FIFTH EDITION
REVISED AND
ENLARGED BY
CARL L. SVENSEN

Mechanical Drawing

A Text with Problem Layouts

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MECHANICAL DRAWING

MECHANICAL DRAWING FOR HIGH SCHOOLS

Preface to the Fifth Edition

This edition, like the previous ones, represents the progress and improvements that have resulted from the test of actual use by the teachers of mechanical drawing, old and young, in large and small schools.

Changes and additions have been made to bring about conformity with modern industrial practice and with the high standards of today's teachers. The text has been rewritten, most of the illustrations have been improved, and a large number of new illustrations and problems have been incorporated in the book. New chapters have been included on Production Drawing, Aircraft Drawing, and Welding Drawings. For convenience of reference, tables and teaching-aid suggestions have been placed together in an Appendix.

Visual materials (McGraw-Hill Text-Films) are now available to extend further the effectiveness of this book as a tool for teaching mechanical drawing. These films are correlated with the text and with the greatly increased number of movie-type illustrations in this edition.

The valuable suggestions of the authors' friends, the teachers, have made it possible to continue to meet present-day requirements and ideals. Credit for this professional assistance is here acknowledged to all who have contributed in any way. In particular, thanks are due to Professor S. M. Cleland and Mr. W. F. Tate, Jr., for their work on many of the new drawings; to Professor Ralph Paffenbarger for his contribution of several new problems; and especially to Dr. W. E. Street for his interest and suggestions.

CARL L. SVENSEN

Preface to the First Edition

Industrial educators are generally agreed that a textbook is necessary for the most successful teaching of mechanical drawing. However, several important considerations are involved in the selection of a suitable text. It "should be more than a collection of problems. It should present the subject in a clear, orderly and logical arrangement of the divisions, explaining *why* each rule or custom is made, and illustrating with examples representing good modern practice."

A survey of mechanical drawing in high schools* recently made by the authors showed that "a system of standardization appears to be needed to give the subject the standing to which it is entitled as a cultural subject as well as a practical one, a real language to be studied and taught in the same way as any other language."

The purpose of this book is to present mechanical drawing as a definite educational subject with the following objectives:

To develop the power of visualization;

To strengthen the constructive imagination;

To train in exactness of thought;

To teach how to read and write the language of the industries;

To give modern commercial practice in making working drawings.

The standardizing of mechanical drawing by the logical arrangement of its subject matter into grand divisions will, it is believed, make both teaching and learning easier.

The first seven chapters comprise a complete textbook which may be used with any problems. The paragraphs are numbered for easy reference. The eighth chapter is a complete problem book, in which the number of problems in each division is such that a selection may be made for students of varying ability, and that a variation from year to year may be had. The problems have references to articles in the text, and the order may be varied to suit the particular needs of a school. Definite specifications and layouts are given for most of the problems, thus making it possible for the instructor to use his time efficiently in teaching rather than in the drudgery of detail, while the

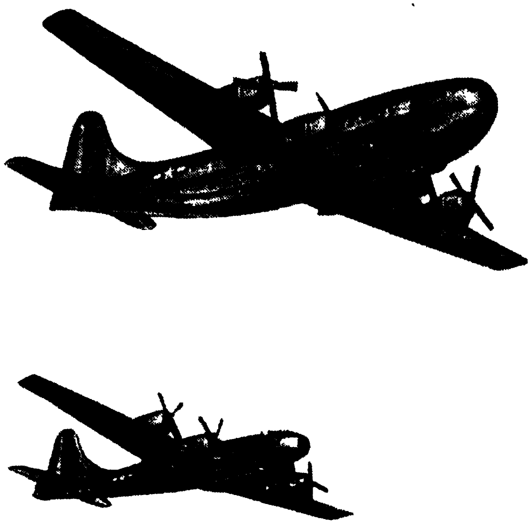
*Bulletin issued by Department of Public Instruction, State of Ohio.

time ordinarily wasted by the pupil in getting started can be used in actual drawing.

More than enough is included for two years' work in the average high school. The authors will at any time be pleased to advise in the selection of problems or arrangement of courses.

Thomas E. French
Carl L. Svensen

Contents



CHAPTER I. The Language of Drawing

1·1 Engineering and science enter into the affairs of everyday life to such an extent that it is impossible to be informed on events and progress without some facility in reading the language of industry—*mechanical drawing.* The reading of drawings is as important as the making of them. The use of pictorial methods for production illustration emphasizes the importance of making mind pictures visible as an aid to reading mechanical drawings. While mechanical drawing is a necessary part of the education of the engineer and the scientist, it is also an important part of the *language education* of every well-informed person.

1·2 Language is defined as the expression of thought. Every educated person wishes to be able to express himself readily and easily, to convey his thoughts so accurately that they cannot be misunderstood, and to be able to understand the exact meaning expressed by another person. For this reason we make an extended study of English, until we know its grammar, idioms, and style. We read literature and practice composition in order to become thoroughly familiar with the language.

1·3 If we attempt to describe in words the appearance and details of a machine, a bridge, or a building, we find it not only difficult but in most cases impossible. Here we must use another language, the universal graphic language of drawing. Thus when words fail to give a complete or accurate description, we find books, magazines, and newspapers using pictures, diagrams, and drawings of various kinds.

1·4 Photographs (Figs. 1·1 and 1·2) are the commonest and most familiar forms of illustrations. To show a structure pictorially, as it actually appears to the eye or as it will appear when built, perspective drawing is often used (Fig. 1·3).

A written description of a new piece of furniture would have to be very long to tell *all* about it and even then might be misunderstood. A picture of it would serve the purpose much better, but the picture

Figure 1·1 Photograph of B-29 and B-17 airplanes built by the Boeing Aircraft Company (top). Figure 1·2 Steam turbine locomotive built by the Baldwin Locomotive Works for the Pennsylvania Railroad (bottom).

would not show the exact method of construction. It would give only the external appearance without telling what was inside. It would be impossible to construct an airplane or a locomotive from either a word description or a picture.

1·5 Fortunately another form of description has been developed by which the exact shape of every detail of any structure may be defined accurately and quickly. This method consists of the making of a series of views arranged according to a definite system, with figures added to tell the sizes. This is known as "mechanical drawing," and it forms so important a part of all industrial and mechanical work that it is called the "language of industry."

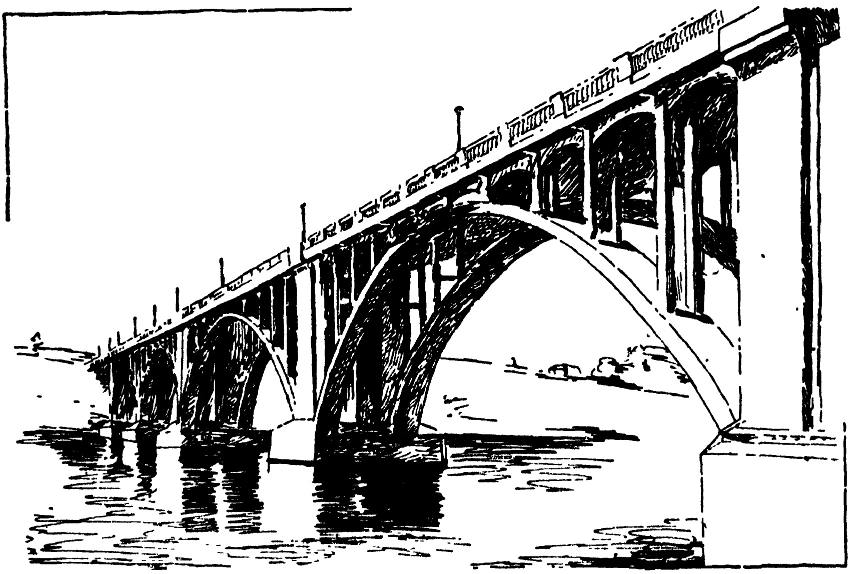


Figure 1·3 A perspective drawing.

The language of drawing has its own orthography, grammar, and style, its own idioms and abbreviations, and the study of it not only gives one the ability to express thoughts hitherto impossible but develops the constructive imagination and the habit of exact thinking.

1·6 Learning drawing then is much more than simply learning how to draw. It is learning to read and write a new language, just as real a language as English or French. Its mastery requires study and practice, with close attention to details, but its importance to anyone who expects to go into any branch of technical designing or manufacturing or building justifies all the time spent in studying it.

TEXT-FILMS

The following McGraw-Hill Text-film has been correlated directly with Chap. 1:

The Language of Drawing (10-min. sound motion picture)

This film attempts to stimulate the interest of beginning students in the subject through glimpses of actual jobs in factories, shipyards, and shops. The importance of coordinating the work of many people is established, as well as the necessity of understanding mechanical drawing—the technical language of modern production activities.

CHAPTER 2. Learning to Draw

Figure 2·1 A drafting room.

2·1 The Drafting Room. Engineering work of all kinds starts in the drafting room (Fig. 2·1) where the designs are worked out and the necessary drawings are made and checked. Chapter 1 explained the necessity for drawing in all industrial work and the fact that it was really a new language. Sometimes drawings are made freehand, but for accurate work it is necessary to use instruments. In learning to read and write in this language we must first learn what tools and instruments to use and how to use them accurately, skillfully, and quickly.

2·2 Attaching the Paper. Mechanical drawings are usually made on unruled paper, either fairly heavy cream color or white, or tracing paper. If a soft pine drawing board is used, the paper is held in place by thumbtacks, wire staples, or Scotch drafting tape. For a composition board or any other hard-surfaced board, drafting tape is used. In many drafting rooms the drawings are made directly in pencil on tracing paper or pencil cloth, from which blueprints are made.

To fasten the paper, place it on the drawing board with the left edge an inch or so from the left edge of the board, place the T-square in the position shown in Space 1 of Fig. 2·2 and true up the paper with the T-square blade. Holding the paper in position, move the T-square down, as in Space 2, and fasten each corner with thumbtacks or tape. If thumbtacks are used, be sure to push them in until the heads are in contact with the paper. Sheets of firm drawing paper not larger than 12″ × 18″ (to trim to American Standard Size, 11″ × 17″) may be held in place by two tacks placed in the two upper corners, or by the use of tape.

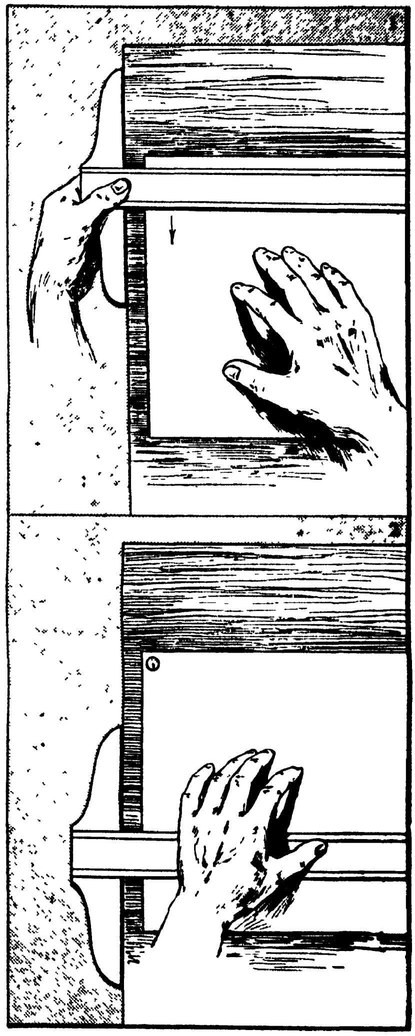


Figure 2·2 Aajusting and fastening the paper.

2.3 American Standard trimmed sizes of drawing paper and cloth are based upon the commercial letter head which is 8½″ × 11″. Multiples of this size give standard dimensions as follows: A, 8½″ × 11″; B, 11″ × 17″; C, 17″ × 22″; D, 22″ × 34″; E, 34″ × 44″.

2.4 Drawing pencils are made with uniformly graded leads designated by letters and have a range of 6B (very soft and black), 5B, 4B, 3B, 2B, B, HB, F, H, 2H, 3H, 4H, 5H, 6H, 7H, 8H, 9H (extremely hard). 4H and 6H are usual grades of hard pencils for drawing lines on fairly hard surface paper, while H or 2H are used on tracing paper or tracing cloth for blueprinting. Softer pencils are used for sketching and lettering (HB, F, H, or 2H) according to the result to be secured on the paper being used.

2·5 Sharpening the Pencil. Sharpen the pencil by cutting away the wood, on the plain end, at a long slope; be careful not to

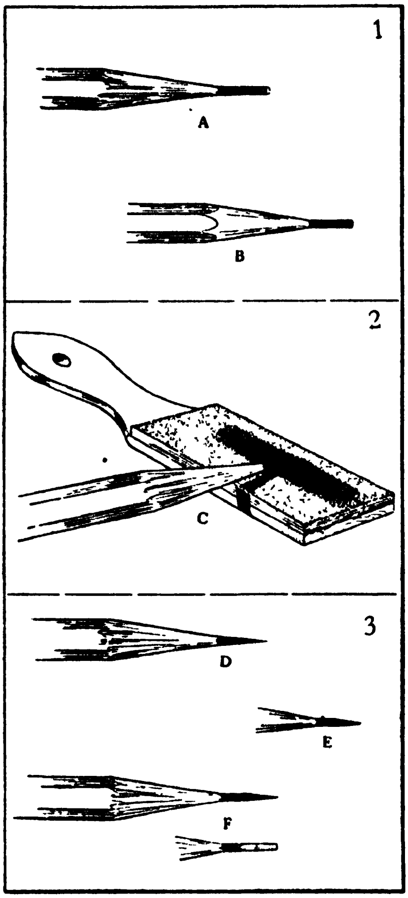


Figure 2·3 Sharpening the pencil.

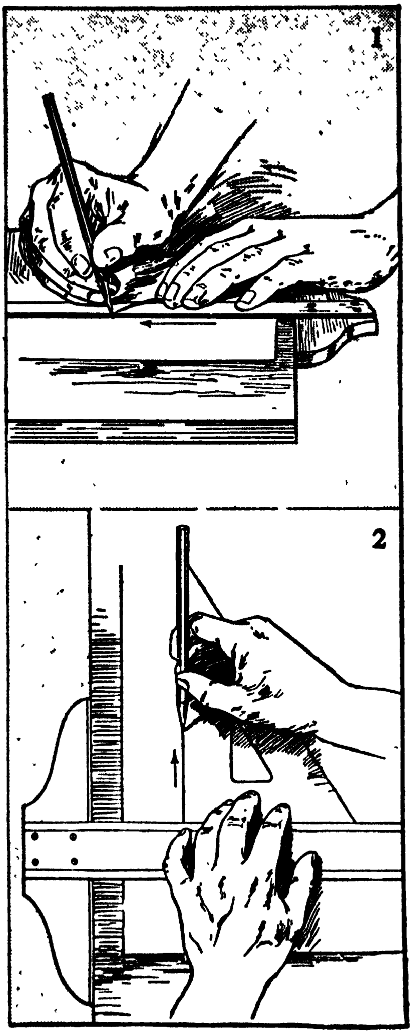


Figure 2·4 Drawing horizontal and vertical lines (right).

cut the lead but expose it about ¼ in. or more (Fig. 2·3 at A in Space 1). Mechanical sharpeners with a draftsman's special cutter are in quite general use to cut the wood away from the lead (Space 1 at B). Then shape the lead to a long conical point by rubbing it back and forth on a sandpaper pad (Space 2 at C) or on a fine file, rotating it slowly in the fingers to form the point (Space 3 at D and E). Have the sandpaper pad or file close at hand so that the lead can be kept sharp by frequent rubbing. Some draftsmen prefer a flat or chisel point (Space 3 at F) especially for drawings with a large number of long straight lines.

Never sharpen a pencil over the drawing board. Pencil lines must be thin, clear lines. Develop the habit of rotating the pencil so as to keep the sharp conical point.

2·6 Ruling Lines. All lines in a mechanical drawing are made with the aid of some instrument as a guide for the pencil or pen. Horizontal lines are drawn with the upper edge of the T-square blade as a guide (Fig. 2·4, Space 1). Hold the head of the T-square against

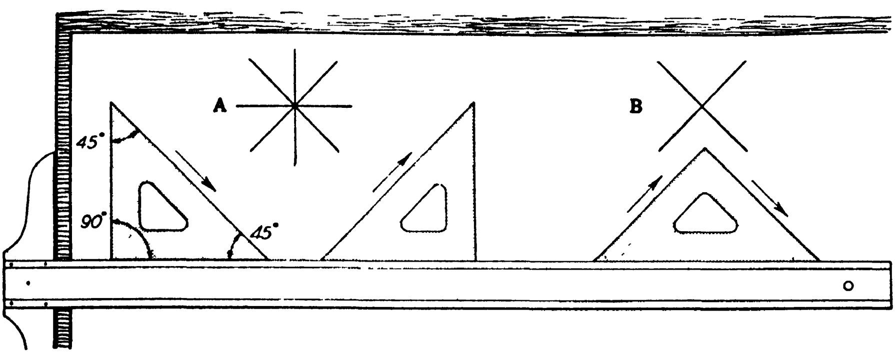


Figure 2·5 The 45° triangle.

the left-hand edge of the board with the left hand,[1] and always move the pencil from left to right.

The pencil should be held about an inch from the point and inclined slightly in the direction in which the line is being drawn. A plane through the pencil and the line being drawn should make right angles with the paper. This will keep the point of the lead away from the corner formed by the guiding edge of the T-square blade and the paper. A little practice may be necessary in order to keep the line parallel to the guiding edge, but it soon becomes a habit.

Vertical lines are drawn with a triangle in combination with the T-square (Fig. 2·4, Space 2). Always have the vertical edge of the triangle toward the left and draw upward.

2·7 Inclined Lines. The 45° triangle has two angles of 45° and one of 90° (Fig. 2·5). Inclined lines at 45° are drawn with the triangle, held against the T-square, as shown for three positions at A and B in Fig. 2·5. Note that the lines drawn with the triangle in the two positions shown at A are at right angles to each other. The two lines drawn at B in Fig. 2·5 are at right angles to each other.

[1] Left-handed persons reverse this rule and use the T-square on the right edge.

The 30°–60° triangle has angles of 30°, 60°, and 90° (Fig. 2·6). Inclined lines at 30° and 60° are drawn with the triangle held against the T-square. Several positions for the triangle are shown in Figs.

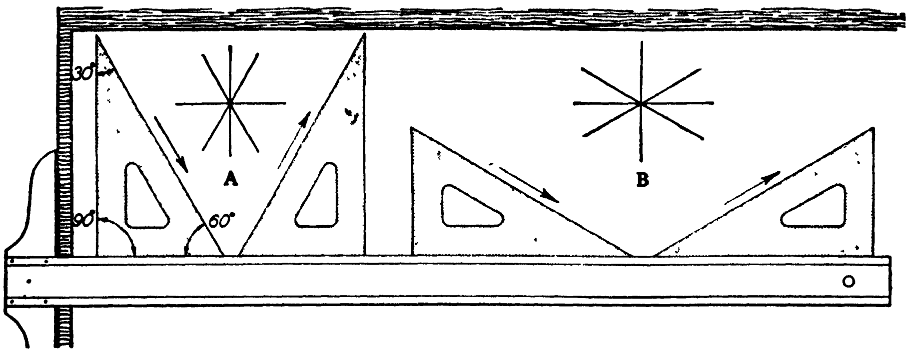


Figure 2·6 The 30°–60° triangle.

2·6 and 2·7. Note that lines drawn with the triangle in the first and last positions of Fig. 2·6 are at right angles to each other and that lines drawn with the triangles in the second and third positions are at right angles to each other. Also, lines drawn with the triangle in position A or B of Fig. 2·7 are at right angles to each other. By using both positions of the triangle in Fig. 2·7, lines at 30° angles with each other may be drawn as at C.

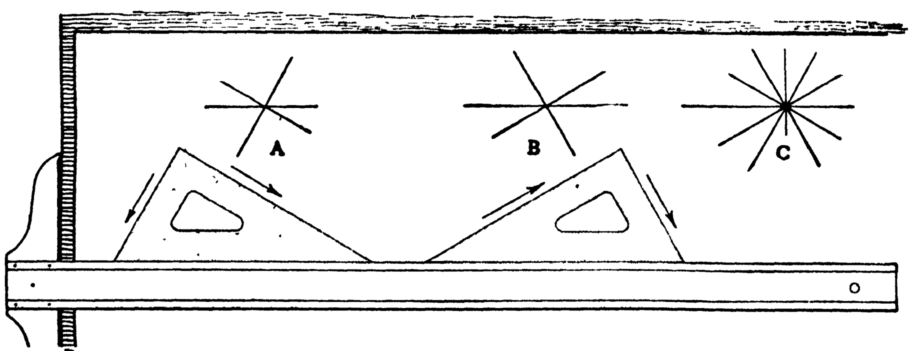


Figure 2·7 The 30°–60° triangle.

Inclined lines at other angles varying by 15° may be drawn by using two triangles in combination with the T-square. The methods of obtaining the different angles are shown in Fig. 2·8, Spaces 1 to 15. In Space 15 of Fig. 2·8 the lines make angles of 15° with each other. By using the arrangements of Spaces 2 and 13, or Spaces 6 and 9, two angles of 30° and two angles of 150° will be obtained. Try different combinations of triangles until you are familiar with them.

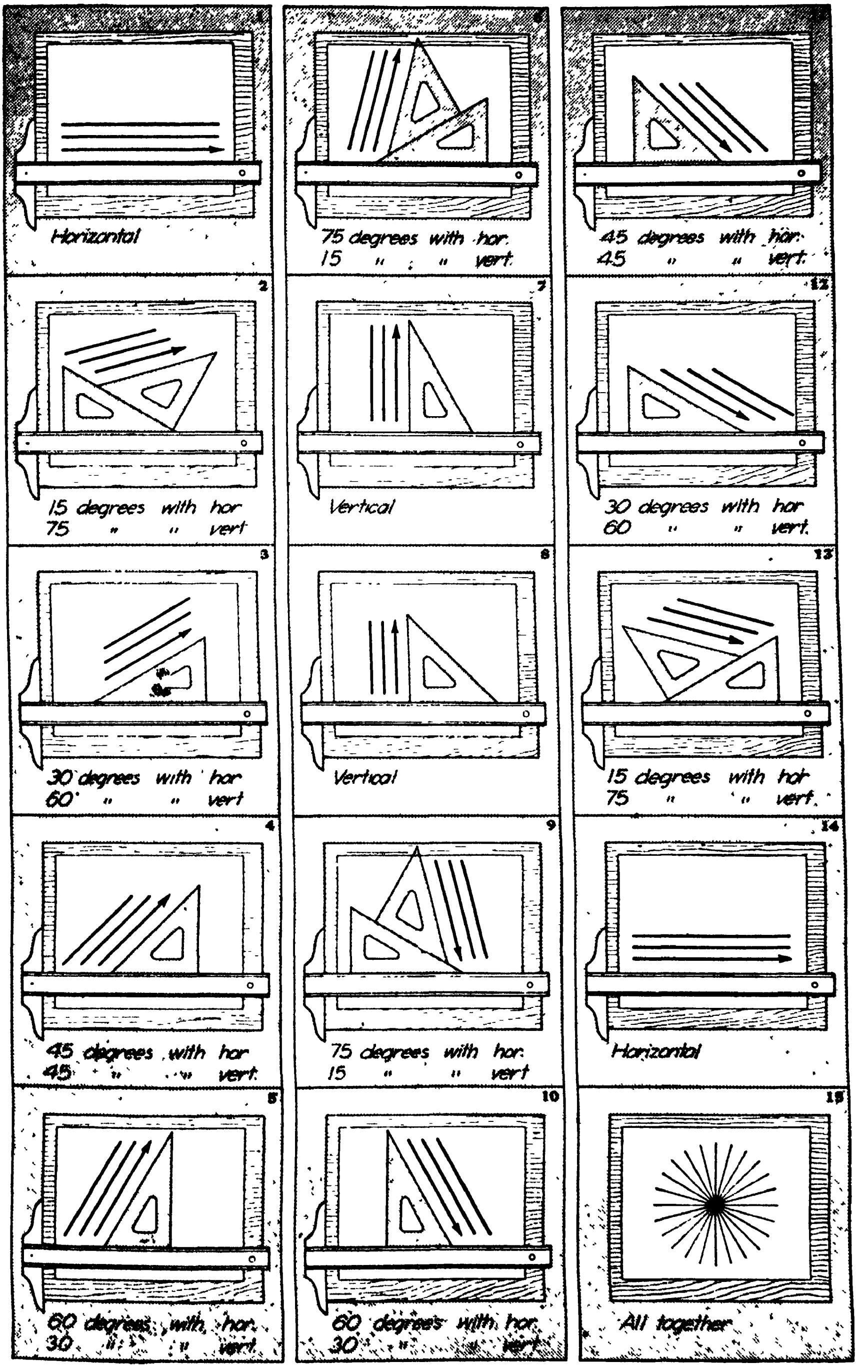


Fig. 2·8 Drawing lines with T-square and triangles.

2·8 Parallel lines may be drawn directly with a drafting machine (Fig. 2·16). Parallel horizontal lines can be drawn with the T-square. Other parallel lines are drawn by using a triangle in combination with a T-square (or other triangle), as shown in the "movies" of Fig. 2·9. To draw a line parallel to a given line (Fig. 2·9, Space 1), place a triangle against the T-square (Space 2), and move them together until the hypotenuse of the triangle matches the line (Space 3). Hold the T-square firmly, and slide the triangle in the direction of the arrow until the desired position of the line is reached (Space 4).

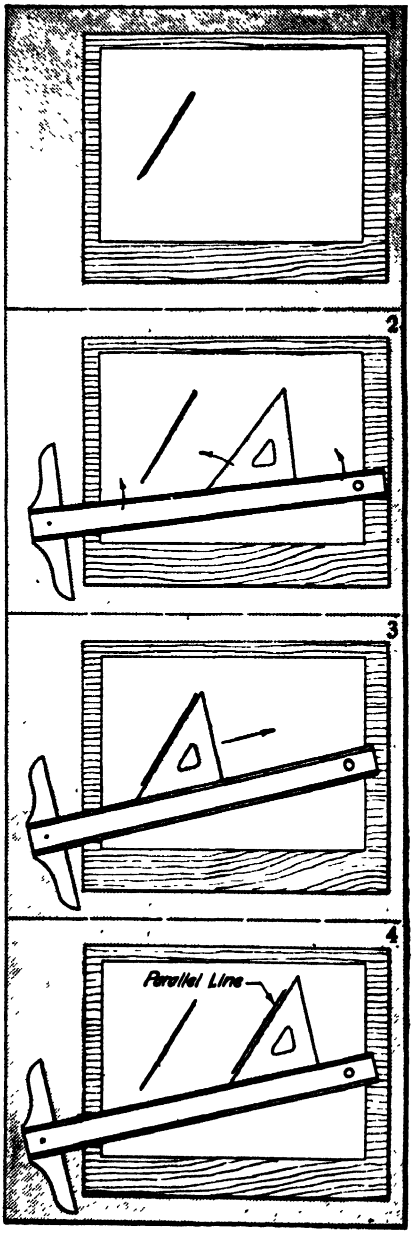


Figure 2·9 Drawing a parallel line.

2·9 Lines perpendicular to each other may be drawn directly with a drafting machine. They may be drawn with a triangle in combination with the T-square (or other triangle) as shown in the movies of Figs. 2·10 and 2·11. To draw a line perpendicular to a given line (Fig. 2·10, Space 1), place a triangle with the hypotenuse against the T-square, one side matching the given line (Space 2), and slide the triangle in the direction of the arrow until the desired position of the perpendicular line is reached (Space 3). In Space 4, the 45° triangle has been used.

Another method is shown in Fig. 2·11. To draw a line perpendicular to a given line (Space 1), place a triangle against the T-square with the hypotenuse matching the given line (Space 2). Turn the triangle about its right-angled corner

(Space 3), until it is in the position shown in Space 4 when the perpendicular line can be drawn on the hypotenuse of the triangle.

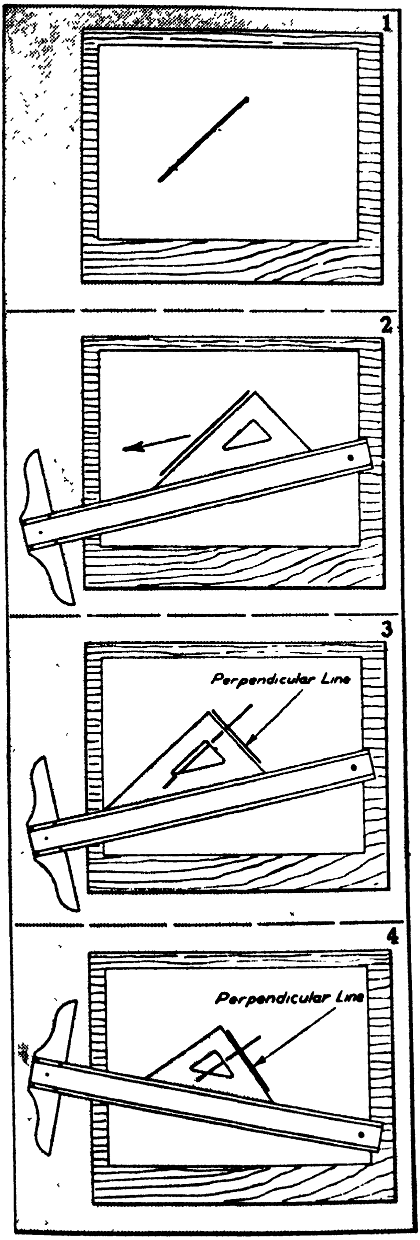


Figure 2·10 Drawing a perpendicular line. First method.

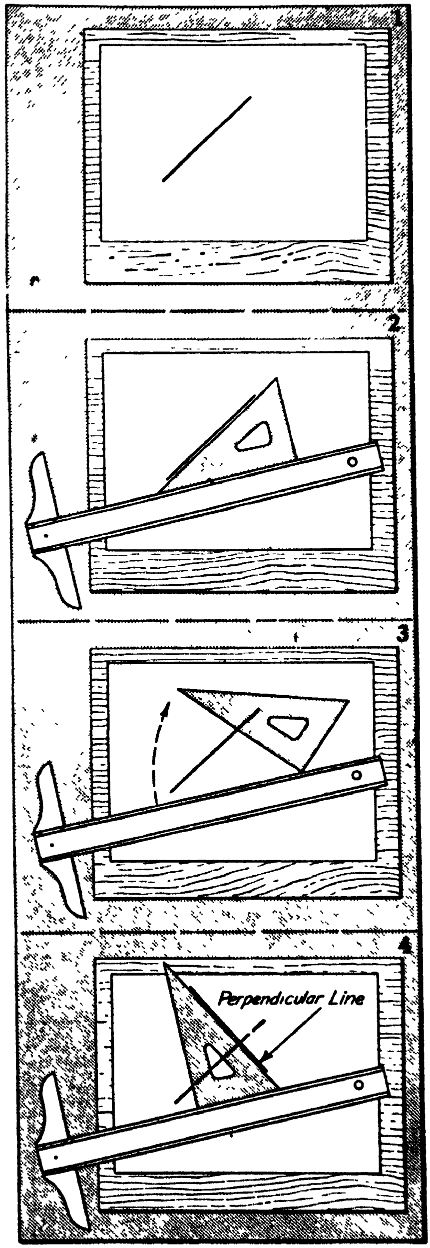


Figure 2·11 Drawing a perpendicular line. Second method.

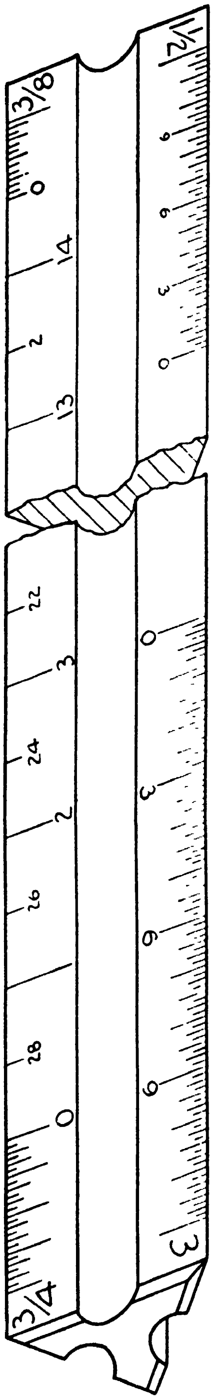


Figure 2·12 Mechanical engineers' (or architects') scale.

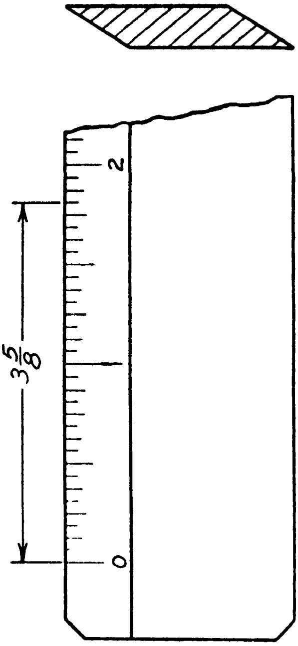


Figure 2·14 Measuring to half size.

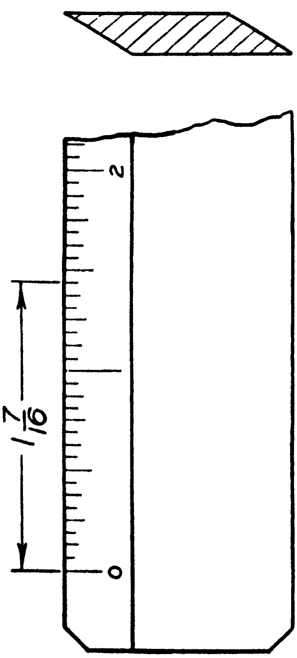


Figure 2·13 Making a measurement (1 7/16").

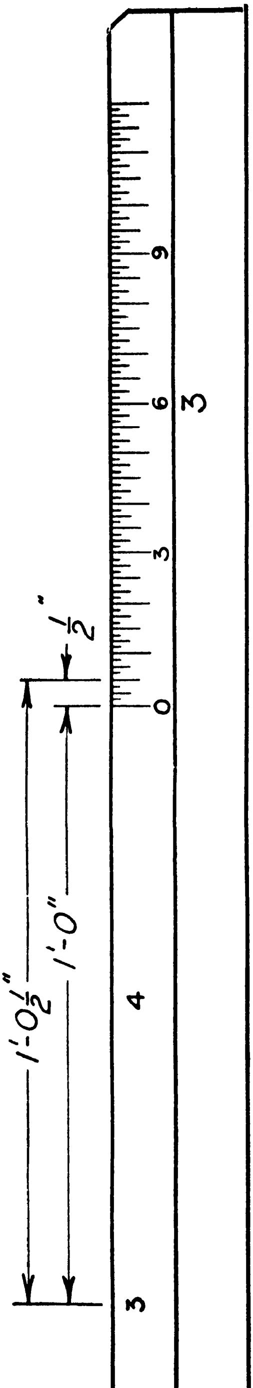


Figure 2·15 Reading the scale.

2·10 Measuring. All measurements of lengths or distances on a drawing are made with the *scale*. Scales are made with different divisions for different purposes. For machine, structural, and architectural drawing, the mechanical engineers' (or architects') scale of proportional feet and inches is used. For school purposes the triangular scale (Fig. 2·12) is much used although the flat shapes are preferred by many draftsmen. The symbol ′ is generally used for feet and ″ for inches. Thus three feet four and one-half inches is written 3′-4½″. When all the dimensions are in inches, it is usual to omit the symbol.

When the object is not too large for the paper, it is drawn in its full size, using the scale of inches and sixteenths. To lay off a full-size distance, put the scale down on the paper against the line to be measured. Make a short dash on the paper opposite the zero on the scale and another short dash opposite the division representing the desired distance (Fig. 2·13). Do not make a dot or punch a hole in the paper.

2·11 Drawing to Scale. If the object is too large to go on the paper in its full size, it is drawn in reduced proportion. The first reduction is to the scale of 6″ = 1′, commonly called "half size." To measure a distance at the scale of 6″ = 1′, use the full-size scale and consider each half inch as representing an inch, each quarter inch as a half inch, etc. Thus the 12″ scale will become a 24″ scale.

Example: To lay off 3⅝″, start at zero and count three *one-half inches*, and five-eighths of the next half inch, as shown in Fig. 2·14. *Do not divide the size of the piece by two.*

If the drawing cannot be made half size, the next scale is 3″ = 1′, often called "quarter size." Find this scale and examine it. The actual length of three inches becomes one foot, divided into 12 parts, each representing 1 in., and these are further divided into eighths. Learn to think of these as real *inches* in *reduced* scale.

Example: To lay off the distance 1′-0½″ (Fig. 2·15). Notice the position of the zero mark, placed so that inches are measured in one direction from it and feet in the other, as shown in the figure. Other scales found on a triangular scale are, 1½″ = 1′; 1″ = 1′; ¾″ = 1′; ½″ = 1′; ⅜″ = 1′; ¼″ = 1′; 3/16″ = 1′; ⅛″ = 1′; 3/32″ = 1′.

Flat scales are made with graduations for all the scales found on the regular triangular scale and for 6″ = 1′; 4″ = 1′; and 2″ = 1′; but the last two scales are seldom used. The scale to which the views are made should be given on the drawing, either in the title or, if several parts are drawn to different scales, near the views, as 1″ =

Figure 2·16 Paragon drafting machine. (Keuffel & Esser Co., New York.)

1′-0″. This tells that one inch on the drawing represents one foot on the part.

For small parts enlarged scales may be used; as, 24″ = 1′, for double size views. Very small parts may have the views drawn 10, 20, or more times full size.

2·12 Drafting Machines. Engineering offices and industrial drafting rooms are making increasing use of drafting machines, one type of which is illustrated in Fig. 2·16. Such machines combine the functions of the T-square, triangles, scale, and protractor. Lines can be drawn the exact lengths in the required places and at any angle by moving the ruling edge directly to the desired positions. This results in greater speed with less effort in making drawings.

2·13 Drawing Arcs. Drawings are made up of straight lines and curved lines. Most of the curved lines are circles or parts of circles (arcs). Circles larger than 1½ or 2 in. in diameter are drawn with the large compasses (Fig. 2·17). The usual size measures about 6 in. in height. Smaller circles are drawn with the bow pencil (Fig. 2·18 at A) or the bow pen (Fig. 2·18 at B). A common size measures about 3¾ in. in height. Large bow instruments are made (Master or Giant bows) that will describe circles 9 in. or more in diameter.

Before circles are drawn, the lead should be sharpened as shown in Fig. 2·19 for the compasses and bow pencil; then the shouldered end of the needle point should be adjusted until it is a very little longer than the pencil point.

2·14 Using the Compasses. The compasses are manipulated entirely with the right hand (see Fig. 2·17). They are opened by pinching them between the thumb and second finger (Space 1) and set to the proper radius by placing the needle point at the center and adjusting the pencil leg with the first and second fingers (Space 2). When the radius is set, raise the fingers to the handle (Space 3) and revolve the compasses by twirling the handle between the thumb and finger. Start the arc near the lower side and revolve clockwise (Space 4), inclining the compasses slightly in the direction of the line. Do not force the needle point way into the paper.

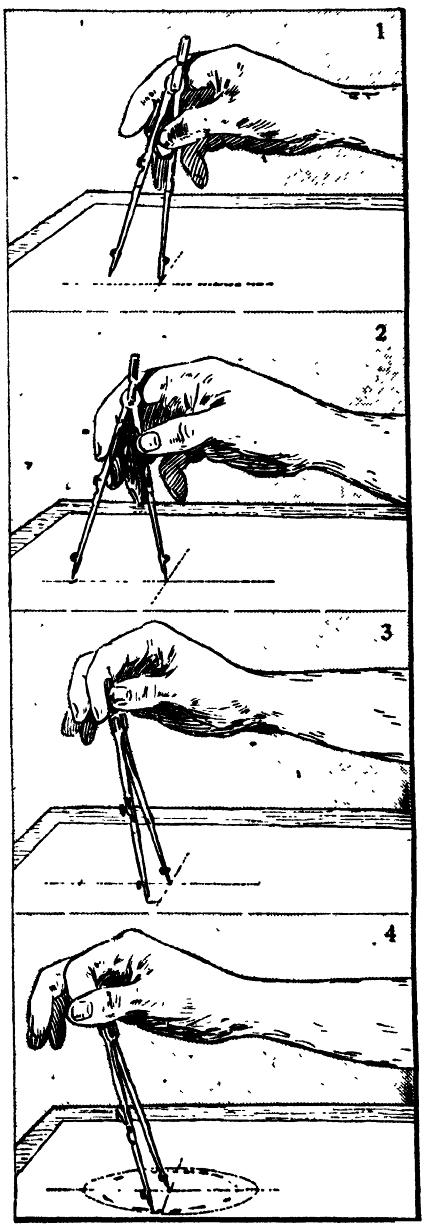
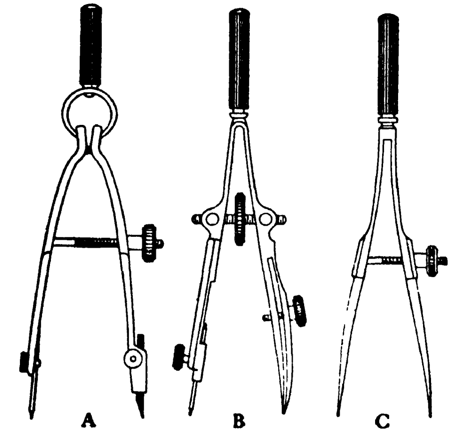
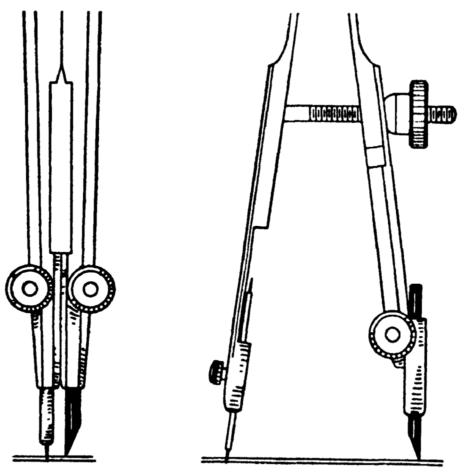


Figure 2·17 Using the compasses.





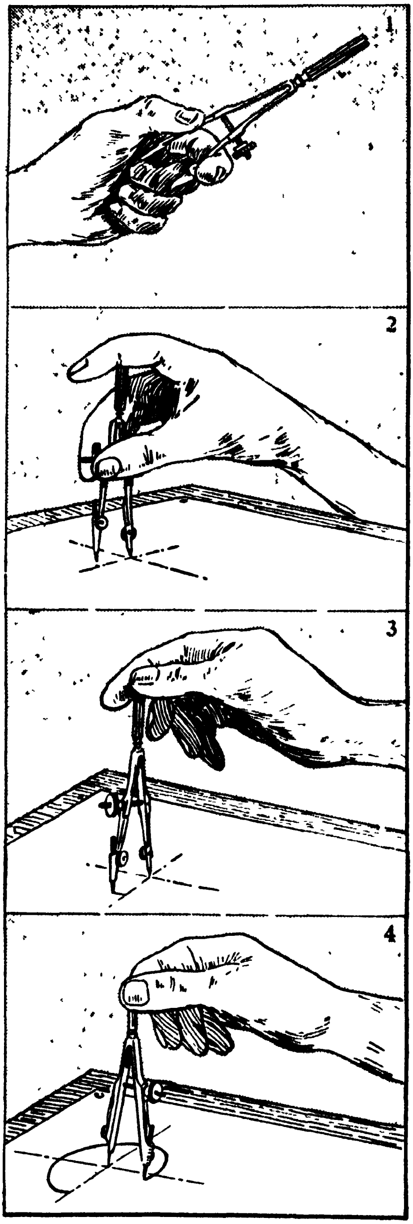


Figure 2·18 The bow instruments (top).
Figure 2·19 Adjusting the points (bottom).
Figure 2·20 Using the bow pencil (right).

2·15 A set of bow instruments (Fig. 2·18) consists of the bow pencil A, the bow pen B, and the bow spacers (or bow dividers) C. They may be any one of the three patterns shown, ring bow A, center screw B, or side screw C. The bow pencil (Fig. 2·20) is used to draw small circles and arcs. Adjust the lead and needle point as in Fig. 2·19, and set the radius as in Fig. 2·20, Space 2. Start the circle on the lower part of the vertical center line and revolve clockwise (Space 4).

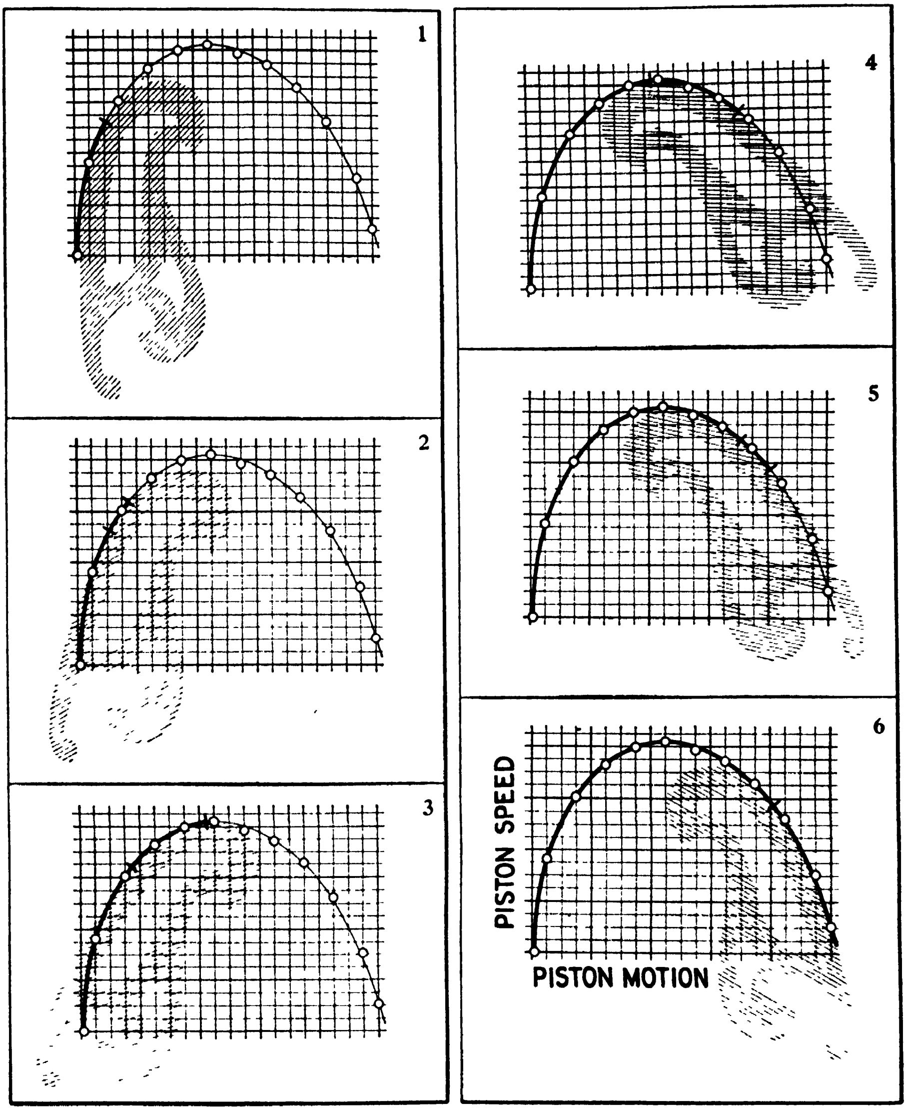


Figure 2·21 Using the curve.

2·16 Curves are drawn with the irregular or French curve. These come in different forms. The curve is fitted by trial against a part of the line to be drawn, then shifted to match the next portion, and so on (Fig. 2·21). In general, each new position should fit at least three points on the part of the line just drawn. It is necessary to notice if the radius is increasing or decreasing and to place the curve accordingly. Do not try to go too far with one position of the curve.

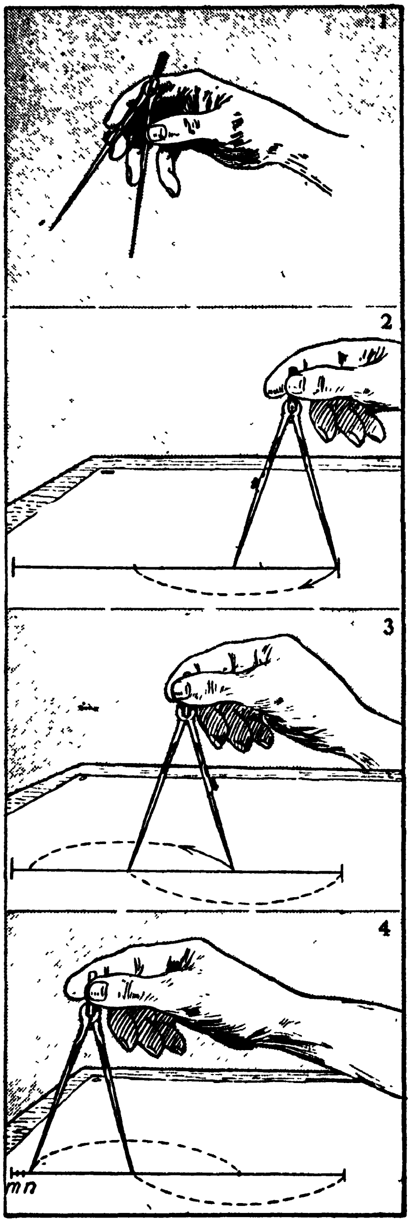


Figure 2·22 Using the dividers.

2·17 Spacing. Dividing lines into spaces and transferring distances is done with the dividers or bow spacers. The dividers are held in the right hand and adjusted, as shown in Fig. 2·22, Space 1.

The method of dividing a line into three equal parts is shown in Fig. 2·22. Adjusting the points of the dividers until they appear to be about one-third the length of the line, place one point on one end of the line and the other point on the line as shown in Space 2. Turn the dividers about the point that rests on the line as in Space 3, then in the alternate direction as in Space 4. If the last point falls short of the end of the line, increase the distance between the points of the dividers by an amount estimated to be one-third the distance *mn*, and start at the beginning of the line again. Several trials may be necessary. If the last point overruns the end of the line, decrease the distance between the points by one-third the extra distance.

For four, five, or more spaces, proceed as described except that the correction will be one-fourth, one-fifth, etc., of the overrun or underrun. A curved line or the circumference of a circle is divided in the same way as a straight line by using the distances between the points of the dividers as a chord. The small knurled screw halfway up one of the legs of the dividers is used to regulate a hairspring to make small adjustments in the distance between the points of the dividers.

The bow spacers (Fig. 2·18 at C) are used when working with small distances.

The dividers should not be used for small distances (of about 1 in. or less) as the distance between the points is too easily affected by handling or putting on the drawing board. For accurate work with small distances, the bow spacers (Fig. 2·18 at C) should be used, as the distance between the points can be easily maintained once they are set. The method of dividing a line with the bow spacers is the same as that described for the dividers. The bow spacers are very useful for many purposes and should receive careful treatment. If the points become dull or bent, they should be put into proper condition before they are used.

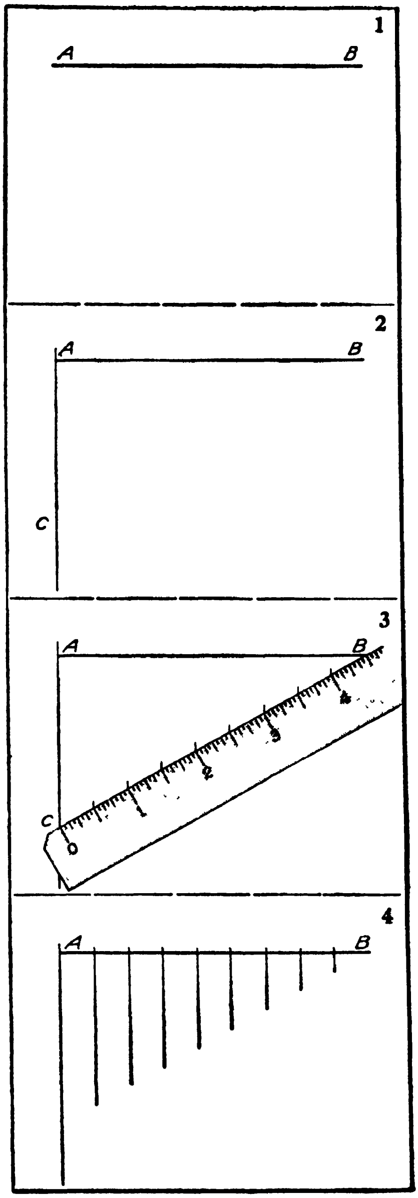


Figure 2·23 Dividing a line.

2·18 It is often convenient to use the scale as a means of dividing a line. If the distance is not easily divisible, the scale may be used as shown in the "movie" of Fig. 2·23, where the line to be divided into nine equal parts is shown in Space 1. Draw a perpendicular line *AC* through an end of the line as in Space 2. Apply the scale so that nine divisions of the scale (in this case half inches) are included between point *B* and line *AC*, as shown in Space 3. Mark opposite each ½ in. and draw vertical lines, which will divide the given line into nine equal parts (Space 4). The geometrical method upon which Fig. 2·23 is based is given in Art. 16·3.

CHAPTER 3. Lettering

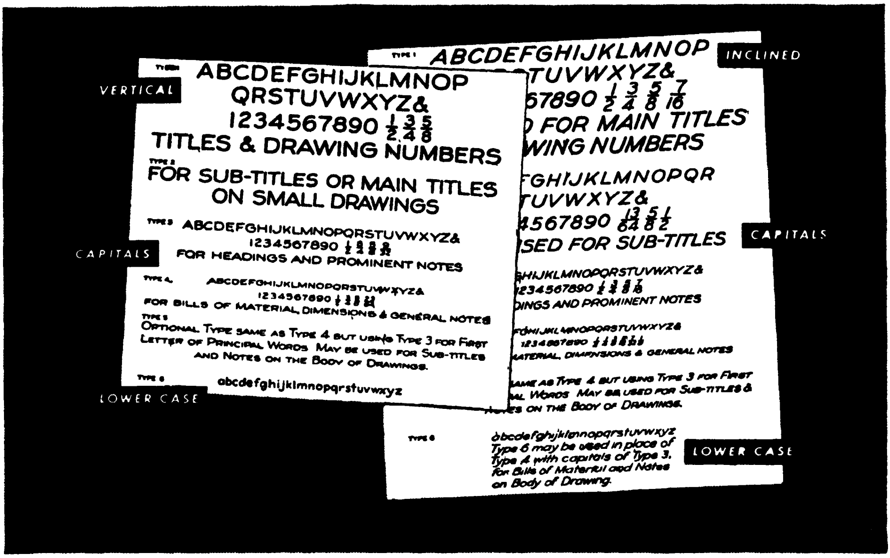


Figure 3·1 American Standard letters.

3·1 Lettering. The complete description of any machine or structure requires the use of the *graphical language* to describe shapes, and the *written language* to tell sizes, methods of making, kinds of material, and other information in the form of notes. The written language as used on drawings is always in the form of LETTERING and not script writing. Simple freehand lettering, perfectly legible and quickly made, is an important part of modern engineering drawings.

3·2 Various styles of lettering are used in display lettering and printing, each appropriate for a particular purpose. The standard form of letter used on working drawings is the style known as "single-stroke commercial gothic," appropriate because of its legibility and comparative ease of execution. There are two varieties of *capital* and *lower-case* letters, *vertical* and *inclined* (Fig. 3·1). Some concerns use vertical letters exclusively, some use inclined letters exclusively, others use vertical for titles and inclined for dimensions and notes. In the same way, some schools adopt vertical lettering as a standard, and some adopt inclined lettering. The draftsman accepting a position with a company must be able to use the standard of that company. In learning both styles it is better to take up vertical lettering first. The single-stroke letters presented in this chapter are in agreement with the forms presented in the "American Standards for Drawings and Drafting Room Practice." The Standard recommends widths of strokes and heights of letters for certain purposes. For regular dimensions and notes, dimensions and capitals are made ⅛ in. high.

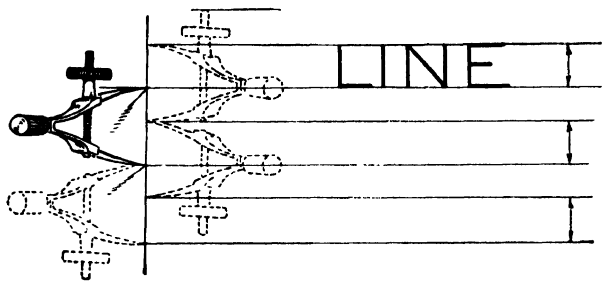


Figure 3·2 Spacing guidelines.

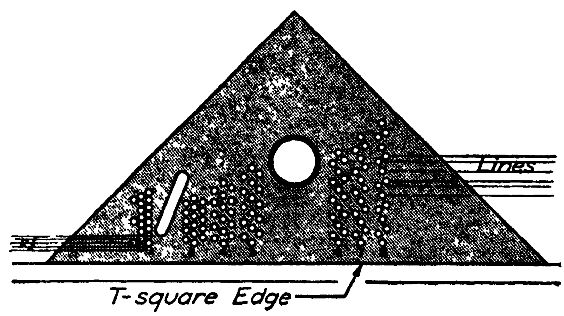


Figure 3·3 Braddock-Rowe triangle.

The ability to letter well and rapidly can be acquired only by persistent and careful practice. The form and proportion of each letter must be thoroughly mastered by study and practice, and the letters must be combined into uniformly written, easily read words.

3·3 Guidelines ruled lightly with a sharp pencil should always be drawn for both tops and bottoms of each line of letters. The clear distance between lines of letters varies from one-half to one and one-half times the height of the capitals. Figure 3·2 illustrates one method of spacing guide lines when several lines of letters are to be made. Mark the height of the letter on the first line, then set the dividers to the distance wanted between base lines, and step off the required number of lines. With the same setting, step down again from the top point or guideline.

The Braddock-Rowe triangle (Fig. 3·3) and the Ames lettering instrument (Fig. 3·4) are timesaving and useful devices for ruling guidelines. Lines are ruled by inserting a sharp pencil point in the holes of the device and moving it back and forth guided by the T-square edge. Different spacing of groups of holes provides for different sizes of letters, either capital or lower case. The numbers give the heights of capital letters in thirty-seconds of an inch. Thus, No. 4 is $\frac{1}{8}$ in. between the top and bottom of the group of three holes.

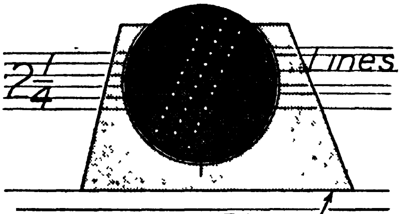
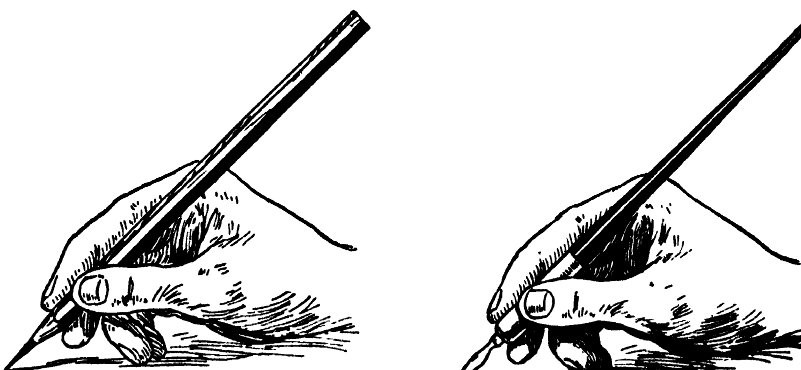


Figure 3·4 Ames lettering instrument.

3·4 Lettering practice with the pencil and the pen should precede the lettering of words and sentences. Particular attention should be given to numbers and fractions as these form a very important part of every working drawing. The instructions given in Arts. 3·7 to 3·12 apply to both pencil and pen lettering.



A B

Figure 3·5 Position of pencil and pen for lettering.

3·5 Pencil Lettering. The order of strokes and the proportions of the letters should be learned by practice with the pencil before attempting to use pen and ink. The constantly increasing use of pencil tracings in commercial drafting rooms makes the ability to do good pencil lettering a necessary part of the draftsman's qualifications. Use an HB, F, or H pencil selected to give a firm opaque line on the paper being used. Cut away the wood and sharpen the lead to a long conical point, Fig. 3·5 at A. Learn to use an even pressure and to revolve the pencil in the fingers after every few strokes to ensure uniform lines. Hold the pencil just firmly enough to control the strokes.

3·6 Pen Lettering. The term "single stroke" means that the width of the stem of the letter is the width of the stroke of the pen. A pen for single-stroke lettering must, therefore, make the required width of line in any direction without pressure enough to spread the nibs. For large letters (¼ in. high) Esterbrook's 802 or Hunt's 512, which are ball-pointed pens, are among those most desirable. For ordinary dimensions and notes, Esterbrook's 819 or Gillott's 404 is satisfactory. (Do not use a ruling pen for freehand lettering.) The pen should be held in the position shown in Fig. 3·5 at B, the strokes drawn with a steady even motion of the fingers and a slight uniform pressure, not enough to spread the nibs of the pen.

