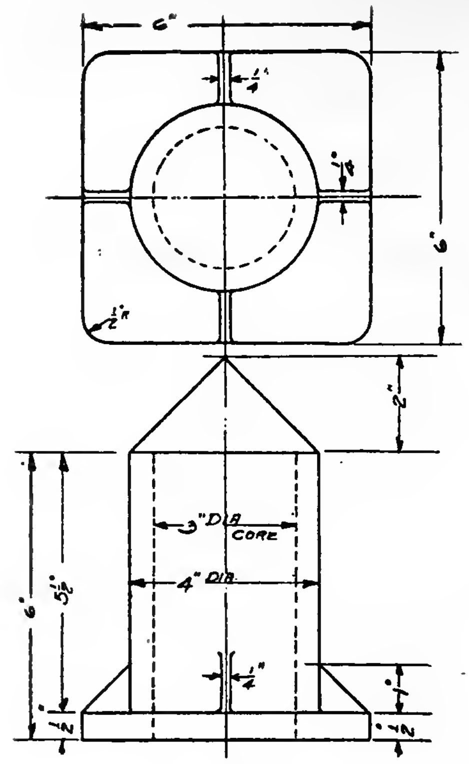



FIG. 180
MATERIAL CAST IRON

The square inch area of walls of a hollow cylinder is equal to the area of the inner circle subtracted from the area of the outer circle. As the areas of various circles have been worked out, they may be used instead of the formulas for the hollow cylinder, Fig. 176. It is to be remembered that the end area of the cylinder must be multiplied by its length.

**The Cylinder**:—By referring to the areas of circles on page 192 it will be seen that the area of a 4″ circle is 12.566 and a 3″ circle is 7.068—the difference in these two areas will be the square inch area of one end of the cylinder. This multiplied by the length (5.5) will equal the cubic inches in the cylinder, and the complete operation will be written:

```
  12.56
 —7.06
 ------
   5.50  net area of one end.
   x5.5  length.
 ------
   2750
  2750
 ------
 30.25 cu. in.—cubical contents of cylinder.
```

**Flat Plate**:—6 x 6 x ½″ equals the cubical contents of the flat plate, but it will be seen that this plate has a 3″ hole thru its center and also that the four corners are rounded with ½″ radius. Subtract the cubical contents of this 3″ hole. It is customary to ignore the loss of the cubical contents caused by the ½″ radius.

$6 \times 6 = 36$ sq. in. Subtracting the area of a 3″ hole (see page 192)

36.

7.068

———

28.932 sq. in. area 3″ hole (multiplying this by the thickness of ½″)

x.5

———

14.4660 cu. in. total in flat plate, minus hole.

**Ribs**:—The square inch area of one rib is equal to $\frac{b\ h}{2}$,

$\frac{\text{base x height}}{2}$, which is equal to $\frac{1 \times 1}{2} = \frac{1}{2}$ or .5

.5 sq. in. As there are four ribs multiply by 4.

4

———

2.0 sq. in. These ribs being ¼″ thick (.25) multiply by .25.

.25

———

100

40

———

.500 or a total of .5 cu. in.

Total cubic inches in casting:

| | |
|---|---|
| Cone | 8.377 |
| Cylinder | 30.25 |
| Flat Plate | 14.466 |
| Ribs | .5 |
| | 53.593 cu. in. |

By referring to page 219, it will be seen that 1 cu. in. of cast iron weighs .26 lbs.—there being 53.593 cu. in. in this casting, the total weight will be:

53.593

x.26

———

321558

107186

———

13.93418 lbs.

## ESTIMATING THE WEIGHT OF CAST IRON FLYWHEEL SHOWN IN FIG. 181.

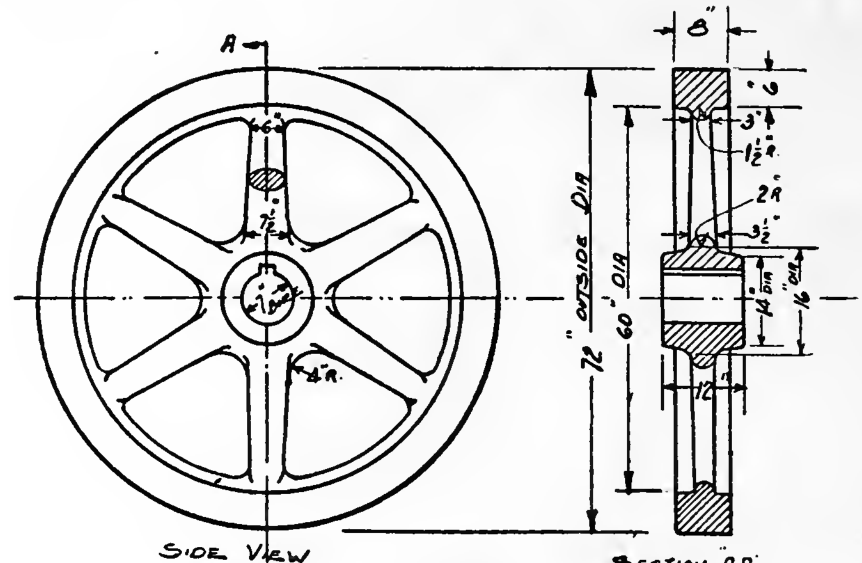



Fig-181

**Rim.**—There are two methods of finding the cubic inches in the rim; first, the net area between the outside and the inside diameter (side view) multiplied by the width, 8″. Example:

Rim = 72″ outside diameter
60″ inside diameter
8″ wide

| | | |
|---|---|---|
| Area 72″ circle | = 4071.50 | (see table, page 196) |
| Area 60″ circle | = 2827.43 | |
| Area of side of rim | = 1244.07 sq. in. | |
| | x8 | |
| | 9952.56 cu. in. in rim. | |

The second method is—find the area thru the cross section of the rim (6 x 8″ = 48) and multiply this by the average circumference, which is

```
   72
   60
2 ) 132
   66" average diameter
   x3.1416
   -------
   396
   66
  264
  66
 198
 ------------
 207.3456 average circumference.
```

```
  207.3456
      x48
 ---------
 16587648
 8293824
 ---------
 9952.5888 cu. in. in rim.
```

Either method may be used.

You will note there is a small section around the inner circumference of the rim (see sectional view) which has the shape of one-half circle and is marked 1½″ R—equal to 3″ diameter.

The area of ½ of a 3″ circle is equal to

$$\frac{7.0686}{2} = 3.5343 \text{ sq. in.}$$

The average circumference of this section is 183.78360″

$$\begin{array}{rr} & 60'' \\ 60 - 3 = & 57 \\ \hline & 117 \end{array}$$

$$\frac{117}{2} = 58\tfrac{1}{2}'' \text{ diameter x } 3.1416 =$$

$$\begin{array}{r} 58.5 \\ \text{x}3.1416 \\ \hline 3510 \\ 585\phantom{0} \\ 2340\phantom{00} \\ 585\phantom{000} \\ 1755\phantom{0000} \\ \hline 183.78360 \end{array} \text{ average circumference} \qquad \begin{array}{r} 183.78 \\ \text{x}3.53 \\ \hline 55134 \\ 91890\phantom{0} \\ 55134\phantom{00} \\ \hline 648.7434 \end{array} \text{ cu. in. half center section}$$

**Hub**:—Outside diameter at center 16″ (Not taking into con-
Diameter at edge 14″ (sideration the ½ cir-

$$2 \,\big)\, \overline{30''} \quad \text{(cular section which is}$$

(around the hub

Average outside diameter 15″ (proper.

$$\begin{array}{rl} \text{Area of a } 15'' \text{ circle} = 176.71 & \text{sq. in.} \\ \text{x}12 & \text{width} \\ \hline 35342 & \\ 17671\phantom{0} & \\ \hline 2120.52 & \text{cu. in.} \end{array}$$

However, the hub has a large hole thru the center, which is 7″ in diameter and 12″ long; this must be deducted from the solid hub.

Area of a 7″ circle = 38.48 sq. in.

$$\begin{array}{r} 38.48 \\ \times 12 \\ \hline 7696 \\ 3848\phantom{0} \\ \hline 461.76 \end{array}$$

461.76 cu. in. to be deducted for center hole.

$$\begin{array}{r} 2120.52 \\ -461.76 \\ \hline 1658.76 \end{array}$$

1658.76 cu. in. in hub.

Here again we have a half circle section around the outside of the hub—2″ radius or 4″ diameter. The area of ½ of 4″ circle is

$$\frac{12.56}{2} = 6.28.$$

The average diameter of this section is 16 + 4 = 20″ outside

$$\begin{array}{r} 20'' \text{ outside} \\ 16'' \text{ inside} \\ \hline 2 \,)\, 36 \\ \hline 18'' \text{ average} \end{array}$$

diameter. The circumference for this diameter is equal to 56.54 (see table page 193). Multiplying this by the area of the half circular section, which is 6.28 sq. in. equals the cubic inches.

$$\begin{array}{r} 56.54 \\ \times 6.28 \\ \hline 45232 \\ 11308\phantom{0} \\ 33924\phantom{00} \\ \hline 355.0712 \end{array}$$

355.0712 cu. in.

**Arms**:—The arms are oval in shape, and the average dimensions are as follows:

$$\begin{array}{r} 6 \\ 7\tfrac{1}{2} \\ \hline 2 \,)\, 13\tfrac{1}{2} \\ \hline 6\tfrac{3}{4}'' \end{array} \qquad \begin{array}{r} 3'' \\ 3\tfrac{1}{2} \\ \hline 2 \,)\, 6\tfrac{1}{2} \\ \hline 3\tfrac{1}{4}'' \end{array}$$

6¾″ average length of sec. 3¼″ average width of section.

See formula for the area of an oval section, Fig. 159, page 202.

$A = .7854 \times D \times d$

$D = 6\frac{3}{4} = 6.75$

$d = 3\frac{1}{4} = 3.25$

```
     .7854
     x6.75
   -------
     39270
    54978
   47124
   -------
  5.301450
  x3.25
  -------
    265
   106
  159
  -------
  17.225 sq. in. area of arm.
```

The length of an arm may be taken as being

```
60 — 3 = 57"
16 + 4 = 20
       2 ) 37"
           -----
           18½" long.
```

The area of the cross section of the arm multiplied by this length equals the cubic inches in one arm—

```
    17.22
    x18.5
   ------
     8610
   13776
   1722
   ------
   318.570
```

As there are six arms, multiply 318.57

```
   318.57
       x6
  -------
  1911.42 cu. in. in the six arms.
```

Now total up all the cubic inches in the various sections, thus

| | |
|---|---|
| Rim | 9952.58 |
| Cubic inches in ½ ring of inside diameter of rim | 648.74 |
| Hub | 1658.76 |
| Cubic inches in ½ ring on outside of hub | 355.07 |
| 6 arms | 1911.42 |
| | 14526.57 cu. in. in fly wheel. |
| | x.26 weight of 1 cu. in. of cast iron. |
| | 8715942 |
| | 2905314 |
| | 3776.9082 total weight of fly wheel in lbs. |

**Note**:—The majority of flywheels, pulleys, etc., will not have the half circular sections around the inside of the rim and the outside of the hub so pronounced, or in other words, they will be much flatter —in that case allowance may be made for these by increasing or decreasing the diameter.

## EXAMINATION

## LESSON 21

1. Fig. 161. (a) If the fly wheel were made of steel, how much would it weigh?

(b) If made of cast iron, what would be the weight of the rim, if it were 144 inches outside diameter and 132 inches inside diameter x 8 inches wide?—Include half circular section on inside of rim, 1½ inch radius, in calculating.

# LESSON TWENTY .TWO

## SPECIFIC GRAVITY.

The specific gravity of a body is the ratio between its weight and the weight of a like volume displaced of distilled water at a temperature of 62° F.

The specific gravity of a gas is the ratio between its weight and a like volume of air at 32° F.

The weight of 1 cubic foot of distilled water at 62° F. is equal to 62.355 lbs. and the weight of 1 cubic foot of air at 32° F. is .08073 lbs.

In order to find the weight per cubic foot of any substance, knowing its specific gravity, it is necessary to multiply its specific gravity by 62.355 lbs. The weight of 1 cubic foot of any gas at atmospheric pressure and at 32°F. is found by multiplying its specific gravity by .08073 lbs.

The specific gravity of water is taken as a unit of 1 for substances; and the specific gravity of air is taken as a unit of 1 for all gases.

| Name of Substance Metals | Specific Gravity | Weight per cu. in. lbs. |
|---|---|---|
| Platinum, rolled | 22.67 | .818 |
| Platinum, wire | 21.04 | .759 |
| Gold | 19.32 | .697 |
| Mercury, at 60° F | 13.58 | .490 |
| Lead | 11.37 | .410 |
| Silver | 10.53 | .380 |
| Bismuth | 9.80 | .354 |
| Copper, pure | 8.82 | .318 |
| Bronze | 8.85 | .319 |
| Brass, common | 8.50 | .307 |
| Steel | 7.80 | .281 |
| Iron, wrot and rolled | 7.85 | .283 |
| Iron, cast | 7.20 | .260 |
| Tin, English | 7.29 | .263 |
| Zinc, rolled | 7.15 | .258 |
| Antimony | 6.71 | .242 |
| Aluminum | 2.56 | .092 |

## AVERAGE SPECIFIC GRAVITY OF MISCELLANEOUS SUBSTANCES.

| Substance | Specific Gravity | Weight per cu. ft. lbs. |
|---|---|---|
| Asbestos | 2.8 | 175 |
| Asphaltum | 1.4 | 87 |
| Borax | 1.75 | 109 |
| Brick, common | 1.8 | 112 |
| Brick, fire | 2.3 | 144 |
| Brick, hard | 2.0 | 125 |
| Brick, pressed | 2.15 | 134 |
| Brickwork, in mortar | 1.6 | 100 |
| Brickwork, in cement | 1.8 | 112 |
| Cement, Portland | 3.1 | 194 |
| Chalk | 2.6 | 163 |
| Charcoal | .4 | 25 |
| Coal, anthracite | 1.5 | 94 |
| Coal, bituminous | 1.27 | 79 |
| Concrete | 2.2 | 137 |
| Earth, loose | 1.2 | 75 |
| Earth, rammed | 1.6 | 100 |
| Emery | 4.0 | 250 |
| Glass | 2.6 | 163 |
| Granite | 2.65 | 166 |
| Gravel | 1.75 | 109 |
| Gypsum | 2.2 | 137 |
| Ice | .9 | 56 |
| Ivory | 1.85 | 115 |
| Limestone | 2.6 | 163 |
| Marble | 2.7 | 169 |
| Masonry | 2.4 | 150 |
| Mica | 2.8 | 175 |
| Mortar | 1.5 | 94 |
| Phosphorus | 1.8 | 112 |
| Plaster of Paris | 1.8 | 112 |
| Quartz | 2.6 | 163 |
| Salt, common | 2.1 | 131 |
| Sand, dry | 1.6 | 100 |
| Sand, wet | 2.0 | 125 |
| Sandstone | 2.3 | 144 |
| Slate | 2.8 | 175 |
| Soapstone | 2.7 | 169 |
| Soil, common black | 2.0 | 125 |
| Sulphur | 2.0 | 125 |
| Trapp | 3.0 | 187 |
| Tile | 1.8 | 112 |

The weight per cubic foot is calculated on the basis of the specific gravity, and considers the material solidly packed. With many substances this is practically impossible, and a cubic foot of ordinary anthracite coal, for example, does not weigh more than from 55 to 65 lbs. due to the air spaces between the pieces of coal.

