SHOP SKETCHING

INDUSTRIAL EDUCATION SERIES

SHOP SKETCHING

PREPARED IN THE

EXTENSION DIVISION OF

THE UNIVERSITY OF WISCONSIN

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SOMETIME INSTRUCTORS IN MECHANICAL ENGINEERING IN THE UNIVERSITY EXTENSION DIVISION

FIRST EDITION

McGRAW-HILL BOOK COMPANY, Inc.

239 WEST 39TH STREET, NEW YORK

6 BOUVERIE STREET, LONDON, E. C.

1913

THE · MAPLE · PRESS · YORK · PA

PREFACE

This volume presents the instruction papers prepared and used by the University Extension Division as a course for apprentices and older shop men who need a knowledge of mechanical drawing. The method of instruction is founded on those basic laws of successful vocational instruction: that the instruction must give the man just what he is going to use in his everyday work, and that this must be given in the most direct and efficient manner with the least expenditure of his time and money.

Every good mechanic must have a knowledge of drawing for two reasons. First and most important, he must be able to read mechanical drawings; the lines on a blueprint must not be merely so many white lines on a blue background, but they must delineate an actual object in his mind. In other words, he must be taught to visualize the object from the drawing. Second, he must be able to make such occasional sketches as the better mechanics are often called upon to make. He may be on a repair job which requires that a sketch be made of a broken part; or he may want to convey to another his ideas of a special tool or fixture or machine part. At times he may find it necessary to make a pictorial representation for the benefit of someone who can not understand a regular drawing. In making drawings for any of these reasons, he would use only the simplest outfit—a pencil, a piece of plain paper (often a scrap of wrapping paper of the back of an envelope), a scale or ruler for a straight-edge, and possibly a pencil compass.

This text is not intended to make draftsmen, but to teach shop men the knowledge of drawing that they need as shop men. Ability to read drawings is developed by examples from simple and well-known objects. This is further brought out and tested by problems requiring the student to construct other views from given drawings. To do this he must be able to visualize the thing represented and at the same time he is taught to make simple sketches. Other problems give practice in sketching from actual objects.

No attempt has been made to establish a standard of conventions. Those more generally accepted are given and, while suggestions are made for the unattached student, it is expected that each shop man will use those that are accepted in his own shop. Experience has shown that mechanics frequently resort to a pictorial method of representation, especially in conveying ideas to those unfamiliar with mechanical drawings. The isometric method has therefore been introduced, believing that it is in general the simplest of the oblique methods of representation. Freehand work, while desirable, introduces an added complication to the instruction and has therefore been left until the last.

The student should not be taught to depend on the use of drawing instruments which are not available "on the job." The following simple outfit is suggested: A pad of large size letter paper with a hard, unruled surface; a 2-H pencil; a steel scale or a folding rule; an eraser; and a pencil compass such as the Eagle Pencil Co's. No. 569. When a student shows marked ability and interest he may be encouraged to use a regular drafting outfit and to do ink work and tracing if he desires to spend the extra time required.

The course was originally written by Mr. Woolley and was later revised by Mr. Meredith, who incorporated such additions and changes as his experience in teaching it to several classes of shop men showed to be desirable. The illustrations were drawn by Mr. Ralph W. Hills, Instructor in Mechanical Drawing in the Extension Division. Mr. Hills has also contributed many valuable suggestions in the development of the course.

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Associate Professor of
Mechanical Engineering.

The University of Wisconsin
Madison, Wisconsin.
October 1, 1913.

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SHOP SKETCHING

CHAPTER I

PRINCIPLES OF MECHANICAL DRAWING

ASSIGNMENT 1

1. Projections.—The principle of projections is the basis of mechanical drawing and must be thoroughly understood in order to read a mechanical drawing or to make one.

In making a mechanical drawing of any object, a draftsman deals with one face at a time, and makes separate drawings or views showing how the different sides or faces look. Thus we sometimes make as many *different* drawings or views of an object as the piece has *different* sides. Each view is made as if the

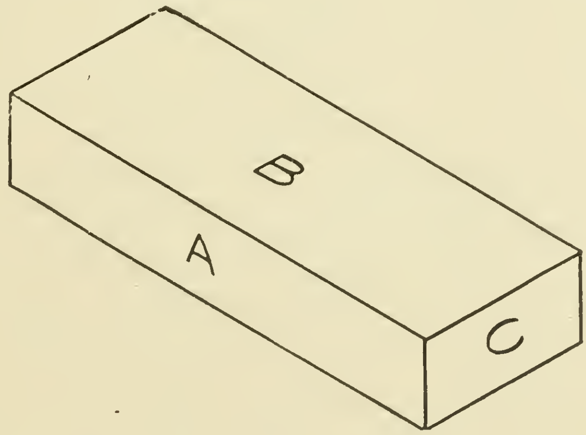


FIG. 1.

draftsman were looking squarely at the particular side he is drawing. In Fig. 1 is shown a picture of an oilstone, such as might be made by an artist or a photographer. Looking toward the corner, as in this figure, we see three faces, the side *A*, the end *C*, and the top *B*. Fig. 2 shows a mechanical drawing of this same oilstone. Notice that the stone has its three different faces shown by the three views *A*, *B*, and *C*. In all there are six faces but, since the two ends are alike, and likewise the two sides, and the top and bottom, it is necessary to show only the three *different* faces. Each view is a picture of one side as we

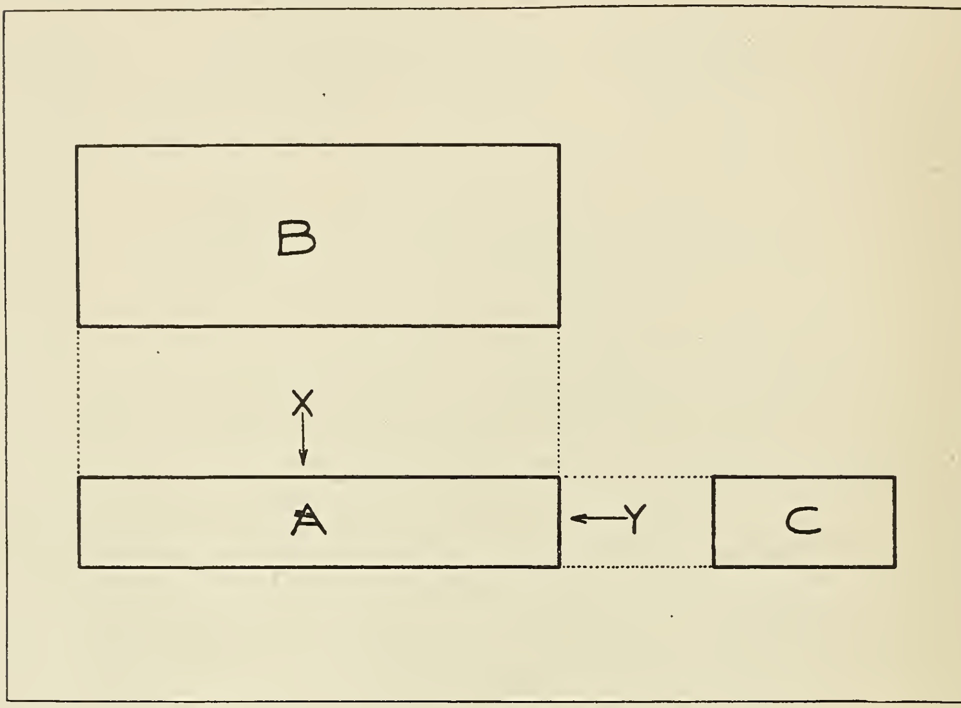


FIG. 2.

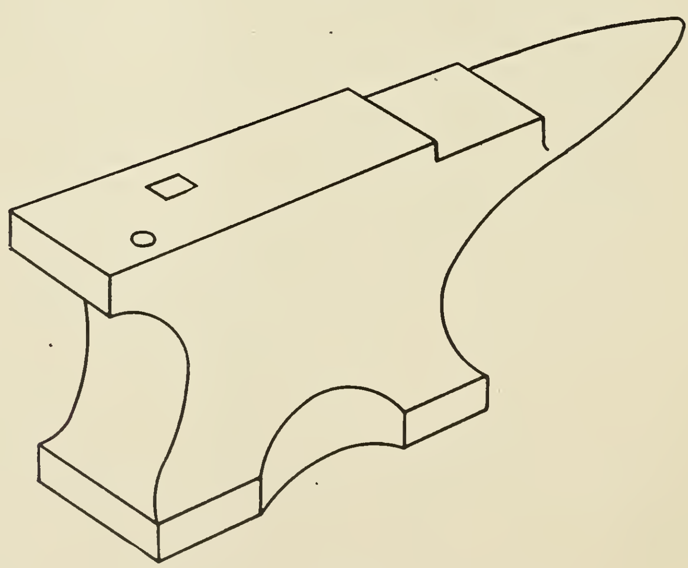


FIG. 3.

would see it if the stone were held squarely in front of, and on a level with the eye.

In making these views showing the different sides of any object, they should be placed in such a way as to show how they are related to each other in their position on the object. This is done by the principle of projection as follows: Referring to Fig. 2, notice that the top view *B* is placed directly above the side view *A*, so that the edges of *B* are on the same line as those of *A*, as shown by the dotted lines. Also, end view *C* is directly in line with *A*. This is the principle of projection. In other words, the length of *A* is "projected" directly upward to form the length of *B* and the height of *A* is "projected" to the right to form the height of *C*. The dotted lines are never actually

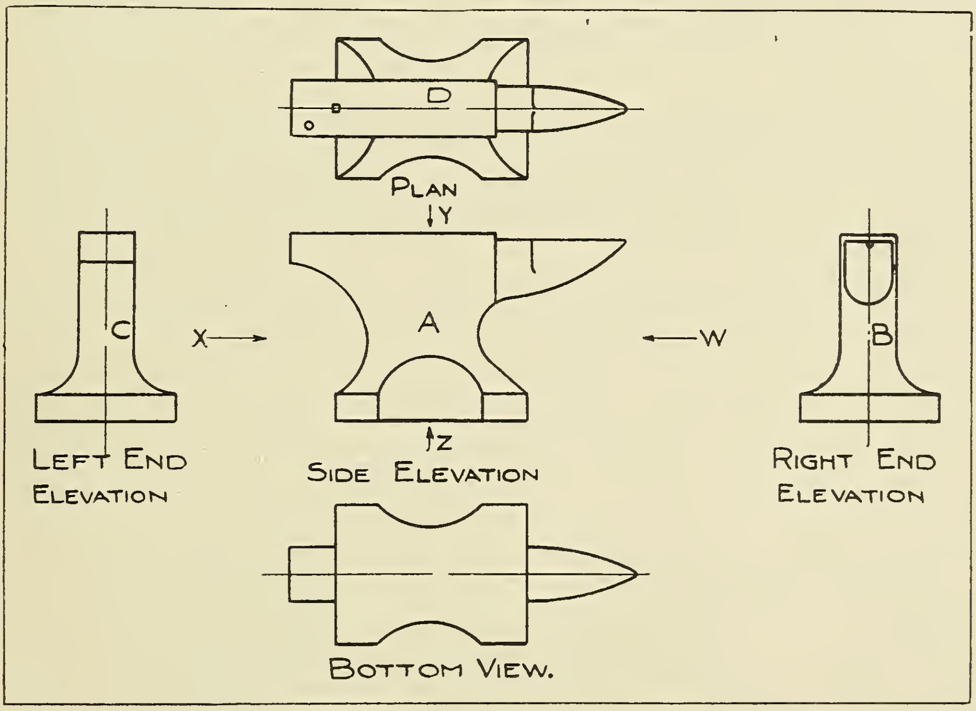


Fig. 4.

drawn, but simply indicate the position of the straight edge in laying out the work.

Fig. 3 shows a picture of an anvil. Fig. 4 shows the complete mechanical drawing of this anvil with the correct names of the different possible views that might be shown. As a general rule, we follow this grouping: In the center we place the side view which shows the object set up in its natural position before the eye, and project the other views from it, placing the plan or top view above, the bottom view below, the right-end view or elevation on the right, and the left-end view on the left.

The views of an object which show it set up before the eye in its natural position are called *elevations* and are further designated as *front, side,* or *end elevations.* The top view, obtained by looking down upon an object is usually called the *plan.* The names which we give to the elevation views differ with different objects and different people. Usually we have two elevations given in a mechanical drawing, but people look at things differently and the view that some people would call a front view others might consider a side view. So we might have *front* and *side* elevations, or *front* and *end* elevations, or in the case of any object that does not have any particular face that could be called the front, we might call the elevations the *end* and *side* elevations.

Note Carefully.—We seldom need more than two or three views of a piece in order to show it. Generally a plan and side and end elevations are all that is necessary. It is only with very irregular objects like the anvil that we need as many as five views.

2. Relations Between Views.—Fig. 5 shows a sketch in one

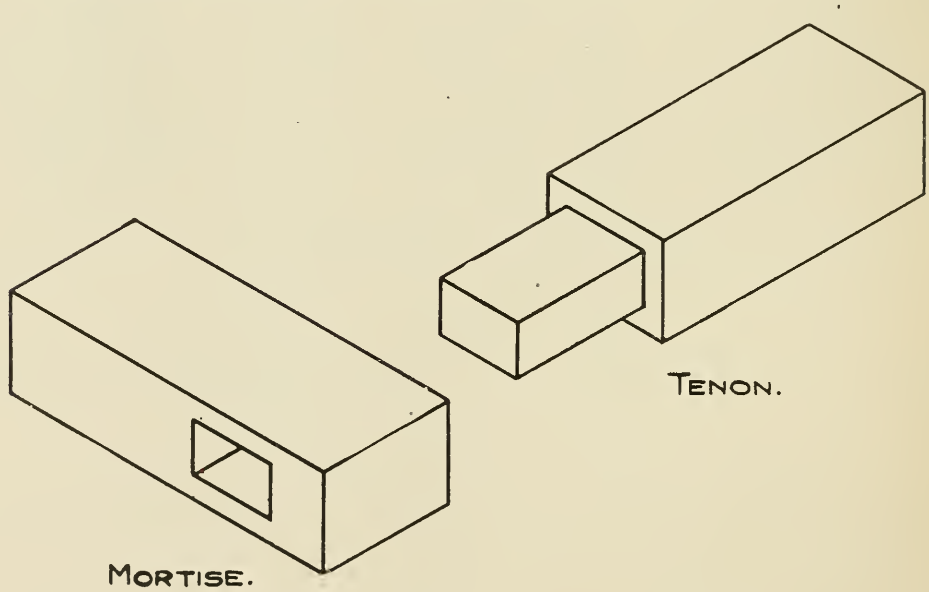


Fig. 5.

view of two blocks of wood which are formed so that they may be joined together with a mortise-and-tenon joint. A mechanical drawing of the tenon is shown in Fig. 6. Three views are shown, namely, the side elevation *AB,* the plan *CD,* and the left-end view *EF.* The left-end view is shown rather than the right-end view because the form of the block and also of the tenon are shown in the left-end view. The surface A in the side elevation is shown in the other two views by the lines a. The surface B in the side elevation is represented by the lines b in the other two views. The student should check over the rest of the drawing with the aid of the letters so as to see just what each line in one view represents in the other views. The capital letters are used to mark the surfaces. The small letters mark the lines which in other views represent these same surfaces. These letters are shown merely by way of explanation and would not appear upon a working drawing. From this drawing it will be seen that *whenever a surface lies flat and on a level with the eye, it is represented by a line.*

3. Making the Drawing.—In making the drawing in Fig. 6,

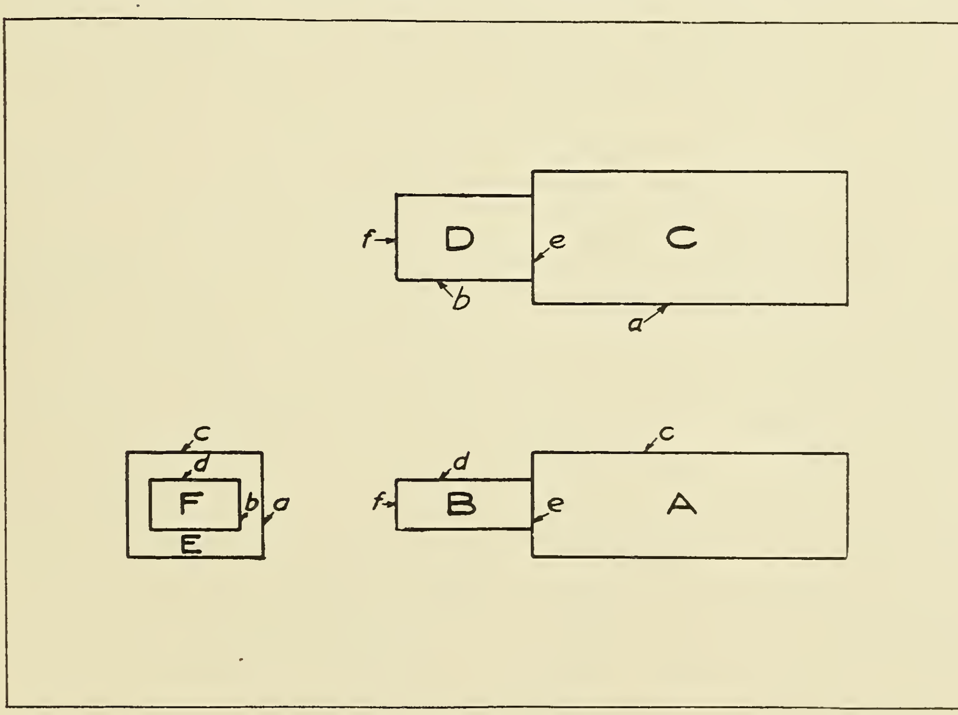


FIG. 6.

we would draw the side elevation (view AB) first, laying off the various dimensions with the scale. Then in drawing the plan view (view CD) we would use the principle of projections to simplify the work and to locate the view properly with respect to the side elevation. The vertical (up and down) lines on the side elevation we would extend or project upward with the straight edge. These lines would then show the lengths of the horizontal (crosswise) lines of the top view. After deciding how much space to leave between the views, we would then draw the horizontal lines of this view, spacing them properly with the aid of the rule or scale, to show the desired width of the object. The left-end view is drawn in a similar manner, by extending toward the left the horizontal lines of the side elevation and locating the vertical lines with the aid of the rule. These lines which are drawn from the side elevation in determining the other two views are called *projection lines.* They are usually drawn lightly so that they may be readily erased from the finished drawing. The distance to be left between the views is largely a matter of choice. The considerations which govern it will be developed later. From the preceding discussion it will be seen that the following relations exist between the different views:

The horizontal dimensions of the side elevation and of the plan or top view are equal.

The vertical dimensions of the side and end elevations are equal.

The horizontal dimensions of the end view and the vertical dimensions of the top view are equal.

4. Dimensioning the Drawing.—After the representation of the object is completed, it must be dimensioned for the guidance of the mechanics who are to have a part in its manufacture. Fig. 7 shows a shop drawing of the tenon shown in Fig. 5. It will be noticed that the extension lines and dimension lines have been added.

Dimension lines are light lines broken at the center for the insertion of the dimensions, and having arrowheads at their ends to show the distances which they measure. The arrowheads should be made very sharp. As shown in Fig. 8, they should have a sharp wedge shape with a slight curve to the sides rather than a V-shape. They should not be blocked in solidly.

Extension lines are light lines which show the points on the object between which the dimension is measured. Extension lines should be drawn up to about $\frac{1}{16}$ in. from the object and should project about $\frac{1}{8}$ in. beyond the dimension lines.

Dimension lines should be spaced equally apart and equally distant from the object lines. About $\frac{5}{16}$ in. is a good average for this spacing. Dimensions should be placed in one or two views when possible. Notice in Fig. 7 that all the dimensions are shown in two views. *It is bad practice to repeat dimensions—that* *is, to put the same dimension in more than one of the views.* Dimensions which are closely related should be placed near to each other, as shown by the arrangement of dimensions in the left-

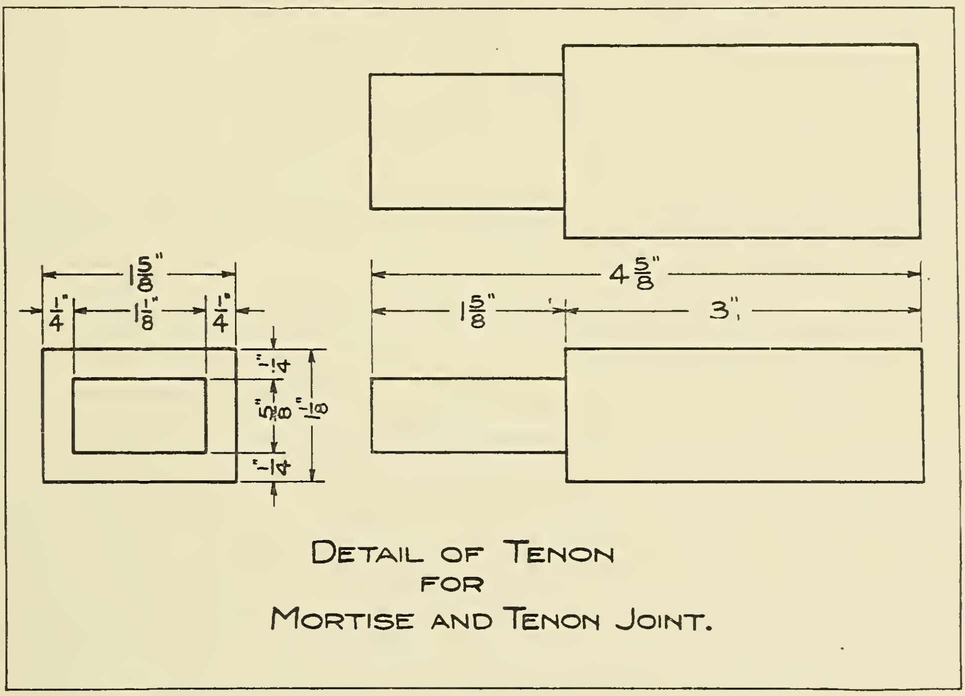


FIG. 7.

end view of Fig. 7. The dimension $4\frac{5}{8}$ in. is known as the *over-all* dimension. It is usually given so that the workman may know the total length of material required. The over-all dimen-

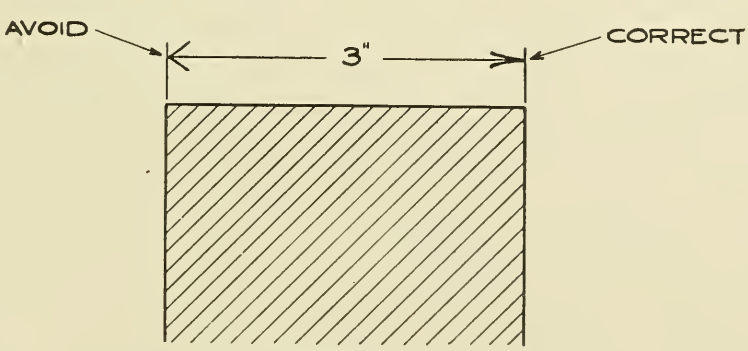


FIG. 8.

sion should be placed just outside the dimensions of which it is the sum, so that its dimension line will not be cut by any extension lines. Be sure that your small dimensions add up to be the same as the over-all dimension.

Dimensions are usually shown by vertical figures about $\frac{1}{8}$ in. high. Fig. 9 shows the type of numerals generally used. The total height of fractions should equal twice the height of the whole numbers. The dividing line of a fraction should be opposite the middle of the whole number and should be on a level with

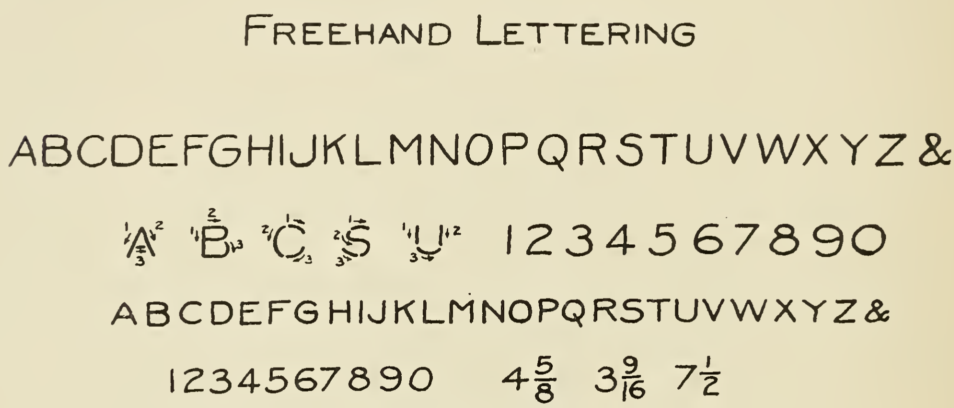


Fig. 9.

the dimension line. The figures of the fraction should not touch the dividing line. *All horizontal dimensions should read from the bottom of the sheet, and all vertical dimensions from the right-hand side of the sheet.* Notice Figs. 11, 13, and 15, in this

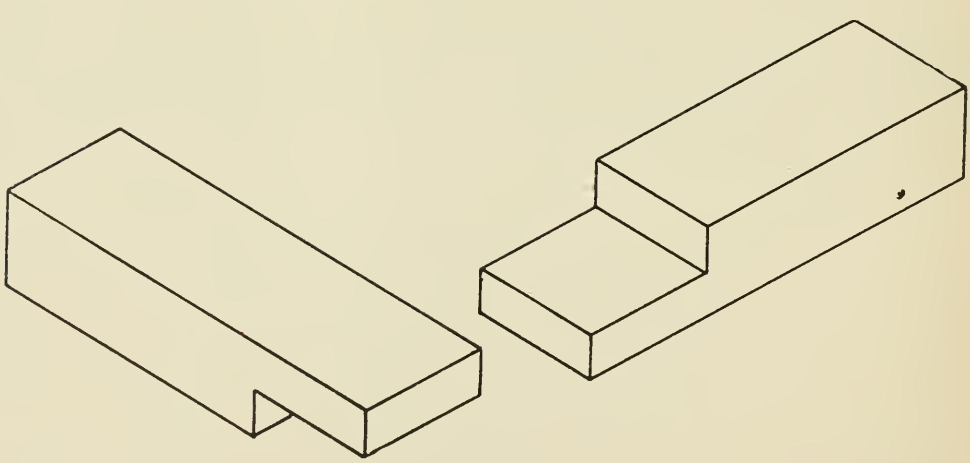


Fig. 10.

respect. In all of the dimension lines that run up and down the sheet the dimensions are placed so that they can be read from the right-hand end of the sheet.

In Fig. 10 is shown a picture of two pieces that form an end lap joint. A mechanical drawing of one of the pieces is shown in Fig. 11. Fig. 12 shows a cornerwise picture of an angle brace. Fig. 13 shows a complete shop drawing of the same angle. These

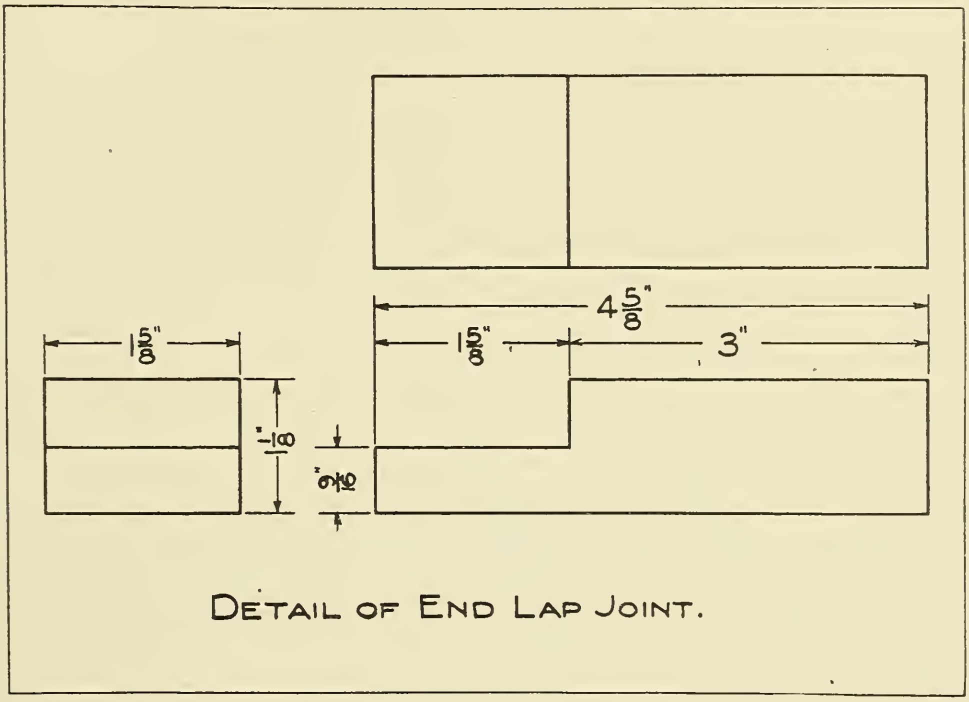


FIG. 11.

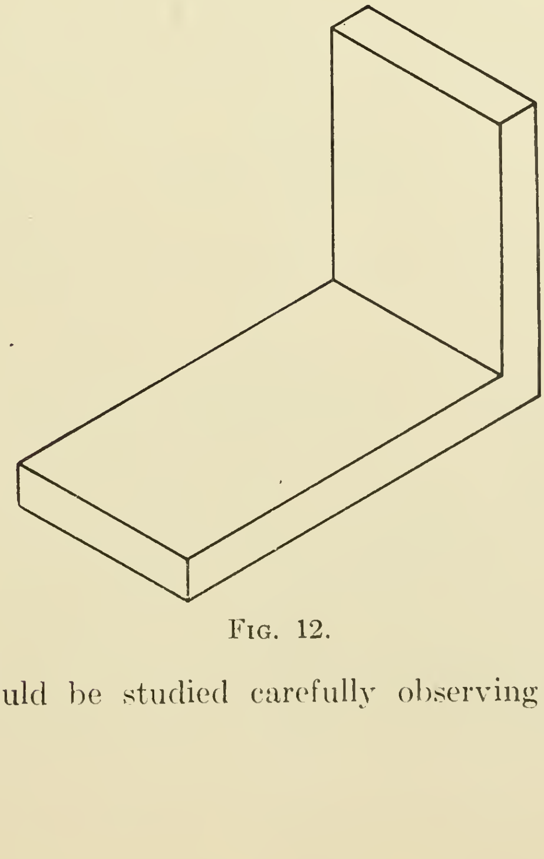


FIG. 12.

drawings should be studied carefully observing the following points:

Relative positions of the views.
Relations between lines in the different views.
Arrangement and position of dimensions.
Extension lines and arrowheads.

5. Order of Procedure.—In making a drawing, the first thing is to select the views to be shown and then plan their arrangement so that they will look well balanced on the sheet. If the left-end view is to be shown, the side elevation should be placed to the right to leave room for it; if the right-end view is shown, the side elevation should be placed to the left of the center. If

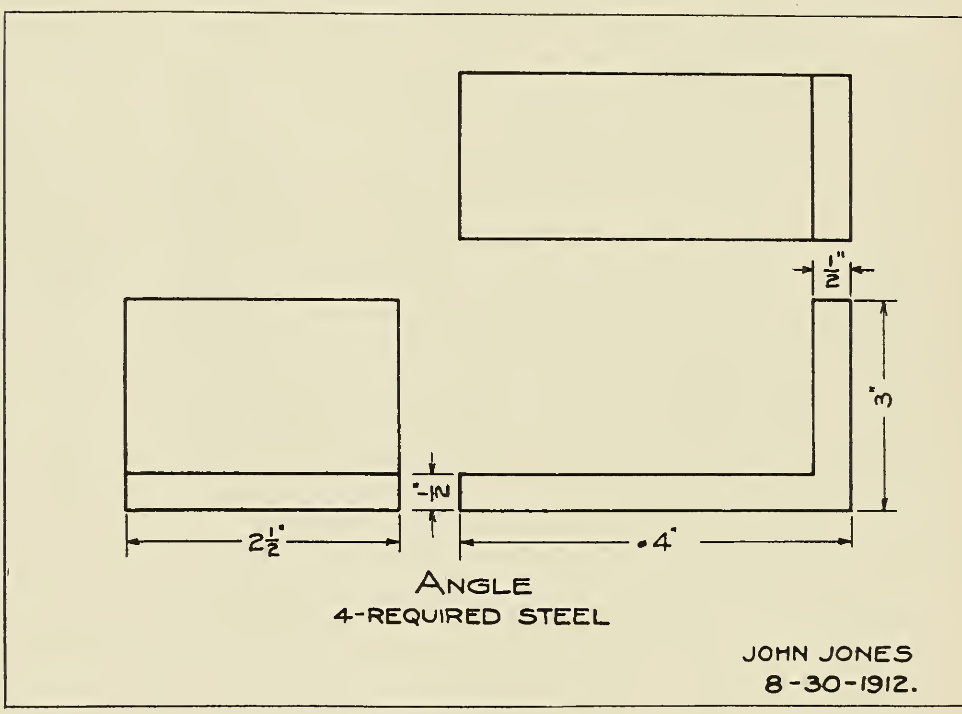


Fig. 13.

both ends are shown (which is only when they are very different), then the side elevation would be placed about in the center. The elevations should be placed enough below the center of the space so as to leave room for the top view, if it is to be shown.

The lines of the object should then be drawn, probably constructing the front or side elevation first and then constructing the other views by the aid of projections from this view.

After the representation of the object is complete, the extension and dimension lines should be drawn, making them lighter than the object lines; next, the arrowheads should be put on; and then the dimensions should be shown in vertical numerals about $\frac{1}{8}$ in. high and similar in form to those shown in Fig. 9.

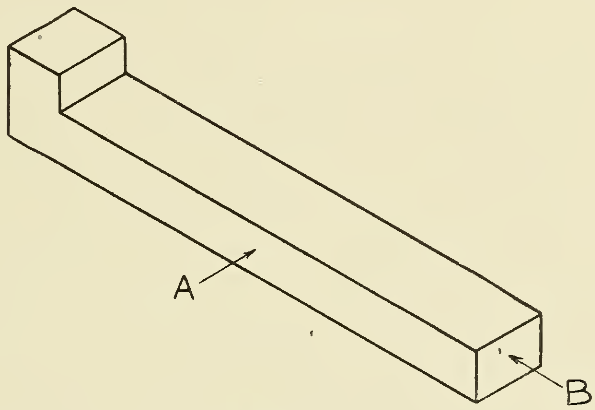


Fig. 14.