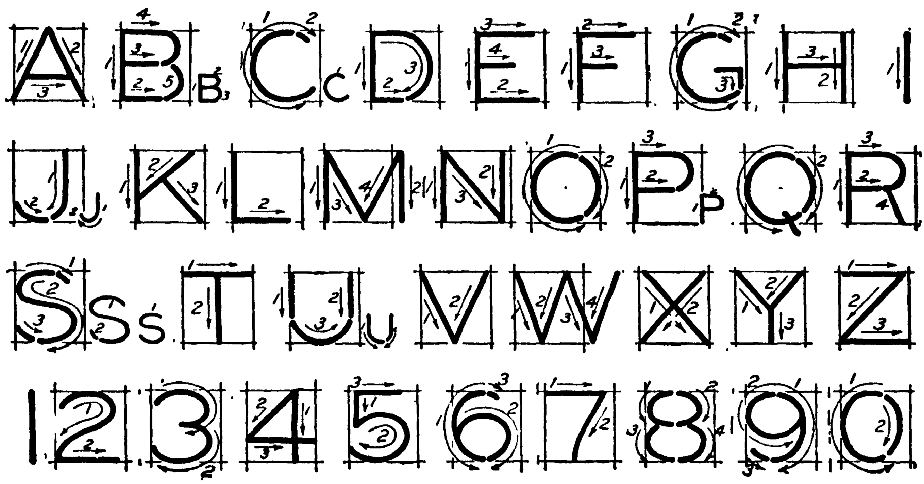


Figure 3·6 Single-stroke vertical capitals.

3·7 Single-stroke Vertical Capitals. An alphabet of vertical capitals and the vertical numerals are shown in Fig. 3·6. Each letter is shown in a square, so that the proportions of its width to height may be easily learned. Observe that the T, Z, X, A, O, and Q fill the square, whereas H, L, E, N, etc., are narrower, and the M and W are wider, than their height.

In learning to letter, the first step is to study the shapes and proportions of the individual letters and the order in which the strokes are made. The arrows and numbers on the letters give the order and direction of the strokes. Vertical strokes are always made downward and horizontal strokes from left to right. Two forms of the ampersand, or character used to represent "and," are shown in Fig. 3·7 at *B* and *C*, with the construction at *A* for type B.

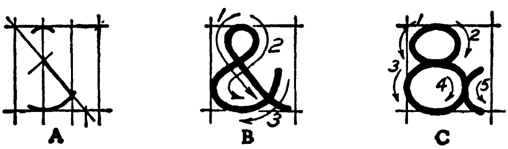


Figure 3·7 Ampersands.

3·8 Numerals require special care and practice. Notice that their shapes are just as different from those used in ordinary figuring as the letters are from ordinary writing. Particularly is this true of the 2, 4, 6, 8, and 9. Fractions (Fig. 3·8) are always made with a horizontal division line, with figures two-thirds the height of the whole numbers and with a clear space above and below the division line.

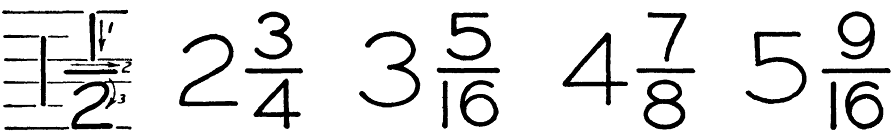


Figure 3·8 Fractions.

3·9 Single-stroke vertical lower-case letters (Fig. 3·9) are usually made with the *bodies* two-thirds the height of the capitals, with

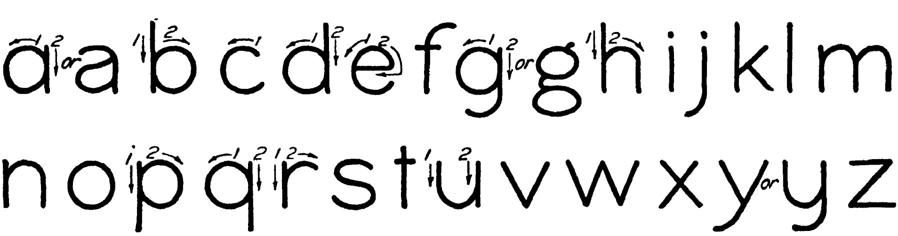


Figure 3·9 Single-stroke vertical lower-case letters.

ascenders (b, d, f, etc.) extending up to the *cap line* (Fig. 3·10) and the *descenders* (g, j, p, etc.) dropping the same distance below (Fig. 3·10). Vertical lower-case letters are based on the combination of circles and straight lines. The monogram in the figure contains 18 of the 26 letters.

3·10 Single-stroke Inclined Capitals. An alphabet of inclined capitals and numerals with the order and direction of strokes is given in Fig. 3·11. There are two things to watch: first, to keep a uniform slope and, second, to get the correct shape of the curves of the rounded letters.

Inclined direction lines should be drawn by one of the methods

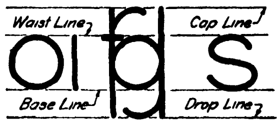


Figure 3·10

illustrated in Fig. 3·12. At A a slope of 2 to 5 is set by marking two units on a horizontal line and five units on a vertical line, then using

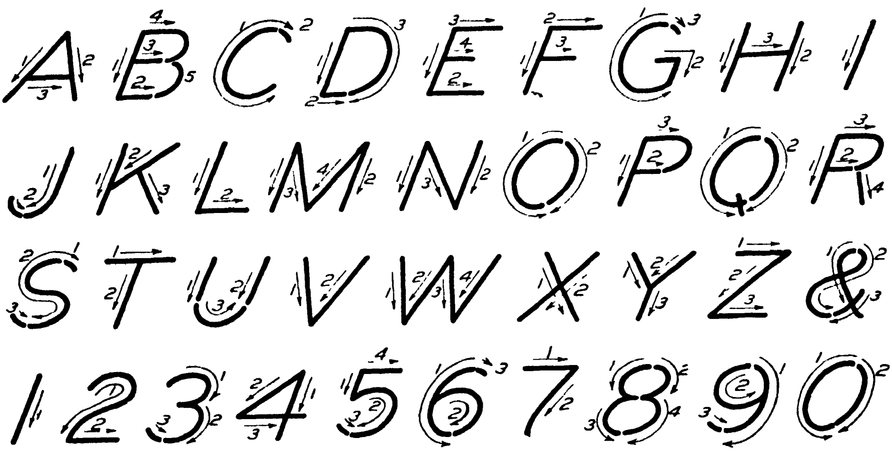


Figure 3·11 Single-stroke inclined capitals.

the T-square and triangle. A lettering triangle (with an angle of about 67½°) is shown at B, the use of the slot in the Braddock-Rowe triangle is shown at C, and the use of the Ames Instrument is shown at D.

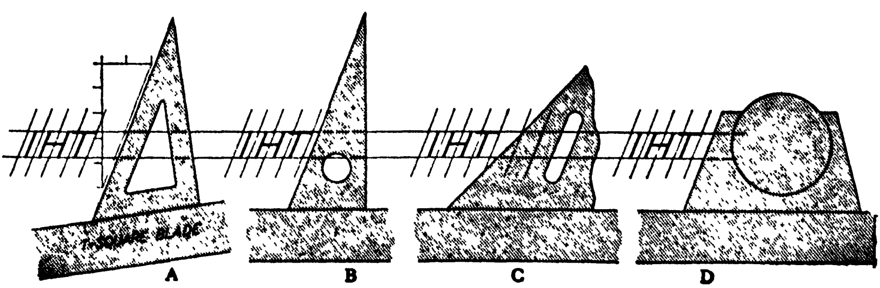


Figure 3·12 Direction lines.

The form taken by the rounded letters when inclined is illustrated in Fig. 3·13, showing that the curves are sharp in the upper right-hand and lower left-hand corners, and flattened in the other two corners. Note the horizontal direction of the cross bar of the letter H in Fig. 3·14, and that the lines of A, V, and W make equal angles on each side of an inclined center line.

Figure 3·13

Figure 3·14

3·11 Single-stroke inclined lower-case letters are shown in Fig. 3·15. This letter, sometimes called the "Reinhardt letter," is in general use for notes on drawings as it is very legible and effective

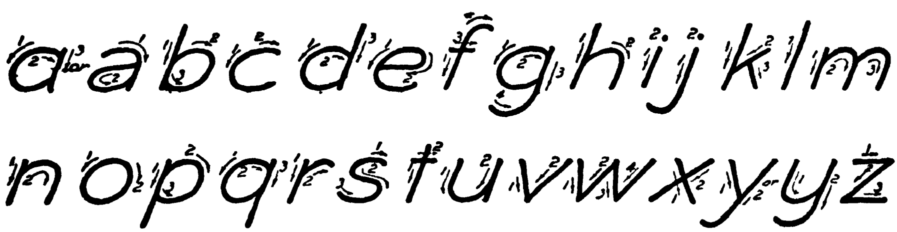


Figure 3·15 Single-stroke inclined lower-case letters.

and can be made very rapidly. The bodies are two-thirds the height of the capitals, with the ascenders extending to the cap line and the descenders dropping the same distance below the base line.

For study, the letters may be divided into four groups:

Group I: ijkltvwxyz	Group III: hmnruy
Group II: abdfgpq	Group IV: ceos

Group I contains the straight-line letters. Keep the slope uniform by following direction lines penciled lightly on the sheet. Be particularly careful about the slant of the angle letters v, w, x, and y and have their sides make equal angles with a sloping center line.

The letters of Group II are made up of a partial ellipse whose major axis slants 45°, and a straight line (Fig. 3·16). The "hook" letters of Group III are made with part of the same ellipse. The letters of Group IV are made with the same shape of ellipse as the capitals (Fig. 3·17).

3·12 Composition. Composition in lettering means the arrangement and spacing of words and lines, with letters of appropriate style and size. After the shapes of the separate letters have been mastered, all practice work should be on words and sentences, and the keynote of success is *uniformity*. Uniform height is obtained by having each letter meet the top and bottom guidelines; uniform weight by making all strokes of the same thickness; uniform direction by drawing and following direction lines either vertical or inclined; and uniform color by careful spacing.

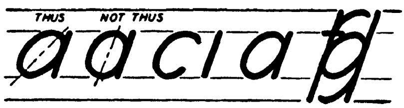


Figure 3·16

Figure 3·17

3·13 Letters in words are not placed at equal distances from each other but are spaced so that the areas of white spaces included between the letters are approximately equal, thus making them appear to be

LETTERING COMPOSITION
INVOLVES THE SPACING OF LETTERS
WORDS AND LINES AND THE CHOICE
OF APPROPRIATE STYLES AND SIZES

Figure 3·18 An example of spacing.

spaced uniformly. Thus two adjacent letters with straight sides would be spaced much further apart than two curved letters. Note the variation in spacing in the word "lettering" in Fig. 3·18. In general, keep

PENCILED — PENCILED

Extended letters. — *Compressed letters.*

Figure 3·19

letters fairly close together. In spacing words, the clear distance between them should not be more than the height of the letters, or they may be spaced by allowing room for the letter O between them. Many variations in letters are possible, such as extending or compressing them (Fig. 3·19). In such cases all the letters of an alphabet must be extended or compressed in proportion.

For contents and composition of titles, see Art. 9·10.

3·14 Wide-stroke Letters. The usual lettering on working drawings has been described in the preceding articles. Larger sizes of letters may be made in single strokes with special lettering pens such

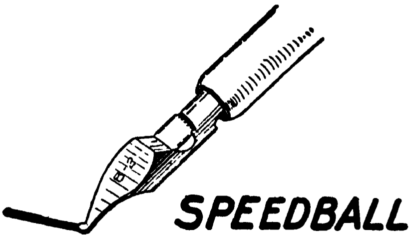


Figure 3·20 Speedball pen.

as the Speedball pen shown in Fig. 3·20, or other wide-stroke pens such as the Drawlet, Payzant, Leroy, or Edco. These pens are made in different sizes to give a variety of widths of strokes.

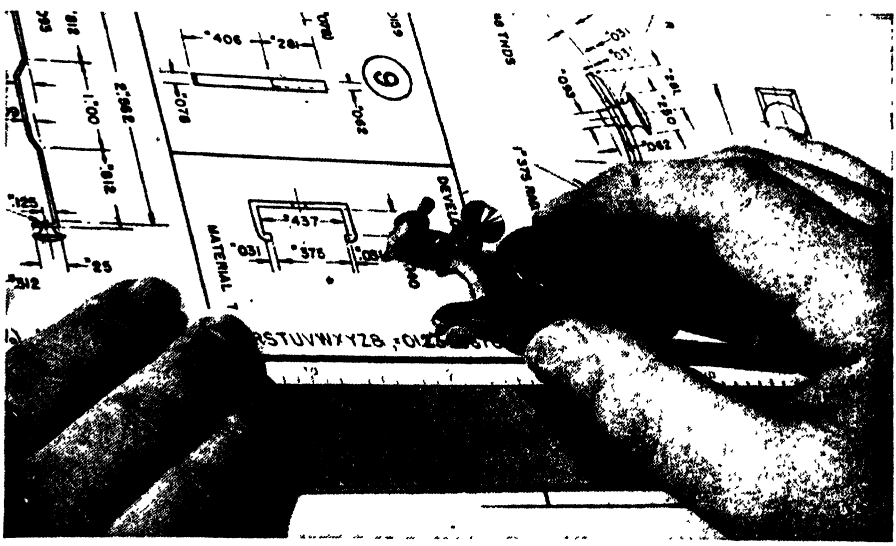


Figure 3·21 Leroy lettering guide.

3·15 Lettering devices or guides (Fig. 3·21) provide a means of producing uniform lettering in standard sizes ranging from 0.1 to 0.5 in. high or more. Different pen points are used to obtain different widths of strokes. Wrico, Wrico-Print, Leroy, and Edco are well-known devices.

Lettering guides are made for different kinds of alphabets and for both vertical and inclined letters. Similar guides are made for forming many of the symbols used on drawings such as those in Figs. 15·5, 15·15 and 19·28.

One of the principal advantages of such devices is in maintaining uniform lettering where a large number of draftsmen are employed. Another important use is for lettering titles, note headings, and numbers on drawings and reports.

Figure 3·22 Commercial gothic alphabet.

3·16 A commercial gothic alphabet is shown in Fig. 3·22. It may be drawn either freehand or, if rather large, with instruments and filled in with a brush. For some purposes the letters may be left in outline as shown for V, W, and X in Fig. 3·22. Commercial gothic letters may be compressed or extended and may have either plain or

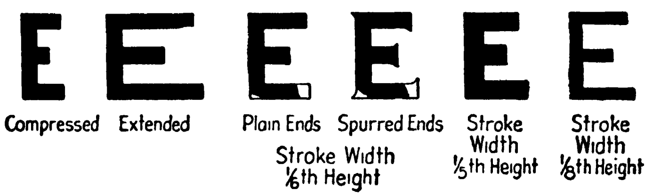


Figure 3·23 Variations.

spur ends (Fig. 3·23). The width of stroke may be from one-eighth to one-fifth the height of the letters.

When commercial gothic letters are drawn with the round-point pens mentioned in Art. 3·14, the ends of the letters may be left rounded as formed by the pen or they may be squared or spurred with a fine-point pen.

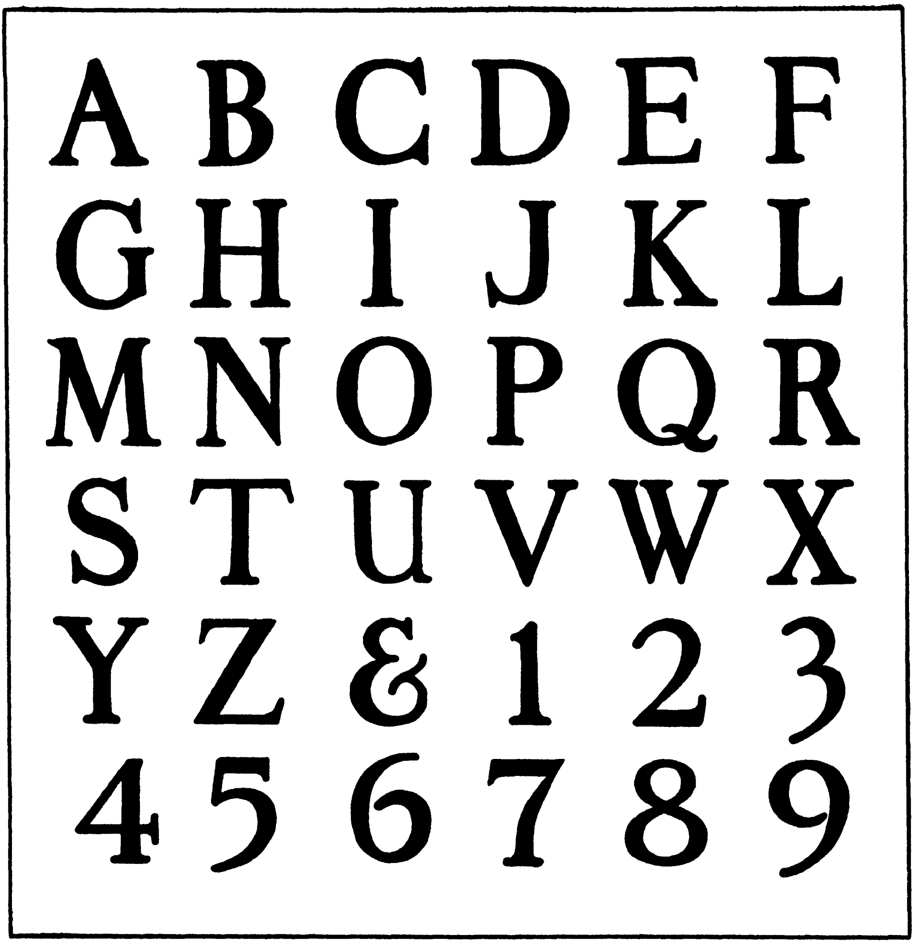


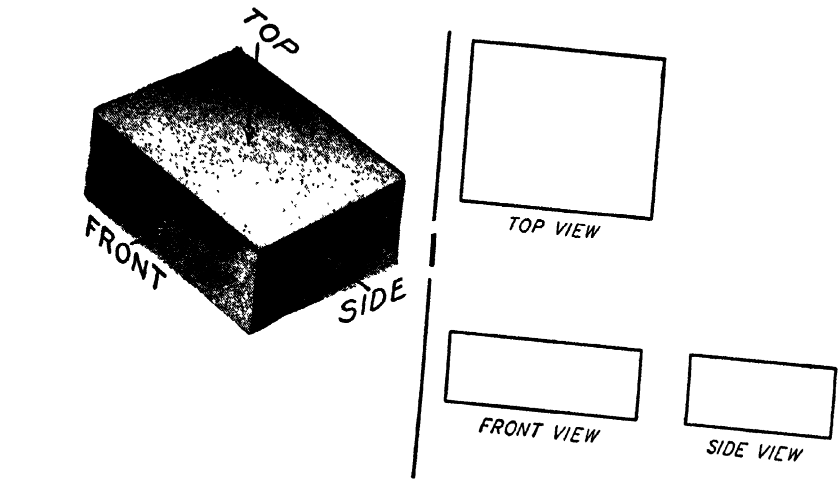
Figure 3·24 Roman alphabet.

3·17 Poster Letters. Legibility at a distance is the first requirement for poster letters. Rather wide strokes should be considered. The alphabets shown in Figs. 3·24 and 3·25 indicate two kinds of letters that are suitable for posters. Other letters, both vertical and inclined, will be observed on good posters and in books devoted to lettering.[1]

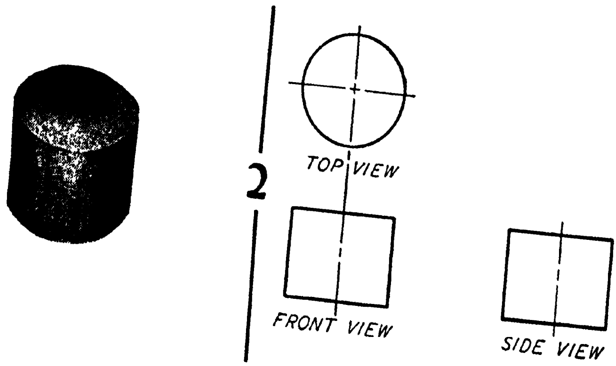
3·18 A Roman alphabet is shown in Fig. 19·10 derived from Old Roman letters. A single-stroke letter based upon the Roman alphabet (Fig. 19·11) is much used on architectural drawings.

[1] French, T. E., and Robert Meiklejohn, "Essentials of Lettering," 3d ed., McGraw-Hill Book Company, Inc., New York, 1912. Svensen, Carl Lars, "The Art of Lettering," 2d ed., D. Van Nostrand Company, Inc., New York, 1947.

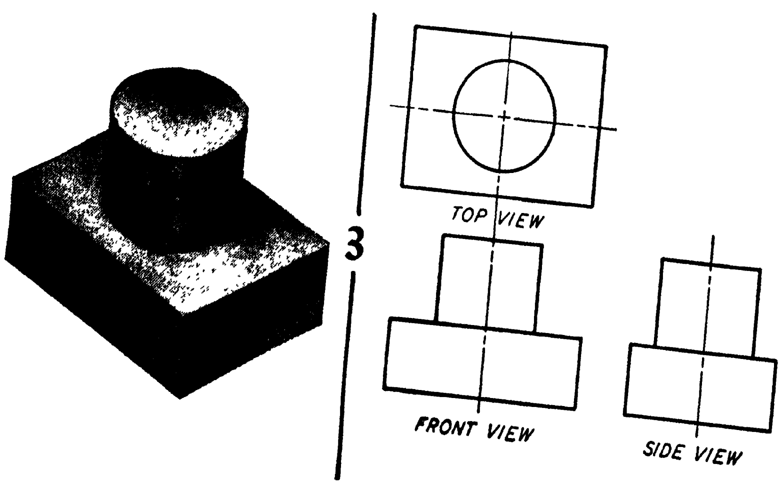
Figure 3·25 Modern alphabet.


TOP
FRONT
SIDE
TOP VIEW
FRONT VIEW
SIDE VIEW

2


TOP VIEW
FRONT VIEW
SIDE VIEW

3


TOP VIEW
FRONT VIEW
SIDE VIEW

CHAPTER 4. Theory of Shape Description

4·1 There are two things that a designer, inventor, or builder must be able to do: (1) he must be able to *visualize* or see clearly in his mind's eye what an object looks like without actually having the object, (2) he must be able to describe it so that it could be built. A few lines properly drawn on paper will describe an object more accurately and more clearly than a photograph or a written description. Ability to describe the true shape of an object by means of lines and to read and understand such descriptions requires a thorough knowledge of the theory upon which this method is based.

4·2 Describing Objects by Views. For the graphical description of an object we should have available the paper, pencil, and instruments explained in Chap. 2. On the paper we can make measurements in a single plane only, while all objects have dimensions perpendicular to the paper as well as parallel to it. A picture can be made that would show, just as a photograph would, the general appearance of the object, but it would not show the *exact* forms and relations of the parts of the object. It would show it as it *appears* and not as it really is.

Our problem then is to represent solid objects on a sheet of paper in such a manner as to tell the exact shape. This is done by drawing a system of *views* of the object as seen from different positions, and arranging these views in a definite manner.

In Space 1 of Fig. 4·1, arrows indicate directions for viewing a rectangular prism. Views in each of these directions are shown and named. In Space 2, a picture of a cylinder is shown together with the three views. Notice that the *top view* shows the true circular shape of the cylinder as seen from above. The *front* and *side views* appear as rectangles and are the same size, so the cylinder might be described by two views, the top view to show the shape, and the front view to show the diameter and height.

In Space 3, the cylinder has been placed on the prism. Notice how

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Figure 4·1 Shape description.

the views from Space 1 and Space 2 combine to form the views in Space 3. Complete views are composed of views of the separate parts.

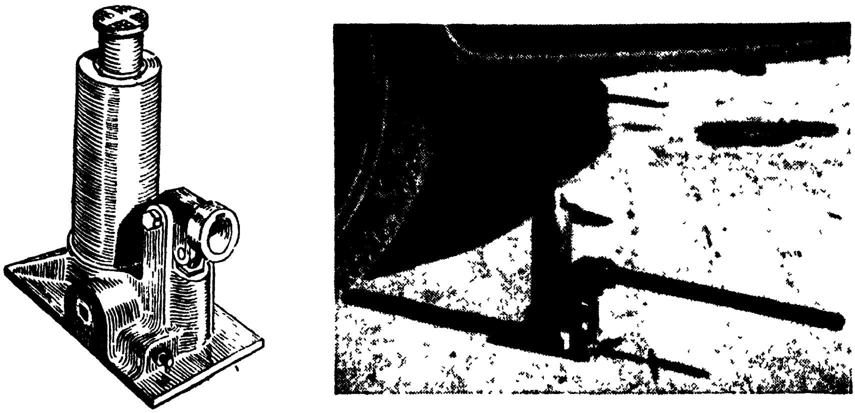


Figure 4·2

4·3 The Relation of Views. A picture of a hydraulic jack for an automobile (Fig. 4·2) shows this tool as it ordinarily appears to us, but it does not show the true shapes of the parts. The top of the cylinder appears as an ellipse, although we know it really is circular.

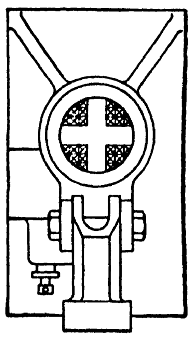


Figure 4·3 Top view.

If we look down at the jack from above, we obtain a *view*, showing the exact shape of the cylinder or stem, and the outline of the other parts as seen from above. This is called a *top view* or plan (Fig. 4·3). As this view does not tell us the height of the jack, it is necessary to take another view from a position directly in front or else from the left or the right side. In this way either a *front view* or a *side view* to show the height is added to the top view. Often, as in this case, both the front and side views, in addition to the top view, are needed to describe an object (Fig. 4·4).

Since the top of the cylinder or stem is level, it will show as a straight line in the front and side views. The base shows as a rectangle in the top view, but the bottom of the base appears as a straight line in the front and side views. Notice that the cylinder and hole for the lever rod, which appear as circles at *a* and *b* in the front view, appear as straight lines at *a-b* in the side and top views.

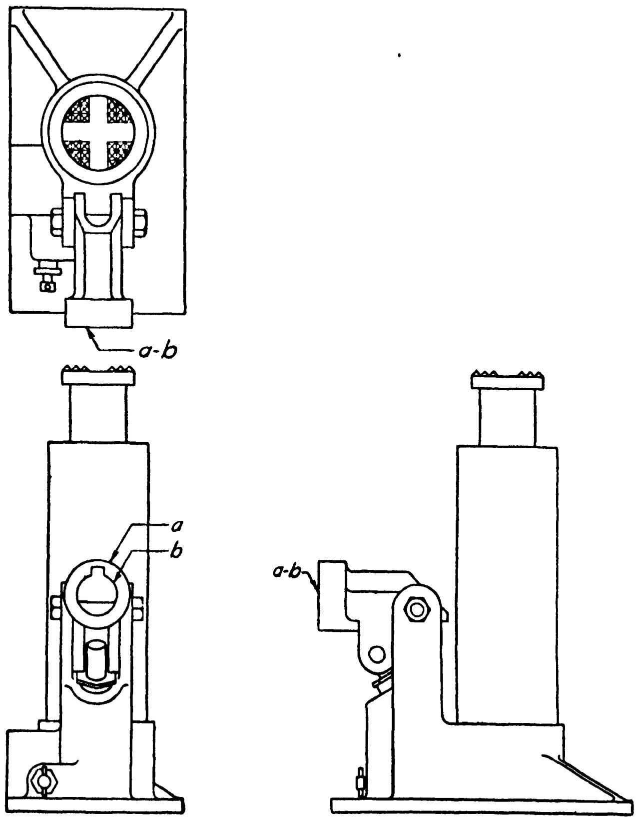


Figure 4·4 Top, front, and right-side views.

The three views taken together completely define the shapes of all visible parts of the jack and their exact relations to each other.

It is evident that the front and side views are exactly the same height. When drawn, they are placed directly across from each other. The top view is placed directly above the front view, and the three views together appear as in Fig. 4·4.

Sometimes a left-side view will describe an object more clearly than the right-side view, and in such cases it should be used. Figure 4·5 shows the top, front, and left-side views of the jack. Notice that it shows the boss *c* which cannot be seen in the right-side view. For some objects it may be necessary to show both the right- and left-side views in order to provide a complete description.

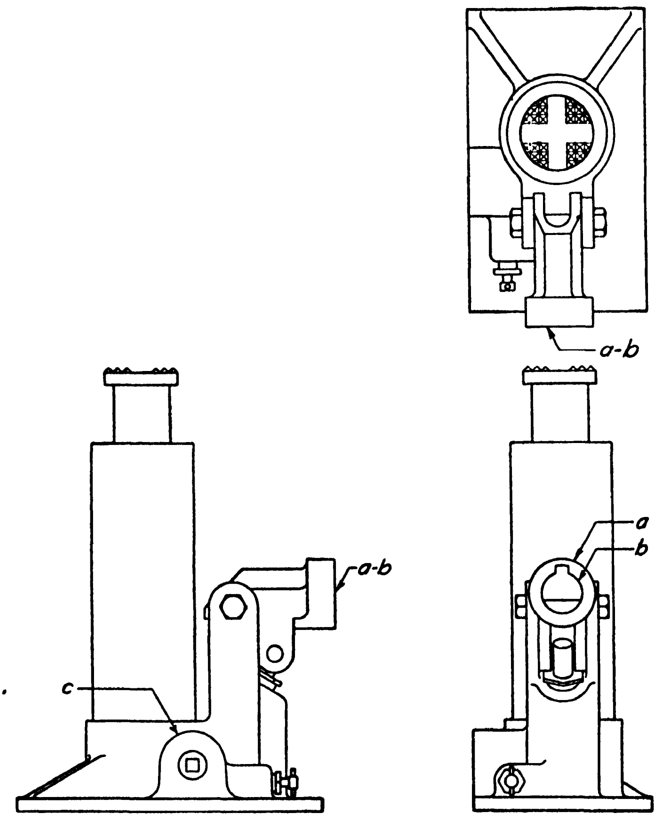


Figure 4·5 Top, front, and left-side views.

Notice the positions of the different views in relation to each other. In Figs. 4·4 and 4·5 it will be observed that the lever rod opening *ab* is toward the front in the top view and that it is toward the front view in both the right- and left-side views.

As a further explanation of the relation of the three views, study the drawing of the chair shown in Fig. 4·6. Notice that the magazine holder is at the right in the top and front views and therefore shows in the right-side view. The front of the chair is toward the front view in the top and two side views.

4·4 Theory of the Relation of Views. The principle of representing objects by different views as described in Arts. 4·2 and 4·3 is called *orthographic projection* and is the basis of all kinds of industrial drawing. The real theory must be well understood before complicated or difficult drawings can be made or read.

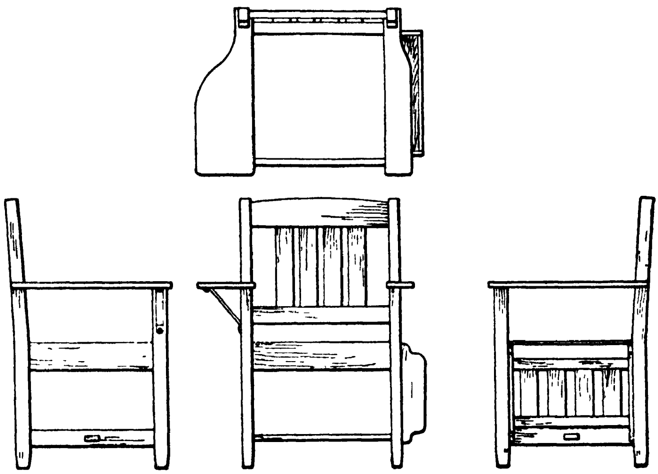


Figure 4·6 Relation of views.

The following definition has been given: *Orthographic projection is the method of representing the exact form of an object in two or more views on planes generally at right angles to each other, by dropping perpendiculars from the object to the planes.*

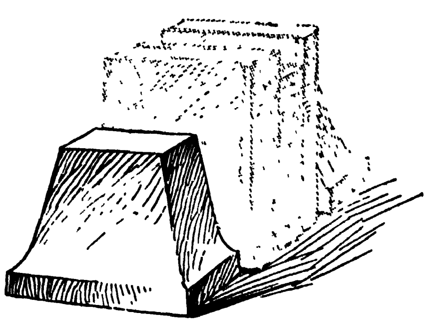


Figure 4·7 Book end.

Suppose the book end shown in Fig. 4·7 is to be represented. The draftsman imagines himself to be looking through a transparent plane set up in front of the object (Fig. 4·8). If, from every point of the object, perpendiculars are imagined as extended or projected to the plane, the result on the front of the plane would be the *projection* on that plane, called the *vertical projection*, or *front view*, or in architectural drawing the *front elevation*. This view will show the true width and height of the object.

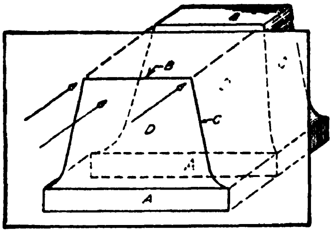


Figure 4·8 The frontal plane.

Suppose now that a horizontal plane is hinged at right angles to the first plane, with the observer looking through it at the top of the object, as in Space 1 of Fig. 4·9. Perpendiculars from the object to this plane will give the *horizontal projection*, or *top view*, or, as called in architectural drawing, the *plan*. This view will show the depth of the object from front to back, as well as the width already shown on the front view. These two planes represent the drawing paper, and if the horizontal plane is imagined as swung up on the hinges until it lies in the extension of the front plane as in Space 2 of Fig. 4·9, the two views will be shown in their correct relationship as they would be drawn on the paper, and together give the width, depth, and height. This explains the reason for the statement made in Art. 4·3, that the top view is always drawn directly over the front view.

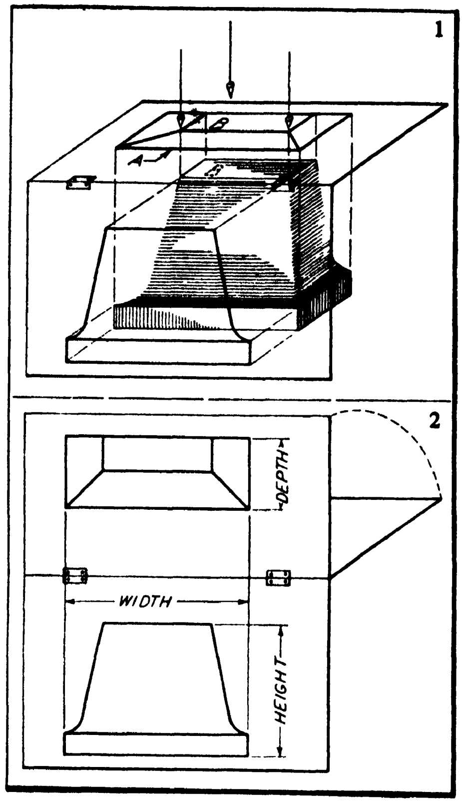


Figure 4·9 The top plane.

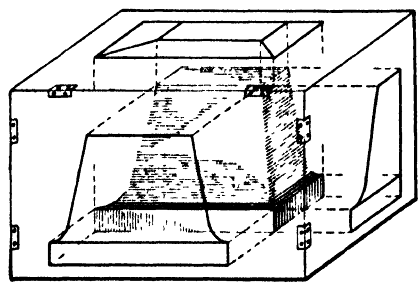


Figure 4·10 The glass box.

The *side view*, *side elevation*, or *profile projection* is imagined as made on a plane perpendicular to both the front and the top planes. Thus the object can be thought of as being inside a glass box or show case, as in Fig. 4·10. The projections on the sides of this box would be the *views*, which we have discussed, and when these sides are opened up into one plane the views take their relative positions as on the paper,

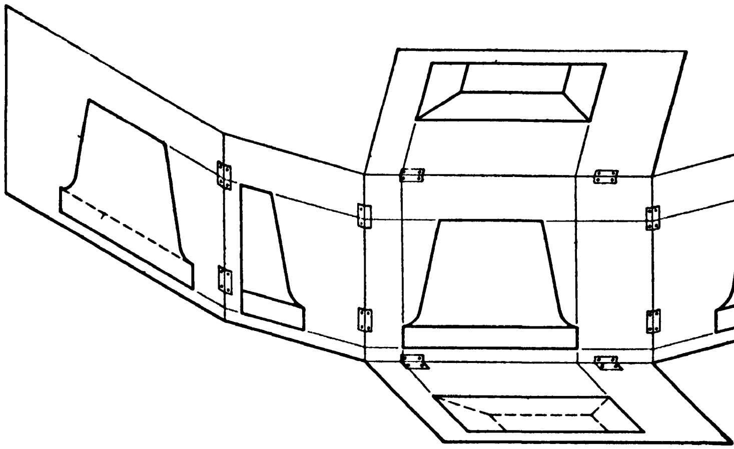


Figure 4·11 Opening the box.

as in Figs. 4·11 and 4·12, which show views projected onto all six faces or planes of the box. This is the American Standard arrangement

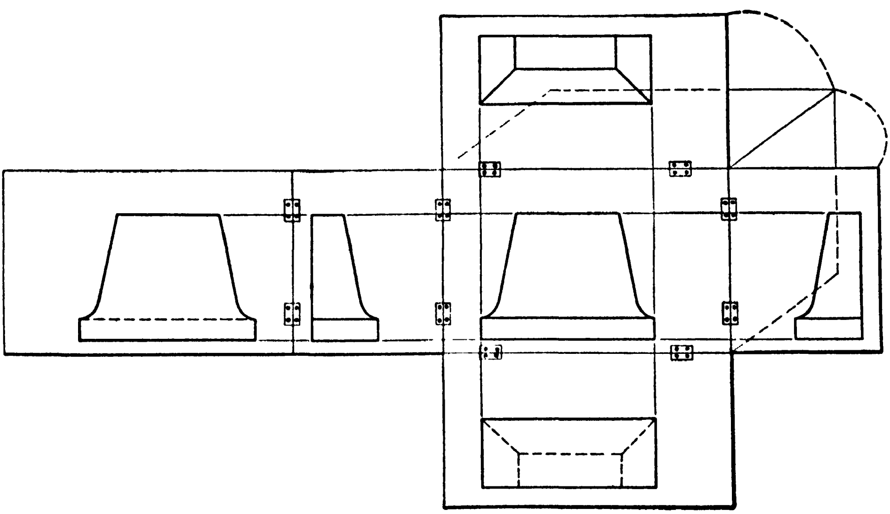


Figure 4·12 The box opened.

of the six views. It is unnecessary to show all six views for a working drawing, though a *rear view* or a *bottom view*, or a part of one of these, may be desirable in certain infrequent cases.

The top, front, and right-side views as ordinarily drawn are shown in Fig. 4·13. When the left view is drawn, it is placed as in Fig. 4·12.

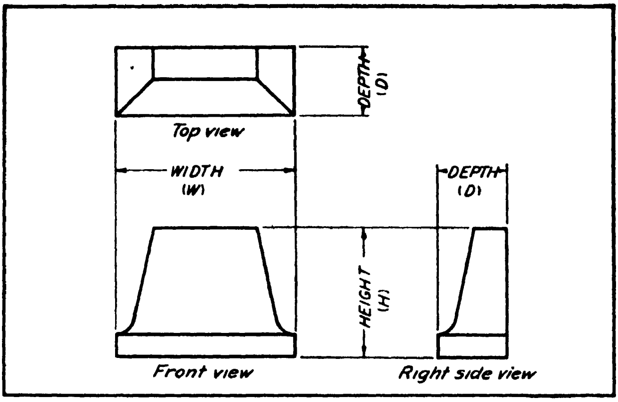
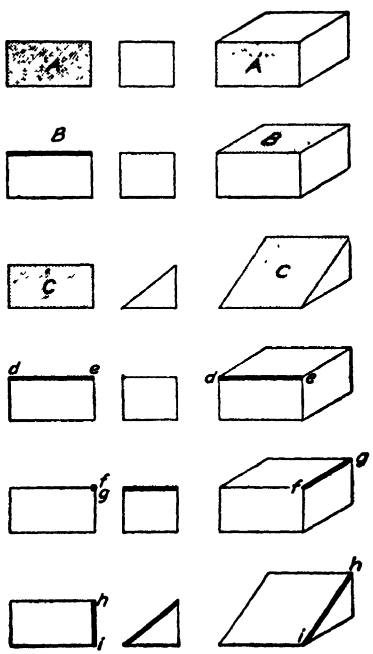


Figure 4·13 Top, front, and right-side views.

4·5 Principles. From a study of the illustrations in this article, the following principles will be noted:



1. A face parallel to a plane of projection is shown in its true size, as surface *A* when projected to the front plane.

2. A face perpendicular to a plane of projection is projected as a line, as surface *B* when projected to the front plane.

3. A surface inclined to a plane of projection appears foreshortened, as the surface *C* when projected to the front plane.

4. A line parallel to a plane of projection will show in its true length, as the line *de* when projected to the front plane.

5. A line perpendicular to a plane of projection will be projected as a point, as the line *fg* when projected to the front plane.

6. A line inclined to a plane of projection will have a projection shorter than its true length on that plane, as line *hi* when projected to the front plane.

4·6 Studies. As a further explanation of how the theory of projection is applied, study the drawings of the objects in the following figures: In Space 1 of Fig. 4·14 each view represents a single surface. In Space 2 the top view shows two surfaces *A* and *B* at different levels, and, as shown by the front view, surface *A* is above surface *B*. In the side surfaces, *C* and *D* are shown but it is necessary to look at the front view to see which surface is closer to the side plane. In Space 3 the surface *B* is inclined and shows slightly foreshortened in the top view and very much foreshortened in the side view. To obtain the true size of the surface *B* the distance *de* must be taken from the front view where it shows in its true length (it is parallel to the front plane) and the distance *ef* from the top or side view. A surface inclined to all three planes is shown in Space 4 (the corner of the block has been cut away). The true size of the surface *B* does not show in any of the views.

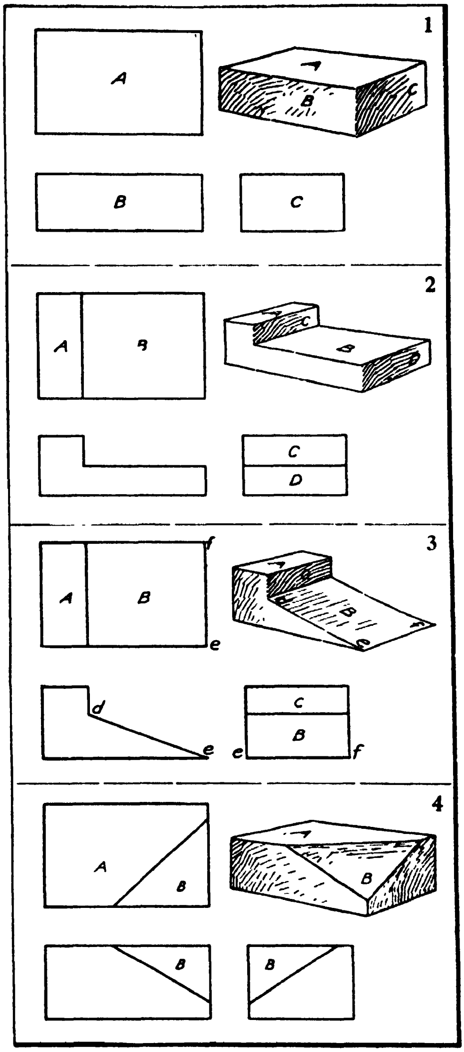


Figure 4·14 Views for study.

More pictures and drawings are given in Fig. 4·15 for study and comparison. Consider the reason for the views that have been selected and the meaning of each line on the views. Could any of the views be omitted for any of the objects? Notice how the inclined surfaces are represented and that the views do not show the true sizes of such surfaces. In Space 1 of Fig. 4·15 the inclined surfaces make angles with the top and front planes but are perpendicular to the side plane. Study and describe the positions of the inclined surfaces in Spaces 2, 3, and 4.

4·7 Hidden Lines. Since it is necessary to describe every part of an object, all surfaces must be represented whether they can be seen or not. To distinguish surfaces that cannot be seen in the views,

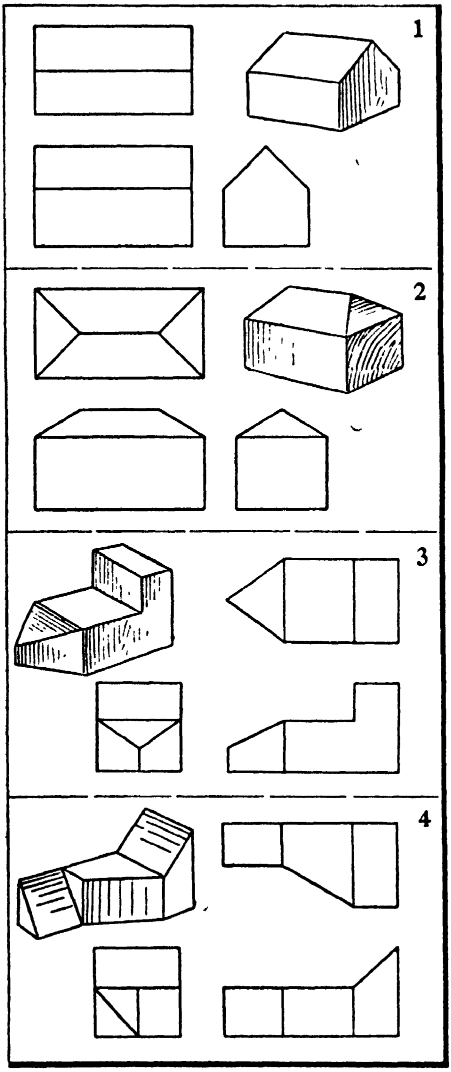


Figure 4·15 Views for study.

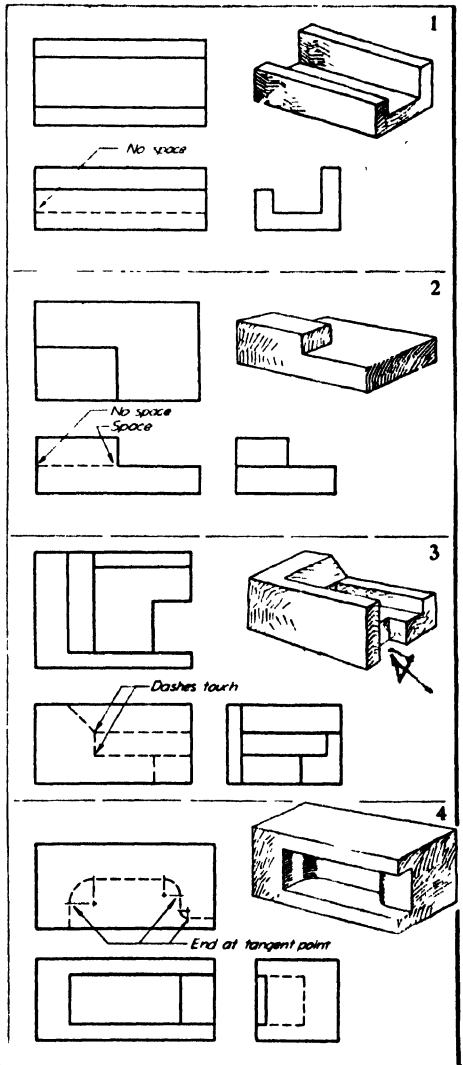


Figure 4·16 Views with hidden lines.

the surfaces are represented by *hidden* lines composed of short dashes, as line 3 in Fig. 9·2. Study the views in Fig. 4·16. Notice that the first dash of a hidden line touches the line at which it starts (Space 1).

If a hidden line is a continuation of a full line, a space is left between the full line and the first dash of the hidden line (Space 2). If hidden lines show corners, the dashes touch at the corners (Space 3). Dashes for hidden arcs start and end at the tangent points (Space 4).

4·8 Center lines (Fig. 9·2 at 4) are used to locate views and dimensions. Primary center lines, marked *P* in Fig. 4·17, are axes of symmetry on symmetrical views. Secondary center lines, marked *S* in Fig. 4·17, are axes for details of a part or construction. Primary

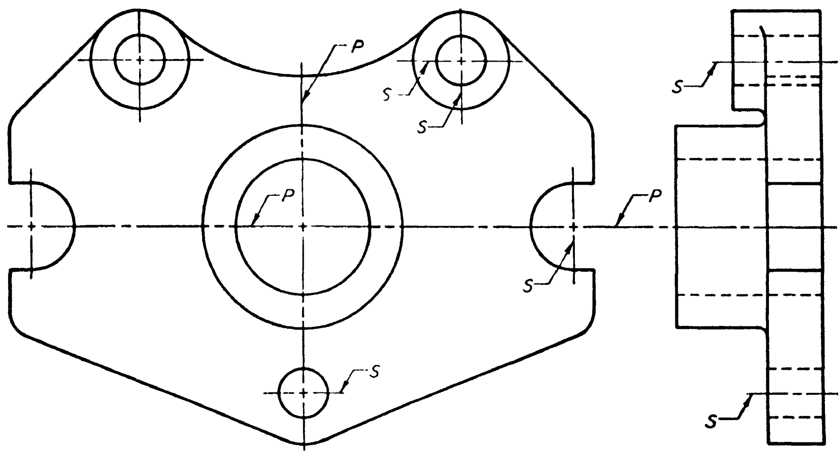


Figure 4·17 Center lines.

center lines are, therefore, the first lines to be drawn, and the views are worked up from them. Note that center lines represent the axes of cylinders in the side view, and that the centers of circles or arcs are located in the front view by intersecting center lines. Center lines are located first so that measurements can be made from them to locate the lines of the views. The use of center lines on the various drawings in this book should be observed.

4·9 Curved Surfaces. The fact that some curved surfaces such as cylinders and cones do not show as curves in all the views is illustrated in Fig. 4·18 at 1, 2, and 3. A cylinder appears as a circle in one view and as a rectangle in the others. Three views of a cylinder when placed in different positions are shown in Spaces 1 and 2. A cone appears as a circle in one view and as a triangle in the others, as in Space 3. For the frustum of a cone, one view appears as two circles.

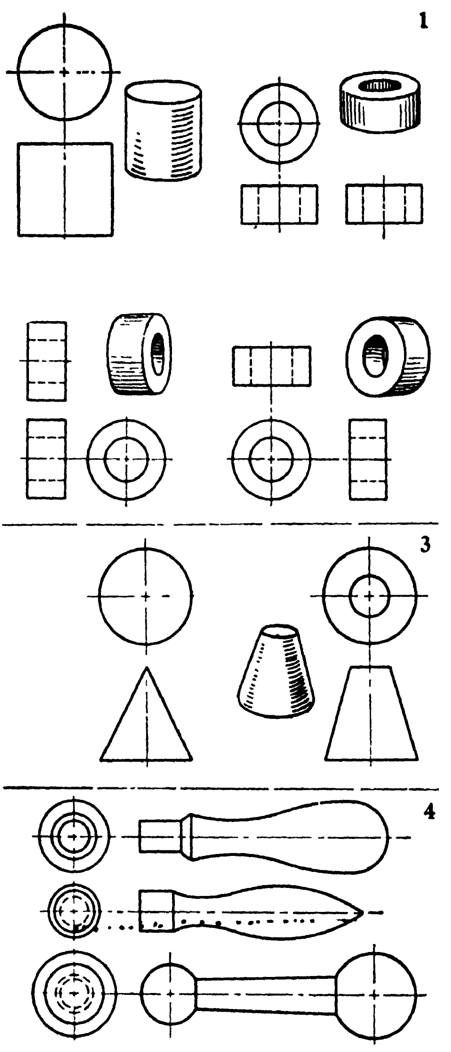


Figure 4·18 Curved surfaces.

Cylinders, cones and frustums of cones have *single curved surfaces* and are represented by circles in one view and straight lines in the other. The handles in Space 4 have *double curved surfaces* which are represented by curves in both views. The ball handle has spherical ends, and both views of the ends are circles because a sphere appears as a circle when viewed in any direction.

The slotted link of Fig. 4·19 is an example of tangent curved surfaces. Notice how the rounded ends join the sides of the link and how the ends of the slot are tangent to the sides.

4·10 What Views to Draw. As already mentioned, the six views of Fig. 4·12 are not needed to describe the book end. The three views of Fig. 4·13 are sufficient. The six views explain the theory of making drawings, but it is not necessary to draw them in order to tell which views are needed. The general characteristics of an object will indicate the views required to describe its shape. Three properly selected views will describe most shapes, but sometimes there are features that will be more clearly described by using more views or parts of extra views.

There are some objects that can be described with two views, as indicated in Fig. 4·20. When two views are used, they must be the right ones to describe the shape of the object. Thus, in Fig. 4·21, the top and front views at *A* and *B* are the same. As the side views are needed, the front and side views could be used to describe these objects. At *C* the top view is needed, so the top and front views might be used.

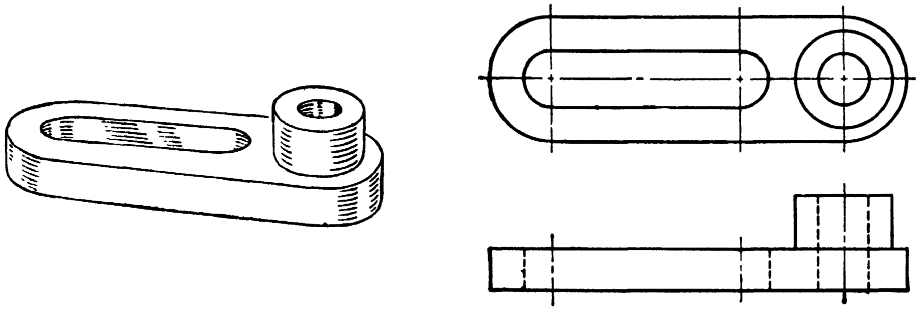


Figure 4·19 Curved surfaces.

The purpose of the views in all cases is to describe the object, and this should be kept in mind at all times. In general, the views should

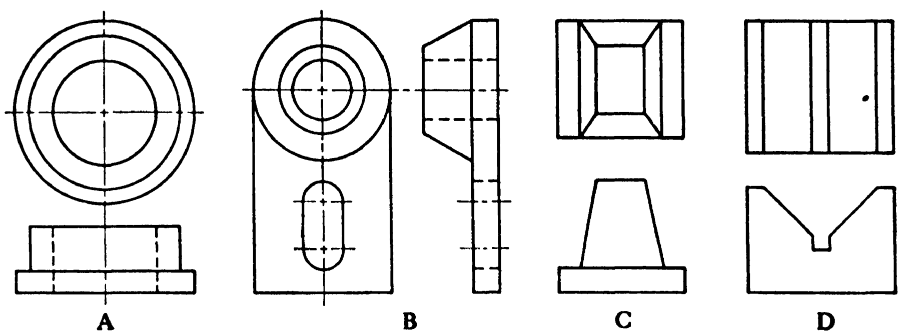


Figure 4·20 Two-view drawings.

be drawn to represent the object in the position it occupies in use. This is not always possible. For example, tall objects, such as vertical

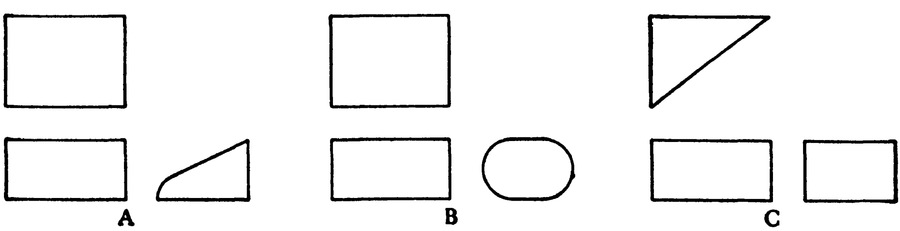


Figure 4·21 Choice-of-view studies.

shafts, are more readily drawn in a horizontal position. Always consider all possible views and select the ones that will give the clearest and most easily read exact description of the object.

Six views are shown for the object in Fig. 4·22. Study the picture and the views. It will be evident that the top, front, and right-side

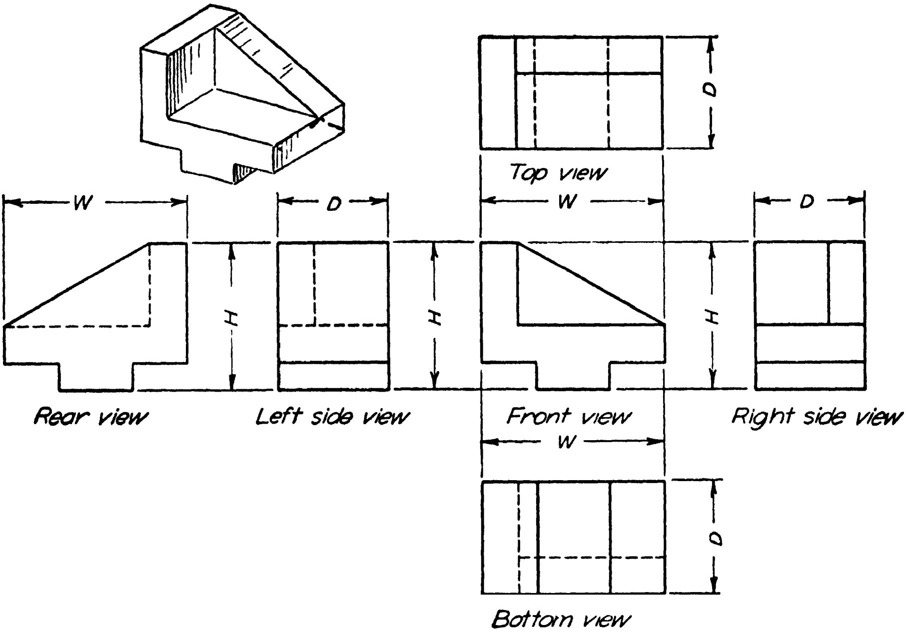


Figure 4·22 Position of bottom view and rear view.

views will give the best description of the shape and have the fewest hidden lines.

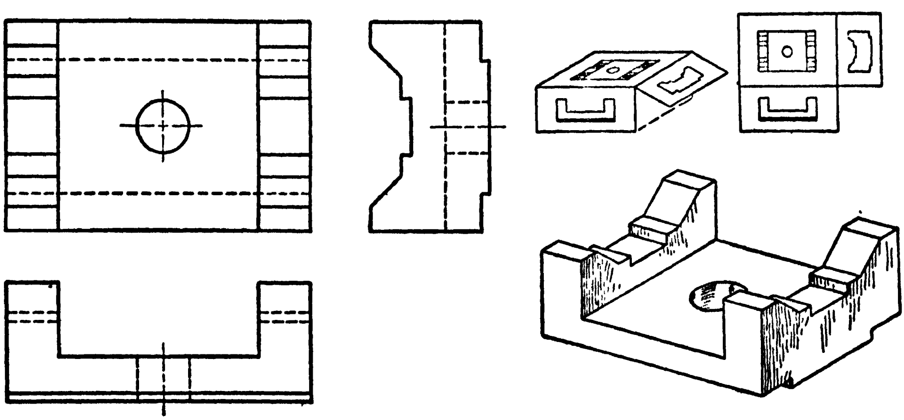


Figure 4·23 Second position of the side view.

The proportions of an object or the size of the sheet sometimes makes it desirable to show a side view in the second position or directly across from the top view, as in Fig. 4·23. This position is obtained by revolving the side plane about its intersection with the top plane.

Consideration of a "mind's eye picture" of an object will indicate which views should be drawn to describe its shape.

4·11 Reading the Views. The reading of a drawing consists of a study of the views to pick out the surfaces of the elementary parts that make up the object.

The bearing shown in Fig. 4·24 is made up of cylinders, parts of cylinders, and rectangular prisms. There are flat surfaces and curved surfaces that require visible and invisible (hidden) lines. Notice that surface *A* of the side view is shown by a full line *ab* in the front view

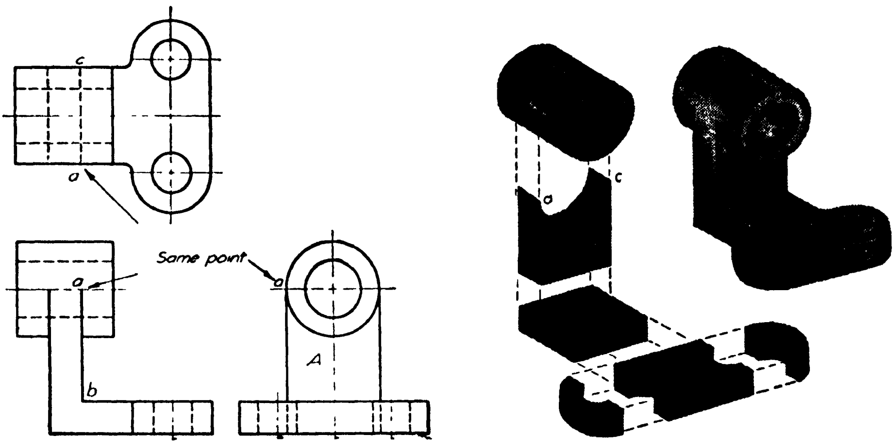


Figure 4·24 Reading the views.

and by a hidden line *ac* in the top view. Compare the three views with the picture and notice how the various parts are described in the different views. Study the reason for the visible or hidden lines in each case as well as the necessity for three views to give a complete description of the bearing. Considering the view shown to be the top, front, and right-side views, try to see how the bottom, rear, and left-side views would look and which lines would be visible and which ones would be hidden. For a casting, the working drawing would show *fillets* or rounded-in corners at *b* and between the cylinder and the vertical support. Fillets are omitted in Fig. 4·24 to simplify the views for study purposes and to show how point *a* in the front view is determined by the tangent point in the right-side view.