## SPECIFIC GRAVITY AND AVERAGE WEIGHT PER CUBIC FOOT OF WOOD

| | Specific Gravity | Average weight per cubic foot |
|---|---|---|
| Beech | .73 | 46 lbs. |
| Cedar | .62 | 39 lbs. |
| Cherry | .66 | 41 lbs. |
| Linden | .60 | 37 lbs. |
| Mahogany | .81 | 51 lbs. |
| Maple | .68 | 42 lbs. |
| Oak, white | .77 | 48 lbs. |
| Oak, red | .74 | 46 lbs. |
| Pine, white | .45 | 28 lbs. |
| Pine, yellow | .61 | 38 lbs. |
| Walnut | .75 | 38 lbs. |

## SPECIFIC GRAVITY OF GASES.

(At 32° F.)

| Gas | Specific Gravity | Gas | Specific Gravity |
|---|---|---|---|
| Air | 1.000 | Hydrogen | .069 |
| Acetylene | .910 | Illuminating gas | .040 |
| Alcohol vapor | 1.601 | Mercury vapor | 6.940 |
| Ammonia | .592 | Marsh gas | .555 |
| Carbon dioxide | 1.520 | Nitrogen | .971 |
| Carbon monoxide | .967 | Nitric oxide | 1.039 |
| Chlorine | 2.423 | Nitrous oxide | 1.527 |
| Ether vapor | 2.586 | Oxygen | 1.106 |
| Ethylene | .967 | Sulphur dioxide | 2.250 |
| Hydrofluoric acid | 2.370 | Water vapor | .623 |
| Hydrochloric acid | 1.261 | | |

1 cubic foot of air at 32° F. and atmospheric pressure weighs .0807 lbs.

## SPECIFIC GRAVITY OF LIQUIDS.

| Liquid | Specific Gravity | Liquid | Specific Gravity |
|---|---|---|---|
| Acetic acid | 1.06 | Muriatic acid | 1.20 |
| Alcohol, commercial | .83 | Naphtha | .76 |
| Alcohol, pure | .79 | Nitric acid | 1.22 |
| Ammonia | .89 | Olive oil | .92 |
| Benzine | .69 | Palm oil | .97 |
| Bromine | 2.97 | Petroleum oil | .82 |
| Carbolic acid | .96 | Phosphoric acid | 1.78 |
| Carbon disulphide | 1.26 | Rape oil | .92 |
| Cotton-seed oil | .93 | Sulphuric acid | 1.84 |
| Ether, sulphuric | .72 | Tar | 1.00 |
| Fluoric acid | 1.50 | Turpentine oil | .87 |
| Gasoline | .70 | Vinegar | 1.08 |
| Kerosene | .80 | Water | 1.00 |
| Linseed oil | .94 | Water, sea | 1.03 |
| Mineral oil | .92 | Whale oil | .92 |

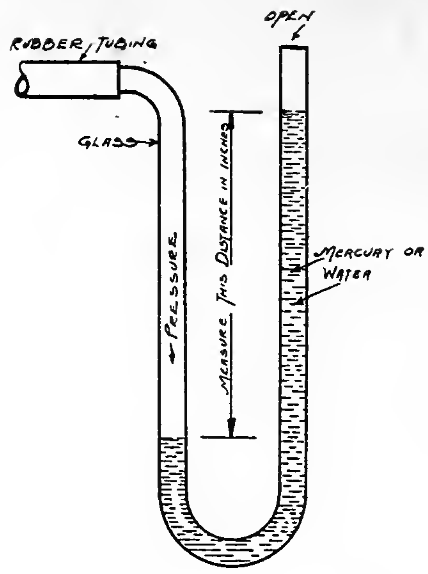



Fig. 182

## HOW TO READ "U" GAUGES.

Fig. 182 shows a "U" gauge and is used to determine the pressure caused by air or some other gas which may be confined under pressure or flowing thru a chamber.

The gauge is read as follows: Rubber tubing connects one end of the tube to the chamber in which the gases are confined under pressure, or are flowing. A valve is generally placed between the U gauge and the chamber. When the valve is opened, the gas will flow into the gauge and cause the liquid which formerly stood level in both upright portions of the tube to rise in one and be lowered in the other. (See Figure). By measuring the distance in inches between the high and low level, using an ordinary rule, and multiplying this distance by .5774 when water is used, and by 7.859 when mercury is used, will give the ounce pressure per square inch.

Tables have been compiled giving the resulting ounces for various heights in inches when either water or mercury is used.

**Ounces Pressure** corresponding to different heights of **water** in "U" gauge.

| Inches | | Ounces Pressure Per Square Inch | Inches | | Ounces Pressure Per Square Inch | Inches | | Ounces Pressure Per Square Inch |
|---|---|---|---|---|---|---|---|---|
| ½ | = | .2887 | 7 | = | 4.04 | 16 | = | 9.25 |
| 1 | | .5774 | 7½ | | 4.33 | 18 | | 10.39 |
| 2 | | 1.15 | 8 | | 4.62 | 20 | | 11.54 |
| 2½ | | 1.44 | 8½ | | 4.90 | 22 | | 12.70 |
| 3 | | 1.73 | 9 | | 5.19 | 24 | | 13.86 |
| 3½ | | 2.02 | 9½ | | 5.48 | 26 | | 15.00 |
| 4 | | 2.31 | 10 | | 5.77 | 28 | | 16.16 |
| 4½ | | 2.59 | 10½ | | 6.06 | 30 | | 17.32 |
| 5 | | 2.88 | 11 | | 6.35 | 34 | | 19.63 |
| 5½ | | 3.17 | 11½ | | 6.64 | 36 | | 20.78 |
| 6 | | 3.46 | 12 | | 6.93 | | | |
| 6½ | | 3.75 | 14 | | 8.08 | | | |

Corresponding to the different heights of **mercury** in "U" gauge

| Inches | Ounces Pressure per square inch | Approximate Pounds per square inch |
|---|---|---|
| ½ | 3.929 | |
| 1 | 7.859 | |
| 2 | 15.72 | |
| 2½ | 19.647 | |
| 3 | 23.577 | 1.47 |
| 3½ | 27.50 | 1.72 |
| 4 | 31.436 | 1.97 |
| 4½ | 35.36 | 2.2 |
| 5 | 39.29 | 2.46 |
| 5½ | 43.22 | 2.7 |
| 6 | 47.154 | 2.94 |
| 6½ | 51.083 | 3.2 |
| 7 | 55.01 | 3.43 |
| 7½ | 58.94 | 3.68 |
| 8 | 62.87 | 3.92 |
| 8½ | 66.80 | 4.17 |
| 9 | 70.73 | 4.42 |
| 9½ | 74.66 | 4.66 |
| 10 | 78.59 | 4.92 |

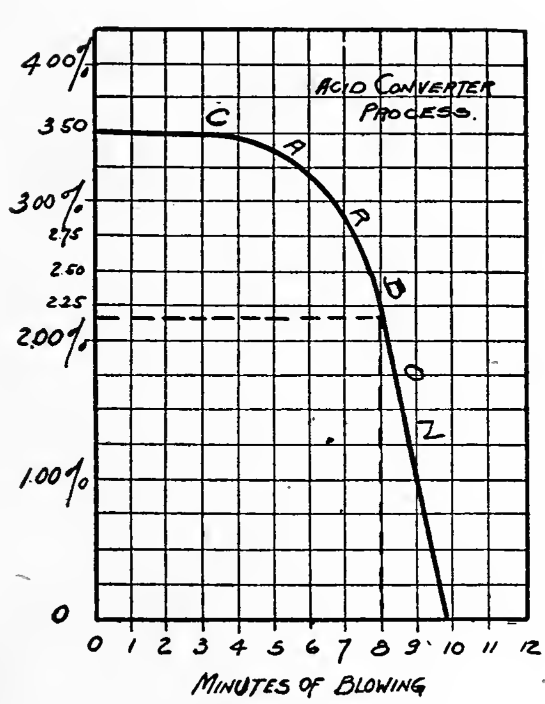



FIG- 183

## CURVE OR GRAPH READINGS.

A curve is the graphic representation of the results obtained from a series of tests, or the result of formulas or equations. Fig. 183 is a curve representing the results of tests taken every minute during the refining period in the manufacture of steel by the converter process.

By the use of a curve properly made, it is convenient to read at a glance, much that would require considerable data and other printed matter to explain. Curves are made in great variety. The reading of complicated curves is generally explained.

No doubt you know that steel and iron contain carbon. The curve in Fig. 183 shows the reduction of carbon for every minute of the blow in the manufacture of steel by the converter process. As will be noted at the bottom, the total time of blow is ten minutes. The liquid metal poured into the converter contained 3.50 carbon (see figures at left); after 8 minutes of blowing air thru or over the metal, the carbon in the liquid metal was reduced to about 2.15. The dotted line indicates the method of reading—first up from the 8, then horizontally to the left.

## SHRINKAGE OF CASTINGS PER FOOT.

| Metals | Fractions of an inch | Decimals of an inch |
|---|---|---|
| Pure aluminum | 13/64 | .2031 |
| Nickel aluminum casting alloy | 3/16 | .1875 |
| "Special Casting Alloy," made by the Pittsburgh Reduction Co. | 11/64 | .1718 |
| Iron, small cylinders | 1/16 | .0625 |
| Iron, pipes | 1/8 | .1250 |
| Iron, girders, beams, etc | 1/64 | .1000 |
| Iron, large cylinders, contraction of diameter at top | 5/8 | .6250 |
| Iron, large cylinders, contraction of diameter at bottom | 5/64 | .0830 |
| Iron, large cylinders, contraction in length | 3/32 | .0940 |
| Cast iron | 1/8 | .1250 |
| Steel | 3/16 to 1/4 | .1875 to .2500 |
| Malleable iron | 1/8 | .1250 |
| Tin | 1/12 | .0833 |
| Britannia | 1/32 | .03125 |
| Thin brass castings | 11/64 | .1670 |
| Thick brass castings | 5/32 | .1500 |
| Zinc | 5/16 | .3125 |
| Lead | 5/16 | .3125 |
| Copper | 3/16 | .1875 |
| Bismuth | 5/32 | .1563 |
| Semi-steel | 1/8 | .125 |

The contraction of iron, semi-steel or steel will vary according to the difference in the percentage of metalloids; for instance, high silicon will shrink less than low silicon, and vice versa.

## CAPACITY OF CYLINDRICAL TANKS

To find how many U. S. gallons a cylindrical tank will hold: Multiply the square of the inside diameter by 0.7854, which gives the area; multiply that result by the depth and this gives the cubic contents of the tank. If measurements are in inches, divide the cubic contents by 1728 and you then have contents expressed in cubic feet; then multiply by 7.4805 (U. S. gallons in each cubic foot of water) and the final result is the number of U. S. gallons the tank will contain.