Finally, every plate should contain a title, which should show the name of the object, the number of pieces required for the

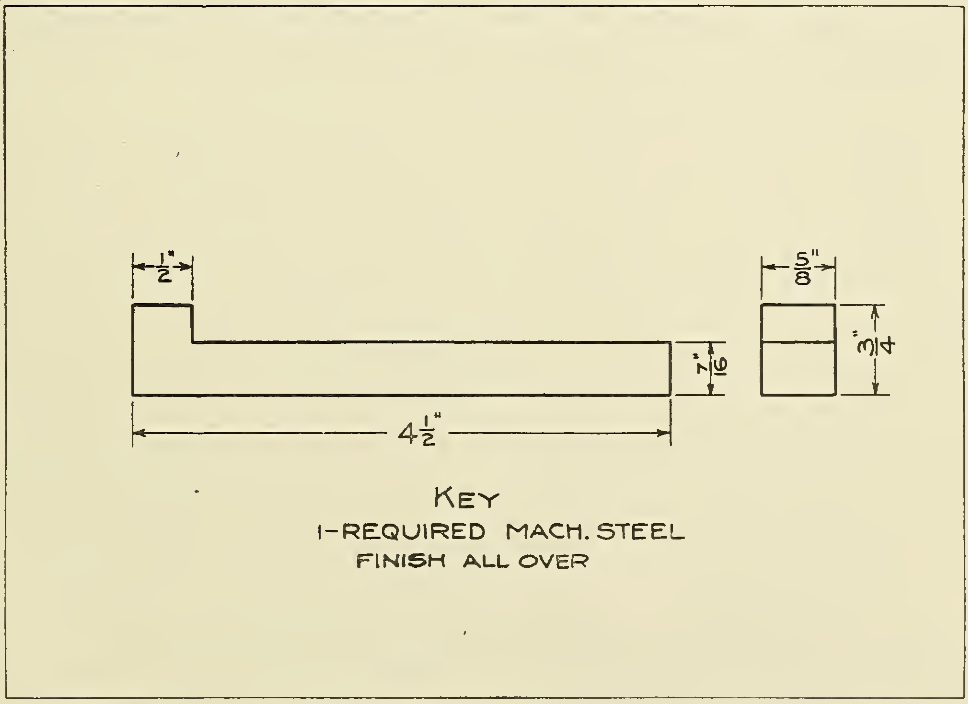


Fig. 15.

machine on which it goes, the material of which they are to be made, and the scale of the drawing. There should also appear, usually in one corner, the name of the draftsman and the date when the drawing was made. The plain vertical capitals shown in Fig. 9 are preferred for titles and notes as they are easily made, are very legible, and require the least practice to do a presentable job. The name of the object, being the most important part of the title, should be put in large letters, about $\frac{3}{16}$ in. high. All other lettering on the plate should be about $\frac{1}{8}$ in. high. In order to get the lettering on a straight line, very light guide lines should be drawn before beginning to letter.

As the mechanic is guided in his work by information which is given entirely on the drawings, it is, therefore, necessary that all drawings should give complete information. Besides showing the shape and size of the parts, the drawings must give full information as to the material to be used, the finish of all surfaces—whether rough, machined, tempered, hardened, etc.—the kinds and sizes of all screws, bolts, etc., and the number of pieces required.

PROBLEM 1

Fig. 14 shows a sketch of a gib key. A working drawing of this key is shown in Fig. 15, with an appropriate title. Such a key is used for fasten-

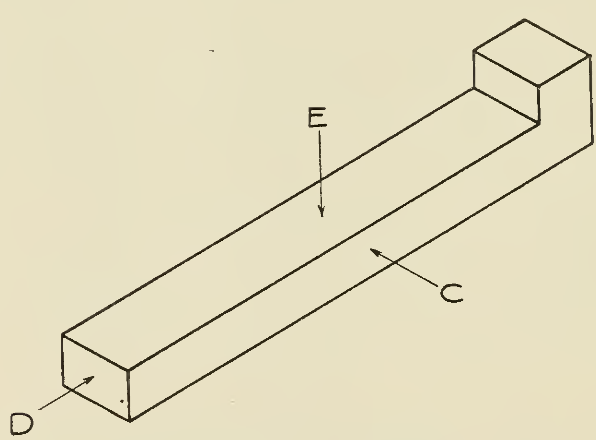


Fig. 16.

ing pulleys, couplings, or collars to shafts and is driven into a slot, half of which is cut in the shaft and half in the piece to be fastened to the shaft. The head is used for pulling the key out of the slot. The slots cut in the shaft and pulleys are called "keyways."

Fig. 16 shows the same key as was shown in Figs. 14 and 15, when viewed from a different position.

Make a working drawing of this gib key, making the views the full size of the key according to the dimensions given in Fig. 15. Draw the views of the key that would be obtained by looking along the arrows, *C*, *D*, and *E*, in Fig. 16. The arrangement of the views should be as shown in Fig. 17. Use the scale or rule for pointing off dimensions, and also as a straight-edge for drawing the lines. Dimension the drawing and show a complete title beneath the drawing, with your name and the date in the lower right-hand corner of the plate.

Before starting any drawing, always see that your pencil is properly sharpened to a good point. Good clean lines cannot be made with a dull pencil.

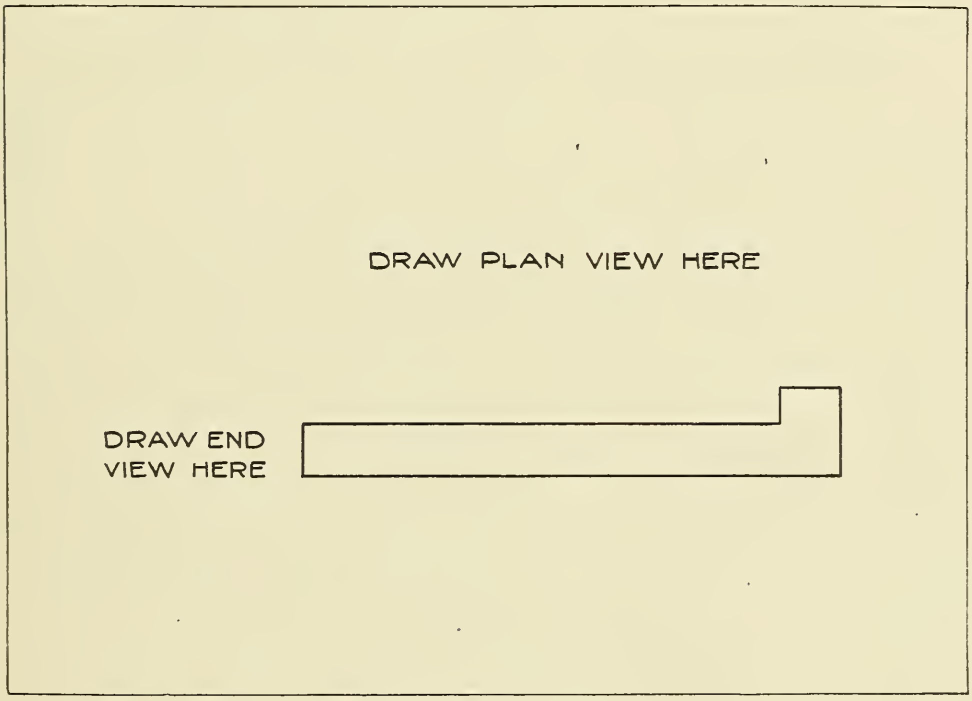


Fig. 17.

ASSIGNMENT 2

6. Broken Lines.—In drawing any view, if a surface is hidden from sight but needs to be shown in some manner, it is customary to use a broken line. This line will show the location and extent of the hidden surface, but, by being broken, will indicate that the surface represented is not on the front but is out of sight.

Broken lines are drawn with dashes about $\frac{1}{8}$ in. long with spaces about $\frac{1}{32}$ in. long between them. See Fig. 31. In drawing broken lines, they are usually made just a little lighter than the full object lines of the drawing.

In Fig. 13, the angle was represented by solid lines throughout, because, in the views selected all the surfaces represented were

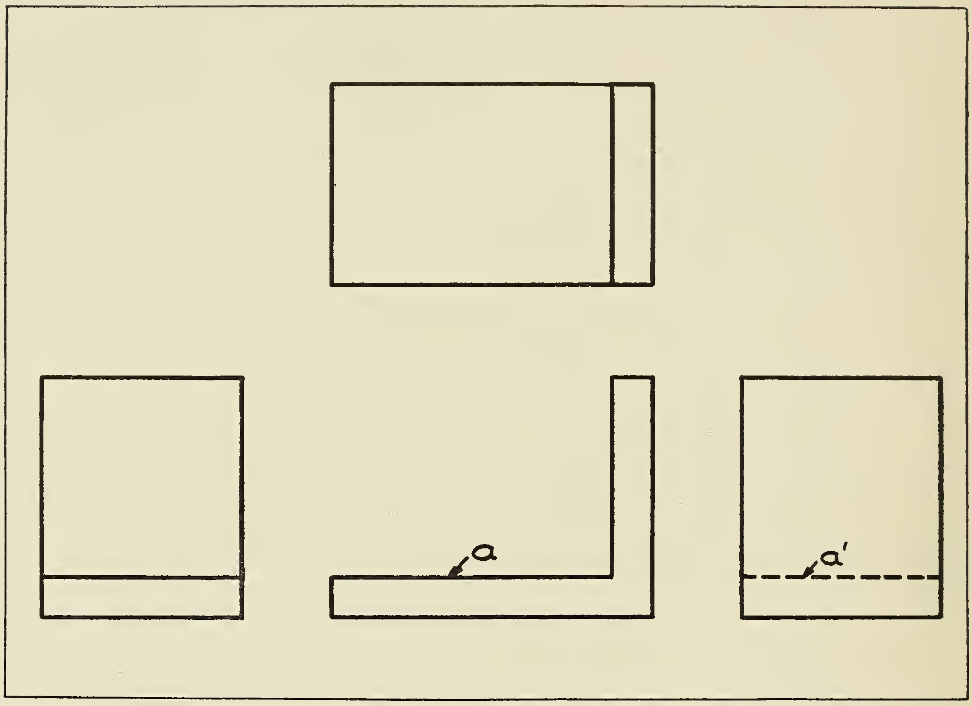


Fig. 18.

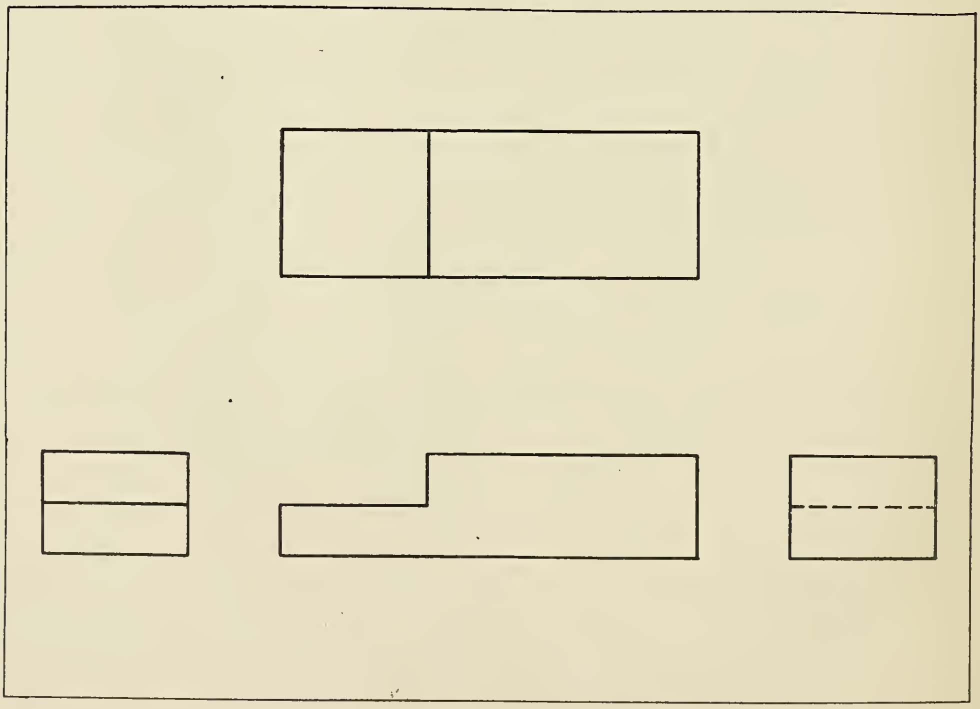


Fig. 19.

visible. If, however, we wish to show the right-end view, it will appear as shown in Fig 18; the surface *a* is shown in the right-end view by the broken line *a′*, because the surface *a* is concealed from the eye by the upright leg of the angle. The right-end view of Fig. 11 would appear as in Fig. 19, and the right-end view of Fig. 7 would appear as in Fig. 20, for the same reasons. *Hidden surfaces must always be shown by broken lines.* The student should practise making broken lines so that he can space them uniformly by eye.

A judicious selection of the views to be shown will often avoid

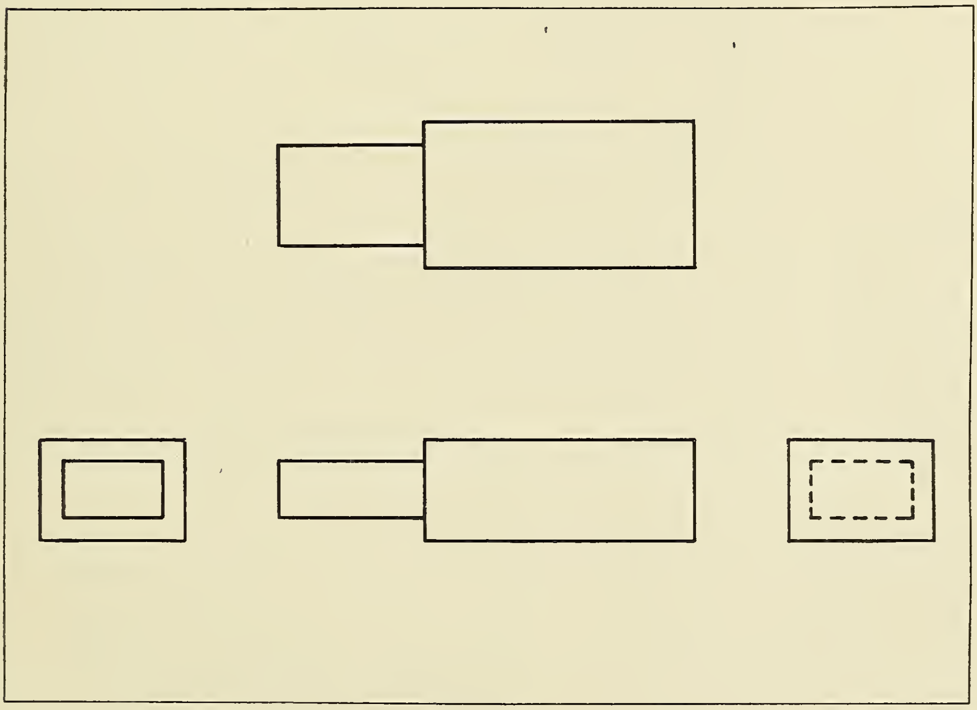


Fig. 20.

the necessity of using broken lines. For example, the left-end view of Fig. 20 shows the end outline of the tenon in full view and therefore is preferable to the right-end view. Figs. 21 and 22 show a case where the broken lines are needed. These figures show a picture and a mechanical drawing of a bronze bushing. This is a hollow cylinder, the hole extending clear through from end to end. In the side view of Fig. 22 it is necessary to represent the hole by two broken lines. These lines extend throughout the length of the side view and thus indicate that the hole extends from one end of the piece to the other. Without these lines we could not tell how far the hole extended. These lines are located by projecting the top points of the inner circle of the end view.

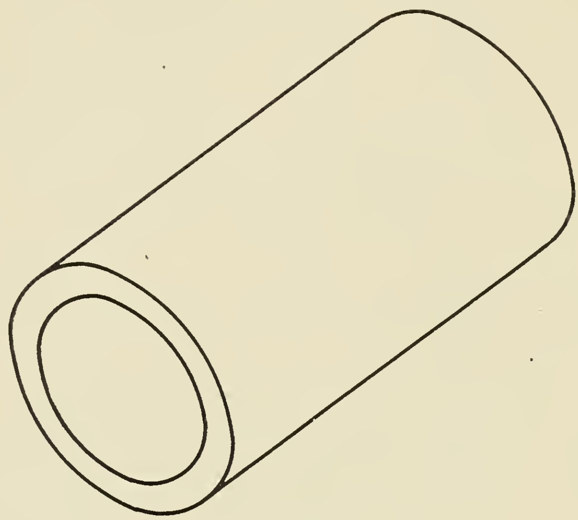


Fig. 21.

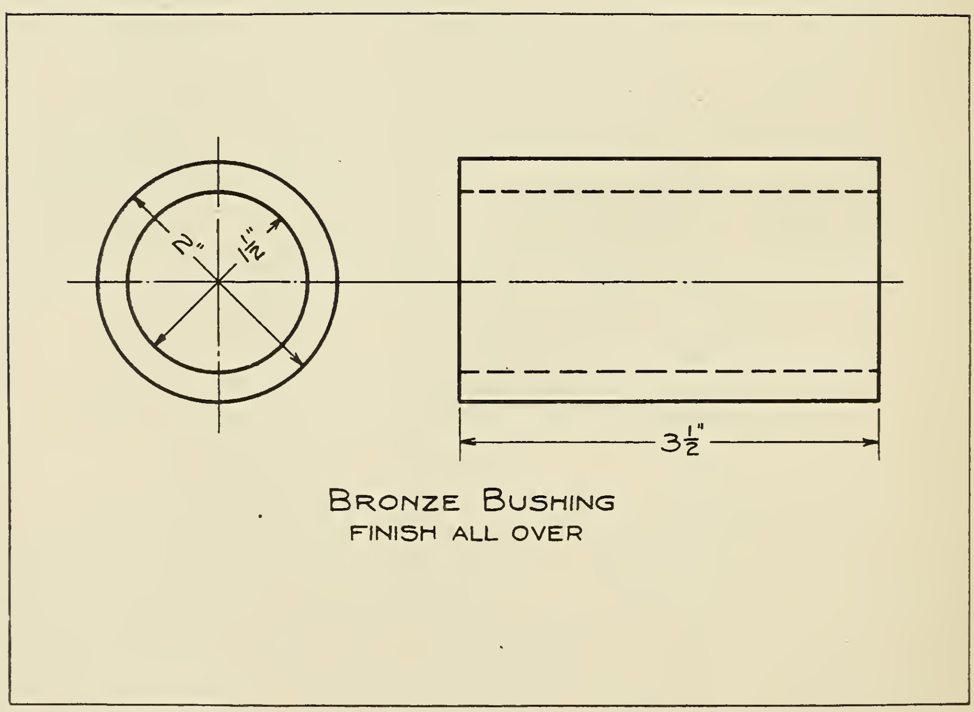


Fig. 22.

Suppose now that we were to make a cylinder like that of Fig. 22 but closed at one end so that it would look like a cap for a pipe. It might then be shown by the side elevation and left-end view of Fig. 23. Notice how the broken outline in the side elevation shows the form of the interior and indicates that the hole does not extend all the way through the piece. These two views would be sufficient to give a clear idea of the cap. If the right-end view were desired, it would appear as shown at the right. The inner circle of this view is broken, because it represents a hidden surface.

Fig. 24 shows a "stop" such as is commonly used on planer beds for bracing castings. It is shown by four views in Fig. 25. These views are not all needed but are given to show how the

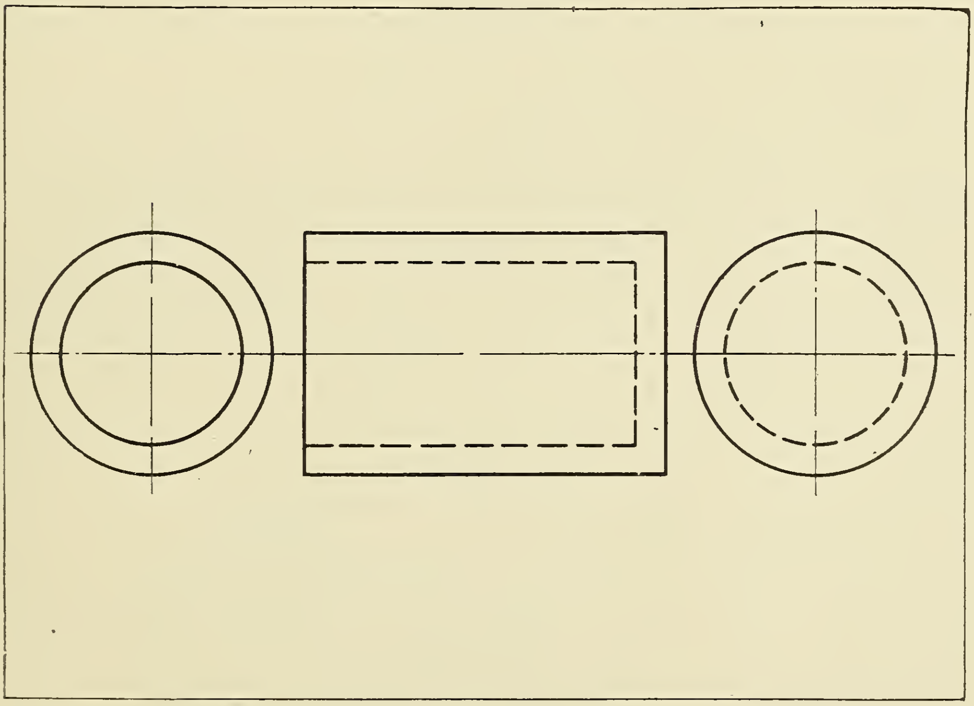


Fig. 23.

stop would appear in the different views. The right-end view contains a broken circle, because the surface which it represents is concealed when the stop is viewed from the right end. The side elevation and left-end view are all the views needed to give a complete idea of the shape of this stop.

Fig. 26 shows a sketch of a flange bushing. A complete shop drawing of this flange bushing is shown in Fig. 27. When the bushing is viewed from the left end, the 2-in. cylindrical surface is concealed from sight by the flange and is therefore shown by a broken line in the left-end view.

Always end a broken line with a dash running right up to the point where the surface ends which the line represents. Compare

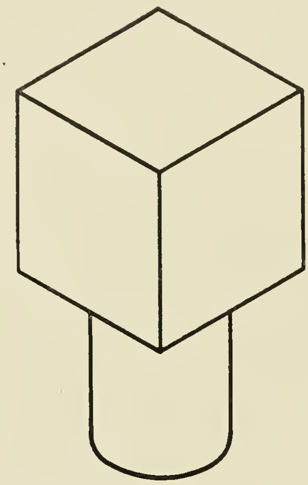


FIG. 24.

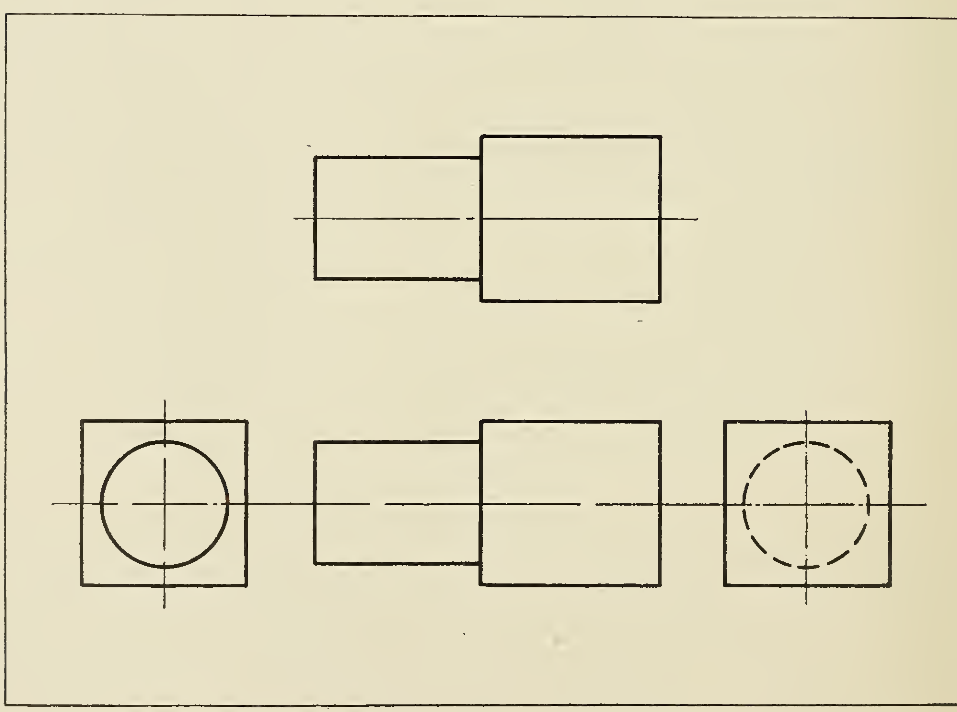


FIG. 25.

the ends of the lines in Figs. 28 and 29. Whenever a broken line *crosses* a full line, always make one of the dashes definitely cross the full line. The correct method of observing this is also shown in Fig. 28, and the improper method is shown in Fig. 29.

If the bushing is shown on a shaft, the diameter of which is

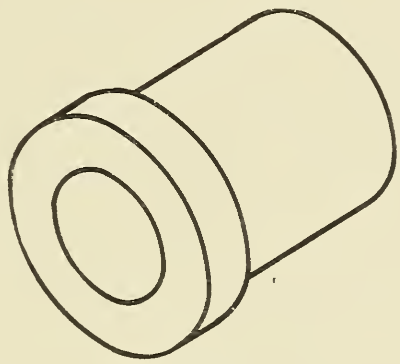


FIG. 26.

the same as that of the hole, then the broken lines will terminate as shown in Fig. 30. This explanation applies not only to this particular problem, but to all similar cases.

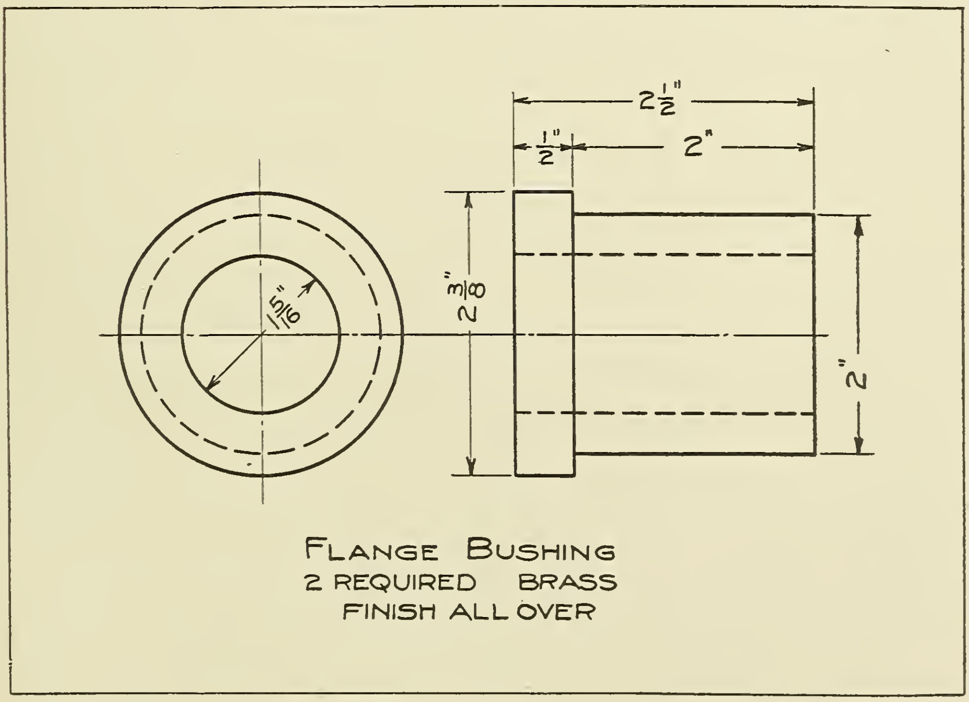


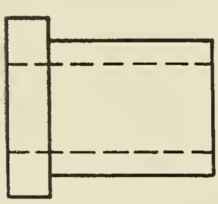
FIG. 27.

In all work in drawing, full-line views should be shown rather than broken-line views. For instance, in drawing the cap of

Fig. 23, it is better practice to show the side elevation and *left*-end view rather than the side elevation and *right*-end view, because in the former case all of the lines of the end view are full lines while in the latter case one of the circles is broken.

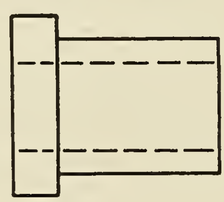
7. The Compass.—Circles are drawn by means of a compass. This consists of two legs hinged at the top; one leg contains the center point while the other contains the pencil point. In order to have all lines on the drawing of uniform weight and quality, it is well for the student to break some lead from his sketching pencil and insert it in the compass. The best results will be obtained if the lead in the compass is sharpened only from the outside, either with the knife or, better, by rubbing it on a smooth file, emery cloth, or sandpaper. Do not touch the

CORRECT AND INCORRECT METHODS OF SHOWING BROKEN LINES.



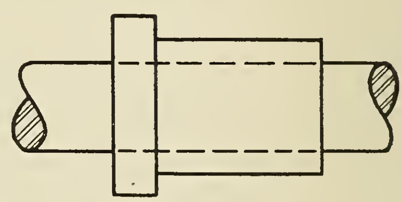
CORRECT

Fig. 28.



AVOID

Fig. 29.



CORRECT

Fig. 30.

inside. The point will then produce sharp lines and stand considerable usage without resharpening.

Only enough pressure should be exerted on the compass to produce distinct, clean-cut lines. Some draftsmen become quite proficient at drawing circles freehand, but a compass is always a valuable part of a sketching outfit.

It will be seen that light dot-and-dash lines are shown through the center of the views of Figs. 22, 23, 25, and 27. These are known as *center lines.* Whenever an object is symmetrical about a common center line (that is, just alike on both sides of the center line) it is customary to show the center line on the drawing. The most common method is to use a line made up of dashes about an inch long with dots between. Center lines should be drawn lightly. The horizontal and vertical center lines of all circular views should be shown. *In starting a sketch, the center lines should always be the first lines drawn.*

In making a drawing like Fig. 22, the center lines would be drawn first, and the circular end view next. The side view may then be constructed with the aid of projection lines from the end view. The object lines of a drawing, whether full or broken, should be be heavier than the center, extension, and dimension lines, as shown in Fig. 31. To obtain this result, the pencil should be sharpened carefully at the beginning of the work. This will enable the student to draw fine but distinct center lines. The object should then be drawn, making the lines heavier. After completing the views, the pencil should be sharpened again preparatory to drawing the extension and dimension lines, which should also be fine lines.

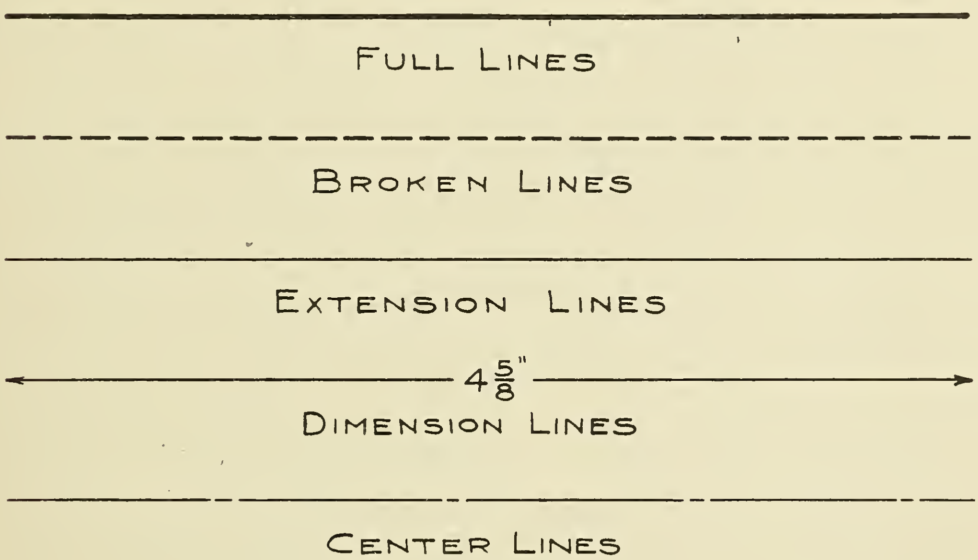


Fig. 31.

8. Arrangement of Dimensions.—Always dimension full-line views rather than broken-line views. Dimensions should be placed as close as possible to the place which they measure so as to avoid the use of unnecessarily long extension lines; for example, in Fig. 27, notice how the extension lines for the $2\frac{3}{8}$-in. dimension are drawn to the side elevation rather than to the end view. Dimensions should always be carried outside of the views of the drawing when convenient, so that the drawing may be the more easily read.

In Fig. 27, it will be noticed that the hole is dimensioned on the end view, in which it appears as a circle. This is done because to dimension it on the other view would necessitate dimensioning from hidden lines, which is undesirable. Dimensions placed in this way should be put on a slant so as to avoid the center lines. A single dimension should slope 45°; that is, half way between the horizontal and vertical center lines. Fig. 32 shows how a number of dimensions would be arranged on a circular end view, the dimension lines being arranged so as to divide evenly the spaces between the center lines.

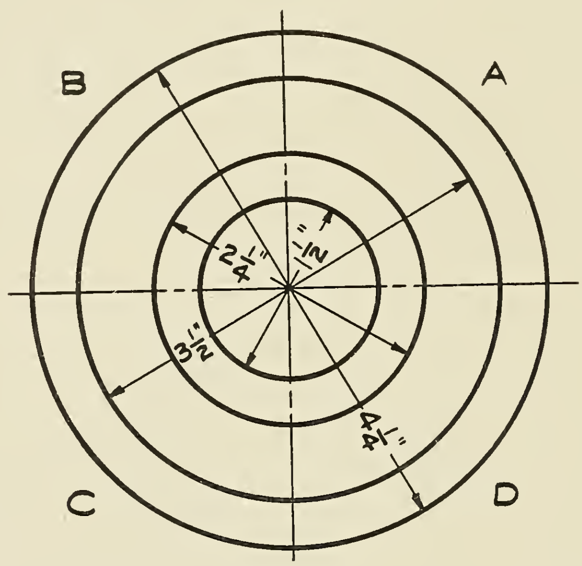


Fig. 32.