Sketching the views as described in Chap. 5 is an excellent means of learning to read drawings.

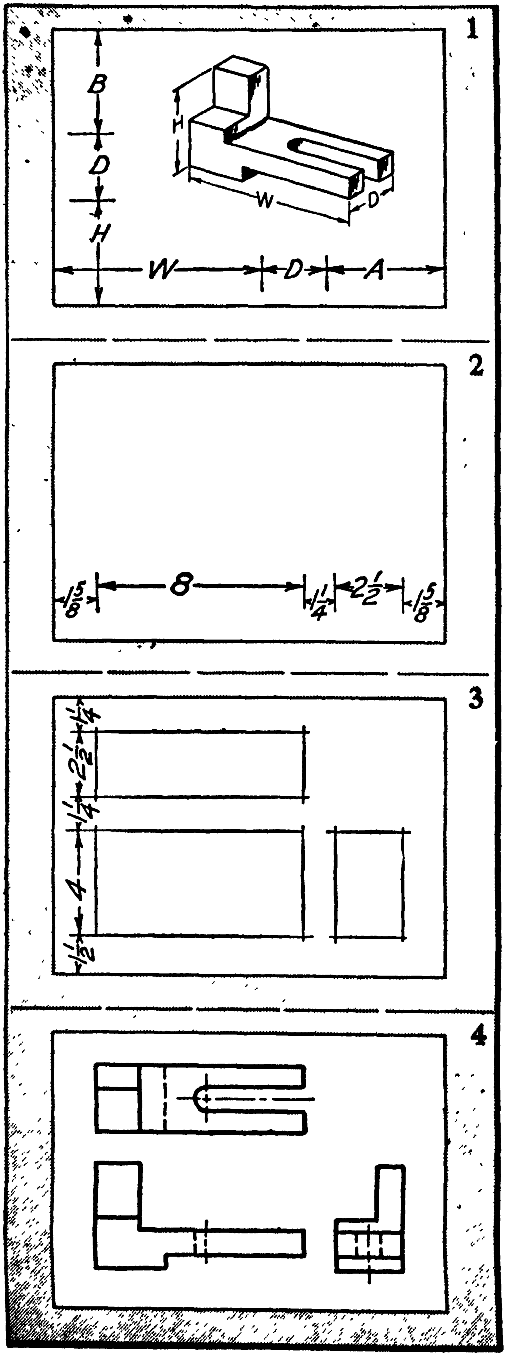


Figure 4·25 Placing views.

4·12 Placing Views. The size of drawing sheet selected should provide for views that will give a clear description of the object. The size used for most of the problems in this book is 11″ × 17″ with a working space of $10\frac{1}{2}$ by 15 in. For the piece shown in Space 1, Fig. 4·25, the dimensions are $W = 8$, $H = 4$ and $D = 2\frac{1}{2}$. An easy way of locating the views is to lay off the width ($W = 8$ in.) and the depth ($D = 2\frac{1}{2}$ in.) from the left border line as shown in Space 1. The remaining distance, A, will measure $4\frac{1}{2}$ in. which is to be divided into three parts to provide a space between the front and side views, the space at the left of the front view, and the space at the right of the side view. If the space between the views is made $1\frac{1}{4}$ in., it will leave two spaces of $1\frac{5}{8}$ in. Then lay off the height ($H = 4$ in.) and the depth ($D = 2\frac{1}{2}$ in.) upward from the bottom border line as in Space 1. This will leave a distance B of 4 in. If $1\frac{1}{4}$ in. is left between the front and top views, there will be $2\frac{3}{4}$ in. of which $1\frac{1}{2}$ in. can be used below the front view and $1\frac{1}{4}$ in. above the top view. More

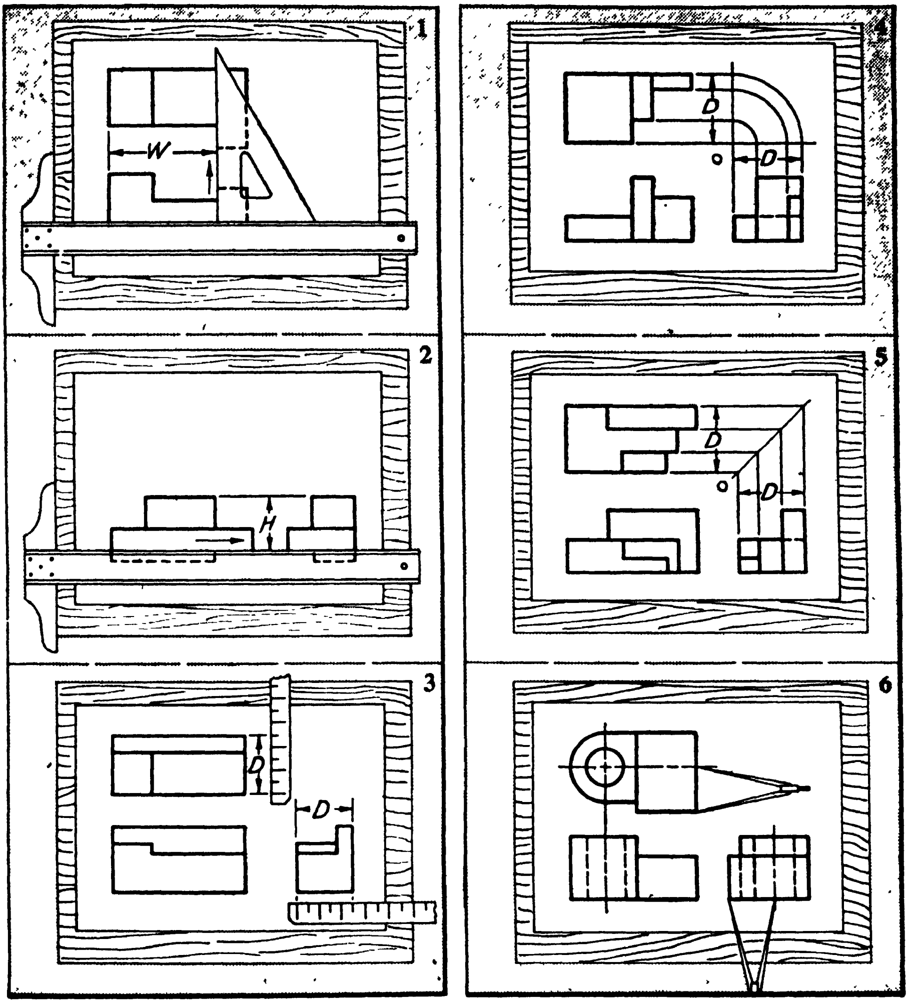


Figure 4·26 Locating measurements.

space is generally used below the front view because this makes the views look better on the sheet. Spaces between views and around them depend upon such things as the shapes of the views, the number of dimensions needed, and the size of the sheet.

4·13 Locating Measurements. After lines have been drawn to locate the views on the sheet, horizontal or width (*W*) measurements made on the front view can be located on the top view by drawing up from the front view with a triangle (Fig. 4·26, Space 1). In like manner, measurements may be projected from the top view to the front view.

Vertical or height (*H*) measurements on the front view can be located on the side view by drawing across with the T-square (Space 2). In like manner, measurements may be located on the front view from the side view.

Depth measurements (*D*) show as vertical distances in the top view and as horizontal distances in the side view. Such measurements can be taken from the top view to the side view, or from the side view to the top view, by using the scale as in Space 3, by drawing arcs from center *O* as in Space 4, by using a 45° line through *O* as in Space 5, or by using the dividers as in Space 6.

TEXT-FILMS

The following McGraw-Hill Text-films have been correlated directly with Chap. 4:

Shape Description, Part I (15-min. sound motion picture)

This film, describing the theory of orthographic projection, uses animated diagrams and special models to obtain three-dimensional effects. The projection of the frontal, horizontal, and profile planes are shown as fully representing an object and providing all the necessary information to construct it.

A coordinated silent filmstrip designed as a follow-up to this film summarizes important facts about orthographic projection and reemphasizes the key points in the film.

Shape Description, Part II (10-min. sound motion picture)

This film follows the preceding film, "Shape Description, Part I," and presents step-by-step procedure in constructing an actual drawing. The reasons for each step are explained, and principles are established which the student can apply in making drawings of his own.

A correlated filmstrip designed as a follow-up to the film presents questions for discussion and review, and reemphasizes key points of the motion picture.

CHAPTER 5. Sketching

5·1 Freehand drawing or sketching is a convenient and valuable means of shape description in the practice of engineering as well as in the study of view drawing.

Accuracy of observation, development of a good sense of proportion, and sureness in the handling of the pencil are necessary requirements for making good sketches. Such skill has become not only important but it is a "must" for draftsmen and designers in present-day progressive industry.

5·2 Necessary sketching equipment includes an F or H pencil, sharpened to a long conical point, an eraser, and suitable paper. Plain paper is suggested for beginning practice. Many kinds of squared or coordinate papers are available, which can be used for scale and proportion in making sketches. Other rulings provide for pictorial sketches and special purposes. Working sketches can be made quickly and conveniently by placing tracing paper over suitable coordinate paper. Measuring tools and other equipment used in making dimensioned sketches from parts of machines or constructions are explained in Arts. 8·20 to 8·22.

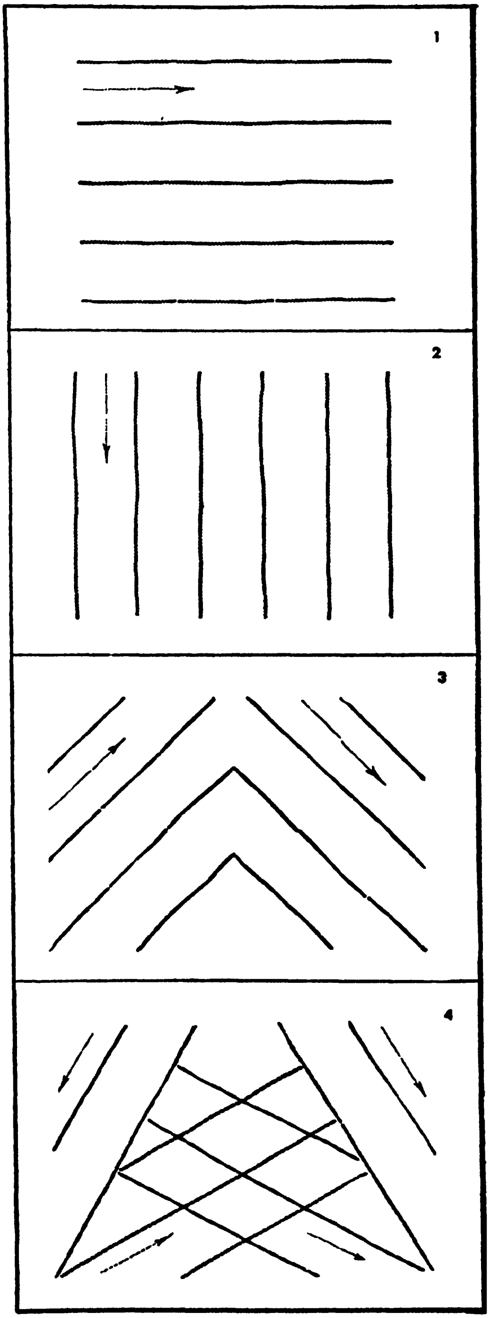


Figure 5·1 Sketching straight lines.

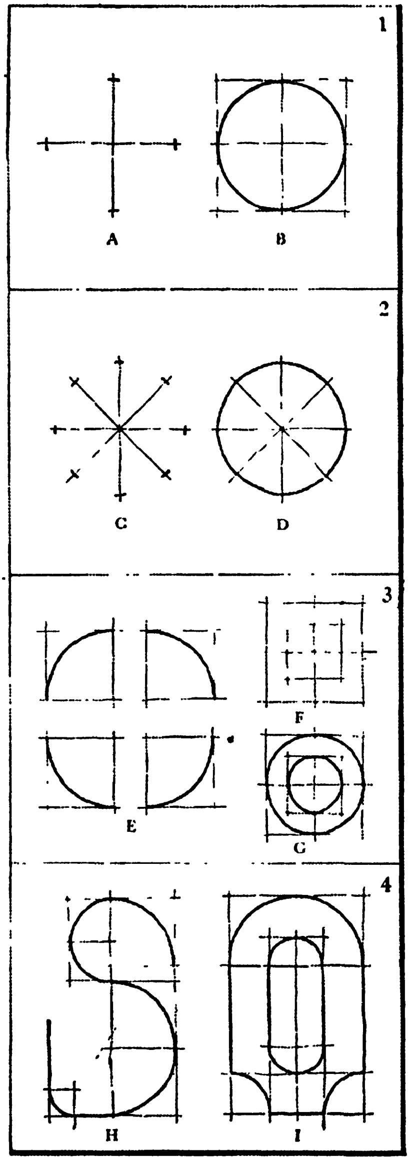


Figure 5·2 Sketching circles and curves.

5·3 Sketching Practice. As views are made up of straight lines and curves, the student should become proficient in these elements before sketching the views of an object.

Horziontal lines are sketched from left to right, as in Space 1 of Fig. 5·1, vertical lines downward as in Space 2, and inclined lines as in Spaces 3 and 4.

Methods of sketching circles and arcs are shown in Fig. 5·2. In Space 1 at *A* and *B*, radii are estimated and marked off on vertical and horizontal center lines to locate a square in which the circle is sketched.. In Space 2 at *C* and *D*, radii are estimated and marked off on the lines indicated to locate points through which the circle is sketched. Arcs, tangent arcs, and curves are conveniently sketched by blocking in with straight lines, as suggested in Spaces 3 and 4.

A picture of a V-block is shown in Fig. 5·3. In Fig. 5·4 the views necessary to describe the shape of the V-block have been sketched freehand. Notice how the proportions have been observed and how the blocking-in lines have been sketched in for all the views so that they are properly located in the available space. Never attempt to sketch or complete one view at a time; block them all in, and then proceed to work up the corresponding details in all the views.

5·4 Making a Sketch. Careful practice and systematic methods of working are necessary in order to attain skill in making sketches.

The stages in making a sketch are shown in Fig. 5·5. Observe the object, pictured in Space 1, select the views necessary to describe its

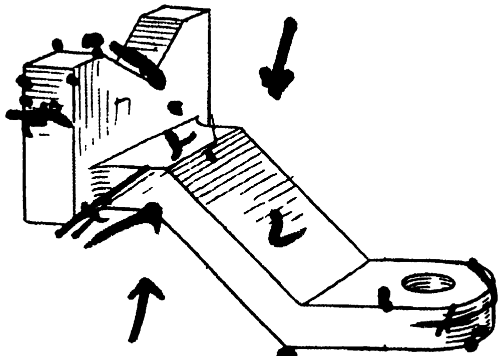


Figure 5·3 An object to be sketched.

shape, and judge the proportions. Estimate the proportions carefully and mark off distances for the three views as in Space 2. Block in the enclosing rectangles for the views as in Space 3. Locate the details in

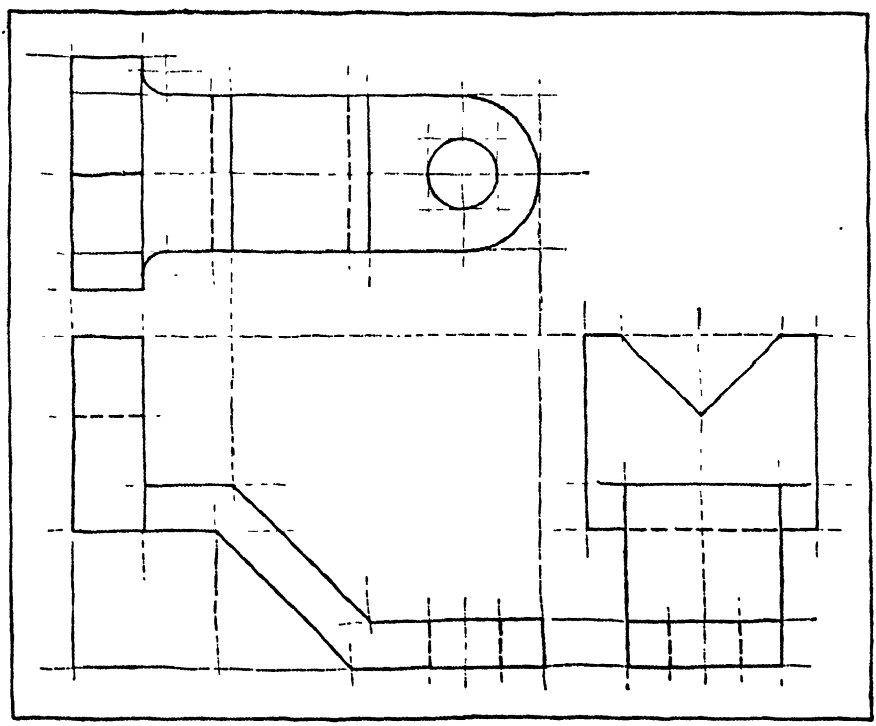


Figure 5·4 A pencil sketch.

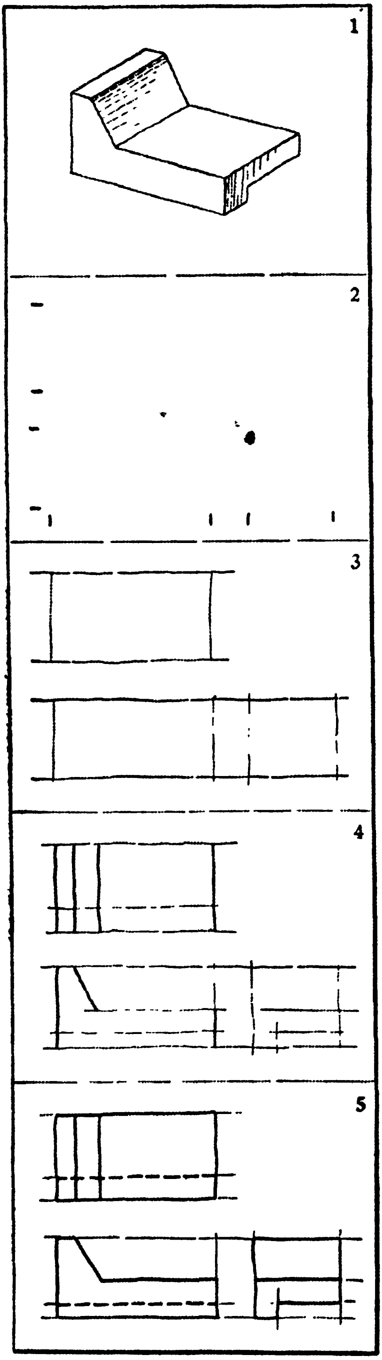


Figure 5·5 Stages in making a sketch.

each of the views and block them in as in Space 4. Finish the sketch by brightening up the lines as in Space 5. The preliminary blocking-in lines should be drawn so light that they will not have to be erased and that the dashes for hidden lines can be drawn over them.

5·5 Freehand Studies. Line exercises are given in Fig. 5·6 for preliminary practice. All distances mentioned and angles indicated are to be estimated. Exercises *A*, *B*, *C*, and *D* may be sketched in 2- or 3-in. squares with the parallel lines equally spaced. Exercises *E*, *F*, *G*, and *H* may be sketched in rectangles 2 by 4¼ in. or 3 by 6⅜ in. Exercises *I*, *J*, *K*, *L*, *M*, and *N* may have a radius of 1 or 1½ in. for the largest circles. The proportions should be observed very carefully, and the blocking-in lines should be located as accurately as possible by eye.

The objects shown in Figs. 5·7 to 5·10 are designed to give the student practice in shape description by freehand sketching either in pencil on plain or squared paper or on the blackboard. The sketches should be made large enough to give a clear description of the shape of the object. Consider the proportions of the object and the choice of views necessary for a complete description. Block in the views and brighten the result as in Fig. 5·4 and in space 5 of Fig. 5·5.

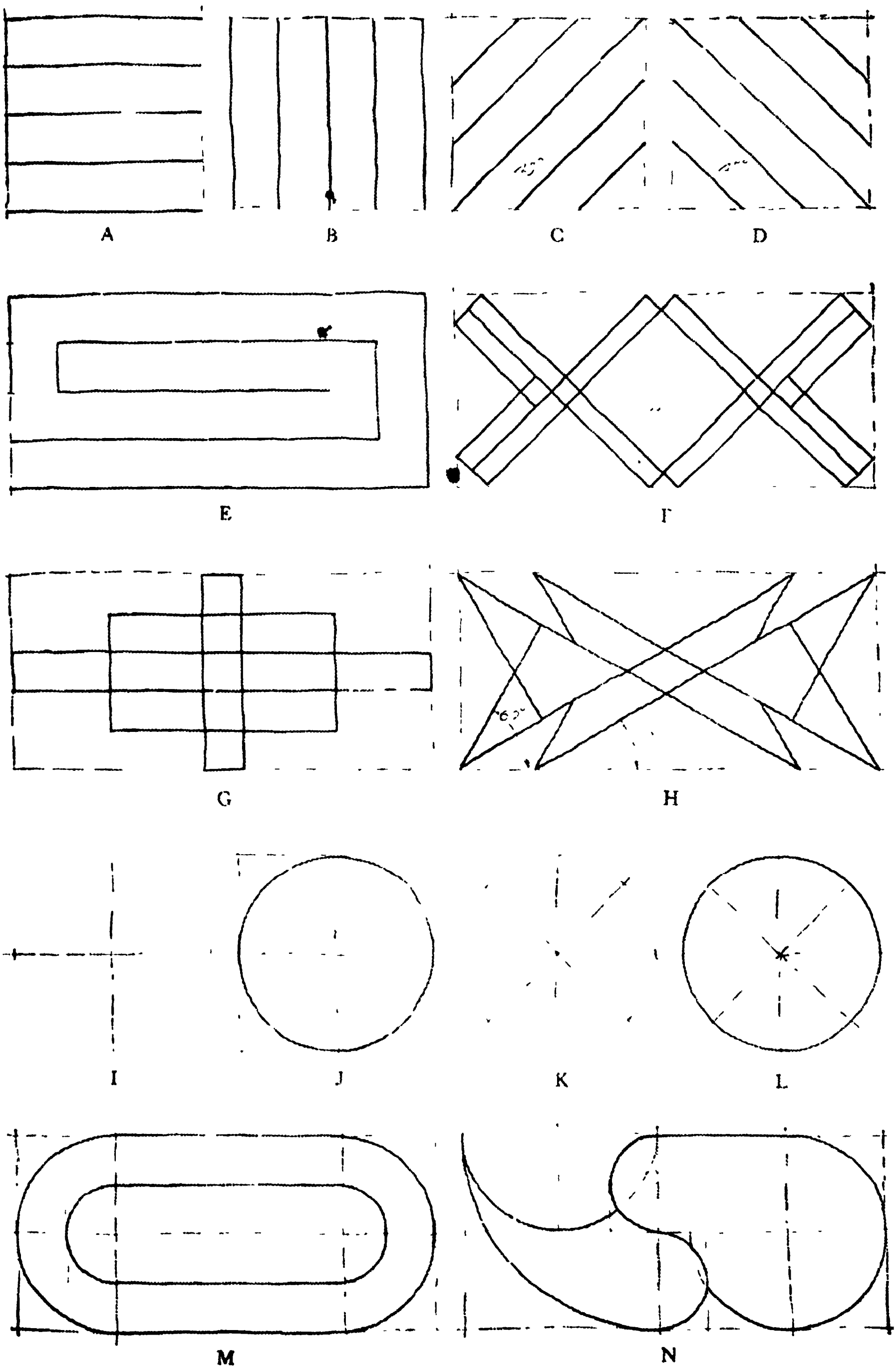


Figure 5·6 Line exercises.

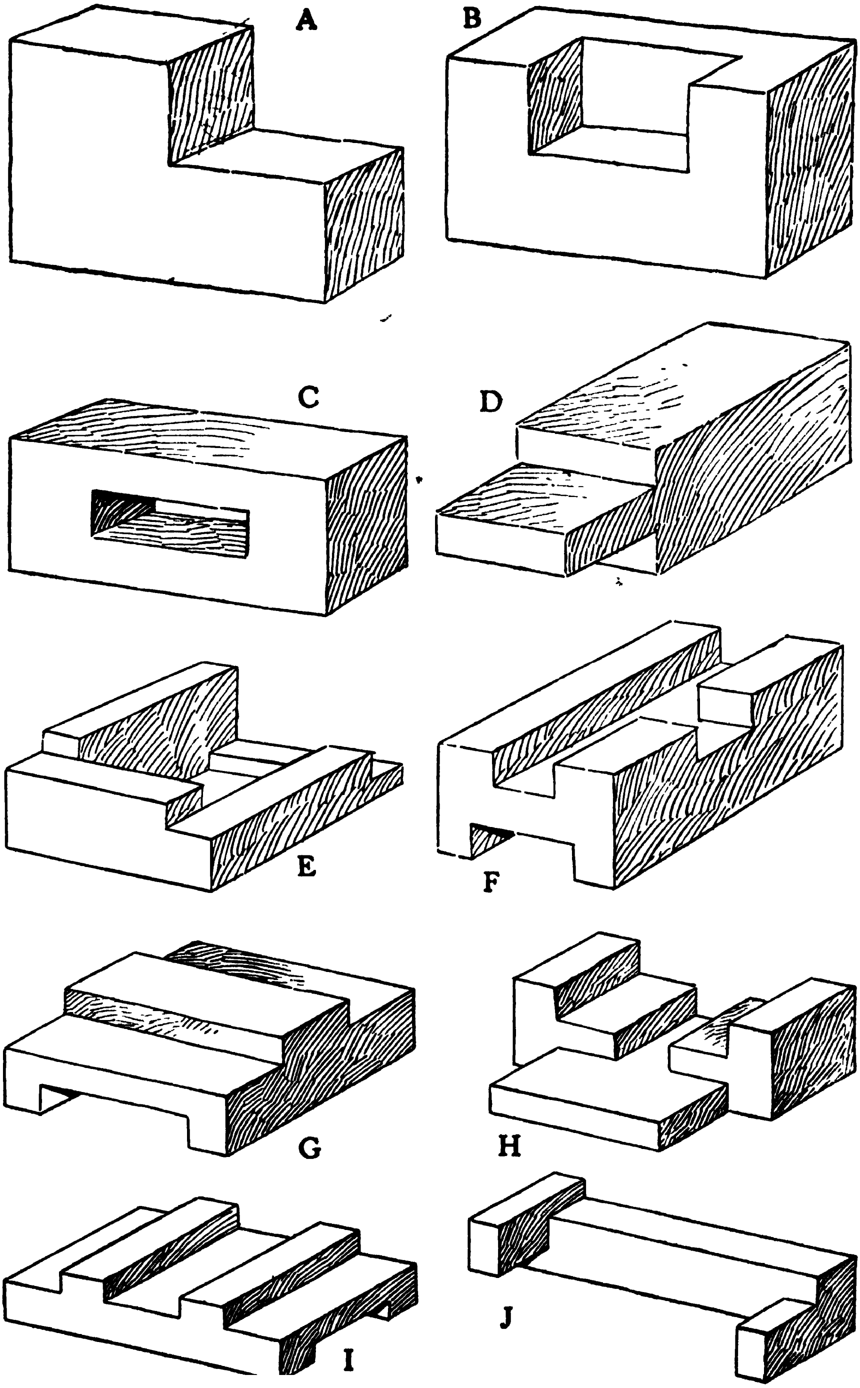


Figure 5·7 Problems for freehand sketching.

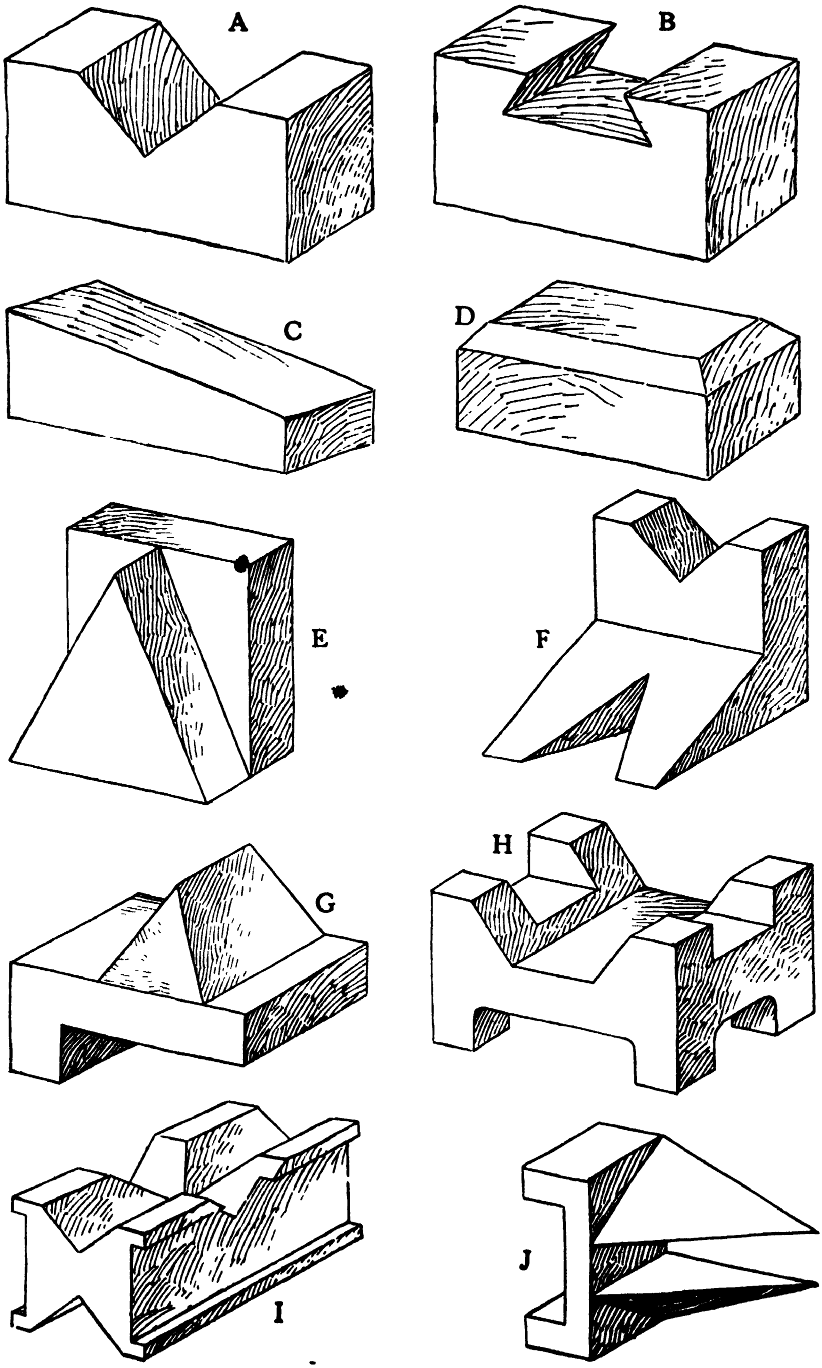


Figure 5·8 Problems for freehand sketching.

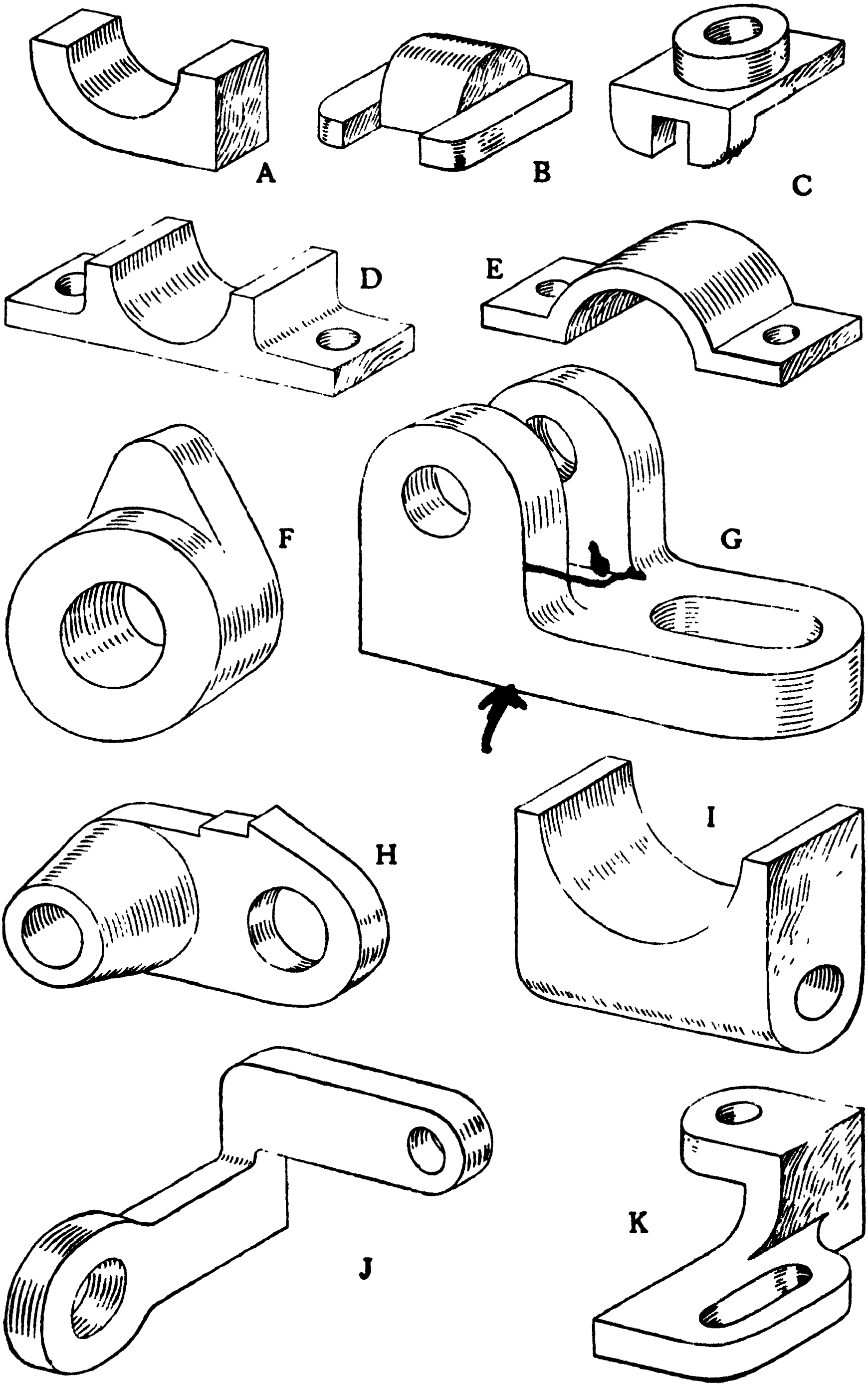


Figure 5·9 Problems for freehand sketching.

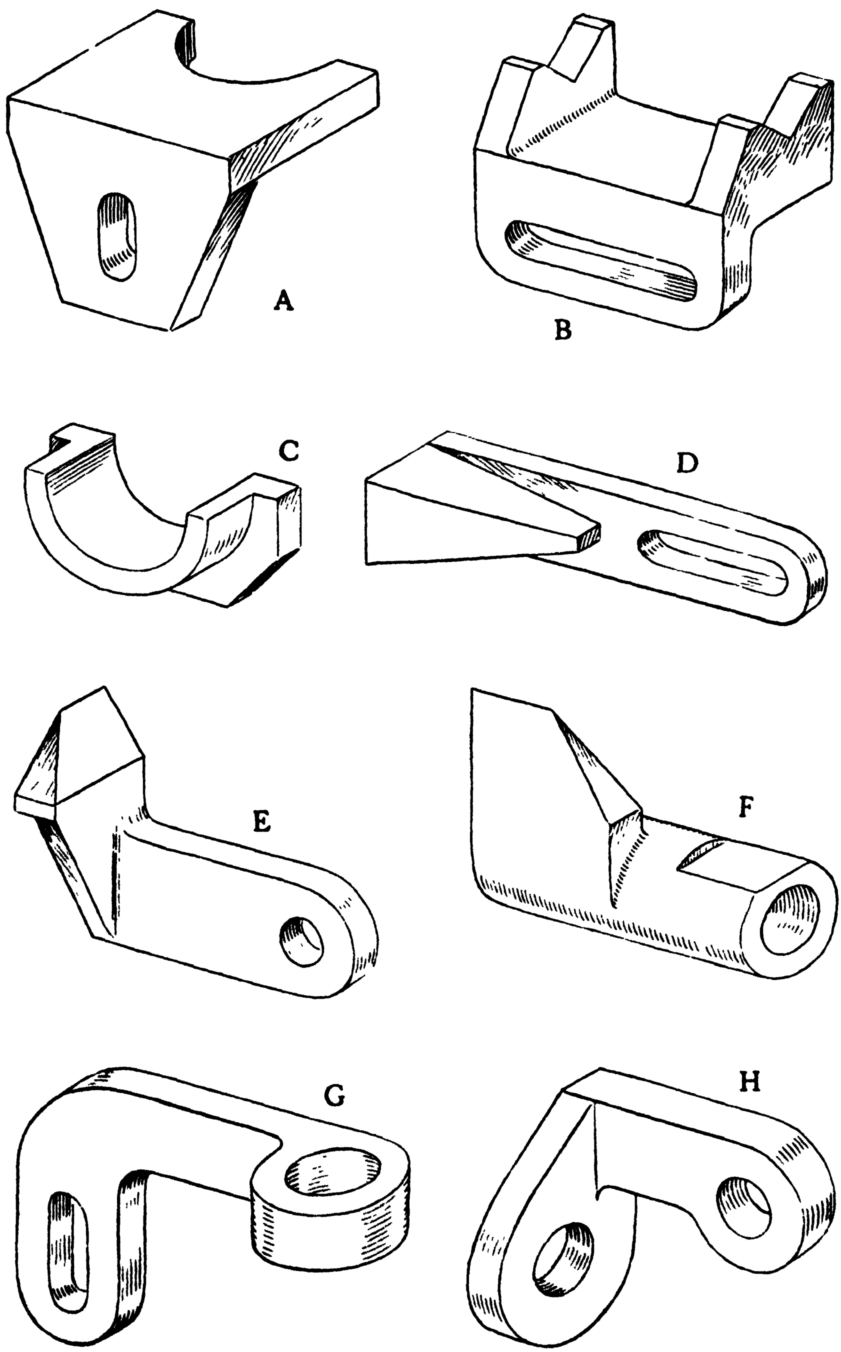


Figure 5·10 Problems for freehand sketching.

CHAPTER 6. Sections

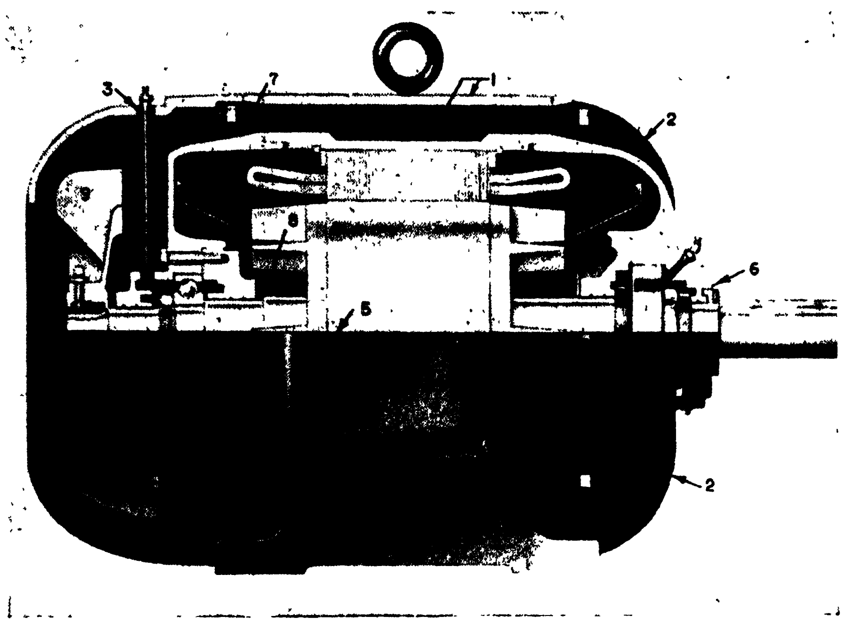


Figure 6·1 Cutaway view of Tri-Clad electric motor. (1) A cast-iron double-wall frame. (2) Ribbed cast-iron end shields. (3) Pressure-relief greasing systems. (4) Cast-iron conduit box diagonally split for wiring convenience. (5) Leads are sealed in a non-shrinking compound at the point where they emerge from frame. (6) Rotating labyrinth seal prevents infiltration of grit or liquids. (7) Large free-flowing easy-to-clean air passages. (8) Modern "ageless" insulation treatment. (9) Powerful external fan. (*General Electric Company.*)

6·1 We have learned that the parts of an object that cannot be seen are represented by hidden lines (composed of short dashes). This method is satisfactory where the object is solid or the interior simple. There are many cases, especially where there is considerable interior detail or where several pieces are shown together, in which the hidden lines become confusing or hard to read. In such cases views, called sections, may be drawn to show the object as if it were cut apart.

The picture in Fig. 6·1 shows how an electric motor would look if cut through the center and halfway down, with the cutaway part removed. Compare the upper part of the picture with the lower part. Then imagine how a regular drawing of the motor would look with part cut away as in the picture. Think how confusing it would be if one attempted to show all the interior details on an exterior view by using hidden lines.

6·2 A sectional view is obtained by supposing the piece to be cut apart by an imaginary cutting plane, and the part in front of the plane removed, thus exposing the interior. This is shown in pictorial form in Spaces 1 and 2 of Fig. 6·2. The imaginary cutting plane is shown in Space 1 and the appearance of the cut surface, after removing the front portion, in Space 2. The sectional view is shown in Space 3. On a drawing, the cut surface is represented by section lining with uniformly spaced fine lines generally at 45° (Space 3). In the top view, the edge of the cutting plane is indicated by a cutting plane line (see alphabet of lines, Fig. 9·2), but the part supposed to be cut away is not left out. The regular full views are shown in Space 4 for comparison.

6·3 A full section is a view of the object as it would appear if cut entirely across, as in Fig. 6·2, Space 3. The cutting plane is usually taken straight through on the main axis, but it may be offset in any part of its length to go through some detail not on the axis (Figs. 6·3 and 6·4).

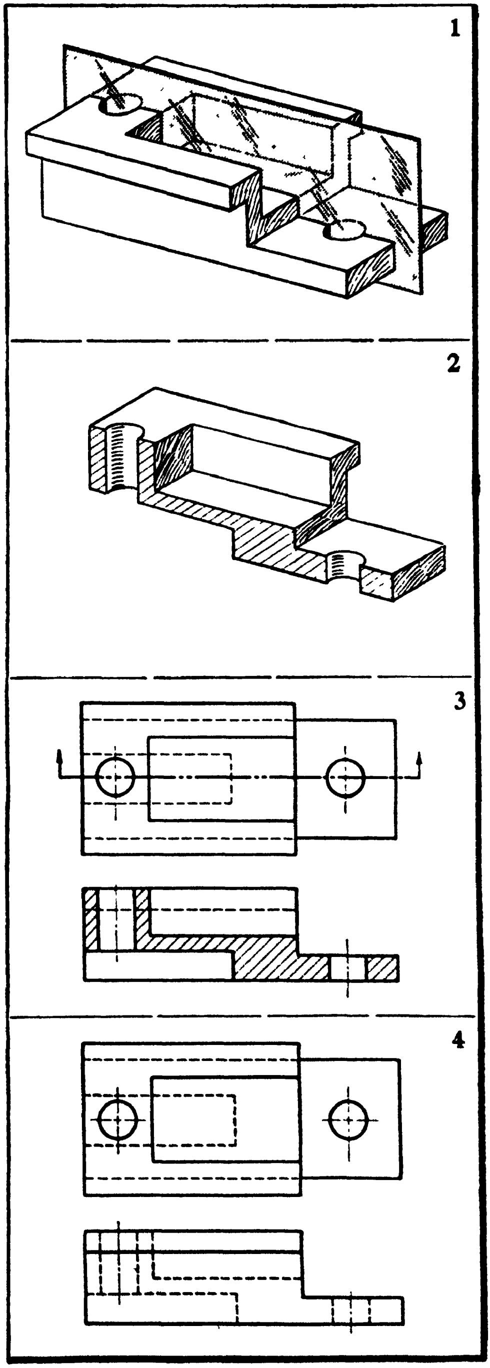


Figure 6·2 Obtaining a sectional view.

6·4 A half section is a view obtained when the cutting plane extends only halfway across, leaving the other side of the piece as a half outside view. It can be used to advantage with a symmetrical

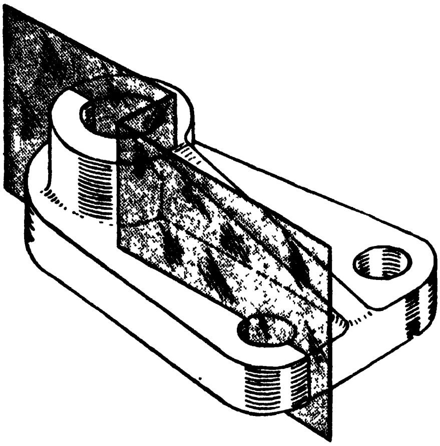


Figure 6·3 Offset cutting plane.

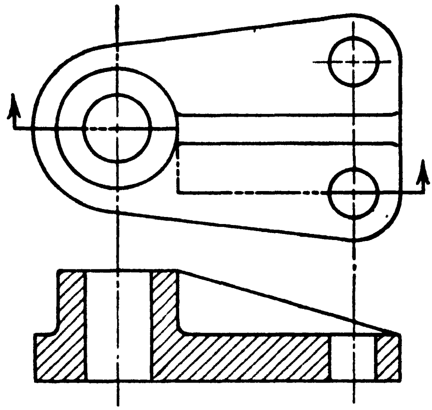


Figure 6·4 An offset section.

piece to show both the exterior and interior on one view (Fig. 6·5). Hidden lines are generally left out on both sides.

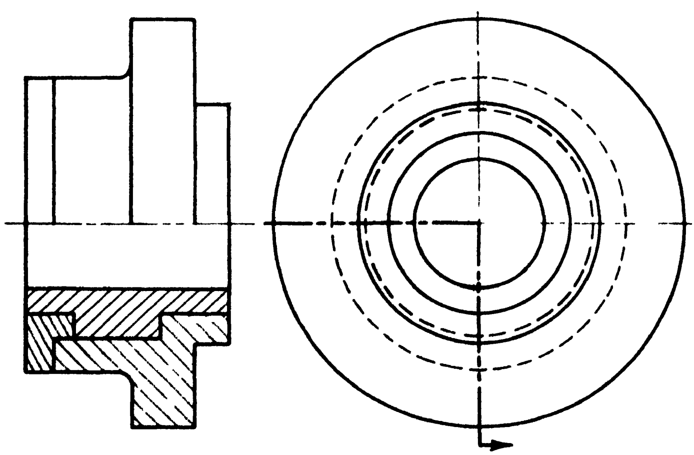


Figure 6·5 A half section.

6·5 To Make a Sectional View. Think how the object would look if actually sawed in two. Draw all the lines that are in the plane of the section and all visible edges back of the plane, but only such hidden (invisible) edges as are necessary to describe the shape of the object.

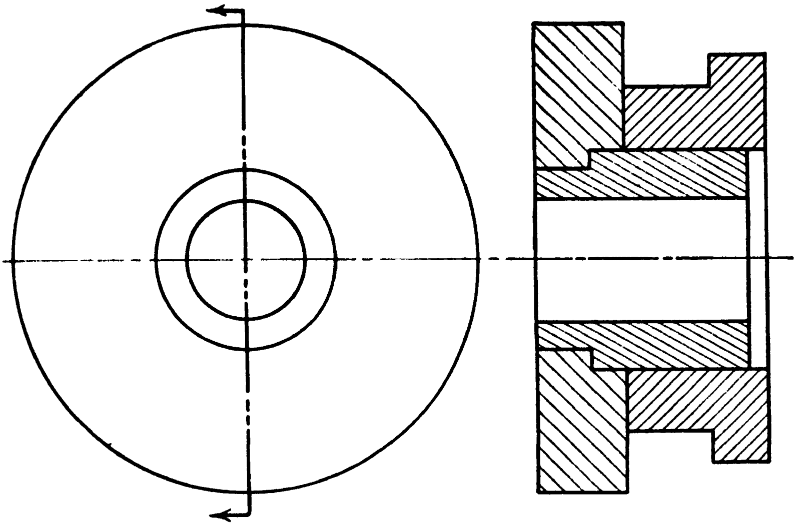


Figure 6·6 Adjacent pieces in section.

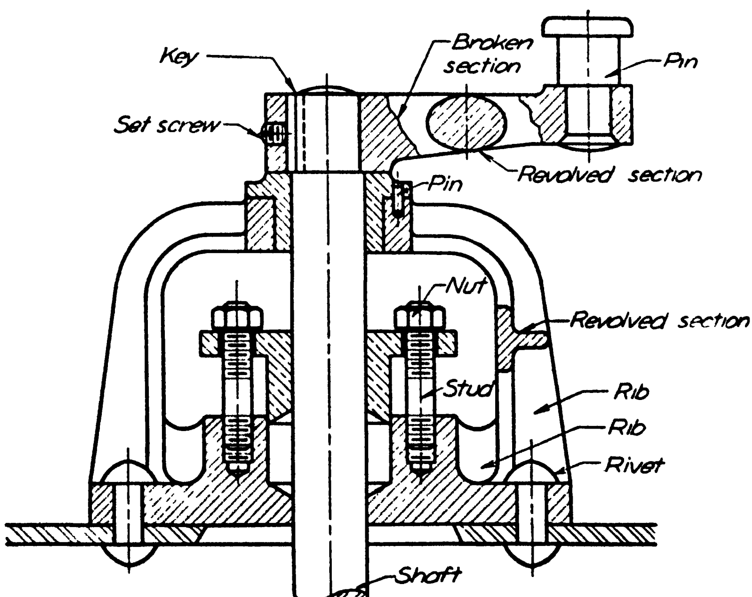


Figure 6·7 Bolts, shafts, etc., on sectional views.

When two or more pieces are shown together, they are sectioned in different directions (Fig. 6·6). Any one piece must have the section lines in the same direction on all parts of its cut surface.

6·6 Section Lining. The spacing of section lines should be such as will give the effect of an even tint. For most purposes, the distance between lines is about $\frac{1}{16}$ in., spaced entirely by eye. Uneven spacing not only will ruin the appearance of a drawing but will make it harder to read. Very small pieces require somewhat closer spacing than large ones.

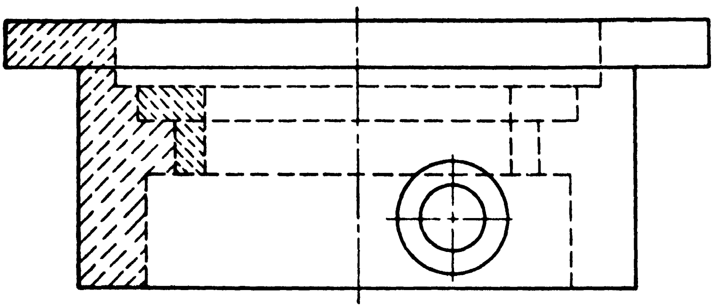


Figure 6·8 A phantom section.

Sometimes different materials are indicated by varying the kinds of section lining. The symbols used when this is done are shown in Fig. 9·8. Ordinarily it is better to use the regular section lining and specify the material by a note.

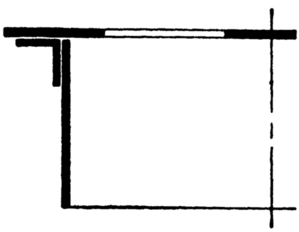


Figure 6·9 A blacked-in section.

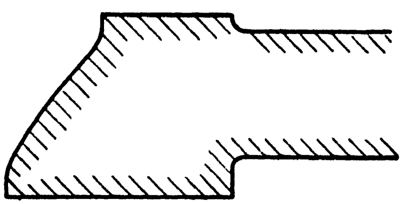


Figure 6·10 Outline section.

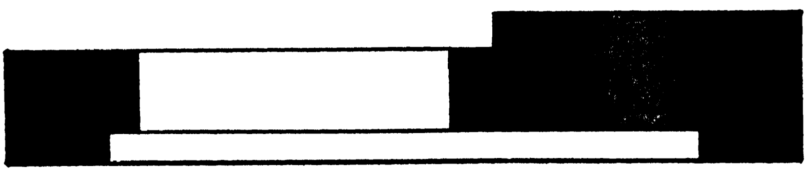


Figure 6·11 Shaded section.

6·7 Special Sections. When shafts, bolts, nuts, screws, keys, etc., occur in the section, they are not cut through but are left in full as indicated in Fig. 6·7, where the usual treatment is shown. The purpose of a sectional view is to make interior details clear. Therefore, when parts are solid (have no interior details), they are best represented by full views. Broken sections often permit a single view to show both interior and exterior features. Revolved sections provide a convenient means of showing the shape of a rib or arm. Note the method of showing the break at the lower end of the shaft.

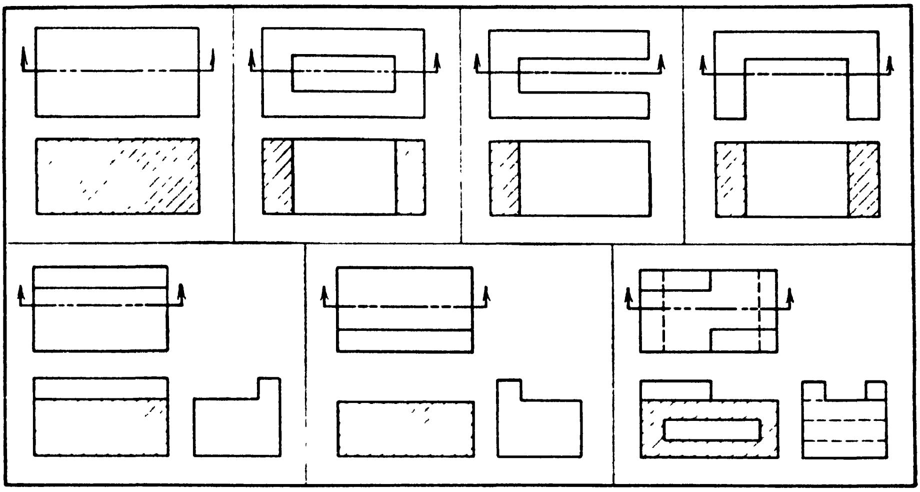


Figure 61·2 Sections for study.

The hidden, or phantom, section (Fig. 6·8) is used when it is necessary to show the interior and the exterior on the same view.

When the sectioned area is very small, as for thin plates, sheets, and structural shapes, blacked-in sections may be used as in Fig. 6·9. Note the white space between the parts.

A timesaving method of indicating a large sectioned area is to use outline sectioning, as shown in Fig. 6·10. This method is often used on design drawings with the section lines drawn freehand. Still another method is to gray the sectioned area with a pencil or by rubbing pencil dust over the area (Fig. 6·11).

6·8 Sectional View Problems. Study each piece shown in Figs. 6·12 and 6·13 until the reason is clear. Then the objects shown in Figs. 6·14 to 6·16 are to be redrawn freehand, changing one of the views of each to a full section, as indicated by the cutting plane. The surfaces that are cut should have light, uniformly spaced section lines, drawn at approximately 45°. Draw the views large enough so that they can be easily read, perhaps about four times the size shown in the book (estimated).

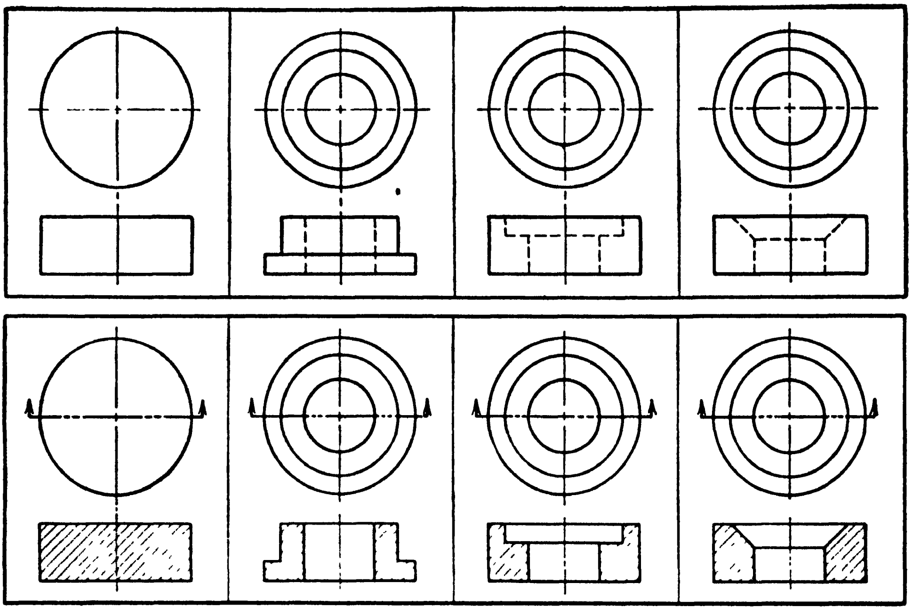


Figure 6·13 Sections for study.

TEXT-FILMS

The following McGraw-Hill Text-film has been correlated directly with Chap. 6:

Sections (10-min. sound motion picture)

This film shows that sectional views, which are formed by an imaginary cutting away of part of an object to reveal interior details, make the drawing easier to read. Symbols used in sectioning are explained: crosshatching, broken lines, reference letters, etc. The construction of a full sectional view is demonstrated: other types of sectional views—half sections, broken-out sections, revolved sections, etc.—are explained.

A correlated follow-up filmstrip summarizes important points of sections and reemphasizes the key points of the film.

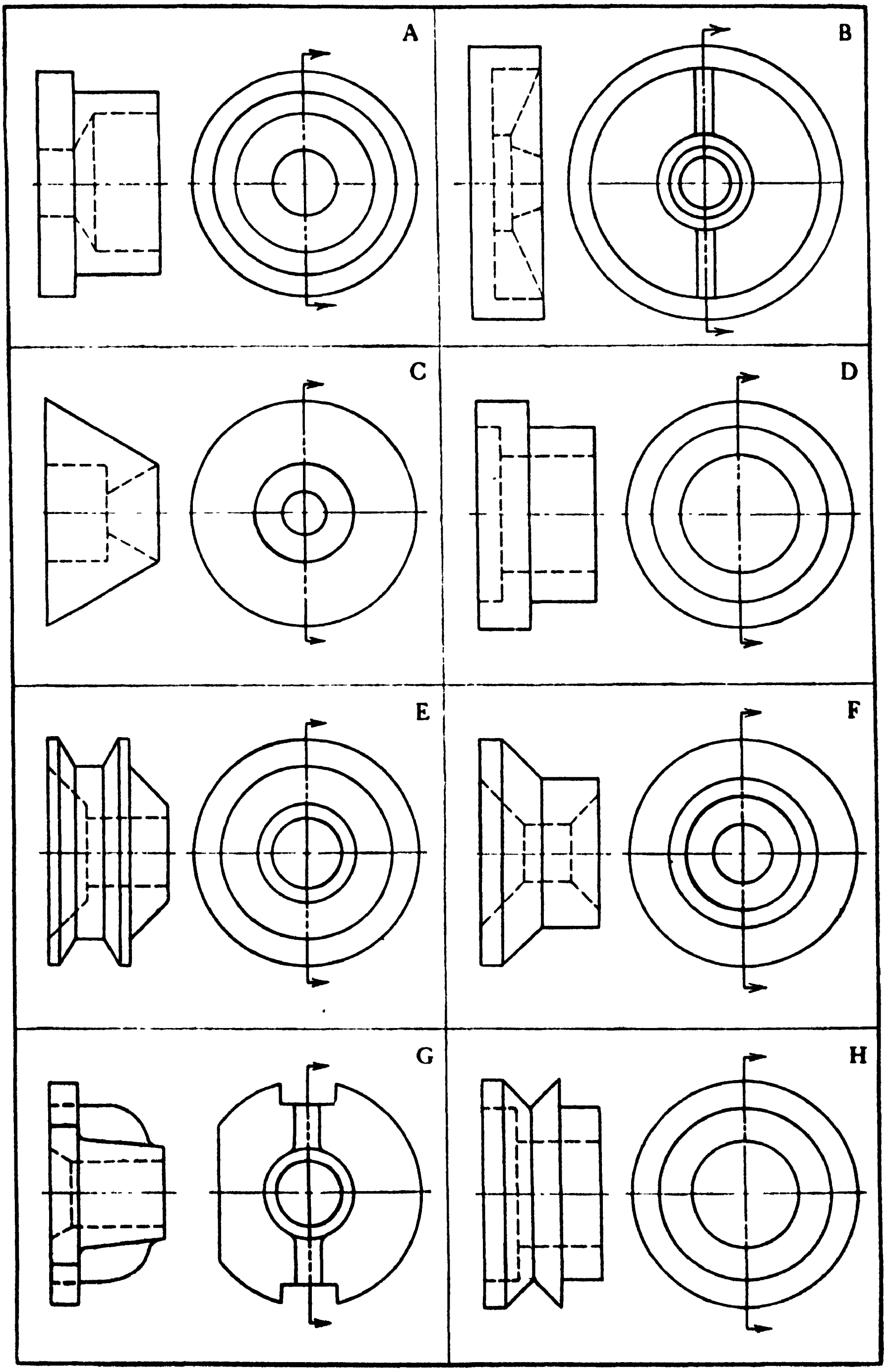


Figure 6·14 Sectional view problems.