## NUMBER OF GALLONS IN ROUND TANKS

| Length or Depth in Feet | Diameter in Inches | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 18 | 24 | 30 | 36 | 42 | 48 | 54 | 60 | 66 | 72 |
| 2 | 26 | 47 | 73 | 105 | 144 | 188 | 238 | 294 | 356 | 424 |
| 2½ | 33 | 59 | 90 | 131 | 180 | 235 | 298 | 367 | 445 | 530 |
| 3 | 40 | 71 | 109 | 157 | 216 | 282 | 357 | 440 | 534 | 636 |
| 3½ | 47 | 83 | 127 | 183 | 252 | 329 | 416 | 513 | 623 | 742 |
| 4 | 54 | 95 | 145 | 209 | 288 | 376 | 475 | 586 | 712 | 848 |
| 4½ | 61 | 107 | 163 | 235 | 324 | 423 | 534 | 659 | 801 | 954 |
| 5 | 68 | 119 | 180 | 261 | 360 | 470 | 593 | 732 | 890 | 1060 |
| 5½ | 75 | 131 | 200 | 287 | 396 | 517 | 652 | 805 | 979 | 1166 |
| 6 | 82 | 143 | 217 | 313 | 432 | 564 | 711 | 878 | 1068 | 1272 |
| 6½ | 89 | 155 | 235 | 339 | 468 | 611 | 770 | 951 | 1157 | 1378 |
| 7 | 96 | 167 | 253 | 365 | 504 | 658 | 829 | 1024 | 1246 | 1484 |
| 7½ | 103 | 179 | 271 | 391 | 540 | 705 | 888 | 1097 | 1335 | 1590 |
| 8 | 110 | 191 | 289 | 417 | 576 | 752 | 947 | 1170 | 1424 | 1696 |
| 8½ | ... | 203 | 307 | 443 | 612 | 799 | 1006 | 1243 | 1513 | 1802 |
| 10 | ... | 239 | 361 | 521 | 720 | 940 | 1183 | 1462 | 1780 | 2120 |
| 12 | ... | 287 | 433 | 625 | 864 | 1128 | 1419 | 1754 | 2136 | 2544 |
| 14 | ... | ... | ... | ... | 1008 | 1316 | 1655 | 2046 | 2492 | 2968 |
| 16 | ... | ... | ... | ... | 1152 | 1504 | 1891 | 2338 | 2848 | 3392 |
| 18 | ... | ... | ... | ... | .... | .... | 2127 | 2630 | 3204 | 3816 |
| 20 | ... | ... | ... | ... | .... | .... | 2363 | 2922 | 3560 | 4240 |

| Depth in Feet. | DIAMETER IN FEET. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 8 | 9 | 10 | 1 | 12 | 13 | 14 | 15 | 16 | 18 | 20 | 22 |
| 5 | 1,875 | 2,380 | 2,925 | 3,550 | 4,237 | 4,960 | 5,765 | 6,698 | 7,520 | 9,516 | 11,750 | 14,215 |
| 6 | 2,250 | 2,855 | 3,510 | 4,260 | 5,084 | 5,952 | 6,918 | 8,038 | 9,024 | 11,419 | 14,100 | 17,059 |
| 7 | 2,625 | 3,330 | 4,095 | 4,970 | 5,931 | 6,944 | 8,071 | 9,378 | 10,528 | 13,322 | 16,450 | 19,902 |
| 8 | 3,000 | 3,805 | 4,680 | 5,680 | 6,778 | 7,936 | 9,224 | 10,718 | 12,032 | 15,225 | 18,800 | 22,745 |
| 9 | 3,375 | 4,280 | 5,265 | 6,390 | 7,625 | 8,928 | 10,377 | 12,058 | 13,536 | 17,128 | 21,150 | 25,588 |
| 10 | 3,750 | 4,755 | 5,850 | 7,100 | 8,472 | 9,920 | 11,530 | 13,398 | 15,040 | 19,031 | 23,500 | 28,431 |
| 11 | 4,125 | 5,250 | 6,435 | 7,810 | 9,319 | 10,913 | 12,683 | 14,738 | 16,544 | 20,934 | 25,850 | 31,274 |
| 12 | 4,500 | 5,705 | 7,020 | 8,520 | 10,166 | 11,904 | 13,836 | 16,078 | 18,048 | 22,837 | 28,200 | 34,117 |
| 13 | 4,875 | 6,180 | 7,605 | 9,230 | 11,013 | 12,896 | 14,989 | 17,418 | 19,552 | 24,740 | 30,550 | 36,960 |
| 14 | 5,250 | 6,655 | 8,190 | 9,940 | 11,860 | 13,888 | 16,142 | 18,758 | 21,056 | 26,643 | 32,900 | 39,803 |
| 15 | 5,625 | 7,130 | 8,775 | 10,650 | 12,707 | 14,880 | 17,295 | 20,098 | 22,260 | 28,546 | 35,250 | 42,646 |
| 16 | 6,000 | 7,605 | 9,360 | 11,360 | 13,554 | 15,872 | 18,448 | 21,438 | 24,064 | 30,449 | 37,600 | 45,489 |
| 17 | 6,375 | 8,080 | 9,945 | 12,070 | 14,401 | 16,864 | 19,601 | 22,778 | 25,568 | 32,352 | 39,950 | 48,332 |
| 18 | 6,750 | 8,535 | 10,530 | 12,780 | 15,248 | 17,856 | 20,754 | 24,118 | 27,072 | 34,255 | 42,300 | 51,175 |
| 19 | 7,125 | 9,010 | 11,115 | 13,490 | 16,095 | 18,848 | 21,907 | 25,458 | 28,576 | 36,158 | 44,650 | 54,018 |
| 20 | 7,500 | 9,490 | 11,700 | 14,200 | 16,942 | 19,840 | 23,060 | 26,798 | 30,080 | 38,062 | 47,000 | 56,861 |

# BOARD FEET IN PATTERN LUMBER.

The accompanying table, which gives the number of board feet in planks of various sizes, will be found of value to pattern makers and others in calculating the cost of lumber for patterns and flasks. The size of the pieces is given at the left and their length in the various columns across the top of the table.

A board foot contains 144 cubic inches of lumber; that is, a plank 12″ square and 1″ thick contains 1 board foot; if it were 2 inches thick, it would contain 2 board feet. However, in selling lumber, dealers always figure boards **less than** 1″ thick as if they were inch boards.

| | Length in Feet. | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Size. | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| | Feet Board Measure. | | | | | | | | | | | | |
| 1 x 1 | 0.33 | 0.41 | 0.5 | 0.58 | 0.66 | 0.75 | 0.83 | 0.91 | 1.00 | 1.08 | 1.16 | 1.25 | 1.33 |
| 1 x 2 | 0.66 | 0.82 | 1.0 | 1.16 | 1.32 | 1.50 | 1.66 | 1.82 | 2.00 | 2.16 | 2.32 | 2.50 | 2.66 |
| 1 x 3 | 1.00 | 1.25 | 1.5 | 1.75 | 2.00 | 2.25 | 2.50 | 2.75 | 3.00 | 3.25 | 3.50 | 3.75 | 4.00 |
| 1 x 4 | 1.33 | 1.66 | 2.0 | 2.33 | 2.66 | 3.00 | 3.33 | 3.66 | 4.00 | 4.33 | 4.66 | 5.00 | 5.33 |
| 1 x 5 | 1.66 | 2.08 | 2.5 | 2.91 | 3.33 | 3.75 | 4.16 | 4.58 | 5.00 | 5.41 | 5.83 | 6.25 | 6.66 |
| 1 x 6 | 2.00 | 2.50 | 3.0 | 3.50 | 4.00 | 4.50 | 5.00 | 5.50 | 6.00 | 6.60 | 7.00 | 7.50 | 8.00 |
| 1 x 7 | 2.33 | 2.91 | 3.5 | 4.08 | 4.66 | 5.25 | 5.81 | 6.37 | 7.00 | 7.57 | 8.16 | 8.75 | 9.33 |
| 1 x 8 | 2.66 | 3.33 | 4.0 | 4.66 | 5.33 | 6.00 | 6.66 | 7.33 | 8.00 | 8.66 | 9.33 | 10.00 | 10.66 |
| 1 x 9 | 3.00 | 3.75 | 4.5 | 5.25 | 6.00 | 6.75 | 7.50 | 8.25 | 9.00 | 9.75 | 10.50 | 11.25 | 12.00 |
| 1 x 10 | 3.33 | 4.16 | 5.0 | 5.83 | 6.66 | 7.50 | 8.33 | 9.16 | 10.00 | 10.82 | 11.66 | 12.50 | 13.33 |
| 1 x 11 | 3.66 | 4.58 | 5.5 | 6.41 | 7.33 | 8.25 | 9.16 | 10.08 | 11.00 | 11.90 | 12.82 | 13.75 | 14.66 |
| 1 x 12 | 4.00 | 5.00 | 6.0 | 7.00 | 8.00 | 9.00 | 10.00 | 11.00 | 12.00 | 13.00 | 14.00 | 15.00 | 16.00 |
| 1¼ x 1 | 0.41 | 0.52 | 0.62 | 0.73 | 0.83 | 0.93 | 1.04 | 1.14 | 1.25 | 1.35 | 1.45 | 1.56 | 1.66 |
| 1¼ x 2 | 0.83 | 1.04 | 1.25 | 1.45 | 1.66 | 1.87 | 2.08 | 2.28 | 2.50 | 2.70 | 2.91 | 3.12 | 3.33 |
| 1¼ x 3 | 1.24 | 1.56 | 1.87 | 2.18 | 2.50 | 2.81 | 3.12 | 3.43 | 3.75 | 4.05 | 4.37 | 4.68 | 5.00 |
| 1¼ x 4 | 1.66 | 2.08 | 2.50 | 2.91 | 3.32 | 3.75 | 4.16 | 4.57 | 5.00 | 5.41 | 5.82 | 6.25 | 6.66 |
| 1¼ x 5 | 2.08 | 2.60 | 3.12 | 3.64 | 4.16 | 4.68 | 5.20 | 5.72 | 6.25 | 6.76 | 7.28 | 7.81 | 8.32 |
| 1¼ x 6 | 2.50 | 3.12 | 3.75 | 4.37 | 5.00 | 5.62 | 6.25 | 6.87 | 7.50 | 8.10 | 8.75 | 9.37 | 10.00 |
| 1¼ x 7 | 2.91 | 3.64 | 4.38 | 5.10 | 5.83 | 6.56 | 7.29 | 8.01 | 8.75 | 9.47 | 10.20 | 10.93 | 11.66 |
| 1¼ x 8 | 3.32 | 4.16 | 5.00 | 5.82 | 6.65 | 7.50 | 8.32 | 9.15 | 10.00 | 10.82 | 11.66 | 12.50 | 13.32 |
| 1¼ x 9 | 3.75 | 4.66 | 5.62 | 6.56 | 7.50 | 8.43 | 9.37 | 10.29 | 11.25 | 12.18 | 13.12 | 14.05 | 15.00 |
| 1¼ x 10 | 4.16 | 5.20 | 6.25 | 7.27 | 8.33 | 9.57 | 10.30 | 11.54 | 12.50 | 13.52 | 14.55 | 15.62 | 16.64 |
| 1¼ x 11 | 4.58 | 5.72 | 6.87 | 8.01 | 9.17 | 10.31 | 11.45 | 12.60 | 13.75 | 14.88 | 16.03 | 17.18 | 18.35 |
| 1¼ x 12 | 5.00 | 6.25 | 7.50 | 8.75 | 10.00 | 11.25 | 12.50 | 12.75 | 15.00 | 16.25 | 17.50 | 18.75 | 20.00 |
| 1½ x 1 | 0.5 | 0.61 | 0.75 | 0.87 | 1.0 | 1.12 | 1.23 | 1.36 | 1.5 | 1.62 | 1.74 | 1.87 | 2.0 |
| 1½ x 2 | 1.0 | 1.23 | 1.50 | 1.74 | 2.0 | 2.25 | 2.46 | 2.73 | 3.0 | 3.24 | 3.48 | 3.75 | 4.0 |
| 1½ x 3 | 1.5 | 1.84 | 2.25 | 2.61 | 3.0 | 3.37 | 3.75 | 4.13 | 4.5 | 4.86 | 4.72 | 5.62 | 6.0 |
| 1½ x 4 | 2.0 | 2.49 | 3.00 | 3.49 | 4.0 | 4.50 | 4.99 | 5.49 | 6.0 | 6.49 | 6.99 | 7.50 | 8.0 |
| 1½ x 5 | 2.5 | 3.09 | 3.75 | 4.36 | 5.0 | 5.62 | 6.18 | 6.75 | 7.5 | 8.11 | 8.73 | 9.37 | 10.0 |
| 1½ x 6 | 3.0 | 3.75 | 4.50 | 5.25 | 6.0 | 6.75 | 7.50 | 8.25 | 9.0 | 9.75 | 10.50 | 11.25 | 12.0 |
| 1½ x 7 | 3.5 | 4.36 | 5.25 | 6.12 | 7.0 | 7.87 | 8.72 | 9.61 | 10.5 | 11.35 | 12.24 | 13.12 | 14 0 |
| 1½ x 8 | 4.0 | 5.00 | 6.00 | 7.00 | 8.0 | 9.00 | 10.00 | 11.00 | 12.0 | 13.00 | 14.00 | 15.00 | 16.0 |
| 1½ x 9 | 4.5 | 5.43 | 6.75 | 7.87 | 9.0 | 10.12 | 11.25 | 12.37 | 13.5 | 14.62 | 15.74 | 16.87 | 18.0 |
| 1½ x 10 | 5.0 | 6.24 | 7.51 | 8.73 | 10.0 | 11.25 | 12.49 | 13.74 | 15.0 | 16.23 | 17.49 | 18.75 | 20.0 |
| 1½ x 11 | 5.5 | 6.87 | 8.25 | 9.61 | 11.0 | 12.37 | 13.74 | 15.12 | 16.5 | 17.85 | 19.23 | 20.62 | 22.0 |
| 1½ x 12 | 6.0 | 7.50 | 9.00 | 10.50 | 12.0 | 13.50 | 15.00 | 16.50 | 18.0 | 19.50 | 21.00 | 22.50 | 24.0 |

# TABLE

Showing the Number of Feet, Board Measure, contained in a Piece of Joist, Scantling or Timber of the Sizes given.