9. Finish.—In several of the drawings shown, there appear in the title the words "Finish All Over." This indicates that all the surfaces are to be machined to the dimensions shown in the drawing. The piece must therefore come to the machinist with extra stock all over and on the inside so that he can machine it to size. If a piece is cast, the pattern-maker must allow for this in making the pattern; if forged, the blacksmith must leave the extra material in forging. Different shops may use different phrases, such as Finish, Finished, Finished All Over, Fin., or the letters F. A. O.

PROBLEM 2

Make a full size working drawing of the flange bushing shown in Figs. 26 and 27, drawing the *side elevation* and *right-end* view. Careful attention must be given to all directions contained in articles 6 to 9, inclusive.

ASSIGNMENT 3

10. Drawing to Scale.—Both of the drawings made by the student thus far (Problems 1 and 2) have been made *full size.* In

Problem 1, the key was $4\frac{1}{2}$ in. long, and we drew the top and side views each $4\frac{1}{2}$ in. long. Also we made the end view $\frac{3}{4}$ in. wide, the full width of the key. Each view was a full-sized representation of that side of the key.

This method is all right for small pieces, but when we get large objects to draw we cannot, of course, draw them full size on an ordinary sheet of paper. Neither is it always desirable to get sheets of paper as large as the objects to be shown. To overcome this difficulty and at the same time to keep the various parts of a large piece in proportion, we draw them *to scale.* This means that all lengths are reduced in the same ratio when laid down on the paper. Thus, a drawing might be one-half, one-fourth, or one-eighth of the size of the actual object. Suppose we had to make a drawing of a casting whose over-all dimensions were 32 in.$\times$27 in.$\times$16 in. If we drew this one-quarter size, our drawing would be 8 in.$\times 6\frac{3}{4}$ in.$\times$4 in. The proportions would be exactly the same but the views look as if we were looking at the object at long range. The dimensions placed on the drawing would be the full-size dimensions of the object, since the dimensions are for the guidance of the workman in making the piece.

The title of the drawing always tells to what scale the drawing has been made. The title may say: *Scale—half size* or *scale—quarter size,* or whatever the case may be. The reduction is also frequently expressed by giving the number of "inches per foot"; that is, the number of inches on the drawing sheet used to represent 1 ft. on the actual object. On a half-size drawing, an object 1 ft. long would occupy only 6 in. Consequently a half-size drawing would be marked *Scale*: 6 *in.* = 1 *ft.* On a quarter-size drawing, 3 in. would represent 1 ft. Hence the scale would be 3 in. = 1 ft. Likewise, an eighth-size drawing would be to the scale of $1\frac{1}{2}$ in. = 1 ft., a sixteenth size would be $\frac{3}{4}$ in. = 1 ft., and so on.

Fig. 33 shows a rocker arm drawn to a scale of 6 in. = 1 ft., or one-half size. *Notice particularly that the full size of the part is always given in the dimensions.* No matter what scale you choose in dimensioning, always give the full size of the finished object. This drawing also illustrates several features that have not been explained before.

11. Finish Marks.—This rocker arm is not to be finished all over, but only on the faces and through the holes of the head

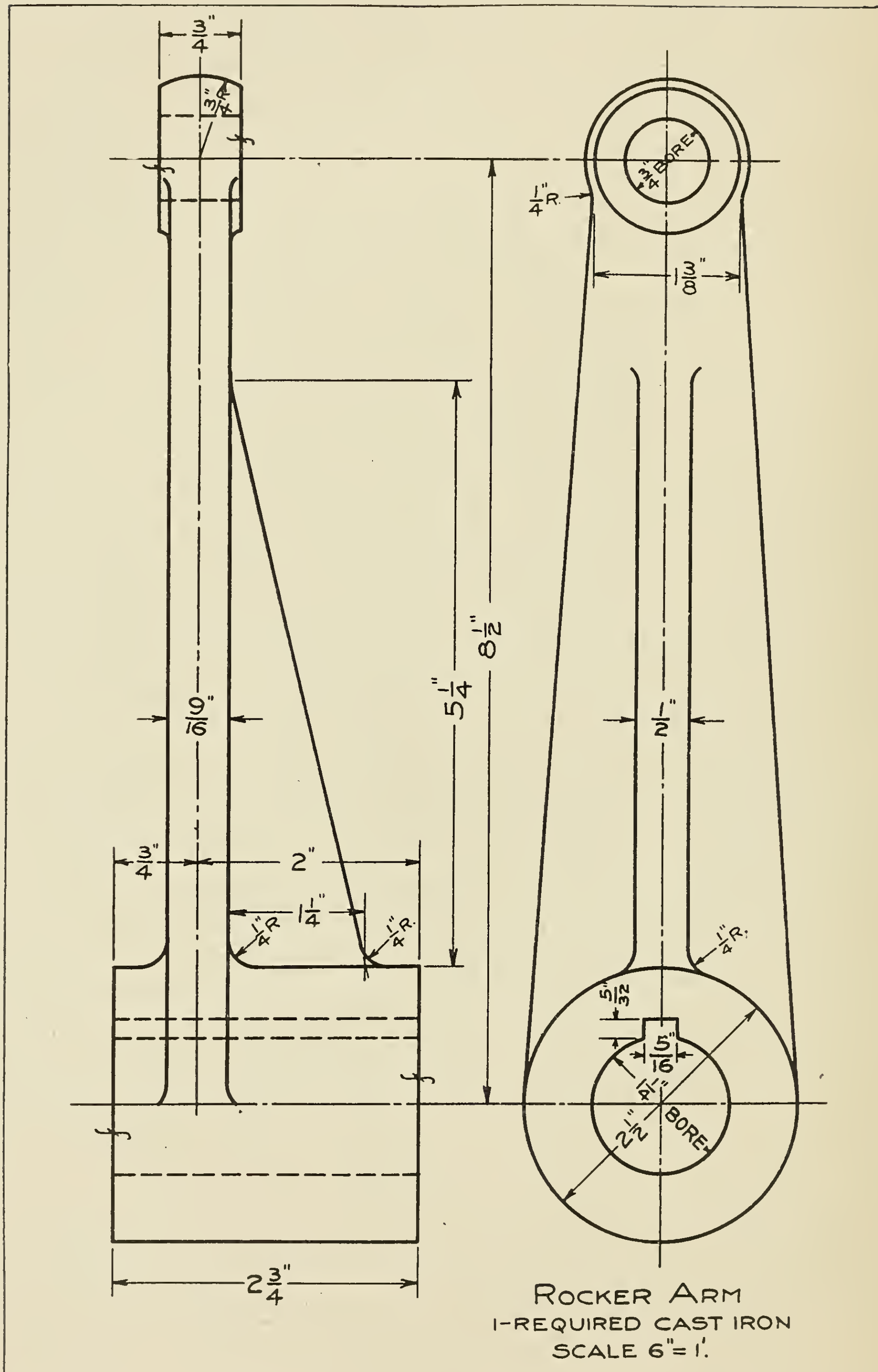


FIG. 33.

and the hub. When a flat surface, such as the faces of these ends, is to be finished, the general practice is to put a letter *f* across the line representing this surface. Some concerns use the capital *F*, others the abbreviation *Fin.*, while still others put the whole word *FINISH* in capitals just outside of the line. The finish mark shown in Fig. 33 will be used in this course because it is in most general usage. If a student is employed in a shop having different standards, it is suggested that he learn them and use them throughout his work. Notice particularly that, when a surface is to be finished, the finish marks are not placed on the view where the surface is shown in plan, but rather on the view where it is represented by a line. Wherever these marks appear, the pattern-maker or blacksmith allows extra stock. About $\frac{1}{16}$ in. is allowed on small parts, so that, if the draftsman leaves off a finish mark where there should be one, it is the same as making an error of $\frac{1}{16}$ in. The finish marks indicate to the machinist what work is to be done by him on the object.

When a hole in an object is to be machined, it is customary to indicate the process to be used by printing the word after the dimension of the hole. Thus in Fig. 33 we have $\frac{3}{4}$ *in. BORE* and $1\frac{1}{4}$ *in. BORE* to indicate that the holes in the ends of the rocker arm are to be bored out to the given dimensions. In Fig. 34 is shown a hexagonal (six-sided) hole in a wrench. The word *BROACH* indicates that the hole is to be finished by the broaching process. The forging for the wrench must therefore be made so that this hole will be undersize, leaving material to be removed by the broach. Likewise, we find holes marked *REAM*, *DRILL*, or *TAP*, according to the operation to be used in finishing the hole. In a similar manner cylindrical parts that are to be finished by turning in a lathe have the word *TURN* after the dimension.

12. Fillets.—In the views of Fig. 33 it will be noticed that the faces of the arm are rounded into the hub instead of leaving a sharp corner. A further examination of the figure shows that this is done wherever two surfaces meet, so that there will not be any sharp corners on the object when made, except where it is to be finished. These small curves or arcs on the drawing represent fillets. A *Fillet* is a small curve used to avoid sharp corners where two surfaces come together at abrupt angles. *All unfinished corners should be rounded by fillets,* so as to provide for the smooth flow of the metal when casting or forging and also for strength, as a crack will generally start in a sharp corner if the piece is overstrained.

These fillets are dimensioned by giving the radius, as is done with any curve which is not a complete circle.

13. Notes on Dimensioning.—There are several new features in connection with the dimensioning of this drawing in Fig. 33. A fillet is dimensioned by a line drawn from the curve to the center from which the arc was swung. The arrowhead appears only on the one end next to the curve. The note $\frac{1}{4}$ *in. R* is put at the other end and in line with the arrow. If the dimension line had been long enough it might have been broken and the dimension put in the break, as was done in the $\frac{3}{4}$ *in. R* on the head of the rocker arm. Notice that the distance between the center lines of the hub and head is given, rather than the over-all dimension. This is the important dimension and must be made accurate in machining. In the side view at the left, the faces of the head and hub must be located accurately with respect to each other. It would not do to locate these from the unfinished face of the arm, so they are located from the center line of the arm. The width of the head is given as $\frac{3}{4}$ in. over-all, but, since it is symmetrical about the center line, it is understood that this means $\frac{3}{8}$ in. on each side of the center line.

This drawing shows several cases where the space between the extension lines is very limited. This is especially true of the keyway cut through the hub. In giving the width of the keyway there was space enough for the figures but not for the arrows, so we put the arrows outside, pointing inward. The depth of the keyway is still narrower. Here the arrows both point in, and the dimension is placed outside and in line with one of the arrows.

PROBLEM 3

Make a *half-size* drawing of the $\frac{3}{4}$-in. Hexagonal Box Wrench, shown in Fig. 34. In this sketch, only the top and right-end views are shown. The student is to show the top, right-end, and side views. Draw the top and right-end views first, and from them draw the side view by means of the principles of projection.

In making this drawing half-size, the student should draw each dimension only half as large as it is on the finished object, but he should insert the actual dimensions of the finished object in their respective places on the drawings, as before noted.

Order of work: Always start by laying out the center lines. Locate them so that there will be sufficient room between views and so that the three finished views will balance up well on the paper. It is always best to draw the circles and the curved surfaces first and then connect them with straight lines, as smoother joints will result. However, it is not practicable to do this in all cases. In this problem, start with the head of the wrench.

The head of the wrench is formed to fit a hexagonal nut for a $\frac{3}{4}$-in. bolt and is therefore known as a $\frac{3}{4}$-in. wrench. The size of wrench is always

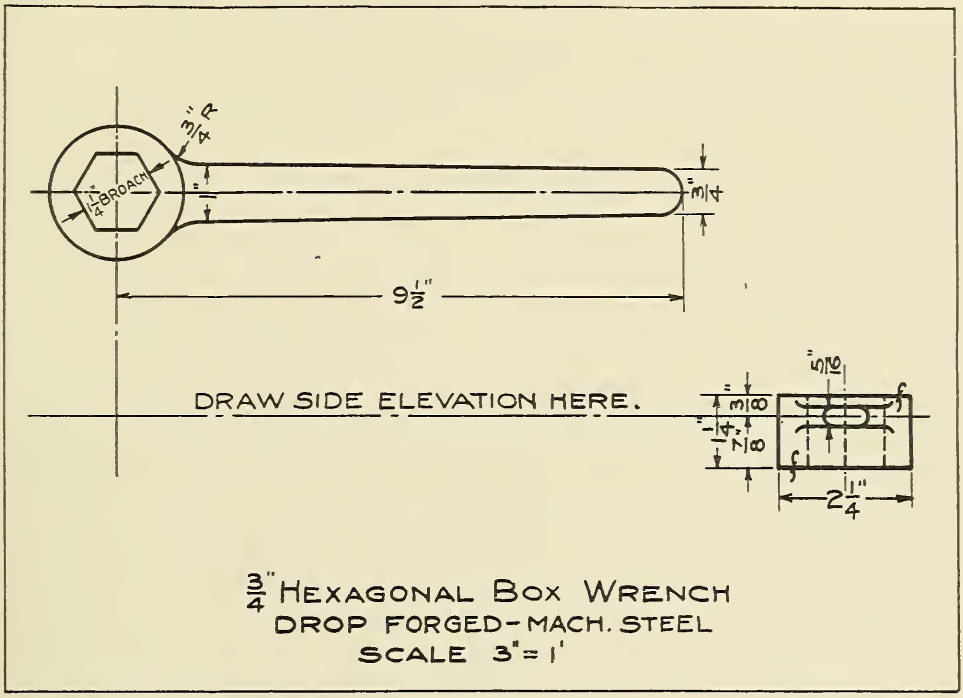


FIG. 34.

designated by the size of the bolt whose nut or head it will span, rather than by the size of opening of its jaws. The hexagon is a regular six-sided figure. All the sides of it are equal and are the same length as the radius of a circle which just passes through the corners. This fact is of use in

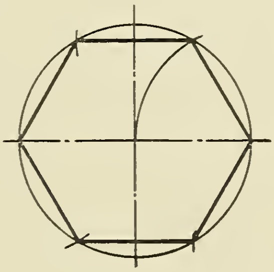


FIG. 35.

laying out the hexagon, as shown in Fig. 35. The width of the hexagon is given as $1\frac{1}{4}$ in. To lay it out, we must calculate the distance between the opposite corners, this being the diameter of the construction circle. This distance is 1.155 times the width of the hexagon.

$$1.155 \times 1\tfrac{1}{4} = 1.444$$

This is very close to $1\frac{7}{16}$ in. For the purpose of making the drawing we can draw a light circle of this diameter or of $\frac{23}{32}$-in. radius; then, beginning where the circle cuts the horizontal center line and using the compass, we can divide the circle into 6 equal parts by stepping off the radius ($\frac{23}{32}$ in.) around the circle as shown in Fig. 35. By connecting the adjacent points thus found, we will have a hexagon approximately $1\frac{1}{4}$ in. across. In dimensioning a hexagon, the short diameter or distance across the flats (in this case, $1\frac{1}{4}$ in.) is always given rather than the distance across the corners, because it is by the short diameter that hexagon stock is designated.

ASSIGNMENT 4

14. Drawing from Objects.—Aside from the ability which he acquires to read drawings, the chief use that the shop mechanic has for a knowledge of drawing is in making occasional sketches for special tools or repair parts for machines. In the case of special tools, the drawing must often be made from a mental picture which the man has of what he wants, getting the principal dimensions from the machine to which it is to be adapted and from the work to be done.

Drawings may be made from actual objects in the case of broken machine parts, so that new parts can be made; or, in the case of pieces to be altered, so as to better adapt them to the work intended; or as a matter of making a shop record of a piece of work already done. For such work, one should have his calipers, both inside and outside, a scale or rule for taking measurements, and in some cases a protractor for measuring angles will also be needed.

There are many points to consider in measuring an object and making a drawing of it, but a good mechanic is often better endowed with common sense in this respect than is a regular draftsman, because he knows better the operations used in making a piece and can see what dimensions are most important. A few *don'ts* by way of caution will point out some of the most common errors in this sort of work. These are taken from "Don'ts for Draftsmen and Machinists," published by "Machinery."

Don't forget fillets.

Don't repeat dimensions.

Don't use fancy lettering.

Don't put unnecessary finish on parts.

Don't forget clearance for moving parts.

Don't ever forget to put the scale on a drawing.

Don't fail to sign all drawings which you make.

Don't give dimensions in 32nds when 8ths are close enough.

Don't put important dimensions where they may be overlooked.

Don't omit minor details; it causes endless confusion and delay.

Don't fail to use stock sizes of drills, reamers, etc., when possible.

Don't make three or four different views of a piece when one or two views will do as well.

Don't forget center lines. A circle without its center lines looks like a bald-headed man.

Don't put a lot of cored work on a "one-casting-only" job. A little extra metal is cheaper.

Don't imagine rough castings come just like the drawing; they vary and you must allow for it.

Don't give the same dimension twice, for it is liable to lead to errors when this dimension is changed.

Don't leave some dimensions to be gotten by adding a lot of other dimensions together or by subtracting them.

Don't forget that the molder despises sharp square corners; internal ones more than the external ones.

Don't, when lines are close together, make arrows so that the workmen cannot tell which line they go to.

Don't put all dimensions on, then all arrowheads; you are sure to miss some of the latter by this method.

PROBLEM 4A

For this problem the student should make a mechanical drawing from some object as discussed in Art. 14. The following things are suggested as being suitable for this work:

- Bearing Cap (from lathe or steam engine)
- Stuffing Box Gland (from steam pump)
- Bracket (of any kind)
- Plain Bearing Block
- Journal Brasses (from railroad car or engine connecting-rod)
- Valve Chest Cover (from steam engine or steam pump)
- Cylinder Head (from steam engine or pump or gas engine)
- Gear Box Cover (from automobile)
- Valve Rocker Arm (from gas engine)

The piece selected should be made in one piece and should not have any threads or tapped holes, as the representation of screw threads has not been discussed as yet.

If such objects, or models of them, are not available, problem 4B may be substituted.

PROBLEM 4B

Fig. 36 shows a side and end view of a cast-iron bracket such as is used to support the cam shaft on a horizontal gas engine. It consists of a flat rectangular plate with four holes drilled through it, an arm strengthened by a deep rib, and a hub on the end drilled for the cam shaft. The bracket is fastened to a planed spot on the base of the engine by four $\frac{3}{4}$-in. cap screws through the holes in the base of the bracket.

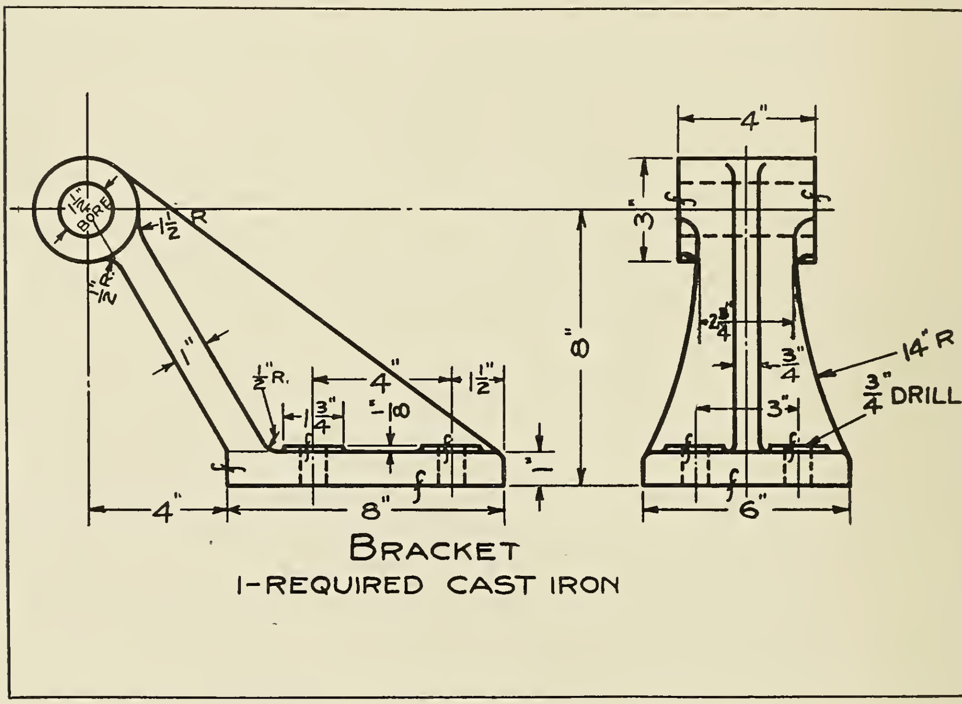


Fig. 36.

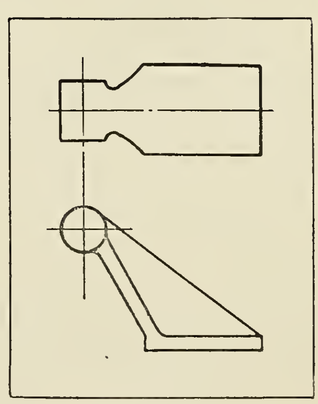


Fig. 37.

The views shown here are not the best. The bracket would be shown to better advantage if the top view were drawn instead of the end view. The student is to make a drawing of this bracket using the side view and the top view. In Fig. 37 are shown roughly the views wanted. The student should select a scale that will make the drawing look well on the sheet.

CHAPTER II

ASSIGNMENT 5

SCREWS AND SCREW FASTENINGS

15. The Nominal or Outside Diameter.—The Nominal Diameter of any screw or bolt is the diameter at the top or outside of the threads. By nominal diameter we mean the diameter by which the bolt is known. This is the diameter given in the first column of the bolt table, page 34. Thus, a $\frac{5}{8}$-in. bolt measures $\frac{5}{8}$ in. in diameter at the top or outside of the threads.

16. The Root or Effective Diameter.—The Root Diameter of a screw is the diameter at the bottom or root of the threads. This is the dimension from which the strength of the screw is

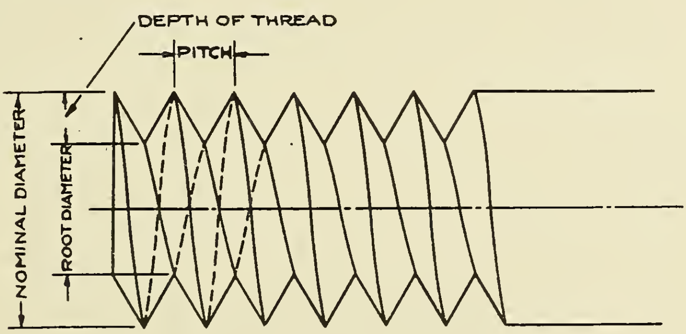


Fig. 38.

calculated, because it is the smallest diameter and hence the weakest. The nominal and root diameters are shown in Fig. 38.

17. Depth of Thread.—The Depth of the thread is the radial distance between the top and bottom of the threads; that is, measured in a direction straight outward from the center.

18. Forms of Threads.—The most common thread forms are the V, U. S. standard, Square, Acme, Worm, and Whitworth. Other shapes may be designed to meet special conditions. Fig. 39 shows the outlines of the above named threads.

19. The V Thread.—The V thread has an angle of 60° between the sides and is pointed at the top and bottom. Its use is confined chiefly to small screws.

20. The U. S. Standard Thread.—The United States standard thread was designed by Mr. William Sellers of Philadelphia and recommended by the Franklin Institute of that city in 1864. It was later adopted in a modified form by the U. S. government and is now variously known as the Seller's, the Franklin Institute, and the U. S. standard thread. It is similar to the V thread with the exception that the top and bottom of the thread are flat, thus leaving a larger root diameter and therefore making a

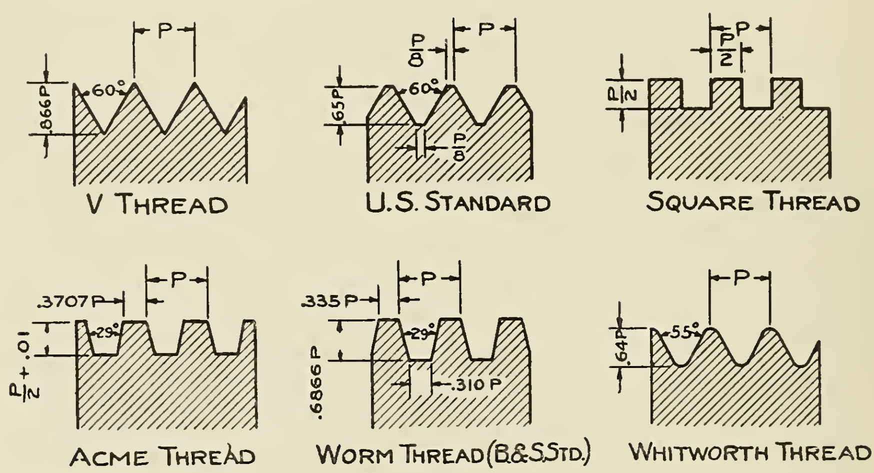


Fig. 39.

stronger bolt than if the V thread were used. It is used generally for bolts, studs and cap screws. The width of the flat surface at the top and bottom of the threads is one-eighth of the pitch.

21. The Square Thread.—The Square thread has not been standardized. It is used for heavy work to transmit motion or power, as in jack screws and screw presses, but each manufacturer has his own standards of pitch. It is quite common practice to use a pitch twice as great as on a U. S. standard bolt of the same diameter. The square thread is more difficult to cut than the other forms of threads.

22. The Acme Thread.—The Acme thread is a compromise between the square and U. S. standard threads. It is as deep as the square thread, but is stronger and easier to cut. It is used a great deal for feed screws, lead screws, etc., on lathes and other machine tools.

23. The Worm Thread (Brown and Sharpe Standard).—This is used for the threads of worms in worm and worm-wheel combinations. It is really a form of gearing, but is cut in a lathe and is therefore given the name of *thread*. It is a much deeper thread than the Acme, with the same angle (29°) between the sides of the threads.

24. The Whitworth Thread.—The Whitworth thread is the standard used in England. It was designed by Sir Joseph Whitworth in 1841, but has been slightly modified since that time. It is more difficult to form than either the V or the U. S. standard, as the thread tools must be ground so as to make the exact curves at the top and bottom.

25. Pitch.—Usually the threading of a bolt or screw is described by telling the number of threads per one inch of length, thus—"8 threads per inch," or simply "8 pitch." However, in giving the proportions of any given thread, we usually describe them in terms of the *pitch*. This is the distance from any point of a thread to the corresponding point on the next thread, as shown in Fig. 38, and is designated by the letter *P*, as shown in Fig. 39. The pitch of a single-threaded screw is the distance the screw or nut will advance in one complete turn. Thus a screw having 8 threads per inch has a pitch of $\frac{1}{8}$ in. and would advance $\frac{1}{8}$ in. in one complete turn.

26. Bolts.—A bolt is a bar with a head on one end and a thread for a nut on the other. It is used to fasten two parts together by passing through them and clasping them together between the head and nut, as shown in the case of the two angles of Fig. 40. Unless otherwise stated, it is understood that bolts have the

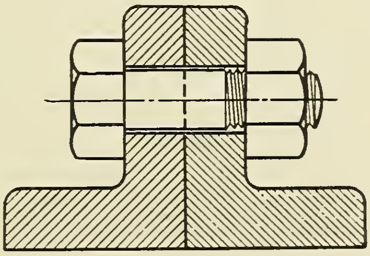


Fig. 40.

U. S. standard thread, as this thread is in common use by bolt manufacturers. Bolts are designated by the shape of the head. The kinds usually employed in machine work are the square head and the hexagon (or "hex") head machine bolts (Figs. 41 and 43). The round or bar length of the bolt is called the *stock*, and carries on its end the thread for the nut. There are numerous special kinds of bolts used in special industries; for example, there are plow bolts, carriage bolts, stove bolts, etc.

DIMENSIONS OF U.S. STANDARD BOLTS, HEADS, & NUTS.

ROUGH.

DIA. OF BOLT	No. OF THDS PER INCH	SHORT DIA. OF HEADS & NUTS HEX. & SQ (DIST. ACROSS FLATS)	LONG DIAMETER OF HEADS & NUTS (DIST. ACROSS CORNERS)		THICKNESS HEXAGON & SQUARE		DIA OF TAP DRILL (NEAREST 64TH)	ROOT DIAMETER
			HEXAGON	SQUARE	HEADS	NUTS		
$\frac{1}{4}$	20	$\frac{1}{2}$	$\frac{37}{64}$	$\frac{23}{32}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{13}{64}$	.185
$\frac{5}{16}$	18	$\frac{19}{32}$	$\frac{11}{16}$	$\frac{27}{32}$	$\frac{19}{64}$	$\frac{5}{16}$	$\frac{1}{4}$	.240
$\frac{3}{8}$	16	$\frac{11}{16}$	$\frac{51}{64}$	$\frac{31}{32}$	$\frac{11}{32}$	$\frac{3}{8}$	$\frac{5}{16}$	.294
$\frac{7}{16}$	14	$\frac{25}{32}$	$\frac{29}{32}$	$1\frac{7}{64}$	$\frac{25}{64}$	$\frac{7}{16}$	$\frac{23}{64}$	.344
$\frac{1}{2}$	13	$\frac{7}{8}$	$1\frac{1}{64}$	$1\frac{1}{4}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{27}{64}$	.400
$\frac{9}{16}$	12	$\frac{31}{32}$	$1\frac{1}{8}$	$1\frac{3}{8}$	$\frac{31}{64}$	$\frac{9}{16}$	$\frac{15}{32}$	.454
$\frac{5}{8}$	11	$1\frac{1}{16}$	$1\frac{15}{64}$	$1\frac{1}{2}$	$\frac{17}{32}$	$\frac{5}{8}$	$\frac{17}{32}$	.507
$\frac{3}{4}$	10	$1\frac{1}{4}$	$1\frac{29}{64}$	$1\frac{25}{32}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{41}{64}$	.620
$\frac{7}{8}$	9	$1\frac{7}{16}$	$1\frac{43}{64}$	$2\frac{1}{32}$	$\frac{23}{32}$	$\frac{7}{8}$	$\frac{3}{4}$	.731
1	8	$1\frac{5}{8}$	$1\frac{7}{8}$	$2\frac{19}{64}$	$\frac{13}{16}$	1	$\frac{55}{64}$	.837
$1\frac{1}{8}$	7	$1\frac{13}{16}$	$2\frac{3}{32}$	$2\frac{9}{16}$	$\frac{29}{32}$	$1\frac{1}{8}$	$\frac{31}{32}$	.940
$1\frac{1}{4}$	7	2	$2\frac{5}{16}$	$2\frac{53}{64}$	1	$1\frac{1}{4}$	$1\frac{3}{32}$	1.065
$1\frac{3}{8}$	6	$2\frac{3}{16}$	$2\frac{17}{32}$	$3\frac{3}{32}$	$1\frac{3}{32}$	$1\frac{3}{8}$	$1\frac{13}{64}$	1.160
$1\frac{1}{2}$	6	$2\frac{3}{8}$	$2\frac{3}{4}$	$3\frac{23}{64}$	$1\frac{3}{16}$	$1\frac{1}{2}$	$1\frac{21}{64}$	1.284
$1\frac{3}{4}$	5	$2\frac{3}{4}$	$3\frac{3}{16}$	$3\frac{57}{64}$	$1\frac{3}{8}$	$1\frac{3}{4}$	$1\frac{17}{32}$	1.491
2	$4\frac{1}{2}$	$3\frac{1}{8}$	$3\frac{39}{64}$	$4\frac{27}{64}$	$1\frac{9}{16}$	2	$1\frac{3}{4}$	1.712
$2\frac{1}{4}$	$4\frac{1}{2}$	$3\frac{1}{2}$	$4\frac{3}{64}$	$4\frac{61}{64}$	$1\frac{3}{4}$	$2\frac{1}{4}$	2	1.962
$2\frac{1}{2}$	4	$3\frac{7}{8}$	$4\frac{31}{64}$	$5\frac{31}{64}$	$1\frac{15}{16}$	$2\frac{1}{2}$	$2\frac{7}{32}$	2.176
$2\frac{3}{4}$	4	$4\frac{1}{4}$	$4\frac{29}{32}$	$6\frac{1}{64}$	$2\frac{1}{8}$	$2\frac{3}{4}$	$2\frac{15}{32}$	2.426
3	$3\frac{1}{2}$	$4\frac{5}{8}$	$5\frac{11}{32}$	$6\frac{17}{32}$	$2\frac{5}{16}$	3	$2\frac{11}{16}$	2.629

27. Bolt Heads and Nuts.—The heads and nuts of machine bolts may be either square or hexagonal, as desired. These have the same principal dimensions so that the same wrenches can be used on either. The table, page 34, shows the dimensions of the U. S. standard rough-forged nuts and heads. Finished heads and nuts are $\frac{1}{16}$ in. smaller in width than the dimensions given here.

In representing a bolt head or nut on a drawing, we do not go to the trouble to lay it out precisely from the dimensions given in the table, unless the bolt itself is the main part of the drawing. If the bolt is only a detail of the drawing we generally use a simple system which represents very nearly the exact sizes and saves much time in drawing. In Figs. 41, 42, 43 and 44 are shown the different views of square and hexagon bolt heads as they are

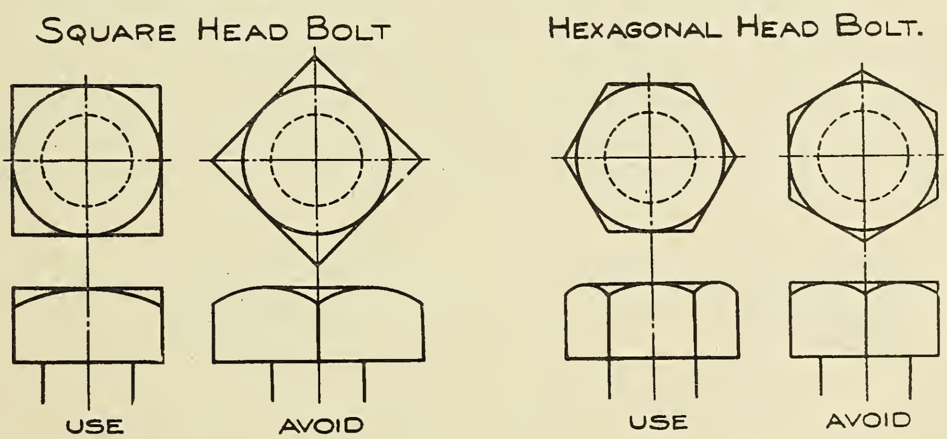


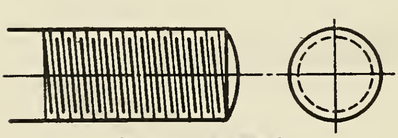
FIG. 41. FIG. 42. FIG. 43. FIG. 44.

usually drawn. The views of Figs. 41 and 43 are usually preferred because they indicate more clearly in the elevation that the heads are square or hexagonal. Figs. 42 and 44 both have two faces showing in the elevation and therefore might be confused.