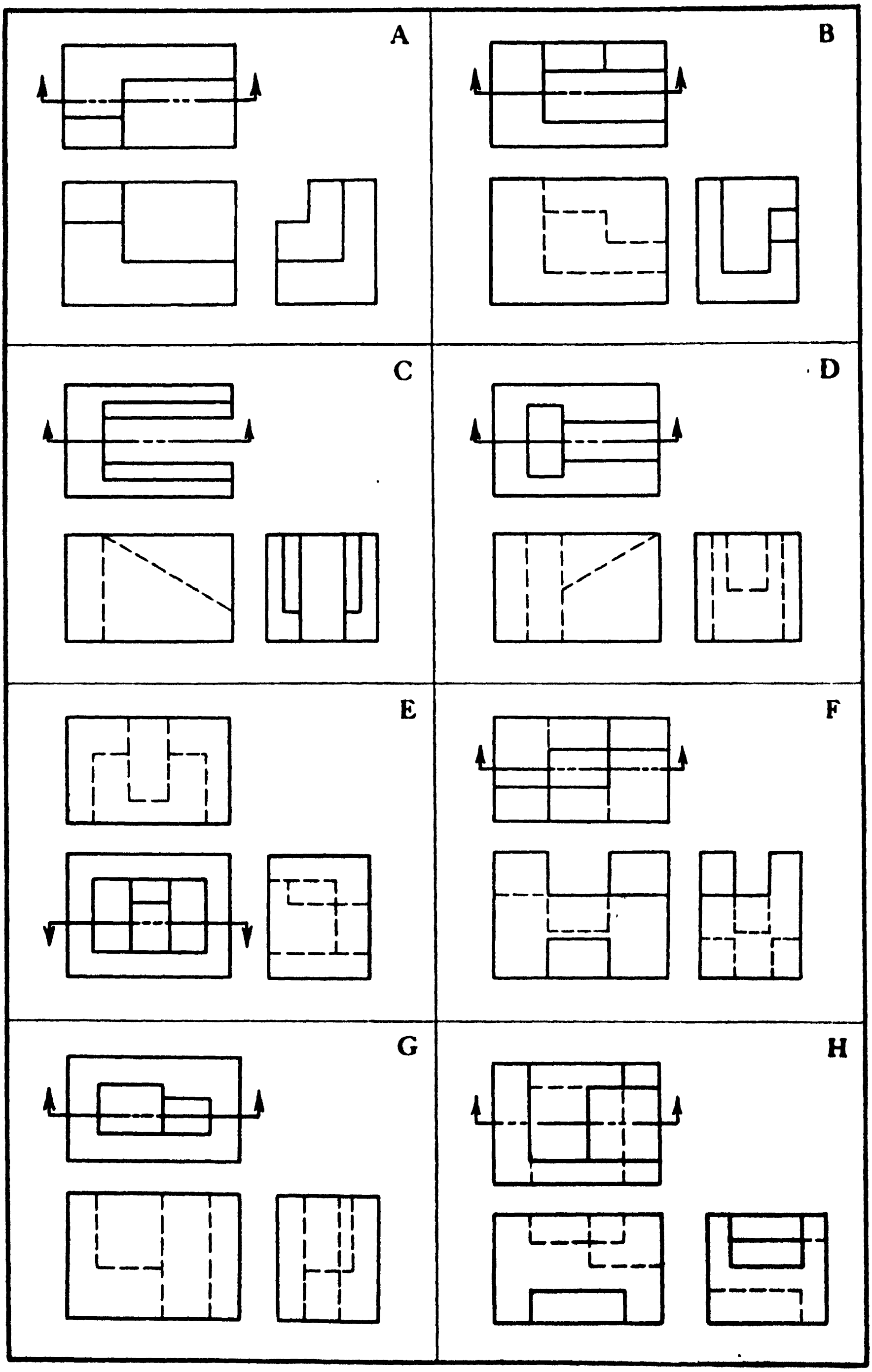


Figure 6·15 Sectional view problems.

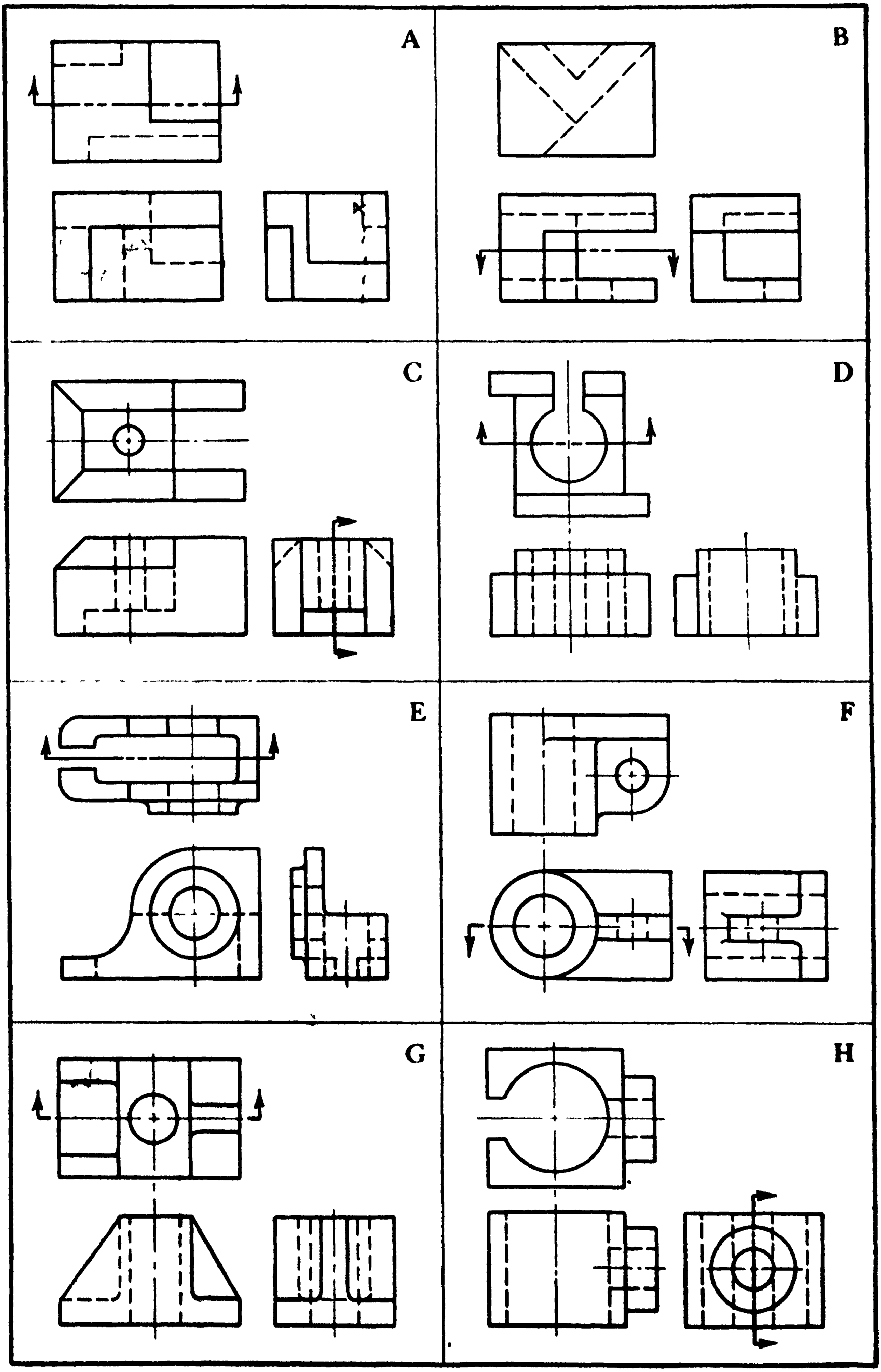


Figure 6·16 Sectional view problems.

CHAPTER 7. Auxiliary Views and Revolutions

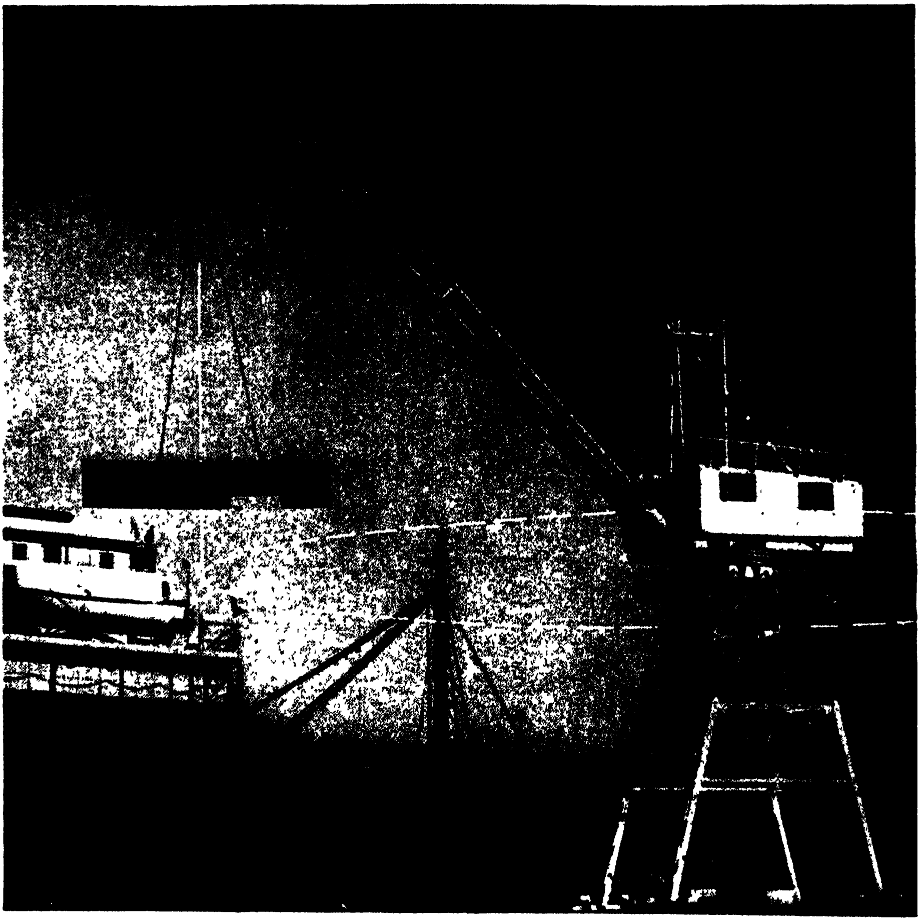


Figure 7·1 Revolution about a vertical axis. A 15-ton, 80-ft. boom shipyard traveling crane. (*McKiernan-Terry Corporation, Harrison, N.J.*)

7·1 In the previous chapters, views have been drawn on three regular planes that are in vertical, horizontal, and profile (or side) positions at right angles to each other and with the object in a normal (regular) position. In this chapter, we shall learn how to draw views of objects that have been revolved about an axis (Fig. 7·1) and to draw views on planes that make any angle with a regular plane (Fig. 7·2).

7·2 Auxiliary Views. The usual views of an object do not show the true shapes of slanting surfaces (Fig. 4·14, Space 3). However, it is sometimes necessary or desirable to show the true shape of a slanting surface, especially when it has an irregular outline. This is done by making a view called an "auxiliary view," looking directly at the slanting surface (Fig. 7·2). Notice that by drawing the auxiliary view of the anchor pictured in Space 1, its shape is completely described in Space 3 with the auxiliary view and one of the regular views, making a top or side view unnecessary. The position of the auxiliary plane is pictured in Space 2.

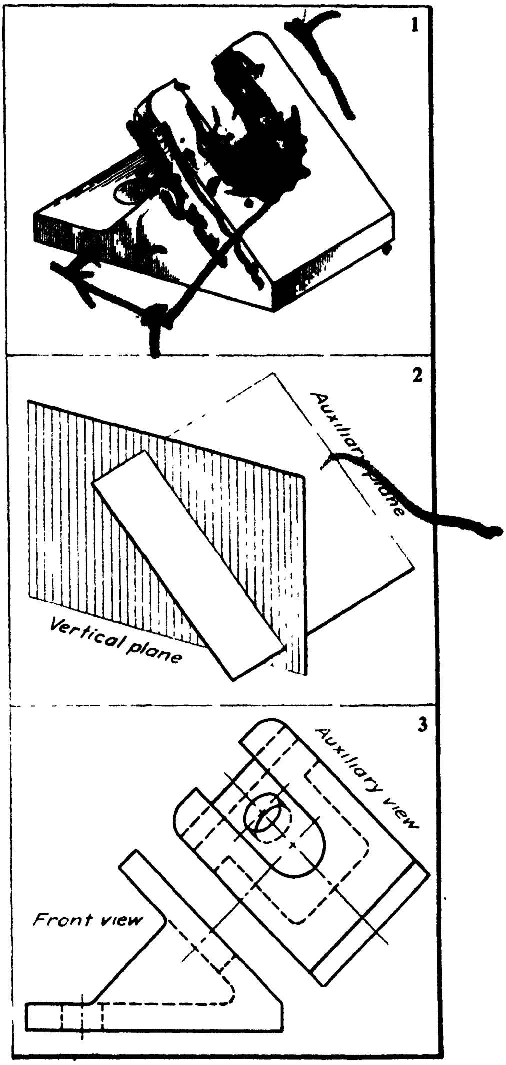


Figure 7·2 An auxiliary view.

The relation of the auxiliary view to the usual views is illustrated by the simple block in Fig. 7·3. The three regular views would be as in Space 1, the side view being obtained by looking in the direction of arrow I. The face *A* does not show in its true shape in this view. If we locate a plane parallel to face *A*, as in Space 2, and look in the direction of arrow II perpendicular to face *A*, we obtain an auxiliary view that will show the true size and shape of face *A*. Such an auxiliary view made on an auxiliary plane and revolved into the plane of the paper is shown in Space 3. The true size and shape of any inclined surface may be shown in a similar way, as described in Arts. 7·2 to 7·5.

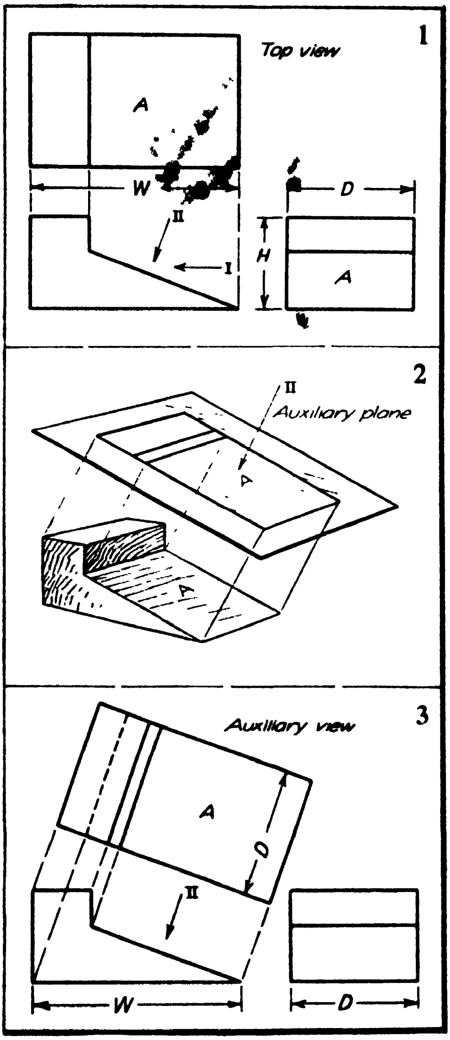


Figure 7·3 Relation of auxiliary view to other views.

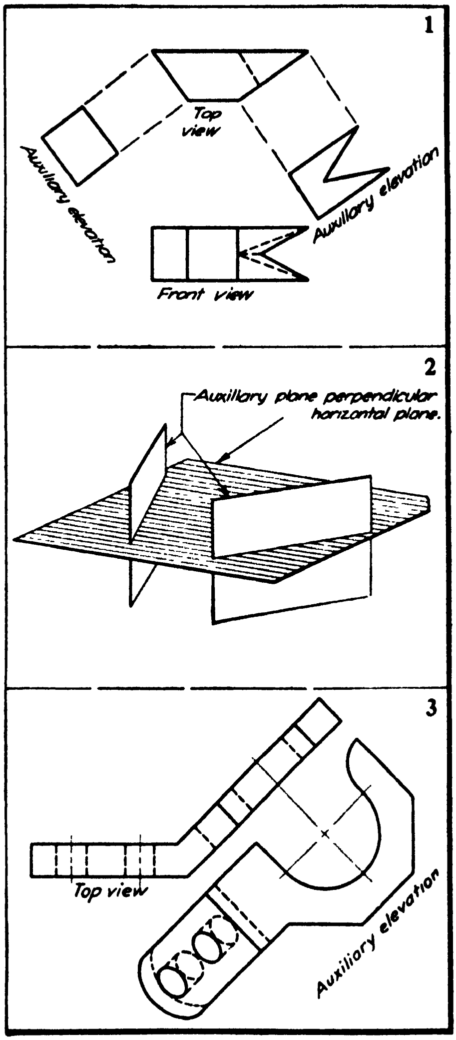


Figure 7·4 Auxiliary elevations.

7·3 Kinds of Auxiliary Views. Auxiliary views may be classified according to the positions of the planes upon which they are drawn.

Auxiliary elevations are auxiliary views made on planes that are perpendicular to the horizontal plane (Fig. 7·4). The positions of the auxiliary planes for the auxiliary elevations of Space 1 are pictured in Space 2. An auxiliary elevation of an angular hook is shown in Space 3.

Left- or *right-auxiliary views* are auxiliary views made on planes that

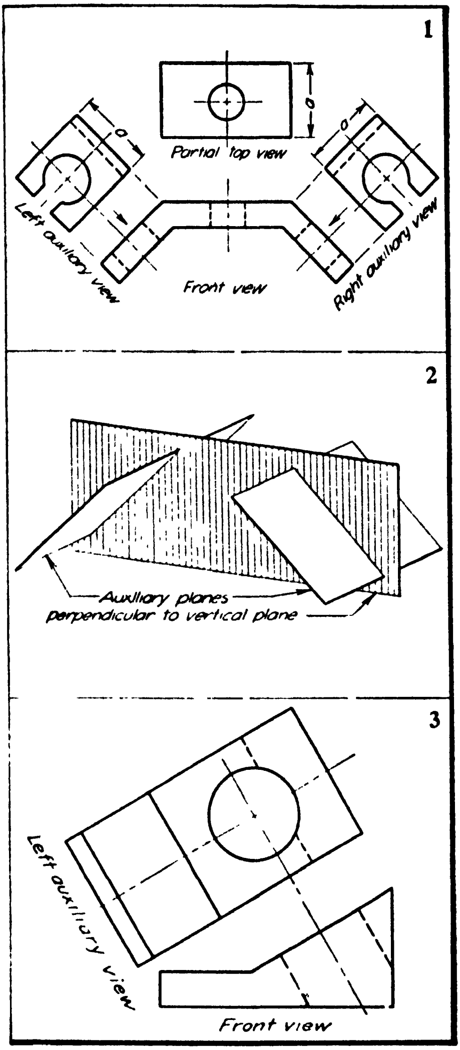


Figure 7·5 Left- and right-auxiliary views.

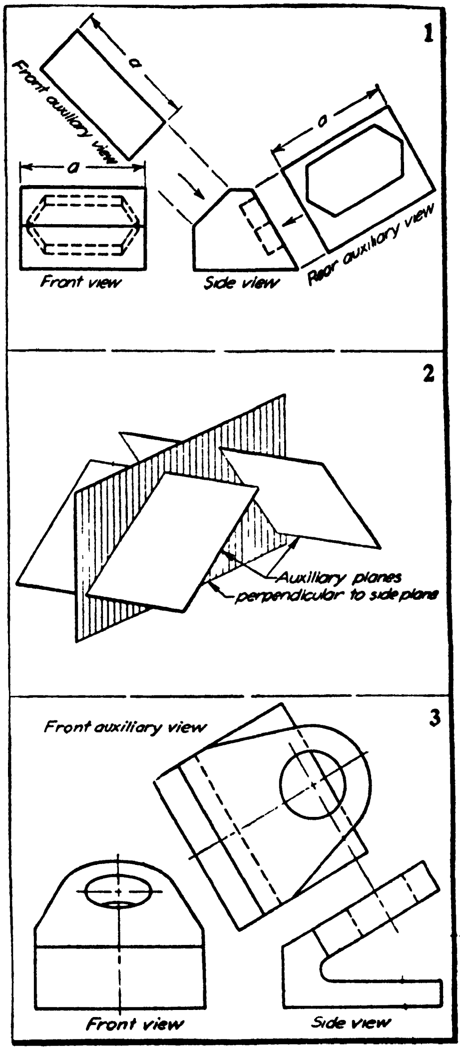


Figure 7·6 Front- and rear-auxiliary views.

are perpendicular to the vertical plane (Fig. 7·5). The positions of the auxiliary planes for the left- and right-auxiliary views of Space 1 are pictured in Space 2. A left-auxiliary view is shown in Space 3.

Front- and *rear-auxiliary views* are auxiliary views made on planes that are perpendicular to the side or profile plane (Fig. 7·6). The positions of the auxiliary planes for the front- and rear-auxiliary views of Space 1 are pictured in Space 2. A front-auxiliary view of a special angle is shown in Space 3.

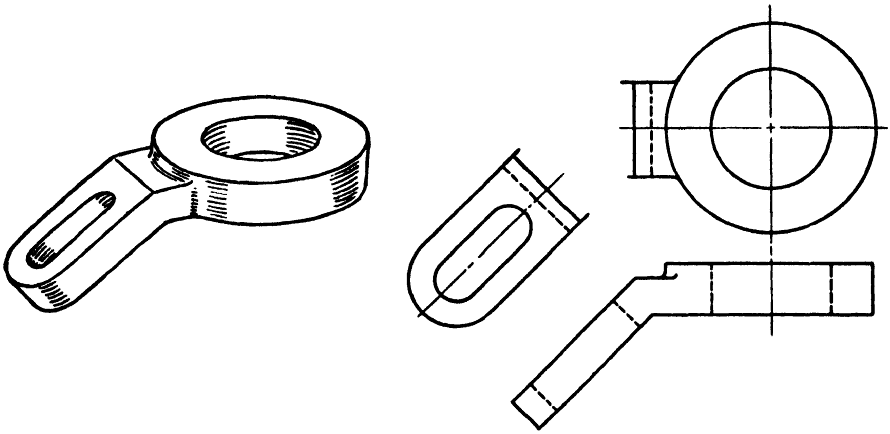


Figure 7·7 Partial auxiliary views.

7·4 Practical Auxiliary Views. When working drawings for practical use are being made, the object can often be described by partial views, as for the casting shown in Fig. 7·7, drawn with a partial auxiliary view and a partial top view.

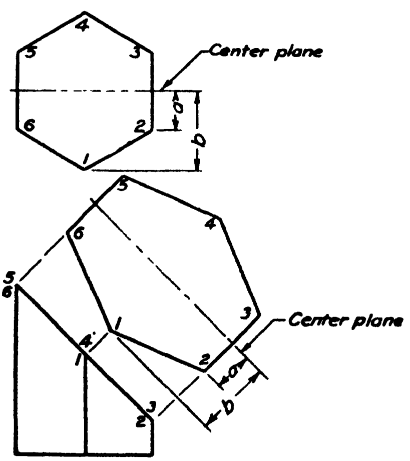


Figure 7·8 Auxiliary view from center plane.

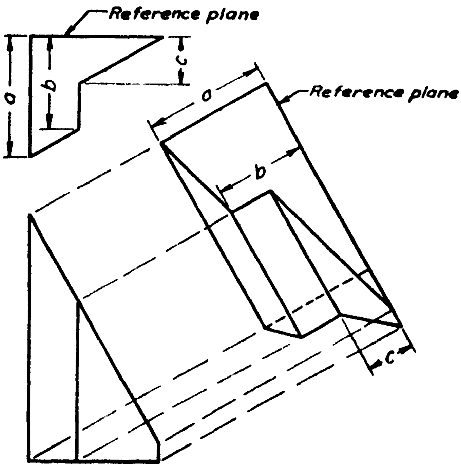


Figure 7·9 Auxiliary view from reference plane.

7·5 To Draw an Auxiliary View. It is evident that the distance *D* of an auxiliary view projected from a front view is the same as the depth of the top or side view (see *D*, Fig. 7·3).

Center lines representing the edges of a center plane are used for the solution of symmetrical objects. Thus for a symmetrical object such as the hexagonal prism (Fig. 7·8), draw a center-plane line for the auxiliary view parallel to the inclined face at any convenient distance from it and a horizontal center-plane line through the top view. Draw projecting lines perpendicular to the inclined face from each point. On each of these lines locate the auxiliary view of the point projected by measuring the distance of the point from the center-plane line on the top view and marking off this distance from the center-plane line of the auxiliary view. Distances *a* and *b* are toward the front of the object as shown in the top view and, therefore, are measured toward the front in the auxiliary view. Since the figure is symmetrical, the

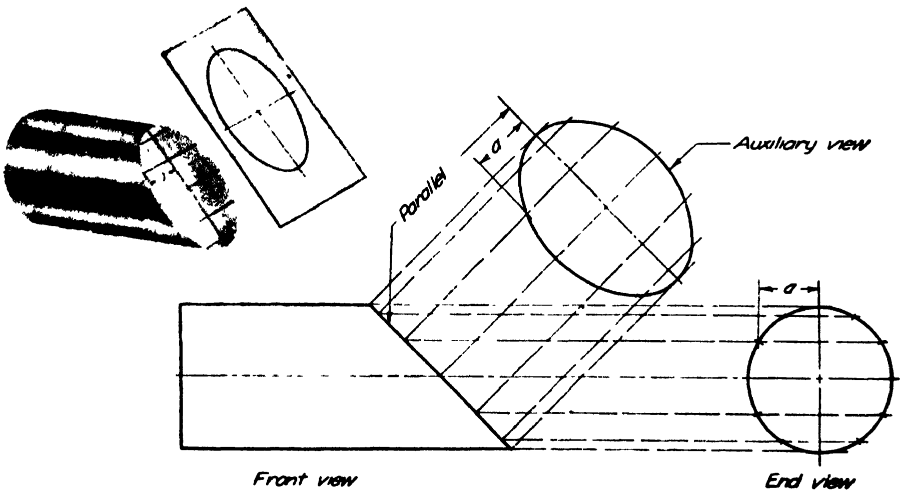


Figure 7·10 Auxiliary view of cut face of cylinder.

same distances would be measured on the other side of the line, and the auxiliary view of the inclined face completed by joining the numbered points. In Fig. 7·8 only the inclined face has been drawn, but the entire object would be projected in the same way.

Reference-plane lines are used for the solution of unsymmetrical objects. Thus for an unsymmetrical object, such as Fig. 7·9, a reference-plane line is used, placed for convenience in taking measurements. In this case the reference-plane line is placed at the back of the object so that all measurements are laid off toward the front view.

Auxiliary views of curved outlines are obtained by locating a number of points on the curves. This is illustrated by the auxiliary view of the inclined surface of a cylinder (Fig. 7·10). In this case the vertical center line (representing a center plane) of the end view, which shows the end of the cylinder, is the line from which measurements are made and transferred to the auxiliary view. Select a convenient number of points on the front view of the inclined surface, and draw perpendicu-

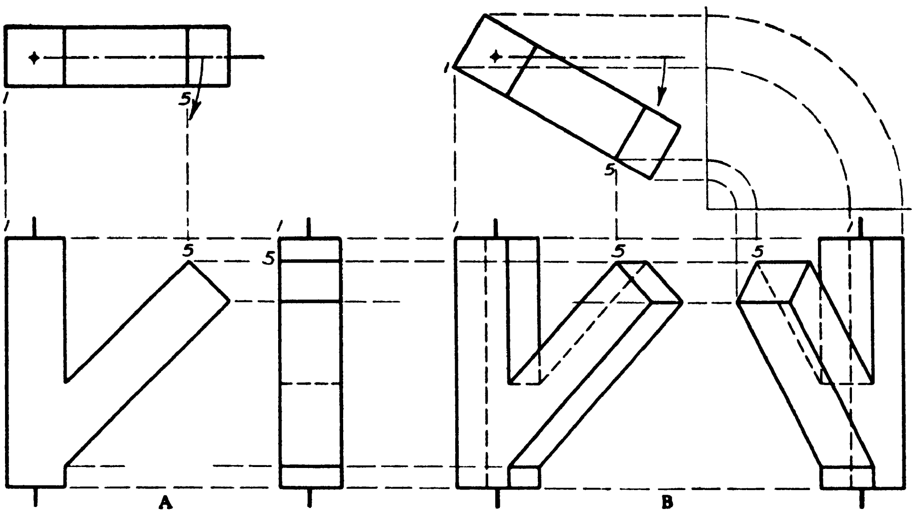


Figure 7·11 Revolution about a vertical axis (clockwise).

lars from them to the auxiliary center line. Project the same points to the side view, measure the distance from the center line to each point, and lay it off on each side of the center line in the auxiliary view.

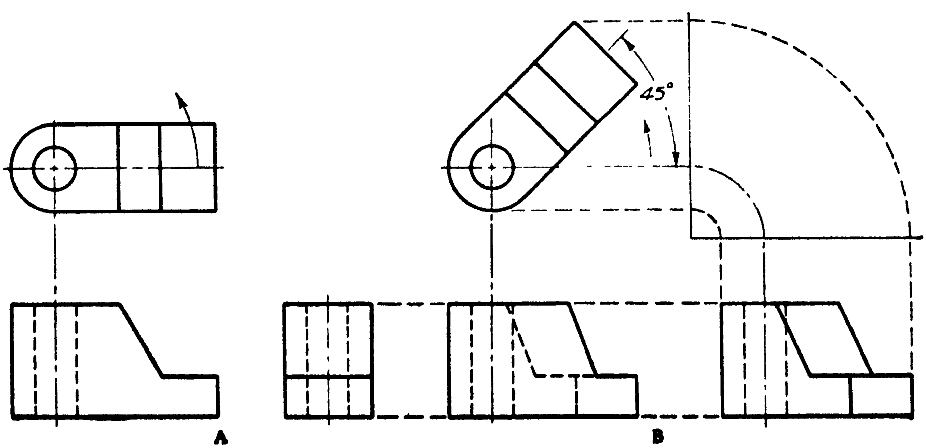


Figure 7·12 Revolution about a vertical axis (counterclockwise).

7·6 Revolutions. It is generally possible to place an object in a simple position so that most of its lines show in their true length or can be easily located in the usual views. Ordinarily, drawings are

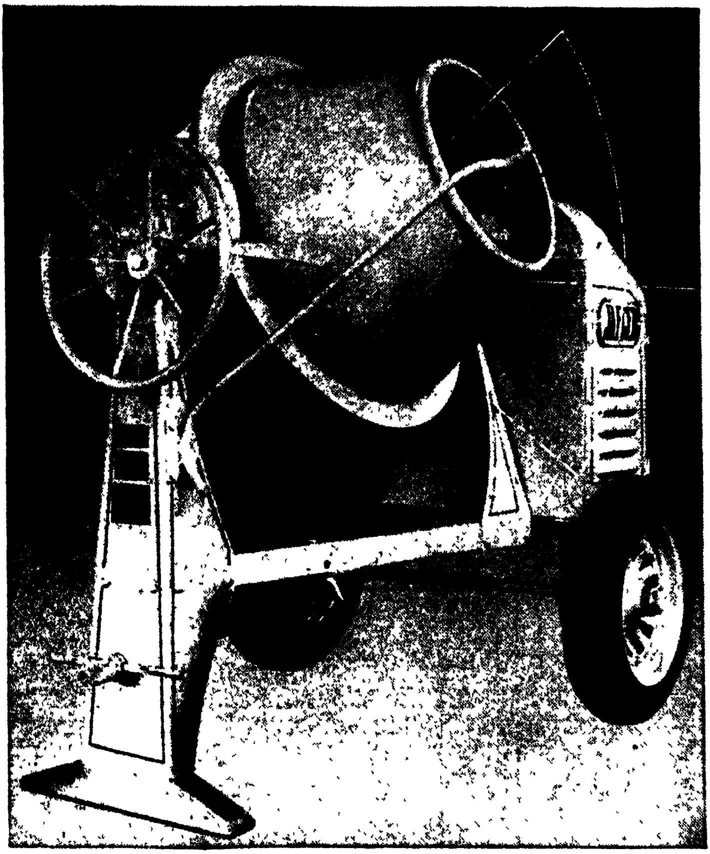


Figure 7·13 Revolution about a horizontal axis. Concrete mixer. (*The Jaeger Machine Co., Columbus, Ohio.*)

made in this way. However, it is, of course, possible to represent an object tipped about one of its edges or resting on one of its corners or revolved about an axis (Fig. 7·1).

7·7 The Rule of Revolution. This rule may be stated in two parts:

1. *The view perpendicular to the axis of revolution is unchanged except in position.*

2. *Distances parallel to the axis of revolution are unchanged.*

7·8 Vertical Axis of Revolution. In Fig. 7·11 the method of drawing an object when revolved about a vertical axis is shown. Given the three views, as at A, it is required to draw three views after the piece has been revolved through 30° about a vertical axis. First

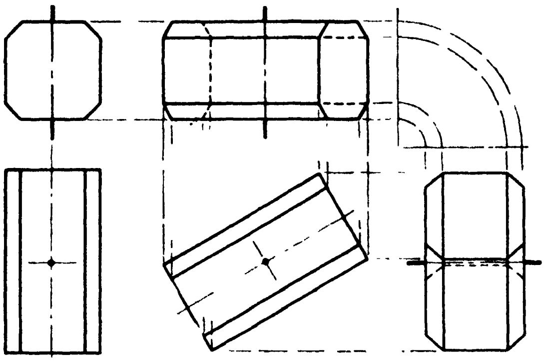


Figure 7·14 Revolution about a horizontal axis.

draw the top view in its new position B. Since the axis is vertical, the height has not been changed; so a horizontal projecting line may be drawn from point 1 of the front view in A and a vertical projecting line from the top view in B. The intersection of the two lines just

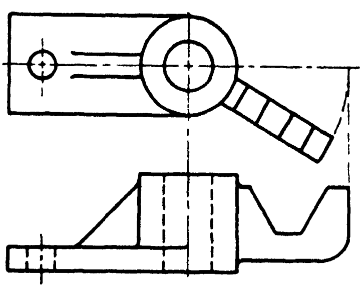


Figure 7·15 Revolution applied; vertical axis.

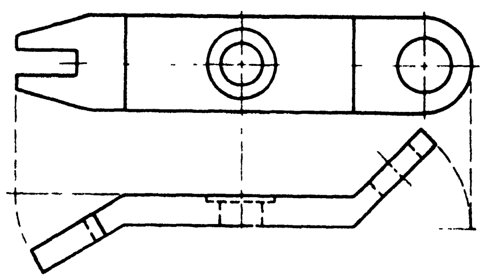


Figure 7·16 Revolution applied; horizontal axis.

drawn will locate the position of point 1 in the new front view. Proceed in the same way for each point, and join the points to complete the view. The side view is obtained from the front and top views in the usual manner.

The object in Fig. 7·11 is revolved clockwise, and the object in Fig. 7·12 is revolved counterclockwise.

7·9 Revolution about a horizontal axis is illustrated in Fig. 7·13. The method of drawing views when an object has been revolved about a horizontal axis is shown in Fig. 7·14. First draw the views of the object in its natural position, then revolve to a new position about an imaginary axis taken perpendicular to a plane of projection.

At A in Fig. 7·14 we have two views of an object in a natural position. Suppose a hole is drilled through from the front and a shaft inserted as shown. The object might be revolved about the shaft or axis into a new position as at B. It will be observed that the front view of B is the same as the front view of A, except that its position has been changed. The top view of B is obtained by projecting up from the new front view and across from the top view of A.

7·10 Practical Revolved Views. When working drawings for practical use are being made, objects often can be described better by drawing one of the views as though a part of the object had been revolved, as in Figs. 7·15 and 7·16.

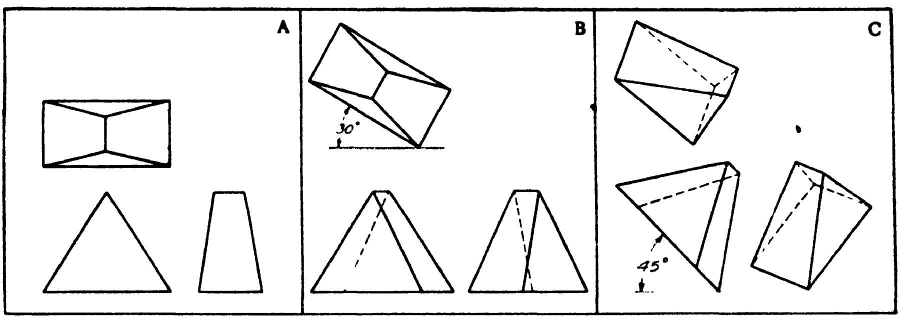


Figure 7·17 Successive revolutions.

7·11 Successive Revolutions. After an object has been revolved about an axis perpendicular to a plane, it may be revolved about an axis perpendicular to another plane. This is double, or successive, revolution and is illustrated in Fig. 7·17, where the piece shown at A has been revolved about a vertical axis through 30° at B and from this position about an axis perpendicular to the vertical plane through

TEXT-FILMS

The following McGraw-Hill Text-films have been correlated directly with Chap. 7:

Auxiliary Views, Part I (10-min. sound motion picture)

This film begins by showing that the three principal views of an object do not represent it fully if it has one or more slanting faces. Projection of the slanting face, or auxiliary projection, is explained and defined, and an auxiliary elevation is constructed step by step on the screen. The different types of auxiliaries—right, left, front, and rear—are briefly discussed.

Auxiliary Views, Part II (10-min. sound motion picture)

Film begins with a review of the principles of auxiliary views treated in Part I. This is followed by a detailed description of the three types of single auxiliaries—auxiliary elevations, right and left auxiliaries, and front and rear auxiliaries. The film concludes with a review of the problem of construction, this time using the construction of a right or left auxiliary as an example.

CHAPTER 8. Principles of Size Description

Figure 8·1 Size accuracy. Hoke Gage Blocks are square, and a stack wrung together stands solidly together on a surface plate. Tie rods through the center holes bind the stack rigidly if desired. Here a complicated magnesium casting is being easily scribed . . . and exactly. Precision gage blocks are the basic master standards of measurement . . . which establish the inch as a definite value. . . . Accuracy here is measured in millionths of an inch. The measuring faces of the blocks are guaranteed flat and parallel in all sizes within four millionths of an inch per inch of length. Blocks are used in stacks to make up any desired dimension. (*Pratt & Whitney Division of Niles-Bement-Pond Company.*)

8·1 Size. We have learned that the two things to be told about an object are its shape and its size. In the previous chapters we studied the methods of representing the shape. When information regarding the *size* is added to the shape description, the two together give the complete working drawing of the object.

Size description is, then, an essential and important part of a working drawing. For some purposes, it is sufficient to specify nominal and ordinary sizes, using common fractions of an inch. Sometimes a note should be added, stating that dimensions are to be plus or minus 1/32 in.; for large castings 1/16 in. or more may be sufficiently close. When accurate dimensions are required, they are given in decimals to hundredths or thousandths of an inch. In other cases extreme accuracy may be necessary, as illustrated in Fig. 8·1 and described by The Pratt & Whitney Division of Niles-Bement-Pond Company.

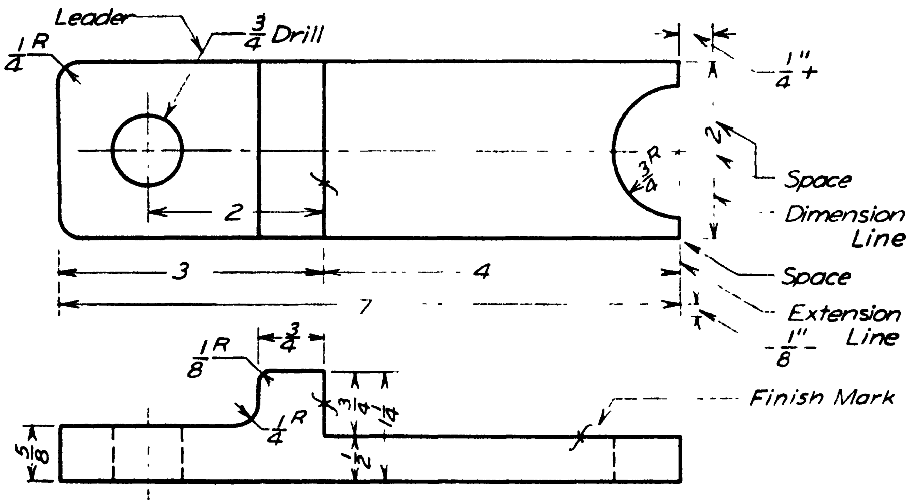


Figure 8·2 Dimensioning.

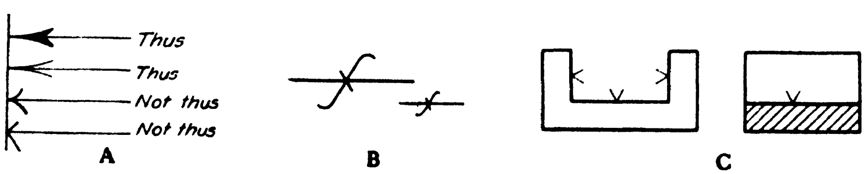


Figure 8·3 Arrowheads and finish marks.

8·2 Dimensions. Although working drawings are always made to scale, it would require too much time to take off distances by applying a scale to the drawing. Furthermore, the chances of making a mistake would be numerous, especially with small distances or for drawings made to small scale.

For convenience in using, in ensuring accuracy, and in saving time, the size description is given in the form of dimensions and notes arranged on the drawing in a definite manner.

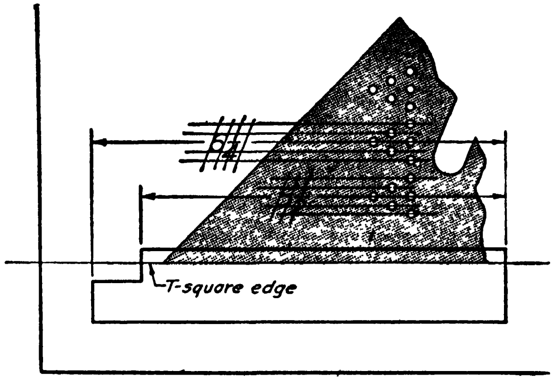


Figure 8·1 Guidelines for fractions.

8·3 Lines, Figures, Arrowheads, etc. Certain conventional lines and symbols are used on drawings. To make a successful drawing, the draftsman must be familiar with these symbols, must know the principles of dimensioning, and must be acquainted with the shop processes that will be used in building or making the object represented.

The dimension line is made a thin full line in contrast with the heavier shape outline (see Art. 9·2, Alphabet of Lines). The line is terminated by long pointed arrowheads (Fig. 8·2). Great care must be taken to have all arrowheads correctly shaped (Fig. 8·3 at A).

8·4 Finished or machined surfaces are indicated by the symbol *f* shown enlarged and natural size at B in Fig. 8·3. A new symbol is being considered for American Standard which consists of a V touching the line that represents the finished surface as shown at C.

A space is left in the dimension line for a figure to tell the actual distance on the full-sized piece. When the dimension is placed outside the outline of the view, *extension* or *witness* lines are drawn from the view to show the points or surfaces measured on the object. Extension lines are thin lines drawn from the outline and extending past the arrowhead. Since extension lines are not part of the shape, they should not touch the outline (see Fig. 8·2).

8·5 Figures must be carefully made and of a size easily readable but not so large as to overbalance the drawing. In general, make them about 1/8 in. high. To avoid crowding, dimension lines should be 1/4 in. or more from the lines of the drawing and from each other. A fraction is *always* made with a horizontal division line. Figures for fractions are made about two-thirds the height of whole numbers.

Light guidelines for figures and fractions may be drawn quickly and easily with the Braddock-Rowe triangle as illustrated in Fig. 8·4, which shows the group of holes in the left-hand part of Fig. 3·3 spaced for this purpose.

8·6 Placing Dimensions. In placing dimensions, the important thing is to keep in mind the man who has to read the drawing and make the piece from it. It is necessary to think of the actual piece in space. Since the shape is already defined, select the view that tells most about the piece and give two dimensions of each part. One of the other views must be used to tell the third distance. In general, it is better to place the dimensions between the views so as to be near both views.

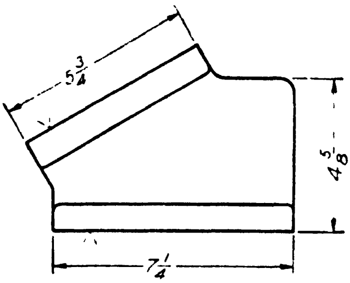


Figure 8·5 Dimensioning, aligned system.

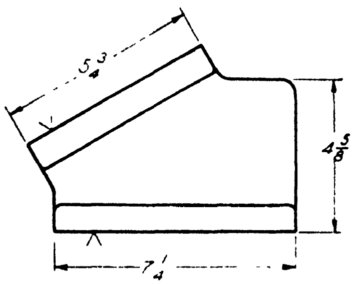


Figure 8·6 Dimensioning, unidirectional system.

The system of placing dimensions that is in general use for most purposes is called the *aligned system*. In this system, the dimensions are placed in line with the dimension lines so that horizontal dimensions always read from the bottom of the drawing, vertical dimensions from the right-hand side of the drawing, and inclined dimensions read in line with the dimension line (Fig. 8·5).

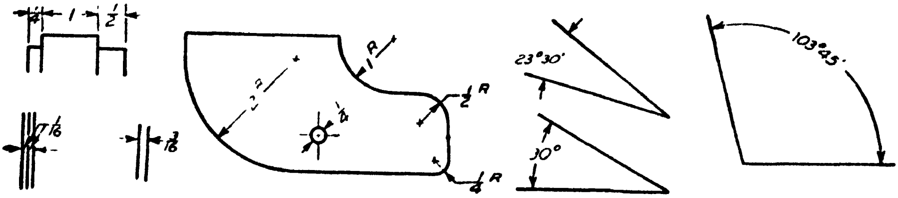


Figure 8·7 Radii, angles, etc.

Aircraft companies and some others have brought about the use of the *unidirectional system*. In this system, the dimensions are all placed to read from the bottom of the sheet no matter what part of the sheet they are on (Fig. 8·6).

Inches are indicated by " and feet by ', and a dash is always placed between feet and inches, thus 5'-7½", or 0'-9¼". When the drawing is dimensioned entirely in inches, the inch marks may be omitted (Fig. 8·2). When the space is too small to admit arrowheads and figures, one of the methods of Fig. 8·7 is used.

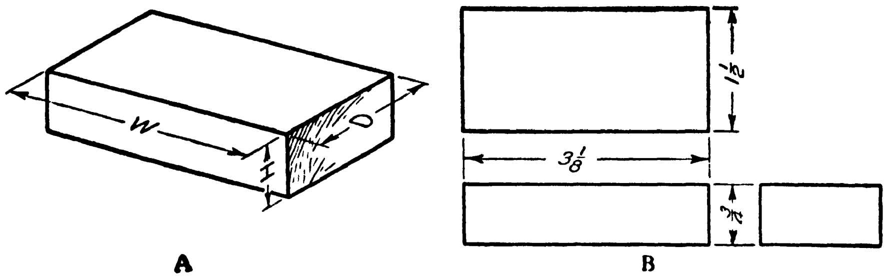


Figure 8·8 The first shape.

Angles are dimensioned by drawing an arc, with the dimension horizontal except for large arcs (Fig. 8·7).

When there are few lines within the outline, dimensions may be placed inside, making it unnecessary to draw extension lines.

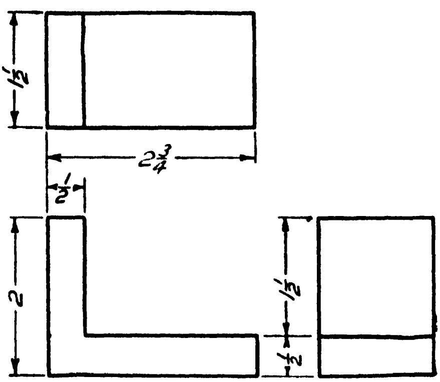


Figure 8·9 First rule applied.

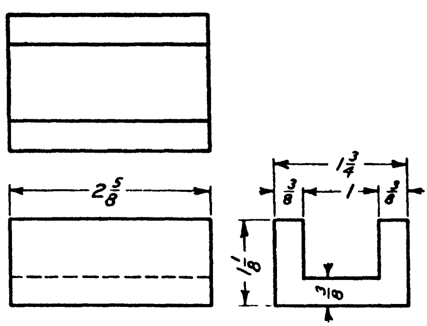


Figure 8·10 First rule applied.

The letter *D* should be placed after a dimension indicating a diameter unless evident from the drawing. The letter *R* should always be placed after the dimension for a radius (Fig. 8·7). Dimension lines should never cross extension lines. Larger dimensions should be placed outside smaller dimensions.

8·7 Theory of Dimensioning. The theory of dimensioning is based upon the idea of considering any object as made up of a number

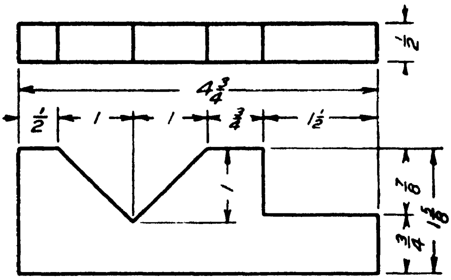


Figure 8·11 An irregular flat shape.

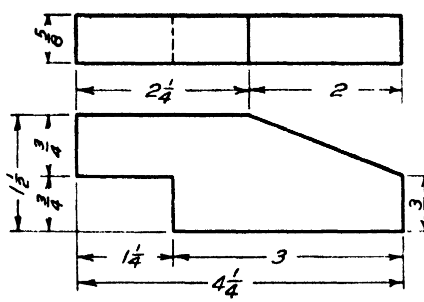


Figure 8·12 An irregular flat shape.

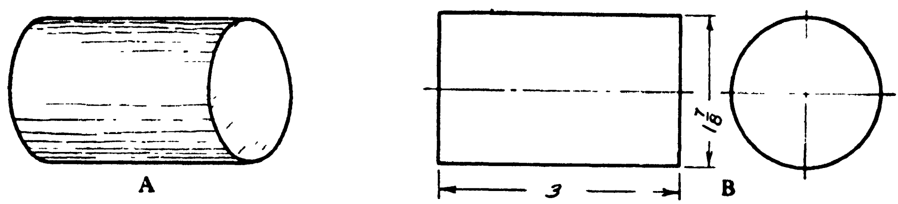


Figure 8·13 The second shape, a cylinder.

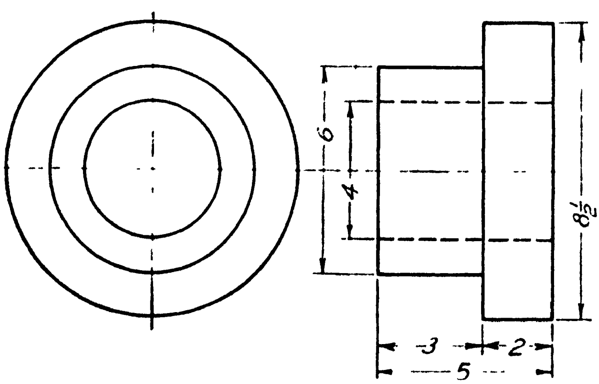


Figure 8·14 Second rule applied.

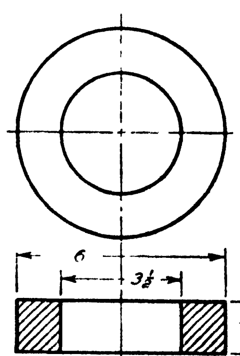


Figure 8·15 Second rule applied.

of geometrical solids such as prisms, cylinders, pyramids, cones, etc., or parts of such solids. A hole or hollow part can be considered as a negative solid. It then becomes a matter of dimensioning a number of simple shapes. When the size of each simple piece is defined and the relative positions are given, the size description is complete. *Size dimensions* are used to define the simple pieces and *location dimensions* to give relative positions. When a number of pieces are assembled, each piece is first considered separately and then in relation to the other pieces. In this way the size description of a complete machine, a piece of furniture, or a building is no more difficult than the dimensioning of a single piece.

8·8 Size Dimensions. The first shape is a flat piece, requiring the *width*, *W*, *height*, *H*, and *depth*, *D*, as indicated in the picture at A in Fig. 8·8 and shown by dimensions at B. Such an elementary shape may appear in a great many ways, a few of which are shown in Figs. 8·9 and 8·10.

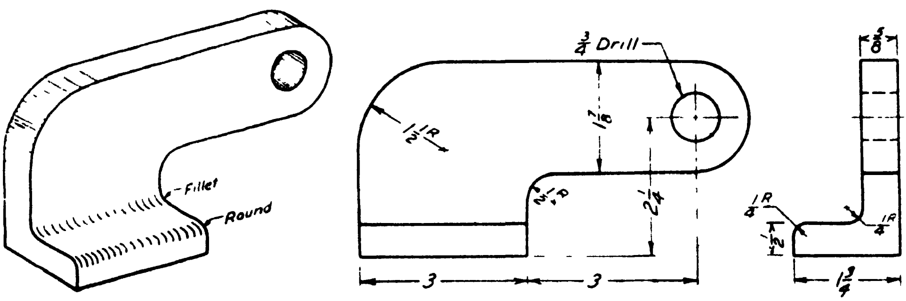


Figure 8·16 Fillets and rounds

Flat pieces of irregular shape are dimensioned in a similar way (Figs. 8·11 and 8·12).

RULE: *For any flat piece, give the height (or thickness) in one of the edge views and all other dimensions on the outline view.*

The second shape is the cylinder, requiring two dimensions: the diameter and the length (Fig. 8·13). Three cylinders are dimensioned in Fig. 8·14, one of which is the hole. Note that the diameter and the length are given for each of them. A washer or other hollow cylinder may be thought of as two cylinders of the same length (Fig. 8·15).

RULE: *For cylindrical pieces, give the diameter and length on the same view.*

When a note is used to give the size of a hole (negative cylinder), it is generally placed on the outline view, especially when the method of forming the hole is specified (Fig. 8·16). When parts of cylinders occur, such as fillets, rounds, and rounded corners, they are dimensioned in the views where the curves show (Fig. 8·16).

Other shapes include the cone, pyramid, and sphere. The cone, or frustum, the square pyramid, or the sphere may be dimensioned in one view. The dimensions for rectangular or other pyramids and parts of pyramids require the use of two views.

8·9 Location dimensions are used to specify the relative positions of the simple parts that make up most constructions and to locate various holes, surfaces, and other features. The relative importance of the various surfaces and axes must be studied together with the question of accuracy. A knowledge of engineering practice in manu-

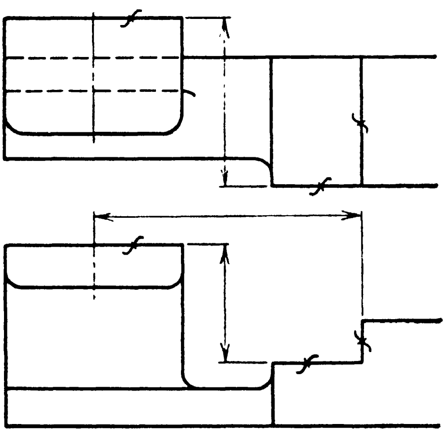


Figure 8·17 Location dimensions for prisms.

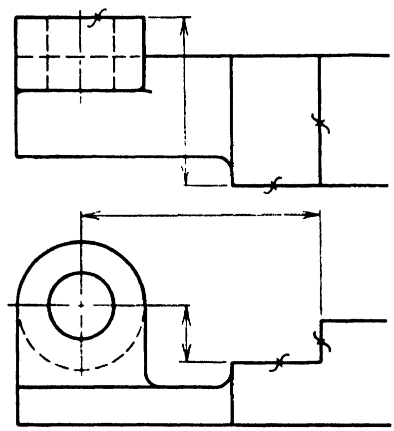


Figure 8·18 Location dimensions for prisms and cylinders.

facture, assembling, and use is sometimes essential to a complete understanding of the necessary dimensions. Finished surfaces and center lines or axes are used to define positions with location dimensions. Two general rules will serve as a basis for the application of location dimensions.

RULE: *Prism forms are located by axes and surfaces* (Fig. 8·17). *Three dimensions are required.*

RULE: *Cylinder forms are located by the axis and the base* (Fig. 8·18). *Three dimensions are required.*

Combinations of prisms and cylinders are shown in Figs. 8·19 and 8·20. The dimensions *A*, *B*, and *C* (Fig. 8·20) are location dimensions.

8·10 General Rules. In the application of dimensioning, certain practices have come to represent good form to such an extent as to have the force of rules.

1. If the *aligned system* is used, dimensions must read in line with the dimension line and from the lower or right-hand side of the sheet.

2. If the *unidirectional system* is used, all dimensions must read from the bottom of the sheet.

3. On machine drawings, detail dimensions up to 72 in. should be given in inches. Above this, feet and inches are generally used, except for gear drawings, bore of cylinders, length of wheel bases, etc.

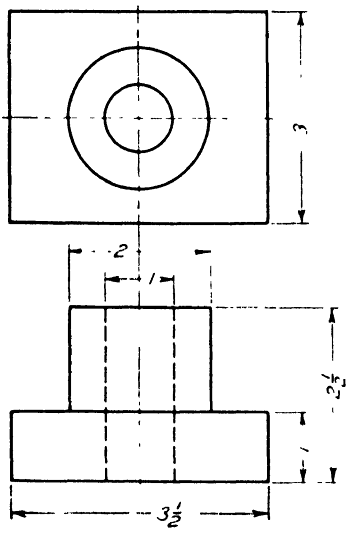


Figure 8·19 First and second shapes.

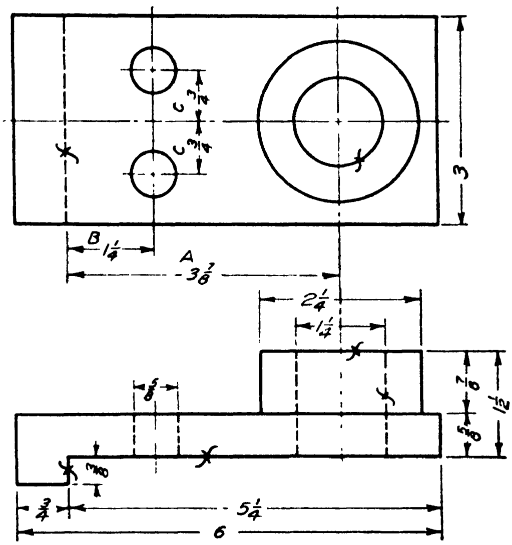


Figure 8·20 First and second shapes.

4. When all the dimensions are in inches, the symbol (″) is preferably omitted.

5. On architectural and structural drawings, dimensions of 12 in. and over are given in feet and inches.

6. Sheet-metal drawings are usually dimensioned entirely in inches.

7. Furniture and cabinet drawings are usually dimensioned in inches.

8. Feet and inches are designated thus, 7′-3″ or 7 ft. 3 in. Where the dimension is in even feet, it is indicated thus, 7′-0″.

9. The same dimension is not repeated on different views unless there is a special reason for it.

10. Over-all dimensions should be placed outside of the smaller dimensions (Fig. 8·20).

11. On circular-end parts the center-to-center dimension is generally given instead of an over-all dimension (Fig. 8·21).

12. When it is necessary to place a dimension within a sectioned area, the section lines are not run across the number (Fig. 8·22).

13. American Standard practice is to avoid placing dimensions in the shaded area indicated in Fig. 8·23.

14. Dimensions should be given from or about center lines, or from finished surfaces.

15. Never use a center line or a line of the drawing as a dimension line.

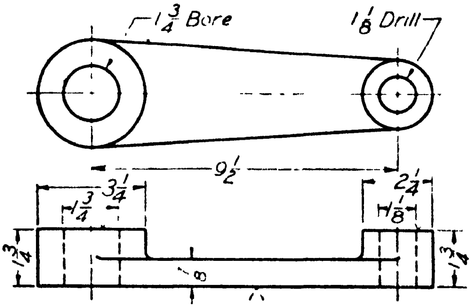


Figure 8·21 Center-to-center dimension.

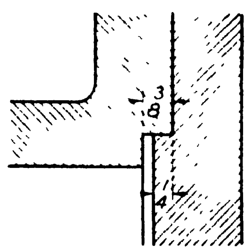


Figure 8·22 Rule 12.

16. Never have a dimension line a continuation of a line of the drawing.

17. Never place a dimension so that it is crossed by a line.

18. Always give the diameter of a circle, not the radius. The abbreviation *D* is used after the dimension, except when it is obviously a diameter.

19. The radius of an arc should always be given. The abbreviation *R* is used after the dimension.

20. In general, dimensions should be placed outside of the views and between views *unless* conditions are such that they are clearer and more easily read inside a view.

8·11 Use of Decimals. Dimensions are given in feet, inches, and fractions of an inch. In ordinary work, binary fractions such as $\frac{1}{2}''$, $\frac{1}{4}''$, $\frac{1}{8}''$, $\frac{1}{16}''$, $\frac{1}{32}''$, $\frac{1}{64}''$ are used. For parts that must fit very accurately, the dimensions are given in decimals instead of the usual fractions, and the workman is required to work within a certain fixed limit of accuracy.