| Size in Inches. | LENGTH IN FEET. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 | 32 |
| 2 x 4 | 6⅔ | 8 | 9⅓ | 10⅔ | 12 | 13⅓ | 14⅔ | 16 | 17⅓ | 18⅔ | 20 | 21⅓ |
| 2 x 6 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 | 32 |
| 2 x 8 | 13⅓ | 16 | 18⅔ | 21⅓ | 24 | 26⅔ | 29⅓ | 32 | 34⅔ | 37⅓ | 40 | 42⅔ |
| 2 x 10 | 16⅔ | 20 | 23⅓ | 26⅔ | 30 | 33⅓ | 36⅔ | 40 | 43⅓ | 46⅔ | 50 | 53⅓ |
| 2 x 12 | 20 | 24 | 28 | 32 | 36 | 40 | 44 | 48 | 52 | 56 | 60 | 64 |
| 2 x 14 | 23⅓ | 28 | 32⅔ | 37⅓ | 42 | 46⅔ | 51⅓ | 56 | 60⅔ | 65⅓ | 70 | 74⅔ |
| 2 x 16 | 26⅔ | 32 | 37⅓ | 42⅔ | 48 | 53⅓ | 58⅔ | 64 | 69⅓ | 74⅔ | 80 | 85⅓ |
| 3 x 6 | 15 | 18 | 21 | 24 | 27 | 30 | 33 | 36 | 39 | 42 | 45 | 48 |
| 3 x 8 | 20 | 24 | 28 | 32 | 36 | 40 | 44 | 48 | 52 | 56 | 60 | 64 |
| 3 x 10 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 |
| 3 x 12 | 30 | 36 | 42 | 48 | 54 | 60 | 66 | 72 | 78 | 84 | 90 | 96 |
| 3 x 14 | 35 | 42 | 49 | 56 | 63 | 70 | 77 | 84 | 91 | 98 | 105 | 112 |
| 3 x 16 | 40 | 48 | 56 | 64 | 72 | 80 | 88 | 96 | 104 | 112 | 120 | 128 |
| 4 x 4 | 13⅓ | 16 | 18⅔ | 21⅓ | 24 | 26⅔ | 29⅓ | 32 | 34⅔ | 37⅓ | 40 | 42⅔ |
| 4 x 6 | 20 | 24 | 28 | 32 | 36 | 40 | 44 | 48 | 52 | 56 | 60 | 64 |
| 4 x 8 | 26⅔ | 32 | 37⅓ | 42⅔ | 48 | 53⅓ | 58⅔ | 64 | 69⅓ | 74⅔ | 80 | 85⅓ |
| 4 x 10 | 33⅓ | 40 | 46⅔ | 53⅓ | 60 | 66⅔ | 73⅓ | 80 | 86⅔ | 93⅓ | 100 | 106⅔ |
| 4 x 12 | 40 | 48 | 56 | 64 | 72 | 80 | 88 | 96 | 104 | 112 | 120 | 128 |
| 4 x 14 | 46⅔ | 56 | 65⅓ | 74⅔ | 84 | 93⅓ | 102⅔ | 112 | 121⅓ | 130⅔ | 140 | 149⅓ |
| 6 x 6 | 30 | 36 | 42 | 48 | 54 | 60 | 66 | 72 | 78 | 84 | 90 | 96 |
| 6 x 8 | 40 | 48 | 56 | 64 | 72 | 80 | 88 | 96 | 104 | 112 | 120 | 128 |
| 6 x 10 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | 130 | 140 | 150 | 160 |
| 6 x 12 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 |
| 6 x 14 | 70 | 84 | 98 | 112 | 126 | 140 | 154 | 168 | 182 | 196 | 210 | 224 |
| 6 x 16 | 80 | 96 | 112 | 128 | 144 | 160 | 176 | 192 | 208 | 224 | 240 | 256 |
| 8 x 8 | 53⅓ | 64 | 74⅔ | 85⅓ | 96 | 106⅔ | 117⅓ | 128 | 138⅔ | 149⅓ | 160 | 170⅔ |
| 8 x 10 | 66⅔ | 80 | 93⅓ | 106⅔ | 120 | 133⅓ | 146⅔ | 160 | 173⅓ | 186⅔ | 200 | 213⅓ |
| 8 x 12 | 80 | 96 | 112 | 128 | 144 | 160 | 176 | 192 | 208 | 224 | 240 | 256 |
| 8 x 14 | 93⅓ | 112 | 130⅔ | 149⅓ | 168 | 186⅔ | 205⅓ | 224 | 242⅔ | 261⅓ | 280 | 298⅔ |
| 10 x 10 | 83⅓ | 100 | 116⅔ | 133⅓ | 150 | 166⅔ | 183⅓ | 200 | 216⅔ | 233⅓ | 250 | 266⅔ |
| 10 x 12 | 100 | 120 | 140 | 160 | 180 | 200 | 220 | 240 | 260 | 280 | 300 | 320 |
| 10 x 14 | 116⅔ | 140 | 163⅓ | 186⅔ | 210 | 233⅓ | 256⅔ | 280 | 303⅓ | 326⅔ | 350 | 373⅓ |
| 10 x 16 | 133⅓ | 160 | 186⅔ | 213⅓ | 240 | 266⅔ | 293⅓ | 320 | 346⅔ | 373⅓ | 400 | 426⅔ |
| 12 x 12 | 120 | 144 | 168 | 192 | 216 | 240 | 264 | 288 | 312 | 336 | 360 | 384 |
| 12 x 14 | 140 | 168 | 196 | 224 | 252 | 280 | 308 | 336 | 364 | 392 | 420 | 448 |
| 12 x 16 | 160 | 192 | 224 | 256 | 288 | 320 | 352 | 384 | 416 | 448 | 480 | 512 |
| 14 x 14 | 163⅓ | 196 | 228⅔ | 261⅓ | 294 | 326⅔ | 359⅓ | 392 | 424⅔ | 457⅓ | 490 | 522⅔ |
| 14 x 16 | 186⅔ | 224 | 261⅓ | 298⅔ | 336 | 373⅓ | 410⅔ | 448 | 485⅓ | 522⅔ | 560 | 597⅓ |

## GENERAL INFORMATION ABOUT FIRE BRICK.

All fire brick should be kept in a dry place.

Moisture, especially in cold weather, will greatly injure any brick.

To obtain the best results from brickwork, observe the following precautions:

Use good fire clay equal in refractoriness to the brick itself, mixing with water to thin soup. Dip brick and rub to make a brick to brick joint.

Warm slowly to expel moisture.

Bear in mind that fire clay brick contract, and silica, chrome and magnesia brick expand under high temperatures.

Sudden variations of temperature cause silica brick to spall, and also reduce their refractoriness. All furnaces in which silica brick are used should therefore be heated up and cooled down slowly and uniformly.

From 250 to 350 pounds of fire clay or silica cement are enough to lay one thousand brick. Fine ground fire clay should be used for laying fire clay brick, silica cement for silica brick, magnesia cement for magnesia brick, and chrome cement for chrome brick.

For estimating on fire brick work, use the following figures:

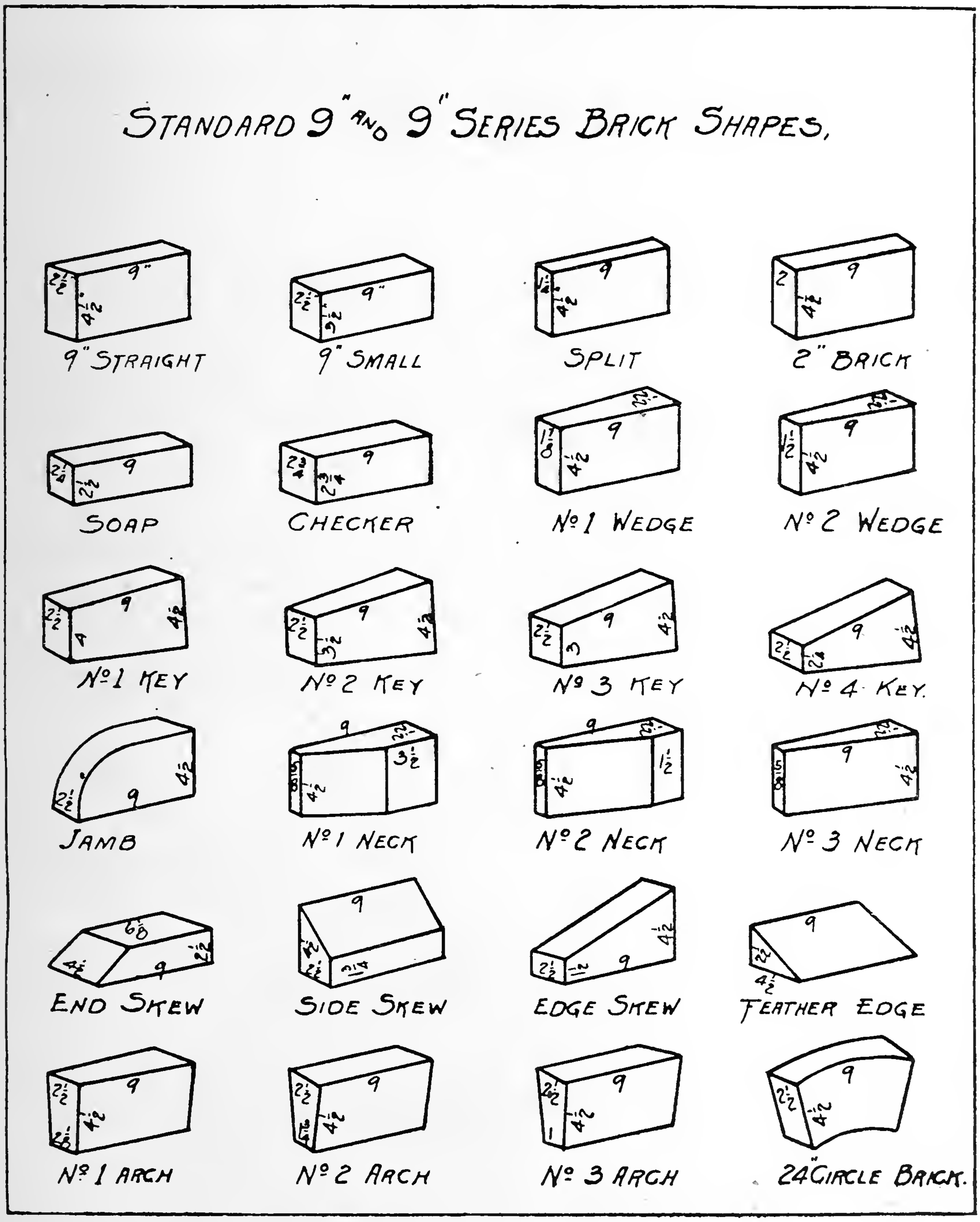
1 square foot 4½-inch wall requires 7 brick,
1 square foot 9-inch wall requires 14 brick,
1 square foot 13½-inch wall requires 21 brick,
1 cubic foot brickwork requires 17 nine-inch straight brick,
1 cubic foot fire clay brickwork weighs 150 pounds,
1 cubic foot silica brickwork weighs 130 pounds,
1,000 brick (closely stacked) occupy 56 cubic feet,
1,000 brick (loosely stacked) occupy 72 cubic feet.

For estimating on red brickwork, figure on nine cubic feet of sand and three bushels of lime for laying 1,000 brick.

## Sizes and Shapes

In order to eliminate as much labor as possible in the laying of refractory bricks for ovens, furnaces, kilns, etc., the manufacturers have made special shapes. These have been standardized and the names, sizes and shapes of the most common are here shown.

Some manufacturers make special shapes in addition to those illustrated and are also in a position to make any shape required from drawings submitted by customers.



## EXAMINATION

## LESSON 22

1. The specific gravity of ice is .9, how would you find its weight per cubic foot?

2. Fig. 182. If the distance between the high and low level is $10\frac{1}{2}$ inches, what would the pressure be if water were used in the tube?

3. How many gallons are there in a tank 5 feet in diameter x 20 feet long?

4. How many board feet in a 6 x 8 inch timber 20 feet long?

# LESSON TWENTY-THREE

## SAFE LOADS FOR ROPES AND CHAINS.

The following table was prepared by the National Founder's Association and published in **Industrial Engineering** September 1914. It shows the safe loads that can be carried by wire rope, crane chain and Manila rope of the sizes given when used in the positions and combinations shown. The loads in the table are lower than those usually specified, in order to insure absolute safety. When handling molten metal, the ropes and chains should be 25 per cent stronger than the figures in the table.

**Safe Loads for Ropes and Chains.**

| NOTE. The safe loads in table are for each SINGLE rope or chain. When used double or in other multiples the loads may be increased proportionately. | | | When Used Straight. | When Used at 60° Angle. | When Used at 45° Angle. | When Used at 30° Angle. |
|---|---|---|---|---|---|---|
| | | Dia. In. | Lb. | Lb. | Lb. | Lb. |
| PLOW STEEL WIRE ROPE. | | 3/8 | 1,500 | 1,275 | 1,050 | 750 |
| | | 1/2 | 2,400 | 2,050 | 1,700 | 1,200 |
| | | 5/8 | 4,000 | 3,400 | 2,800 | 2,000 |
| [6 strands of 19 or 37 wires.] | | 3/4 | 6,000 | 5,100 | 4,200 | 3,000 |
| | | 7/8 | 8,000 | 6,800 | 5,600 | 4,000 |
| | | 1 | 10,000 | 8,500 | 7,000 | 5,000 |
| If crucible steel rope is used reduce loads one-fifth. | | 1 1/8 | 13,000 | 11,000 | 9,000 | 6,500 |
| | | 1 1/4 | 16,000 | 13,500 | 11,000 | 8,000 |
| | | 1 3/8 | 19,000 | 16,000 | 13,000 | 9,500 |
| | | 1 1/2 | 22,000 | 19,000 | 16,000 | 11,000 |
| CRANE CHAIN. | | Diam. of Iron, In. 1/4 | 600 | 500 | 425 | 300 |
| | | 3/8 | 1,200 | 1,025 | 850 | 600 |
| | | 1/2 | 2,400 | 2,050 | 1,700 | 1,200 |
| [Best grade of wrought iron, hand-made, tested, short-link chain.] | | 5/8 | 4,000 | 3,400 | 2,800 | 2,000 |
| | | 3/4 | 5,500 | 4,700 | 3,900 | 2,750 |
| | | 7/8 | 7,500 | 6,400 | 5,200 | 3,700 |
| | | 1 | 9,500 | 8,000 | 6,600 | 4,700 |
| | | 1 1/8 | 12,000 | 10,200 | 8,400 | 6,000 |
| | | 1 1/4 | 15,000 | 12,750 | 10,500 | 7,500 |
| | | 1 3/8 | 22,000 | 19,000 | 16,000 | 11,000 |
| | Dia. In. | Cir. In. | | | | |
| | 3/8 | 1 | 120 | 100 | 85 | 60 |
| MANILA ROPE. | 1/2 | 1 1/2 | 250 | 210 | 175 | 125 |
| | 5/8 | 2 | 360 | 300 | 250 | 180 |
| | 3/4 | 2 1/4 | 520 | 440 | 360 | 260 |
| [Best long fibre grade.] | 7/8 | 2 3/4 | 620 | 520 | 420 | 300 |
| | 1 | 3 | 750 | 625 | 525 | 375 |
| | 1 1/8 | 3 1/2 | 1,000 | 850 | 700 | 500 |
| | 1 1/4 | 3 3/4 | 1,200 | 1,025 | 850 | 600 |
| | 1 1/2 | 4 1/2 | 1,600 | 1,350 | 1,100 | 800 |
| | 1 3/4 | 5 1/2 | 2,100 | 1,800 | 1,500 | 1,050 |
| | 2 | 6 | 2,800 | 2,400 | 2,000 | 1,400 |
| | 2 1/2 | 7 1/2 | 4,000 | 3,400 | 2,800 | 2,000 |
| | 3 | 9 | 6,000 | 5,100 | 4,200 | 3,000 |

USEFUL INFORMATION GIVING THE HEAT UNITS, WEIGHT PER CUBIC FOOT AND SPACE OCCUPIED BY VARIOUS FUELS.