In drawing the square head of Fig. 41 the width of the square is made about $1\frac{3}{4}$ times the bolt diameter. The draftsman does this by eye. The height of the head in the front elevation is made half the width of the head or a little less than the bolt diameter. The height of a nut is made the same as the bolt diameter. The champfer (the bevelling of the corners on top) is shown by the full circle in the top view. In the front view we represent this by an arc, with radius equal to the width of the head, drawn tangent to the top of the head.

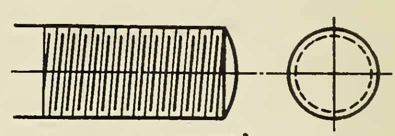
To represent the hexagonal head or nut (Fig. 43) the draftsman extends the lines representing the bolt stock. This gives one face of the head in the front elevation. One-half this width is set out on each side, for the other two visible faces. The top line is next drawn at a height a little less than the bolt diameter. The champfer is then shown. In the front face this is drawn with a radius equal to the bolt diameter. On the side faces a radius about one-third as great is used. In drawing the top view of a hexagon head, we locate the center lines and draw a broken circle to represent the stock of the bolt. With the diameter of the bolt as a *radius* we then draw a light construction circle, and in this we draw a hexagon as shown in Fig. 35. We then erase the construction circle. Within the hexagon and just touching each side of it, we draw a circle to represent the champfering or bevel on the top corners.

28. Thread Conventions.—Draftsmen usually show threads in side view by the conventional straight-line method shown in Figs. 45 and 46. The long light lines represent the tops or



R. H. THREAD.

Fig. 45.



L. H. THREAD.

Fig. 46.

"lands" of the thread while the short heavy lines represent the bottoms or "roots" of the thread. These lines should be evenly spaced and should be given a slight slant. On a single-threaded screw, one end of a light line should lie approximately opposite the other end of its adjacent heavy line. Ordinarily no attempt is made to make the spacing of these lines comply exactly with the pitch of the screw.

The method of representing the end view of a screw is also shown in Figs. 45 and 46. The circle representing the "lands" of the threads is drawn solid, while the root circle is broken because it represents a hidden surface, namely, the bottom of the thread.

29. Right-hand and Left-hand Threads.—The thread shown in Fig. 45 is a right-hand thread; that is, to screw a nut on to such a thread it would be necessary to turn it in a right-hand or clockwise direction. Compare this with Fig. 46, which shows a left-hand thread. Note that the thread lines in this figure are given a slant opposite to those shown in Fig. 45. Where the stock of the bolt ends, a heavy object line should always be shown as in these figures. At the place where the thread terminates a light line should be drawn straight across the bolt. The end of the stock should always be rounded, but its length should only be dimensioned to the corner where the rounded end begins and not to the extreme tip of the bolt.

Left-hand threads are not nearly so common as right-hand threads; hence, when a left-hand thread is desired it should be marked, *L. H. Thread.* It is not generally customary to mark right-hand threads as such; if marked, we would use the note *R. H. Thread.*

30. Tapped Holes.—The thread which is cut in any piece of metal to receive a screw is said to be "tapped." Ordinarily a hole is drilled in the piece to the same diameter as the inner diameter of the thread. A "tap" (which is somewhat like a

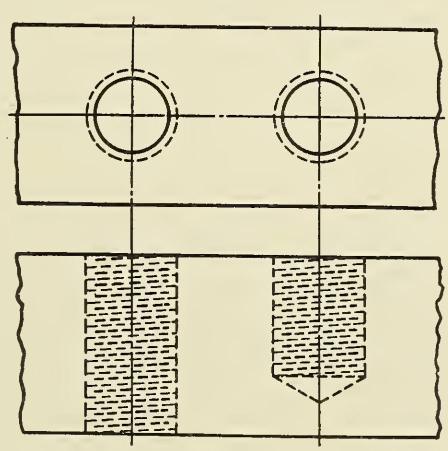


Fig. 47.

hardened bolt, having grooves for the cut metal to escape and sharp cutting edges on its threads) is then screwed into this hole, cutting a thread as it advances.

In representing a tapped hole in a drawing, the plan view of the hole is very simple. As shown in Fig. 47, the plan view shows a solid inner circle representing the hole drilled for the tap; a broken outer circle surrounds it to represent the hidden threads cut by the tap. This outer circle is drawn to the nominal diameter of the screw.

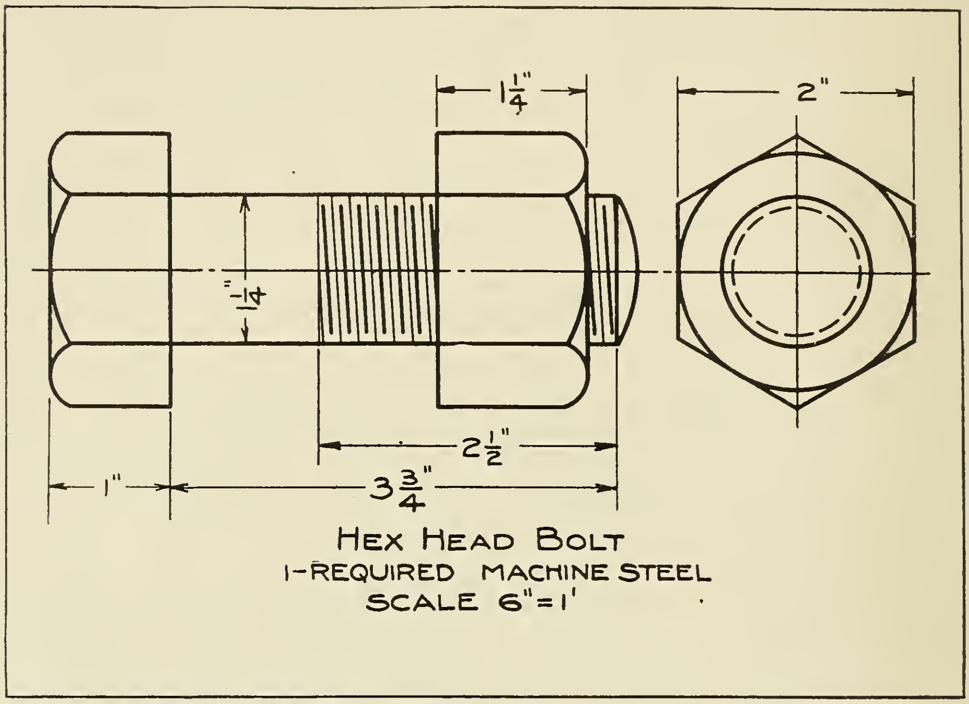

HEX HEAD BOLT
1-REQUIRED MACHINE STEEL
SCALE 6"=1'

FIG. 48.

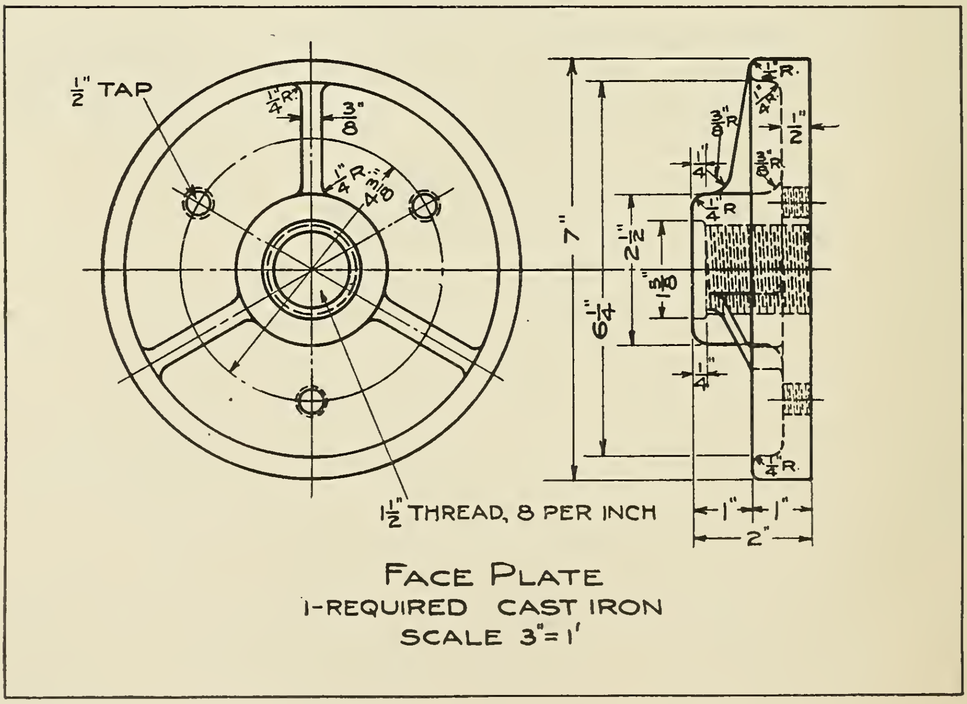

½" TAP
1½" THREAD, 8 PER INCH
FACE PLATE
1-REQUIRED CAST IRON
SCALE 3"=1'

FIG. 49.

The representation of a tapped hole in elevation must naturally be all in broken lines, since the hole is hidden from sight in this view. Fig. 47 shows the most common method of showing this. The threads are represented just as in Fig. 45, but with all broken lines. The hole at the left is drilled and tapped clear through the piece; that at the right, only part way through.

Fig. 48 shows a drawing of a $1\frac{1}{4}$ in.$\times 3\frac{3}{4}$ in. hex head machine bolt with nut using the conventional methods of showing the threads and the head and nut. The actual heights of head and nut and the true width (from the table, page 34) are given for the guidance of the blacksmith and machinist in making the bolt.

Fig. 49 shows a drawing involving several tapped holes. This is a special face plate for a lathe. It is to be tapped with a $\frac{1}{2}$-in. standard bolt tap at three points equally spaced on a circle of $4\frac{3}{8}$-in. diameter. These holes are for studs for attaching a special fixture to the face plate. In the center of the plate is an internal thread for screwing the face plate onto the spindle. The note referring to this hole is marked *THREAD* instead of *TAP*, because this is to be cut with a thread tool in a lathe in order to make it absolutely true.

31. Other Thread Conventions.—In Figs. 50 and 51 are shown

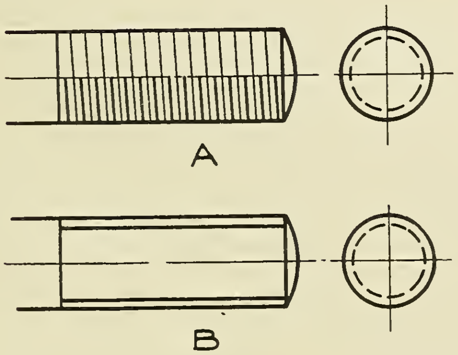


FIG. 50.

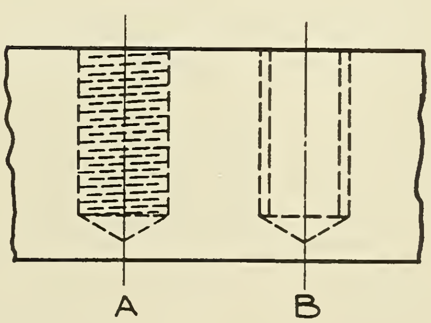


FIG. 51.

other conventions that are occasionally seen. The convention at *B* in these figures is especially simple and convenient for sketching purposes but has the great disadvantage that it bears no resemblance to screw threads and hence is not recommended.

32. Method of Drawing Square Threads.—In looking at any bolt, the threads present a slightly curved appearance as shown by the square threads in Fig. 52. In representing the threads on drawings of bolts, we use straight lines running across the bolt as in Fig. 48. The same principle is applied to showing square threads, as illustrated in Fig. 53. Whenever a square thread, or any thread other than the U. S. standard, is shown on a sketch, it is well to add a note calling attention to the fact and stating the number of threads per inch; thus: 3 *SQ. THDS. PER INCH.*

It is generally simpler to show a square thread or other special

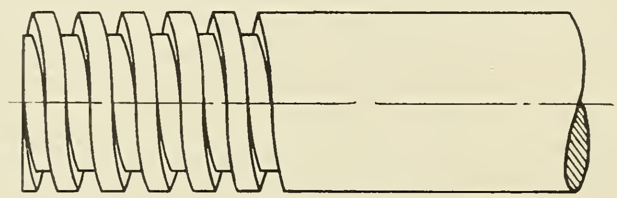


Fig. 52.

thread on a small piece by the "thread line" method of Fig. 45, being careful however to note that it is a square thread.

33. Cap Screws.—A cap screw is similar to a bolt, but is used without a nut. The head may be either square or hexagonal. A cap screw is used by passing it through one of the pieces to be fastened together and screwing the threaded part into the other piece. Fig. 54 shows the method of using cap screws in fastening a bracket to a machine. In this figure, the metal around the cap screw is broken away to show the cap screw clearly.

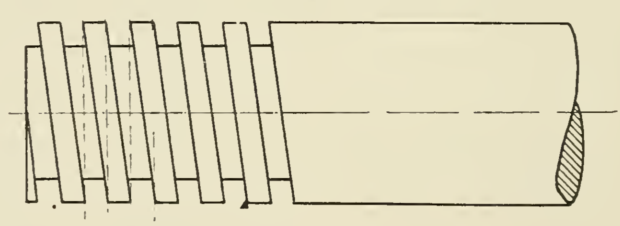


Fig. 53.

The heads of cap screws are smaller than those of bolts. The widths (or the short diameters) of hexagon heads for cap screws are standardized as follows:

For screws up to and including $\frac{7}{16}$ in., the heads are made $\frac{3}{16}$ in. wider than the screw stock.

For sizes $\frac{1}{2}$ in. and larger, the heads are made $\frac{1}{4}$ in. wider than the screw stock.

For square heads, the width is $\frac{1}{8}$ in. greater than the stock for sizes up to and including $\frac{3}{4}$ in. Above $\frac{3}{4}$ in. the heads are $\frac{1}{4}$ in. wider than the stock diameter. The height of the head is equal to the diameter of the screw. The top of the head is not flat like a bolt head, but is rounded with a radius equal to the long diameter of the head. Cap screws can also be obtained with any of the other heads shown in Fig. 55.

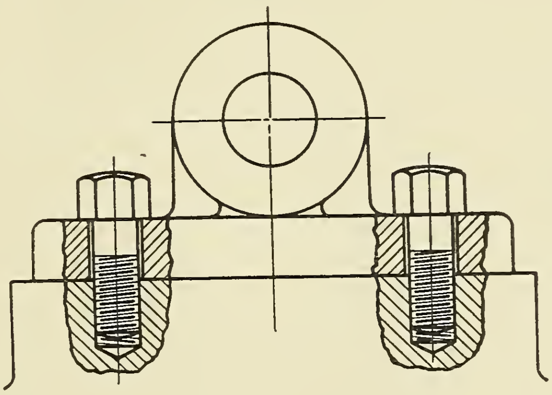
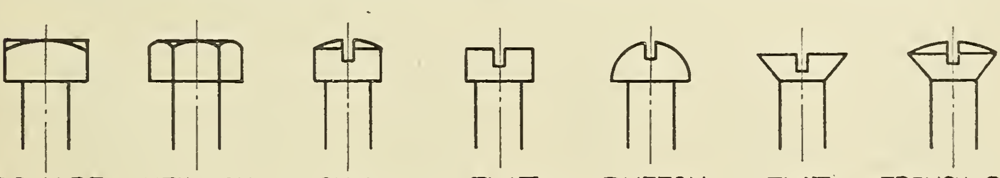


Fig. 54.

34. Machine Screws.—Machine screws are used for the same purpose as cap screws, but for small work only. Machine screws are generally used for sizes below $\frac{1}{4}$ in. They are made in screw gauge sizes and sold by the gauge numbers instead of the fractional inch sizes.

Fig. 55 shows some of the different kinds of heads for machine screws. The square and hexagonal heads are the only ones on



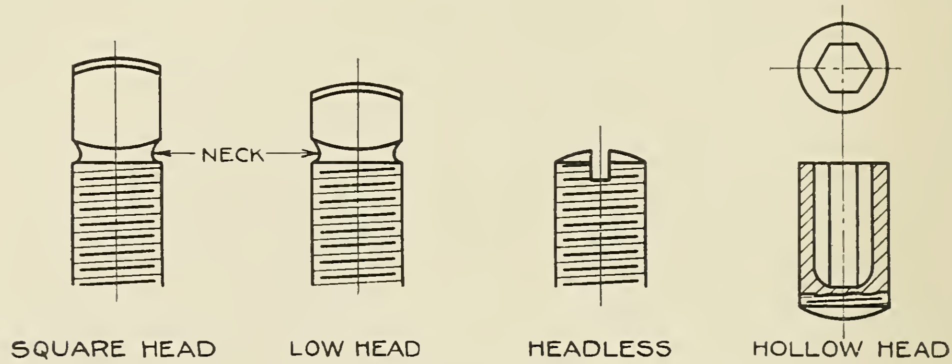
MACHINE SCREW HEADS

Fig. 55.

which a wrench can be used. These heads are usually thicker and of smaller diameter than the U. S. standard bolt heads. All of the other heads are provided with slots for a screw driver.

35. Set Screws.—A set screw is used to fasten two machine parts together by screwing through one part and pressing against the other. For example, in fastening a wheel to a shaft, the set screw passes through the hub of the wheel and presses against the shaft. It is a poor fastening for transmitting power, and should not be used if a key or square shaft can be used.

Fig. 56 shows some of the common forms of heads for set screws. The thickness of the head and the width across the flats are ordinarily made equal to the diameter of the screw. The headless set screw, in which a screw driver is used to turn it into place has the advantage that it can be screwed in so that there

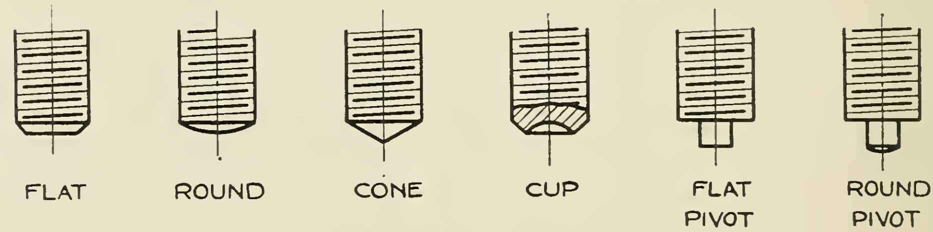


SET SCREW HEADS.

FIG. 56.

are no projecting parts to catch the clothing. It has the objection, however, that one side is apt to break off. To remedy this defect, a hollow head set screw has been designed. This requires a special wrench bent from a hexagon steel bar.

Set screws are sometimes "necked" under the head. This is done by cutting them down so that the diameter is a little less



SET SCREW POINTS.

FIG. 57.

than that of the root of the thread. This makes the "neck" the weakest part of the screw so that, if the screw should break when being tightened, it will break at the neck instead of in the hole.

The most common forms of set screw points are shown in Fig. 57. Any of the heads of Fig. 56 can be used with any of these points. In using a set screw on finished work, where the point of the screw is liable to burr or roughen the part against which it presses, a round brass piece called a "gib" is often dropped into the tapped hole so that the screw point presses against the gib and the gib against the part to be fastened. Set screws are made of steel and are usually case hardened.

36. Multiple Threads.—In all of the threads that we have considered so far, there has been but a single thread on the screw. It is sometimes desirable, however, to have more than one. If there are two separate threads on the screw, it is called a *double thread*, if three threads, a *triple thread;* and if there are four threads, it is a *quadruple thread.*

In Fig. 58 is shown a double-thread screw. Compare it with Fig. 38. The outside diameter of the screw, the root diameter,

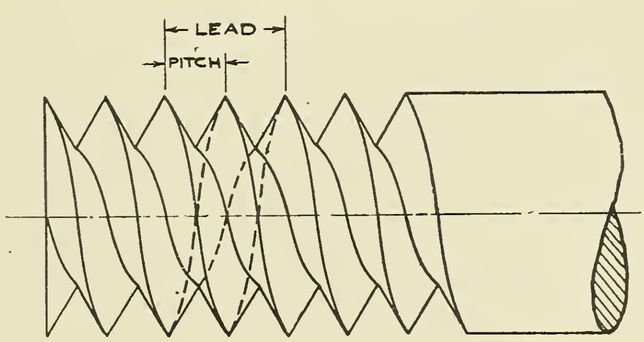


Fig. 58.

the depth of the threads, and the pitch are the same in both cases, but the amount that the thread advances in one turn or revolution of the screw is twice as great in the double thread as in the single thread, and the lines of the threads in the sketches must be given a correspondingly greater slant than in the case of single threads.

37. Lead.—The distance that the thread advances along the screw per revolution is called the *lead* (pronounced as if spelled "leed"). For a triple thread, the lead would be three times the pitch. Multiple threads are used when it is desired to secure a greater advance per revolution, without reducing the root diameter of the screw. Any of the threads of Fig. 39 may be made multiple. Wherever a multiple thread appears on a sketch, a note should state the fact, giving complete information.

PROBLEM 5A

Fig. 59 shows a sketch of a valve stem for a 3-in. globe valve. This sketch only shows one view of the stem, but it will be understood that it is round at all points along its length except where the note indicates that it is to be made square. The hand wheel for operating the valve has a square hole which fits the square on the stem. A $\frac{5}{8}$-in. standard hexagon nut is then screwed on the small threaded end of the stem to hold the hand wheel. The valve disk has a grooved pocket on it which fits around the head shown at the right-hand end of the stem. There are two special features of the sketch that should be noted. The diagonal lines running

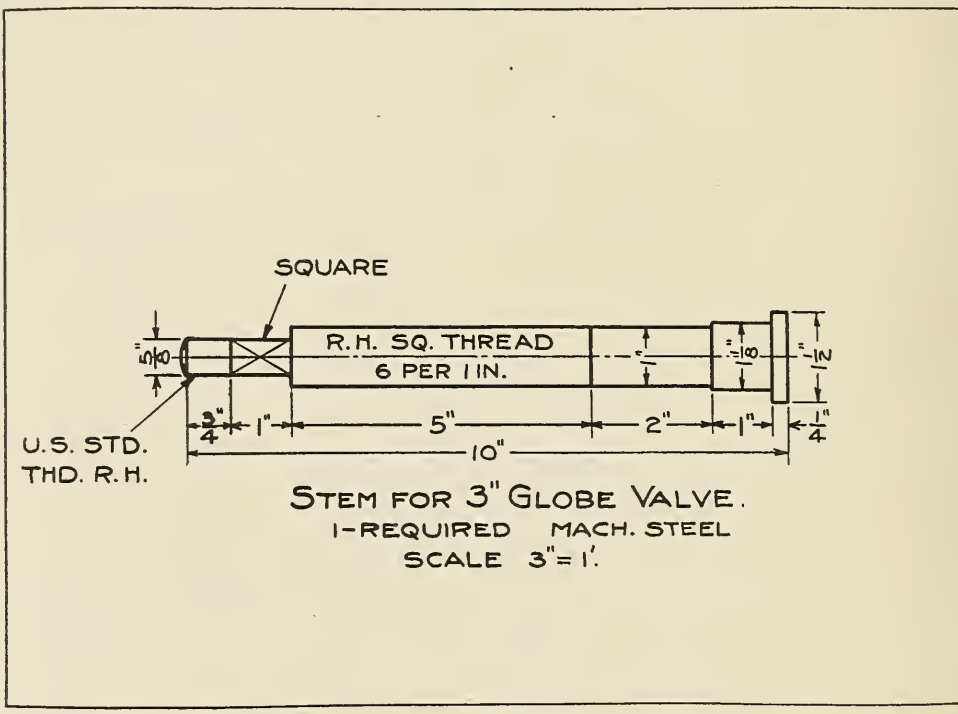


Fig. 59.

across the squared part indicate the extent of the part that is squared. This is a common convention for indicating, on a rough sketch, the side view of a squared part. The threaded parts are indicated only by notes. This is permissible for a preliminary sketch.

Make a drawing of this stem showing the square threading by the method of Fig. 53 and the U. S. S. thread on the end by the convention of Fig. 45. Also show the end view of the stem from the smaller (left) end.

PROBLEM 5B

For sketching from objects or models, the following lists are suggested, at least one drawing to be made from each list.

List A	*List B*
Square head machine bolt and nut	Lathe dog and screw
Hexagon head machine bolt and nut	Lathe cross feed screw
Eyebolt	Screw for jack screw
Turnbuckle and rod ends	Vise screw
Tool post and set screw	Bench screw

CHAPTER III

SECTIONS

ASSIGNMENT 6

38. The Use of Sections.—The uses of broken lines to show hidden parts were explained in Chapter I, Art. 6. Broken lines are not always satisfactory and are often confusing, especially if very numerous. For these reasons, the method of showing objects *in section* is frequently used to show interior constructions. This method consists in cutting away the parts which hide those we want to show, thus allowing the hidden parts to stand out in full view. This is called *cross-sectioning,* or *sectioning.* Such a view is called a *cross-section,* or more simply, a *section.* As a simple illustration, we have in Fig. 60 two ordinary views of a plain cast-iron collar, the hole being indicated in the

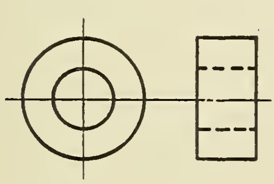


Fig. 60.

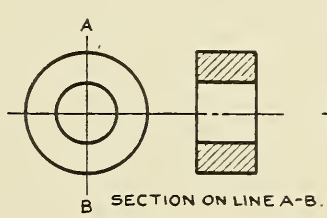


Fig. 61.

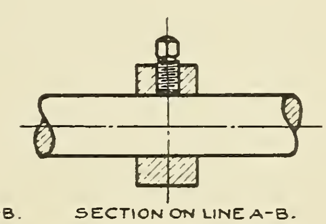


Fig. 62.

right view by the broken lines. Fig. 61 shows the same collar but with the hole shown by a *section* view. The end view is still shown in the usual manner, but, instead of the side view being shown by a front elevation, we imagine that the front half of the collar in this position has been cut away to show the inside. The light diagonal lines across the places where the metal would be cut form what is called the *cross-hatching.* These lines are drawn lightly about $\frac{1}{16}$ in. apart, and usually at an inclination of about 45 degrees. If we imagine that the cross-hatching lines represent the saw marks, then we can always tell what part is to be cross-hatched. When there is a hole or opening in the object there will, of course, be no saw marks and, hence, there is no cross-hatching in the area representing such hole or opening, as is clearly shown in Fig. 61.

Let us suppose that this collar is fastened to a shaft by a set screw. In order to show the arrangement of the shaft and screw inside of the collar, we can cut the collar in the same way, as shown in Fig. 62. To actually cut the collar we would also have to saw into the shaft and screw, but it is customary to consider them as not being cut, as it would only increase the work of making the drawing and would not make the construction of the collar any clearer.

As a general rule it may be stated that: *Bolts, screws, shafts, keys, arms of pulleys, etc., are not shown in section when cut along the line of their greatest dimension, that is, lengthwise.* If the section cuts *across* a shaft, screw, or similar object it might, in such a case, be cross-hatched.

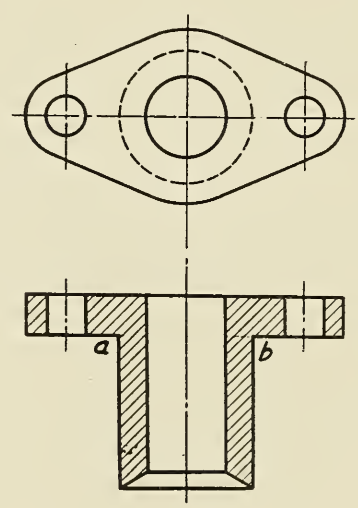
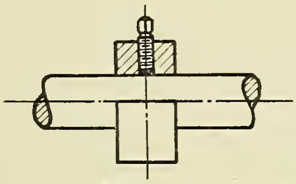


Fig. 63.

Fig. 63 shows a section of a gland for a stuffing box. The flange around the top projects all the way around. Consequently, in the section elevation, the lower edge of the flange might be shown by a broken line crossing the body from a to b. It is much better, however, to keep the section free from such complications and only depend on it to show the interior of the object. If it is necessary to show both inside and outside of the same view of an object it is better to use the principle of half sections.

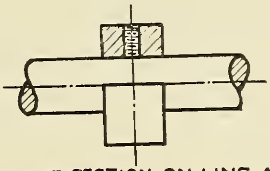
39. Half-sections.—When a figure is symmetrical about an axis (that is, alike on both sides of its center-line), it is a good plan to show only one half in section. Such a drawing is known as a "half-section" because we have only sawed half way through. Fig. 64 shows a half-section of the same collar as in Fig. 62. In Fig. 64 we really consider that the upper front quarter of the collar is removed. The horizontal cut thus produces a surface along the horizontal center-line, which is indicated by a heavy object line on the center-line of Fig. 64. Any peculiarities of the outside of the object would be shown by one half of the view, while the inside would be shown by the sectioned half of the view.

If a section passes through the center of a hole that is tapped with a right-handed thread, the thread is shown in the conventional straight line method, but the thread lines slant in a direction reverse to those of a right-handed outside thread. The threads which appear in the section are those on the far or rear side of the tapped hole; see Fig. 65. Fig. 64 shows the collar



HALF SECTION ON LINE A-B.

FIG. 64.



HALF SECTION ON LINE A-B.

FIG. 65.

with the set screw in place. Fig. 65 shows the same collar with the set screw removed, and the tapped hole which receives it exposed to view.

Half-sections often show the interior construction of an object so well that many broken lines may be conveniently omitted from the other half of the view. In the view that is half-sectioned, avoid running dimensions from the sectional part to the full part; rather show them in the other view of the object, unless the part dimensioned is shown by a full line in both parts of the view. Also avoid placing dimensions, or running extension or dimension lines across the cross-hatched portion of the view, although this is sometimes necessary.

Always put the cross-hatching on *after* putting on the dimensions, so that in case it is necessary to put a dimension in the cross-hatched area, a break may be made in the cross-hatching.

It does not make any difference in which direction the cross-hatching lines slant, so long as they make an angle of 45° with the horizontal, except that on the same piece they should all slant in the same direction. You will find it most natural, however, to begin in the upper left-hand corner of the view to be cross-hatched. The spacing can be judged by the eye, the lines being about $\frac{1}{16}$ in. apart.

40. Broken Sections.—Cutting planes need not always be continuous; they are very often broken or "zigzagged" so as to show the construction of the object in different planes. Fig. 66 shows a drawing of a bearing block. The cutting plane is passed

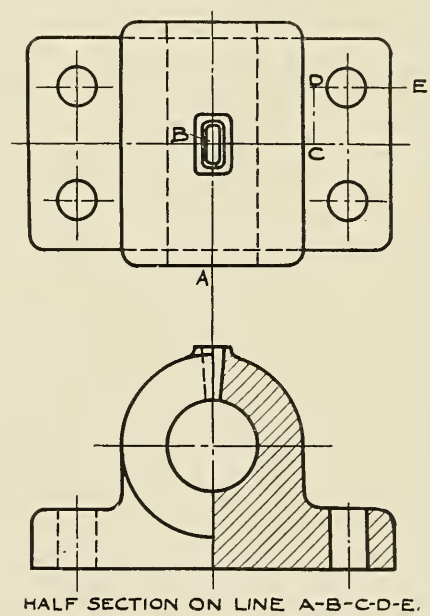


FIG. 66.

along the lines *ABCDE* in the upper plan so as to show the interior construction at the oil hole and also at a bolt hole.

Note that the surface *CD* where the cut is set over is not indicated in the section view. Since the bearing block is symmetrical about its axis, the other half may be shown conveniently as a full elevation view. When a section plane follows a devious outline as in this case, it is shown in the plan by the usual center-line convention. Appropriate letters and notes should show where the cutting plane is passed, and the section view should be labelled accordingly. It is general practice to omit such notes where the cutting plane is passed along the main center-line, as in Figs. 61, 62, 63, 64, and 65. Notes were used on these drawings merely for the information and direction of the student.

PROBLEM 6A

Fig. 67 shows a push-rod bushing or guide, used on a gasoline engine to guide the push-rod to the valve. This bushing is used with the hole vertical, being screwed into a hole tapped in the crank case. The upper part

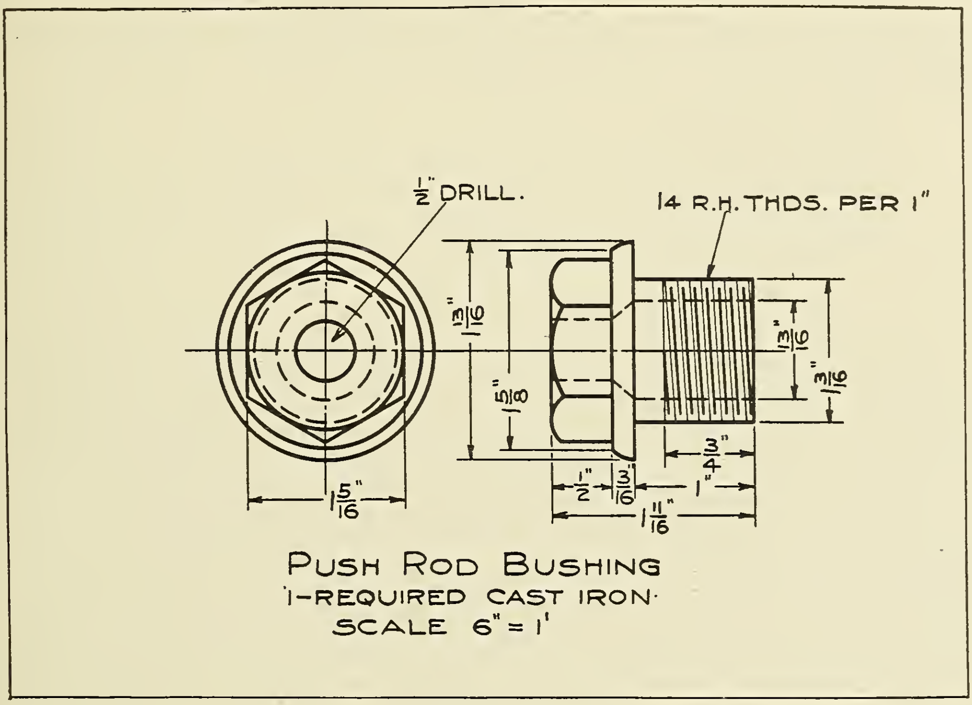


Fig. 67.

is bored to guide the $\frac{1}{2}$-in. push-rod, while the lower part is enlarged to $\frac{13}{16}$ in. to receive a helical spring used to return the push-rod and roller to place. The natural position of the bushing is shown in Fig. 68.