A two-place decimal may be used to give all dimensions in decimals in place of fractions where such accuracy is desired. Instead of the usual fractions, the two figures after the decimal point are in fiftieths such as: .02, .04, .24, which give two-place decimals when divided by two to obtain the radius from the diameter, or for other purposes.

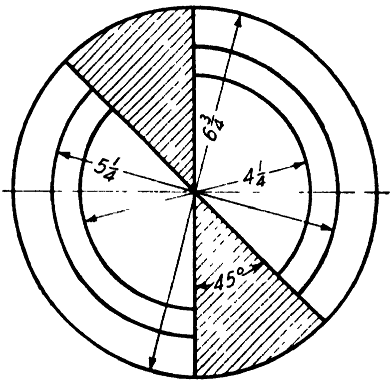


Figure 8·23 Rule 13.

8·12 Limit Dimensioning. When parts must have accurate measurements, the dimensions are given in decimals instead of the usual fractions. Micrometers (Fig. 8·32) and various kinds of gages are used to check for accuracy, such as the gage blocks illustrated in Fig. 8·1.

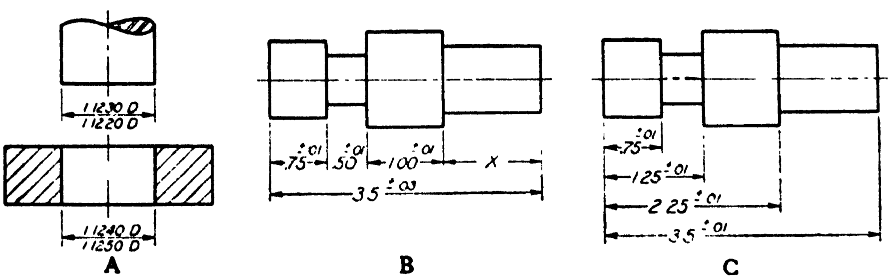


Figure 8·24 Limit dimensions.

Since absolute accuracy cannot be expected, a workman is required to keep within a fixed limit of accuracy. The number of *hundredths*, *thousandths*, or *ten-thousandths* of an inch that are allowed as variance from absolute measurement is called the tolerance. The tolerance may be specified by a note on the drawing as: "Dimension tolerance .01 ± Unless Otherwise Specified." Limiting dimensions, or limits to specify the maximum and minimum dimensions permitted, are used to provide for the necessary degree of accuracy. This is illustrated at A in Fig. 8·24. Note that the maximum limiting dimension is placed above the dimension line for the shaft (external dimension) and that the minimum limiting dimension for the hole in the ring is placed above the dimension line.

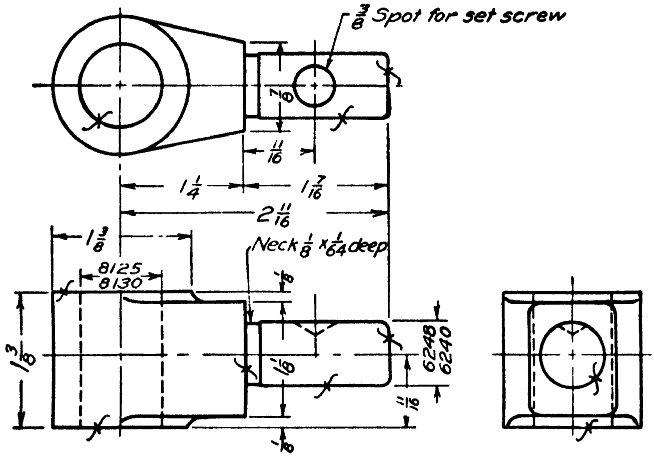


Figure 8·25 A detail drawing with limits.

At B and C in Fig. 8·24 the basic sizes are given and the tolerance specified, plus or minus, as shown. Consecutive dimensions are shown at B, where the dimension designated by *X* could have a considerable variation and no attempt would be made to specify it. Progressive dimensions are shown at C where they are all given from a single surface (sometimes called "base-line dimensioning").

Accurate or limiting dimensions should not be called for except where necessary as they greatly increase the cost. The detail drawing in Fig. 8·25 has limits for only two dimensions; all the others are nominal dimensions.

8·13 Standard Details. The shape of a part, the methods of manufacture, and the purpose for which the part is to be used generally indicate the kind and accuracy of the dimensions that must be given. A knowledge of manufacturing methods, patternmaking, foundry, machine-shop procedures, forging, welding, etc., is very useful when selecting and placing dimensions. In some cases such knowledge is essential. It is also important to consider whether only one part is to be made or whether quantity-production methods are to be used. In addition, there are purchased parts, identified by name or brand, that require few, if any, dimensions. Some companies have their own standard parts for use in different machines or constructions, and these are dimensioned according to use and production methods.

There are, however, certain more or less standard details or conditions for which methods of dimensioning may be suggested.

8·14 Curves may be located by radii from centers as in Fig. 8·26, by offsets as in Fig. 8·27, or by naming the curve and giving the necessary specifications for describing it.

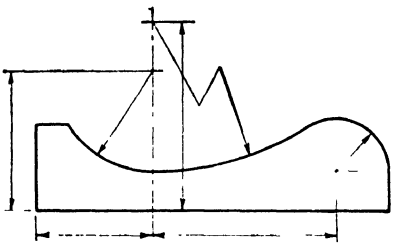


Figure 8·26 Curve dimensions.

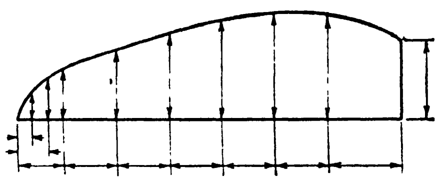


Figure 8·27 Curve dimensions.

8·15 Ordinary angles are dimensioned as in Fig. 8·7. Angular tolerance is generally bilateral as $\pm \frac{1}{2}°$ for degrees, $\pm 0°20'$ for minutes, etc. Angular measurements on structural drawings are given by *run and rise* using 12″ for the longer side of the triangle (Fig. 8·28 at A). A similar method is used for slopes as at B and C where one side of the triangle is made equal to 1.

8·16 Tapers may be specified by giving one diameter or width, the length and the number from American Standard (ASA B5.10-1943). Other methods are shown in Fig. 8·28 at D, where the length and one diameter are shown; and at E, where one diameter and the angle are shown.

8·17 Methods of dimensioning *chamfers* are shown in Fig. 8·28 at F for usual conditions, and at G for accurate conditions.

8·18 The use of notes for specifying dimensions and operations is indicated in Fig. 8·29, where A is for a *drilled* hole, B is for a hole to be *drilled* and *reamed*, C and D specify *counterbore*, E specifies *countersink* for a No. 24 *flat-head* screw, and F, G, and H are for countersunk and counterdrilled holes. Other dimensions with machining operations are suggested at I and J in Fig. 8·29.

8·19 Dimensioning Assembled Parts. The drawing of a separate part is called a "detail drawing." When the different parts of a machine or structure are shown together in their relative positions, the drawing is called an "assembly drawing." The rules and methods given for dimensioning apply to all cases where a complete description of size is required.

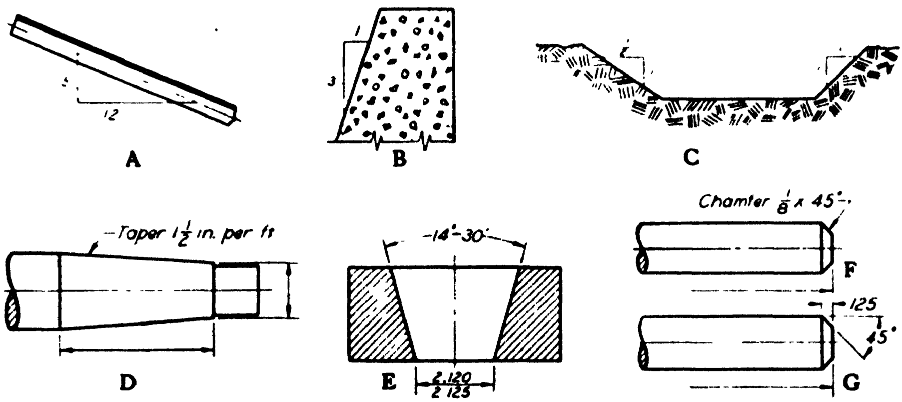


Figure 8·28 Tapers, chamfers, etc.

Drawings of complete machines, pieces of furniture, etc., are made for different uses and have to be dimensioned to serve the purpose required of them. If the drawing is merely to show the arrangement of parts, all dimensions are left off. When it is desired to tell the space required, give over-all dimensions. Where it is necessary to locate parts in relation to each other without giving all the detail dimensions, it is usual to give center distances and sizes of parts that might affect putting together the machine or construction. Assembly drawings may be completely dimensioned either with or without extra part views (see Fig. 11·5). Such drawings serve the purpose of both detail and assembly drawings.

For furniture and cabinetwork only the major dimensions are sometimes given, such as length, breadth, height, and sizes of stock, leaving the details of joints to the cabinetmaker. This is common practice where machinery is used and where many details of construction are standardized.

8·20 Sketching and Measuring. Sketching as a means of shape description and study was considered in Chap. 5. When sketches that are to be used in making drawings are made from machine or furniture parts, it is necessary to define the size, the material, the kinds of surfaces either "finished" or "rough," the limits of accuracy, and all information that might have any possible future value.

8·21 After sketching the views of a piece, add all necessary dimension lines in exactly the same way as for a drawing. The piece

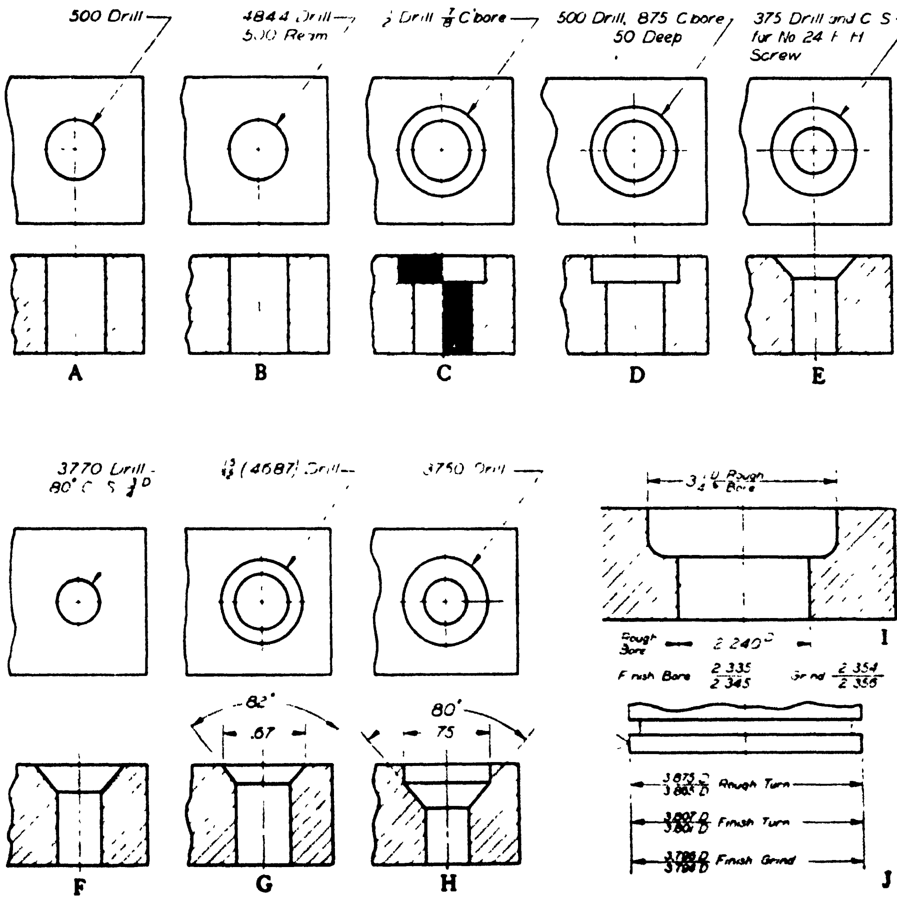


Figure 8·29 Dimensions for holes.

should now be examined, the kind of material noted, together with the kinds of finish and the location of all finished surfaces. When everything else is done, it is time to measure the piece and fill in the figures, telling the size. For this purpose various measuring tools will be required. A 2-ft. rule, a steel scale, and a pair of calipers will be found sufficient for most measurements. Other machinists' tools are

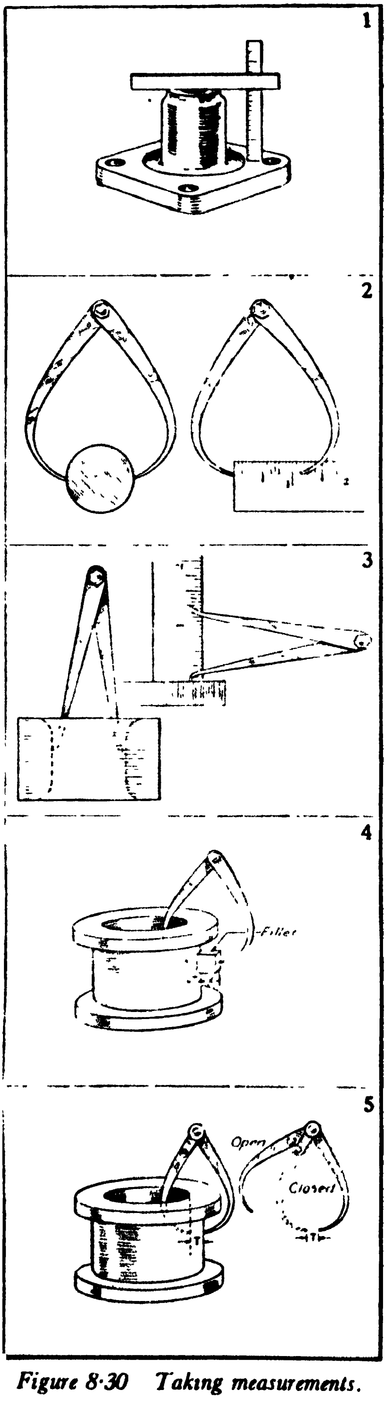


Figure 8·30 Taking measurements.

often necessary or convenient, and the pupil should know something about the tools that are available and how to use them.

8·22 The flat scale or the steel scale and straightedge can be used in many ways, as suggested in Fig. 8·30, Space 1, and the distances read directly.

Whenever possible, always take measurements from finished surfaces. Outside and inside calipers with their use illustrated are shown in Space 2 and Space 3. The distance between the contact points is read by applying the calipers to a scale.

When the calipers cannot be removed from a thickness, the plain calipers may be used by inserting an extra piece or filler (Space 4); or the transfer calipers (Space 5) may be used. The distance x must be subtracted from the total distance to obtain the desired thickness t when a filler is used. The transfer calipers are provided with a false leg, set so that the calipers may be opened and then brought back to the same position after being removed from the casting.

All measurements of wood construction can generally be obtained with sufficient accuracy by using the 2-ft. rule. By way of contrast, photographic and electrical methods have been developed to make extremely accurate measurements necessary in connection with certain types of operating machines.

For very accurate measurements vernier calipers and micrometer calipers (Figs. 8·31 and 8·32) are used. Other tools that are useful, if at hand, are the steel square, try square, combination square, surface gage, depth gage, radius gages, and protractor.

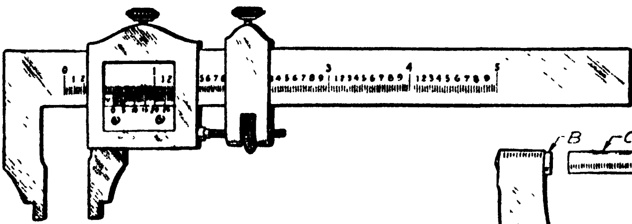


Figure 8·31 Vernier calipers.

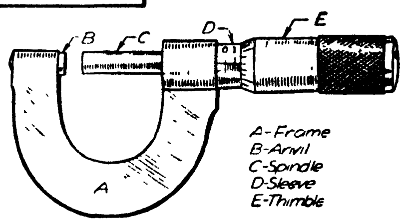


Figure 8·32 Micrometer calipers.

When a pictorial sketch is dimensioned, the only additional consideration is to use care to see that all extension lines are either in or perpendicular to the plane on which the distance is being given (Fig. 8·33).

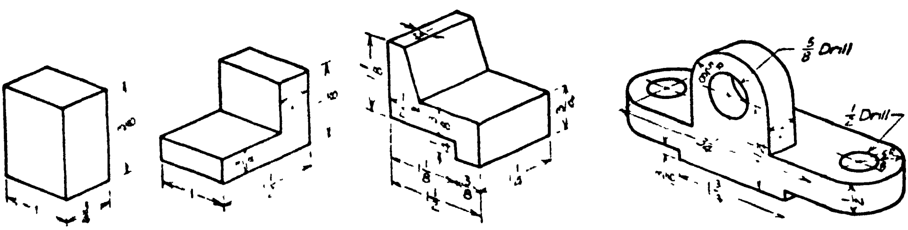


Figure 8·33 Dimensions on pictorial sketches.

8·23 Notes and Specifications. Information that cannot be represented graphically must be given in the form of lettered notes and symbols. Generally understood trade information is often given in this way. Such notes include the following items: number required, material, kind of finish, kind of fit, method of machining, kinds of screw threads, kinds of bolts and nuts, sizes of wire, and thickness of sheet metal.

The materials in most general use are wood, cast iron, wrought iron, steel, and brass. All parts that go together must be of the proper size so that they will fit. Some pieces are left in the rough, and others must have a smooth finish. The wood used for making a piece of furniture is first shaped with woodworking tools. Cast iron and brass are given the required form by molding, casting, and machining. First, a wood pattern of the shape and size required is made and placed in sand to make an impression or mold, into which the melted metal is poured. Wrought iron and steel are made into shapes by rolling or forging in the rolling mill or blacksmith shop. Some kinds of steel may be cast as described for cast iron.

There are many interesting ways of forming metals for special purposes and many special alloys that cannot be described in a drawing book, but the pupil will learn much by observing the shapes of parts of machinery and the materials of which they are made.

After a part is cast or forged, it must be "machined" on all surfaces that are to fit other surfaces. Round surfaces are generally formed on a lathe. Flat surfaces are finished or smoothed on a planer, milling machine, or shaper. Drill presses, boring mills, or lathes are used for making holes.

Extra metal is allowed for surfaces that are to be finished. To specify such surfaces a small *f* is placed on the lines which represent the surfaces. If the entire piece is to be finished, a note, such as "*fin. all over*," may be used, and all other marks omitted.

Specifications as to methods of machining, finish, and other treatment are given in the form of notes, as spot-face, grind, polish, knurl, core, drill, ream, countersink, harden, caseharden, blue, and temper.

It is often necessary to add notes in regard to assembling, order of doing work, or other special directions.

8·24 Checking a Drawing. After a drawing has been completed, it must be very carefully examined before it is used. This is called "checking the drawing." It is very important work and should be done by someone who has not worked on the drawing.

Thorough checking requires a definite order of procedure, and consideration of the following items:

1. See if the views completely describe the shape of each piece.
2. See if there are any unnecessary views.
3. See that the scale is sufficiently large to show all detail clearly.
4. See that all views are to scale and that correct dimensions are given.
5. See that sufficient dimensions are given to define the size of all parts completely.
6. See that the kind of material and the number required of each part are specified.

7. See that the kind of finish is specified, that all finished surfaces are marked, and that finish is not called for where not needed.

8. See that all necessary explanatory notes are given and that they are properly placed.

TEXT-FILMS

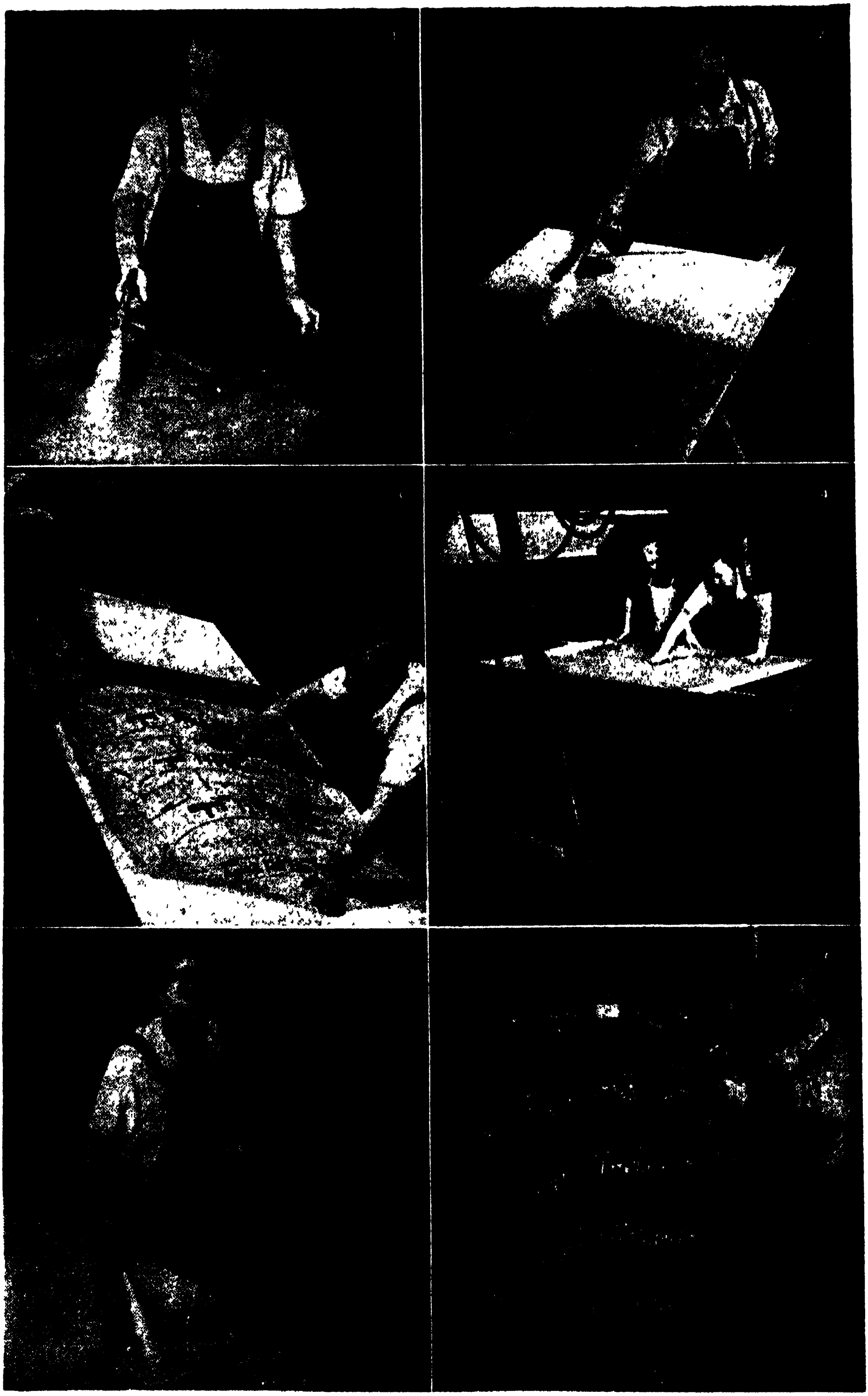
The following McGraw-Hill Text-Films have been correlated directly with Chap. 8:

Size Description (15-min. sound motion picture)

This film presents reasons for uniformity in dimensioning practices, and explains that this uniformity depends on the observance of the use of symbols, choice of dimensions, and location of dimensions. To learn the language of size description, it is necessary to master symbois such as extension lines, dimension lines, and arrowheads. Next, the film describes factors that will enable students to decide what dimensions are needed; finally it shows that location of dimensions must be standardized.

Size Description (silent filmstrip)

This stresses techniques and placement of dimensions in standard practice. Complete dimensions are shown to be made up of dimension lines, arrowheads, extension lines, leaders, figures, notes, and finish marks. The meaning of each is explained, and proper techniques of applying them are demonstrated.



CHAPTER 9. Technique of the Finished Drawing

Many uses are being found for photographic methods in connection with drawings and engineering procedures. One such use is the process illustrated in Fig. 9·1, which shows why accurate drawings and a knowledge of the technique of commercial drafting are important.

The process illustrated uses Kodak Transfax, a light-sensitive solution that can be applied to surfaces with a spray gun, thus enabling drawings, layouts, wiring diagrams, and instrument dials to be printed directly on metals, plastics, wood, or almost any smooth or semiporous material. The processing is explained as follows:

Step 1 Priming (Space 1). In order to obtain a good bond between the light-sensitive Transfax and the base material, some surfaces must be primed with a clear, quick-drying lacquer such as Kodak Transfax primer.

Step 2 Coating (Space 2). The sensitivity of Transfax is such that spraying can be done in subdued room lighting; no darkroom is necessary. When the Transfax coat is dry, the material is ready for printing.

Step 3 Printing (Spaces 3 and 4). The best original is either a black ink drawing on tracing cloth or translucent sheeting, or a high-contrast photographic film negative or positive. Complete fabrication instructions can be included, making reference to the drawing unnecessary during subsequent work on the piece. Printing is done by placing the original in contact with the sensitized surface of the material and exposing to arc, medium-pressure mercury vapor, or Photoflood lamps. Good contact must be maintained between the original and the sensitized surface during exposure.

Step 4 Clearing and Washing (Space 5). After printing, the exposed surface may be either flooded or immersed in Transfax clearing solution which causes the exposed areas to detach themselves from the material, while the unexposed portions remain firmly attached. The clearing bath is followed immediately by a fine spray of warm water under pressure to remove any of the background that did not come off in the clearing bath.

Figure 9·1 The Kodak Transfax process.

Step 5 Drying and Overcoating (Space 6). As soon as the background is removed, the material is placed on edge to drain and dry. Once dry, the image is reasonably strong. To make it resistent to scratches and abrasions, it should be coated over with a clear lacquer.

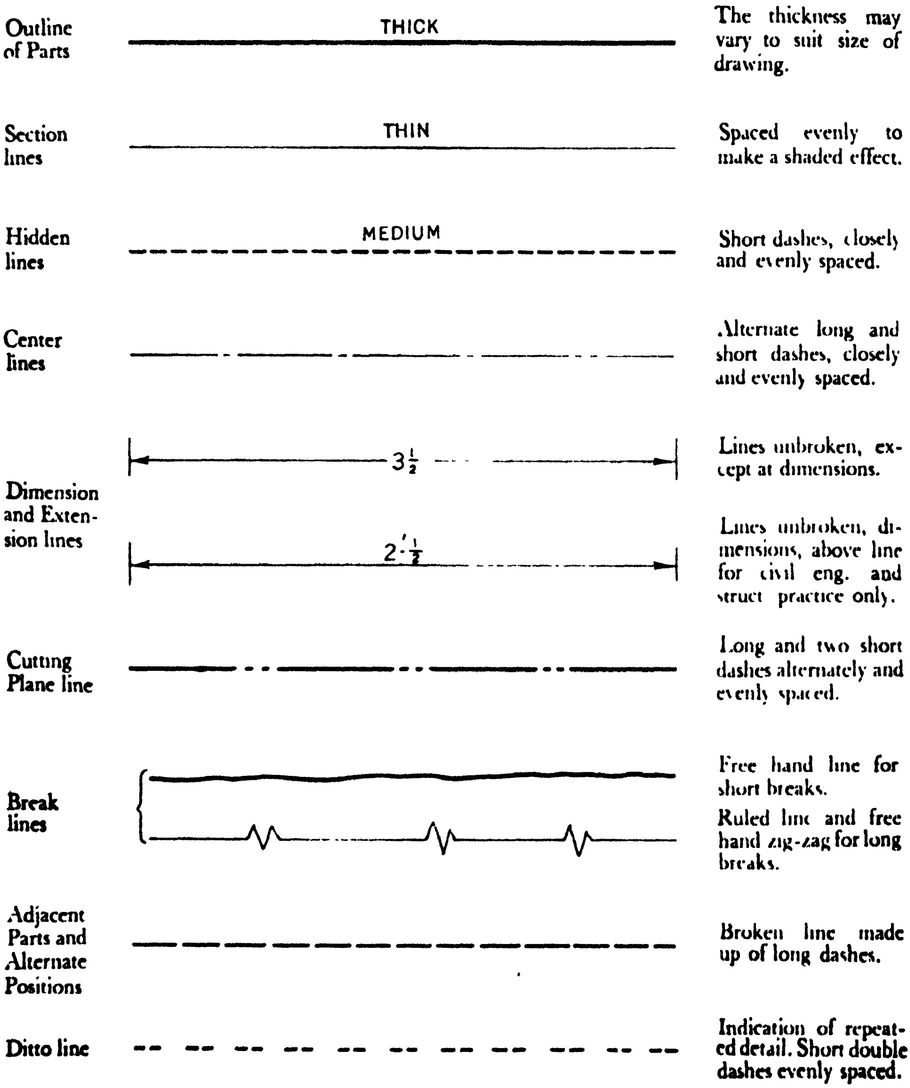


Figure 9·2 The alphabet of lines.

• **9·1** It has been impressed upon us that, in the language of drawing, an object is described by telling its shape and its size. All drawings, whether for machines or buildings, are made on the same principles.

Sometimes an unfavorable comparison is made between a student's drawing and a real drawing. The finished appearance of a real drawing as made by a draftsman or engineer is due to a thorough knowledge of the technique of commercial drafting. The correct order of going about the work and some of the conventional representations in common use are described in this chapter. The student must become thoroughly familiar with this practice if his drawings are to have the style and good form that are so desirable and necessary.

9·2 Alphabet of Lines. The kinds of lines given in the American Standards for use in making drawings are shown in Fig. 9·2. Each line is used for a definite purpose and must not be used for anything else. Detail drawings should have fairly thick outlines with thin center lines and dimension lines so that the drawing will have contrast and be easy to read. If all the lines are the same weight, the drawing has a flat appearance, which makes it hard to read.

The lines shown are for inked drawings and tracings. On pencil drawings two weights of lines may be used: medium and thin.

9·3 Engineering drawings are usually worked up on tracing cloth or tracing paper. The original layout may be on paper, then tracing cloth or tracing paper is placed over it, and the drawing traced with a firm pencil line. Good sharp pencil work is essential, and this requires neat work with the fewest unnecessary erasures. Blueprints or other reproductions are then made from the tracings. Most drawings were formerly traced in ink on tracing cloth, but present practice is to use a pencil except for certain purposes or for especially permanent drawings.

9·4 Order of Penciling. After shape and size description have been learned, the most important thing for the young draftsman to get is good form, a systematic method of working. The order of making the different parts of a drawing is the first item. A drawing is started by drawing the center and base lines, as in Space 1 of Fig. 9·3. These form the skeleton for the views. Then block in the views as in Space 2, draw the arcs, and complete the views as in Space 3. The views should be carried along together. Do not attempt to finish one view before making another. Finally, add the dimension lines and dimensions, as in Space 4. Learn the following order of penciling and follow it as nearly as possible in every drawing:

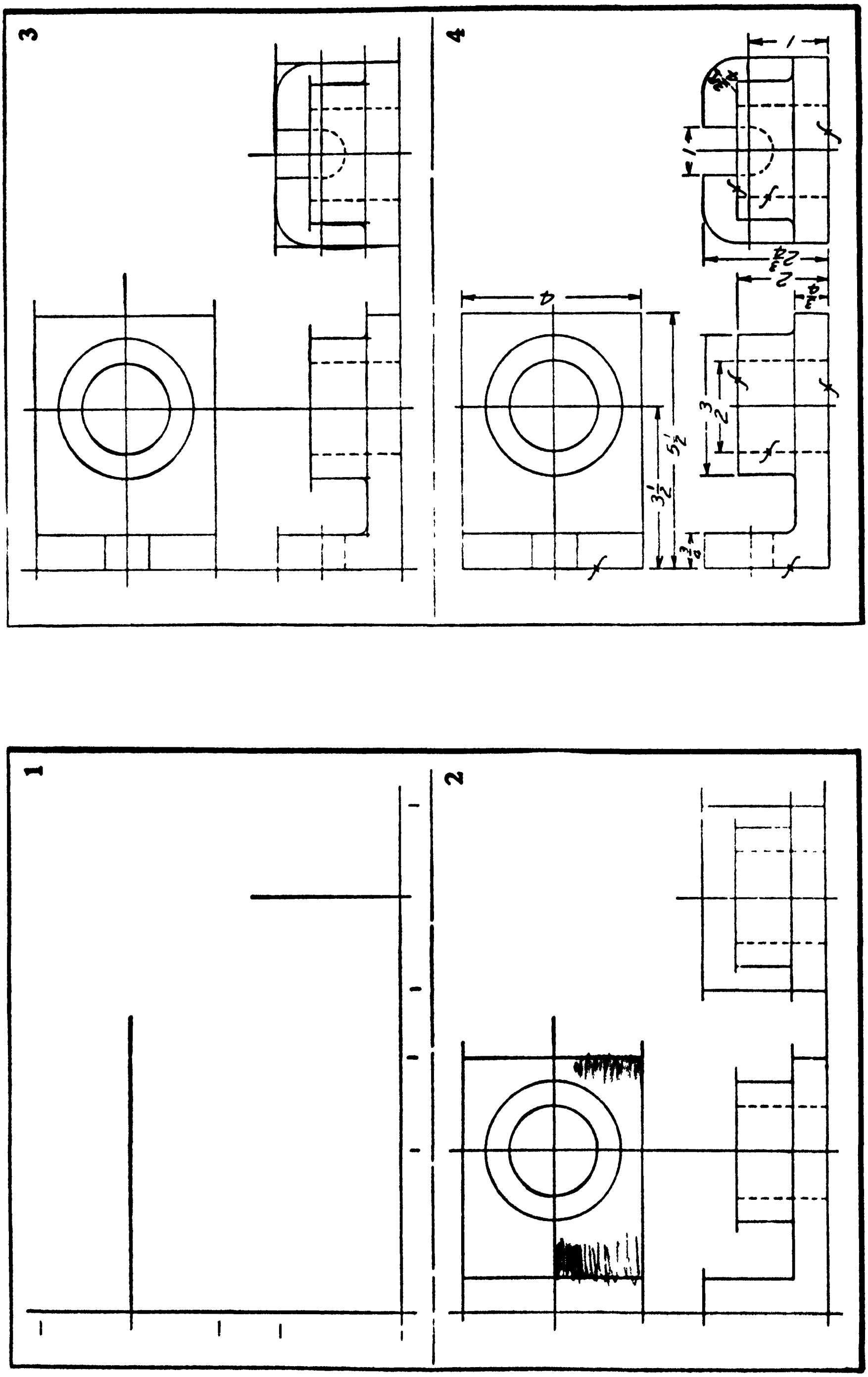


Figure 9·3 Penciling.

1. Lay off the sheet to proper size, and block in the title space or record strip.
2. Plan the arrangement of views.
3. Determine the scale to use.
4. Draw the primary center and base lines.
5. Lay off the principal measurements.
6. Block in the views by drawing the preliminary and final blocking-in lines.
7. Lay off the detail measurements.
8. Draw the center lines for details.
9. Draw all complete circles and the preliminary and final lines for details.
10. Draw part circles, fillets, and rounded corners.
11. Draw such lines as could not previously be drawn.
12. Draw all extension and dimension lines.
13. Put on dimensions and notes.
14. Section line all sectioned surfaces.
15. Letter the title.
16. Check the drawing carefully.

9·5 Inking and Tracing. The method of procedure in inking is the same, whether a tracing is made or whether the original drawing is finished by going over the penciled lines with drawing ink.

All straight lines are inked with the ruling pen.

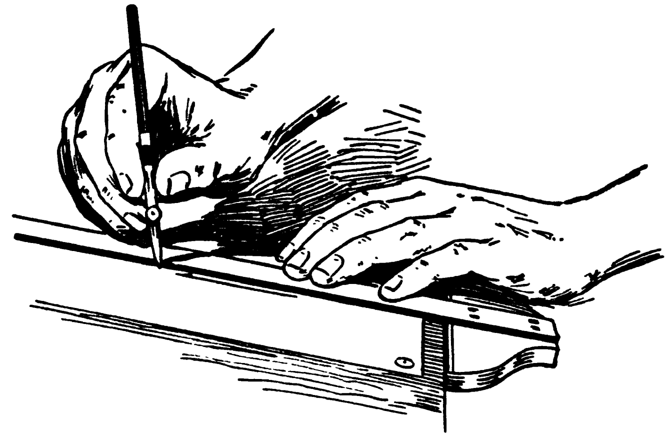


Figure 9.4 Correct position for pen.

Hold the pen point downward and fill by touching the quill on the ink-bottle cork to the inside of the pen blades. The nibs of the pen are set to the desired width of line by turning the adjusting screw, using the thumb and second finger of the pen hand. Then hold the pen against the T-square or triangle in the position shown in Fig. 9·4.

Note the following:

1. Do not hold the pen over the drawing while filling.
2. Keep the blades parallel to the direction of the line.
3. Do not press too hard against the T-square blade.
4. Do not screw the nibs of the pen too tight.
5. Have a pen wiper at hand.
6. Keep the pen clean by frequent wiping. Always wipe it carefully after using.
7. Never dip the pen into the ink bottle or allow ink to get on the outside of the blades.
8. Do not put too much ink in the pen (not over 1/4 in.).

Faulty lines occur from different causes. The pen may need dressing or sharpening. The beginner should not attempt to do this but should ask the teacher to do it for him. Figure 9·5 shows some of the common faults and suggests the remedy.

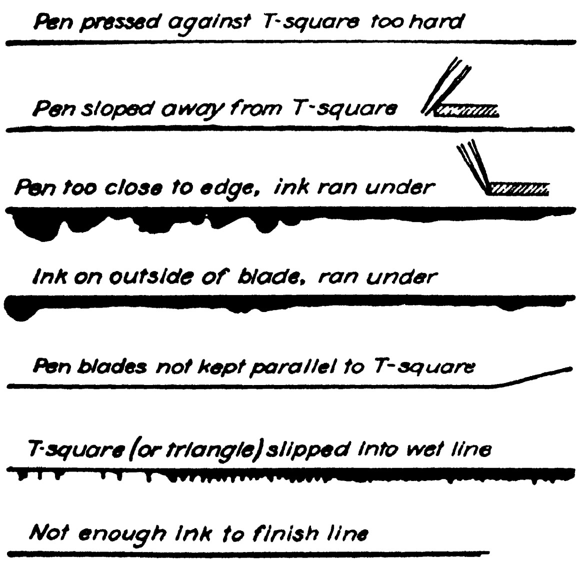


Figure 9·5 Faulty lines

The irregular curve (Fig. 2·21) is used for guiding the pen when curves other than circle arcs are being inked. It is used by matching a portion of the curved line and drawing a piece of the line, then moving the curve to a new position. The new position must always match a part of the line already inked.

For inking circles, the compasses and bow pen are used. Remove the pencil leg from the compasses and insert the pen leg, adjusting the needle point until it is very slightly longer than the pen. The joints of the compasses should be adjusted so that the legs are perpendicular to the paper. Always draw a circle in one stroke, inclining the compasses in the direction of the line and rolling the handle between the thumb and finger (Fig. 9·6).

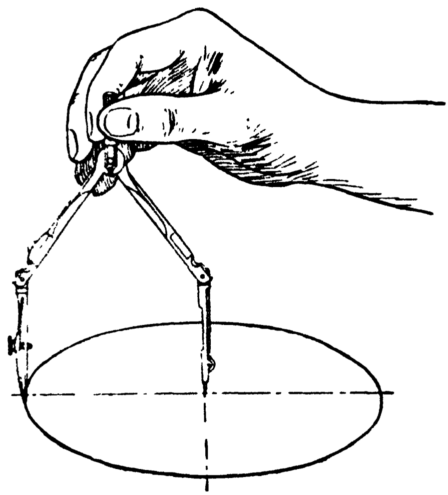


Figure 9·6 Inking a circle.

9·6 To Make a Tracing. If tracing cloth is used, first tear off the selvage and fasten the cloth down smoothly over the pencil drawing. Most draftsmen place the dull side up. Dust the surface with chalk and rub over with a cloth to remove all traces of grease, so that the ink will take. Be sure to remove all dust before starting to ink. In inking on paper, chalking is not necessary.

As tracing cloth is very sensitive to atmospheric changes and will stretch if left overnight, no view should be started that cannot be finished on the same day. When work is again started, the cloth should be restretched.

9·7 Order of Inking. Good inking is the result of two things: careful practice and a definite order of working. Smooth joints and tangents, sharp corners, and neat fillets not only improve the appearance of a drawing but make it easier to read.

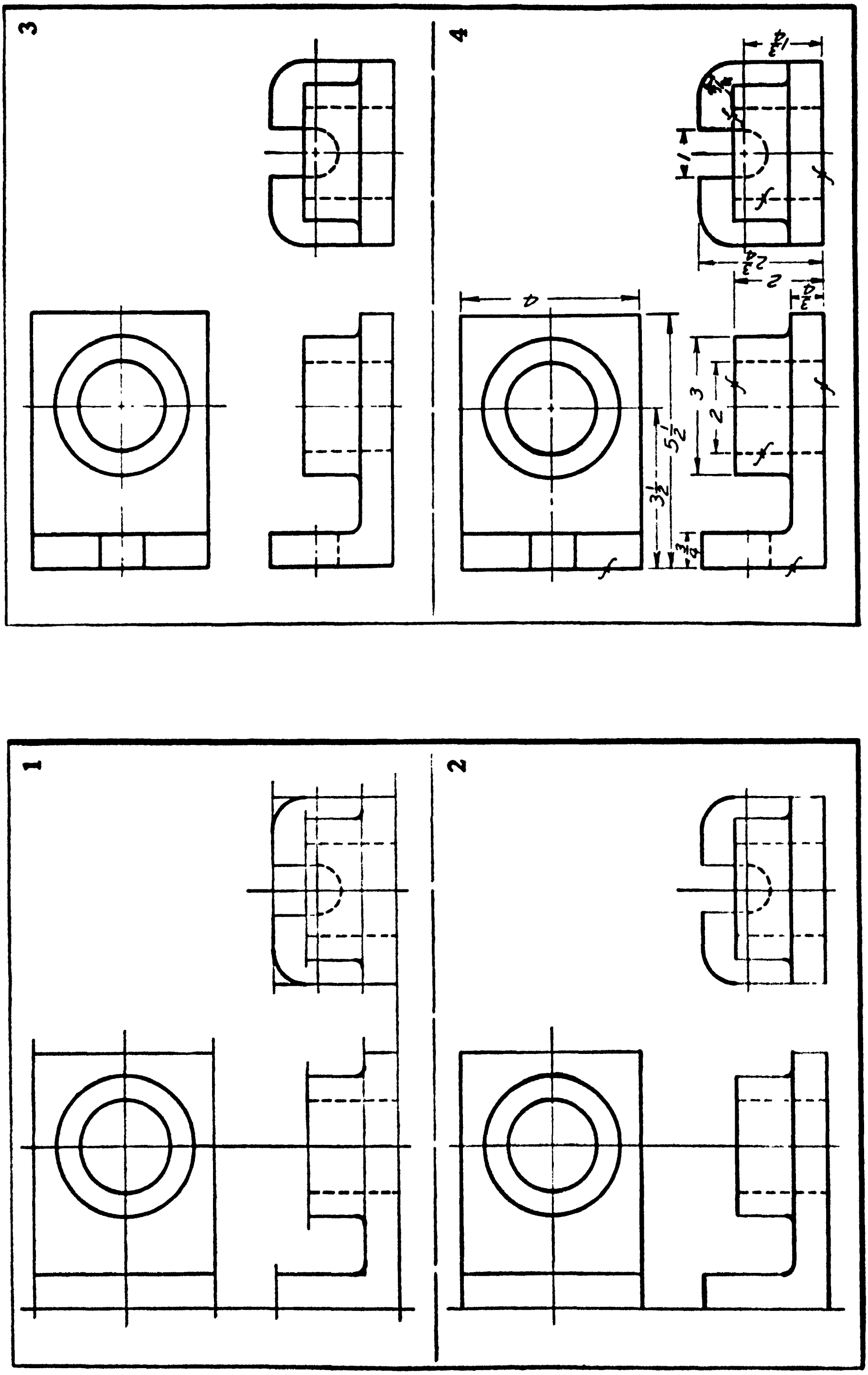


Figure 9·7 Tracing or inking.

The general order of inking or tracing is shown in stages in Fig. 9.7. The arcs are inked first as in Space 1 and should center over the pencil lines. Horizontal lines should be inked as in Space 2 and the drawing completed as in Space 3. Then add the dimension lines, arrowheads, finish marks, etc., and fill in the dimensions.

1. Ink main center lines.
2. Ink small circles and arcs.
3. Ink large circles and arcs.
4. Ink hidden circles and arcs.
5. Ink irregular curves.
6. Ink horizontal full lines.
7. Ink vertical full lines.
8. Ink inclined full lines.
9. Ink hidden lines.
10. Ink center lines.
11. Ink extension and dimension lines.
12. Ink arrowheads and figures
13. Ink section lines.
14. Letter notes and titles.
15. Ink border lines.
16. Check drawing carefully.

9·8 Erasing. The ideal way, of course, is to complete a drawing or tracing without having to do any erasing. Sometimes, however, it is necessary to make an erasure because of a change or a mistake. Ink lines may be removed by rubbing rather hard with a pencil eraser, which does not abrade the surface of the paper or cloth as does an ink eraser. *Do not use a knife or scratcher*. An erasing shield is very convenient. One can be made by cutting a slot in a card or piece of sheet celluloid. Pencil lines are removed with Artgum or a pencil eraser. Electric erasing machines are now used in large drafting rooms. They consist of a small motor with provision for holding a cylindrical eraser on the end of a revolving shaft.

9·9 Conventional Symbols. In drawing there are conventional methods of representing parts and materials, designed for saving time and making reading easier, that might be called "idioms" and "abbreviations" of the graphic language. The commonest are the symbols for indicating screw threads, explained in Chap. 10. Other conventions are used for representing electrical apparatus, piping, wiring, etc.

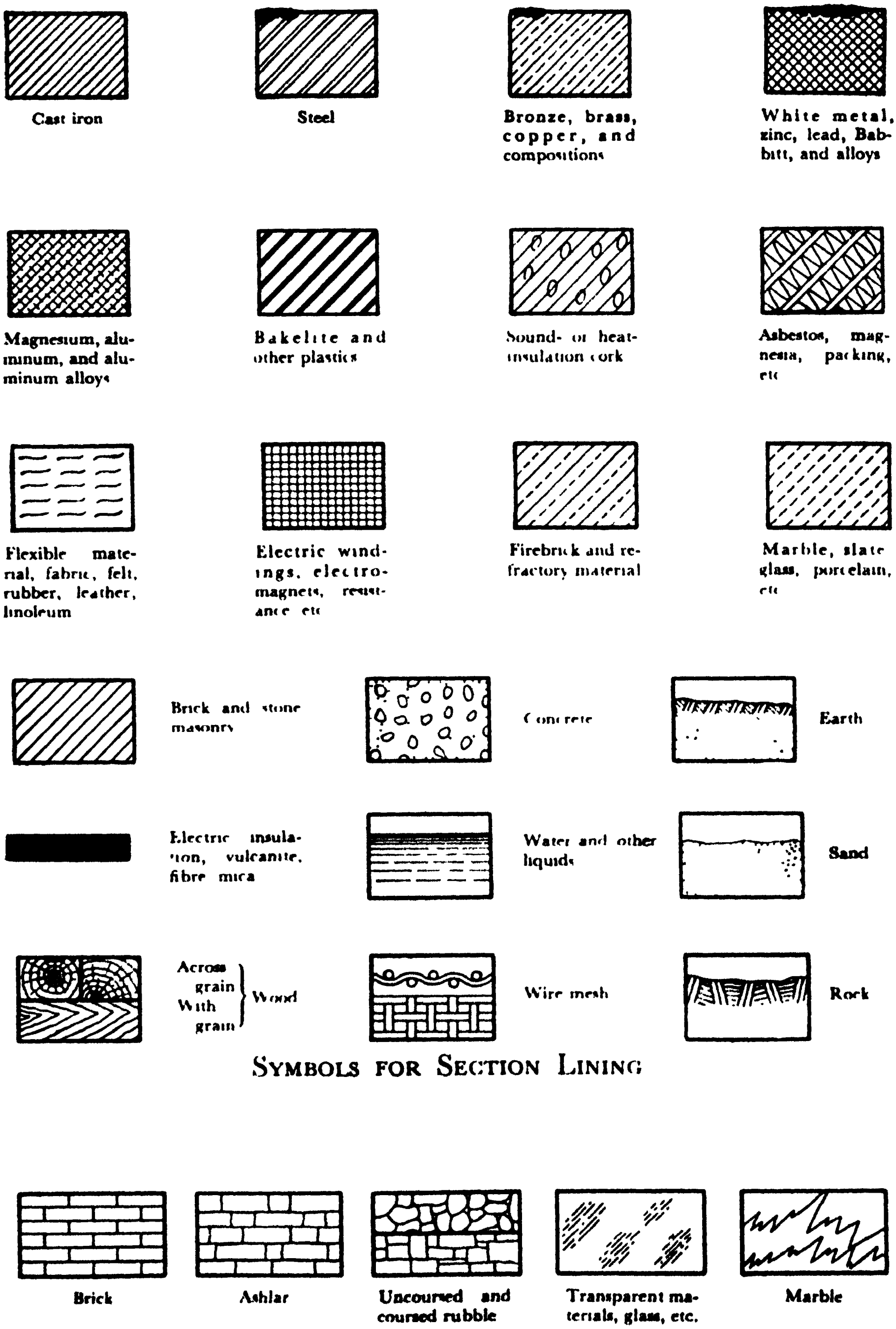


Figure 9·8 Symbols for materials.

In indicating the material of which a piece is to be made, the best rule is to letter the name of the material as a note. When adjacent pieces of different materials are shown in section, they can sometimes be given to better advantage by using symbolic section lining. The symbols for cut surfaces, as given by a committee of the American Standards Association, are shown in Fig. 9·8. Notes are generally used to tell the materials with outside views, but certain distinctive

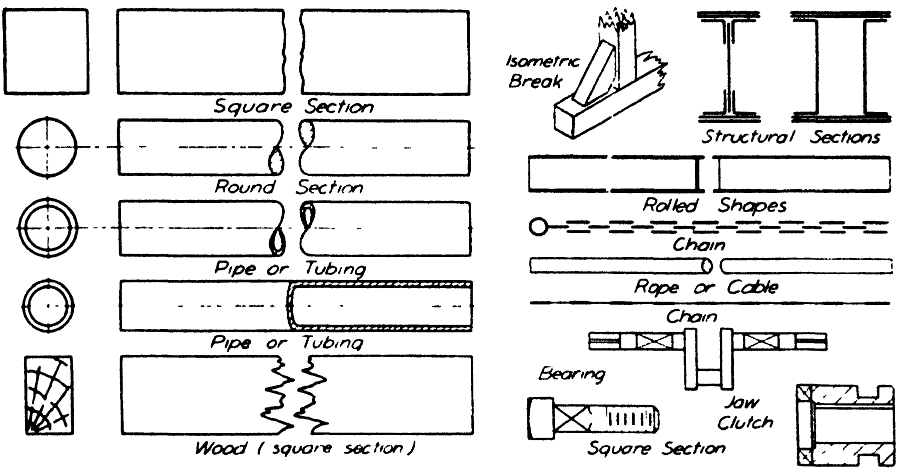


Figure 9·9 Conventional breaks and other symbols.

materials are sometimes indicated by the symbols shown in the lower row of Fig. 9·8. Architectural drawings involve the use of a large number of symbols or conventional representations, some of which are shown in Chap. 19. For showing the cross section of long uniformly shaped pieces and for "breaking out" parts, the representations of Fig. 9·9 are used.

9·10 Titles. Every sketch and drawing must have some kind of title. The form, completeness, and location vary. On working drawings, the title is usually boxed in the lower right-hand corner (Fig. 9·10) or as a part of a record strip extending across the bottom or end of the sheet (Fig. 9·11).

The title gives as much as is necessary of the following information:

1. The name of the construction.
2. The name of the part shown (or simply details).
3. Manufacturer, company, or firm name and address.
4. Date, usually date of completion of tracing.

5. Scale or scales.

6. Drafting-room record; names or initials with dates, of draftsman, tracer, checker, and approval of chief draftsman, engineer, or superintendent.

7. Numbers of the drawing, of the shop order, or of customer's order, according to system used.

In large drafting rooms, the title is generally printed in blank on the paper or cloth used.

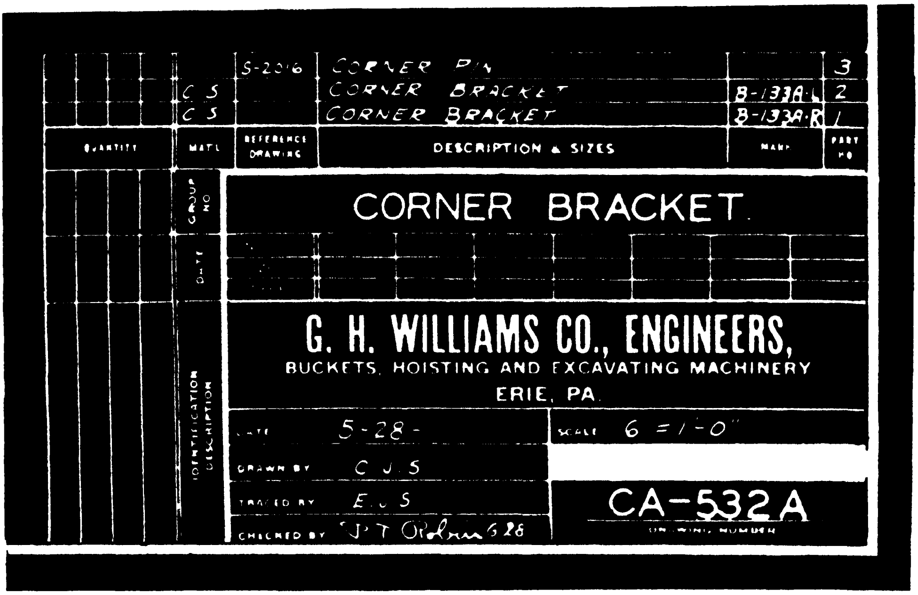


Figure 9·10 A boxed title.

9·11 Bill of Material. Drawings may have the name of the part, material, number required, part number, etc., given in a note near

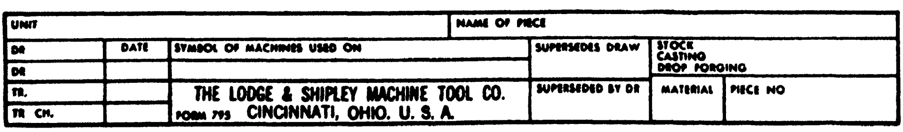


Figure 9·11 A record-strip title.

the views of each part. Another method often used is to place the number of the part in a circle near the views and then to collect all the information in a tabulated list called a "bill of material" or "material list." This list is placed on the drawing over the title; sometimes it is typewritten on a separate sheet. If the drawing is for wood construction, the bill will give the stock sizes, kind and quality of wood, board measure, and number required of each part. Bolts and other metal parts are often specified and marked with the identification number or mark.

9·12 Blueprinting. Much of the work in shops or on structures is done from blueprints, which are copies made from a tracing on chemically treated paper, giving white lines on a blue background.

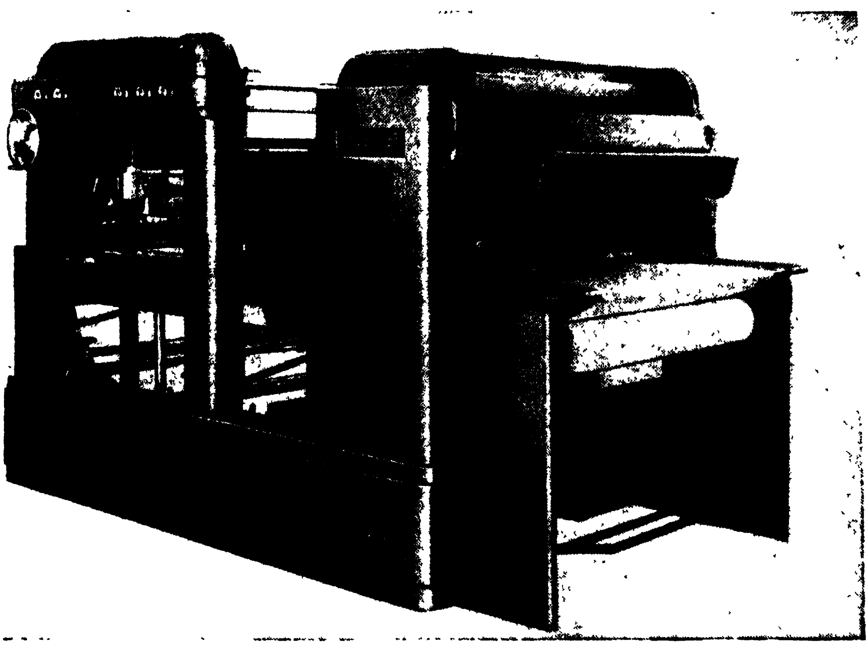


Figure 9·12 Blueprint machine. (The C. F. Pease Company.)

As many copies as desired can be made from a single tracing. Blueprints can be made from pencil or ink drawings on tracing cloth or tracing paper. The original drawing is never allowed to go into the shop but is kept in the files of the drawing room. Blueprint paper is usually bought ready sensitized and may be had in different degrees of rapidity. When fresh, it is of a yellowish-green color, and an unexposed piece should wash out perfectly white. With age or exposure to light or air, it turns to a darker gray-blue color and spoils altogether in a comparatively short time.

9·13 To Make a Blueprint. Blueprints can be made by sunlight by using a framed glass with removable back. More uniform results are obtained with a blueprint machine.

A continuous blueprinting machine made by The C. F. Pease Company is illustrated in Fig. 9·12 and includes washing and drying facilities.

Tracings are fed into the front of the printer onto blueprint paper, and together they are carried around a contact glass where they are exposed to the printing rays of a number of arc lamps. After exposure, the blueprint paper passes through a water wash, potash applicator system, and then through five drying drums. The finished prints are wound in a continuous roll and delivered at the back of the machine. Changes may be made on blueprints by using an alkaline solution in a writing or drawing pen.

9·14 Other methods of reproducing drawings include Van Dyke paper, which gives white lines on a dark-brown background, and a number of special papers that give dark or black lines on a white background. Van Dyke negatives are used to make positive blue or black prints.

A number of companies reproduce tracings by various transfer processes. *Photostat* prints are used to a very considerable extent, especially when reduced-size copies are desired.

CHAPTER 10. Bolts, Screws, and Other Fastenings

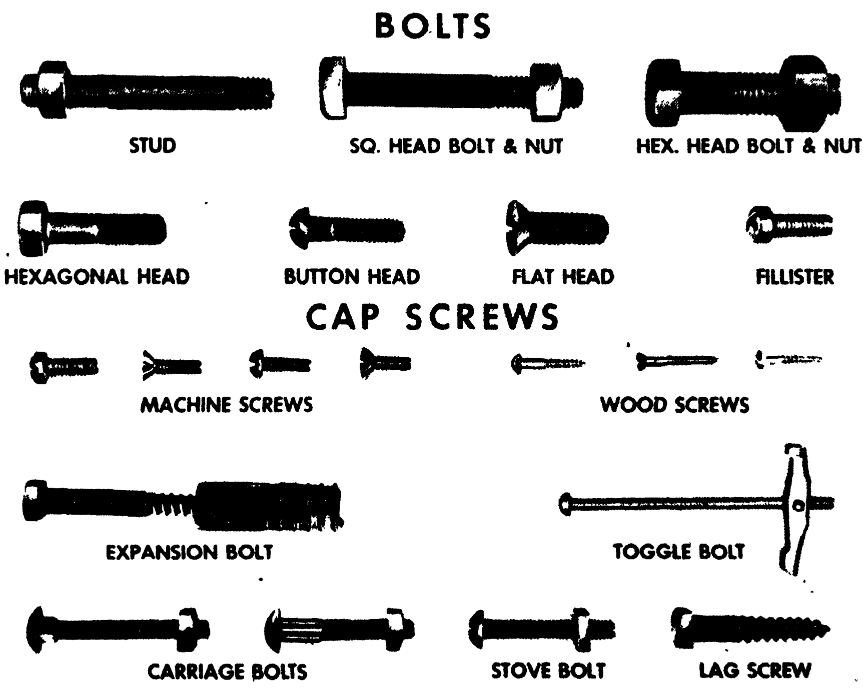


Figure 10·1 Threaded fastenings.

10·1 The application of drafting to engineering uses requires a knowledge of certain elements that are in general use as parts of machines and engineering construction. Such details include keys, shafting, bolts, screws, rivets, and pins. These have been standardized and have developed well-defined characteristics and nomenclature. Threaded fastenings—bolts, nuts, and screws—are made and used in a great variety of forms and sizes (Fig. 10·1).

Screw thread standards in the United States have developed from the system presented by William Sellers in a report to the Franklin

Institute, Philadelphia, in 1864. The standards now in use are tabulated with full information in a report published by the American Standards Association, 29 W. 39 St., New York, N.Y.

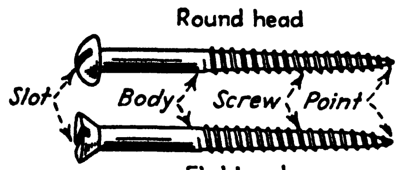


Fig. 10·2 Wood screws.