The unit of heat generally used for practical purposes is known as the British Thermal Unit (B.T.U.) and represents the amount of heat required to raise 1 lb. of water 1° F., when at a temperature of 60° F. Its mechanical equivalent is 772 foot-pounds. A comparison of the heat values of various fuels is made in the following table:

| Fuels | Heat Value in B.T.U's per lb. |
|---|---|
| Anthracite coal | 12,900 to 14,800 |
| Acetylene gas | 20,700 |
| Bituminous coal | 12,500 to 16,200 |
| Charcoal | 13,700 |
| Coke | 12,000 to 14,500 |
| Carbon, complete combustion | 14,500 |
| Coal gas | 19,850 |
| Peat | 7,400 to 10,200 |
| Wood | 4,800 to 7,800 |
| Natural gas | 22,000 |

The thermal value of any fuel will vary according to the amount of moisture contained therein.

| Fuel | Weight lbs. per cu.ft. | Cu.Ft.Storage Space per ton of 2240 lbs. |
|---|---|---|
| Anthracite coal, market size, piled loosely | 52 to 56 | 40 to 43 |
| Bituminous coal, broken, piled loosely | 47 to 52 | 43 to 48 |
| Dry coke | 23 to 32 | 80 to 97 |
| Powdered coal | 38 to 45 | |

| Kind | B.T.U. per lb. | Pounds per gal. | B.T.U. per gal. |
|---|---|---|---|
| Fuel oil (residium of petroleum) | 19,000 | 7.3 | 138,700 |
| Beaumont crude petroleum | 19,060 | 7.5 | 142,950 |
| California crude petroleum | 19,500 | 7.6 | 147,200 |
| Lima crude petroleum | 18,820 | 7.5 | 141,150 |
| Pennsylvania crude petroleum | 18,940 | 7.5 | 142,050 |
| Kerosene | 16,120 | 7.2 | 116,000 |
| Gasoline | 14,200 | 5.9 | 83,780 |
| Denaturized alcohol | 13,140 | 5.7 | 74,900 |
| Alcohol (90 per cent) | 10,080 | 5.6 | 56,500 |
| Coal tar | 16,260 | 10.0 | 162,600 |
| Oil tar | 16,970 | 9.5 | 161,200 |

One barrel of oil contains 42 gallons.

APPROXIMATE WEIGHT IN POUNDS OF SQUARE AND ROUND
CAST IRON PLATES 1 INCH THICK.

| SIZE | □ | ○ | SIZE | □ | ○ | SIZE | □ | ○ |
|---|---|---|---|---|---|---|---|---|
| 12" | 37½ | 29½ | 61" | .970 | 762 | 110" | 3154 | 2477 |
| 13 | 44 | 35 | 62 | 1002 | 787 | 111 | 3212 | 2523 |
| 14 | 51 | 40 | 63 | 1035 | 813 | 112 | 3270 | 2568 |
| 15 | 58½ | 46 | 64 | 1068 | 838 | 113 | 3329 | 2614 |
| 16 | 66½ | 52 | 65 | 1101 | 865 | 114 | 3388 | 2661 |
| 17 | 75 | 59 | 66 | 1136 | 892 | 115 | 3448 | 2708 |
| 18 | 84 | 66 | 67 | 1170 | 919 | 116 | 3508 | 2755 |
| 19 | 95 | 74 | 68 | 1205 | 945 | 117 | 3569 | 2803 |
| 20 | 104 | 82 | 69 | 1241 | 997 | 118 | 3630 | 2851 |
| 21 | 115 | 90 | 70 | 1277 | 1003 | 119 | 3692 | 2900 |
| 22 | 126 | 99 | 71 | 1314 | 1032 | 120 | 3754 | 2948 |
| 23 | 138 | 108 | 72 | 1352 | 1061 | 121 | 3817 | 2998 |
| 24 | 150 | 118 | 73 | 1389 | 1091 | 122 | 3880 | 3047 |
| 25 | 163 | 129 | 74 | 1428 | 1122 | 123 | 3944 | 3098 |
| 26 | 176 | 139 | 75 | 1467 | 1153 | 124 | 4009 | 3148 |
| 27 | 190 | 149 | 76 | 1506 | 1183 | 125 | 4073 | 3199 |
| 28 | 204 | 160 | 77 | 1546 | 1214 | 126 | 4139 | 3251 |
| 29 | 219 | 172 | 78 | 1586 | 1246 | 127 | 4205 | 3302 |
| 30 | 235 | 185 | 79 | 1627 | 1278 | 128 | 4271 | 3355 |
| 31 | 251 | 197 | 80 | 1668 | 1310 | 129 | 4338 | 3407 |
| 32 | 267 | 210 | 81 | 1711 | 1343 | 130 | 4406 | 3460 |
| 33 | 284 | 223 | 82 | 1753 | 1377 | 131 | 4474 | 3514 |
| 34 | 301 | 237 | 83 | 1796 | 1410 | 132 | 4542 | 3567 |
| 35 | 319 | 251 | 84 | 1839 | 1445 | 133 | 4612 | 3623 |
| 36 | 338 | 266 | 85 | 1884 | 1479 | 134 | 4681 | 3676 |
| 37 | 357 | 280 | 86 | 1928 | 1515 | 135 | 4751 | 3731 |
| 38 | 376 | 296 | 87 | 1973 | 1550 | 136 | 4822 | 3787 |
| 39 | 397 | 311 | 88 | 2019 | 1586 | 137 | 4893 | 3843 |
| 40 | 417 | 327 | 89 | 2065 | 1622 | 138 | 4965 | 3899 |
| 41 | 438 | 344 | 90 | 2112 | 1658 | 139 | 5037 | 3956 |
| 42 | 459 | 361 | 91 | 2159 | 1696 | 140 | 5110 | 4014 |
| 43 | 482 | 379 | 92 | 2207 | 1733 | 141 | 5183 | 4071 |
| 44 | 505 | 396 | 93 | 2255 | 1772 | 142 | 5257 | 4128 |
| 45 | 528 | 415 | 94 | 2304 | 1809 | 143 | 5331 | 4187 |
| 46 | 552 | 434 | 95 | 2353 | 1848 | 144 | 5406 | 4246 |
| 47 | 576 | 453 | 96 | 2403 | 1887 | | | |
| 48 | 601 | 472 | 97 | 2453 | 1927 | | | |
| 49 | 626 | 491 | 98 | 2504 | 1967 | | | |
| 50 | 652 | 512 | 99 | 2555 | 2007 | | | |
| 51 | 678 | 533 | 100 | 2607 | 2048 | | | |
| 52 | 705 | 553 | 101 | 2659 | 2088 | | | |
| 53 | 732 | 575 | 102 | 2712 | 2130 | | | |
| 54 | 760 | 597 | 103 | 2766 | 2172 | | | |
| 55 | 789 | 620 | 104 | 2820 | 2215 | | | |
| 56 | 818 | 642 | 105 | 2874 | 2257 | | | |
| 57 | 847 | 665 | 106 | 2929 | 2300 | | | |
| 58 | 876 | 689 | 107 | 2985 | 2344 | | | |
| 59 | 907 | 713 | 108 | 3041 | 2388 | | | |
| 60 | 939 | 737 | 109 | 3097 | 2433 | | | |

## WEIGHTS OF ROUND AND SQUARE STEEL.

Estimated weight per lineal foot. One cubic foot of steel weighs 490 lbs.

| Sizes in Inches. | ● Weight in Lbs. | ■ Weight in Lbs. | Sizes in Inches | ● Weight in Lbs. | ■ Weight in Lbs. | Sizes in Inches | ● Weight in Lbs. | ■ Weight in Lbs. |
|---|---|---|---|---|---|---|---|---|
| 1/16 | .010 | .013 | 4 1/16 | 44.07 | 56.11 | 8 1/16 | 173.6 | 221.0 |
| 1/8 | .042 | .053 | 4 1/8 | 45.44 | 57.85 | 8 1/8 | 176.3 | 224.5 |
| 3/16 | .094 | .119 | 4 3/16 | 46.83 | 59.62 | 8 3/16 | 179.0 | 228.0 |
| 1/4 | .167 | .212 | 4 1/4 | 48.24 | 61.41 | 8 1/4 | 181.8 | 231.4 |
| 5/16 | .261 | .333 | 4 5/16 | 49.66 | 63.23 | 8 5/16 | 184.5 | 234.9 |
| 3/8 | .375 | .478 | 4 3/8 | 51.11 | 65.08 | 8 3/8 | 187.3 | 238.5 |
| 7/16 | .511 | .651 | 4 7/16 | 52.58 | 66.95 | 8 7/16 | 190.1 | 242.0 |
| 1/2 | .667 | .850 | 4 1/2 | 54.07 | 68.85 | 8 1/2 | 193.0 | 245.6 |
| 9/16 | .845 | 1.076 | 4 9/16 | 55.59 | 70.78 | 8 9/16 | 195.7 | 249.3 |
| 5/8 | 1.043 | 1.328 | 4 5/8 | 57.12 | 72.73 | 8 5/8 | 198.7 | 252.9 |
| 11/16 | 1.262 | 1.608 | 4 11/16 | 58.67 | 74.70 | 8 11/16 | 201.6 | 256.6 |
| 3/4 | 1.502 | 1.913 | 4 3/4 | 60.25 | 76.71 | 8 3/4 | 204.4 | 260.3 |
| 13/16 | 1.773 | 2.245 | 4 13/16 | 61.84 | 78.74 | 8 13/16 | 207.4 | 264.1 |
| 7/8 | 2.044 | 2.603 | 4 7/8 | 63.46 | 80.81 | 8 7/8 | 210.3 | 267.9 |
| 15/16 | 2.347 | 2.989 | 4 15/16 | 65.10 | 82.89 | 8 15/16 | 213.3 | 271.6 |
| 1 | 2.670 | 3.400 | 5 | 66.76 | 85.00 | 9 | 216.3 | 275.4 |
| 1 1/16 | 3.014 | 3.838 | 5 1/16 | 68.44 | 87.14 | 9 1/16 | 219.3 | 279.3 |
| 1 1/8 | 3.379 | 4.303 | 5 1/8 | 70.14 | 89.30 | 9 1/8 | 222.4 | 283.2 |
| 1 3/16 | 3.766 | 4.795 | 5 3/16 | 71.86 | 91.49 | 9 3/16 | 225.4 | 287.0 |
| 1 1/4 | 4.173 | 5.312 | 5 1/4 | 73.60 | 93.72 | 9 1/4 | 228.5 | 290.9 |
| 1 5/16 | 4.600 | 5.857 | 5 5/16 | 75.37 | 95.96 | 9 5/16 | 231.5 | 294.9 |
| 1 3/8 | 5.049 | 6.428 | 5 3/8 | 77.15 | 98.23 | 9 3/8 | 234.7 | 298.9 |
| 1 7/16 | 5.518 | 7.026 | 5 7/16 | 78.95 | 100.5 | 9 7/16 | 237.9 | 302.8 |
| 1 1/2 | 6.008 | 7.650 | 5 1/2 | 80.77 | 102.8 | 9 1/2 | 241.0 | 306.8 |
| 1 9/16 | 6.520 | 8.301 | 5 9/16 | 82.62 | 105.2 | 9 9/16 | 244.2 | 310.9 |
| 1 5/8 | 7.051 | 8.978 | 5 5/8 | 84.49 | 107.6 | 9 5/8 | 247.4 | 315.0 |
| 1 11/16 | 7.604 | 9.682 | 5 11/16 | 86.38 | 110.0 | 9 11/16 | 250.6 | 319.1 |
| 1 3/4 | 8.178 | 10.41 | 5 3/4 | 88.29 | 112.4 | 9 3/4 | 253.9 | 323.2 |
| 1 13/16 | 8.773 | 11.17 | 5 13/16 | 90.22 | 114.9 | 9 13/16 | 257.1 | 327.4 |
| 1 7/8 | 9.388 | 11.95 | 5 7/8 | 92.17 | 117.4 | 9 7/8 | 260.4 | 331.6 |
| 1 15/16 | 10.02 | 12.76 | 5 15/16 | 94.14 | 119.9 | 9 15/16 | 263.7 | 335.8 |
| 2 | 10.68 | 13.60 | 6 | 96.14 | 122.4 | 10 | 267.0 | 340.0 |
| 2 1/16 | 11.36 | 14.46 | 6 1/16 | 98.14 | 125.0 | 10 1/16 | 270.4 | 344.3 |
| 2 1/8 | 12.06 | 15.35 | 6 1/8 | 100.2 | 127.6 | 10 1/8 | 273.8 | 348.5 |
| 2 3/16 | 12.78 | 16.27 | 6 3/16 | 102.2 | 130.2 | 10 3/16 | 277.1 | 352.9 |
| 2 1/4 | 13.52 | 17.22 | 6 1/4 | 104.3 | 132.8 | 10 1/4 | 280.6 | 357.2 |
| 2 5/16 | 14.28 | 18.19 | 6 5/16 | 106.4 | 135.5 | 10 5/16 | 284.0 | 361.6 |
| 2 3/8 | 15.07 | 19.18 | 6 3/8 | 108.5 | 138.2 | 10 3/8 | 287.4 | 366.0 |
| 2 7/16 | 15.86 | 20.20 | 6 7/16 | 110.7 | 140.9 | 10 7/16 | 290.9 | 370.4 |
| 2 1/2 | 16.69 | 21.25 | 6 1/2 | 112.8 | 143.6 | 10 1/2 | 294.4 | 374.9 |
| 2 9/16 | 17.53 | 22.33 | 6 9/16 | 114.9 | 146.5 | 10 9/16 | 297.9 | 379.4 |
| 2 5/8 | 18.40 | 23.43 | 6 5/8 | 117.2 | 149.2 | 10 5/8 | 301.4 | 383.8 |
| 2 11/16 | 19.29 | 24.56 | 6 11/16 | 119.4 | 152.1 | 10 11/16 | 305.0 | 388.3 |
| 2 3/4 | 20.20 | 25.00 | 6 3/4 | 121.7 | 154.9 | 10 3/4 | 308.6 | 392.9 |
| 2 13/16 | 21.12 | 26.90 | 6 13/16 | 123.9 | 157.8 | 10 13/16 | 312.2 | 397.5 |
| 2 7/8 | 22.07 | 28.10 | 6 7/8 | 126.2 | 160.8 | 10 7/8 | 315.8 | 402.1 |
| 2 15/16 | 23.04 | 29.34 | 6 15/16 | 128.5 | 163.6 | 10 15/16 | 319.5 | 406.8 |
| 3 | 24.03 | 30.60 | 7 | 130.9 | 166.6 | 11 | 323.1 | 411.4 |
| 3 1/16 | 25.04 | 31.89 | 7 1/16 | 133.2 | 169.6 | 11 1/16 | 326.8 | 416.1 |
| 3 1/8 | 26.08 | 33.20 | 7 1/8 | 135.6 | 172.6 | 11 1/8 | 330.5 | 420.9 |
| 3 3/16 | 27.13 | 34.55 | 7 3/16 | 137.9 | 175.6 | 11 3/16 | 334.3 | 425.5 |
| 3 1/4 | 28.20 | 35.92 | 7 1/4 | 140.4 | 178.7 | 11 1/4 | 337.9 | 430.3 |
| 3 5/16 | 29.30 | 37.31 | 7 5/16 | 142.8 | 181.8 | 11 5/16 | 341.7 | 435.1 |
| 3 3/8 | 30.42 | 38.73 | 7 3/8 | 145.3 | 184.9 | 11 3/8 | 345.5 | 439.9 |
| 3 7/16 | 31.56 | 40.18 | 7 7/16 | 147.7 | 188.1 | 11 7/16 | 349.4 | 444.8 |
| 3 1/2 | 32.71 | 41.65 | 7 1/2 | 150.2 | 191.3 | 11 1/2 | 353.1 | 449.6 |
| 3 9/16 | 33.90 | 43.14 | 7 9/16 | 152.7 | 194.4 | 11 9/16 | 357.0 | 454.5 |
| 3 5/8 | 35.09 | 44.68 | 7 5/8 | 155.2 | 197.7 | 11 5/8 | 360.9 | 459.5 |
| 3 11/16 | 36.31 | 46.24 | 7 11/16 | 157.8 | 200.9 | 11 11/16 | 364.8 | 464.4 |
| 3 3/4 | 37.56 | 47.82 | 7 3/4 | 160.3 | 204.2 | 11 3/4 | 368.6 | 469.4 |
| 3 13/16 | 38.81 | 49.42 | 7 13/16 | 163.0 | 207.6 | 11 13/16 | 372.6 | 474.4 |
| 3 7/8 | 40.10 | 51.05 | 7 7/8 | 165.6 | 210.8 | 11 7/8 | 376.6 | 479.5 |
| 3 15/16 | 41.40 | 52.71 | 7 15/16 | 168.2 | 214.2 | 11 15/16 | 380.6 | 484.5 |
| 4 | 42.73 | 54.40 | 8 | 171.0 | 217.6 | | | |