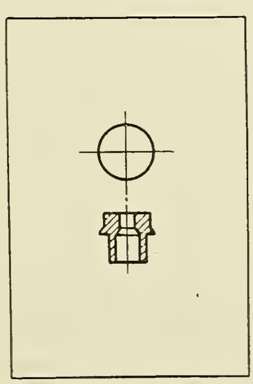


Fig. 68.

Make a full-size drawing of the bushing, giving the views shown in Fig. 68 and making the side elevation a full-section view. Remember that this will expose the broken lines of the bored holes as full lines. In making a section of an object that is threaded on the outside like this, it is necessary to show the threads as actual V-shaped notches on the sides of the object as in the drawing of the V thread, Fig. 39. As this bushing is made from a solid piece, the cross-hatching should all slant the same way.

PROBLEM 6B

The following objects are suggested, from which at least one should be sketched:

Shaft collar
Pipe tee or elbow
Pipe flange
Stuffing box gland
Any small solid pulley or gear blank.

ASSIGNMENT 7

41. Partial Sections.—When a section is needed to show the interior construction of a machine part in only one particular place, we can imagine the metal in front of that place broken away so as to leave the hidden parts exposed. This is the method that was used to show the cap screws in Fig. 54. To do this, a wavy line is drawn free-hand around the part, and the proper cross-hatching is placed inside the broken space. This makes it appear as if the metal had been broken away roughly.

42. Revolved Sections.—The necessity of drawing an extra view of an object may frequently be avoided by the use of a

Fig. 69.

revolved section. For an example of the revolved section see Fig. 69. Notice that it consists in drawing a cross section of the handle on the plan view, thus doing away with the necessity of making a separate end view in order to show the shape of the section of the handle.

Fig. 70 shows how a piece of an object may be broken out to leave room for the revolved section. This is especially desirable in this case because the arm tapers, and consequently the lines of the lower flange would cross the section if it were drawn on the object, as in Fig. 69, without breaking away the arm.

Fig. 71 shows a common method of showing sections where the sections are different at different points along a piece. The sections are drawn off the view but the lines at which they are taken are located on the drawing of the object. This method

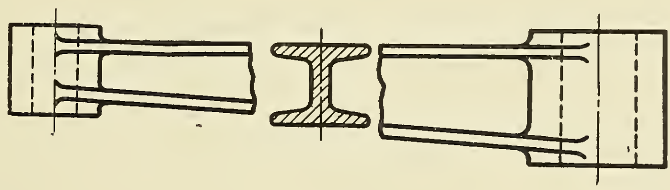


Fig. 70.

is frequently used in showing the shape of long parts such as lathe legs, connecting rods, etc.

Pulleys, hand wheels, gears, and other such circular objects are usually shown by two views, one of which is a section.

Fig. 72 shows a complete conventional drawing of a six-arm pulley. It will be noticed that the section plane is passed along the vertical center-line, but that the arms which would really be cut in making the section are not cross-hatched and, instead, the

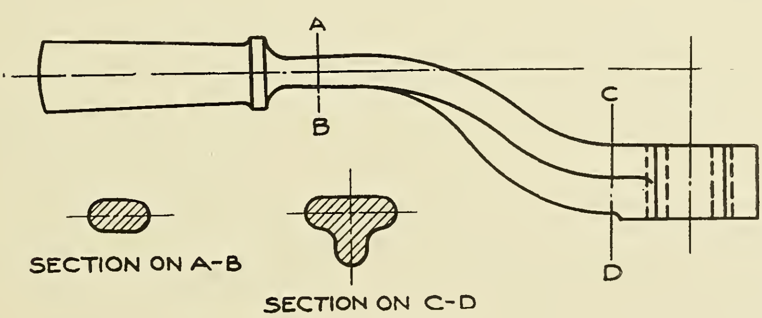


Fig. 71.

section is shown as if it passed just to one side of the arms. As stated in Article 38, it is the general practice not to cross-hatch the arms of pulleys, hand wheels, etc., when cut lengthwise. Only the hub and rim should be cross-hatched. It should be noted that the inside surfaces of the rim should be shown by full object lines all the way across, as if the section plane had been passed just in front of the arms, thus showing only the rim and hub in section.

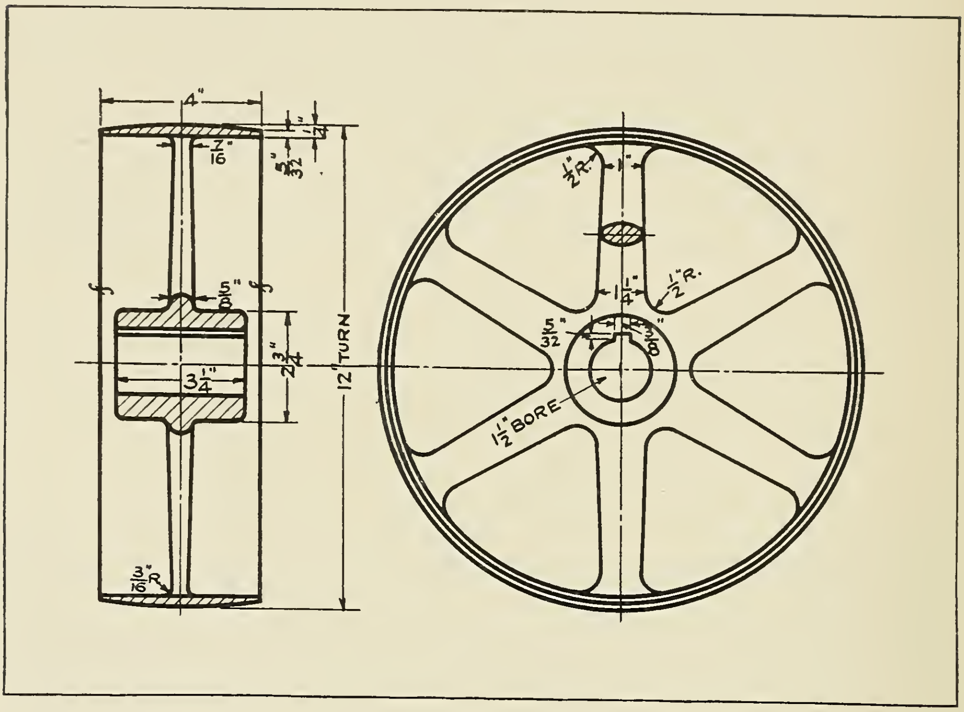


Fig. 72.

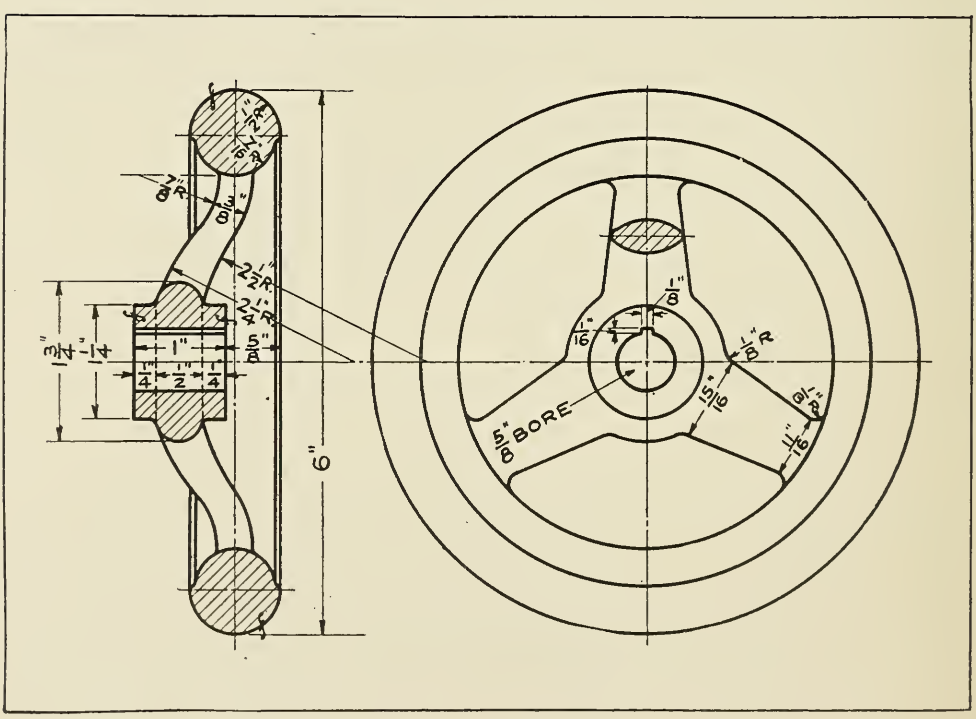


Fig. 73.

For greatest strength, the keyway should always be shown on the center-line of one of the arms, and not midway between two arms. The *face* of this pulley is 4 in. Instead of being flat or straight, it is *crowned*. Different authorities recommend that pulleys should be crowned (or have a rise of) from $\frac{1}{16}$ in. to $\frac{3}{8}$ in. per foot of width, but $\frac{1}{8}$ in. per foot of width is a good average. The crown is for the purpose of keeping the belt on the pulley. Pulleys for use with shifting belts should be straight or flat, that is, without crowning.

Note that the diameter of the pulley is marked *TURN*. This means that enough stock must be left on the pattern so that the pulley can be turned down to the required diameter.

A revolved section on one of the arms is used to give a clear idea of its cross section.

Quite often we encounter wheels of various kinds which have an uneven number of arms or spokes, so that no two arms have a common center-line. Fig. 73 shows a drawing of a hand wheel with three arms. Notice particularly how the arms are shown. In the section view only two arms are shown and they are shown full length as if they were directly opposite each other on the main vertical center-line of the hand wheel. The right-hand view is depended upon to show the number and arrangement of the arms, and also to show a revolved section of one of them. If we attempted to show them in the section view as they really appear when the hand wheel is in this position, the lower arm should appear shortened. It would be more difficult to show such inclined arms as they really are and would make the drawing less easy to read.

43. Shortened Views.—Fig. 70 illustrates a common practice in showing long slender objects, of breaking and leaving out part of the length in order that the piece may be shown on the paper without using too small a scale. The long arm in Fig. 70 is broken and the two end pieces placed closer together than they would actually be if the full arm had been drawn. This permits the use of a larger scale on the parts shown. The full length of the arm should, of course, be given in dimensioning.

PROBLEM 7A

Fig. 74 shows two views of a gate valve hand wheel. Draw the views shown in Fig. 75, making one view a half-section, sectioning the upper half and drawing an outside view of the lower half.

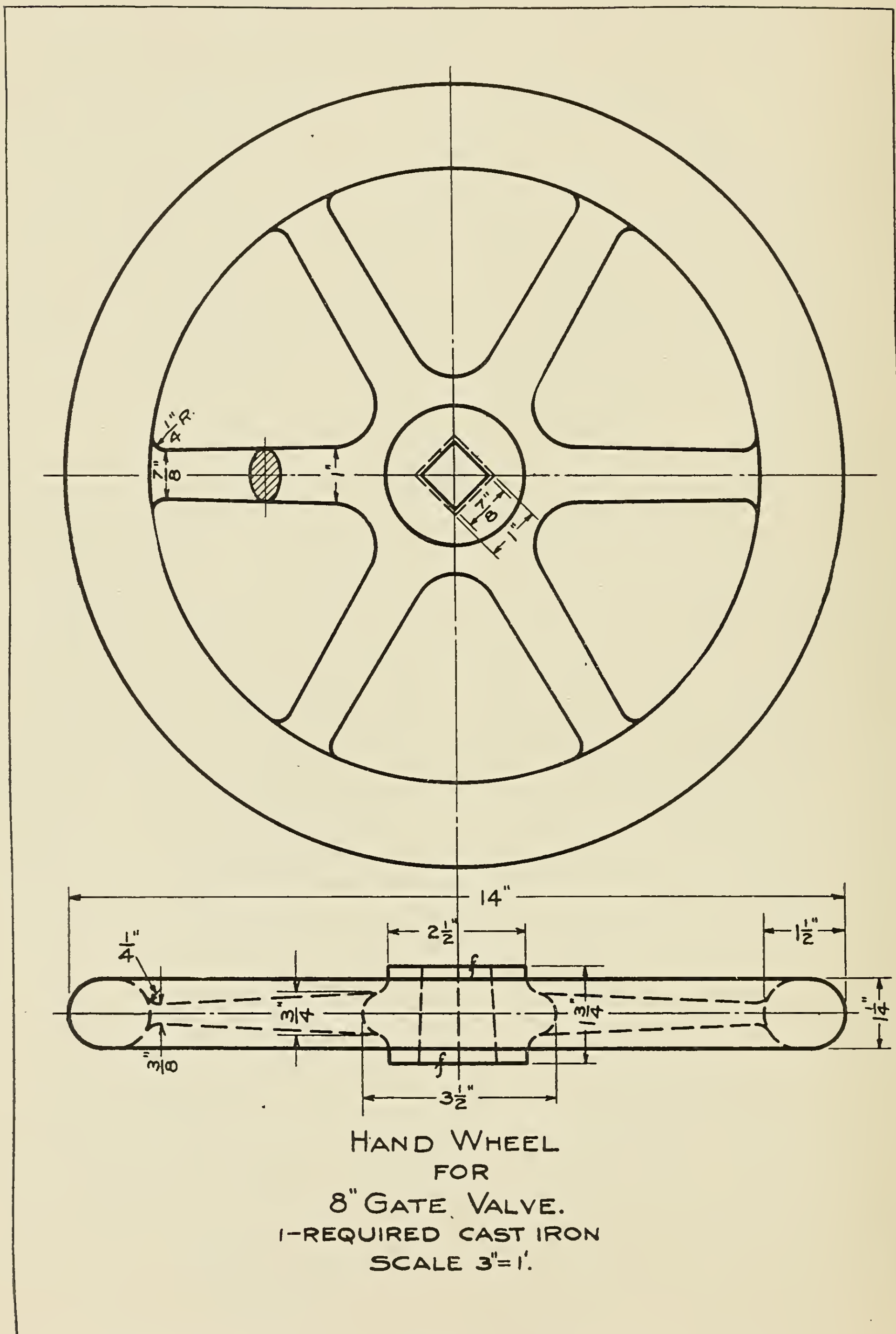

14"
$2\frac{1}{2}$"
$1\frac{1}{2}$"
$\frac{1}{4}$"
$\frac{3}{4}$"
$1\frac{3}{4}$"
$1\frac{1}{4}$"
$\frac{3}{8}$"
$3\frac{1}{2}$"
$\frac{7}{8}$"
1"
f
HAND WHEEL
FOR
8" GATE VALVE.
1-REQUIRED CAST IRON
SCALE 3"=1'.

Fig. 74.

Note that the square hole for the valve stem is tapered from 1 in. to $\frac{7}{8}$ in. Remember that the spoke is not to be cross-hatched.

In the majority of pulleys and wheels of various sorts, as in this case, the section of the spokes is an ellipse. An approximate ellipse can be drawn very readily by the method shown in Fig. 76. To start with, we usually have the long and short diameters of the ellipse. Lay these out and call

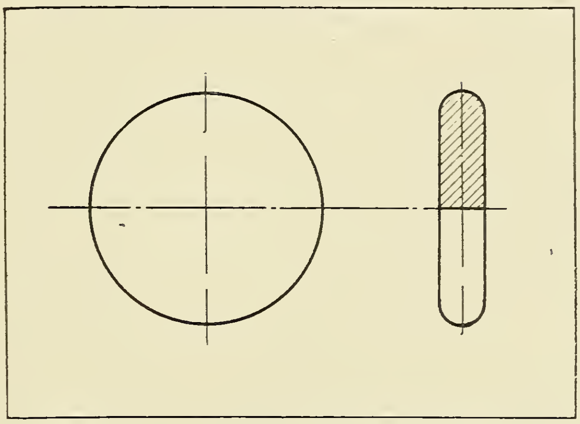


Fig. 75.

their half lengths *a* and *b*. Lay the length of *b* in from *m*, thus locating the point *d*. With the eye, divide the remaining distance from *d* to *o* into three equal parts. With the compass, swing one of these parts back to the other side of *d*, thus locating point *c*. This point *c* is the center of an arc forming the ends of the ellipse and the radius R_2 is the distance *mc*.

The distance *cn*, the remainder of the long diameter, is the radius R_1 for the flatter sides of the ellipse.

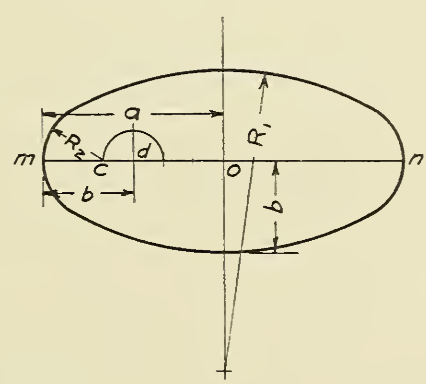


Fig. 76.

PROBLEM 7B

Make a drawing from some object or model involving sections, such as

Hand wheel	Lathe leg
Flywheel	Scythe or sickle blade
Pulley	Solid wrench
Trolley wheel	Drill press table bracket

ASSIGNMENT 8

44. Assembly Drawings in Section.—So far, the drawings have all been of single parts. Such drawings would be used in the shops to guide the men in the manufacture of the various pieces. In the case of a machine made up of several parts, we would have such detail drawings from which to make the several parts. It would also be necessary to have a drawing to show how these parts were to be put together. This drawing, showing the assembled machine, is called the *Assembly Drawing* or the *Assembly*.

Section views as applied to assembly drawings are highly im-

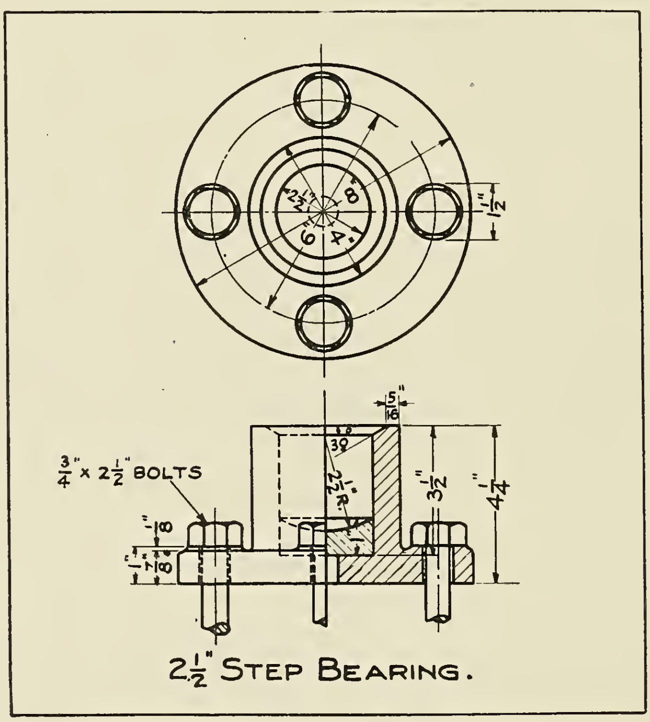


Fig. 77.

portant because of the simple and graphic manner in which they show the relation of the parts to each other. Assemblies in section are also freely used as illustrations in trade journals, in United States Patent Office drawings, in catalogues, and elsewhere, where line mechanical drawings might not be understood by people who had occasion to refer to them.

Assemblies may be drawn either wholly or partly in section, just as in the case of the sectioning of detail parts.

Fig. 62 shows a full section of an assembly—a collar secured to a shaft by means of a set screw. Fig. 64 shows the same assembly in half section. Half sections are sometimes preferable because they show the exterior as well as the interior construction. As in detail drawings, so in assemblies, it may be stated as a general rule that: *Bolts, screws, shafts, arms of pulleys, keys, etc., are not shown in section when cut along the line of their greatest dimension.*

Fig. 77 shows a half-section drawing of a step bearing. Such a bearing is used to support a vertical shaft at its base. It consists of a cast-iron housing enclosing a bronze footing. Cast iron is a poor bearing metal; hence, the use of the bronze footing. The footing is *cupped* on one side to a radius of $2\frac{1}{2}$ in. The end of the shaft is rounded to the same radius. Thus the shaft end and bearing are segments of a ball and socket. This keeps the

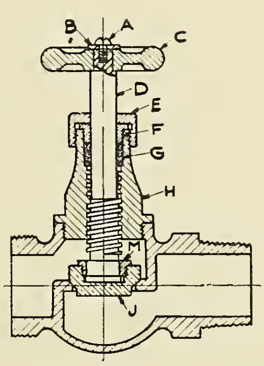


Fig. 78.

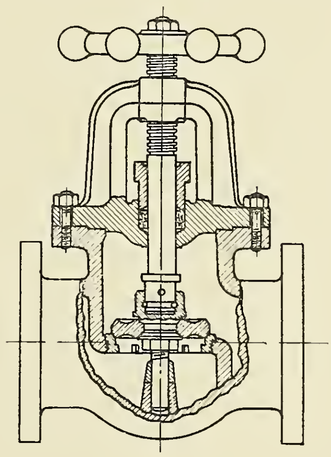


Fig. 79.

shaft centered in the step and yet allows for some flexibility of direction.

Fig. 78 shows a full section view of a simple globe valve. This section shows clearly the relations of the various parts. The valve stem D has a hand-wheel C at the top and a disk J at the bottom. The hand-wheel is secured to the stem by means of the set screw A which seats itself against the washer B and is tapped into the stem. The stem, in conformance with the general rule, is not sectioned, but the upper part of it is broken away to show more clearly the method of attaching the hand-wheel. The stem has a square thread which engages the thread in the hub H. The packing G is retained in place by the gland F, which in turn is caused to compress the packing by screwing down the cap E. The hub H is tapped into the body of the globe valve. It will be seen that the lower end of the stem forms a thin round head. The lock nut M above this ring is tapped into the valve disk J below it. The valve disk is thus responsive to any movement of the valve stem and its hand-wheel. The valve disk J is subjected to severe usage in service and it is, therefore, necessary to regrind or renew it from time to time. The arrangement shown in this view permits of such renewals quite readily.

As in detail drawings, so in assemblies, a section does not always follow a single straight line through the object. Fig. 66 showed such a case, where the section plane was shifted to show the details at different points. If bolts were shown in the bolt holes of this figure it would become an assembly and thus serve as a good example of an assembly section with a somewhat complicated section plane.

Fig. 79 shows a drawing of a globe valve in which only part of the body has been broken away. Only enough has been broken out to show the construction and relation of the important parts which are shown in section. The rest of the drawing is an exterior view and serves to show the external appearance of the valve. In this way, one drawing serves to show practically the entire form and construction, both inside and outside.

45. Conventions for Cross-hatching.—In showing a single object in a section drawing, it is generally considered best practice to do the cross-hatching with lines of uniform weight, spaced about $\frac{1}{16}$ in. apart. In section assembly drawings it is necessary to make some distinction between the different pieces. This is done by using different kinds of cross-hatching lines for different materials and by inclining the lines of adjacent parts in different directions. An examination of Figs. 77, 78, and 79 shows how the lines are given opposite slopes on pieces that touch each other, so that it will be more evident that they are different pieces. It should be noted well that the slant of the cross-hatching of each part is the same for that part wherever it is shown. For instance, in Fig. 78, the sectioning for the cap E is alike in both halves, while the same rule applies to the hub H and the various other parts. It may be stated as a fixed rule without exception that: *In an assembly section, each piece must have the same cross-hatching throughout.* Note also how the section lines of the various parts in contact are, as far as possible, at right angles to each other.

Fig. 80 shows a quite common system of cross-hatching for different materials. Fig. 81 shows a much simpler system, that is quite often used but that does not cover as wide a range of

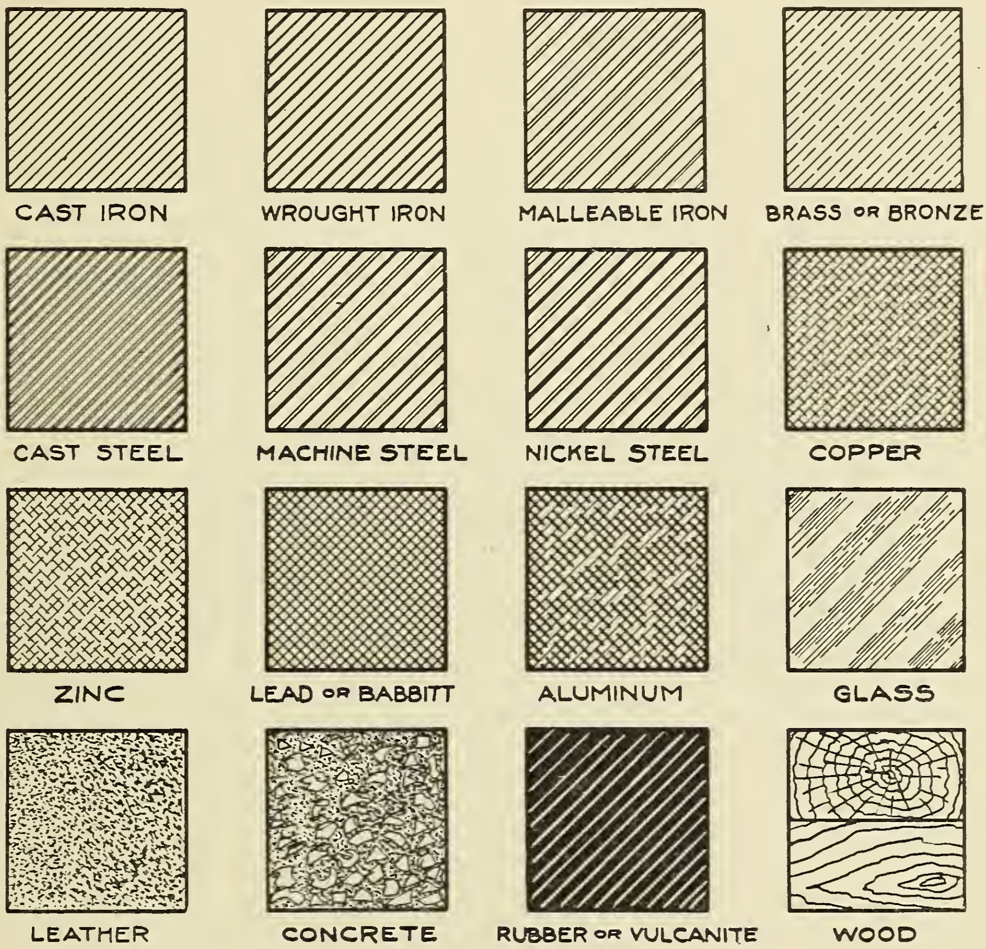


Fig. 80.

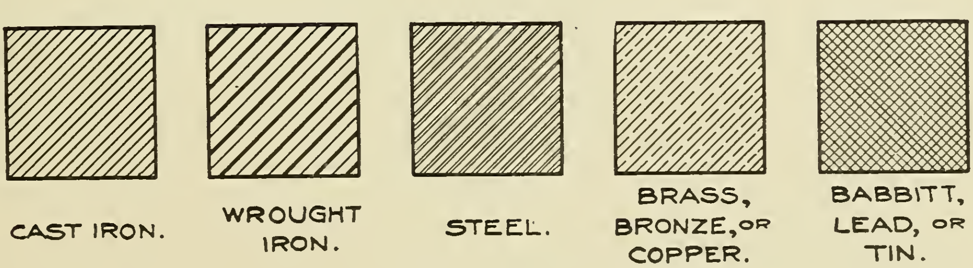


Fig. 81.

metals. There are no fixed rules governing these, as different drawing rooms have different standards. Each man should learn and use the standards of his own shop. It is becoming quite general to use the plain cross-hatching (cast-iron in Figs. 80 and 81) for all drawings of single parts, stating the material in the

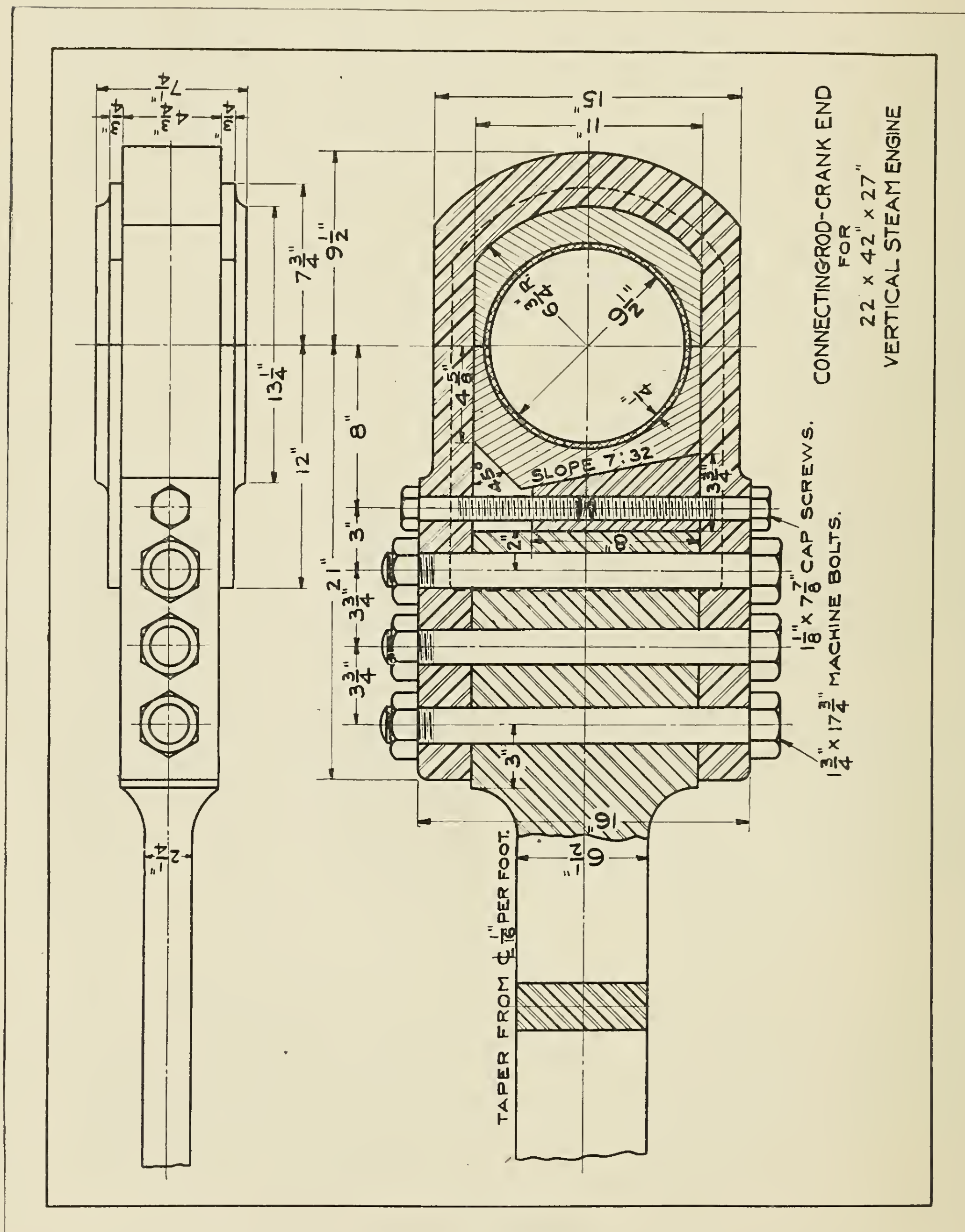


Fig. 82.

title. Then, a system sufficiently elaborate to cover all the work of a shop is used on assembly drawings.