10·2 Screw Threads. The use of screw threads is so frequent that the common forms and methods of representation must be understood. The most familiar occurrence of screw threads is on the ordinary wood screw and common bolt (Figs. 10·2 and 10·3). Wood screw threads have a space between them to allow for part of the difference in the strength of wood and metal.

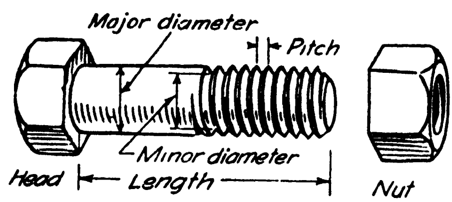


Figure 10·3 Hexagonal-head bolt and nut.

The American Standard form of thread shown in Fig. 10·4, with the names of the parts, is the one generally used in this country for general fastening purposes.

Longitudinal sections are shown in Fig. 10·5 for a number of forms of screw threads used to meet various requirements. Note the difference between the American and the British forms. The square thread and similar forms are designed for transmitting power and hold the forces in line with the axis. The buttress thread is designed to take pressure in one direction, against the surface perpendicular to the axis. The Dardelet thread is a self-locking thread designed by a French military officer. The knuckle thread is familiar on electric-light sockets, etc., and as a "cast" thread.

To draw a true representation of a screw thread, it is necessary to draw the projection of a cylindrical helix, which is a curve generated

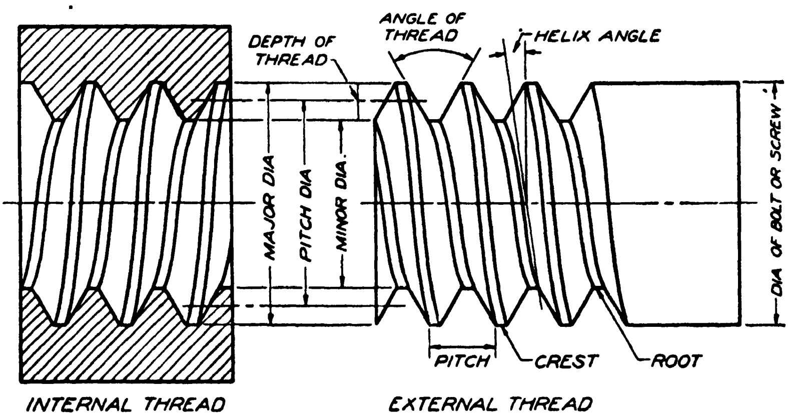


Figure 10·4 American Standard screw thread.

by moving a point uniformly around a cylinder and uniformly lengthwise of the cylinder at the same time. The hypotenuse of a right triangle will form one turn of a helix if it is wrapped around a cylinder,

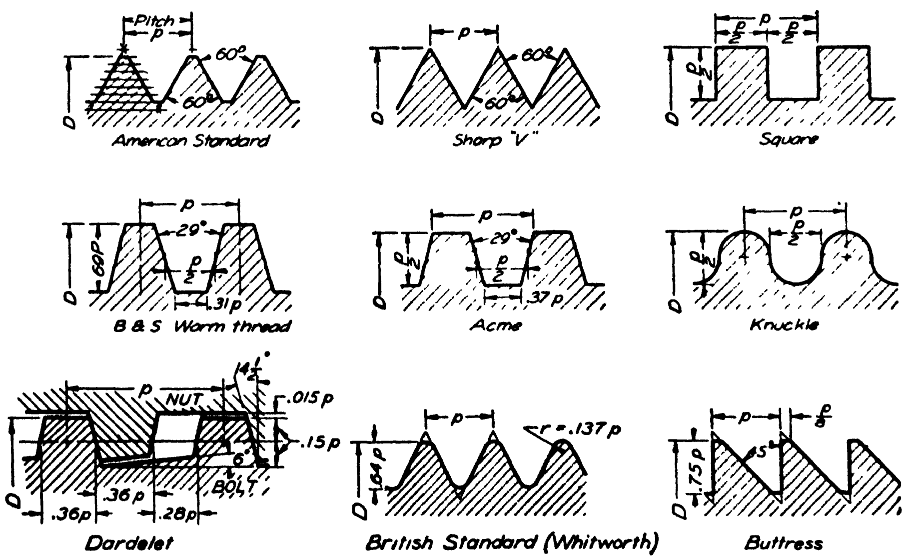


Figure 10·5 Thread profiles.

as in Fig. 10·6. The base of the triangle is equal to the circumference of the cylinder, and the altitude is the pitch of the helix (Fig. 10·7).

10·3 To Draw the Projection of a Helix. Draw two projections of a cylinder, divide the circumference into a number of equal parts and the pitch into the same number of equal parts, as in Space 1 of Fig. 10·8. From each point in the circumference draw horizontal lines to meet vertical lines drawn through corresponding divisions of the

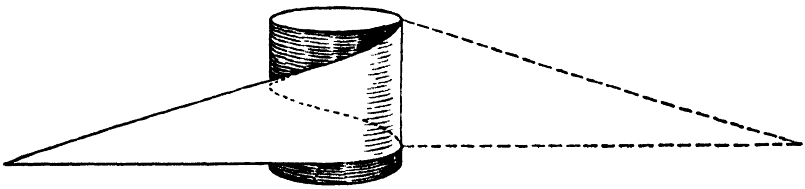


Figure 10·6 Picture of a helix.

pitch as in Space 2 of Fig. 10·8. A smooth curve drawn through the points found will give the projection of the helix as shown. The application of the helix is shown in Space 3 which is the actual projection of a square thread. Such drawings are seldom made, since they require too much time and are no better practically than the conventional

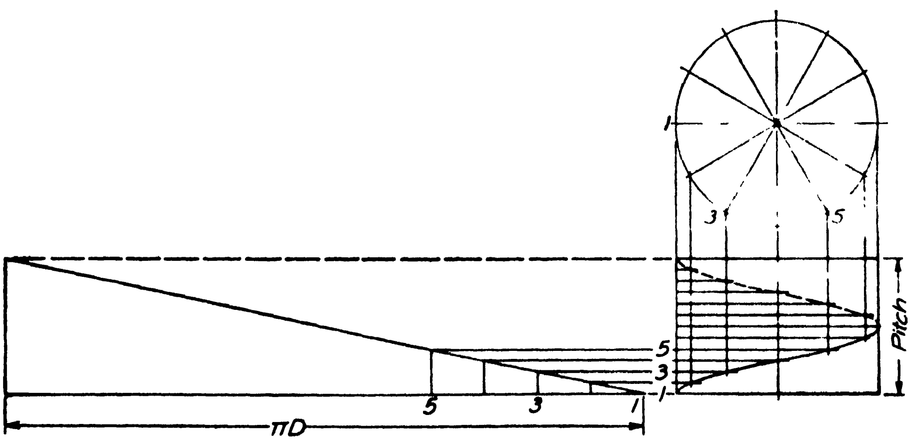


Figure 10·7 Projection of a helix.

representations commonly used. For diameters of more than 1 in., the representations of Fig. 10·9 may be used. The V-form thread is shown in Space 1, the square thread in Space 2, and a more simplified representation of the square thread in Space 3.

The order of drawing the lines for V-threads is shown in Spaces 1, 2, 3, and 4 of Fig. 10·10.

10·4 Thread Symbols. For small diameters, the representation is further conventionalized to one of the forms of Fig. 10·11 which shows external threads. American Standard symbols are given at A, B, C, and D. Regular methods recommended for general use are shown at A and B and simplified methods at C and D. Note the light and heavy lines at A to represent the crests and roots of the thread. At E and F are shown two representations which have been much used

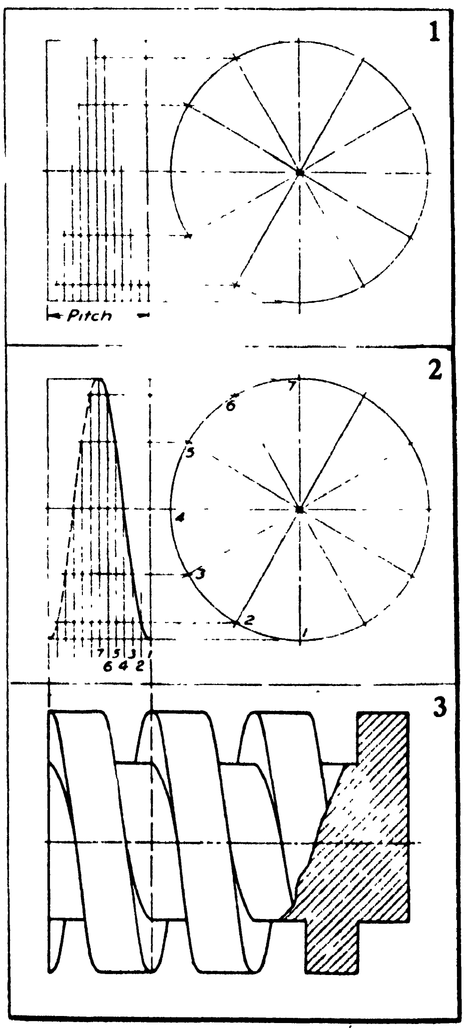


Figure 10·8 Helix and square thread.

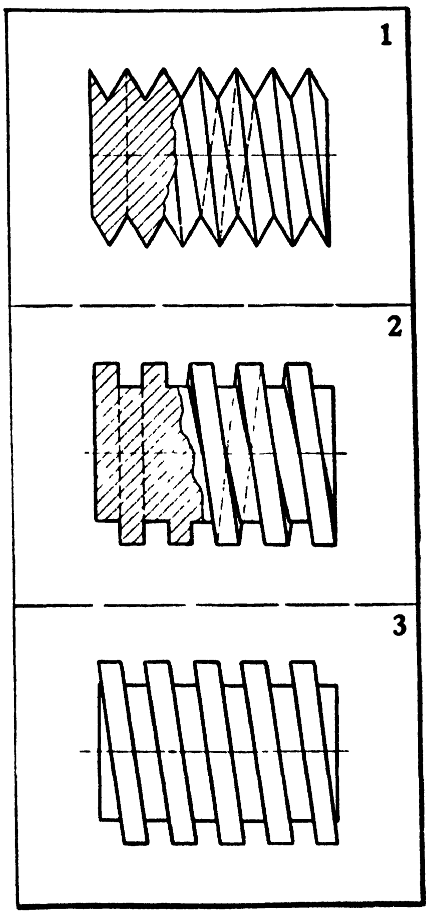


Figure 10·9 Straight-line thread representation.

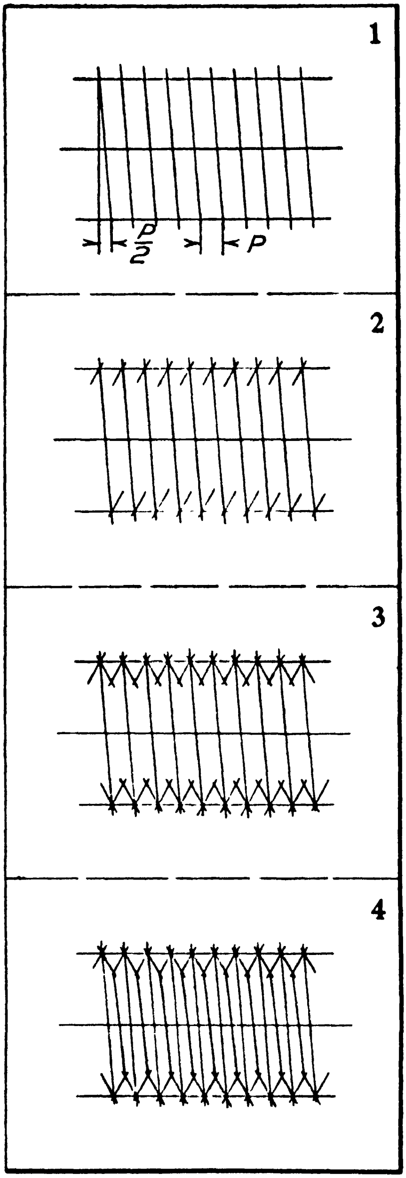


Figure 10·10 Stages in drawing a V-thread.

and which will be seen on many shop drawings. At F the slope of the lines is equal to one-half the assumed pitch. The actual pitch is not measured, but the lines are spaced by eye to look well.

American Standard symbols for internal threads (threaded holes) in section and in elevation and plan are given in Fig. 10·12. The simplified methods at D, E, and F are used to save time on details of separate parts but should not be used on views of assembled parts.

A small threaded hole is called a "tapped" hole, and a note, such as tap ½″-13NC-2, is used on the drawing (see Art. 10·9). If a threaded hole does not go clear through a piece, the drill point or shape of the bottom of the hole should be drawn with the angle as at B and C. Screw threads in section are shown in Fig. 10·13.

10·5 Bolts and Other Fastenings. The various kinds of bolts, screws, and rivets used for fastening parts together occur on so many drawings that the draftsman must know what kind of fastenings to use and how to represent them. In previous paragraphs the methods of representing threads conventionally have been shown. These are always used on shop drawings because of the saving of time.

There are many forms of threaded fastenings made for different purposes. Some of them are for special uses while others are for general use. The ones with which we must be familiar include the Amer-

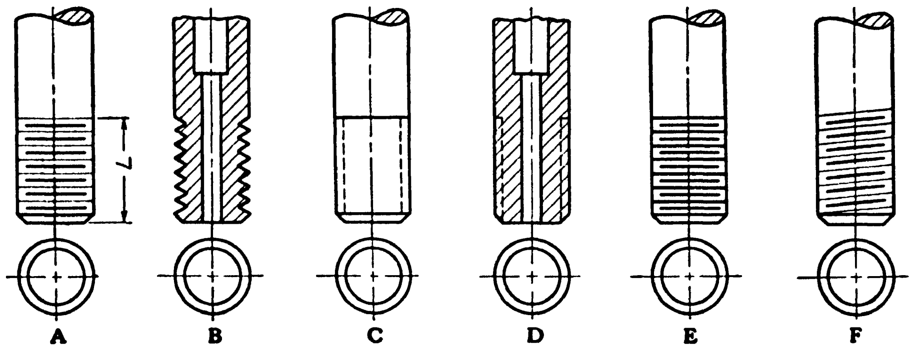


Figure 10·11 External-thread representations.

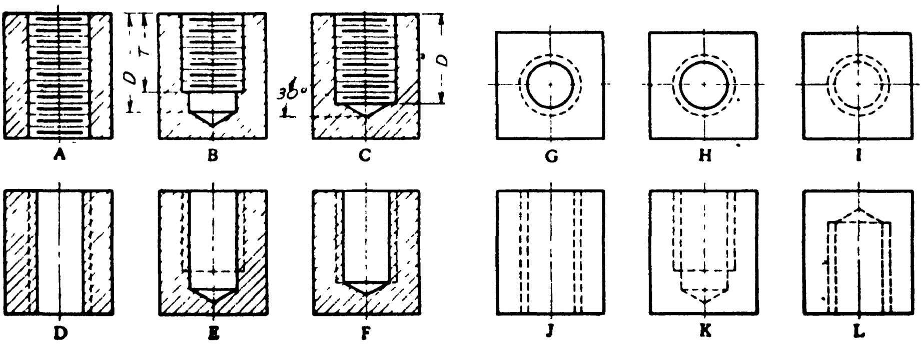


Figure 10·12 Internal-thread representations.

ican Standard hexagon-head and square-head bolts and nuts. The number of threads per inch is standard for each diameter in each of the Standard series. See Appendix, page 419.

The material presented is based upon the report of the American Standards Association on screw threads and on wrench-head bolts and nuts. Sufficient information is included to enable the student to make use of American Standards to draw boltheads and nuts where they occur on his drawings and to provide clearance where needed.

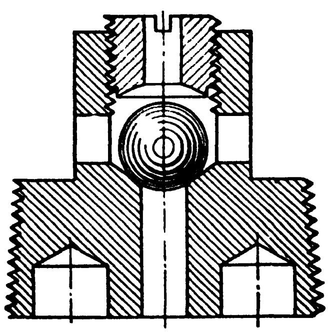


Figure 10·13 Threads in section.

10·6 American Standard Screw Threads. The American (National) form of screw thread is shown in Fig. 10·4. Two series of pitches have been provided: American Coarse Thread Series and American Fine Thread Series. The first corresponds in part with the U.S. Standard which it replaces. The second corresponds in part with the S.A.E. Standard which it replaces. See Appendix for data.

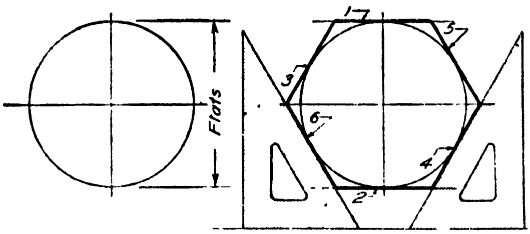


Figure 10·14 Method of drawing a hexagon.

10·7 Names concerning screw threads are given in the report mentioned in Art. 10·1, from which the following are taken (Fig. 10·4). The large or outside diameter is the *major diameter;* the small or inside diameter is the *minor diameter*. The *pitch diameter* is "the diameter of an imaginary cylinder the surface of which would pass through the threads at such points as to make equal the width of the spaces cut by the cylinder."

10·8 Classes of Fits. Four classes of screw-thread fits are given in the American Standards and described in detail with dimensions, tolerances, etc., in the report. The four classes are as follows:

Loose Fit (*Class* 1). Recommended as a commercial standard for tapped holes in the numbered sizes only. May be used with screws of other classes to obtain quality of fit desired.

Free Fit (*Class* 2). Includes the great bulk of screw-thread work of ordinary quality of finished and semifinished bolts, nuts, etc.

Medium Fit (*Class* 3). Includes the better grade of interchangeable screw-thread work, such as automobile bolts and nuts.

Close Fit (*Class* 4). Includes screw-thread work requiring a fine snug fit, somewhat closer than the medium fit, such as high-grade aircraft parts. In this class of fit selective assembly of parts may be required.

10·9 Symbols for Specification. The American (National) Standard screw threads are specified by the following symbols: diameter (or screw number), number of threads per inch, initial letters of the series, as NC for coarse-thread series or NF for fine-thread series and, finally, the class of fit. For 1¼ in. diameter, six threads per inch, coarse thread, Class 2, the specification would read thus:

1¼″-6NC-2

If left-handed, the letters LH should be added after the class fit number. For ⅞ in. diameter, fourteen threads per inch, fine thread, Class 3, left-hand, the specification would read thus:

⅞″-14NF-3 LH

For screw-thread data, see Appendix, page 419.

10·10 To Draw a Hexagon. Since the hexagonal form of bolthead and nut is used to such a large extent, we must know how to draw a regular hexagon. Given the distance between two sides, called the *short diameter*, or *distance across flats* (Fig. 10·14): First draw horizontal and vertical center lines. With the intersection as a center, draw a circle having a diameter equal to the distance across flats. With the T-square and 30°–60° triangle, draw lines tangent to the circle in the order given.

A hexagonal bolthead is a hexagonal prism with the corners chamfered, as shown in Fig. 10·3.

10·11 American Standard Wrench-head Bolts and Nuts. There are two series of standards for boltheads and nuts: *regular* and *heavy*; and a third series for nuts: *light*. The regular series is for general use. The heavy series is for use where a larger bearing surface is required or where a relatively large hole is used. Light series nuts have smaller dimensions across flats than in either of the other series.

There are three classes of finish:

Unfinished boltheads and nuts have no surfaces machined other than the threads.

Semifinished boltheads and nuts are machined on the bearing surface. Boltheads have a washer face. Nuts have a washer face or chamfered corners.

Finished boltheads and nuts are machined as for semifinished and have other surfaces finished as specified to provide a special appearance.

For complete tables of dimensions and other detail dimensions, the report of the American Standards Association, entitled "Wrench-head Bolts and Nuts and Wrench Openings" (ASA-B18.2), should be secured. This chapter will be found sufficient for drawing purposes.

Some dimensions of American Standard boltheads and nuts are given in the Appendix, pages 420 and 421.

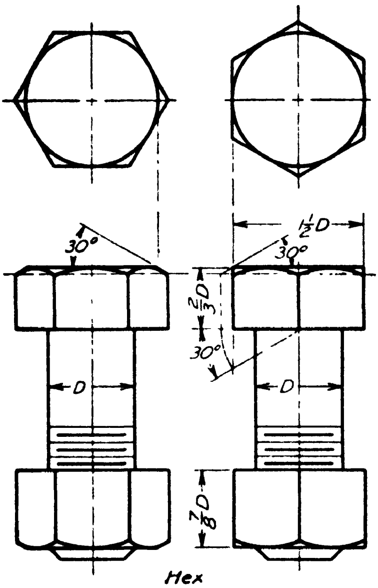


Figure 10·15 Regular unfinished bolthead and nut; hexagon.

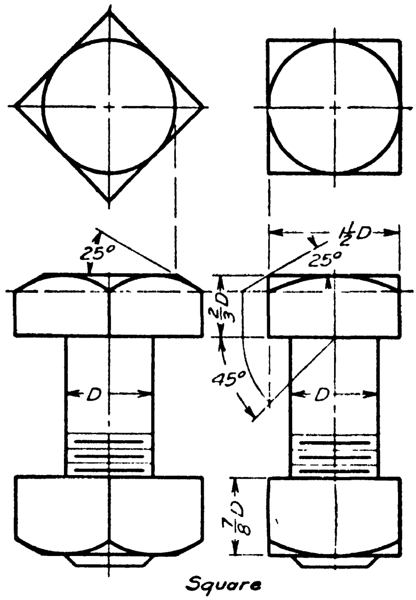


Figure 10·16. Regular unfinished bolthead and nut; square.

10·12 Regular Boltheads and Nuts. For drawing purposes the general dimensions may be taken, as given in Figs. 10·15 and 10·16 for regular unfinished boltheads and nuts. Width across flats of hexagon or square equals 1½*D* adjusted to sixteenths. Height of bolthead equals ⅔*D* adjusted to fractions. Nominal thickness of nut equals ⅞*D*. The chamfer angle with the top may be drawn at 30° for either hexagon or square forms. The radii for the arcs can be found by trial to suit the conditions shown. Semifinished and finished boltheads and nuts are shown in Fig. 10·17. See page 420 for dimensions.

American Standard Unfinished Jam Nuts

Diameter	*Thickness* — *Regular*	*Diameter*	*Thickness* — *Heavy*
¼ to 7/16	½D + 1/32	¼ to 1⅛	½D + 1/16
½ to 1⅛	½D + 1/16	1¼ to 2¼	½D + ⅛
1¼ to 2¼	½D + ⅛	2½ to 4	½D + ¼
2½ to 3	½D + ¼		

10·13 Heavy Boltheads and Nuts. This series is for use where a greater bearing surface is required and so is somewhat larger than the regular series. As indicated in Figs. 10·18 and 10·19 the distance

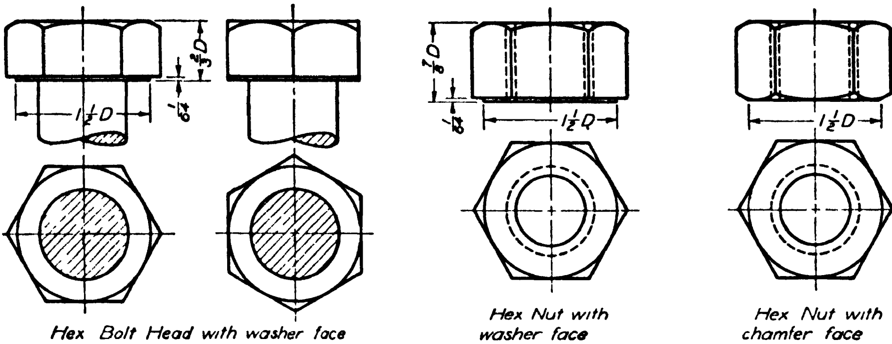


Figure 10·17 Semifinished and finished bolthead and nut.

across flats for the unfinished square and hexagon boltheads and nuts is $1\frac{1}{2}D + \frac{1}{8}''$. The height of the head is $\frac{3}{4}D + \frac{1}{16}''$, and the thickness of the nut is made equal to D. There are slight differences

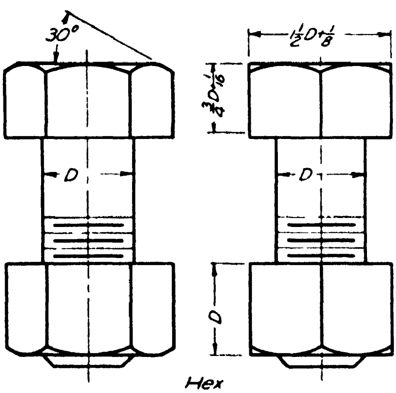


Figure 10·18 Heavy bolthead and nut; hexagon.

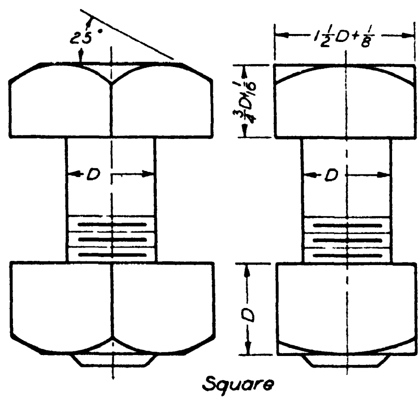


Figure 10·19 Heavy bolthead and nut, square.

in some of the dimensions for the semifinished square and hexagon and for the finished hexagon boltheads and nuts. The proportions given in Figs. 10·18 and 10·19 are satisfactory for drawing purposes. Full details, if required, can be obtained from the American Standards report mentioned in Art. 10·11 (see Appendix, page 418).

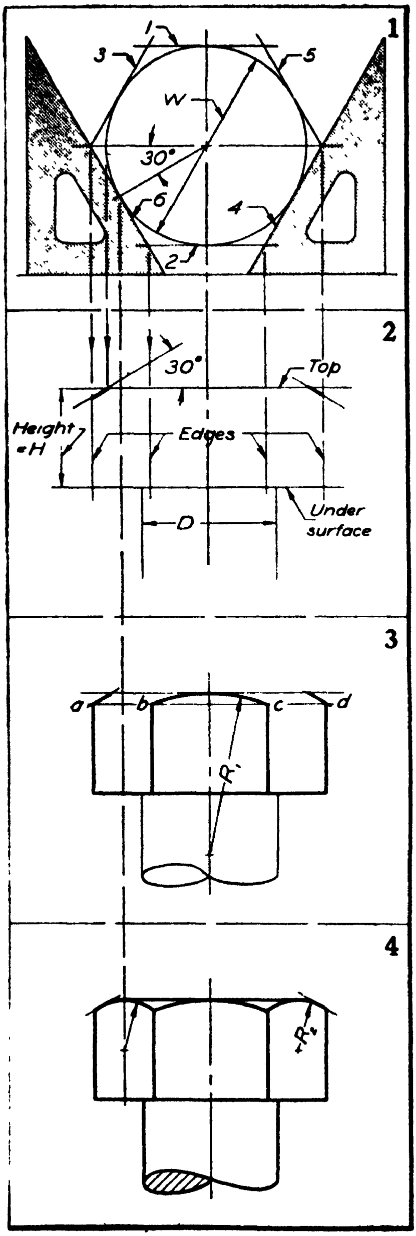


Figure 10·20 Method of drawing a hexagon bolthead across corners.

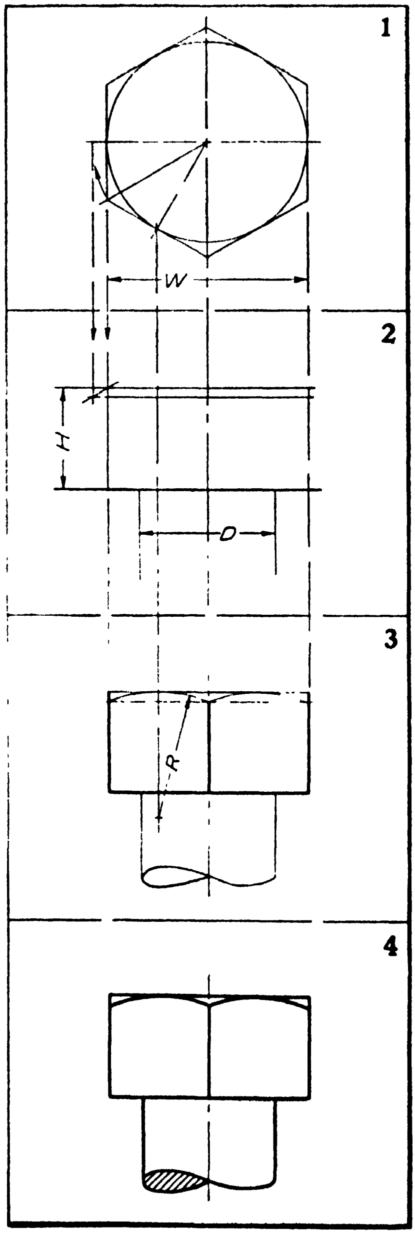


Figure 10·21 Method of drawing a hexagon bolthead across flats.

A method of drawing a hexagonal bolthead is described in Art. 10·14 for Figs. 10·20 and 10·21. A similar method is used for a square head.

10·14 To Draw an American Standard Hexagon Bolthead. Start the top view as in Space 1 of Fig. 10·20 by drawing the chamfer circle with a diameter equal to $1\frac{1}{2}$ times the diameter of the bolt for the regular series or $1\frac{1}{2}D + \frac{1}{8}''$ for the heavy series. About this circle draw a hexagon as described in Art. 10·10. For the front view draw a horizontal line representing the undersurface of the head.

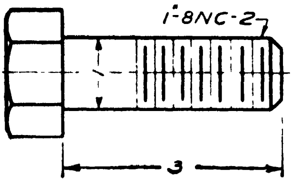


Figure 10·22 Bolt.

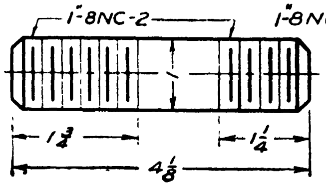


Figure 10·23 Stud.

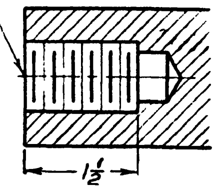


Figure 10·24 Tapped hole.

The height of the head, H, is $\frac{2}{3}D$ for the regular series or $\frac{2}{3}D + \frac{1}{16}''$ for the heavy series. Draw the top line and project from the top view to obtain the vertical edges. Project the diameter of the chamfer circle and draw 30° chamfer lines as shown. The drawing will appear as in Space 2, Fig. 10·20. Draw line *abcd* to locate chamfer intersections, as in Space 3. Radius R_1 can be found by trial so that the arc will pass through points *b* and *c* and be tangent to the top line. Complete the front view as in Space 4 by drawing arcs with radii R_2 (tangent to top line and through points *a*, *b* at left, and *c*, *d* at right, by trial).

To draw a hexagon bolthead across flats proceed as illustrated in stages in Fig. 10·21.

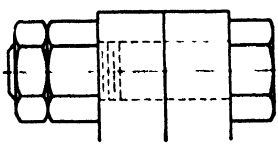


Figure 10·25 Lock nut.

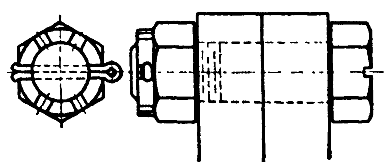


Figure 10·26 Castle nut.

10·15 Bolts and Studs. The proportions of boltheads and nuts are so well standardized that they are not dimensioned on a drawing. For a standard bolt it is necessary to specify only two dimensions: the diameter and the length from under the surface of head to end of bolt, as in Fig. 10·22. If standard minimum length of thread is not used, the length of the thread from the end of the bolt must be added.

A *stud* or stud bolt (Fig. 10·23) has threads on both ends and is used where bolts are not suitable and for parts that must be removed often. One end is screwed permanently into a tapped hole, and a nut is screwed onto the projecting end.

A threaded or tapped hole may be dimensioned as in Fig. 10·24, or a note may be used.

Various arrangements are used to prevent nuts from working loose under vibration. Many patented devices are available. Lock nuts, such as illustrated in Fig. 10·25, are probably the commonest means of holding nuts in place. American Standard jam nuts have the same distance across flats as the unfinished, semifinished, and finished nuts with thicknesses given in the table on page 124. A castle nut with cotter pin is shown in Fig. 10·26.

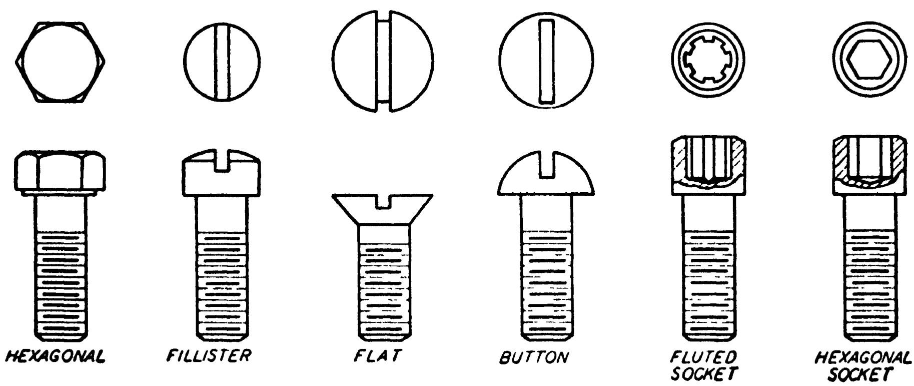


Figure 10·27 Cap screws.

10·16 Cap Screws. Cap screws are used for fastening two pieces together by passing through one and screwing into the other. Some forms of American Standard cap screws are illustrated in Fig. 10·27. Dimensions for hexagon-head cap screws and some general dimensions for the other forms are given in the Appendix, page 422.

10·17 Machine screws are used where small diameters are required. They are specified by number. Some American Standard machine screws are shown in Fig. 10·28. Dimensions are given in the Appendix, page 424.

10·18 Setscrews (Fig. 10·29) are used for holding two parts in a desired position relative to each other by screwing through a threaded hole in one piece and bearing against the other. Some dimensions for American Standard square-head setscrews are given in the Appendix, page 423.

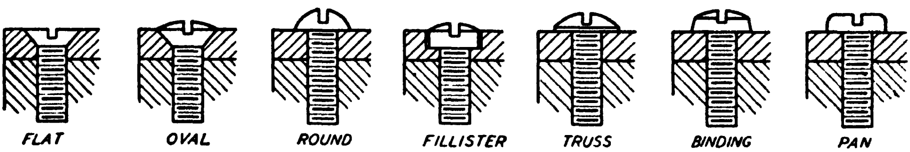


Figure 10·28 Machine screws.

10·19 Wood screws are made of steel, brass, or aluminum and are finished in various ways. Steel screws may be bright (natural finish), blued, galvanized, or copper-plated; both steel and brass screws are sometimes nickel-plated. Round-head screws have the head above the wood; flat-head screws are set flush or countersunk. They are drawn as in Fig. 10·30. Wood screws are specified by number, length,

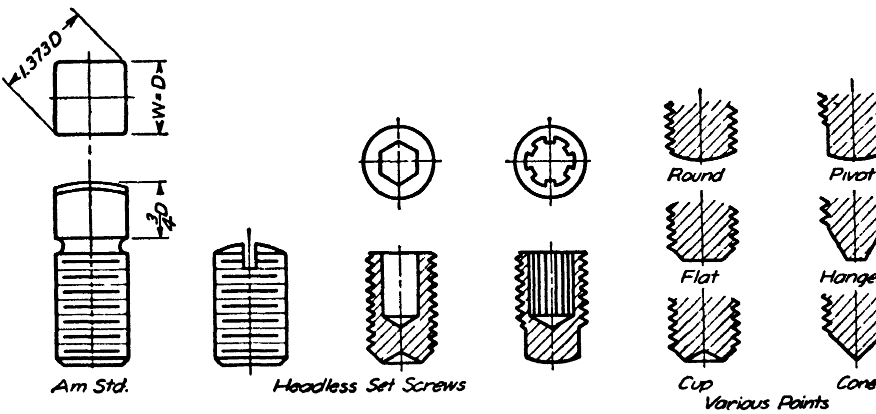


Figure 10·29 Setscrews.

style of head, and finish. Length of flat-head screws is measured overall, round-head screws from under head to point, and oval-head screws from largest diameter of countersink to point (see page 425). Diameters of American Standard wood screws are as follows:

Screw number. .	0	1	2	3	4	5	6	7	8
Diameter. . . .	.060	.073	.086	.099	.112	.125	.138	.151	.164
Screw number. .	9	10	11	12	14	16	18	20	24
Diameter. . . .	.177	.190	.203	.216	.242	.268	294	.320	.372

10·20 A lag screw, drawn as in Fig. 10·31, is used for fastening machinery to wood supports and for heavy wood constructions when a bolt cannot be used. It is similar to a regular bolt but has wood-screw threads. The head may be either square or hexagonal. Lag screws are specified by diameter and length from undersurface of the head to the end of the screw.

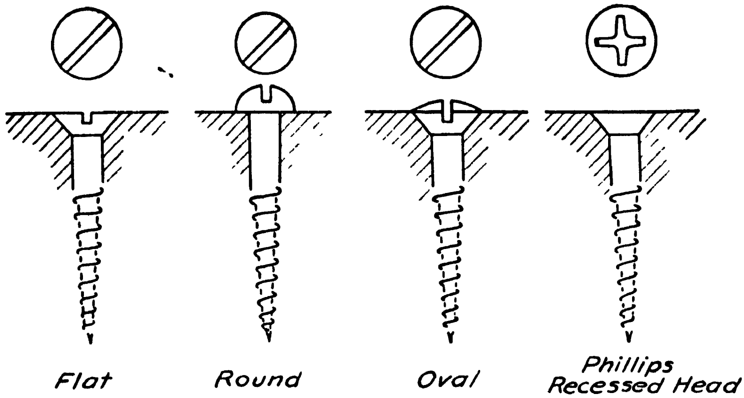


Figure 10·30 Wood screws.

Several other forms of screws and bolts are drawn as in Fig. 10·32. Screw hooks and screw eyes are specified by diameter and length overall.

10·21 Keys. Pulleys, flywheels, cranks, and similar parts are generally secured to their shaft by some form of key (Fig. 10·33). The style of key is selected to fit the duty that it must perform, ranging

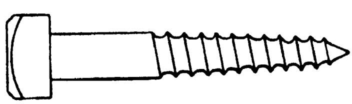


Figure 10·31 Lag screw.

from the saddle key for light duty to special forms or two square keys for heavy duty. The common sunk key may have a breadth of about one-fourth the shaft diameter and a thickness of from five-eighths the breadth to the same as the breadth. The Woodruff key is much used in machine-tool work. It is made in standard sizes and specified by number (see engineering handbooks and Appendix, pages 429 and 430).

10·22 Rivets. Sheet-metal plates, structural-steel shapes, and many other parts are put together with rivets, especially when permanent fastenings are desired.

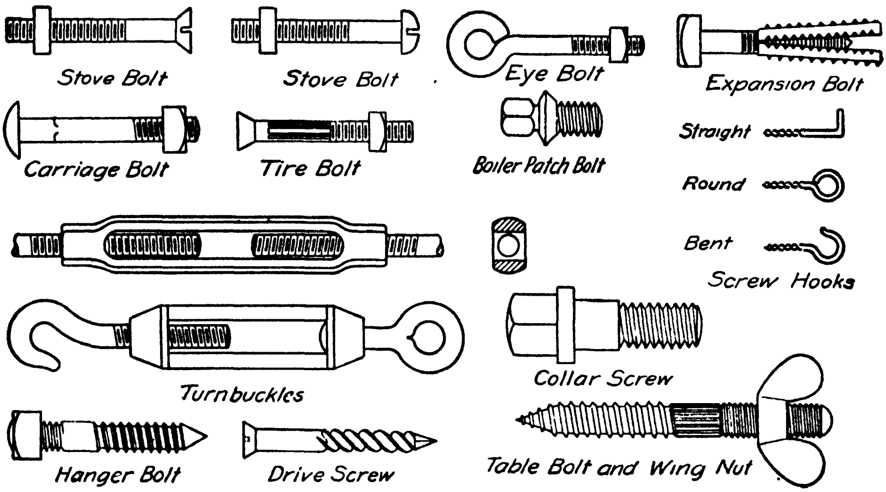


Figure 10·32 Various bolts and screws.

Structural rivets have the forms shown in Fig. 10·34. Boiler and tank rivets have the forms shown in Fig. 10·35.

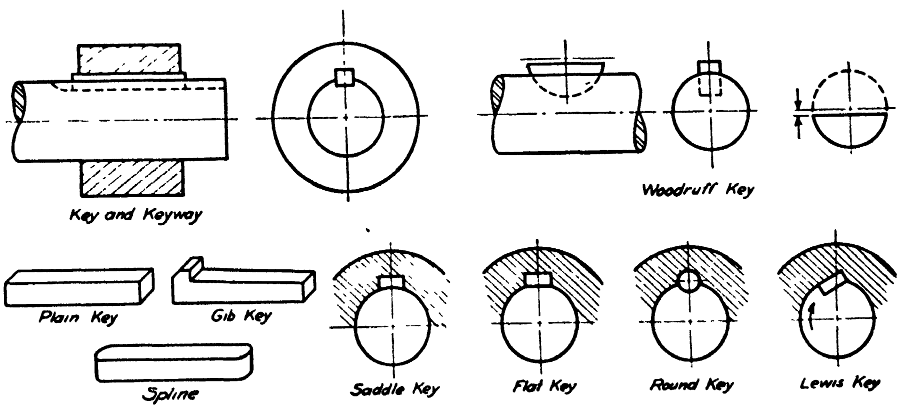


Figure 10·33 Keys.

American Standard small rivets, $\frac{3}{32}$ to $\frac{7}{16}$ in. in diameter, are made with a variety of heads (see Fig. 10·36 and Appendix, page 428).

The du Pont explosive rivet illustrated in Fig. 10·37 has a small explosive charge in the cavity when inserted at *A*. After the charge is exploded a head is formed as at *B*. This makes blind riveting possible as the "head" can be formed inside of closed or inaccessible spaces.

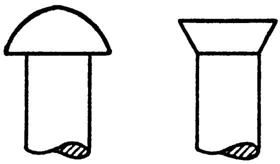


Figure 10·34 Structural rivets.

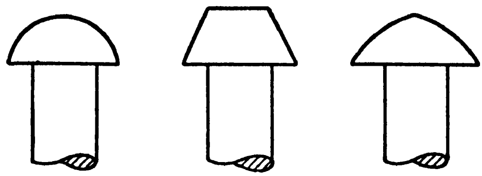


Figure 10·35 Boiler rivets.

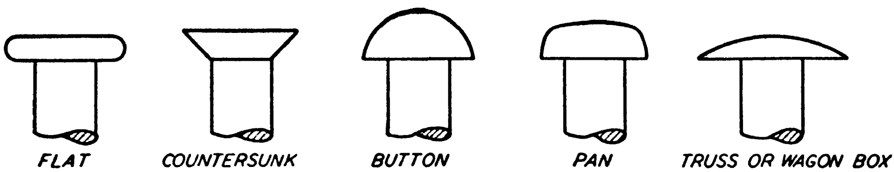


Figure 10·36. American Standard small rivets.

Figure 10·37 Explosive rivet. (Explosive Department, E. I. du Pont de Nemours & Co., Inc.)

CHAPTER 11. Mechanical Drafting

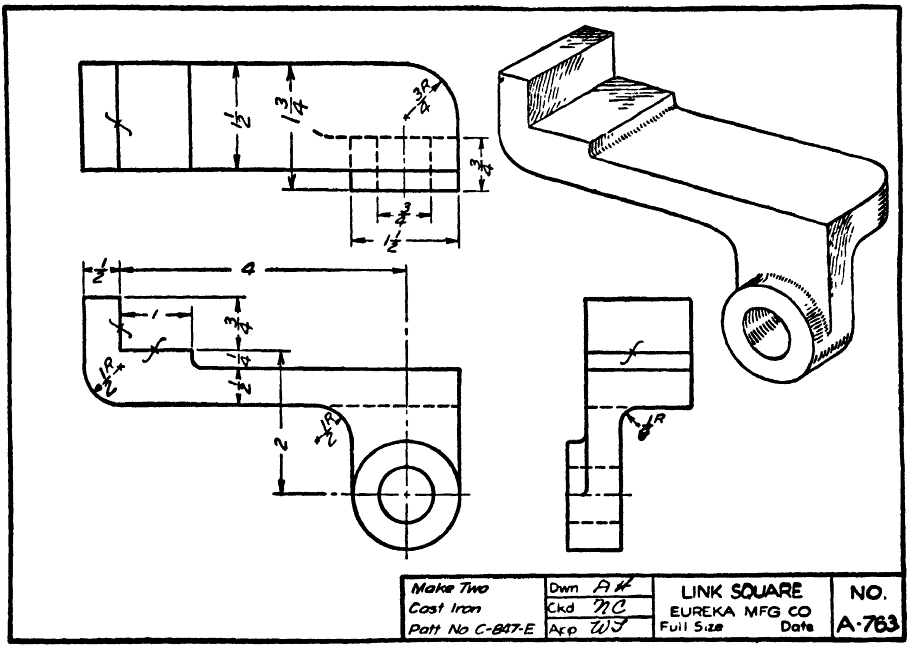


Figure 11·1 A working drawing.

11·1 Drafting Practice. A working drawing is one that completely describes the shape and size and gives specifications for the kinds of material, methods of finish, accuracy required, and all other information necessary for making a single part or a complete machine or structure. A picture and the working drawing of a simple machine part are shown in Fig. 11·1.

11·2 Working drawings are based upon orthographic projection (Chap. 4) with dimensions and notes added as described in Chaps. 8 to 10.

Such drawings must conform in style with good practice as followed in the office where they are made. There must be contrast, obtained by giving proper values to the various lines that compose the views. Legible figures, uniform lettering, and the use of standard terms are essential. When completed, a working drawing must be thoroughly checked for errors and improvements before being submitted for approval.

11·3 Detail Drawings. The drawing of a single piece that gives all the information necessary for making it is called a "detail drawing." This is the simplest form of working drawing and must be a complete and accurate description of the piece, with carefully selected views and well-located dimensions. Sometimes separate detail drawings are made for the use of different workmen, as the patternmaker, blacksmith, machinist, or welder. Such drawings have only the dimensions and information needed by the workmen for whom the drawing is made. An ordinary detail drawing is shown in Fig. 11·2.

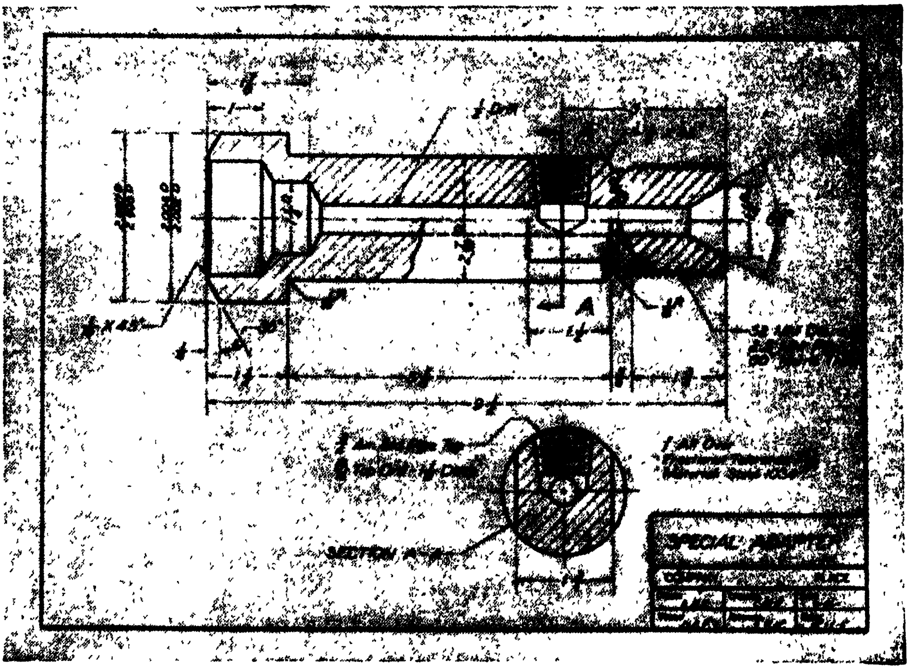


Figure 11·2 A detail drawing.

When a large number of machines are to be manufactured, it is usual to make a detail drawing for each part on a separate sheet.

Figure 11·3 shows a forging as formed and after it has been machined. The working drawing of the superspacer latch pinion, made by the Hartford Special Machinery Company, is shown in Fig. 11·4. Notice the representation of parts to be removed after all work is done and the detailed list of machine operations.

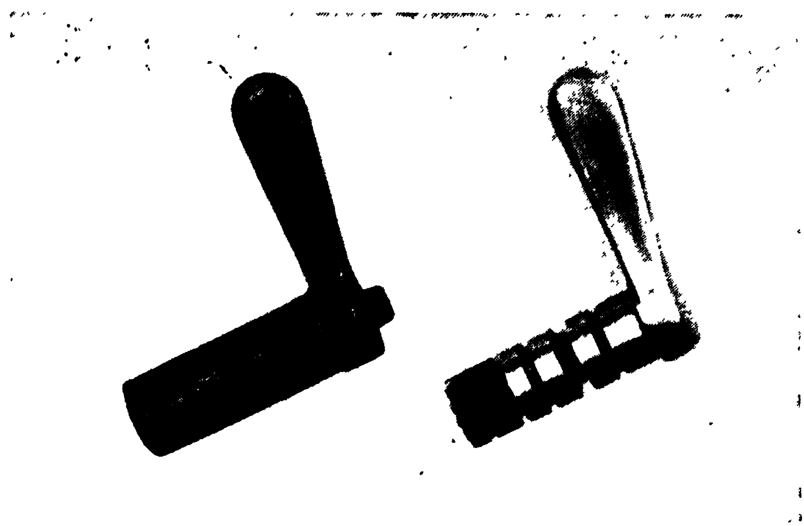


Figure 11·3 Index-plunger operating handle (forging and finished parts).

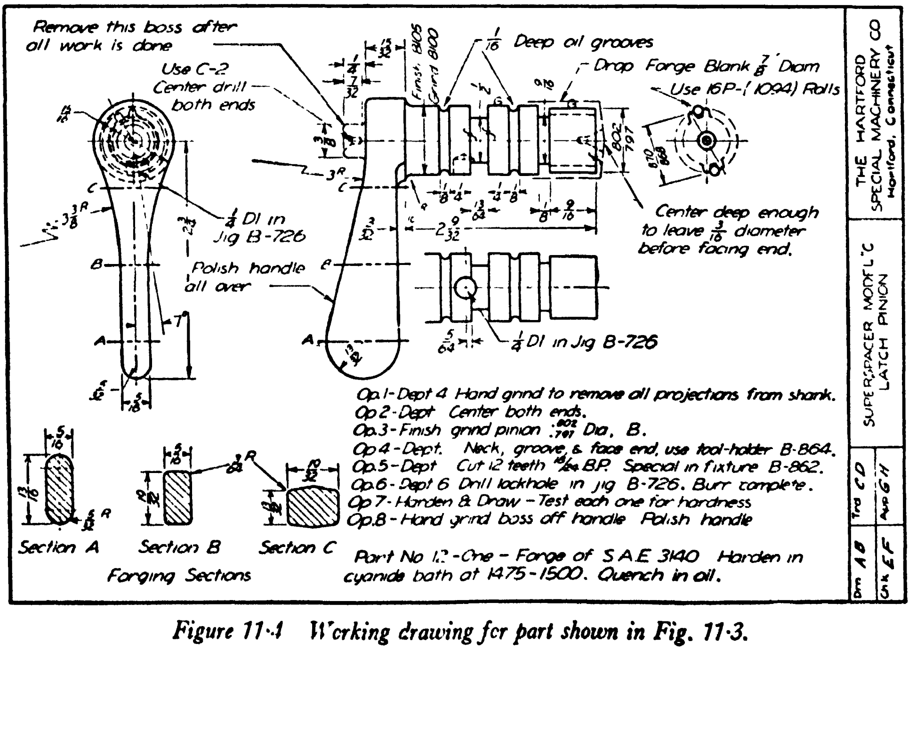


Figure 11·4 Working drawing for part shown in Fig. 11·3.

11·4 Assembly Drawings. A drawing of a completely assembled construction is called an "assembly drawing." Such drawings vary greatly in regard to completeness of detail and dimensioning. Their particular value is in showing the way in which the parts go together and the appearance of the construction as a whole. When complete information is given, they may be used for working drawings. This is possible when there is little or no complex detail. Figure 11·5 shows such a drawing. Furniture and other wood constructions can often

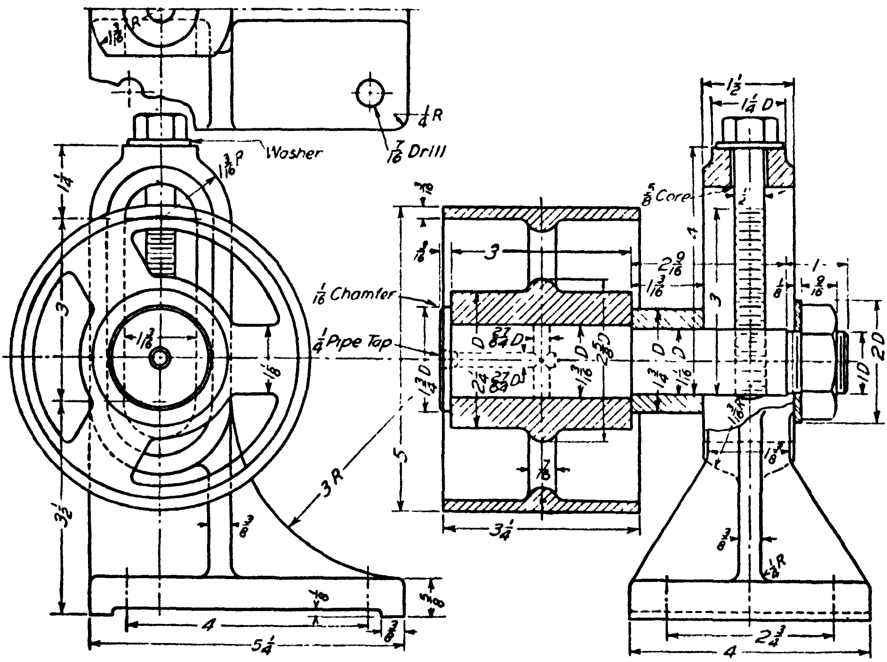


Figure 11·5 An assembly working drawing.

be represented in assembly working drawings by adding necessary enlarged details or additional partial views.

Assembly drawings of machines are generally made to small scale with selected dimensions to tell over-all distances, important center-to-center distances, and location dimensions. All or almost all hidden lines may be left out and, if drawn to a very small scale, unnecessary detail may be omitted. Figure 11·6 is an example.

Either exterior or sectional views may be used. When the general appearance is the main purpose of the drawing, only one view or two views may be used.

11·5 Choice of Views. Much of the ease with which a drawing can be used depends upon the proper selection of views. For the complete description of an object at least two views are required. Although a drawing is not a picture, it is always advisable to select the views that require the least effort to read. Each view must have a part in the description; otherwise it is not needed and should not be drawn.

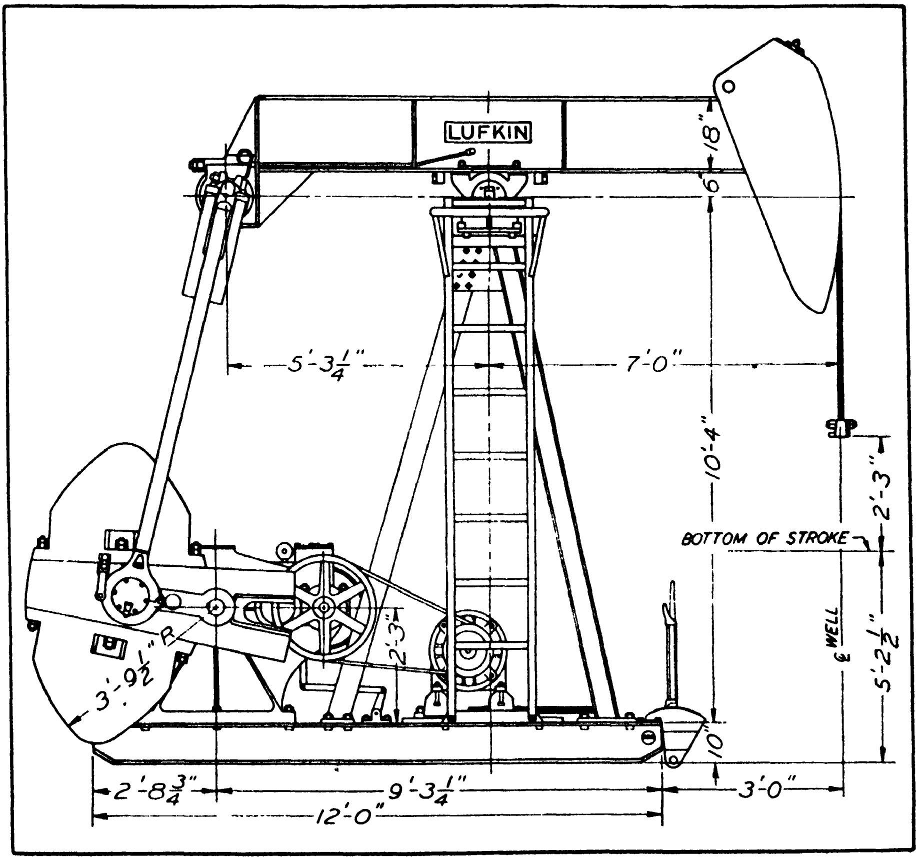


Figure 11·6 An outline assembly drawing. (Lufkin Foundry & Machine Co.)

In some cases one view is all that is necessary, provided a note is added or the shape and size are standard or evident. Complex pieces may require more than three views, some of which may be partial views, auxiliary views, and sectional views. The reason for making the drawing must always be kept in mind when a question arises. The final test of the value of a drawing is its clearness and exactness in giving the complete information necessary for making the piece.

11·6 Choice of Scale. The choice of scale for a detail drawing is governed by three things: (1) the size necessary for showing all details clearly, (2) the size necessary for carrying all dimensions without crowding, and (3) the size of paper used. It is always desirable to make detail drawings to full size. Other scales commonly used are half, quarter, and eighth (see Art. 2·10). Such scales as 2″ = 1′, 4″ = 1′, and 9″ = 1′ are to be avoided. If a part is very small, it is sometimes drawn to an enlarged scale, perhaps twice full size.

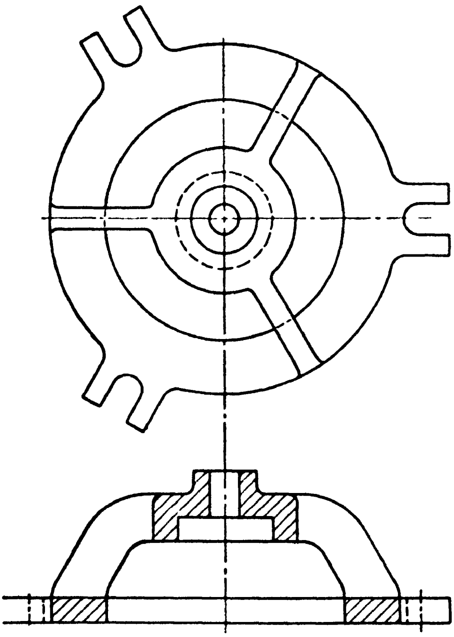


Figure 11·7 A symmetrical section.

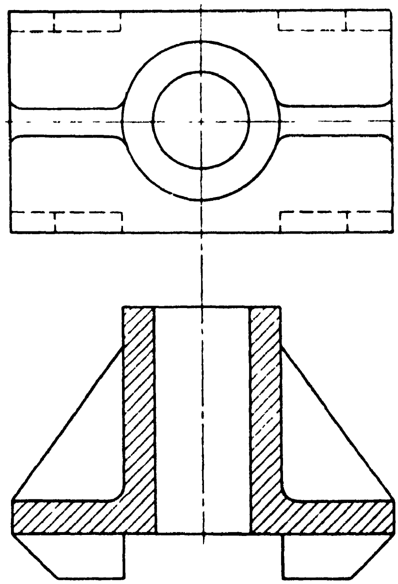


Figure 11·8 Rib in section.

When a number of details are drawn on one sheet, they should, if possible, be made to the same scale. If different scales are used, they should be noted near each drawing. A detail or part detail drawn to a larger scale may often be used to advantage on assembly drawings. This will save the making of separate detail drawings. General assembly drawings can be made to such a scale as will show the desired amount of detail and work up well on the size of paper used. Sheet-metal pattern drawings for practical use are always made full size, although practice models may be constructed from small-scale layouts.

11·7 Grouping and Placing Parts. When a number of details are used for one machine only, they are often grouped on a single sheet or set of sheets. A convenient arrangement is to group the forging details together, the brass details together, and similarly for other materials. In general, it is well to represent parts in the position that they will have in the assembled machine, with related parts near each other. Long pieces, however, such as shafts and bolts, are drawn with their long dimensions parallel to the long dimension of the paper.