## HOW TO USE THE FOREGOING TABLE FOR CAST IRON.

When this table is used for estimating cast iron, multiply the weight given for the size required by .92, which will equal the approximate weight when made of cast iron.

**Example**: A 4″ square bar 12″ long weighs 54.40 lbs., when made of steel (see table), multiply this weight by .92 and the weight of a cast iron bar this size will be 50 lbs.

$$
\begin{array}{r}
54.40 \\
\text{x}.92 \\
\hline
10880 \\
48960\phantom{0} \\
\hline
50.0480 \text{ lbs.}
\end{array}
$$

Assume cast iron to weigh 450 lbs. per cu. ft.

## EXAMINATION

## LESSON 23

1. What is the weight of a piece of cast iron 30 x 30 x 18 inches?

2. What is the weight of a round steel bar 7½ inches in diameter and 18 inches long? See table.

3. What is the approximate weight of the above bar if made of cast iron?

## LESSON TWENTY-FOUR

### THERMOMETER SCALES.

There are three thermometer scales in general use.

The Fahrenheit (F.), which is generally used in English speaking countries;

The Centigrade (C.) or Celsius, which is used in several continental countries and in scientific work;

The Reaumur (R.), which is used to some extent on the European continent, notably in Germany.

In the Fahrenheit thermometer, the freezing point of water is marked at 32° on the scale and the boiling point, at atmospheric pressure, at 212°. The distance between these two points is divided into 180°. On the Centigrade scale, the freezing point of water is at 0° and the boiling point at 100°. On the Reaumur scale, the freezing point is at 0° and the boiling point at 80°. The following formulas may be used for converting temperatures given on any one of the scales to the other scales:

$$\text{Degrees Fahrenheit} = \frac{9 \text{ x degrees C}}{5} + 32 = \frac{9 \text{ x degrees R}}{4} + 32$$

$$\text{Degrees Centigrade} = \frac{5 \text{ x (degrees F} - 32)}{9} = \frac{5 \text{ x degrees R}}{4}$$

$$\text{Degrees Reaumur} = \frac{4 \text{ x degrees C}}{5} = \frac{4 \text{ x (degrees F} - 32)}{9}$$

# TEMPERATURES

| Degrees Fahrenheit and Corresponding Centigrade | | | | | | Degrees Centigrade and Corresponding Fahrenheit | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| F. | C. | F. | C. | F. | C. | C. | F. | C. | F. | C. | F. |
| 32 | 0 | 1040 | 560 | 1740 | 949 | 0 | 32 | 520 | 968 | 860 | 1580 |
| 212 | 100 | 1060 | 571 | 1760 | 960 | 100 | 212 | 530 | 986 | 870 | 1598 |
| 400 | 204 | 1080 | 582 | 1780 | 971 | 200 | 392 | 540 | 1004 | 880 | 1616 |
| 420 | 216 | 1100 | 593 | 1800 | 982 | 210 | 410 | 550 | 1022 | 890 | 1634 |
| 440 | 227 | 1120 | 604 | 1820 | 993 | 220 | 428 | 560 | 1040 | 900 | 1652 |
| 460 | 238 | 1140 | 615 | 1840 | 1004 | 230 | 446 | 570 | 1058 | 910 | 1670 |
| 480 | 249 | 1160 | 626 | 1860 | 1015 | 240 | 464 | 580 | 1076 | 920 | 1688 |
| 500 | 260 | 1180 | 637 | 1880 | 1026 | 250 | 482 | 590 | 1094 | 930 | 1706 |
| 520 | 271 | 1200 | 648 | 1900 | 1038 | 260 | 500 | 600 | 1112 | 940 | 1724 |
| 540 | 282 | 1220 | 659 | 1920 | 1049 | 270 | 518 | 610 | 1130 | 950 | 1742 |
| 560 | 293 | 1240 | 670 | 1940 | 1060 | 280 | 536 | 620 | 1148 | 960 | 1760 |
| 580 | 305 | 1260 | 681 | 1960 | 1071 | 290 | 554 | 630 | 1166 | 970 | 1778 |
| 600 | 316 | 1280 | 693 | 1980 | 1082 | 300 | 572 | 640 | 1184 | 980 | 1796 |
| 620 | 327 | 1300 | 705 | 2000 | 1093 | 310 | 590 | 650 | 1202 | 990 | 1814 |
| 640 | 338 | 1320 | 716 | 2020 | 1105 | 320 | 608 | 660 | 1220 | 1000 | 1832 |
| 660 | 349 | 1340 | 727 | 2040 | 1116 | 330 | 626 | 670 | 1238 | 1010 | 1850 |
| 680 | 360 | 1360 | 738 | 2060 | 1127 | 340 | 644 | 680 | 1256 | 1020 | 1868 |
| 700 | 371 | 1380 | 749 | 2080 | 1138 | 350 | 662 | 690 | 1274 | 1030 | 1886 |
| 720 | 382 | 1400 | 760 | 2100 | 1149 | 360 | 680 | 700 | 1292 | 1040 | 1904 |
| 740 | 393 | 1420 | 771 | 2120 | 1160 | 370 | 698 | 710 | 1310 | 1050 | 1922 |
| 760 | 405 | 1440 | 782 | 2140 | 1171 | 380 | 716 | 720 | 1328 | 1060 | 1940 |
| 780 | 416 | 1460 | 793 | 2160 | 1182 | 390 | 734 | 730 | 1346 | 1070 | 1958 |
| 800 | 427 | 1480 | 804 | 2180 | 1193 | 400 | 752 | 740 | 1364 | 1080 | 1976 |
| 820 | 438 | 1500 | 816 | 2200 | 1204 | 410 | 770 | 750 | 1382 | 1090 | 1994 |
| 840 | 449 | 1520 | 827 | 2220 | 1216 | 420 | 788 | 760 | 1400 | 1100 | 2012 |
| 860 | 460 | 1540 | 838 | 2240 | 1227 | 430 | 806 | 770 | 1418 | 1110 | 2030 |
| 880 | 471 | 1560 | 849 | 2260 | 1238 | 440 | 824 | 780 | 1436 | 1120 | 2048 |
| 900 | 482 | 1580 | 860 | 2280 | 1249 | 450 | 842 | 790 | 1454 | 1130 | 2066 |
| 920 | 493 | 1600 | 871 | 2300 | 1260 | 460 | 860 | 800 | 1472 | 1140 | 2084 |
| 940 | 504 | 1620 | 882 | 2320 | 1271 | 470 | 878 | 810 | 1490 | 1150 | 2102 |
| 960 | 516 | 1640 | 893 | 2340 | 1283 | 480 | 896 | 820 | 1508 | 1160 | 2120 |
| 980 | 527 | 1660 | 904 | 2360 | 1294 | 490 | 914 | 830 | 1526 | 1170 | 2138 |
| 1000 | 538 | 1680 | 915 | 2380 | 1305 | 500 | 932 | 840 | 1544 | 1180 | 2156 |
| 1020 | 549 | 1700 | 927 | 2400 | 1316 | 510 | 950 | 850 | 1562 | 1190 | 2174 |

| Cent. | Fahr. | Cent. | Fahr. |
|---|---|---|---|
| 1200 | 2192 | 1400 | 2552 |
| 1225 | 2237 | 1425 | 2597 |
| 1250 | 2282 | 1450 | 2642 |
| 1275 | 2327 | 1475 | 2687 |
| 1300 | 2372 | 1500 | 2732 |
| 1325 | 2417 | 1525 | 2777 |
| 1350 | 2462 | 1550 | 2822 |
| 1375 | 2507 | 1575 | 2867 |
| | | 1600 | 2912 |

## TEMPERATURES

May be determined approximately by reference to the following table

| | Degrees Centigrade | Degrees Fahrenheit |
|---|---|---|
| Just glowing in the dark | 525 | 977 |
| Dark red | 700 | 1252 |
| Cherry red | 908 | 1666 |
| Bright cherry red | 1000 | 1832 |
| Orange | 1150 | 2102 |
| White | 1300 | 2372 |
| Dazzling white | 1500 | 2732 |

| | Degrees Centigrade | Degrees Fahrenheit |
|---|---|---|
| Mercury melts | 40 | 104 |
| Mercury boils | 349 | 660 |
| Tin melts | 229 | 445 |
| Lead melts | 322 | 612 |
| Lead boils | 1040 | 1904 |
| Zinc melts | 412 | 775 |
| Zinc boils | 1040 | 1904 |
| Aluminum melts | 700 | 1252 |
| Silver melts | 957 | 1775 |
| Brass melts | 1021 | 1870 |
| Copper melts | 1029 | 1885 |
| Gold melts | 1038 | 1900 |
| Cobalt melts | 1100 | 2012 |
| Cast Iron, white, melts | 1135 | 2075 |
| Cast Iron, gray, melts | 1222 | 2230 |
| Steel melts | 1300 | 2372 |
| Iron, wrought, melts | 1500 | 2732 |
| Nickel melts | 1500 | 2732 |
| Platinum melts | 2533 | 4593 |
| Siemens Crucible Steel Furnace varies from | 1230 to 1330 | 2246 to 2426 |

## SEGER CONES.

Seger cones were developed in 1886 in Germany, by Dr. Herman A. Seger. They comprise a series of triagular cones, of pyramidical shape, of differing mineral compositions, each of which requires a different amount of heat work to soften and deform it. They are used principally in the clay, pottery and allied industries to determine the proper heat conditions of kilns, furnaces, etc. The difference in softening point between any two adjoining members of the series, is kept as nearly equal as possible, so that the cones form a sort of pyrometric scale. The softening or fusion is not altogether a matter of temperature, the element of time entering in also.