Fig. 82 shows a broken section assembly of one end of a connecting rod using the conventions of Fig. 80. Instead of running the whole length of the drawing, the section is discon-

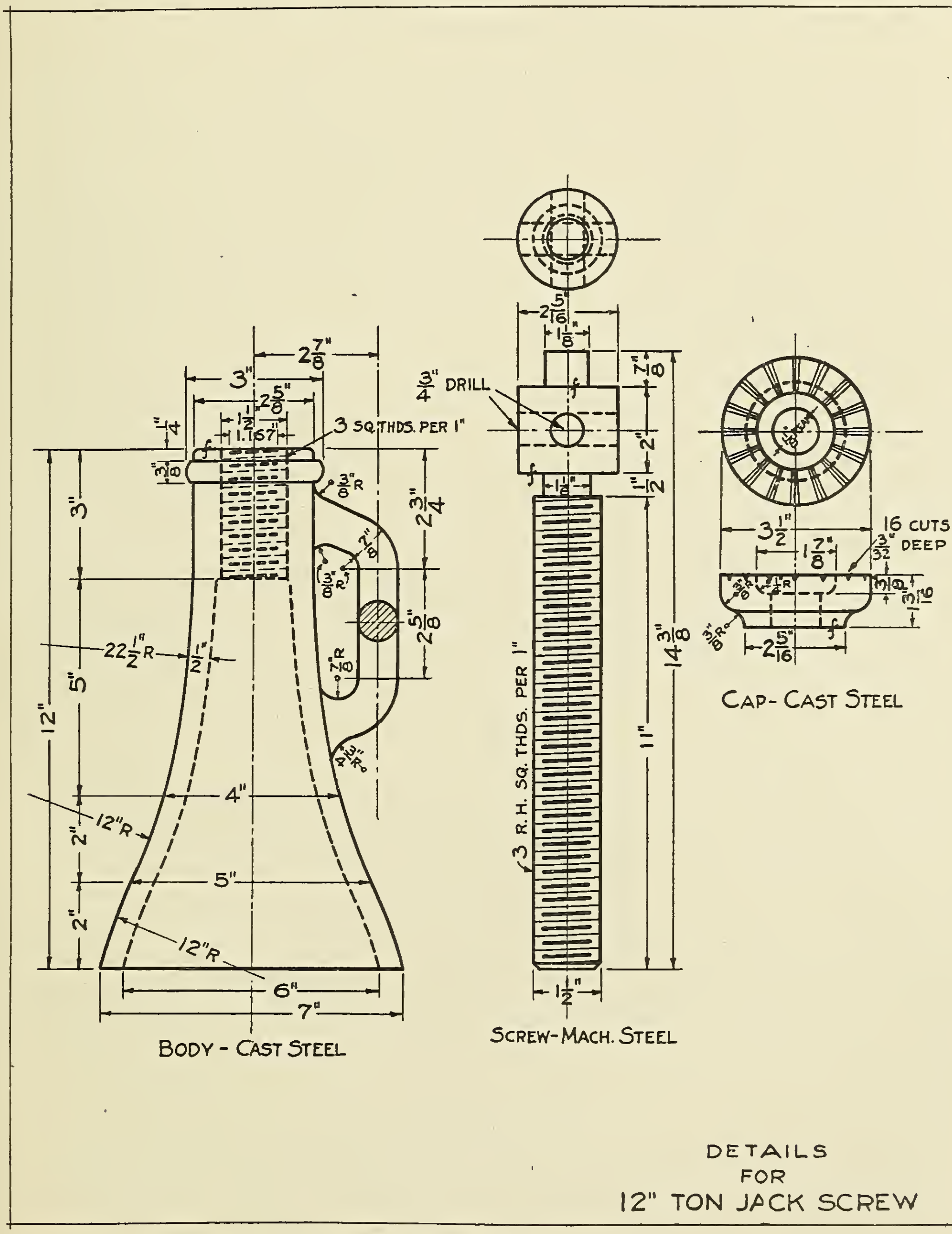


Fig. 83.

tinued by a wavy line, which makes it look as if we had sawed into the rod endwise and then broken the piece out. The section is thus broken to avoid the useless sectioning of the body of the rod. The revolved section gives an idea of the shape of the body of the rod. The cross-hatchings tell the materials of the different parts and, by being inclined at different angles, enable the student to pick out the different pieces. The body of the rod is machine steel, as is also the strap around the end. The boxes are made of cast-iron lined with babbitt. They are adjusted and secured in position by a steel wedge which is raised and lowered by means of two cap screws, tapped into the wedge. Notice that the bolts are not sectioned and that their dimensions are given by notes rather than by actual dimensions on the bolts.

General assembly drawings should not show dimensions of minor details. *Assembly drawings should show only those dimensions which are necessary to show how the parts are to be put together and those which show the working capacity or strength of the mechanism.*

46. Conventions for Pencil Work.—For single parts, use the cast-iron convention for all materials and indicate the material in the title.

For assemblies drawn with instruments, use the conventions of Fig. 81 because, with the single exception of wrought iron, these require only one weight of line. For any material not shown in Fig. 81, use the convention for the nearest similar material, or the cast-iron convention, and then label the part with a note telling the material.

For freehand assembly sketches, always use the cast-iron convention and label all parts with notes.

PROBLEM 8A

Fig. 83 shows the details of a jackscrew. Make a complete assembly drawing of this jack in section, showing all parts put together in their proper positions. Do not section the screw. The upper end of the screw should be shown riveted over slightly, to hold the cap in place.

PROBLEM 8B

Make a section assembly drawing of one of the following, or similar objects, from the actual objects:

- Flanged shaft coupling
- Oldham shaft coupling
- Universal joint
- Grease cup
- Flanged pipe coupling

CHAPTER IV

ASSEMBLY AND DETAIL DRAWINGS

ASSIGNMENT 9

47. Assembly and Detail Sheets.—Every machine or mechanism containing several parts should be represented by both assembly and detail drawings. The assembly shows how the various parts are related to each other and how they are put together; the detail drawings are used by the mechanic in making the separate parts.

If the mechanism involves a large number of parts, there will be a single assembly drawing and one or more sheets of details. There may be a separate detail drawing of each part, or several details may be shown on one sheet. If a mechanism contains only a few parts, the assembly and the details may be shown on a single sheet. In this case, the usual practice is to place the assembly drawing on the upper left-hand corner of the plate, the rest of the plate being given over to the drawings of the details, as in Figs. 84 and 85.

In making detail sheets, the details are sometimes drawn on the plates in the logical order in which they occur in the machine; that is, adjacent parts in the machine are drawn adjacent to each other on the detail sheets. Sometimes the details of units of the machine which are to be made, and perhaps assembled, in one part of the shop, are grouped together on the detail sheets. In other cases, it may be convenient to group together the details of similar parts which are to be made by the same mechanic or department. For instance, we may place together in one group the details of all shafts required; in another group we may have all the gears; in another group all the bolts, screws, and other parts to be made on screw machines. The choice of any such methods as above noted will be determined largely by the local conditions governing the manufacture of the machine and by the number of parts to be shown.

It is generally necessary to make mechanical drawings to some convenient scale. The space allotted to each detail should bear some reasonable proportion to the space allotted to other details. In other words, a comparatively small and insignificant

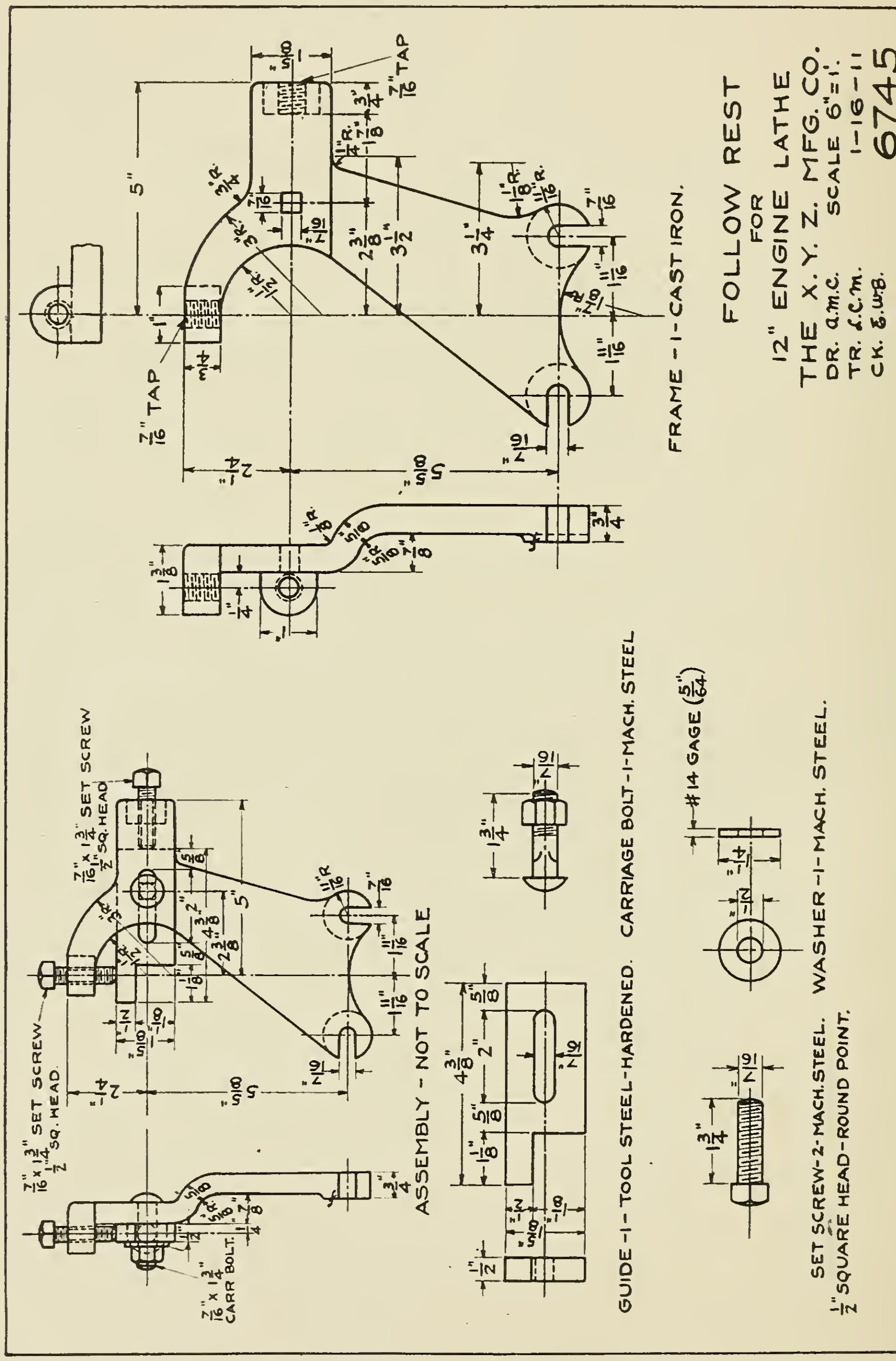


Fig. 84.

part should not be drawn to a large scale while a larger and much more important part is drawn to a much reduced scale. If, however, a certain small part is highly important and complicated in design, it may be advisable to draw it to a large scale in order to show it clearly and to emphasize the fact that it should be accurately made. *Always strive at balance, so that the space given to each detail will be proportional to its importance and size.*

The detail drawing of each part should be complete and give all necessary information. Beneath each detail there should appear a title or "legend" giving the name of the part, the number required for one machine, the material of which it is to be made, whatever finish, if any, is required, and the scale, if different scales are used for the details. As a general rule the same scale should be used throughout. No title or legend is necessary beneath the assembly drawing, except possibly the word *Assembly*.

The title for the whole plate is usually placed in the lower right-hand corner. If the plate contains both assembly and details, the title for the plate may appear somewhat as follows:

FOLLOW REST
FOR
12″ ENGINE LATHE

If the plate contains the assembly drawing only, the title of the plate will appear thus:

FOLLOW REST
FOR
12″ ENGINE LATHE
ASSEMBLY DRAWING

If the plate contains only the drawings of details, the title of the plate will appear thus:

DETAILS OF FOLLOW REST
FOR
12″ ENGINE LATHE

There should also appear the scale, the date, the filing number and the names of the various draftsmen involved in making the drawing.

Fig. 84 shows a complete mechanical drawing (assembly and details) of a follow rest for a 12″ engine lathe. Note carefully the general dimensions given in the assembly drawing. Note also the proper manner of showing sizes of bolts, set screws, etc., on an assembly drawing. The detail of each part gives full and complete information. Each detail has an appropriate legend, and the plate itself bears an appropriate title.

Where a drawing is not intended for production work, but is merely for a single special job such as a machine repair or a part

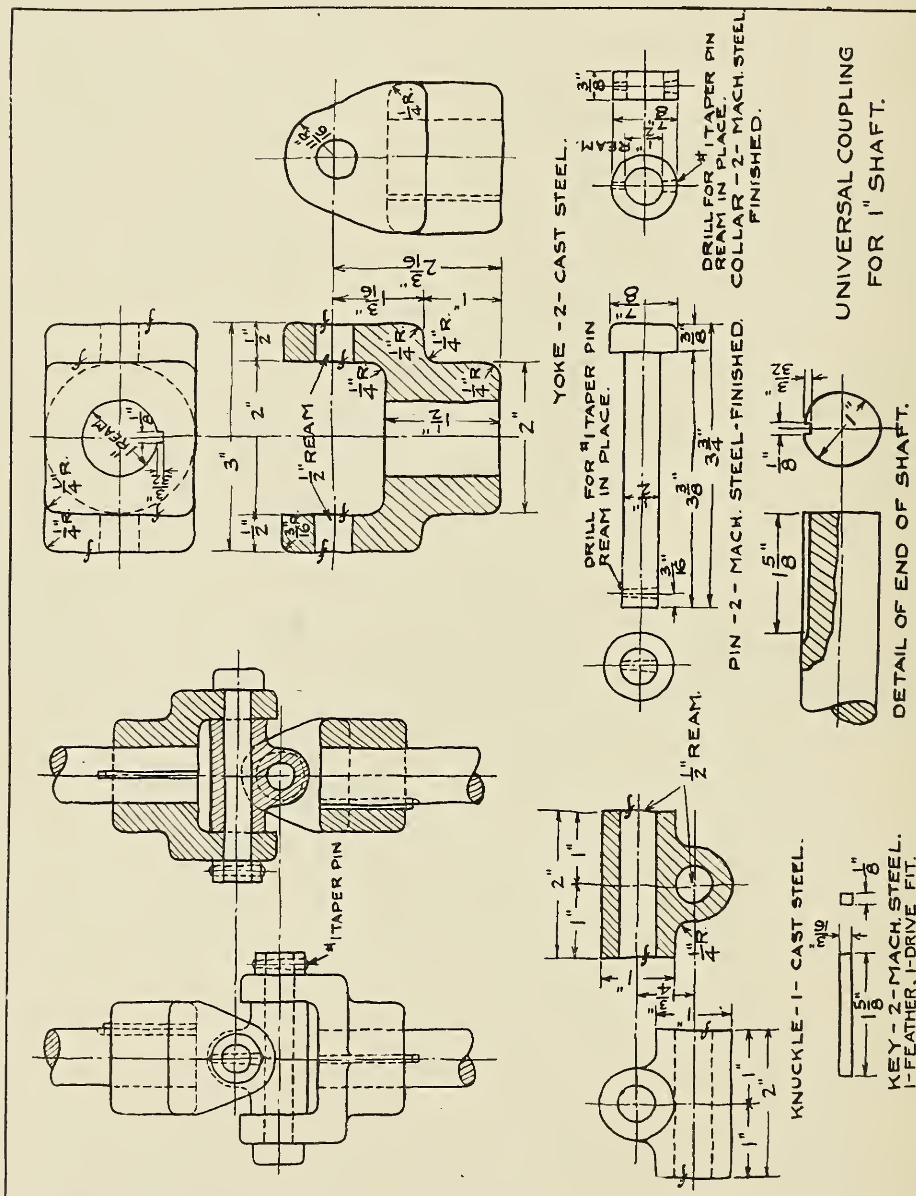


Fig. 85.

of a special machine, a freehand sketch may be made and used. The original sketch may be sent through the shop with the order, or it may be made on thin paper and a blueprint made from it and sent through with the order. Such drawings should never be destroyed, but should be labelled carefully and dated and filed away, as the same repairs may be required again or another machine may be wanted at a future date.

Fig. 85 shows a complete freehand sketch (assembly and

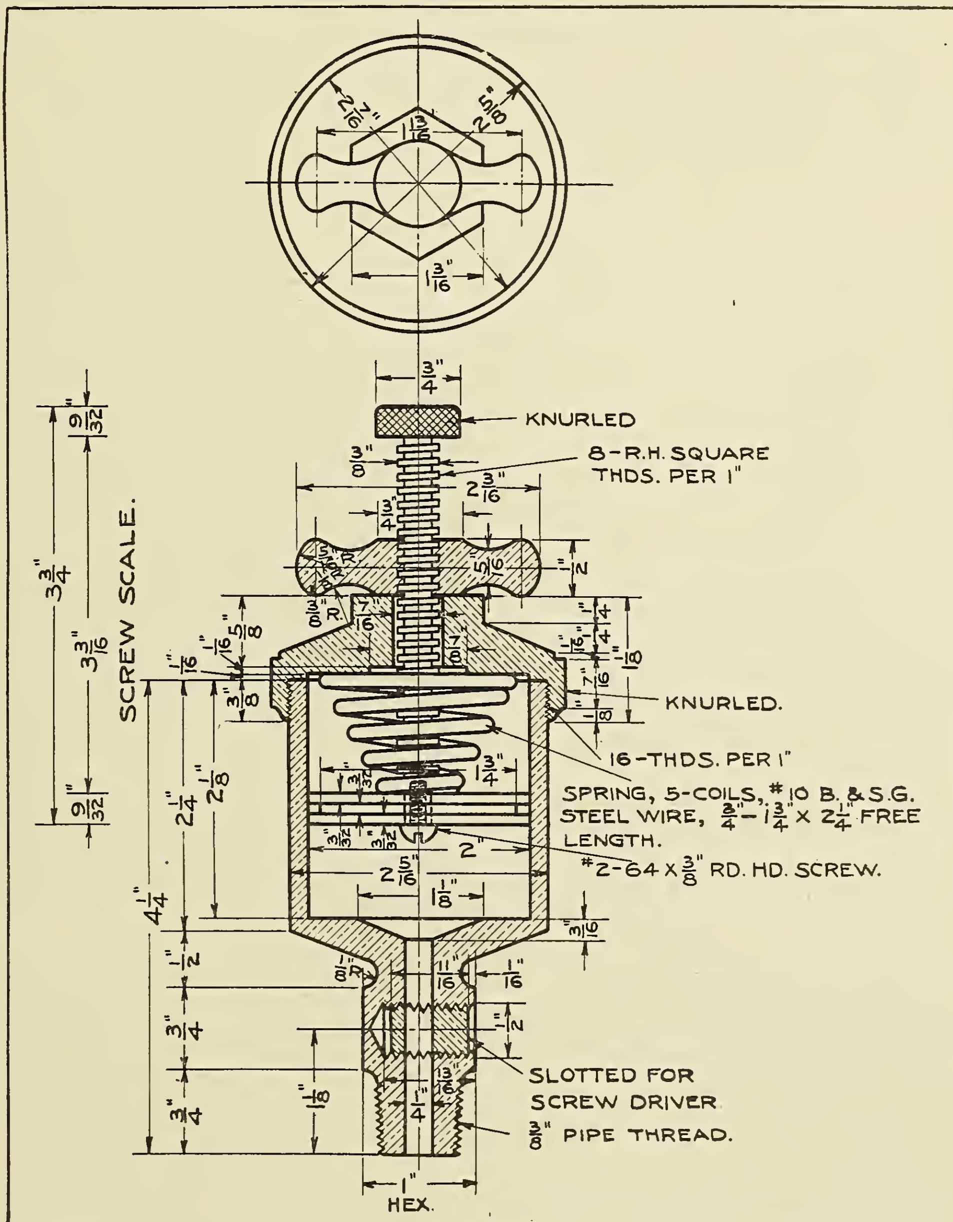


Fig. 86.

details) of a universal coupling. Such a coupling is used to transmit power between two shafts which are set at an angle. The cast-iron cross-hatching is used throughout for all work in freehand sketching and the various materials are noted. The sketches, however, are complete and give sufficient information for the manufacture of the coupling.

PROBLEM 9A

Fig. 86 shows a section assembly of an automatic grease cup. The pressure is applied to the plunger by a coiled spring, the motion of the plunger being regulated by the wing nut. Make an assembly drawing of the cup and detail drawings of the cup, plunger, cover, spring, and wing nut. Group them on the same sheet, if possible.

PROBLEM 9B

Make complete drawings, including assembly drawing with details of separate parts, of any one of the following or similar objects:

Door hinge
Bicycle wrench
Pipe cutter
Hack saw frame
Tap wrench
Machinist's clamp

ASSIGNMENT 10

48. Drafting-room Procedure.—When the design of a machine is first taken up in a drafting office, the chief engineer or a senior draftsman first makes a pencil-sketch assembly. He endeavors to provide for all clearances and to proportion the parts correctly. When a satisfactory sketch has been obtained, it is turned over to a competent draftsman to work up into a finished drawing. This finished assembly is often the result of careful and frequent consultation with the various other draftsmen and engineers, so as to have all the good ideas possible incorporated into the design.

The draftsman who makes the assembly drawing decides what materials or metals it will be advisable to use in the several parts, what their treatment shall be, what proportions they shall have in order to give sufficient strength, etc. His drawing should show all general and vital dimensions and should be finished in such a manner that it may be placed in the hands of a junior draftsman or detailer to detail the various parts. Before going to the detailer, however, the assembly drawing should be submitted to the chief draftsman and chief engineer for their approval.

Under the supervision of the man who made the general assembly, the detailer then makes complete detail drawings of each piece of the machine. These, in similar manner, should also be submitted to the chief draftsman and chief engineer.

In a large, well-regulated office, all these pencil drawings would then be turned over to the "tracer" who would trace them on tracing cloth. Tracing cloth is a tough, semi-transparent cloth which is placed over the pencil drawings. The lines are then traced with black India ink, thus transferring the drawing to the cloth. These tracings should also be approved by the chief draftsman and chief engineer. In smaller offices all these operations might be performed by one man.

The tracings are next properly indexed for filing away in the vaults. Thereafter, they may be issued on a check order system whenever it is desired to have blue prints made from them. Whenever radical changes are made in the construction of a machine, the old tracings are marked "obsolete" or "superseded," and are replaced in the current files by tracings of the new designs. If only one or two dimensions are to be altered, the old dimensions may be crossed out (not erased) and the new dimensions placed above or below the old ones.

Blue prints are made on paper known as blue-print paper, which is sensitive to light. The tracing is placed over a sheet of blue-print paper in a printing frame, and then exposed to a strong light such as daylight or an electric light. This makes an impression on the blue print like the drawing on the tracing. It usually takes a minute or so to make the print in a fairly good light. The blue print is then removed and "fixed" in a water bath for a few minutes so that it will be permanent. The lines of the drawing then appear as white lines on a blue background. When blue prints are subjected to a great deal of hard usage in the shops it is well to mount them on some stiff cardboard or other firm backing and then to shellac or varnish the surface so as to protect them.

PROBLEM 10

Following carefully all directions given in preceding articles make complete assembly and detail drawings of any one of the following or similar objects:

Pipe vise	Expansion arbor
Boiler tube expander	Inserted tooth-milling cutter
Lathe or planer chuck	Stilson or Trimo wrench

Automobile engine circulating pump

CHAPTER V

GEARING

ASSIGNMENT 11

49. Spur Gears.—Spur gears are used for connecting parallel shafts and are, by far, the most common type of gears. Fig. 87 *A* shows a pair of spur gears. If there is much difference in the sizes of a pair of gears, the smaller one is called the *pinion* and the larger one the *gear*. In a pair of gears, the one which drives

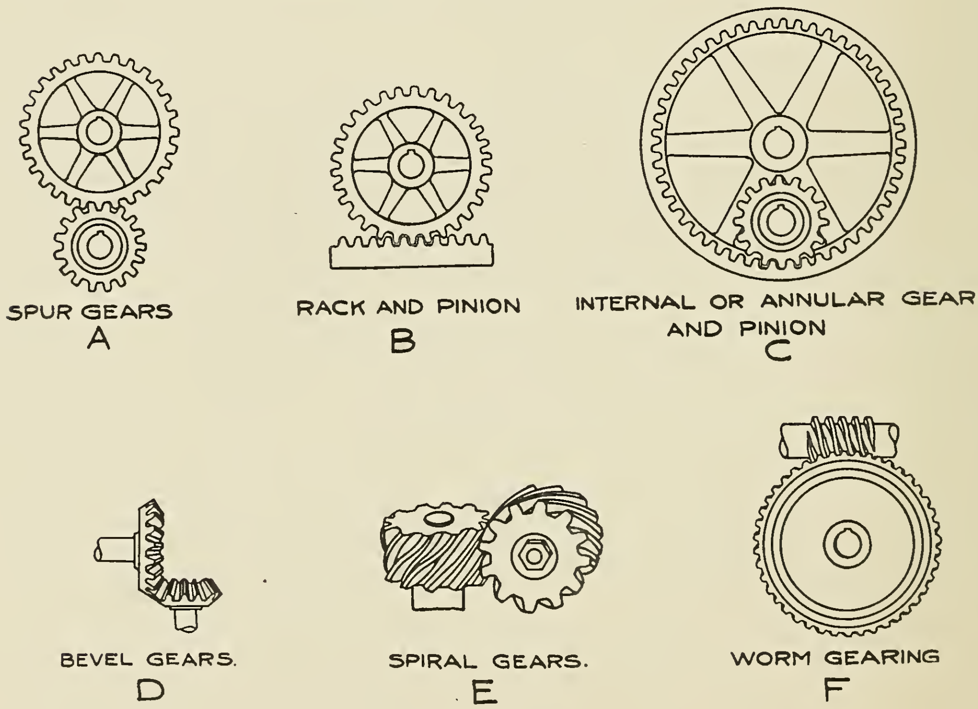


Fig. 87.

the other is called the *driver;* the other one is called the *driven gear* or the *follower*. The change gears of a lathe are good examples of spur gears.

When a gear is used to drive a body in a straight line, a combination known as a *rack and pinion* is used, as shown in Fig. 87*B*. These are sometimes seen on planer tables and on the spindle feeds of drill presses. The straight-line gear is called the *rack*, while the small gear is called the *pinion*.

Occasionally a spur gear is used with teeth cut on the inside of its rim, as in Fig. 87 *C*. This is called an *internal gear*, an example of which may be seen on any lawn-mower.

50. Bevel Gears.—When two shafts lie at an angle, so that their center lines would meet if extended, they may be connected by bevel gears. Bevel gears may usually be found on drill-press drives and on the elevating screws for raising and lowering the cross rails of planers.

The teeth of bevel gears taper toward the intersection of the center-lines of the shafts.

When two bevel gears of equal size connect two shafts at right angles they are called *miter gears*.

51. Spiral and Worm Gears.—When shafts lie at an angle and are also some distance apart they may be connected by spiral or worm gearing, as shown in Fig. 87 *E* and *F*. Worm gearing is used where a considerable reduction in speed is desired.

52. Pitch Circles.—Let us suppose that we have two rolls or cylinders as in Fig. 88, rolling together without slipping. In

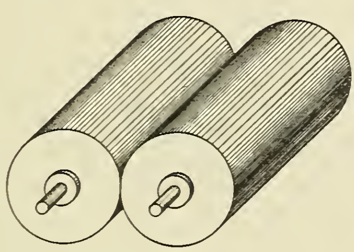


Fig. 88.

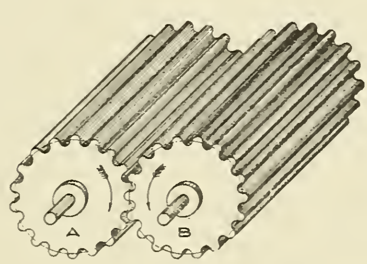


Fig. 89.

order to transmit more power than can be done by the smooth rolling surfaces, projections are placed on *B* parallel to the axis, and corresponding recesses on *A*. If now we consider that *A* is provided with similar projections and *B* with similar recesses, we can see clearly the direct development from the rolling cylinders of Fig. 88 to the toothed cylinders of Fig. 89, and thence to the spur gears of Fig. 87 *A*. The circumferences of the cylinders now become the pitch circles of the gears. Gear teeth project part way beyond the pitch circles, but all calculations of relative speeds depend on the sizes of the pitch circles.

53. Pitch Diameter.—The pitch diameter of a gear is the diameter at its pitch circle and is the diameter used in speed calculations, sizes of teeth, etc.

54. Pitch.—Pitch is a word used to indicate the size of teeth on a gear. There are two systems of denoting pitch.

Diametral Pitch refers to the number of teeth on a gear for each inch of diameter of its pitch circle. For example, if there are 32 teeth on a gear, and the diameter of its pitch circle is 4 in., then there are $\frac{32}{4} = 8$ teeth per inch of diameter of the pitch circle, or the diametral pitch is 8.

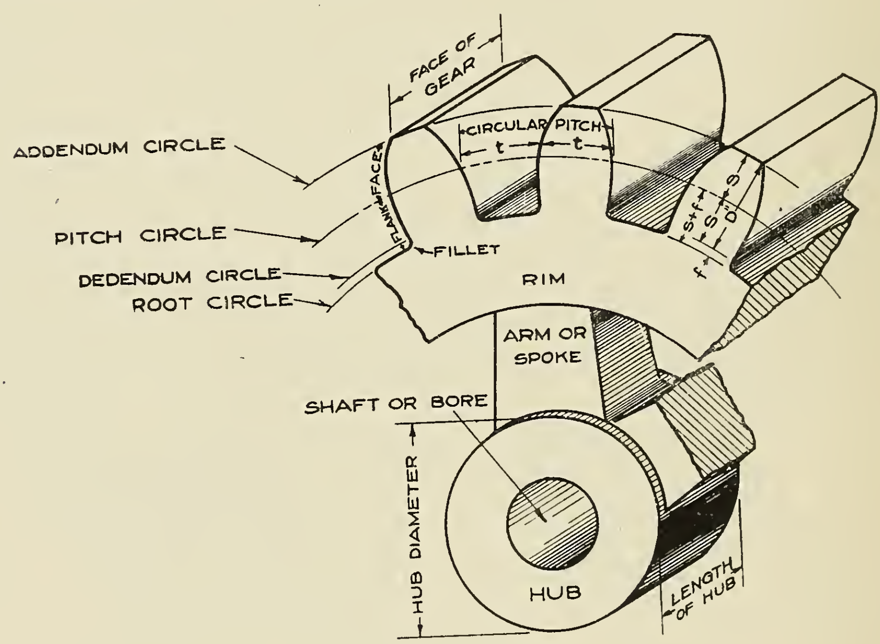


Fig. 90.

Circular Pitch is the distance between corresponding points of adjoining teeth measured on the pitch circle (see Fig. 90); for example, it is the distance from the center of one tooth to the center of the next, or from the side of one tooth to the corresponding side of the next, the distance, in both cases, being measured around on the arc of the pitch circle and not straight across.

Circular pitch is a direct measure of the size of teeth; the greater the circular pitch the greater the size of tooth. Diametral pitch indicates the number of teeth for each inch of diameter and, therefore, the greater the number of the diametral pitch the smaller the size of tooth. Cut gears are almost always designed by the diametral pitch. Circular pitch is generally used in the design of cast gears so as to enable the patternmaker to space the tooth forms uniformly on the circumference of the rim. Any gear might, however, have been built according to either system. To determine which was used, it is necessary to measure or calculate the pitch according to both systems and see which comes out an even figure.

55. Gear Calculations.—Circular pitch may be measured directly from one tooth to the next along the pitch line. It is more accurate, however, to measure the pitch diameter and count the teeth.

The pitch diameter multiplied by 3.1416 will give the pitch circumference.

The pitch circumference divided by the number of teeth will give the circular pitch.

For finding the diametral pitch, the same items are noted; namely, pitch diameter and number of teeth.

The number of teeth divided by the pitch diameter will give the diametral pitch.

Example:

What is the diametral pitch of gear having 48 teeth and a pitch diameter of 6 in.?

Since the diametral pitch is the number of teeth per inch of diameter, for this gear it will be $48 \div 6 = 8$ pitch, *Answer*.

In calculating the pitch diameter of a proposed gear, having given the number of teeth and the diametral pitch, we divide the number of teeth by the diametral pitch.

Example:

What is the pitch diameter of a gear having 66 teeth of 12 diametral pitch?

If there are to be 12 teeth per inch of diameter, the pitch diameter must be $66 \div 12 = 5\frac{1}{2}$ in., *Answer*.

To find the pitch diameter of a gear, having given the circular pitch and the number of teeth, multiply the circular pitch by the number of teeth; this will give the pitch circumference; then divide this by 3,1416 to get the pitch diameter.

56. The Addendum.—This is the technical name given to that part of the gear tooth outside of the pitch circle. In the standard system of gearing in general use, the addendum is made equal to 1 divided by the diametral pitch. Thus, if a gear is 8 pitch the addendum of the teeth is made $\frac{1}{8}$ in. high. If a gear is 4 pitch, the addendum is $\frac{1}{4}$ in.

The outside diameter of a gear is calculated by adding twice the addendum to the pitch diameter. We have already found how to calculate the pitch diameter for a gear that is to have a given number of teeth of a given diametral pitch.

$$\text{Pitch Diameter} = \frac{\text{Number of teeth}}{\text{The diametral pitch}} = \frac{N}{P}$$

$$\text{The Addendum} = \frac{1}{\text{The diametral pitch}} = \frac{1}{P}$$

Adding twice the addendum to the pitch diameter, we get

$$\text{The Outside Diameter} = \frac{N}{P} + \frac{2}{P} = \frac{N+2}{P}$$

This may be stated in words as follows:

To find the outside diameter of a gear, add 2 to the number of teeth and divide by the diametral pitch. This is the diameter to which a gear blank must be turned before the teeth are cut.

Example:

What should be the outside diameter for a 40-tooth gear of 10 pitch?

$40+2=42.$ $42 \div 10 = 4.2$ in., *Answer.*

57. The Dedendum.—This is the technical name for the working depth of a tooth inside the pitch circle. It indicates the depth to which the teeth of one gear fit into the spaces of the other gear below the pitch circle and, therefore, for standard teeth, is the same distance *inside* the pitch circle that the addendum circle is *outside* the pitch circle.

A certain amount of clearance is usually cut at the bottom of the spaces to allow for dirt and other foreign matter to work out of the gears without breaking the teeth. The amount of this clearance below the dedendum, or working depth circle, is usually made 0.157 divided by the diametral pitch. The circle at the base of the clearance is usually called the *root circle.* See Fig. 90. The depth of a standard tooth is therefore

$$\text{Addendum} + \text{Dedendum} + \text{Clearance}$$
$$= \frac{1}{\text{pitch}} + \frac{1}{\text{pitch}} + \frac{0.157}{\text{pitch}}$$
$$= \frac{2.157}{\text{pitch}}$$

Example:

To what depth should a 6-pitch tooth be cut?
Depth = 2.157 ÷ Pitch = 2.157 ÷ 6 = 0.3595 in., *Answer.*

58. Gear Repairs.—Gear repair jobs are common in a large industrial plant. The mechanic who can handle such jobs intelligently is therefore a valuable man. The student should familiarize himself with the names of the various gear parts shown in Fig. 90.

When repairing a cut gear it is necessary to determine its diametral pitch and pitch diameter. The number of teeth on the gear should first be determined and then the outside diameter. We have shown that the outside diameter of a standard gear is $\frac{N+2}{P}$. This rule can be reversed to get the pitch from the outside diameter.