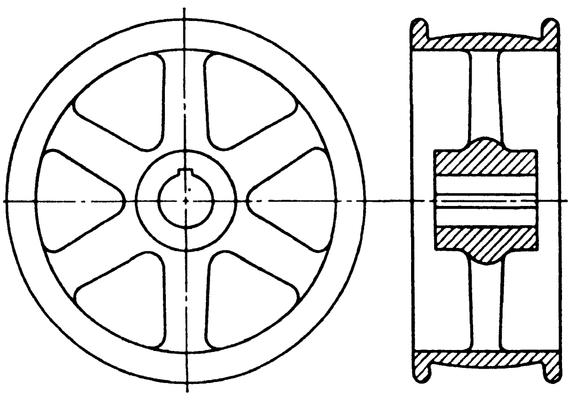


Figure 11·9 Pulley in section.

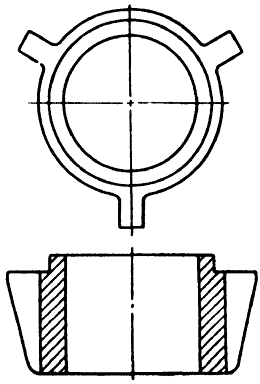


Figure 11·10 Lugs in section.

11·8 Conventional Representation. The principles upon which the description of shape by means of views is based have been explained. They form the basis for working drawings. In the actual use of mechanical drawing, it has been found desirable under certain conditions to violate the rules previously given. The reason for this must be thoroughly understood in every case, as well as the method of making the necessary changes in representation.

11·9 Sectional Views. Regular sectional views were explained in Chap. 6. When regular sections result in complicated or misleading views, they are modified. Thus the sectional view of a symmetrical piece, drawn as in Fig. 11·7, gives a better representation than a true section.

11·10 Sections through Ribs, Arms, etc. When a section passes through a rib or pulley arm, the drawing is made as in Figs. 11·8 and 11·9, where the plane is thought of as being just in front of the rib or arm. In Fig. 11·10 the lugs are shown as symmetrical and are not sectioned. A true section in these figures would give the idea of a very heavy solid piece. Shafts, rivets, and bolts are represented in full as in Figs. 11·11 to 11·13. When a section or elevation of a drilled flange is drawn, the holes are shown at their true distance from the center regardless of where they would project (Fig. 11·14).

A revolved section is sometimes inserted in a view to show the shape, as in Fig. 11·15.

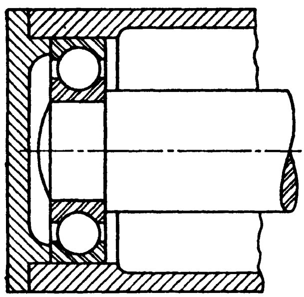


Figure 11·11 Ball bearing in section.

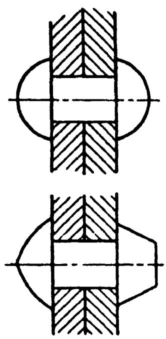


Figure 11·12 Rivets.

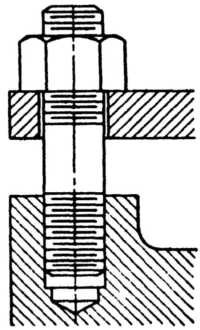


Figure 11.13 Stud.

11·11 Rule of Contour. In general, preserve the characteristic contour of an object. Sections or elevations of symmetrical pieces are sometimes hard to read when drawn in true projection. It is usual in

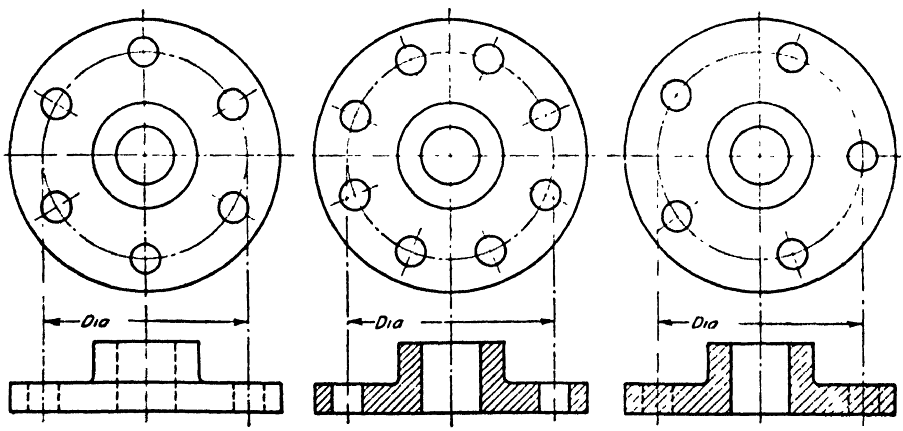


Figure 11·14 Flanges in elevation and section.

such cases to revolve a portion of the object until the characteristic contour shows. This has been done in Figs. 11·16 and 11·17 which illustrate applications of the rule of contour.

It is always desirable to show true distances even though the views do not project. This may be illustrated by bent levers and similar pieces which are represented by revolved or stretched-out views as in Fig. 11·18.

Figure 11·15 Revolved sections.

11·12 Rough and Finished Castings. Castings are made by pouring melted cast iron into molds formed in sand. Wooden patterns are used to form the mold. The cooled iron as removed from the mold has surfaces roughened by contact with the sand. Sometimes the casting can be used in this form, but more often some of the surfaces must be finished or made smooth and brought to size by machining.

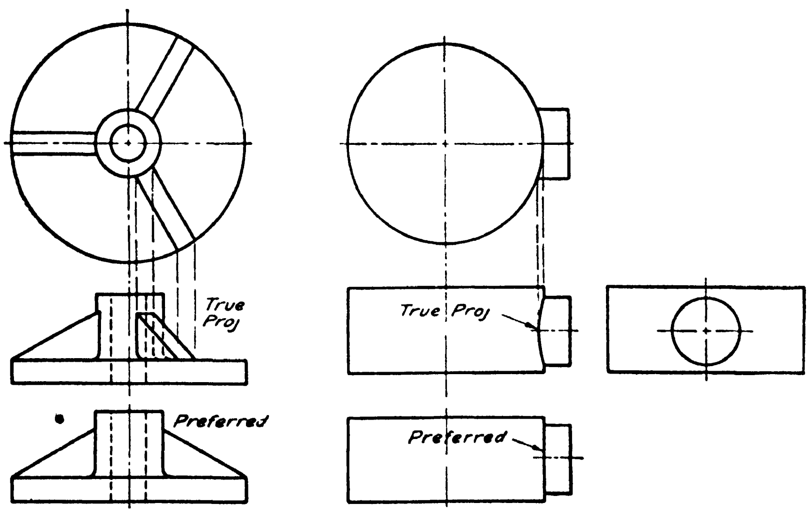


Figure 11·16 The rule of contour.

Round surfaces are finished on a lathe or similar machine. Flat surfaces are finished on a shaper, planer, milling machine, or similar machine.

Finished surfaces must always be indicated on a drawing and, when necessary, the degree of accuracy must be specified.

11·13 Fillets and Rounds. Sharp corners and edges are generally undesirable on unfinished machine parts with respect to strength and appearance. For this reason, interior corners are filled in with fillets, and exterior corners are rounded.

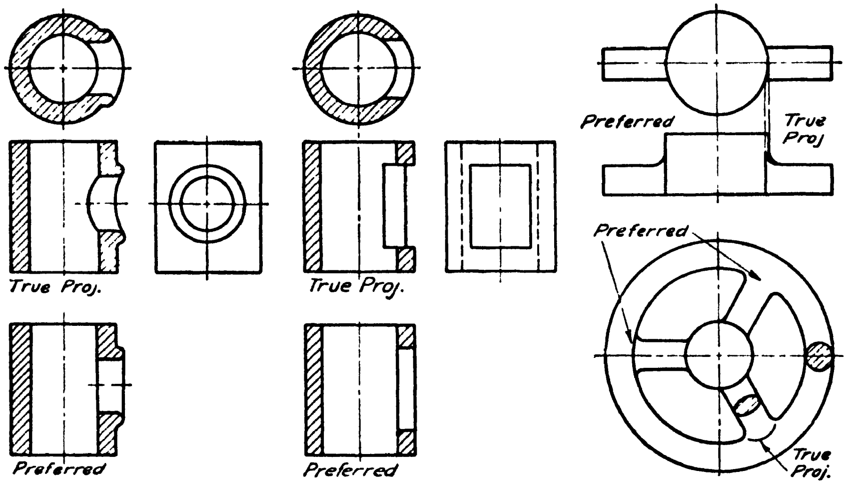


Figure 11·17 The rule of contour.

11·14 Pulleys and Flywheels. Included under this general head are pulleys for belt transmission, flywheels for the storing of energy, and handwheels for adjustment. Each has a rim, arms, and a hub.

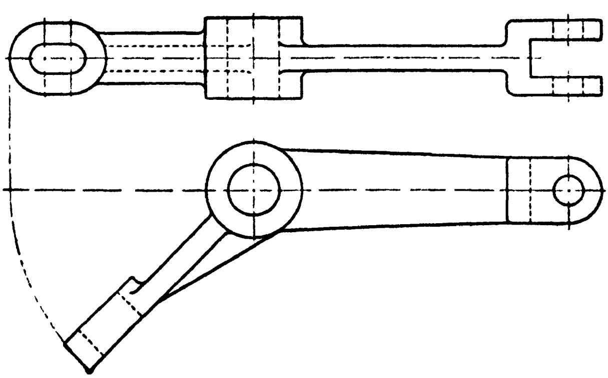


Figure 11·18 A stretched-out view.

Belt pulleys (Fig. 11·19) are made of cast iron, steel, wood, paper, etc. The face of a belt pulley is generally crowned (made higher in the center). The crown tends to keep the belt centered. Sometimes flanges are used on small belt pulleys. For V-belts, specially shaped pulleys are used as illustrated. For rope driving, grooved pulleys are used.

Flywheels have heavy rims which store up or give out energy when the speed changes. The rim of a flywheel is, therefore, thick in proportion to its width in order to concentrate weight. Flywheels are made in many forms for use on steam engines, gas engines, presses, and other machinery where their regulating action is needed.

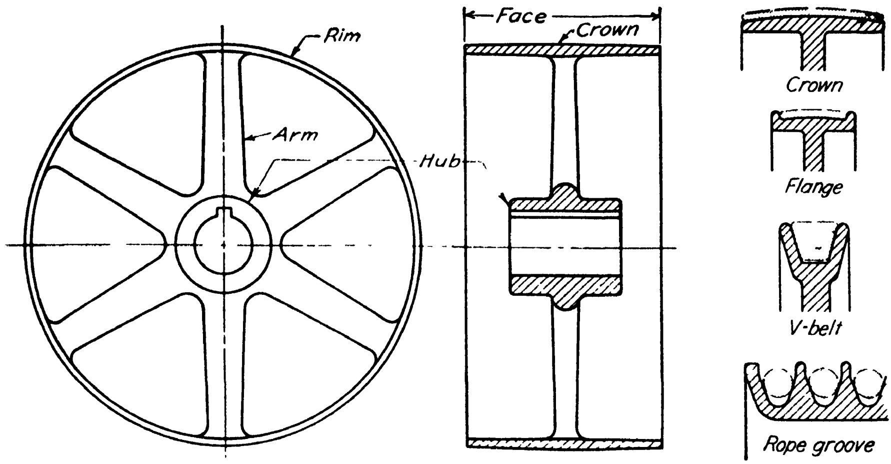


Figure 11·19 Pulleys and flanges.

11·15 Bearings. Bearings may be either flat, as used on planer ways, or round, as used for shafts. Plain, ball, or roller bearings are designed for use under varying conditions of load and speed.

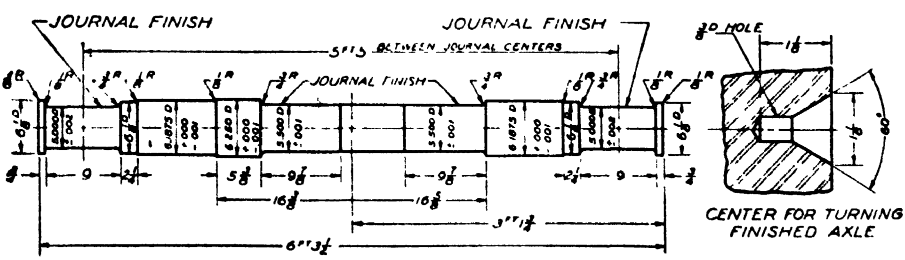


Figure 11·20 A shaft drawing.

Plain bearings are generally lined with Babbitt metal or some other substance that is softer than the shaft in order to reduce losses due to friction. A hole through a piece of metal is the simplest type of bearing. It may or may not be lined or bushed.

11·16 Shafting. Shafting drawings are of two general kinds. Transmission or line-shaft drawings are made to show the location of pulleys, gears, bearings, keyways, etc. The diameter and length of the shaft must be shown, together with the locating dimensions and notes specifying the sizes and kinds of the various features. Shafting is made of either hot-rolled or cold-rolled steel.

Drawings for machine shafts are made in the same way as for other machine parts (Fig. 11·20). Complete information must be given by dimensions and notes. Shafts are made of steel of a grade suited to the purpose for which they are used and are machined to size.

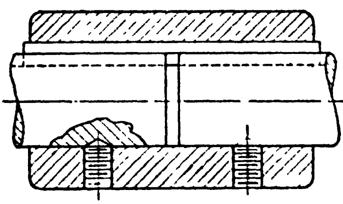


Figure 11·21 Sleeve coupling.

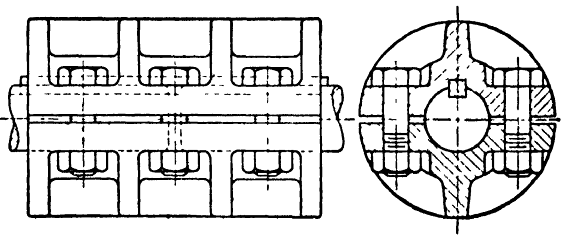


Figure 11·22 Split coupling.

11·17 Shaft Couplings. For joining lengths of line shafting end to end, couplings of various types are used. Two forms of sleeve couplings are illustrated in Figs. 11·21 and 11·22. A flange coupling is shown in Fig. 22·151, and an Oldham coupling in Fig. 22·195. The latter is used when the shafts are parallel but may be slightly out of line with each other.

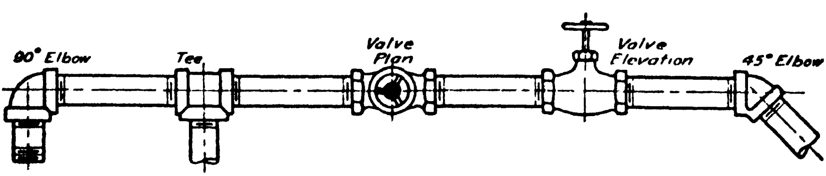


Figure 11·23 Screwed pipe fittings.

11·18 Pipe. Pipe is used in conveying fluids and is made of various materials—lead, brass, wrought iron, steel, cast iron, wood, concrete, etc.

For steam, gas, and similar purposes standard pipe of steel or iron is commonly used. Such pipe is specified by the *nominal* inside diameter, which differs from the actual diameter. The dimensions for pipe in general use (formerly known as "Standard") are given in the Appendix, page 426.

This former standard was used for ordinary pressures of around 125 lb. per sq. in. In addition extra heaxy (X) pipe was made with thicker

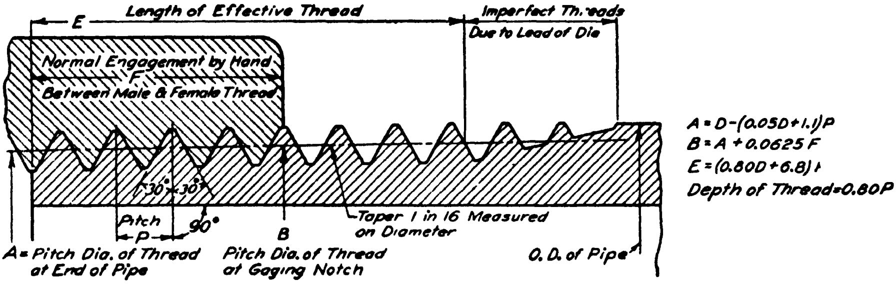


Figure 11·24 American Standard pipe thread.

walls for heavier pressures, but with the same outside diameter as for the standard pipe. This reduced the inside diameter for the same nominal size. Double extra heavy (XX) pipe kept the same outside diameter but reduced the inside diameter, and was for still higher pressures. Large pipe, over 12 in. in diameter, was called "O.D. pipe" and was specified by the outside diameter and thickness of metal.

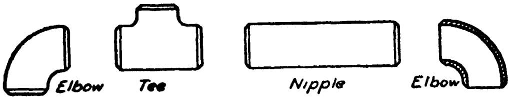


Figure 11·25 Welded fittings.

Present practice is covered in the published standard of the American Standard Association, "American Standard Wrought-iron and Wrought-steel Pipe" (ASA B36-1939). This gives wall thicknesses and weights for different schedule numbers and replaces the former Standard, Extra Heavy (X), and Double Extra Heavy (XX) standards.

11·19 Pipe Threads and Fittings. Ordinarily, pipe is made up or put together with fittings. The ends of the pipe may be threaded or plain. Several forms of screwed (threaded) fittings are shown in Fig. 11·23. The American Standard form of pipe thread (Fig. 11·24) is used on screwed pipe and fittings. Plain (beveled)-end pipe and fittings (Fig. 11·25) are welded together. Flanged fittings and pipe (Fig. 11·26) may be used for large sizes of pipe, or the pipe may be welded.

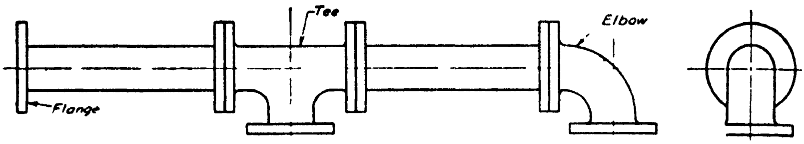


Figure 11·26 Flanged fittings.

11·20 Sizes of fittings are specified by the nominal size of pipe with which they are used. Reducing fittings are used to join different sizes of pipe. The size is specified by giving the largest run opening first, then the opposite end of the run. For tees and crosses the side outlets are given last (Fig. 11·27).

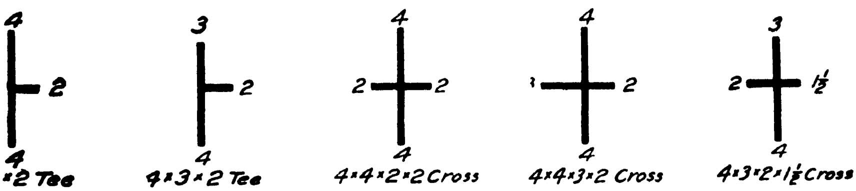


Figure 11·27 Sizes of pipe fittings.

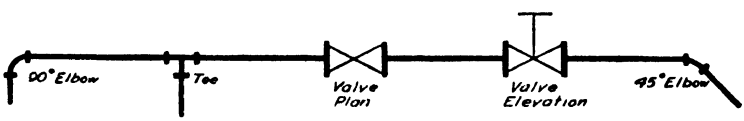


Figure 11·28 Single-line conventions

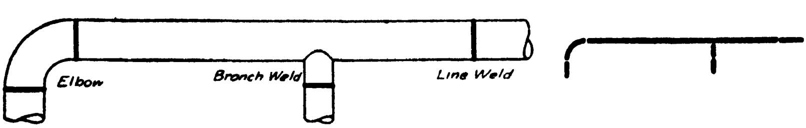


Figure 11·29 Welded-pipe representations.

11·21 Piping Drawings. Drawings for piping layouts are made as illustrated in Fig. 11·23, with dimensions and notes added to specify sizes, kinds, and location. For small-scale drawings and sketches, the single-line conventions of Fig. 11·28 are used. Welded piping may be shown as in Fig. 11·29. Pictorial methods of representation are often convenient.

TEXT-FILMS

The following McGraw-Hill Text-film, although not correlated directly with it, may be used profitably as a follow-up to Chap. 11:

Shop Procedures (10-min. sound motion picture)

This film shows how drawings are used in every stage of shop production—in the patternmaking shop, the foundry, the forging shop, the machine shop, and the assembly shop. As this theme is developed, the student is provided with a glimpse of the operation of basic machines. Finally, the film points out that people can work together only if draftsman and shop worker share the common knowledge of the language of mechanical drawing.

A follow-up filmstrip summarizes important points of the film and presents questions for review and discussion.

CHAPTER 12. Pictorial Drawing

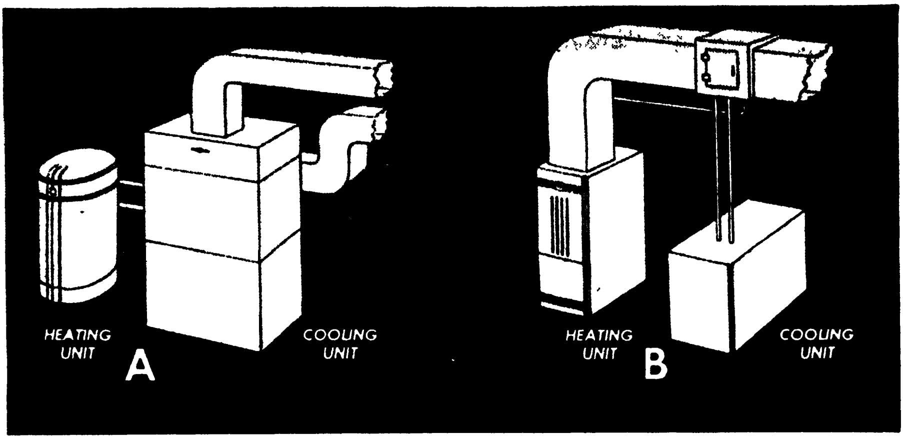


Figure 12·1 All-year air-conditioning units represented by pictures.

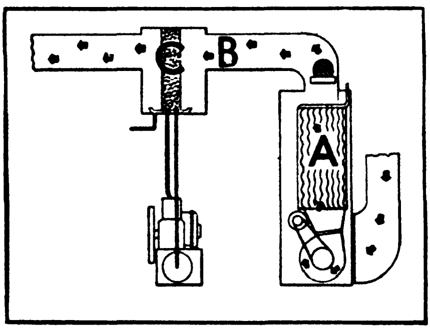


Figure 12·2 All-year air conditioning.

12·1 On working drawings the shape description is always done by the exact method of separate views, or orthographic projection, as studied in the previous chapters. In addition to a knowledge of this system of drawing, a draftsman should be able to make a pictorial view, either freehand or with instruments. The ability to make a pictorial sketch or drawing quickly and effectively is of great value in preliminary designing, in aiding in the reading and visualization of a drawing, in showing the appearance of an object to persons not able to read orthographic projection, and in illustrating notes, reports, and published articles. In the study of drawing, one of the best exercises is to translate orthographic drawings into pictorial drawings.

12·2 Pictorial drawings are used extensively to show *exploded views* on production drawings (Chap. 13), to illustrate parts lists, and to explain the operation of machines, apparatus, and equipment. For example, Figs. 12·1 and 12·2 are illustrations used by the General Electric Company to explain air-conditioning units for homes. The

G-E boiler teamed with a G-E air conditioner is pictured at A in Fig. 12·1 and a G-E warm air conditioner teamed with a cooling unit is pictured at B. The working of a year-round air conditioner is shown in Fig. 12·2 and described as follows:

In summer, air comes down the return duct to the conditioner (A) where it is first filtered and gently blown into the supply duct (B). The burner is off, but the cooling coil (C) in the supply duct is on. Air is cooled and relieved of moisture (dehumidified) before it goes upstairs to refresh your rooms. In winter, the cooling coil is off but the burner is in use. Returning air comes down the same duct, is cleaned by the same filter, circulated by the same blower, warmed, humidified, and sent up the same supply ducts.

These two figures show how pictures and diagrams can be used together to explain operations and equipment.

12·3 Pictorial Views. By those familiar with the subject, sketches are often made in *perspective*, showing the object as it would actually appear to the eye as illustrated in Fig. 12·3, Spaces 1 and 2. An easier way, although the result is not so pleasing in appearance as a well-made perspective, is to use one of the pictorial methods of projection, such as isometric drawing, Space 3, and oblique projection, Space 4. These all show three faces in one view and have the advantage that the principal lines can be measured directly. Although similar in effect, these three methods should not be confused.

12·4 Isometric Drawing. This simple method is based on revolution, as illustrated in Fig. 12·4, which shows three views of a cube in the usual position in Space 1; three views when the cube has

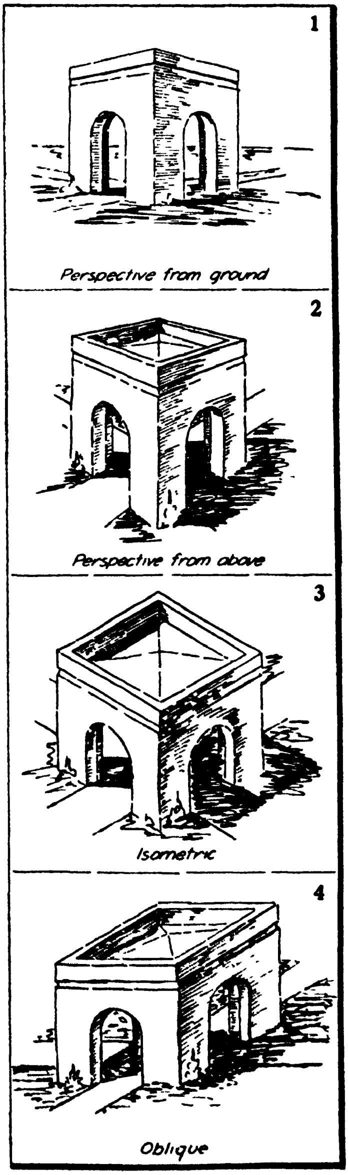


Figure 12·3 Kinds of pictorial drawing.

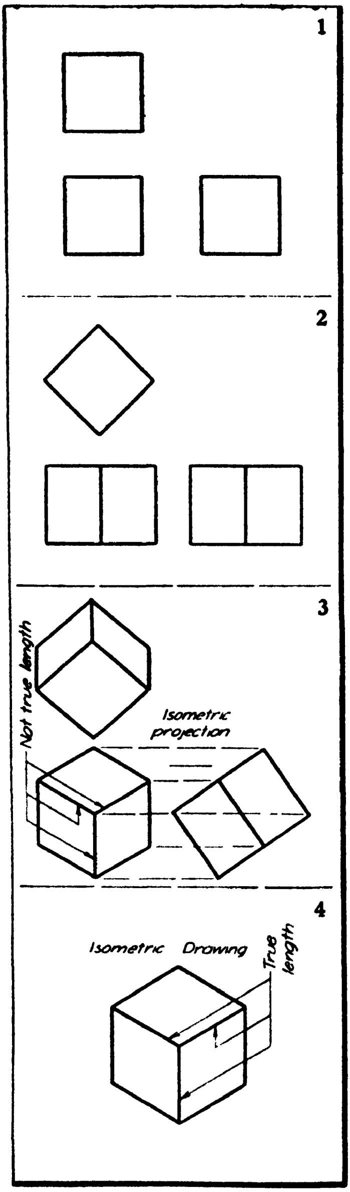


Figure 12·4 The isometric cube.

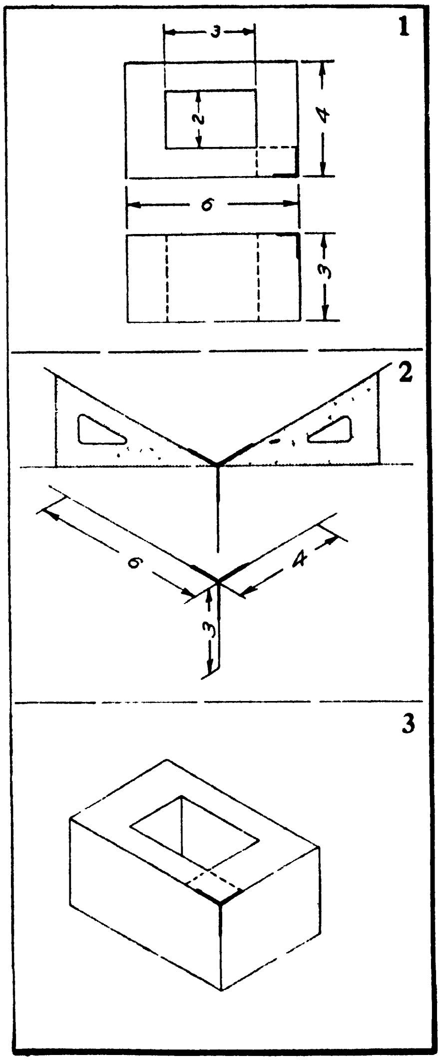


Figure 12·5 Isometric axes. First position.

been revolved about a vertical axis, so that two faces show as equal rectangles in the front view (Space 2); and three views when the cube has been revolved forward (tilted up on one corner) through such an angle that the front view shows three faces equal in shape and size (Space 3). This front view is called an *isometric*[1] projection.

[1] Isometric, equal measure.

In this position, the edges would evidently not show in their true length. An *isometric drawing* of the same cube is of the same shape (Fig. 12·4 in Space 4) but a little larger in size as the edges are drawn in their true length instead of in the foreshortened length. This variation in size does not affect the pictorial value of the view for shape description, but it does simplify the drawing of the view because all measurements can be made with the regular scale. This makes it possible to draw the desired pictorial view at once without projecting from other views or using a special scale.

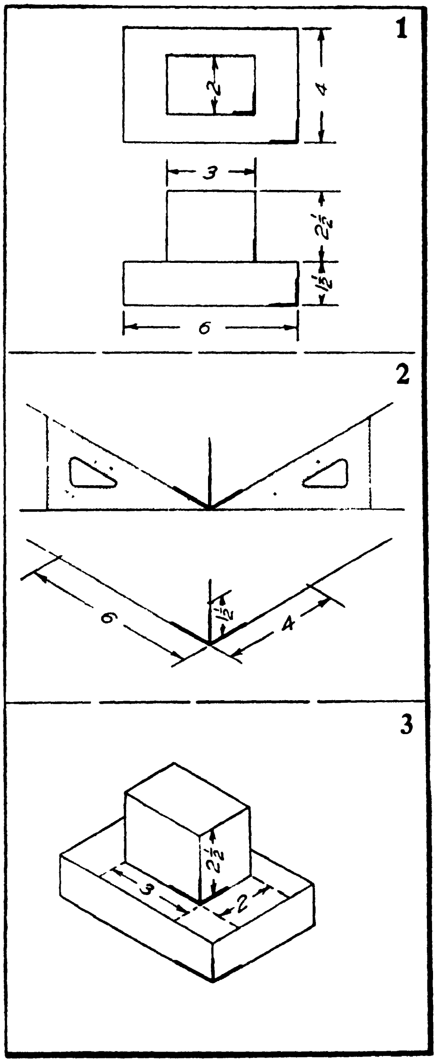


Figure 12·6 Isometric axes. Second position.

Isometric drawings are thus built on a skeleton of three lines representing the three edges of the cube. These three lines form three equal angles of 120° and are called the "isometric axes." One is drawn vertically, the others with the 30° triangle, as shown in Fig. 12·5. The intersection of these lines would be the front corner of a block with square corners. Measuring the length, breadth, and thickness of the block on the three axes and drawing lines through these points parallel to the axes will give the isometric drawing of the block. The arrangement of the axes in Fig. 12·5 is the first position and is based upon the three edges of the cube that meet at the front corner as in Fig. 12·4, Space 3. The axes may be arranged in different ways provided their relative positions are not changed. It is often more convenient to place the axes in the second position using the lower corner, Fig. 12·6.

Any line on the object parallel to one of these edges is drawn parallel to it and is called an *isometric line*. The first rule of isometric drawing is: *Measurements can be made only on isometric lines.* The second rule is: *Remember the isometric cube.*

12·5 Nonisometric Lines. Lines not parallel to any of the isometric axes are called "nonisometric" lines. Such lines will not show in their true length and cannot be measured; they must be drawn by locating their two ends.

Angles between lines on isometric drawings do not show in their true size and cannot be measured in degrees. All the angles of a cube are right angles, but in the isometric drawing some would measure 120° and some 60°. In the drawing of angles other than 90°, the lines forming them must be transferred from the orthographic views as shown in Fig. 12·7. To make an isometric drawing of the packing block shown (Space 1), first drop perpendiculars on the front view from the points *D* and *E*, giving the construction lines *DF* and *EG*. Then draw the two isometric axes, *AB* and *AC*, as in Space 2, and measure the distances *AF* and *CG*. Draw vertical construction lines at *F* and *G* equal in length to lines *DF* and *EG* taken from the front view in Space 1 to locate points *D* and *E*. The nonisometric lines *AD* and *CE* can then be drawn and the isometric view finished as in Space 3. The isometric representations of the angles will be as shown at *DAF* and *ECG*. Any angle may be located on the isometric view by laying off the two legs of a right triangle.

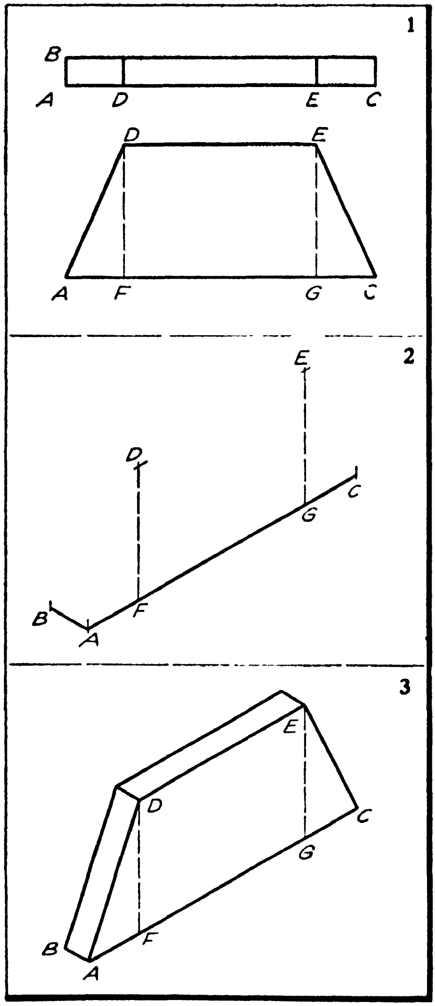


Figure 12·7 Construction for nonisometric lines.

12·6 Circles will appear as ellipses in isometric drawing, but instead of drawing a true ellipse, a four-centered approximation is usually made. To draw an isometric circle, first make the isometric drawing of the square that will contain it (Fig. 12·8, Space 1 at B). From the points of tangency, draw perpendiculars, as indicated at B. Their intersections will give four centers from which arcs may be drawn tangent to the sides of the isometric square. Two of these centers will fall on the intersections of the perpendiculars, as shown at C, and two at the corners as shown at D. Thus the entire construction may be made with the 60° triangle. Circles on the left or right surfaces of the object may be drawn in the same way, as shown at E, F, G, H in Fig. 12·8, Space 2.

The construction for quarter rounds is the same as for one-quarter of a circle. This is illustrated in Spaces 3 and 4 of Fig. 12·8. Note that the radius is measured along the tangent lines from the corner in each case and that actual perpendiculars are then drawn to locate the centers for the isometric arcs. It will be observed that r_1 and r_2 are found in the same way as the short and long radii of a complete isometric circle.

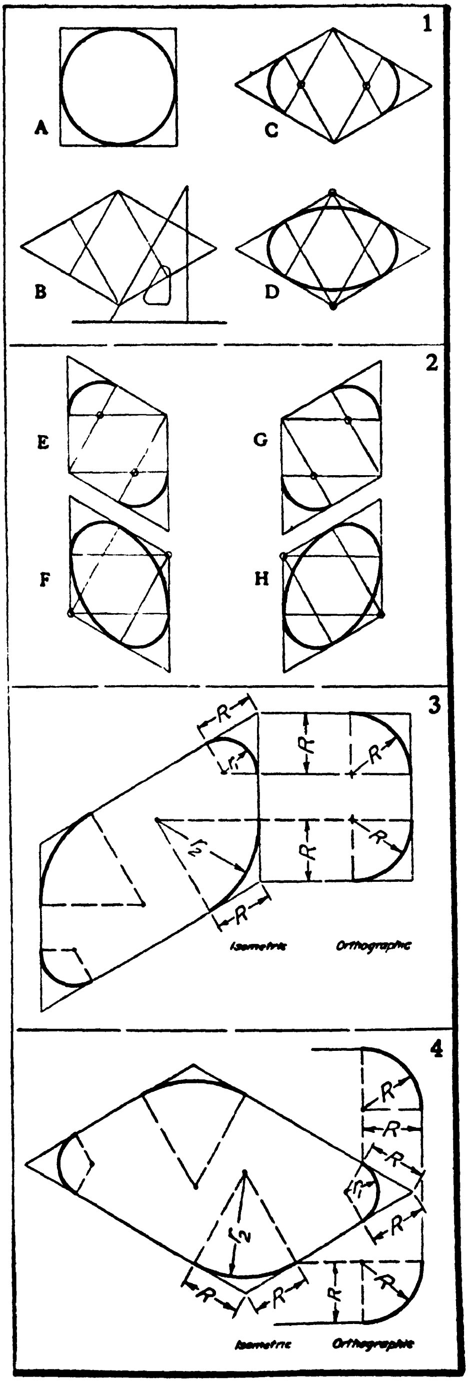


Figure 12·8 Construction for isometric circles.

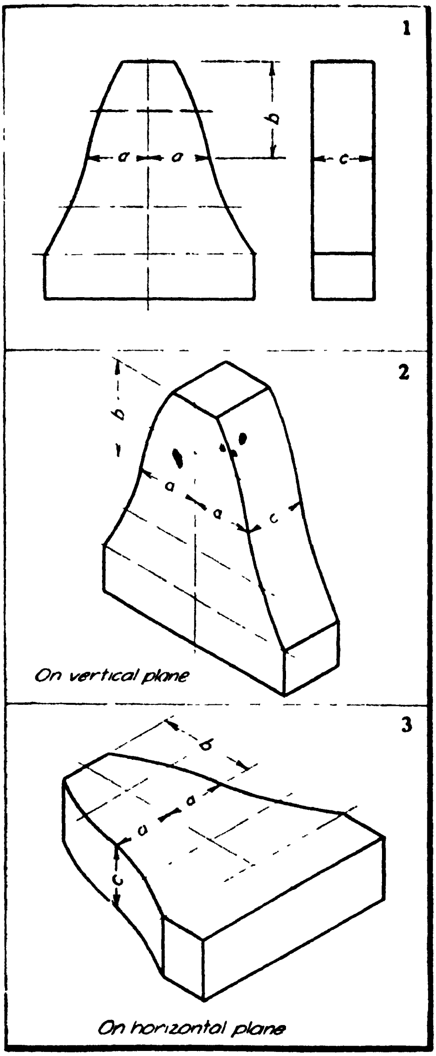


Figure 12·9 Isometric curves.

When an arc is more or less than a quarter circle it is sometimes possible to draw all or part of a complete isometric circle and use as much of it as is needed. In other cases it may be necessary to plot points as explained in Art. 12·7 for isometric curves.

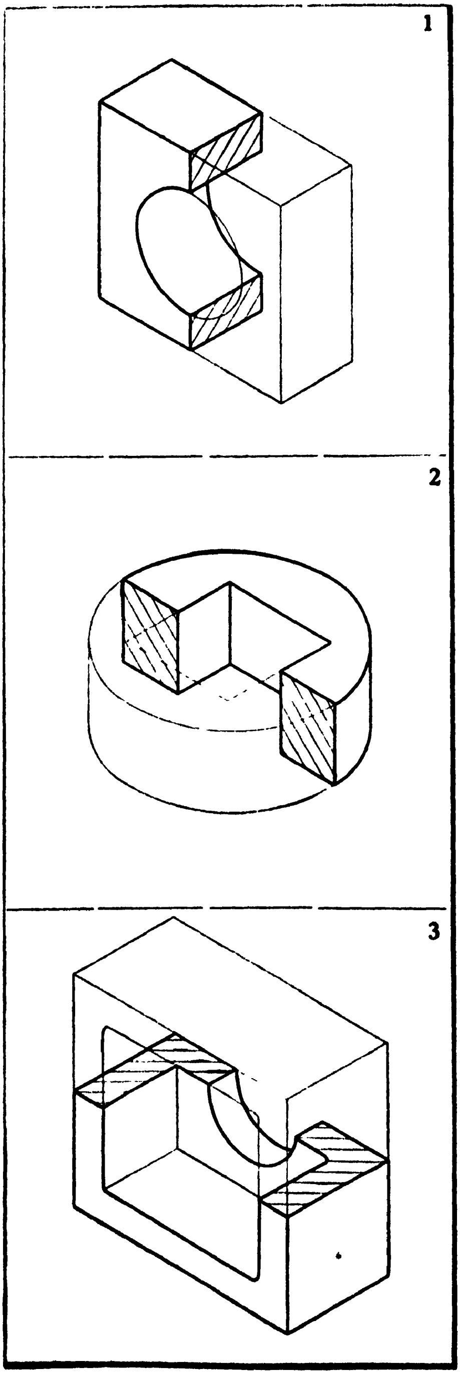


Figure 12·10 Isometric sections.

12·7 Isometric Curves. Curves other than circle arcs are drawn by plotting a series of points. This is illustrated in Fig. 12·9. First draw the orthographic view (Space 1) and locate a number of points by drawing lines as shown. Draw these same lines in isometric as illustrated for a vertical plane (Space 2) and a horizontal plane (Space 3). Then plot points by transferring distances from the orthographic to the isometric view, and draw a smooth curve through the points.

12·8 Sections. Isometric drawings are generally made as outside views, but sometimes a sectional view is needed. The section is taken on an "isometric plane," that is, on a plane parallel to one of the faces of the cube. Figure 12·10 shows isometric full sections taken on a different plane for each of the three objects (Spaces 1, 2, and 3). Note the fine lines indicating the part that has been cut away. Isometric half sections are illustrated in Fig. 12·11. The construction lines of Space 1 are for the object shown in Space 2. The construction lines of Space 3 are for the object shown in Space 4. Note the outlines of the cut surfaces in Spaces 1 and 3. The cut surfaces are sectioned with lines drawn with the 60° triangle. The section lines are drawn in opposite directions on the two surfaces so that they would coincide if revolved together.

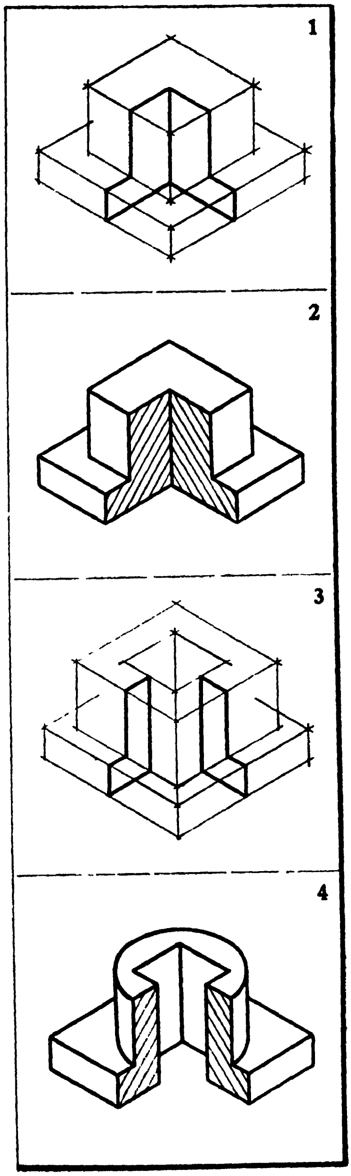


Figure 12·11 Isometric half sections.

There are two general methods of constructing isometric sections. One method is to draw the complete outside view, then draw the isometric cutting plane and remove the part of the view that has been cut away. A second method is to draw the section on the isometric cutting plane and then work from it to complete the view.

12·9 Making an Isometric Drawing. Problem: Make an isometric drawing of the guide shown in Fig. 12·12, Space 1.

1. Draw the axes *AB*, *AC*, and *AD*, in second position (Fig. 12·12, Space 2).

Measure from *A*, the length 3 in. on *AB*.
Measure from *A*, the width 2 in. on *AC*.
Measure from *A*, the thickness ⅝ in. on *AD*.

Through these points draw isometric lines, blocking in the base.

2. Block in the upright, making two measurements only, 2 in. and ¾ in.

3. Locate the center of the hole, and draw its center lines as shown. Block in a ¾-in. isometric square and draw the hole as an approximate ellipse by Art. 12·6. At the upper corners measure the ½-in. radius on each line as in Space 3, and draw real perpendiculars to find the centers of the quarter circles.

4. Finish the drawing as in Space 4.

12·10 Reversed Axes. Sometimes it is desirable to represent a part as viewed from below. This is done by reversing the axes, as in Fig. 12·13. Draw the orthographic views as in Space 1, then draw the axes in

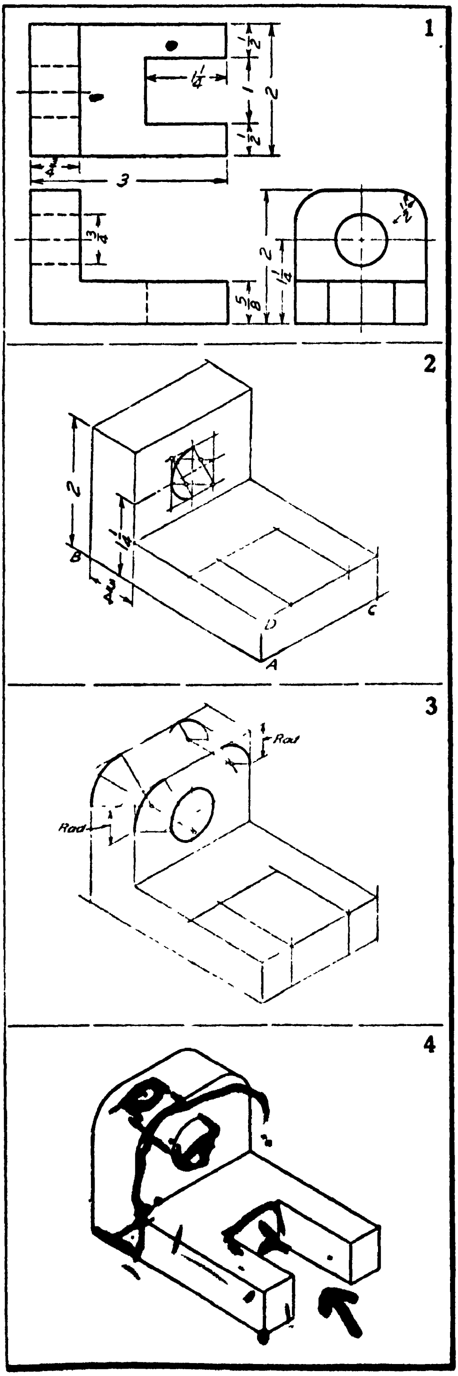


Figure 12·12 Making an isometric drawing.

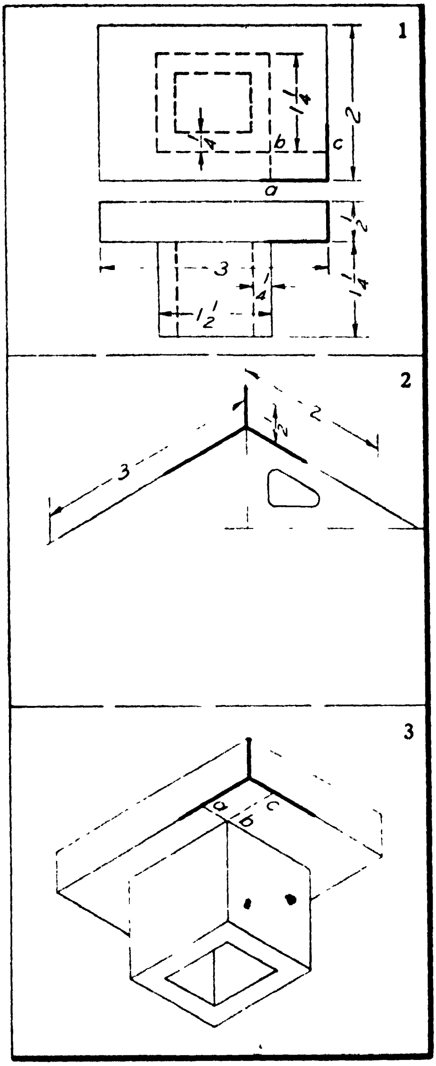


Figure 12·13 Reversed axes.

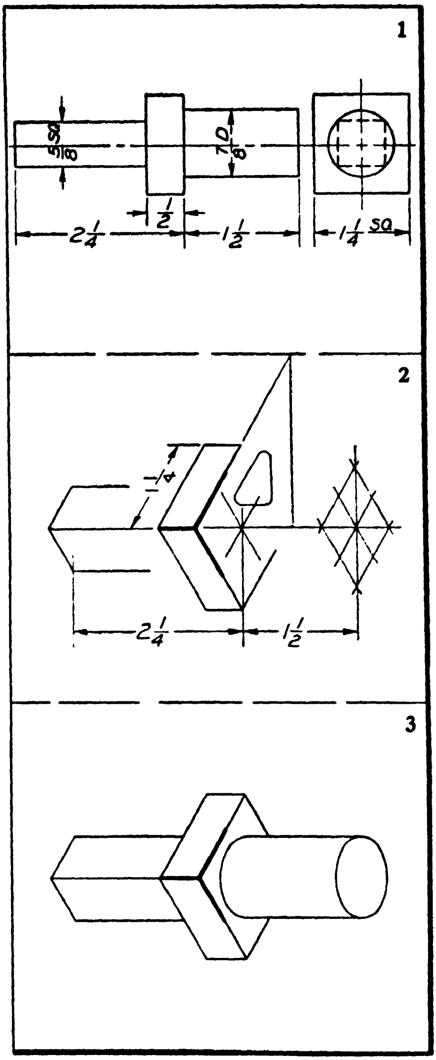


Figure 12·14 Long axis horizontal.

reversed position as in Space 2. Lay off the measurements and complete the view as in Space 3.

12·11 Long Axis Horizontal. Long pieces may be drawn with one axis horizontal as in Fig. 12·14. For the object shown in Space 1 draw the axes as shown by the heavy lines in Space 2. Lay off measurements as indicated parallel to the axes and proceed in the usual way to complete the view as in Space 3. Except for the positions of the axes, the view is drawn in the same way as any other isometric view.

12·12 Oblique Drawing. This form of pictorial drawing is based upon the theoretical principle that the object is placed parallel to the plane of projection and projected to it by oblique projecting lines instead of perpendicular ones. Practically, it is drawn on three axes, just as in isometric drawing, but two of the axes always make right angles with each other; *i.e.*, one axis is drawn vertically, one horizontally, and the third at any convenient angle (Fig. 12·15).

The same methods and rules that were used in isometric drawing apply to oblique drawing, but compared with isometric, oblique drawing has the distinct advantage of showing one face without distortion. Thus objects with irregular outlines can be drawn by this method much more easily and effectively than in isometric, and many draftsmen prefer it for practically all pictorial work.

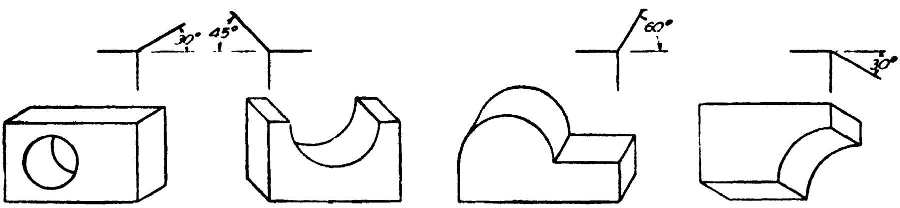


Figure 12·15 Axes in oblique drawing.

The first rule in oblique drawing is: *Place the object so that the irregular outline or contour faces the front.*

If there is no irregular outline, the second rule should be followed: *Always place the object so that the longest dimension shows in the front.*

12·13 Circles. On the front face, circles and curves show in their true shape (Fig. 12·16, Space 1). On other faces, circles and arcs may be approximated as in isometric, by drawing perpendiculars from the tangent points. In Space 1, a circle is shown as it would be drawn on a front plane, as it would be drawn on a side plane, and on a top plane. In Space 2, a circle is shown as it would appear on three faces of a cube, with the construction for locating the centers of the arcs. In Space 3, an oblique drawing is shown with arcs in a horizontal plane. In Space 4, an oblique drawing is shown with arcs in a side plane.

12·14 Making an Oblique Drawing. Problem: Make an oblique drawing of the bearing of Fig. 12·17, Space 1. Observe that all but two small circles can be shown in their true shape.

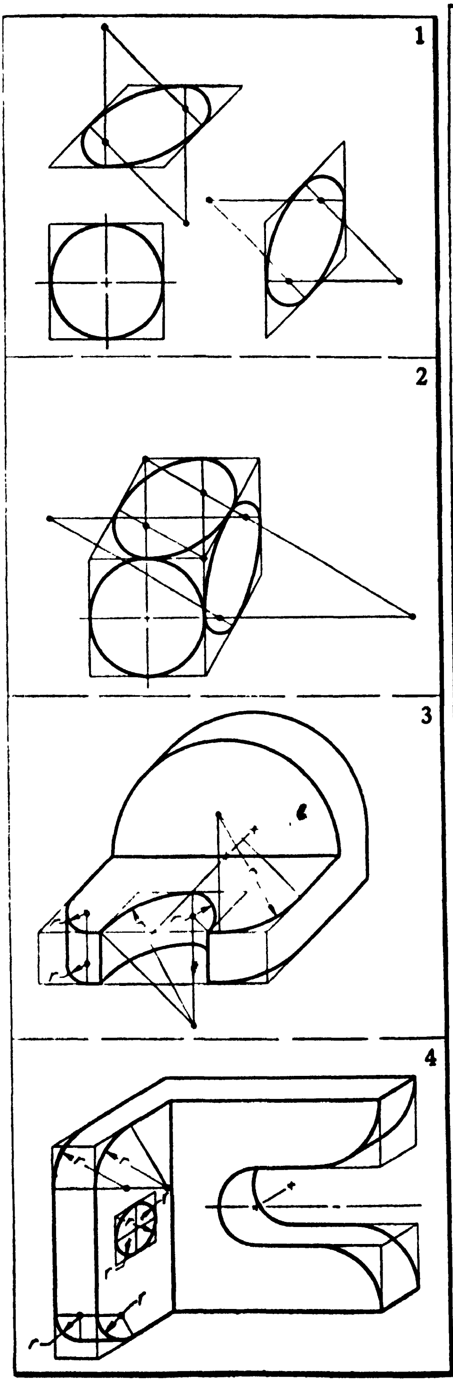


Figure 12·16 Circles on oblique drawings.

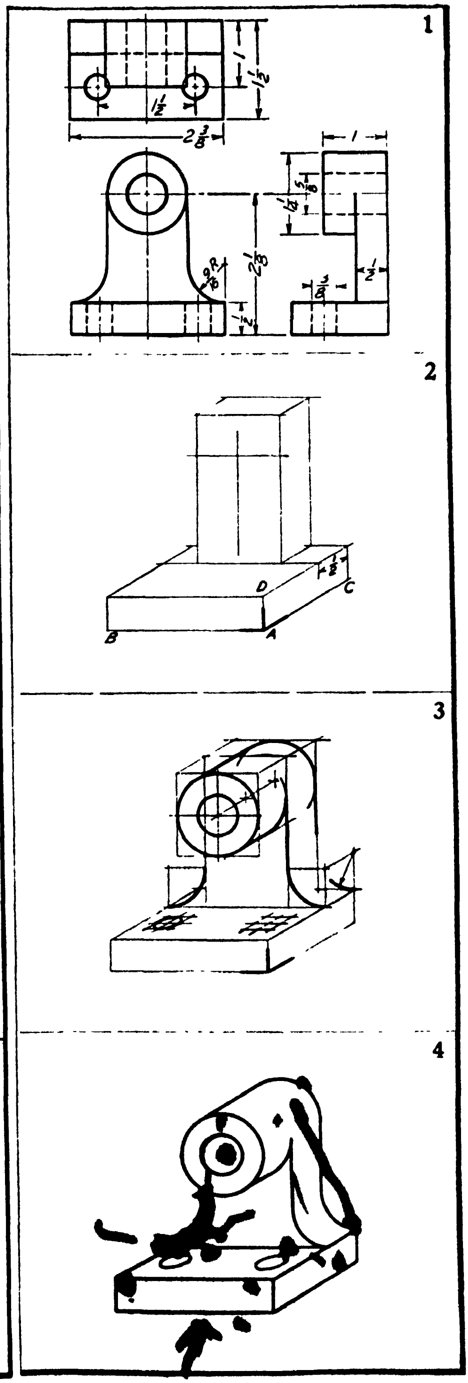


Figure 12·17 Making an oblique drawing.

1. Draw the axes for the base, *AB*, *AC*, and *AD*, in second position, and measure on them the length, width, and thickness of the base as in Space 2. Draw the base, and on it block in the upright, omitting the projecting boss, as shown in the figure.

2. Block in the boss, as in Space 3, and find the centers of all circles and arcs.

3. Draw the circles and circle arcs.

4. Finish the drawing as in Space 4.

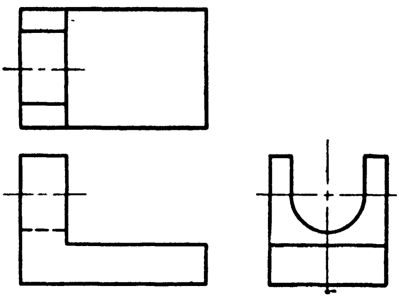


Figure 12·18 Yoke bracket.

12·15 Cabinet Drawing. In this form of drawing the axes are taken the same as in oblique drawing, but all measurements parallel to the oblique or cross axis or, in other words, all thickness measurements from front to back, are reduced one-half. It is used sometimes in making drawings of wood construction.

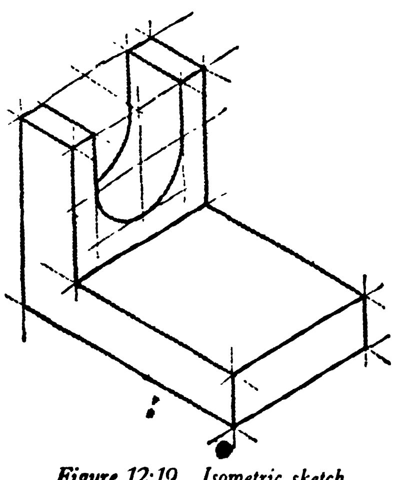


Figure 12·19 Isometric sketch.

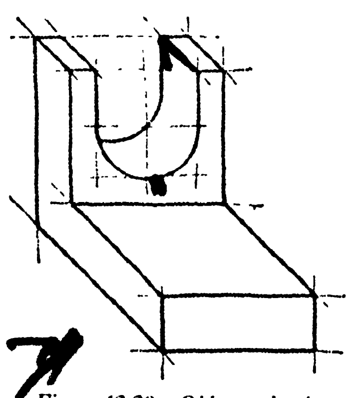


Figure 12·20 Oblique sketch.

12·16 Isometric Sketching. Freehand isometric sketches are of great help in reading orthographic views and in explaining objects or parts of construction. The orthographic views of a yoke bracket are shown in Fig. 12·18 and an isometric sketch in Fig. 12·19. The principles of isometric drawing form the basis of isometric sketching but, since sketches are not made to scale, their appearance may be improved by flattening, *i.e.*, by giving the axes an angle less than 30° with the horizontal, and by slightly converging the lines, as well as foreshortening the lengths, thus avoiding the distortion and giving the effect of perspective. This is sometimes called "fake perspective."

Always block in construction squares before sketching circles or arcs, and remember that the long axes of ellipses representing circles on the top face are horizontal.

Dimensioning a pictorial sketch is illustrated in Fig. 8·33.

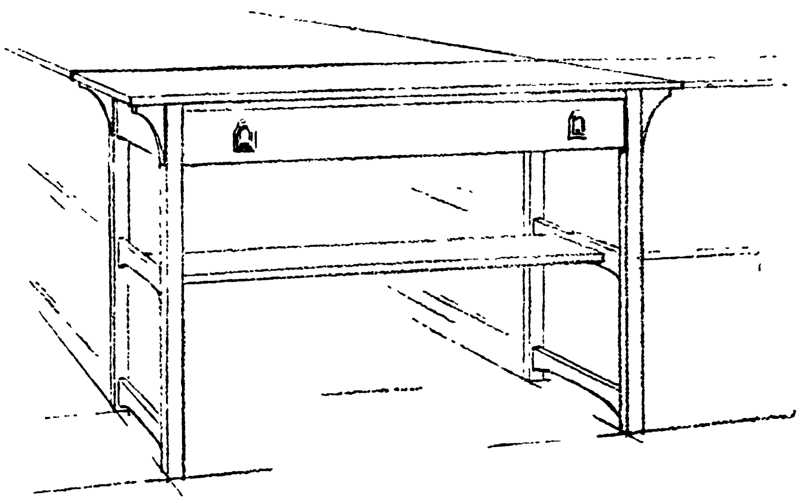


Figure 12·21 Angular perspective sketch.

12·17 Oblique Sketching. An oblique sketch is shown in Fig. 12·20 for the yoke bracket of Fig. 12·18. The principles of oblique drawing form the basis of oblique sketching, but the appearance can often be improved by reducing the thickness measurements.

Always block in construction squares before sketching circles or arcs (see Fig. 12·16).