The following table gives the approximate fusion points of the various cones:

| Number of Cone | Fusing Point | | Number of Cone | Fusing Point | |
|---|---|---|---|---|---|
| | Degrees Fahr. | Degrees Centig. | | Degrees Fahr. | Degrees Centig. |
| .022 | 1,094 | 590 | 10 | 2,426 | 1,330 |
| .021 | 1,148 | 620 | 11 | 2,462 | 1,350 |
| .020 | 1,202 | 650 | 12 | 2,498 | 1,370 |
| .019 | 1,256 | 680 | 13 | 2,534 | 1,390 |
| .018 | 1,310 | 710 | 14 | 2,570 | 1,410 |
| .017 | 1,364 | 740 | 15 | 2,606 | 1,430 |
| .016 | 1,418 | 770 | 16 | 2,642 | 1,450 |
| .015 | 1,472 | 800 | 17 | 2,678 | 1,470 |
| .014 | 1,526 | 830 | 18 | 2,714 | 1,490 |
| .013 | 1,580 | 860 | 19 | 2,750 | 1,510 |
| .012 | 1,634 | 890 | 20 | 2,786 | 1,530 |
| .011 | 1,688 | 920 | 21 | 2,822 | 1,550 |
| .010 | 1,742 | 950 | 22 | 2,858 | 1,570 |
| .09 | 1,778 | 970 | 23 | 2,894 | 1,590 |
| .08 | 1,814 | 990 | 24 | 2,930 | 1,610 |
| .07 | 1,850 | 1,010 | 25 | 2,966 | 1,630 |
| .06 | 1,886 | 1,030 | 26 | 3,002 | 1,650 |
| .05 | 1,922 | 1,050 | 27 | 3,038 | 1,670 |
| .04 | 1,958 | 1,070 | 28 | 3,074 | 1,690 |
| .03 | 1,994 | 1,090 | 29 | 3,110 | 1,710 |
| .02 | 2,030 | 1,110 | 30 | 3,146 | 1,730 |
| .01 | 2,066 | 1,130 | 31 | 3,182 | 1,750 |
| 1 | 2,102 | 1,150 | 32 | 3,218 | 1,770 |
| 2 | 2,138 | 1,170 | 33 | 3,254 | 1,790 |
| 3 | 2,174 | 1,190 | 34 | 3,290 | 1,810 |
| 4 | 2,210 | 1,210 | 35 | 3,326 | 1,830 |
| 5 | 2,246 | 1,230 | 36 | 3,362 | 1,850 |
| 6 | 2,282 | 1,250 | 37 | 3,398 | 1,870 |
| 7 | 2,318 | 1,270 | 38 | 3,434 | 1,890 |
| 8 | 2,354 | 1,290 | 39 | 3,470 | 1,910 |
| 9 | 2,390 | 1,310 | | | |

# EQUALIZATION OF PIPES.

It is frequently desired to know what number of pipes of a given size are equal in carrying capacity to one pipe of a larger size. The figures opposite the intersection of any two sizes is the number of the smaller-sized pipes required to equal one of the larger. Thus one 4-inch pipe is equal to 5.7 2-inch pipes.

| Diam. In. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 14 | 16 | 18 | 20 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 5.7 | 1 | | | | | | | | | | | | | | |
| 3 | 15.6 | 2.8 | 1 | | | | | | | | | | | | | |
| 4 | 32.0 | 5.7 | 2.1 | 1 | | | | | | | | | | | | |
| 5 | 55.9 | 9.9 | 3.6 | 1.7 | 1 | | | | | | | | | | | |
| 6 | 88.2 | 15.6 | 5.7 | 2.8 | 1.6 | 1 | | | | | | | | | | |
| 7 | 130 | 22.9 | 8.3 | 4.1 | 2.3 | 1.5 | 1 | | | | | | | | | |
| 8 | 181 | 32.0 | 11.7 | 5.7 | 3.2 | 2.1 | 1.4 | 1 | | | | | | | | |
| 9 | 243 | 43.0 | 15.6 | 7.6 | 4.3 | 2.8 | 1.9 | 1.3 | 1 | | | | | | | |
| 10 | 316 | 55.9 | 20.3 | 9.9 | 5.7 | 3.6 | 2.4 | 1.7 | 1.3 | 1 | | | | | | |
| 11 | 401 | 70.9 | 25.7 | 12.5 | 7.2 | 4.6 | 3.1 | 2.2 | 1 7 | 1.3 | | | | | | |
| 12 | 499 | 88.2 | 32.0 | 15.6 | 8.9 | 5.7 | 3.8 | 2.8 | 2.1 | 1.6 | 1 | | | | | |
| 13 | 609 | 108 | 39.1 | 19.0 | 10.9 | 7.1 | 4.7 | 3.4 | 2.5 | 1.9 | 1.2 | | | | | |
| 14 | 733 | 130 | 47.0 | 22.9 | 13.1 | 8.3 | 5.7 | 4.1 | 3.0 | 2.3 | 1.5 | 1 | | | | |
| 15 | 871 | 154 | 55.9 | 27.2 | 15.6 | 9.9 | 6.7 | 4.8 | 3.6 | 2.8 | 1.7 | 1 2 | | | | |
| 16 | .... | 181 | 65.7 | 32.0 | 18.3 | 11.7 | 7.9 | 5.7 | 4.2 | 3.2 | 2.1 | 1.4 | 1 | | | |
| 17 | .... | 211 | 76.4 | 37.2 | 21.3 | 13.5 | 9.2 | 6.6 | 4.9 | 3.8 | 2 4 | 1.6 | 1.2 | | | |
| 18 | .... | 243 | 88.2 | 43.0 | 24.6 | 15.6 | 10.6 | 7.6 | 5.7 | 4.3 | 2.8 | 1.9 | 1.3 | 1 | | |
| 19 | .... | 278 | 101 | 49.1 | 28.1 | 17.8 | 12.1 | 8.7 | 6.5 | 5.0 | 3.2 | 2.1 | 1.5 | 1.1 | | |
| 20 | .... | 316 | 115 | 55.9 | 32.0 | 20.3 | 13.8 | 9.9 | 7.4 | 5.7 | 3.6 | 2.4 | 1.7 | 1.3 | 1 | |
| 22 | .... | 401 | 146 | 70.9 | 40.6 | 25.7 | 17.5 | 12.5 | 9.3 | 7.2 | 4.6 | 3.1 | 2.2 | 1.7 | 1.3 | |
| 24 | .... | 499 | 181 | 88.2 | 50.5 | 32.0 | 21.8 | 15.6 | 11.6 | 8.9 | 5.7 | 3.8 | 2.8 | 2.1 | 1.6 | 1 |
| 26 | .... | 609 | 221 | 108 | 61.7 | 39.1 | 26.6 | 19.0 | 14.2 | 10.9 | 7.1 | 4.7 | 3.4 | 2.5 | 1.9 | 1.2 |
| 28 | .... | 733 | 266 | 130 | 74.2 | 47.0 | 32.0 | 22.9 | 17.1 | 13.1 | 8.3 | 5.7 | 4.1 | 3.0 | 2.3 | 1.5 |
| 30 | .... | 871 | 316 | 154 | 88.2 | 55.9 | 38.0 | 27.2 | 20.3 | 15.6 | 9.9 | 6.7 | 4.8 | 3.6 | 2.8 | 1.7 |
| 36 | .... | .... | 499 | 243 | 130 | 88.2 | 60.0 | 43.0 | 32.0 | 24.6 | 15.6 | 10.6 | 7.6 | 5.7 | 4.3 | 2.8 |
| 42 | .... | .... | 733 | 357 | 205 | 130 | 88.2 | 63.2 | 47.0 | 36.2 | 19.0 | 15.6 | 11.2 | 8.3 | 6.4 | 4.1 |
| 48 | .... | .... | .... | 499 | 286 | 181 | 123 | 88.2 | 62.7 | 50.5 | 32.0 | 21.8 | 15.6 | 11.6 | 8.9 | 5.7 |
| 54 | .... | .... | .... | 670 | 383 | 243 | 165 | 118 | 88.2 | 67.8 | 43.0 | 29.2 | 20.9 | 15.6 | 12.0 | 7.6 |
| 60 | .... | .... | .... | 871 | 499 | 316 | 215 | 154 | 115 | 88.2 | 55.9 | 38.0 | 27.2 | 20.3 | 15.6 | 9.9 |

**Table of Necessary Increased Pipe Diameters for Different Lengths**

| Length of Pipe | 30 Ft. | 60 Ft. | 90 Ft. | 120 Ft | 150 Ft. | 180 Ft. | 210 Ft. | 240 Ft | 270 Ft. | 500 Ft |
|---|---|---|---|---|---|---|---|---|---|---|
| Diameter of Blower Outlet in inches. | Diameter of Pipe should be | Diameter of Pipe should be | Diameter of Pipe should be | Diameter of Pipe should be | Diameter of Pipe should be | Diameter of Pipe should be | Diameter of Pipe should be | Diameter of Pipe should be | Diameter of Pipe should be | Diameter of Pipe should be |
| 3 | 3¼ | 3⅝ | 4 | 4¼ | 4½ | 4¾ | 5 | 5⅛ | 5⅜ | 5½ |
| 3½ | 3¾ | 4⅛ | 4½ | 4⅞ | 5 | 5¼ | 5½ | 5⅝ | 5⅞ | 6⅛ |
| 4 | 4⅜ | 4¾ | 5⅛ | 5⅜ | 5¾ | 6 | 6¼ | 6½ | 6¾ | 7 |
| 4½ | 5 | 5⅜ | 5¾ | 6 | 6⅜ | 6⅜ | 7 | 7¼ | 7½ | 7⅞ |
| 5 | 5½ | 6 | 6⅜ | 6¾ | 7⅛ | 7½ | 7¾ | 8⅛ | 8⅜ | 8¾ |
| 6 | 6½ | 7 | 7⅝ | 8 | 8½ | 9 | 9⅜ | 9¾ | 10⅛ | 10½ |
| 7 | 7⅝ | 8¼ | 8⅞ | 9⅜ | 10 | 10⅜ | 10⅞ | 11⅞ | 11¾ | 12⅛ |
| 8 | 8¾ | 9½ | 10⅛ | 10¾ | 11⅜ | 11⅞ | 12⅜ | 12⅜ | 13⅜ | 13⅞ |
| 9 | 10 | 10¾ | 11½ | 12⅛ | 12¾ | 13⅜ | 14 | 14½ | 15⅛ | 15⅝ |
| 10 | 11 | 11⅞ | 12¾ | 13½ | 14¼ | 14⅞ | 15½ | 16⅛ | 16¾ | 17⅜ |
| 11 | 12 | 13 | 13⅞ | 14¾ | 15⅝ | 16⅜ | 17⅛ | 17¾ | 18½ | 19⅛ |
| 12 | 13⅛ | 14¼ | 15¼ | 16⅛ | 17 | 17⅞ | 18⅝ | 19⅜ | 20⅛ | 20⅞ |
| 13 | 14¼ | 15⅜ | 16½ | 17½ | 18⅜ | 19¼ | 20⅛ | 21 | 21¾ | 22⅝ |
| 14 | 15⅜ | 16⅝ | 17¾ | 18⅞ | 19¾ | 20¾ | 21¾ | 22⅝ | 23½ | 24¼ |
| 15 | 16½ | 17¾ | 19 | 20⅛ | 21¼ | 22¼ | 23¼ | 24¼ | 25⅛ | 26 |
| 16 | 17½ | 19 | 20⅜ | 21½ | 22⅝ | 23¾ | 24¾ | 25⅞ | 26⅞ | 27¾ |
| 17 | 17⅝ | 20⅛ | 21½ | 22¾ | 24 | 25¼ | 26⅜ | 27½ | 28½ | 29½ |
| 18 | 19¾ | 21⅜ | 22¾ | 24¼ | 25½ | 26¾ | 27⅞ | 29⅛ | 30⅛ | 31¼ |
| 19 | 20⅞ | 22½ | 24 | 25½ | 27 | 28¼ | 29½ | 30¾ | 31⅞ | 33 |
| 20 | 22 | 23⅝ | 25⅜ | 27⅞ | 28⅜ | 29¾ | 31 | 32¼ | 33½ | 34¼ |
| 21 | 23 | 24⅞ | 26⅝ | 28¼ | 29¾ | 31⅛ | 32½ | 33⅞ | 35¼ | 36⅜ |
| 22 | 24⅛ | 26⅛ | 27⅞ | 29½ | 31⅛ | 32⅝ | 34⅛ | 35½ | 36⅞ | 38⅛ |
| 23 | 25¼ | 27¼ | 29⅛ | 30⅞ | 32½ | 34⅛ | 35⅝ | 37⅛ | 38½ | 39⅞ |
| 24 | 26½ | 28½ | 30⅜ | 32¼ | 34 | 35⅝ | 37¼ | 38¾ | 40¼ | 41⅞ |
| Length of Pipe.......... | 30 ft. | 60 ft. | 90 ft. | 120 ft. | 150 ft. | 180 ft. | 210 ft. | 240 ft | 270 ft. | 300 ft. |
| Length of Mouth-piece | 9 in | 15 in | 21 in | 27 in | 33 in | 39 in | 42 in | 48 in | 54 in | 60 in |

VOLUME OF AIR DISCHARGED THRU A ROUND ORIFICE IN RECEIVER INTO ATMOSPHERIC PRESSURE.

Given in cubic feet of free air per minute.

Mott Sand Blast Mfg. Co.