The diametral pitch, $P = \frac{N+2}{O.D.}$; that is, the diametral pitch of a gear is obtained by adding 2 to the number of teeth and dividing by the outside diameter of the gear.

The pitch diameter is then obtained by dividing the number of teeth by the pitch.

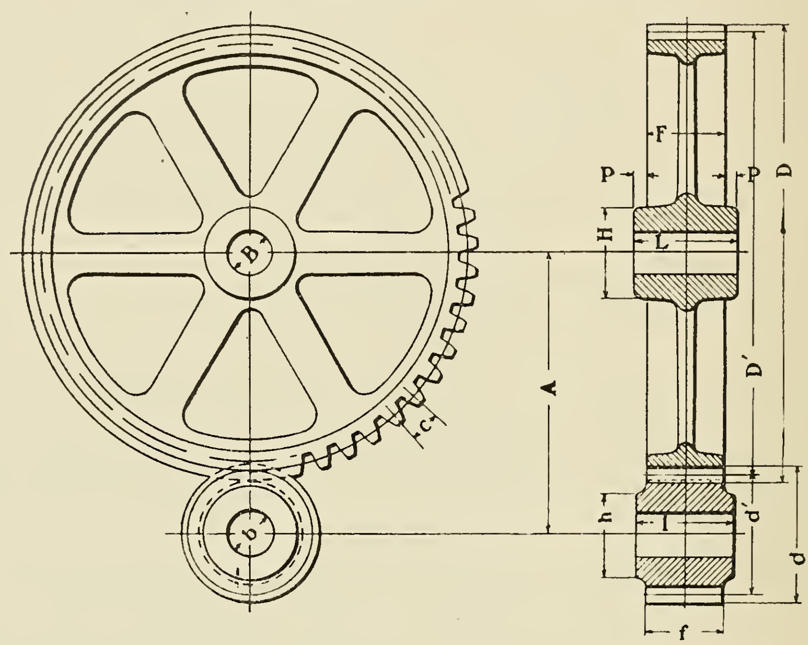
The depth to cut a tooth is obtained by dividing 2.157 by the diametral pitch.

Fig. 91 shows the necessary data to be given in ordering new gears from a maker. This gives complete information, and if carefully followed makes misfits almost an impossibility.

59. Gear Drawings.—In detail drawings of gears, generally not more than three or four teeth are shown. Fig. 92 shows a typical working drawing of a spur gear. Notice that the number of teeth and the pitch are given in the title.

The outside diameter and the pitch diameter are dimensioned

DATA FOR ORDERING
SPUR GEAR AND PINION



	Gear	Pinion
Number required		
Material		
Outside Diameter	D	d
Pitch Diameter	D	d
Face	F	f
Bore	B	b
Keyseat		
Number of Teeth		
Pitch { Diametral		
Pitch { Circular	C	
Diameter of Hub	H	h
Length Through Hub	L	l
Projections	P	p
Center Distance	A	

When ordering Spur Gears to transmit a certain horsepower, do not fail to state number of revolutions, size of bores, and largest and smallest permissible diameters.

Fig. 91.

on the drawing. The depth of tooth is not always given, but may be dimensioned or given in a note if desired.

In making a drawing of a cut gear it is necessary to calculate the circular pitch in order to lay out the few teeth to be shown. The circular pitch is obtained from the diametral pitch by dividing 3.1416 by the diametral pitch. Thus, the circular pitch for a gear of 4 diametral pitch is 3.1416 ÷ 4 = 0.7854 in. The teeth and

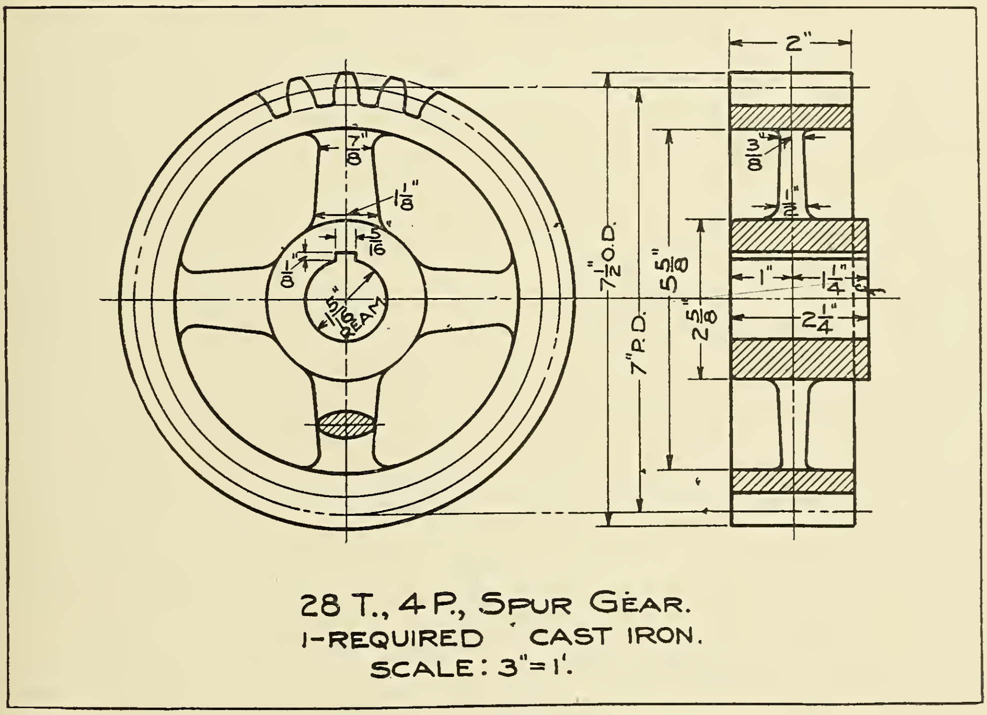


Fig. 92.

spaces are each one-half of this in width on the pitch line. A good looking representation of a tooth may be drawn with the compass by using the circular pitch as a radius and setting the center about half way between the pitch circle and the base circle. Draw the tooth outline in this manner and then round it slightly into the base circle, freehand, instead of leaving the sharp corner.

PROBLEM 11

Make a working drawing of any cut spur gear to which you may have access.

CHAPTER VI

ISOMETRIC DRAWING

ASSIGNMENT 12

60. Pictorial Drawing.—All the drawing work we have done so far has been straight mechanical projection. That is, we have shown only one side of an object in each separate view. It is often desirable, in making sketches or drawings, to show the entire object in one view. This is especially needed in the shop when we want to convey an idea of a desired object to a workman who is

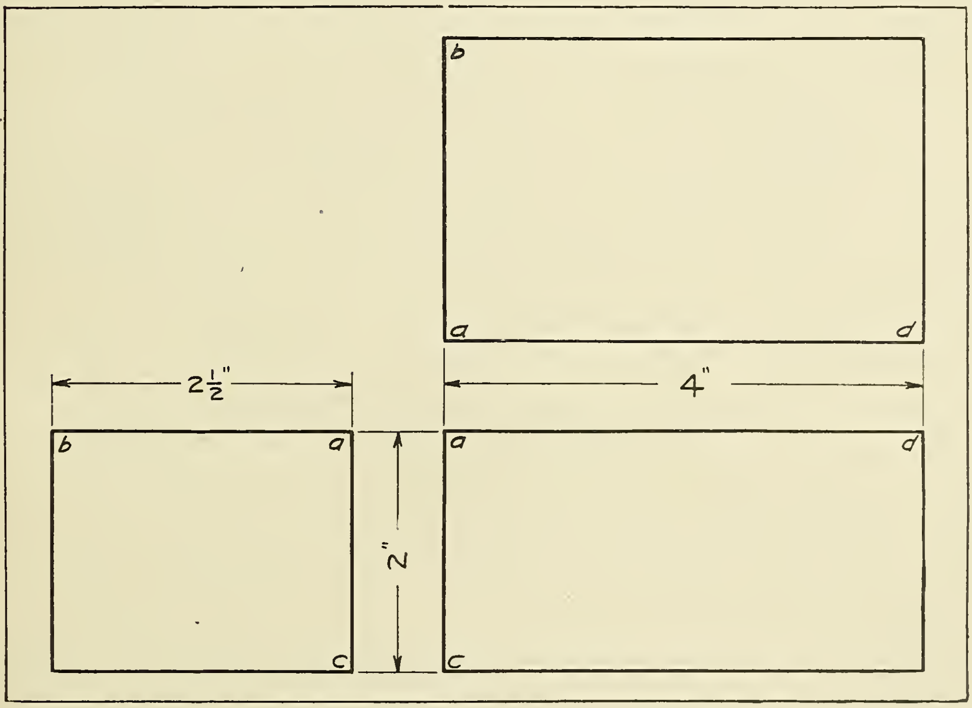


Fig. 93.

unable to read and understand a regular mechanical drawing. Such a drawing must naturally give a more or less faithful picture of the subject and the name "pictorial" drawing is used to describe it. There are several styles of pictorial drawing. The simplest for shop use is known as *isometric drawing.*

Isometric drawing aims to give a picture of the object showing the three dimensions of length, breadth, and depth at equal angles with the eye. As we shall see, it is not exactly a true picture, as it takes no account of perspective. "Perspective" is the name we give to the apparent tapering of objects as they get more and more distant from the eye. A common example of perspective is a long straight line of railroad track whose rails seem to meet at a distant point. Isometric drawing does not allow for this perspective or foreshortening, but shows all parallel lines on an object drawn parallel on the paper and to their true length.

61. Isometric Axes.—In isometric drawing we assume that we are looking toward one corner of an object, in such a manner that

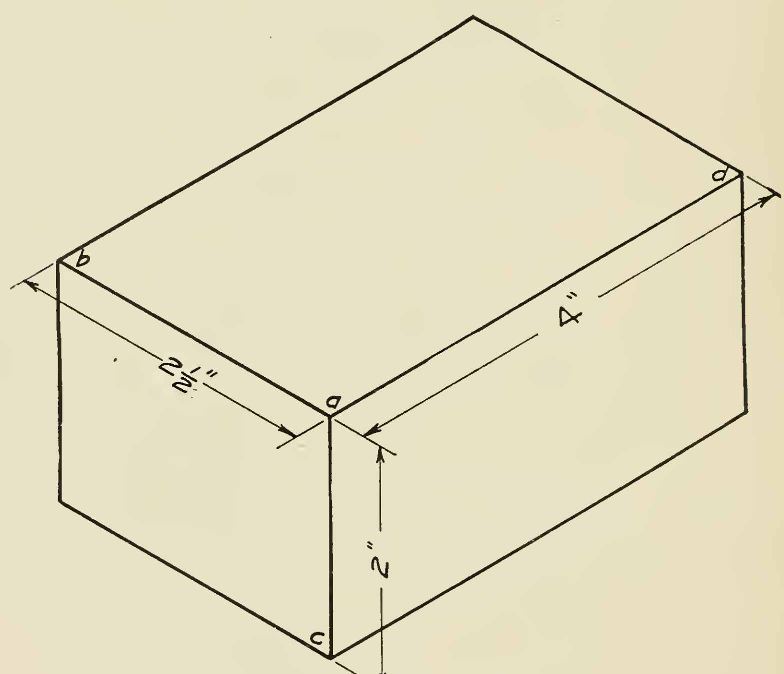


Fig. 94.

the three sides are shown in equal proportion. Then, in a rectangular figure, the three nearest edges would appear to run out from the corner at equal angles with each other. Fig. 93 shows a half size mechanical drawing of a plain rectangular block. In making a half size isometric drawing of it, as in Fig. 94, we would view the bar from such a point that the three near edges *ab*, *ac*, and *ad*, would appear to make equal angles with each other. Their isometric projections would then be drawn as in Fig. 94 with the edges *ab*, *ac*, and *ad* meeting at angles of 120°. The same block could also be shown set upon end as in Fig. 95 by the same method.

The three lines or directions are known as "isometric axes," and in isometric drawing always intersect at angles of 120°. *One axis is usually drawn on the vertical, while the other two are drawn at inclinations of* 30° *above the horizontal.* It is not necessary, however, that one should be drawn vertical so long as the lines make angles of 120° with each other.

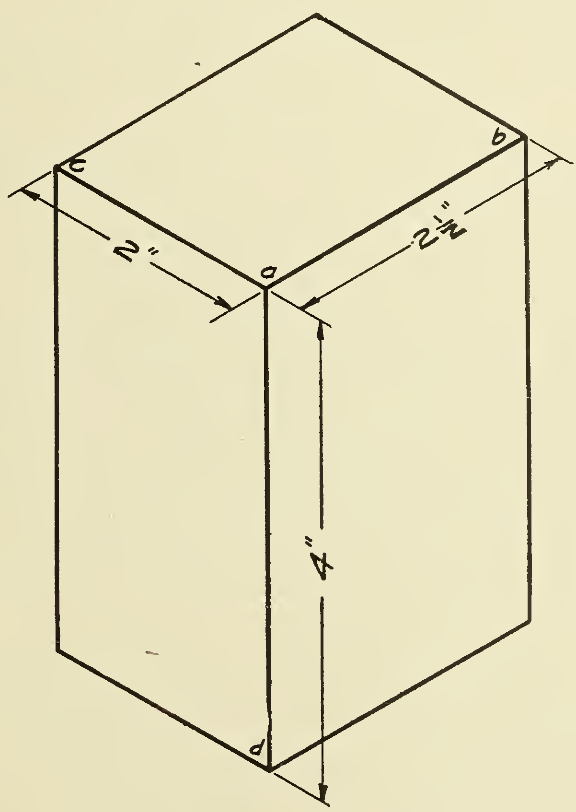


FIG. 95.

Horizontal and cross dimensions in isometric are drawn at an angle of 30° *above the horizontal; vertical dimensions are drawn vertical.* All dimensions are usually laid out on these lines to their true length according to the scale desired. In reality, the lengths of these lines would appear shorter than they really are because they are sloping away from the eye. But we never bother about this, but simply lay them out to the true lengths. Drawings are thus laid out to different scales in isometric just as in regular mechanical drawing.

62. Circles in Isometric.—If there are circles on any of the faces of an object, they will not appear as true circles in an isometric drawing. As soon as we view a circle from an angle it appears to assume an oval or elliptical form. Figs. 97 and 99 show the form taken by a circle in isometric drawing and the method of constructing it is as follows:

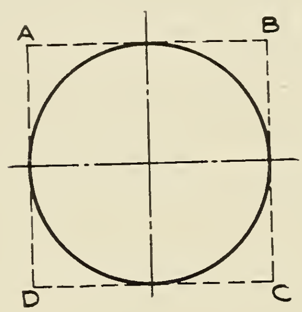


Fig. 96.

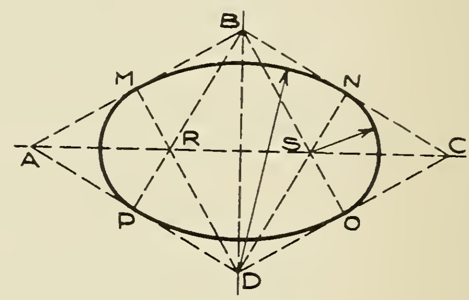


Fig. 97.

Suppose we wish to represent a 1-in. circle on the top isometric plane; see Figs. 96 and 97. We first imagine that the circle is enclosed by a 1-in. square *ABCD*, Fig. 97, *being sure to get the sides of this square parallel to the proper isometric axes.* After the square is outlined, we draw the diagonals of this square, *AC* and *BD*. Then we connect the middle points of *AB* and *BC* with *D*, getting the lines *MD* and *ND*. In the same manner,

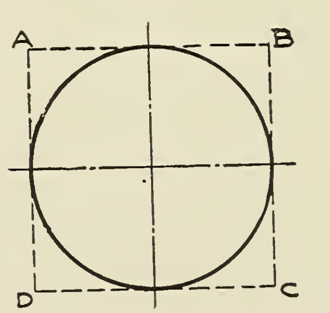


Fig. 98.

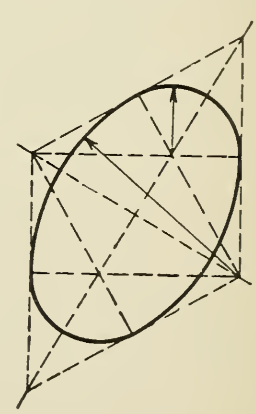


Fig. 99.

we join *B* with the middle points of the sides *AD* and *DC*, giving lines *BO* and *BP*. These lines cross the diagonal *AC* at points *R* and *S*, which are the centers for the short arcs at the ends of the ellipse, extending from *M* to *P* and from *N* to *O*. We set the center point of the compass at *R* and with a radius equal to *RM* draw the arc *MP*. Then we do the same at *S* drawing *NO*. The centers for the long arcs are at *B* and *D*. With the compass point on *D* and a radius equal to *DN*, we connect *M* and *N*. With the same radius we then put the compass on *B* and connect *P* and *O*. This gives us the complete isometric circle *MNOP* having four centers; namely, *R*, *S*, *B*, and *D*.

The construction lines should be drawn in very lightly so that after the circle is drawn they can be erased easily, leaving only the circle.

If a circle is to be shown on one of the side or end planes instead of on the top, the construction is exactly the same, except

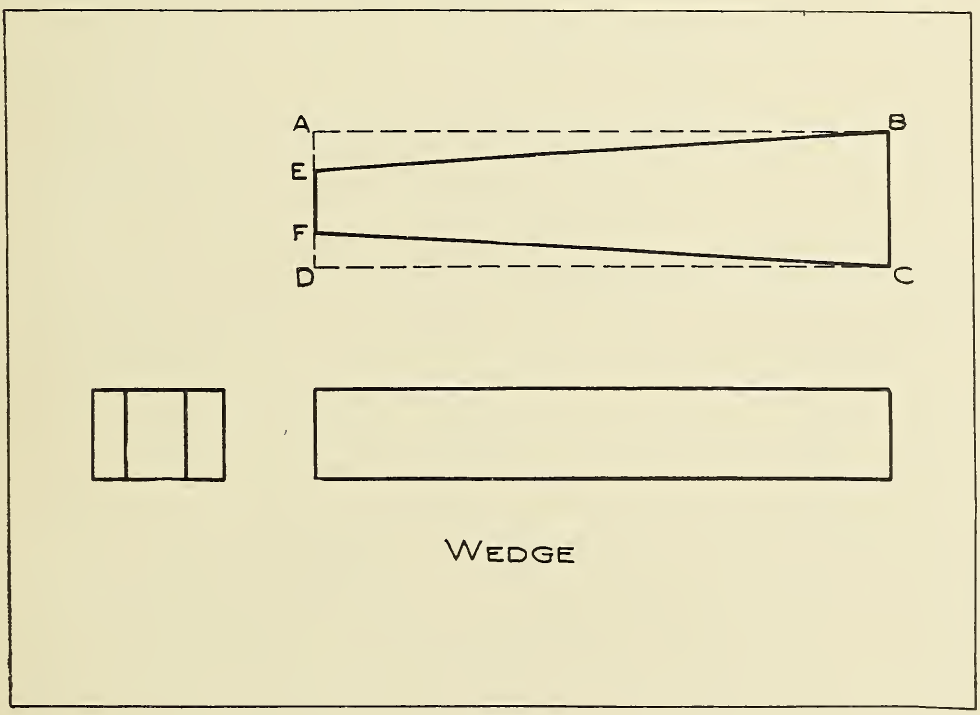
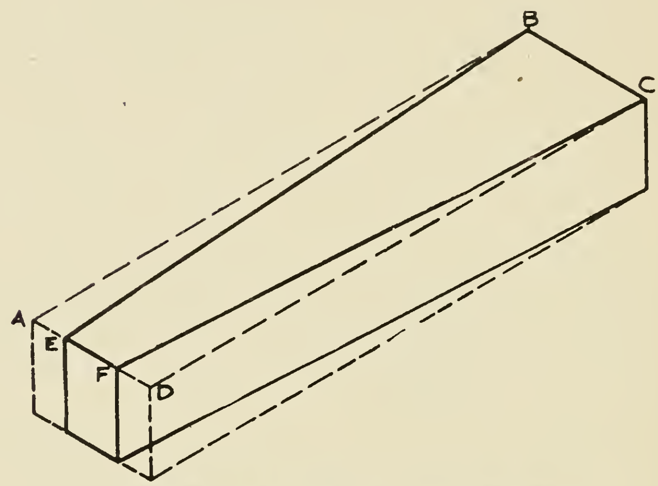


FIG. 100.

that the enclosing square is drawn with its sides running in different directions, depending upon which face the circle is to be on. Figs. 98 and 99 show how a circle is constructed on the right-hand face of an isometric drawing.

63. Oblique Surfaces in Isometric.—In making isometric drawings, we frequently encounter figures such as wedges, hexagons, etc., whose sides are neither parallel nor at right angles. These lines will not follow the usual isometric axes, but must have their angles determined by reference to some isometric axis. We will show this by making an isometric drawing of the wedge shown in

Fig. 100. Here we have the mechanical drawing of a wedge, and we wish to make the isometric. The side view consists



ISOMETRIC VIEW OF WEDGE.

FIG. 101.

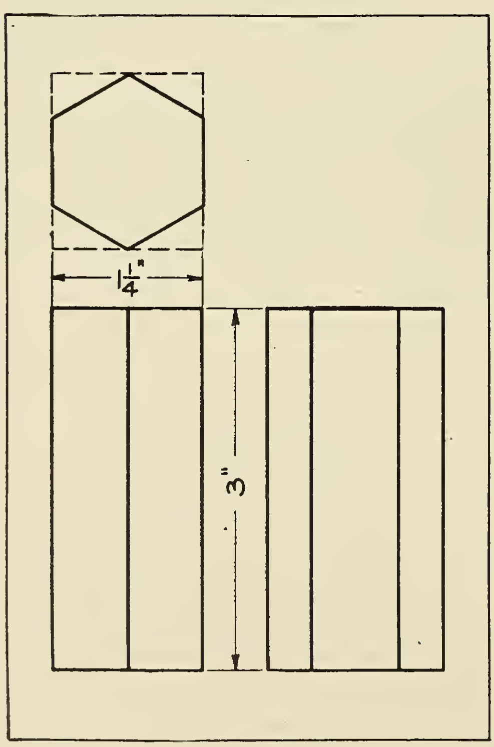


FIG. 102.

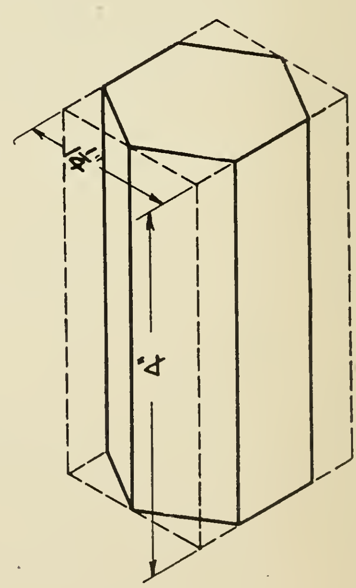


FIG. 103.

entirely of lines at right angles or parallel to each other. The plan view, however, has lines which are not parallel, but that run at smaller angles. To construct the isometric, we first enclose the plan in a rectangle *ABCD*. Then we lay off this rectangle on the isometric paper as shown by the broken lines in Fig. 101. Then we measure the distance *AE* in Fig. 100 and lay it off on the rectangle in Fig. 101. Next, we do the same with the distance *DF*. By connecting *E* with *B*, and *F* with *C* in Fig. 101, we have the correct representation for the lines *BE* and *CF*. The other lines on the ends of the wedge can be drawn in the usual manner. The line along the lower edge is then drawn parallel to *FC*. After the drawing is completed, the construction lines for the rectangle *ABCD* can be erased, leaving the completed wedge.

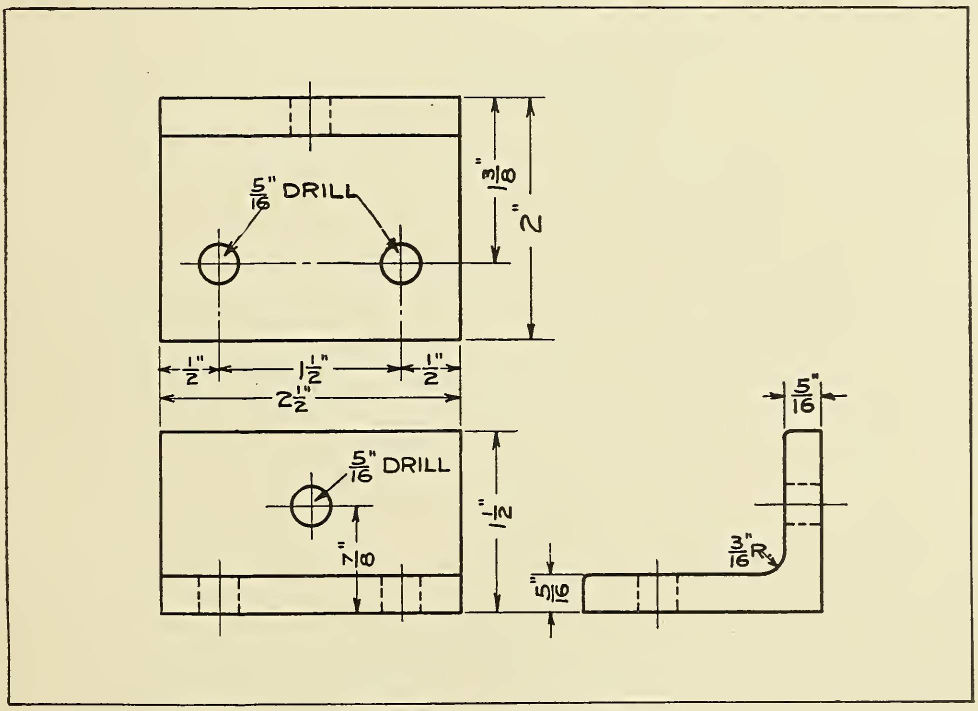


Fig. 104.

If we wish to make an isometric drawing of a segment of a hex bar, we may proceed by the steps shown in Fig. 102 and 103. First, we make a mechanical drawing as shown in Fig. 102, and then draw a circumscribing rectangle about the hexagon of the upper plan view. Next, we draw this rectangle lightly in isometric as shown in Fig. 103. We can then locate on this rectangle the corners of the hexagon, using the distances as measured from the top view of the mechanical drawing.

64. Examples of Isometric Drawing.—Fig. 104 shows a mechanical drawing, and Fig. 105 an isometric drawing of a 2 in. $\times 1\frac{1}{2}$ in. $\times \frac{5}{16}$ in. angle with rivet holes, drawn one-half size. It embraces the principles of isometric drawing laid down in the

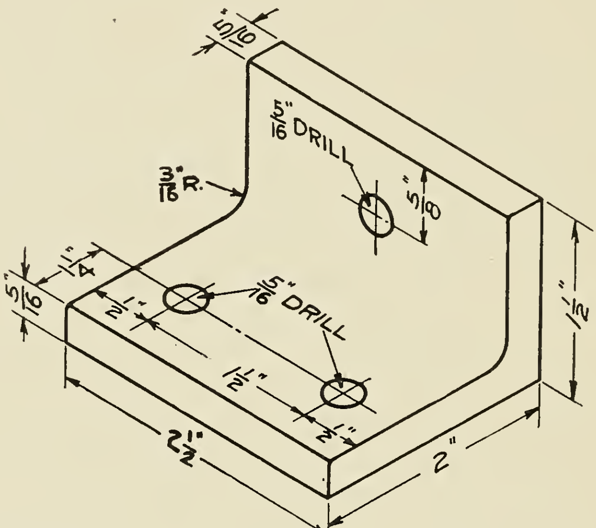


Fig. 105.

preceding articles and serves to show the adaptability of this method to simple cases. Note that all the lines of this isometric sketch are either vertical or make angles of 30° with the horizontal. In like manner the rivet holes, being circular, are laid out by

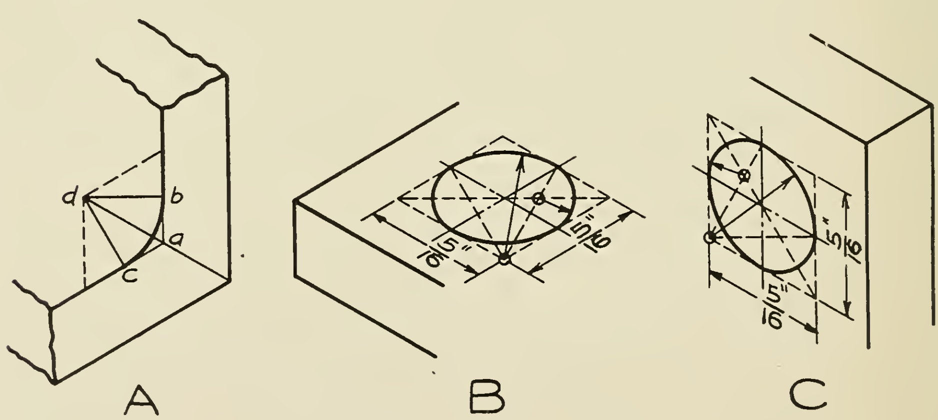


Fig. 106.

first drawing circumscribing squares whose sides make angles of 30° with the horizontal. The method of constructing these rivet holes and the $\frac{3}{16}$-in. fillet is shown in the enlarged views of Fig. 106. Note that the holes appear different in the horizontal and

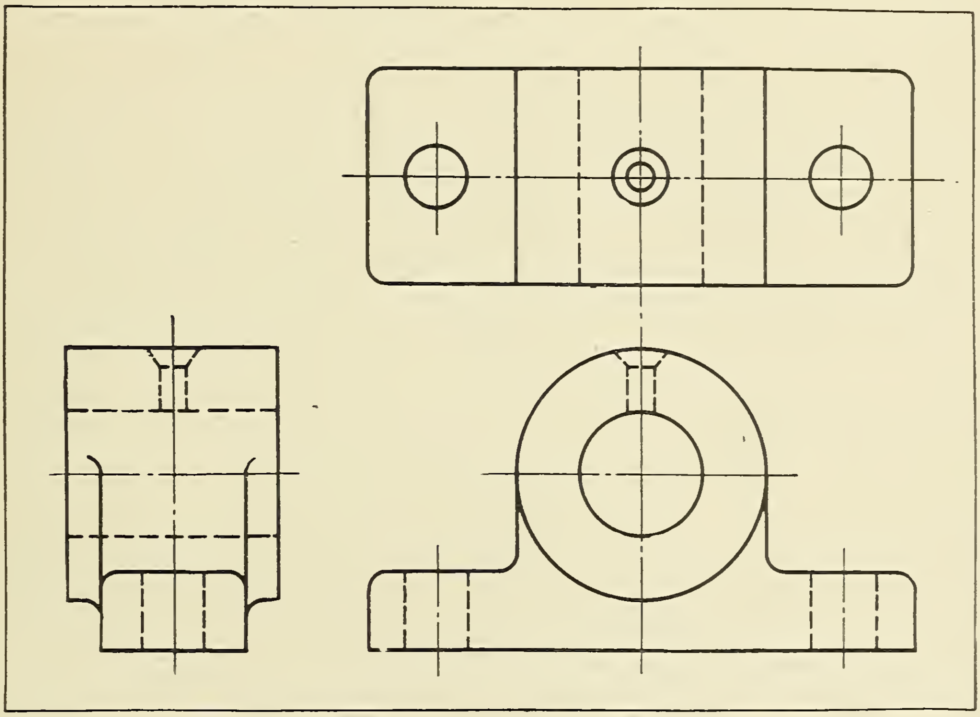


Fig. 107.

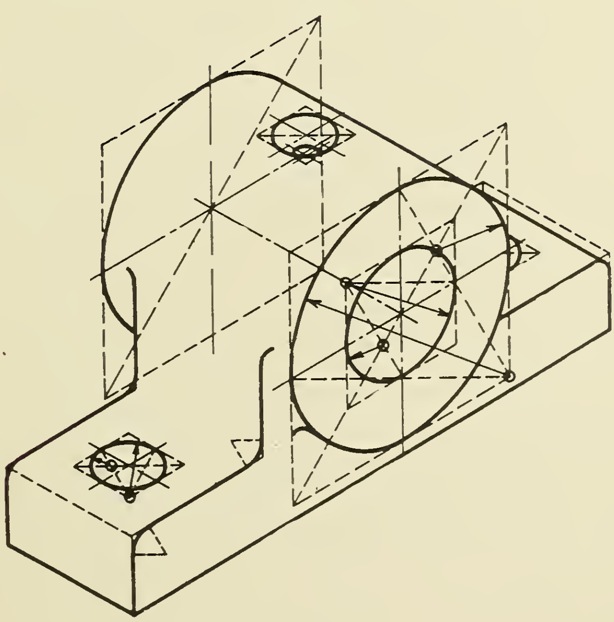


Fig. 108.

vertical parts of the angle iron, although the construction is the same. If the accurate curvature of the $\frac{3}{16}$-in. fillet or any other such arc is desired, we may determine it by the construction shown in the small sketch, Fig. 106*A*. Consider the two isometric lines as parts of a square. We know that the arc will be tangent to the two isometric lines. Since the arc is one-fourth of a circle, we know that the two points of tangency will be mid-points on a $\frac{3}{8}$-in. isometric square constructed on these two isometric lines. Therefore, we lay off *ab* and *ac* equal to $\frac{3}{16}$ in. At *c* and *b*, we draw *bd* and *cd* at right angles to the two lines *ac* and *ab*. From

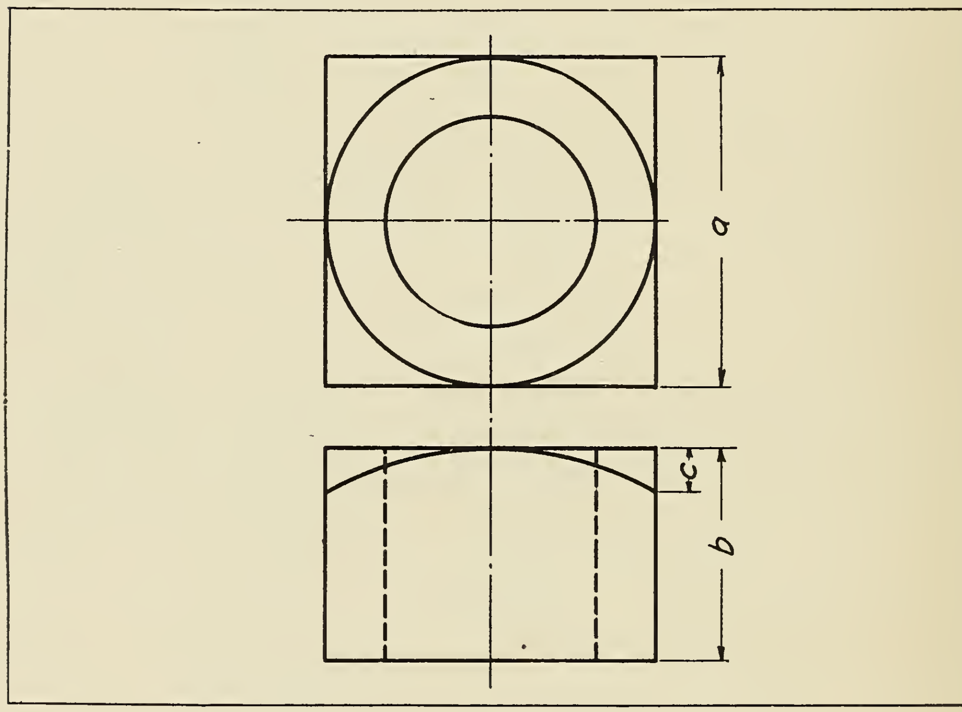


Fig. 109.

their point of intersection, *d*, as a center, we strike the arc with a radius *db*.

Fig. 107 is a mechanical drawing and Fig. 108 is an isometric drawing of a bearing block. It shows all necessary construction lines, but these should not appear upon the finished drawing.

Fig. 109 shows a mechanical drawing and Fig. 110 an isometric drawing of a square nut blank, with all construction lines. Notice how the champfer is provided for.

65. Isometric Paper.—To do isometric drawing perfectly on plain paper requires the use of a T square and 30° triangle,

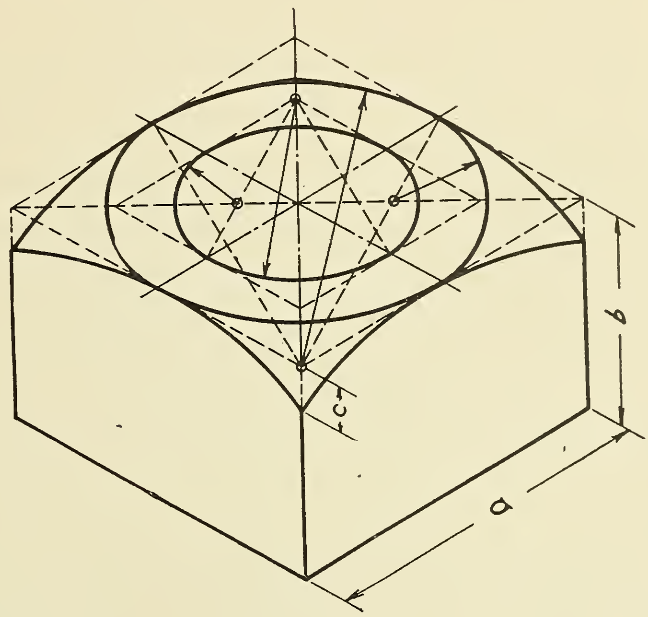


Fig. 110.

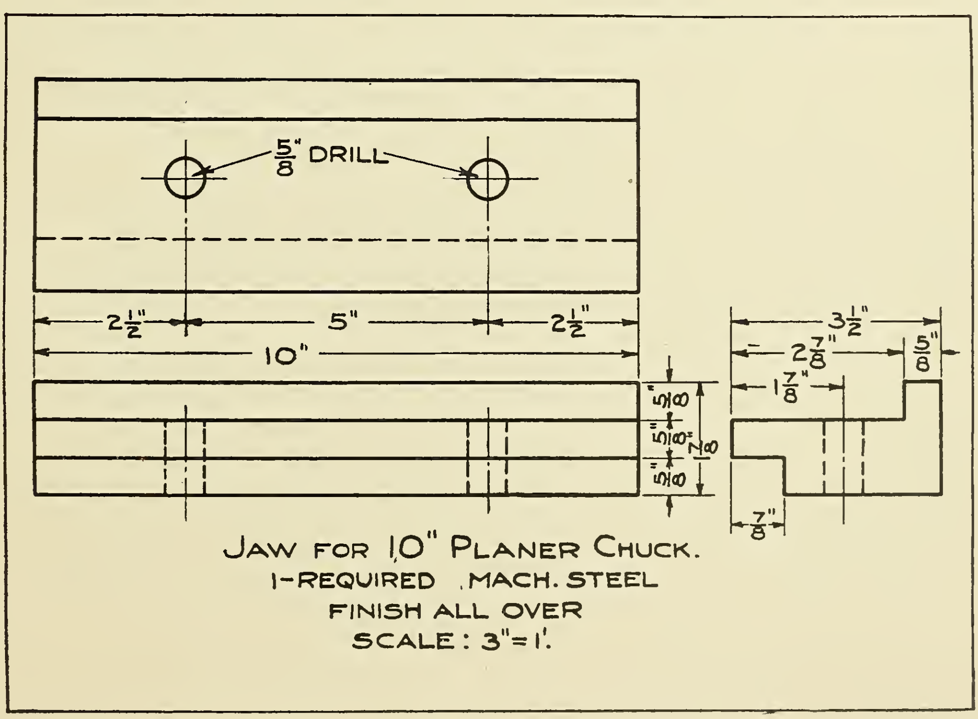


Fig. 111.

instruments which we do not have in this course. This can be avoided by making use of isometric sketching paper, such as shown on page 91. This paper is ruled to the correct 30° axes for this work, and you can lay down your dimensions directly on the ruled lines. Use the paper with its long dimension running from left to right.

PROBLEM 12A

Make an isometric drawing of the planer chuck jaw shown in Fig. 111.

PROBLEM 12B

Make an isometric drawing of the cast-iron foundation washer shown in Fig. 112.

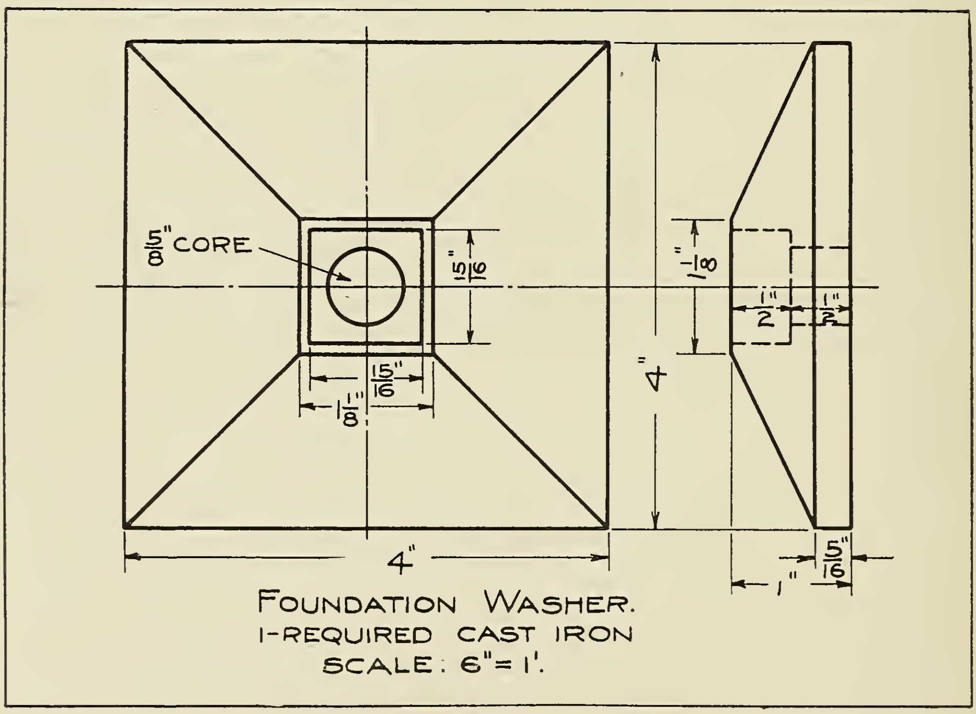
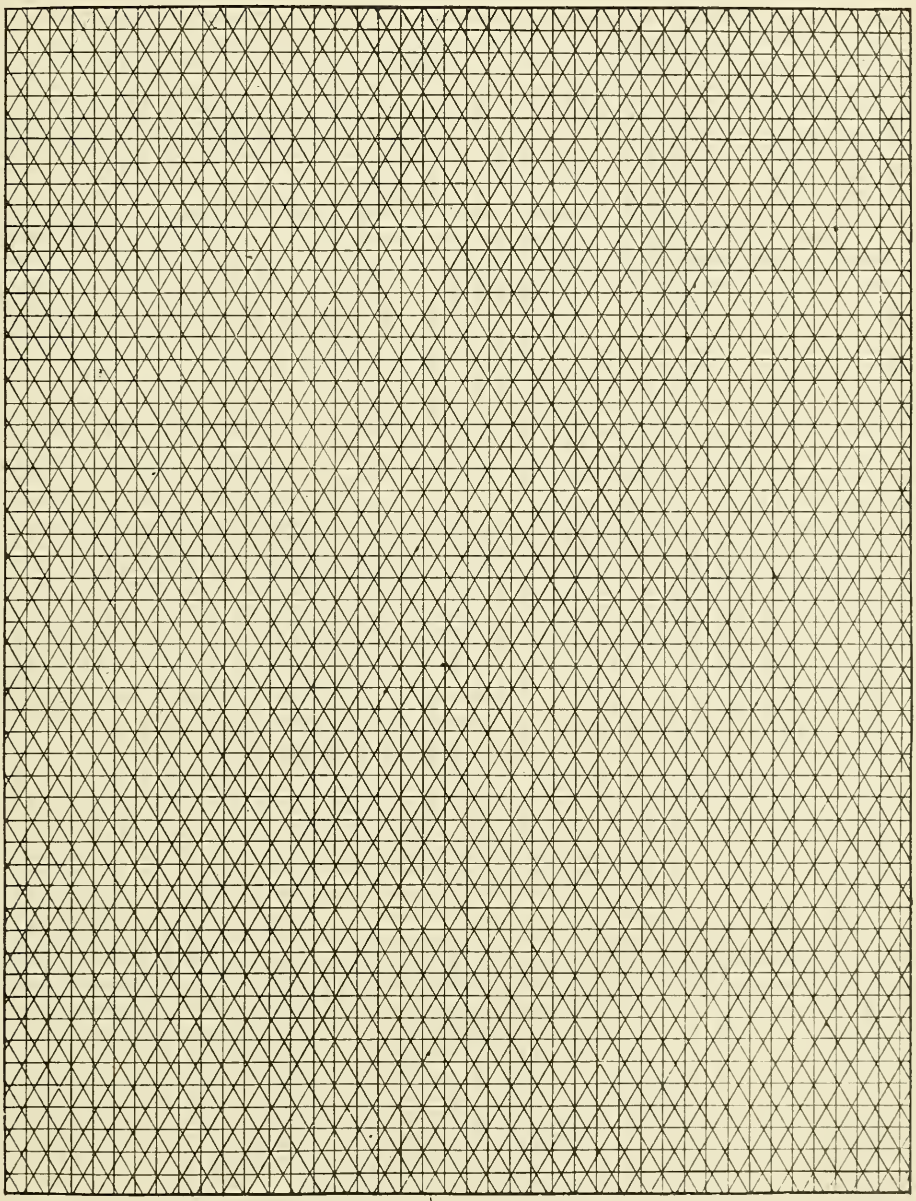


Fig. 112.

PROBLEM 12C

Isometric sketches should be made from some of the following or similar objects, using isometric paper:

Steady rest guide
Slotting tool
Cutting off tool
Solid steel wrench
Tool post wrench
Gib key



Isometric Drawing Paper

ASSIGNMENT 13

66. Isometric Drawing on Plain Paper.—Ability to make good, clear isometric sketches or drawings with ease is the result of careful and conscientious practice. Therefore, it is to be hoped that the student will make many more isometrics than are actually called for in this work, in order to perfect himself. It is evident, of course, that ruled paper will not always be available for working drawings. It then becomes necessary to use plain unruled paper, and to estimate the angles by the eye alone.

After having made the drawings of the problems 12*A*, 12*B*, and 12*C*, on the ruled paper, the student should have a good clear idea of the proper locations of the isometric axes. In starting an

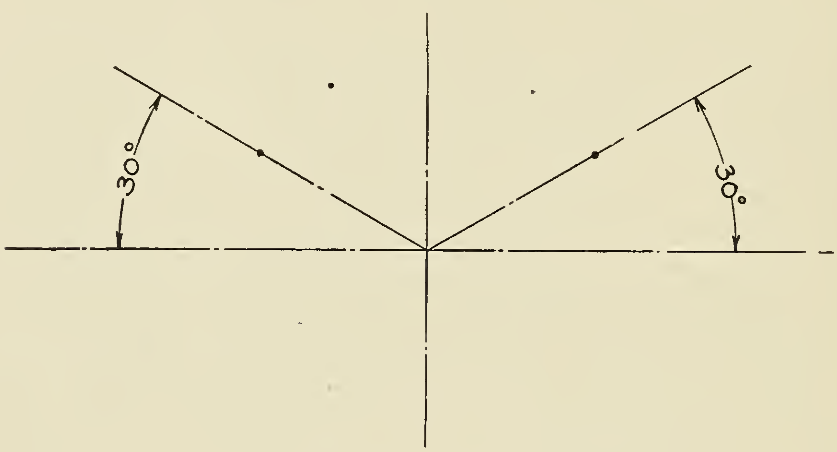


Fig. 113.

isometric sketch on plain paper it is best to first decide the proper place on the sheet for the near corner of the object. Through this point draw horizontal and vertical lines as shown in Fig. 113. Then, with the eye, divide each of the two right angles above the horizontal into three equal parts and thus locate the two other isometric axes at angles of 30° above the horizontal. These will help in estimating the proper angles and in keeping parallel lines, where such are required. Keep in mind the fact that it is only proper to lay down dimensions in the direction of the isometric axes, or center lines. Outline the general shape of the object and put in small details afterward. Too careful attention to minor lines in starting will often lead to distorted finished drawings.

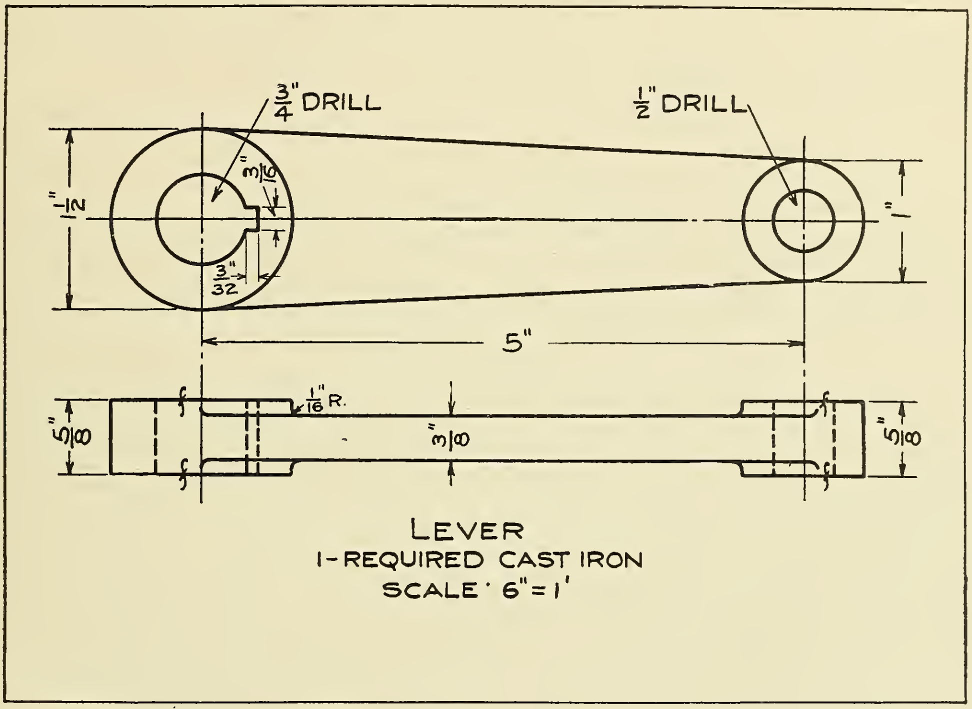


Fig. 114.

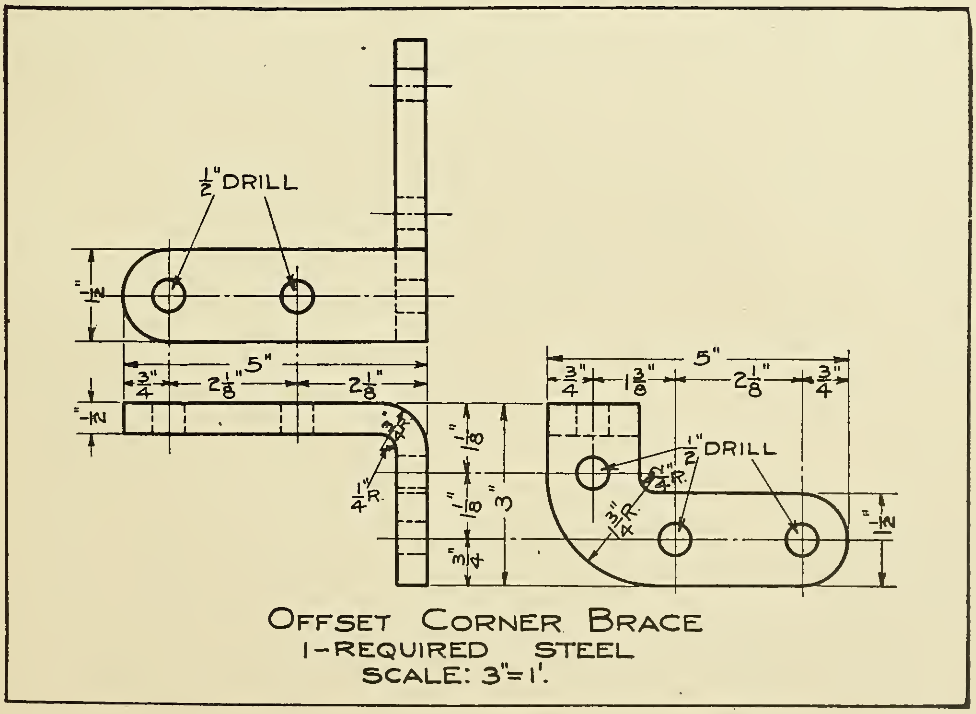


Fig. 115.

Many of the circles and arcs for fillets, etc., can be drawn freehand with a little practice and thus save considerable time in the making of isometric sketches.

PROBLEM 13A

Make a complete isometric drawing on plain, unruled paper of the cast-iron lever shown in Fig. 114. Draw the $1\frac{1}{2}$-in. and 1-in. circles according to the method explained in Article 62, and then sketch in the $\frac{3}{4}$-in. and $\frac{1}{2}$-in. circles freehand, following the outlines of the large ones.

PROBLEM 13B

Make a dimensioned, isometric sketch of the offset corner brace shown in Fig. 115. The isometric sketch will show the shape of this brace very clearly to a workman who could not read the mechanical drawing of Fig. 115.

CHAPTER VII

FREEHAND DRAWING

ASSIGNMENT 14

67. The Use of Sketching Paper.—While the student has used the rule and compass in all drawings made so far, he will appreciate the fact that it is often necessary to make sketches freehand.

The draftsman generally works up his preliminary rough drafts of drawings as freehand sketches which serve as a guide in making finished drawings. He usually keeps a sketch book in which he draws all sketches, and he learns by experience that it pays to make them neatly and to dimension them fully. Sketching paper with lines ruled both ways, to form squares, makes a very convenient material for these sketches. Fig. 117 illustrates the use of this paper in freehand work. Quadrille ruled paper is excellent for the work as it has light-blue ruling both ways, forming $\frac{1}{8}$-in. squares on the paper. The lines on the paper will serve as a guide in drawing straight lines and in laying out circles. The divisions will also assist in laying out sketches to an approximate scale if desired. In all work in freehand sketching, the pencils should be kept well sharpened, so as to make clear, well defined lines, and the drawing should be kept as neat and clean as possible. The order of work for freehand sketching is the same as for making finished mechanical drawings with the aid of the drawing instruments. The center lines are first located. Then, usually, one view is sketched in completely and the others developed in their proper relations to it.

The extension lines and dimension lines should all be drawn next, and the arrow heads put on all dimension lines, as in Fig. 118. Then the piece may be measured up and the dimensions placed on the drawing. By this procedure, necessary dimensions are not so apt to be omitted. Suppose, for instance, that we wish to make a freehand sketch of the object shown in Fig. 116. Figures 117, 118, and 119 show the various stages of the work as just enumerated. A title is added to show the name of the object, the number required, and the material.

Usually, in making freehand sketches, no attempt is made to draw the objects to scale, although the various parts of the drawing should bear the proper relative proportions to each other.

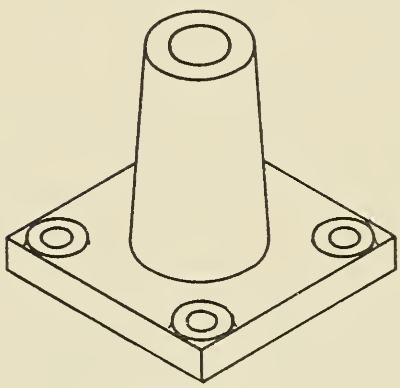


Fig. 116.

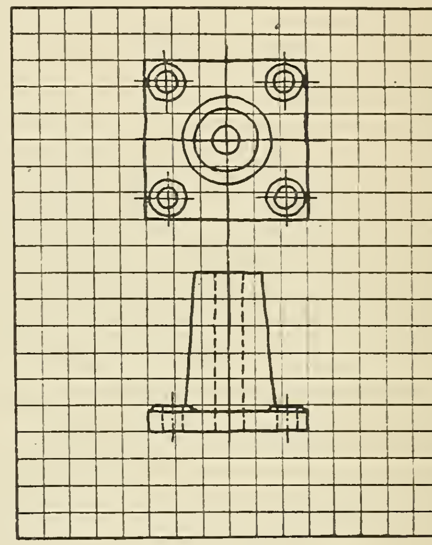


Fig. 117.

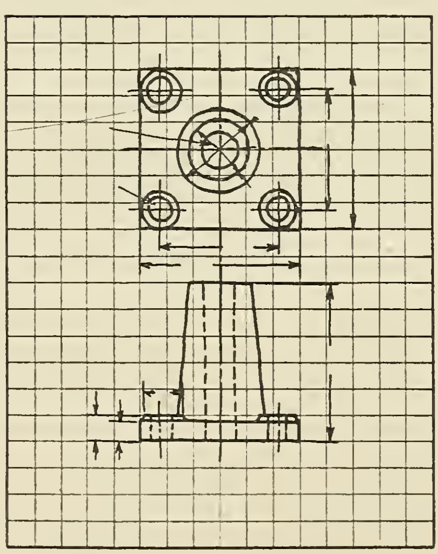


Fig. 118.

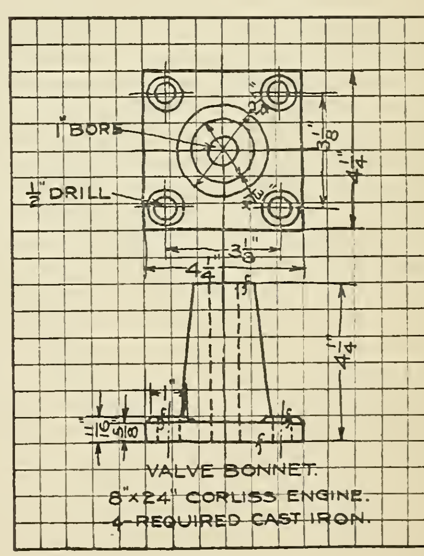


Fig. 119.

Dimensions should always be given from center lines and finished surfaces. When a circle is to be drawn, the radius should be pointed off each way on the center lines from the point where the two center lines cross. Through the four points thus located, a circle may readily be passed freehand. Always put a complete title and the date on every sketch so that it can be identified at any later period.

PROBLEM 14A

Using ruled sketching paper, make freehand dimensioned sketches of the side and end views of the tool post shown in Fig. 120.

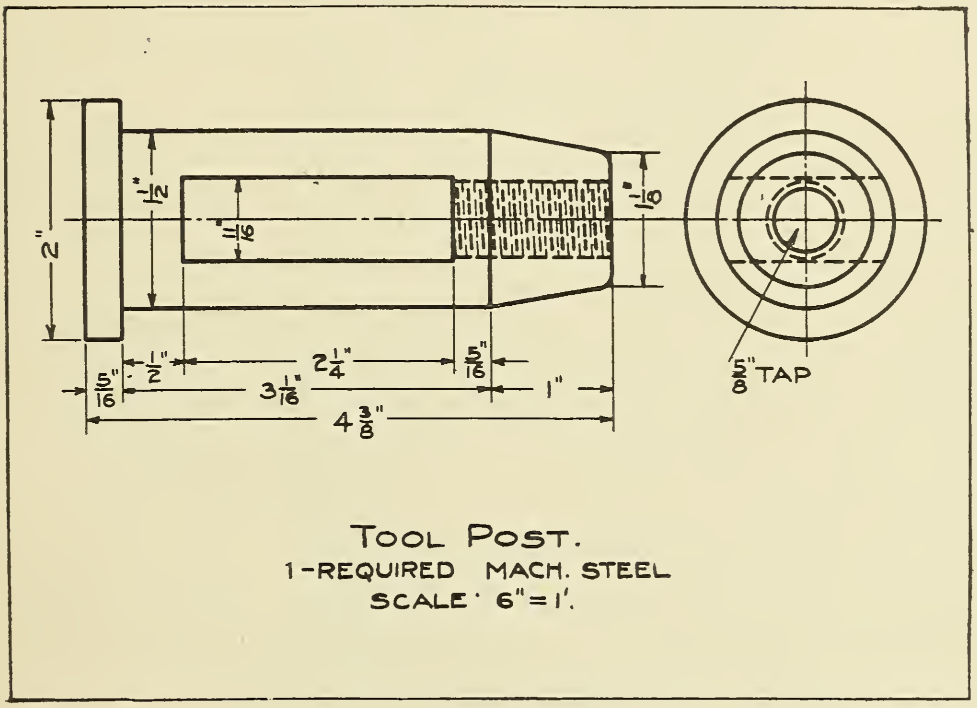


FIG. 120.

PROBLEM 14B

Make complete freehand dimensioned sketches of two objects—one from each of the following lists:

Tool post wrench	Lathe tool
Socket wrench	Steel mandrel
Milling machine crank wrench	Square center for lathe
Lever for car pusher	Wrecking bar
Cape chisel	Planer or shaper knife

ASSIGNMENT 15

68. Sketching on Plain Paper.—After having made sketches on ruled paper, the student should have a sufficiently clear idea of the difficulties and methods of freehand drawing to attempt the most common and useful form of freehand work; namely, sketches on plain unruled paper.

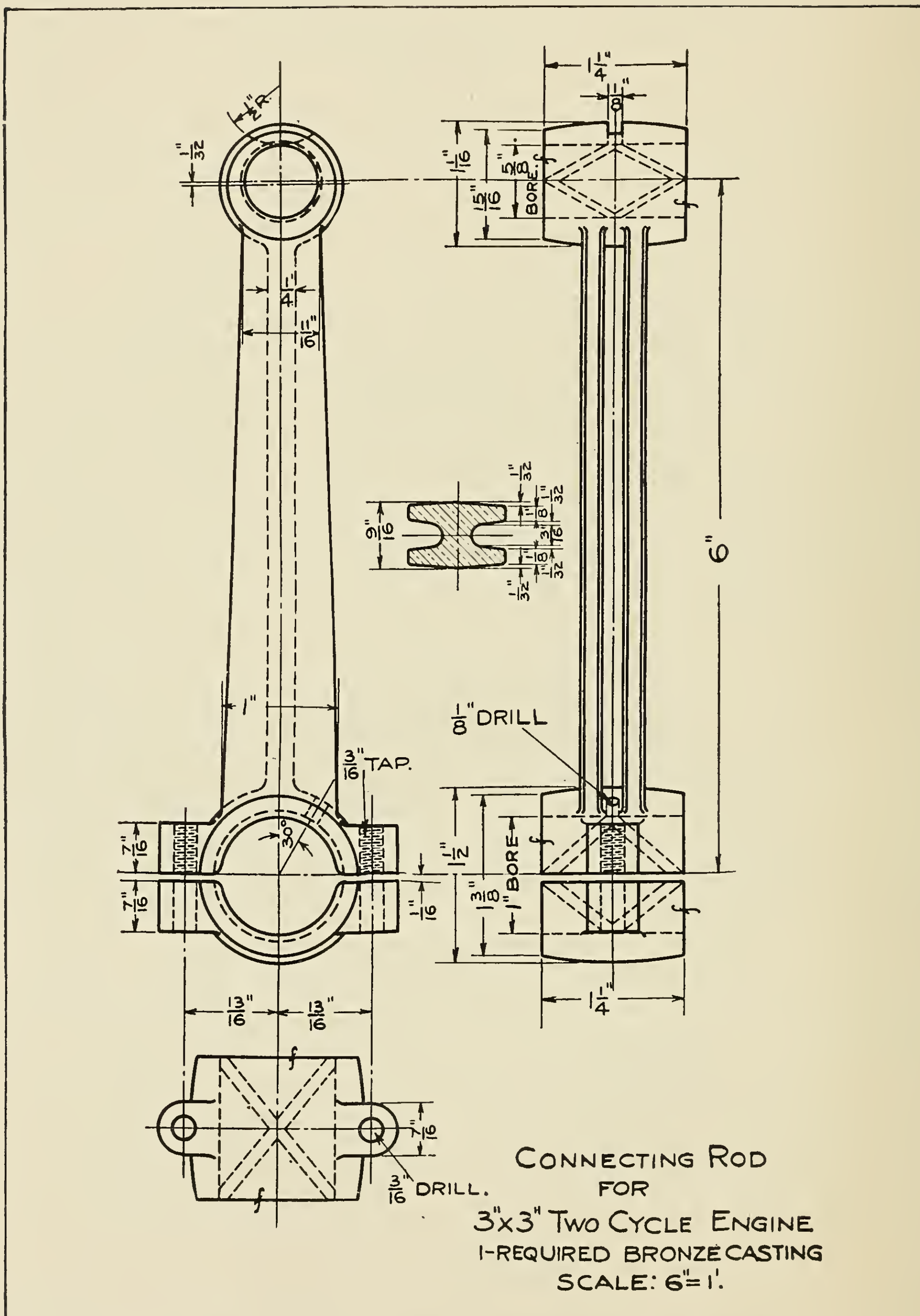

CONNECTING ROD
FOR
3"x3" TWO CYCLE ENGINE
1-REQUIRED BRONZE CASTING
SCALE: 6"=1'.
1/8" DRILL
3/16" TAP.
3/16" DRILL.
BORE
6"

FIG. 121.

In drawing a straight line, do not grip the pencil tightly nor endeavor to make the line with one slow continuous stroke. Rather make a series of short-strokes joined together. In drawing vertical lines, hold the hand to the right of the line so that the pencil swings freely up and down in the fingers while the hand rests firmly on the paper. Watch the edges of the paper to see that the long lines do not slant. Well laid out center-lines are of great assistance in keeping lines straight and parallel.

PROBLEM 15A

Make dimensioned, freehand sketches, on plain paper, of the views of the gas engine connecting rod shown in Fig. 121.

PROBLEM 15B

Sketch one object from the following list, or some similar object.

Drill press table
Steam engine slide valve
Steam pump piston
Gas engine cylinder head
Milling machine over-arm
Automobile steering wheel

ASSIGNMENT 16

69. Freehand Isometric Sketching.—Quite often isometric sketches have to be made freehand without the aid of ruler or

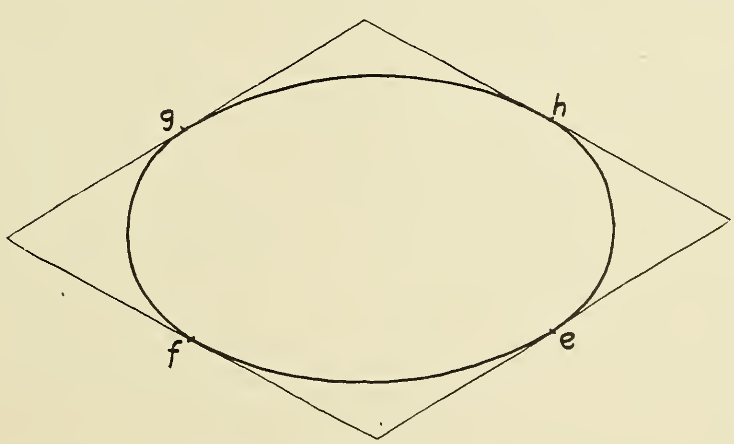


Fig. 122.

compass. In starting a freehand isometric sketch, locate the near corner of the object on the paper and sketch in the isometric axes through this point, as illustrated in Fig. 113.

Circles in isometric may be drawn by an approximate freehand method as follows. Sketch in lightly the circumscribing rectangle. Locate the middle points of its four sides by the points *e*, *f*, *g*, and *h*; see Fig. 122. Next in order, draw the two long arcs *gh* and *fe*, and finally the two end arcs *fg* and *eh* to close the ends of the ellipse. This approximate method may be applied to the representation of circles in any plane.

Dimension and extension lines should be drawn in the directions of the isometric axes, as illustrated in Figs. 94, 95, 103 and 105.

PROBLEM 16

Make complete isometric drawings, freehand, of any one article chosen from List A; and one from List B. Draw each on a separate sheet, and do not use a straight edge or compass. All work on these sketches is to be freehand. Dimension your drawing, showing your dimension and extension lines extending in the direction of the isometric axes.

List A

Bench rammer
Tool post
Any blacksmith's tools (without handles) such as hardie, flatter, sledge, heading tool, swage, hot chisel, etc.

List B

Anvil
Tool rest for lathe
Bearing block
Die block for press
Ram for steam or drop hammer
Over-arm for miller

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