RECEIVER GAUGE PRESSURE.

| Diam. Orifice | 2 lbs. | 5 lbs. | 10 lbs. | 15 lbs. | 20 lbs. | 30 lbs. | 40 lbs. | 50 lbs. | 60 lbs. | 70 lbs. | 80 lbs. | 90 lbs. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/64" | .04 | .05 | .08 | .10 | .12 | .15 | .19 | .22 | .26 | .29 | .33 | .36 |
| 1/32" | .15 | .24 | .34 | .41 | .48 | .63 | .77 | .91 | 1.05 | 1.19 | 1.33 | 1.47 |
| 1/16" | .64 | .96 | 1.36 | 1.67 | 1.93 | 2.52 | 3.07 | 3.64 | 4.20 | 4.76 | 5.32 | 5.87 |
| 1/8" | 2.43 | 3.86 | 5.45 | 6.65 | 7.70 | 10.00 | 12.27 | 14.50 | 16.80 | 19.00 | 21.20 | 23.50 |
| 1/4" | 9.74 | 15.40 | 21.80 | 26.70 | 30.80 | 40.00 | 49.09 | 58.20 | 67.00 | 76.00 | 85.00 | 94.00 |
| 3/8" | 21.95 | 34.60 | 49.00 | 60.00 | 69.00 | 90.00 | 110.45 | 130.00 | 151.00 | 171.00 | 191.00 | 211.00 |
| 1/2" | 39.00 | 61.60 | 87.00 | 107.00 | 123.00 | 161.00 | 196.35 | 232.00 | 268.00 | 304.00 | 340.00 | 376.00 |
| 5/8" | 61.00 | 96.50 | 136.00 | 167.00 | 193.00 | 252.00 | 306.80 | 364.00 | 420.00 | 476.00 | 532.00 | 587.00 |
| 3/4" | 87.60 | 133.00 | 196.00 | 240.00 | 277.00 | 362.00 | 441.79 | 522.00 | 604.00 | 685.00 | 765.00 | 843.00 |
| 7/8" | 119.50 | 189.00 | 267.00 | 326.00 | 378.00 | 493.00 | 601.32 | 622.00 | 710.00 | 930.00 | 1004.00 | |
| 1" | 156.00 | 247.00 | 350.00 | 427.00 | 494.00 | 645.00 | 785.40 | 930.00 | | | | |
| 1 1/4" | 242.00 | 384.00 | 543.00 | 665.00 | 770.00 | 1000.00 | | | | | | |
| 1 1/2" | 350.00 | 550.00 | 780.00 | 960.00 | | | | | | | | |
| 2" | 625.00 | 985.00 | | | | | | | | | | |

This table may be useful in determining the amount of air consumed by a sand blast nozzle or any other opening when the pressure and size of opening are known.

## VOLUME OF AIR DISCHARGED AT LOW PRESSURES PER MINUTE.

| Diam. of Openings in. | 8oz | 16oz | 24oz | 32oz | 40oz | 48oz | 56oz | 64oz |
|---|---|---|---|---|---|---|---|---|
| ¼ | cu. ft. 3.5 | cu. ft. 4.5 | cu. ft. 5.5 | cu. ft. 6.5 | cu. ft. 7.5 | cu. ft. 8 | cu. ft. 9 | cu. ft. 9.5 |
| ⅜ | 7 | 8 | 12.5 | 14.5 | 16.5 | 18 | 20 | 21.5 |
| ½ | 12.5 | 17.5 | 22 | 25.5 | 29 | 32.5 | 35.5 | 39.5 |
| ⅝ | 19 | 29 | 34 | 40 | 45.5 | 50.5 | 55.5 | 60 |
| ¾ | 27.5 | 39.5 | 49 | 57.5 | 65.5 | 72.5 | 79.5 | 86 |
| ⅞ | 37.5 | 54 | 67 | 78.5 | 89 | 98.5 | 108 | 118 |
| 1 | 49 | 70 | 87 | 103 | 116 | 128 | 141 | 153 |
| 1⅛ | 62 | 89.5 | 111 | 130 | 147 | 163 | 179 | 194 |
| 1¼ | 76.5 | 110 | 135 | 160 | 181 | 201 | 220 | 239 |
| 1⅜ | 92.5 | 132 | 164 | 193 | 218 | 243 | 266 | 289 |
| 1½ | 110 | 157 | 196 | 233 | 260 | 289 | 317 | 244 |
| 1¾ | 150 | 214 | 266 | 312 | | | | |
| 2 | 195 | 280 | 348 | 409 | | | | |
| 2½ | 345 | 437 | 545 | 638 | | | | |

This table may be used for estimating the amount of air flowing thru any size pipe by finding the square inch area of the pipe and multiplying this by the figure in the horizontal line with the 1⅛″ opening, which corresponds to the pressure. Example:

A 10″ pipe has an area of 78.54 sq. in., if the pressure is found to be 32 ounces, multiply

$$\begin{array}{r} 78.54 \\ \text{x}130 \\ \hline 235620 \\ 7854\phantom{0} \\ \hline 10210.20 \end{array}$$

10210.20 cu. ft. of air flowing thru a 10″ pipe into the atmosphere at a pressure of 32 ounces in the pipe per minute.

**Note:** The 1⅛-inch size is used as this has an area of approximately 1 square inch.

## AIR REQUIRED TO VENTILATE SAND BLAST ROOMS.

Suction fans are used to ventilate sand blast rooms.

The suction side of the fan is connected to the sand blast chamber and the discharge end of fan opening to the atmosphere.

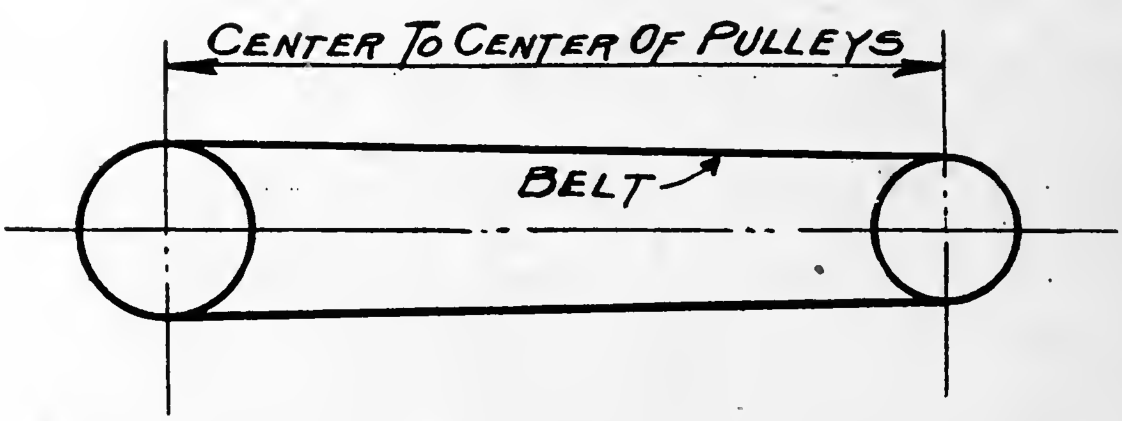
The air in a sand blast room should be changed from three to four times per minute. Example:

Assume the room is 8 x 8 x 7 ft. high. Then, the cubic feet in the room will be 448; allowing 4 changes per minute—448 x 4 equals 1792 cu. ft. of air must be eliminated per minute. A fan having this capacity should be selected.

Note:—Be sure to allow 1792 cu. ft. of air to enter room thru suitable openings.

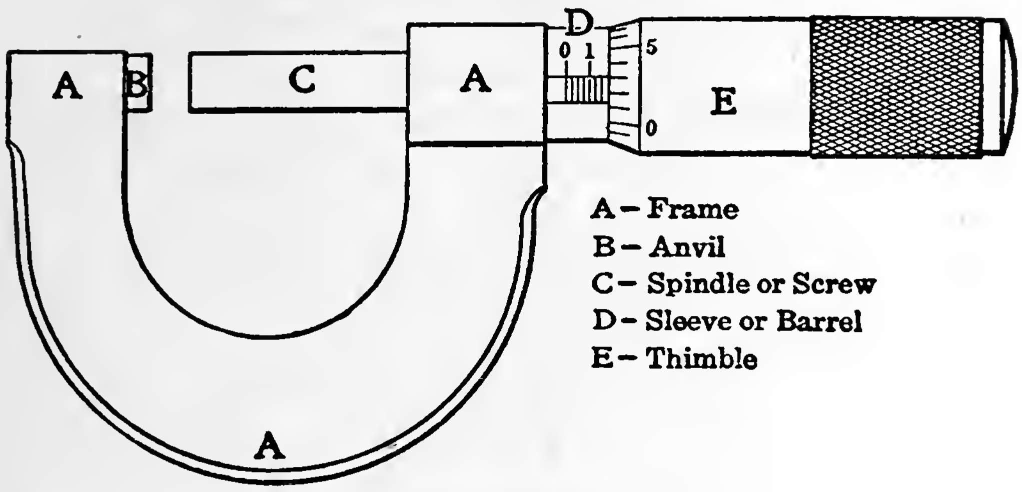
## DISTANCE BETWEEN PULLEY CENTERS

When installing belt driven equipment, it is often desired to know the best distance between centers of pulleys—the table here given may be used as a guide providing no idlers are used.




| WIDTH OF BELT. | CENTER TO CENTER OF PULLEYS | | |
|---|---|---|---|
| | MINIMUM | IDEAL. | MAXIMUM. |
| 3 INCH. | 4 FEET. | 8 FEET | 25 FEET |
| 6 " | 6 " | 12 " | 30 " |
| 12 " | 9 " | 17 " | 32 " |
| 18 " | 11 " | 20 " | 34 " |
| 24 " | 12 " | 22 " | 37 " |

## HOW TO READ A MICROMETER.




—Micrometer.

The various parts of a micrometer are known as follows:

| | |
|---|---|
| Frame | A |
| Anvil | B |
| Spindle | C |
| Sleeve | D |
| Thimble | E |

The object to be measured is placed between the anvil B and spindle C. The spindle C is capable of being moved in or out, having a thread cut on its circumference which passes thru the inside of sleeve D. To the right hand end of spindle C is fastened thimble E which is hollow and passes over sleeve D.

The thread cut on the spindle C has 40 threads per inch therefore by revolving the thimble E one complete revolution, the spindle C will advance 1/40 of 1 inch and four revolutions will advance the spindle 4/40 or 1/10 of an inch. This distance is represented between the 0 and the 1 on the sleeve D. Each smaller division between the 0 and the 1, represents 1/40 or .025 of an inch.

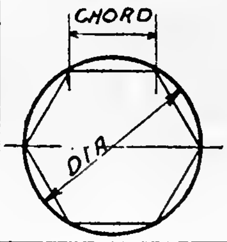
The thimble E has 25 equal divisions around its circumference, each division representing 1/25 of 1/40 inch, or .001 inch.

To read the distance between the anvil B and spindle C, add the number of divisions visible on the sleeve D—multiply this by .025 and then add to this .001 for each division on thimble E that has passed the upper horizontal line on sleeve D.

The micrometer now reads:

$$
\begin{array}{rl}
.025 \times 7 = .175 & \text{on D} \\
.001 \times 3 = .003 & \text{on E} \\
\hline
.178 & \text{answer}
\end{array}
$$

Note:—By close observation it will be seen that six divisions only are visible on sleeve D. However the 0 on thimble E has passed the upper horizontal line on sleeve D, indicating that the seventh division has been passed.




TO FIND THE LENGTH OF A CHORD WHICH WILL DIVIDE THE CIRCUMFERENCE INTO "N" EQUAL PARTS --- MULTIPLY THE DIAMETER BY "S".

| N | S | N | S | N | S | N | S |
|---|---|---|---|---|---|---|---|
| 1 | .00000 | 26 | .12054 | 51 | .061560 | 76 | .041325 |
| 2 | .10000 | 27 | .11609 | 52 | .060379 | 77 | .040788 |
| 3 | .86603 | 28 | .11197 | 53 | .059240 | 78 | .040267 |
| 4 | .70711 | 29 | .10812 | 54 | .058145 | 79 | .039757 |
| 5 | .58779 | 30 | .10453 | 55 | .057090 | 80 | .039260 |
| 6 | .50000 | 31 | .10117 | 56 | .056071 | 81 | .038775 |
| 7 | .43388 | 32 | .098018 | 57 | .055089 | 82 | .038303 |
| 8 | .38268 | 33 | .095056 | 58 | .054139 | 83 | .037841 |
| 9 | .34202 | 34 | 092269 | 59 | .053222 | 84 | .037391 |
| 10 | .30902 | 35 | .089604 | 60 | .052336 | 85 | .036953 |
| 11 | .28173 | 36 | .087156 | 61 | .051478 | 86 | .036522 |
| 12 | .25882 | 37 | .084804 | 62 | .050649 | 87 | .036103 |
| 13 | .23932 | 38 | .082580 | 63 | .049845 | 88 | .035692 |
| 14 | .22252 | 39 | .080466 | 64 | .049068 | 89 | .035291 |
| 15 | .20791 | 40 | .078460 | 65 | .048312 | 90 | .034899 |
| 16 | .19509 | 41 | .076549 | 66 | .047582 | 91 | .034516 |
| 17 | .18375 | 42 | .074731 | 67 | .046872 | 92 | .034141 |
| 18 | .17365 | 43 | .072995 | 68 | .046184 | 93 | .033774 |
| 19 | .16460 | 44 | .071339 | 69 | .045515 | 94 | .033415 |
| 20 | .15643 | 45 | .069756 | 70 | .044865 | 95 | .033064 |
| 21 | .14904 | 46 | .068243 | 71 | .044232 | 96 | .032719 |
| 22 | .14232 | 47 | .067893 | 72 | .043619 | 97 | .032381 |
| 23 | .13617 | 48 | .065401 | 73 | .043022 | 98 | .032051 |
| 24 | .13053 | 49 | .064073 | 74 | .042441 | 99 | .031728 |
| 25 | .12533 | 50 | .062791 | 75 | .041875 | 100 | .031411 |

## HOW TO USE THE CHORD TABLE

The shortest distance between any two adjacent points on the circumference of a circle is known as the chord. Assume the circumference of a circle 54″ in diameter is to be divided into 14 equal parts, this may be found as follows:

N = 14 (see table)
S = .22252 (see table)
Dia. = 54 inches
Multiply S x DIA. = .22252 x 54 = 12.01 inches.

## EXAMINATION

## LESSON 24

1. At what temperature F. does brass melt?

2. How many 8-inch diameter pipes will it take to equal the same carrying capacity as a 20-inch pipe? See table.

3. How much air per minute will be discharged from a receiver thru a $\frac{1}{2}$-inch opening into the atmosphere if the pressure in receiver is 40 lbs?

4. How much air at 16 oz. pressure will be discharged thru an 18-inch pipe? See table and text.

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