12·18 Perspective Drawing.[1] Perspective drawing is the representation of an object as it actually appears to the eye. A sketch made in perspective thus gives the best pictorial effect. The elementary

[1] In the scope of this book the interesting subject of mechanical perspective construction cannot be taken up. With a knowledge of its methods, perspective drawings can be made from working drawings, as, for example, when an architect makes a picture of a proposed building, the result being as accurate as a photograph of the building (Fig. 19·1).

principles of perspective are familiar to most students through the study of freehand drawing, and they will find this knowledge of value in studying shape description.

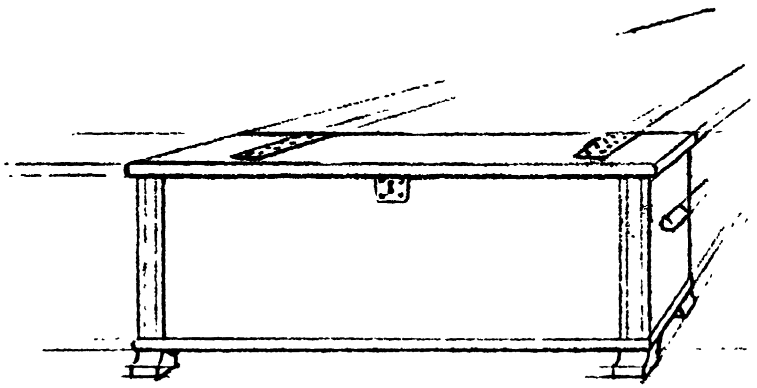


Figure 12·22 Parallel perspective sketch

In the perspective sketch shown in Fig. 12·21, it will be noted that the vertical lines remain vertical and that the two sets of horizontal lines each converge toward a point called the "vanishing point." These two vanishing points lie on a horizontal line at the level of the eye called the "horizon." The first rule is: *All horizontal lines vanish on the horizon.*

When the subject is turned at an angle, as in Fig. 12·21, the drawing is said to be in angular or "two-point" perspective.

If the object is turned so that one face is parallel to the front plane, the horizontal lines on that face, or parallel to it, remain horizontal and have no vanishing point. This drawing is called "parallel," or "one-point," perspective (Fig. 12·22).

12·19 Making a Perspective Sketch from the Object. In sketching from the object, place it below the level of the eye (unless very large) and so as to show the outline of shape to the best advantage. Start by drawing a line for the nearest vertical corner. From this, sketch lightly the directions of the principal lines, running them past the limits of the figure. Test the directions and proportionate lengths with a pencil as follows: With the drawing board or sketch pad held *perpendicular* to the line of sight from the eye to the object, hold the pencil at arm's length *parallel* to the board and rotate the arm until the pencil appears to coincide with the line on the model, then move it parallel to this position back to the board. This gives the direction of the line. To estimate the apparent lengths, hold the pencil in the same way and mark with the thumb (Fig. 12·23) the length of the pencil that covers the line. Rotate the arm with the thumb held

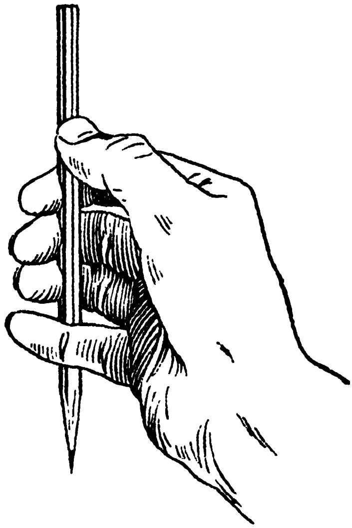


Figure 12·23 Estimating proportions.

in position until the pencil coincides with another line, and estimate the proportion of this measurement to the second line.

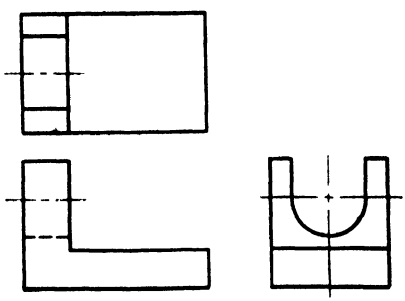


Figure 12·24 Yoke bracket.

Block in the enclosing squares for all circles and circle arcs. Work with light, free, sketchy lines, and do not erase any lines until the whole sketch is blocked in. Draw the main outlines first, then add details. Finally, brighten the sketch with heavier lines.

12·20 Making a Perspective Sketch from the Views. Orthographic views of a yoke bracket are shown in Fig. 12·24 and as sketched in angular perspective in Fig. 12·25.

To make a sketch or drawing in angular perspective when the orthographic views are given instead of the object itself, the method generally used is what is known as the "cone of rays" method. In this method, the plan is first drawn with its front corner against a line representing the picture plane, as shown in Fig. 12·25. Think of this as the top view of the object, with the picture plane standing up against the front edge. Imagine the observer standing out in front of the plane at the point *S*, looking at the object through the plane. There will be a ray of light from each point of the object to the observer's eye, and the picture as seen from this point will be the intersection of all these rays with the picture plane *VV'*. (To avoid distortion the station point *S* is taken at a distance from the picture plane at least twice the width or height of the object.) Thus, if lines are drawn from the point *S* to the different points on the plan, their intersections with *VV'* will give the widths of the picture. Remember that so far we are looking down on the edge of the picture plane and the picture is all in the line *VV'*. A horizontal line on the picture plane at a height above the ground equal to the height of the observer's eye will be the horizon. From *S* lines drawn parallel to the lines of the plan will pierce the picture plane on the horizon, giving the vanishing points *V* and *V'*. Now imagine the picture plane to be detached and moved forward, then laid down into the plane of the paper. In the figure this has been done for convenience so that the horizon of the picture plane coincides with the line *VV'*, which means practically that the line *GL*, which is the bottom edge of the picture plane, was drawn as far below *VV'* as the height of the observer's eye. At the intersection of *GL* and a perpendicular from the front corner of the plan, draw a vertical line representing the front edge of the object, and lines to *V* and *V'* for the lower horizontal edges. Perpendiculars dropped from the intersection of the rays with the picture plane will give the length and width of the object. Vertical measurements must all be made on the vertical line in the picture plane and vanished back to meet the location of the point to be measured. A study of Fig. 12·25 will show the method of finishing the sketch.

Compare the views in Figs. 12·19, 12·20, and 12·25, which are all pictures of the same object (the yoke bracket of Fig. 12·18 or 12·24).

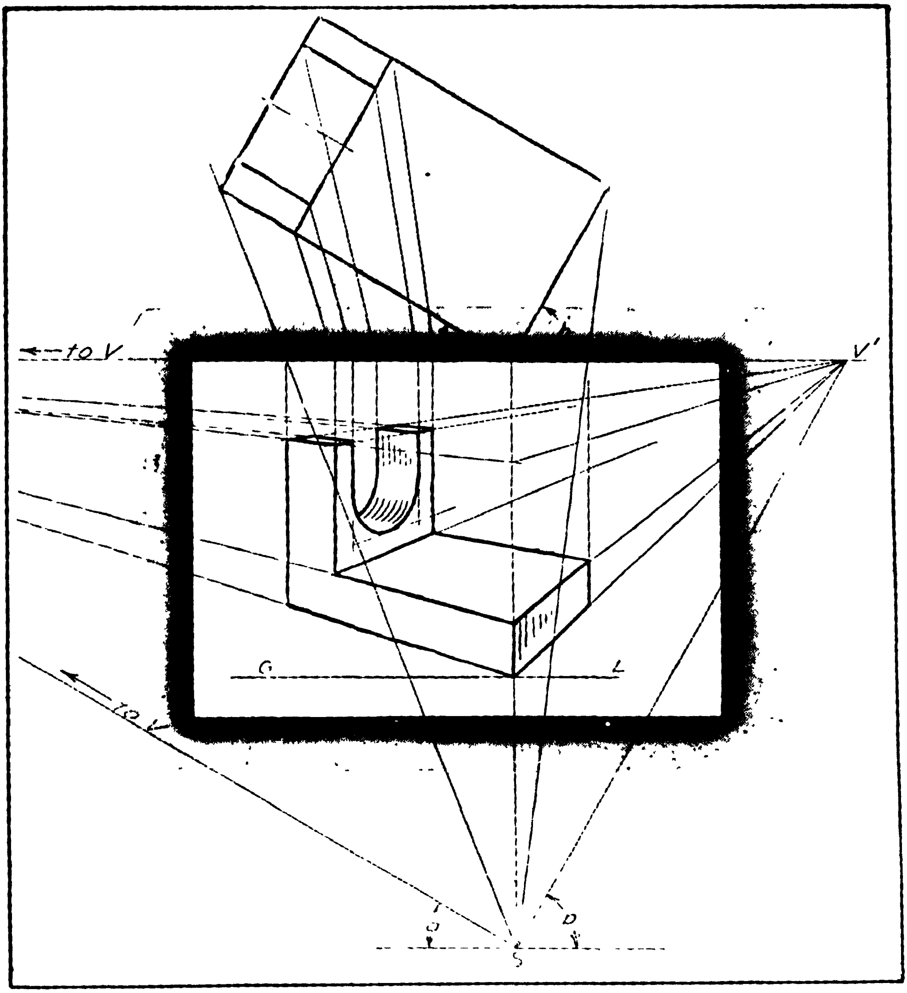


Figure 12·25 Making a perspective sketch.

CHAPTER 13. Production Illustration

Figure 13·1 Explaining a production drawing. (Boeing Aircraft Company.)

13·1 Production illustration consists of the use of pictorial drawings for the description of parts and their related positions, for the description of manufacturing processes, for separate parts or for a complete assembly line, for the description of installations and their operation, for the description of assembling operations, and for any other industrial or engineering purposes where they can expedite work and make understanding easier and more definite. In Fig. 13·1, two production drawings are being explained at the Boeing Aircraft Company. These two drawings are shown separately in Figs. 13·2 and 13·3. Observe the broken out and enlarged views to show details and the descriptive notes which are included.

Production drawings vary from simple sketches to elaborate shaded drawings. They may be based upon any of the pictorial methods, perspective, oblique, isometric, etc. The complete project may be shown or parts or groups of parts, and the views may be exterior, interior, sectional, *cut away*, *phantom*, etc. The purpose in all cases is to provide a clear and easily understood description. The previous chapters, in particular the chapters on Sketching and on Pictorial

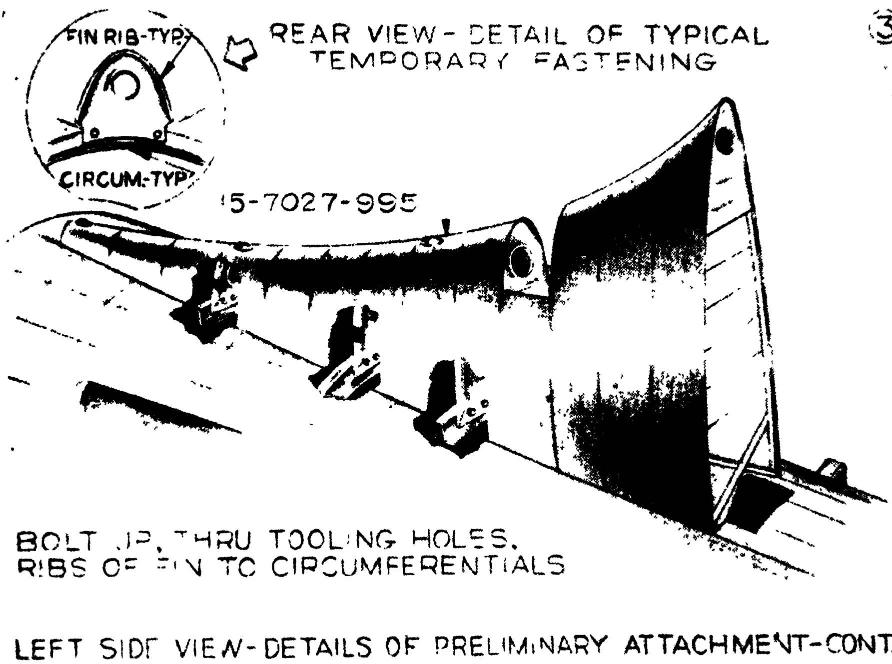


Figure 13·2 A production drawing. (Boeing Aircraft Company.)

Drawing, furnish the basis for making production illustrations. Drawings for use within the company's plant can be made by the regular draftsmen. Where artistic skill is necessary the work is done by specially trained artist-draftsmen or commercial artists.

Production illustration (pictorial drawing) has been used for many years for illustrated parts lists, for operation and service manuals and process manuals, and for similar purposes, but the aircraft industry has brought out its greatest values in all the stages of production from the preliminary design through the manufacturing processes and assembling to the completed plane together with illustrated service, repair, and operation handbooks.

13·2 Exploded Views. A single piece may be shown separated into elementary parts, or a whole construction may be broken down into either single pieces or into part assemblies. Such pictures are called "exploded views."

A single piece shown by orthographic views at A in Fig. 13·4, and pictorially at B may be exploded as at C which illustrates the principle

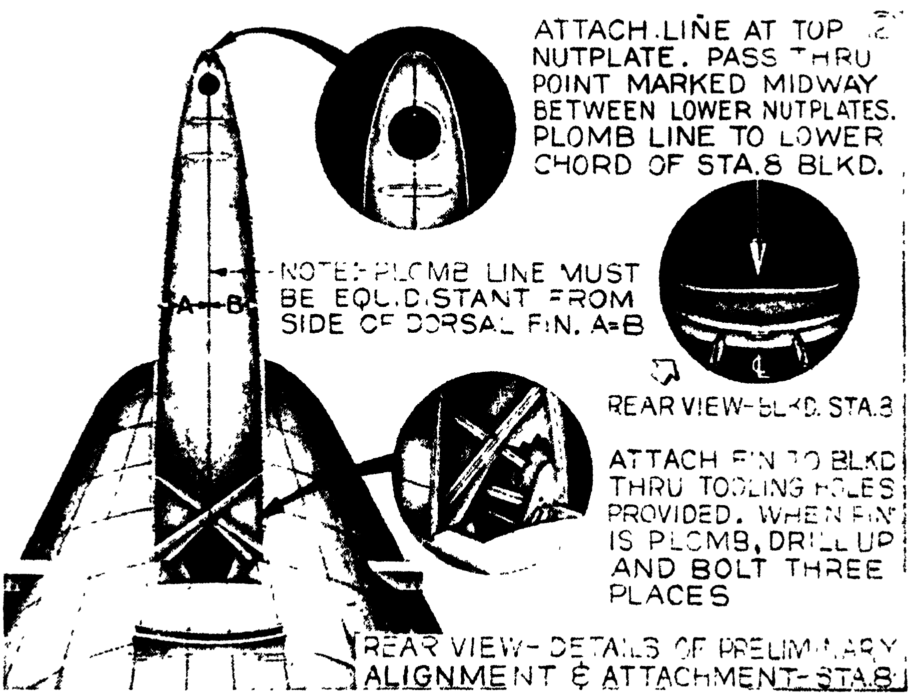


Figure 13·3 A production drawing. (Boeing Aircraft Company.)

of such views. The elementary parts are drawn as though projected from each other. Holes and other spaces may be thought of as negative parts.

Exploded views of simple constructions are shown in Figs. 13·5 and 13·6 and for a large assembly in Fig. 13·7 (major assembly breakdown for Bomber). All such views are based upon the same principle —projecting the parts from the positions that they occupy when put together, or just "pulling them apart."

13·3 Identification Illustrations. Pictorial drawings are very useful for identifying parts, especially for those people who have difficulty in reading regular drawings or blueprints, and for saving

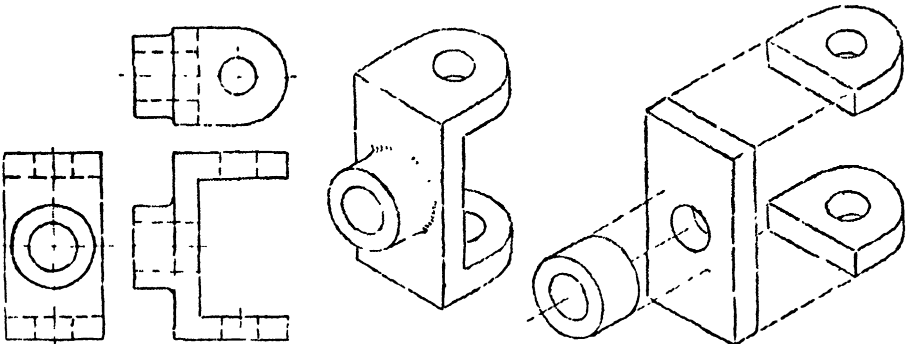


Figure 13·4 An exploded view.

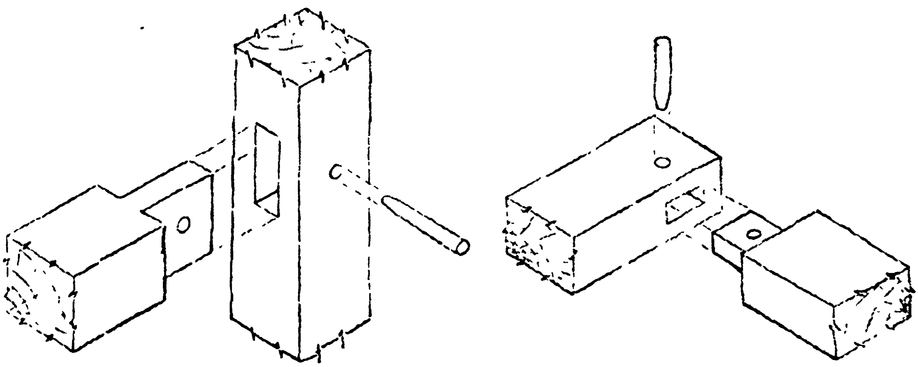


Figure 13·5 Exploded views.

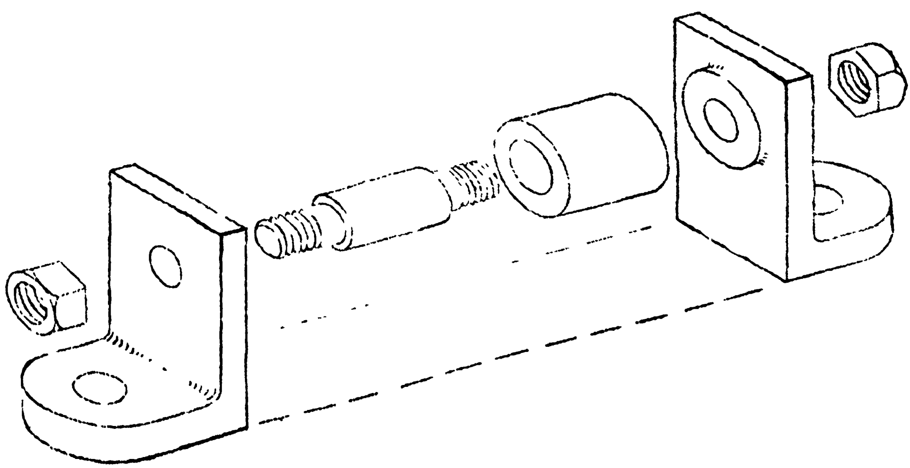


Figure 13·6 An exploded view.

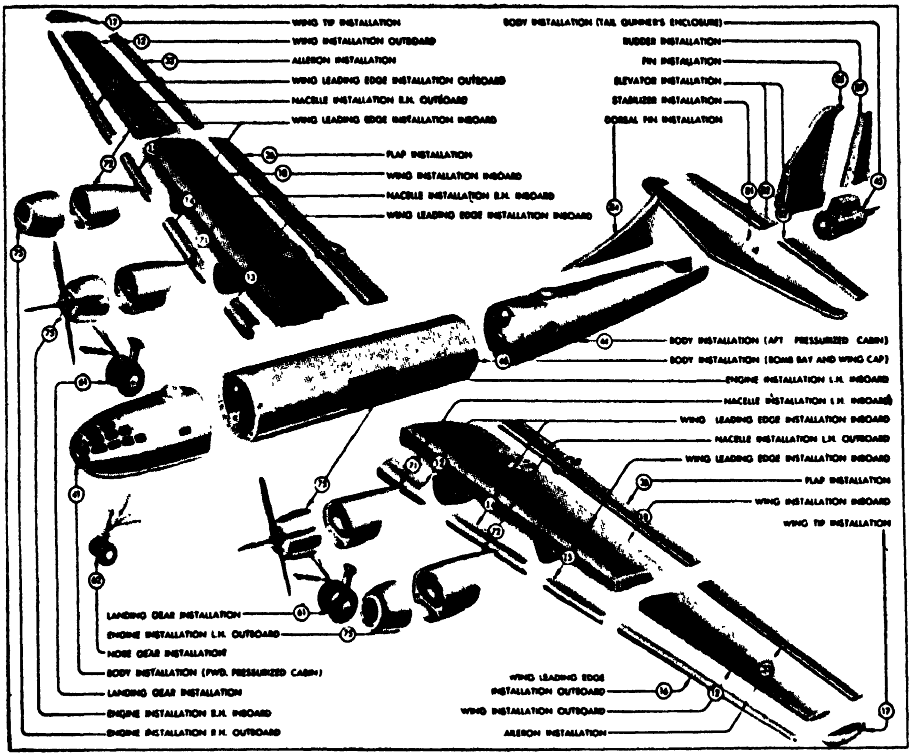


Figure 13·7 Major assembly breakdown. (Boeing Aircraft Company.)

time. This applies to parts being manufactured or put into place as well as for operating instructions, and for ordering spare parts.

Figure number 13·8			*Units per assembly*
Item	*Part number*	*Nomenclature*	
1608	3–31010	Ring Assembly Fuselage Sta. 100.375–106.25	1
595	3–71016	Assembly Control Cable Bracket Front	1
1621	AN210–1A	Pulley	2
599	3–70054	Bracket—Rudder Cable Pulley	2
642	3–70060	Backing Plate—Pulley Bracket	4
601	3–68015	Assembly Bearing Housing	1
1610	3–68015–2	Casting	1
1611	AN200–K4	Bearing	1
1612	3–68016	Plate Bearing Housing	1
1613	3–79020	Assembly—Glider Release Cable—Front	1
1614	3–79021	Bracket—Glider Release Cable—Front	1

One form of identification illustration is shown in Fig. 13·8, with the names of the parts given in the table on page 170.

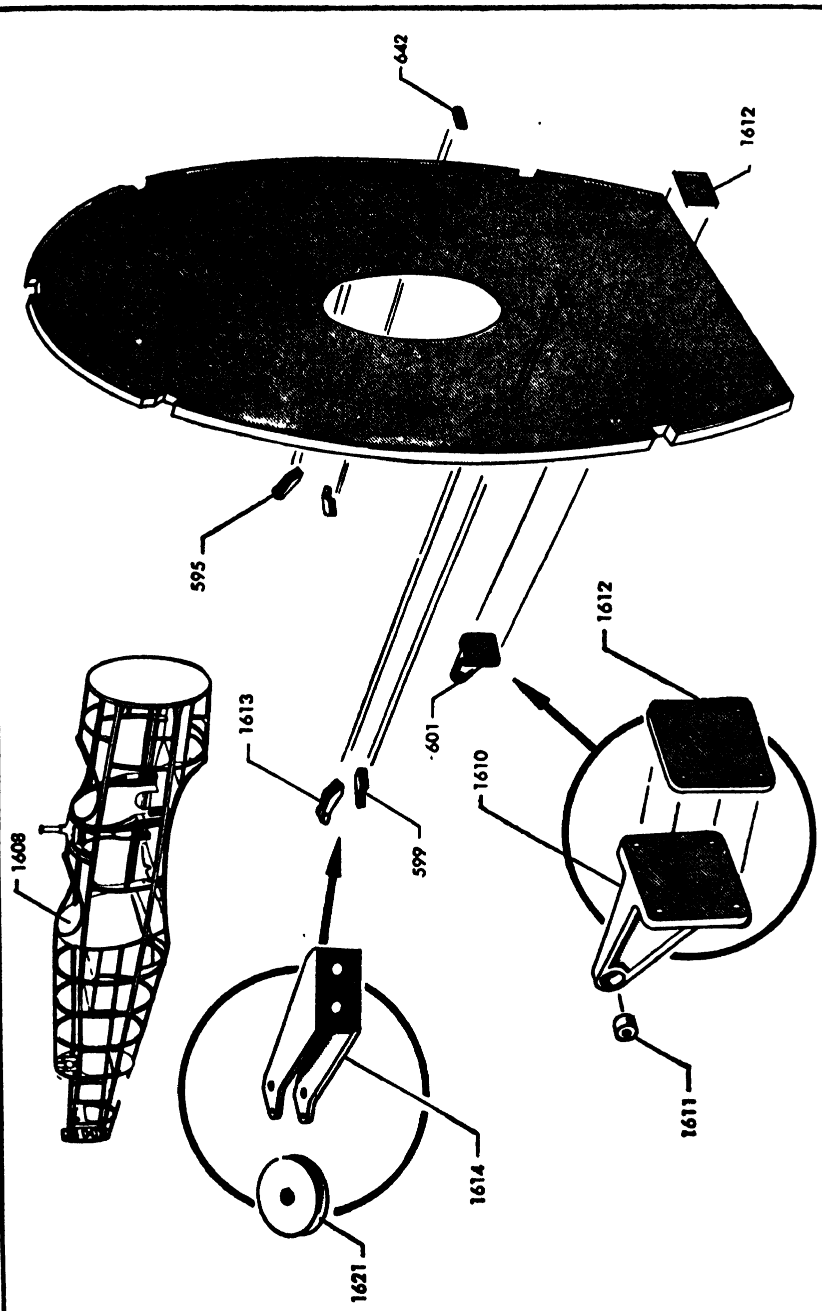


Figure 13·8 *Identification illustration. (Timm Aircraft Corporation.)*

13·4 Space Diagrams and Installation Illustrations. Pictorial drawings save a lot of time in showing where parts go and especially in showing operating controls, piping installations for oil and hydraulic systems, wiring, etc., and avoiding interferences. Such drawings vary according to the purpose for which they are used. The plane or machine may be shown in more or less outline form in order to fix the positions of the installations. A pictorial space drawing is shown in Fig. 13·9.

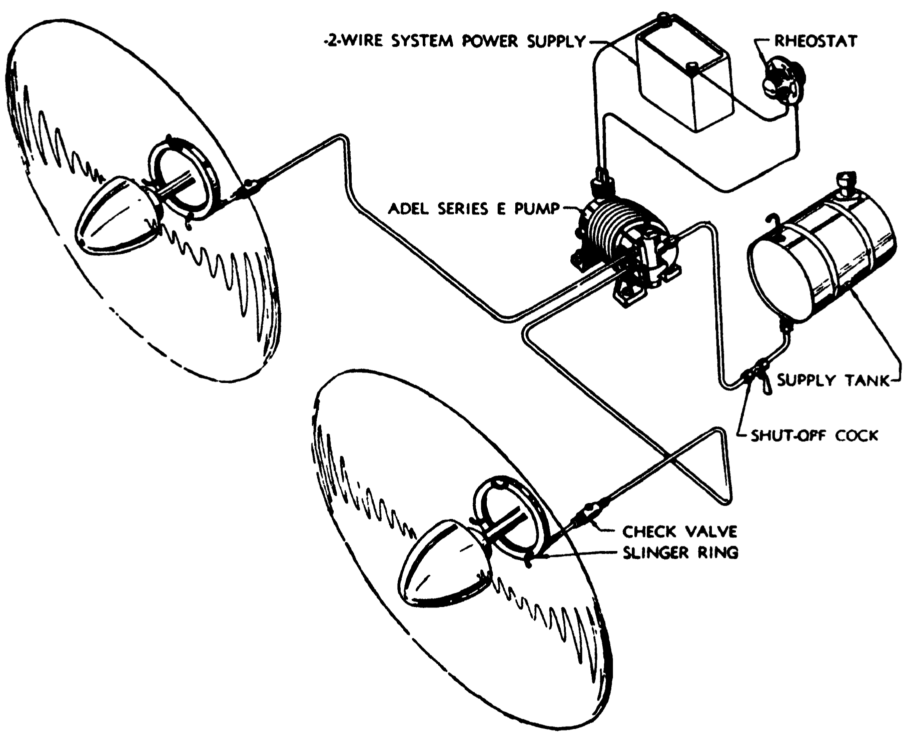


Figure 13·9 Space drawing. (Adel Precision Products Corporation.)

13·5 Rendering. For certain purposes or where shapes may be difficult to read, surface shading or rendering of some kind is desirable. A study of commercial art would be necessary to develop professional skill in the many ways of shading drawings, but the student should learn to recognize some of the methods that are used. A few illustrations are included for this purpose.

For most industrial production illustrations, accurate descriptions of shapes and positions are more important than fine artistic effects.

Desired results can often be obtained without any shading. In general, when surface shading is used, it should be limited to the least amount necessary to define the shapes illustrated.

13·6 Line shading may be done mechanically or freehand, sometimes by a combination of both. The light is generally considered to come from in back of, and above, the left shoulder of the observer in the direction of the body diagonal of a cube (Fig. 13·10 at A and B).

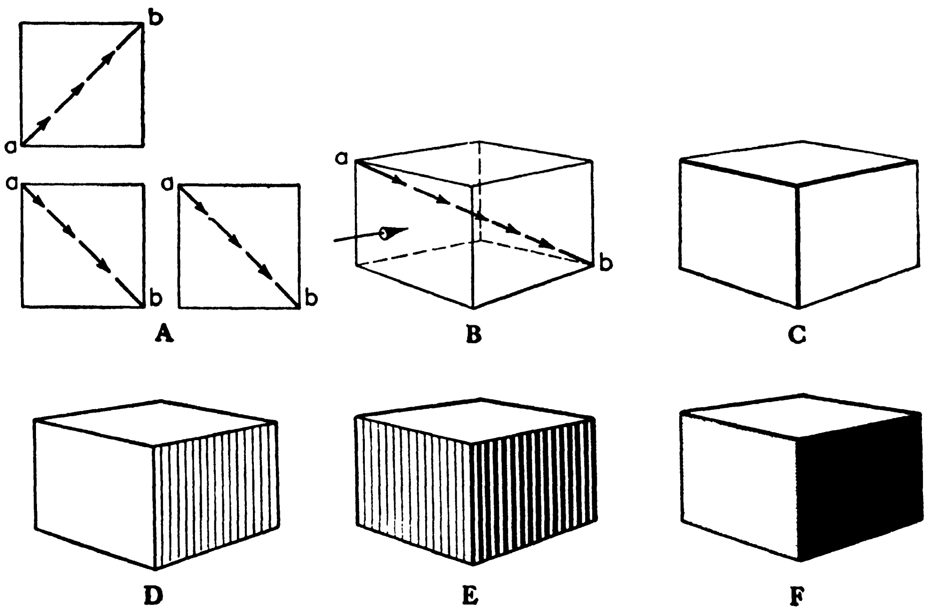


Figure 13·10 Some methods of rendering a cube.

The three lines meeting at the front corner accented as at C will bring out the shape where the surfaces are left plain. Since the top and front are lighted, they might be left clear with the right-hand surface shaded as at D. The front surface can have a light shading, with heavy shading on the right-hand surface as at E. Solid shading may be used as at F.

13·7 Some shaded surfaces are indicated in Fig. 13·11. An unshaded view is shown in Space 1 for comparison. Ruled surface shading is shown in Space 2, freehand shading in Space 3, stippled shading in Space 4, Craftint shading in Space 5, and Ben Day shading in Space 6.

Stippling (Fig. 13·11, Space 4) consists of dots, short crooked lines, or similar treatment to produce a shaded effect. It is a good method when well done but requires considerable time. Craftint paper (Fig. 13·11, Space 5) is made with a great variety of invisible allover

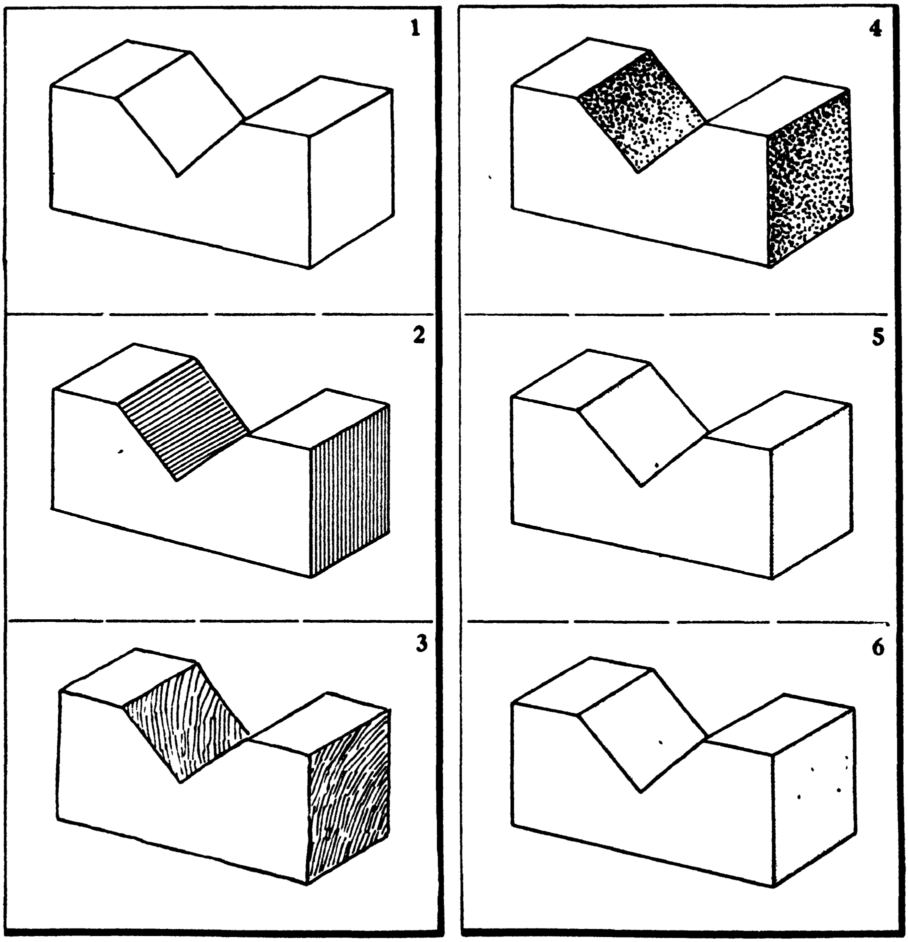


Figure 13·11 Some kinds of rendering.

dots, lines, and patterns which can be made visible by the application of a developing solution. The Ben Day process (Fig. 13·11, Space 6) uses films to cover the surface with dots or lines.

13·8 Airbrush rendering (Fig. 17·2), for which compressed air is used to spray the solution for obtaining the different shading effects, produces pictures that resemble photographs. Wash drawings are another method of producing similar results by using a brush as for water colors.

13·9 Cylinder shading is illustrated in Fig. 13·12, where shade lines follow the curvature at A, lines parallel to the elements are used at B, C, and E, stippling is used at D, and surface shading at F.

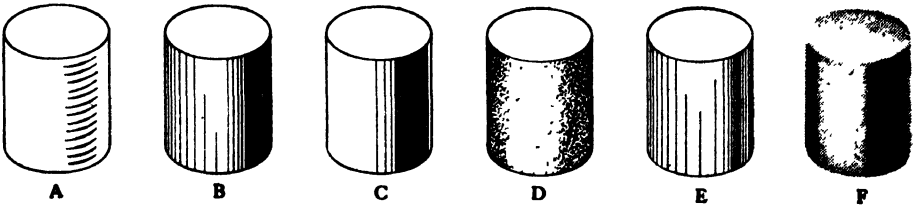


Figure 13·12 Some methods of rendering a cylinder.

13·10 Building Construction Illustration. Details of the construction for buildings can be made clear and easily understood by pictorial sketches or drawings. Any of the methods may be used for

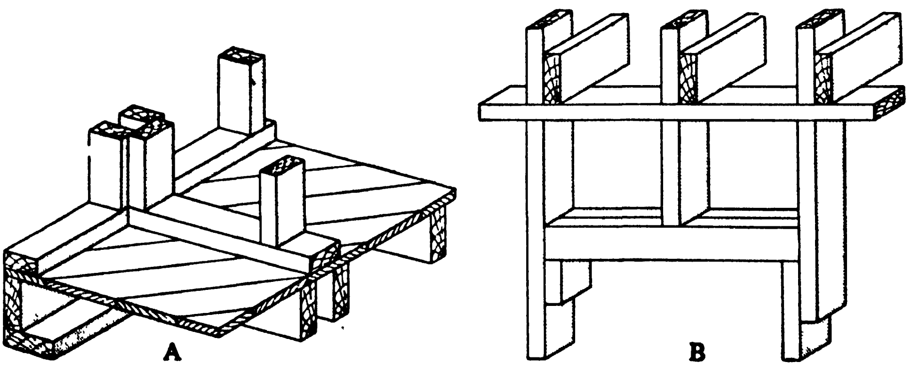


Figure 13·13 Building construction.

this purpose, but simple isometric and oblique views are about all that are necessary in most cases, as indicated in Fig. 13·13.

13·11 Furniture Construction Illustration. Pictorial methods have been much used for furniture and are especially adapted for this purpose. Isometric is useful, as well as other pictorial methods, for showing joints and how parts go together. Study the illustrations on pages 350 to 357.

13·12 Reproduction of Illustrations. Illustrations made on tracing cloth or thin paper may be reproduced the same size by making direct contact prints as described in Arts. 9·12 and 9·13. Regular photographic paper may be used with such drawings or with photographic negatives at a reduced size. Photostats are frequently made.

Where a large number of copies are required, line cuts, half tones, or offset prints are made.

Line cuts (Fig. 13·10) are photoengravings made on zinc or copper plates from black-line or pen-and-ink drawings. The drawing is made larger than the desired copy and reduced when photographed on the plate. All lines, dots, figures, lettering, etc., must be black in order to reproduce. The plate is etched and used in a printing press.

Half tones (Fig. 11·3) are photoengravings made by photographing through a screen formed by two glass plates with lines ruled at uniform distances apart and placed so that squares are formed. In this way, a negative is made showing the view as made up of minute dots, and from it a photographic contact print is made on a copper plate. This plate is etched and used in a printing press. The half-tone process is used to make cuts from photographs, wash drawings, airbrush drawings, shaded pencil drawings, and whenever there are different shades of gray as well as black and white to be reproduced.

The offset process can be used to reproduce any kind of drawing by photographing it on a metal plate from which it is transferred to printing cylinders. It is a kind of mechanical lithograph and will reproduce solid lines as well as all the various tones of photographs or wash drawings.

CHAPTER 14. Aircraft Drafting

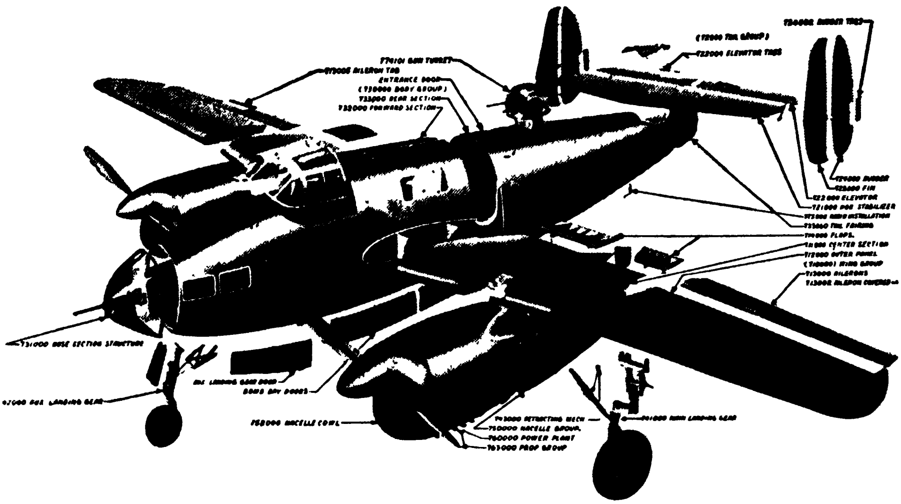


Figure 14·1 Exploded view. (Fairchild Aircraft Division of Fairchild Engine and Airplane Corporation.)

14·1 Aircraft drafting has to do with the drawings made for airplanes: details, three-view exterior outlines, subassemblies such as wing construction, layouts, production drawings, and the many other kinds needed to meet manufacturing requirements.

The variety of materials used and the different methods involved in making and assembling parts make it necessary for the draftsman to become familiar with the materials and the manufacturing processes. The frequent use of pictorial views (Fig. 14·1) requires the ability to read such drawings; the ability to make them is a valuable accomplishment and has become a profession for many artist-draftsmen. However, the fundamental principles are the same for aircraft drawings as for all other drawings. A thorough knowledge of shape description by orthographic projection is necessary.

14·2 A general arrangement drawing is shown in Fig. 14·2. Note that the side view shows the front of the plane toward the left-hand end of the drawing. This is the standard arrangement for either assembly or detail drawings. Parts are left-hand or right-hand according to the position that they occupy relative to the pilot seated in the plane.

14·3 Aircraft drafting practice has developed certain methods necessary for efficiency in the manufacture of airplanes. Engineering manuals have been prepared by different companies to set out the

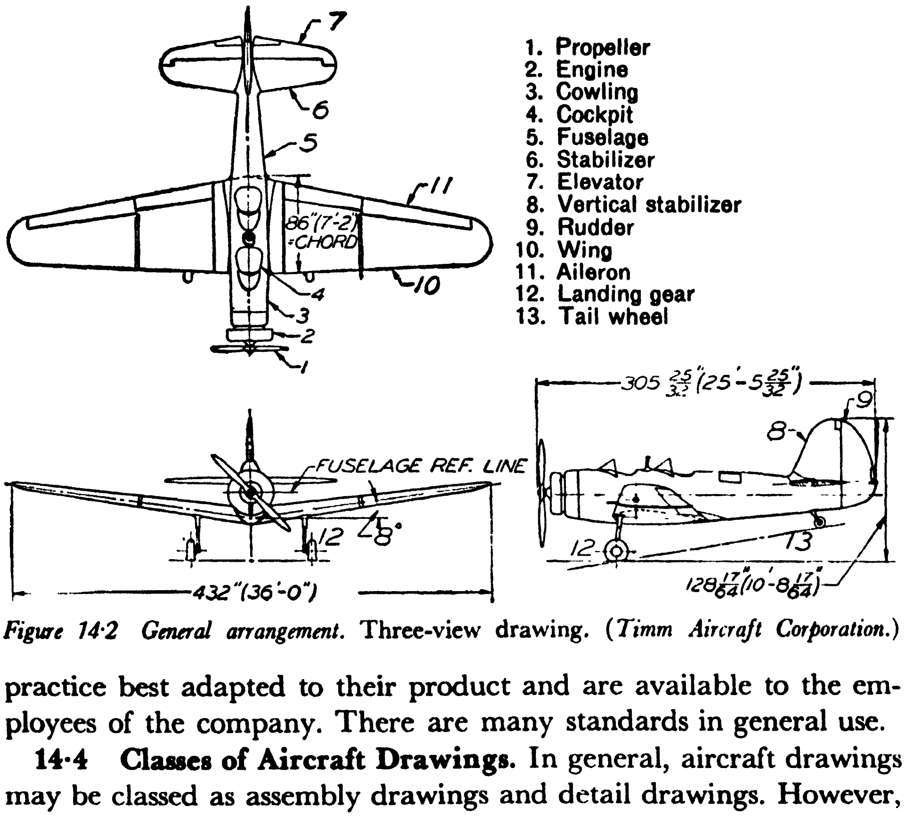


Figure 14·2 General arrangement. Three-view drawing. (*Timm Aircraft Corporation.*)

practice best adapted to their product and are available to the employees of the company. There are many standards in general use.

14·4 Classes of Aircraft Drawings. In general, aircraft drawings may be classed as assembly drawings and detail drawings. However, these vary in some respects from the usual machine drawings. Thus *assembly drawings* may or may not contain some or all dimensions and information and may show the whole plane, groups of parts as subassembly drawings, or as few as two parts. A drawing for a tube assembly is shown in Fig. 14·3 where three tubes are joined by welding. The stabilizer frame assembly shown in Fig. 14·4 is of welded tubes. This is a type of subassembly drawing. Another form of assembly drawing is the *installation drawing* which may give information for making certain parts but has the major purpose of locating the various parts in the assembly of the plane with dimensions and all necessary information for the purpose. Some drawings take the form of *diagrams* for the operating controls and the wiring, piping, etc. There are also *charts* for lubrication and other matters that require attention.

Tabulated drawings may be used for either assembly or detail drawings where only a small number of dimensions are different.

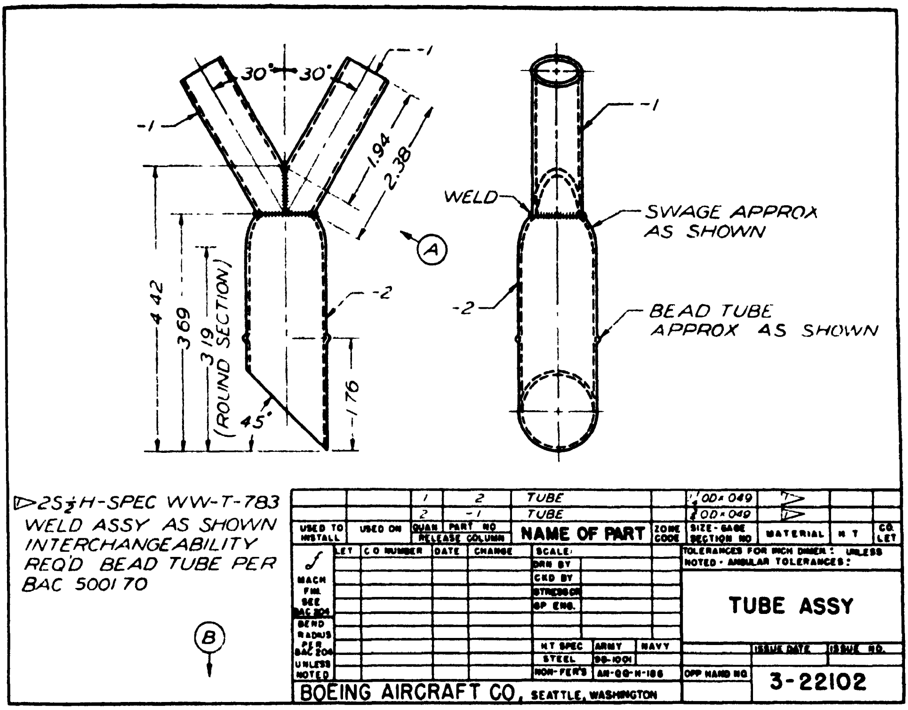


Figure 14·3 Tube assembly drawing. **Prob. 416.** (*Boeing Aircraft Company.*)

14·5 Aircraft detail and assembly drawings include such a variety that only a general list will be included here. The names are sufficiently descriptive to indicate the general character of the drawings.

General arrangement drawings	Production drawings
Layout drawings	Casting drawings
Fairing drawings	Forging drawings
Assembly drawings	Die-casting drawings
Large subassembly drawings	Sheet-metal drawings
Small subassembly drawings	Welded drawings
Detailed subassembly drawings	Tabulated drawings
Installation drawings	Electrical drawings
Diagram drawings	Sketches

A casting drawing is shown in Fig. 14·5 for a flap hinge made of aluminum. A forging drawing is shown in Fig. 14·6 for a fitting made of X4130 steel.

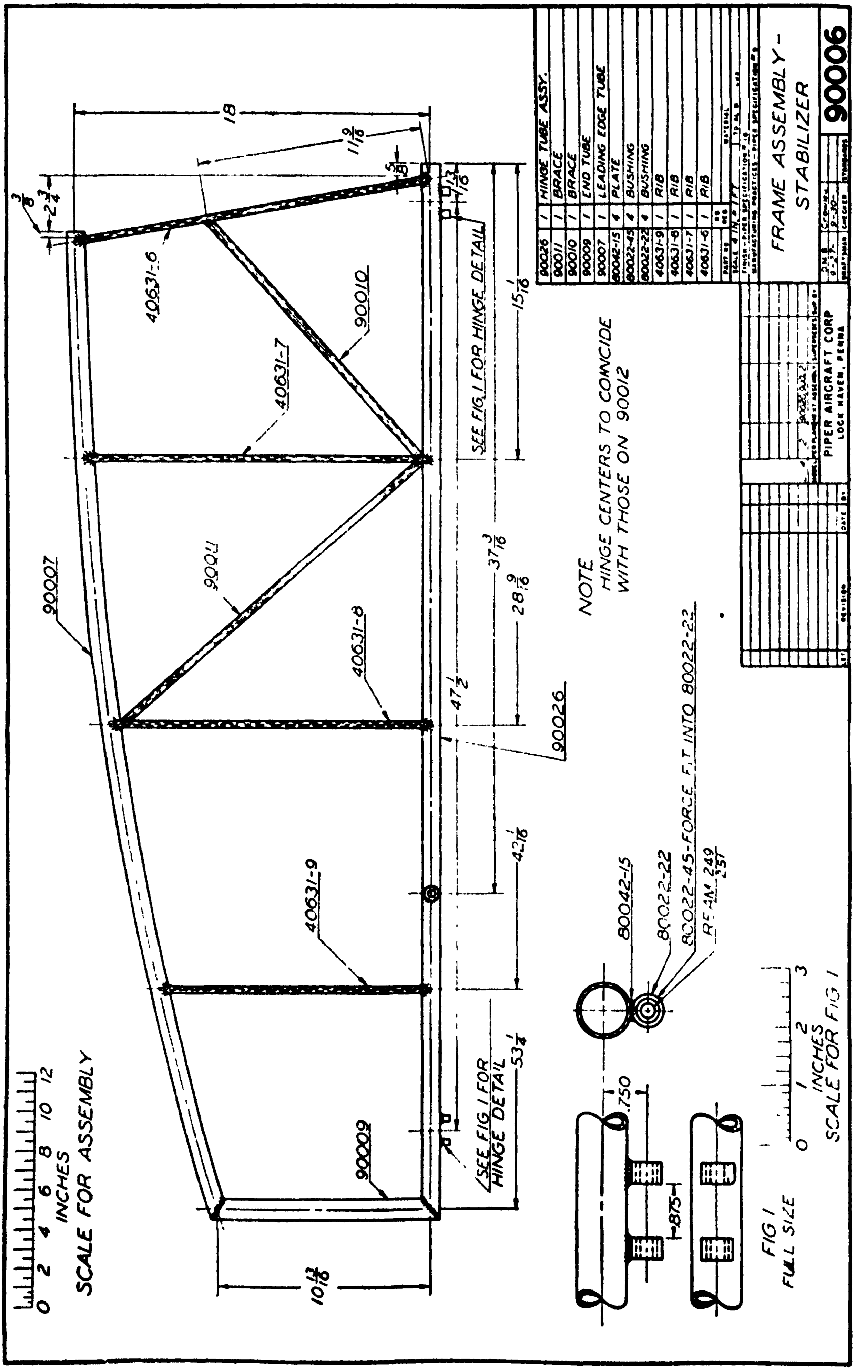


Figure 14·4 Stabilizer frame. **Prob. 417.** (*Piper Aircraft Corporation.*)

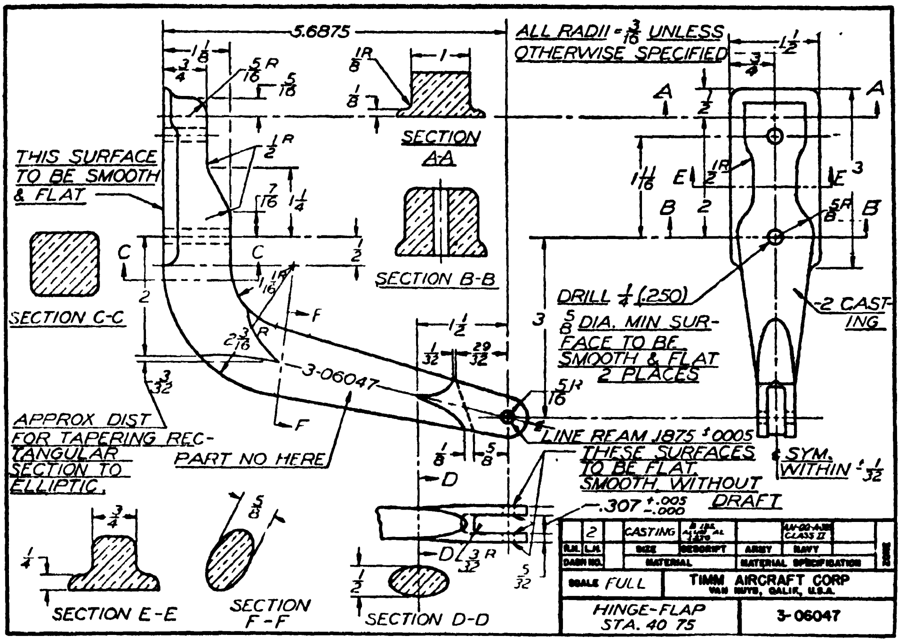


Figure 14·5 *Flap hinge.* **Prob. 418.** (*Timm Aircraft Corporation.*)

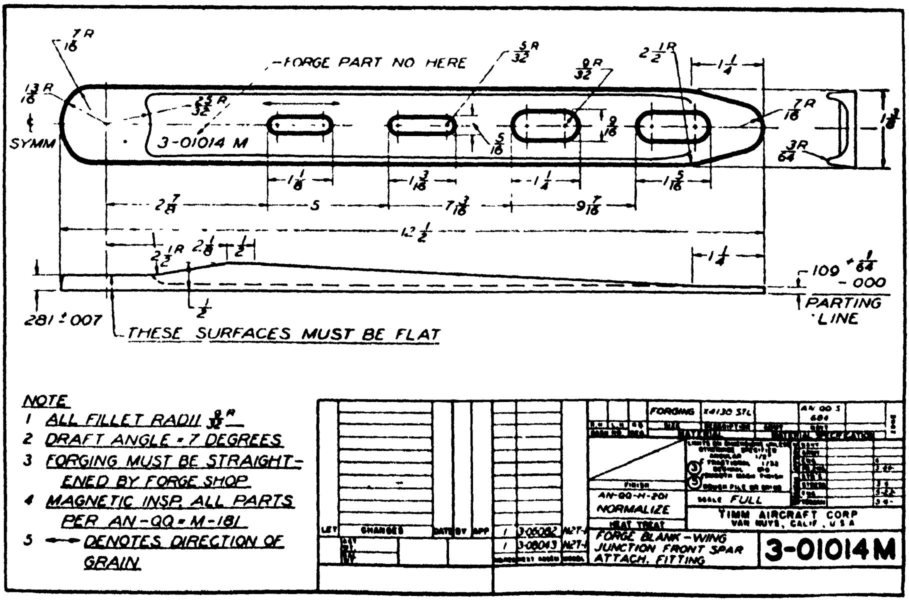


Figure 14·6 *Forge blank.* **Prob. 419.** (*Timm Aircraft Corporation.*)

14·6 Layouts of various kinds form an important part of aircraft design and drafting from the general over-all design to pencil layouts for subassemblies and groups of parts. Such drawings provide for the relations of the parts, manufacturing procedure, operating and other equipment, etc. Layout drawings show all necessary information for

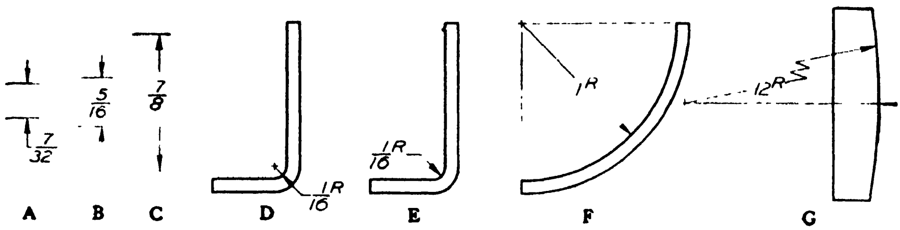


Figure 14·7 Dimensions for vertical distances and radii.

making details and assembly drawings, for stress analysis, for calculation of weights, for detailing shapes, for dimensioning, and for specifying materials and treatments.

14·7 Dimensions and Notes. Usual practice is to give all dimensions in inches and to omit the inch mark except on the three-view assembly drawing (see Fig. 14·2) where feet and inches are used.

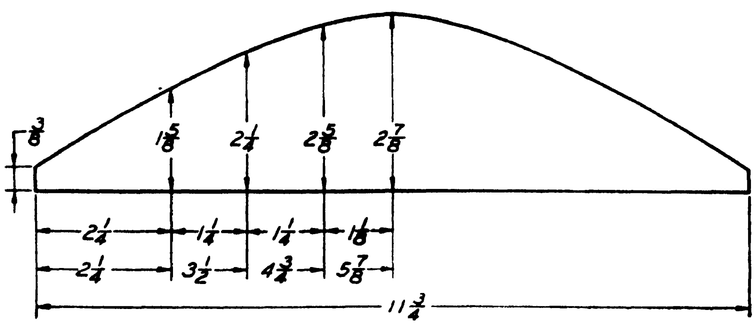


Figure 14·8 Progressive dimensioning.

All notes and dimensions are placed to read from the bottom of the drawing, regardless of the direction of the dimension lines, whether horizontal, vertical, or at an angle, as shown on the illustrations in this chapter. Dimensions less than 5⁄16 are shown as at A in Fig. 14·7, and 5⁄16 and larger as at B and C. Capital letters are generally used for all lettering, either vertical or inclined, according to the practice of the particular company.

Radii are given for the inside radius on all bends (Fig. 14·7 at D, E, F, and G). Progressive dimensioning is sometimes used with regular dimensioning (Fig. 14·8). Linear dimensions are preferred to degrees for angles (Fig. 14·9), but degrees may be given for reference.

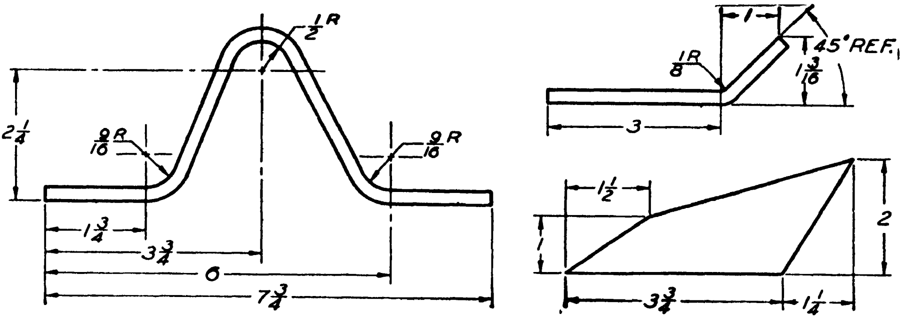


Figure 14·9 Dimensions for angles.

Notes are used to give necessary information and instructions. They should not be used in place of dimensions. However, when used to specify an operation, the dimension may be included for such purposes as the diameter and depth of drilled or reamed holes. Other notes are indicated on the illustrations.

The basic principles of dimensioning as described in Chap. 8 apply with the exceptions here noted and any special company practice.

14·8 Dash Numbers. When two or more detail parts are drawn on a detail drawing or an assembly drawing, they are identified by dash numbers of the drawing. The basic number is the drawing number. This number followed by a dash number identifies a piece shown on that drawing. Thus 3279-3 would indicate part -3 on drawing 3279. On the drawing the -3 may be enclosed in a circle or left in the clear, but must be placed close to the part that it identifies. *Even* dash numbers may be used for right-hand parts and *odd* dash numbers for left-hand parts, or the numbers may be followed by the letters R or L.

Particular practice in the use of dash numbers varies with different companies.

14·9 Titles and Nomenclature. Titles used on aircraft drawings vary according to the practice of different companies. In general, the title may include such information as model, title of assembly or detail, drawing number, calculated weight, actual weight, dimensional limits, scale, date, identification of draftsman, tracer, checker, engineer, etc., and provision for a material list.

The name on aircraft parts should locate the part as to the group or subgroup to which it belongs so far as possible. Breakdown parts lists are available in company drafting rooms. In general the name of the part or noun is placed first followed by the main group and subgroup. This is well explained in the following quotation which gives the practice of the Aeronca Aircraft Corporation.

DRAWING TITLES

In naming drawings, U.S. Army Air Corps standard practice is followed. The drawing title must consist first of the basic identifying word (noun) entered on the top line of the title block followed on the second line by a suitable description and modifying words.

Example:

BRACKET
WING AILERON HINGE

This is read: "WING AILERON HINGE BRACKET" and the title will be entered in the number book thus. Bracket—"Wing Aileron Hinge."

No basic names of more than one word can be used.

Names such as "tie rods," "push rods," and "push tubes" can be written similar to the following example:

ROD—AILERON CONTROL PUSH

The details of an assembly must be named in agreement with the name of the assembly and consistently with each other as follows:

(*a*) ASSEMBLY—FLOATING INSTRUMENT PANEL
BOTTOM BRACKET

(*b*) BRACKET—FLOATING INSTRUMENT PANEL
BOTTOM

The parts may be further identified when there is danger of confusion of parts with similar names, by the addition of such words as right, left, upper, lower, end, and center or such as long, short, main, or auxiliary.

The words *and* and *for* can be omitted from the title as the title should be as concise as possible.

14·10 Standard Parts. Some parts are manufactured for general use and are available in standard sizes and dimensions. Such parts are "called out" or identified by numbers or symbols as are the company's own standard parts which are made for their own use.

There are standard sections for various extruded shapes and tubes, standard fabrics, bolts, eyebolts, nuts, castle nuts, stop nuts, cotter pins, taper pins, turnbuckles, bushings, rivets, keys, sheet-metal screws, etc. Other standards include those of the American Standards Association (ASA), Society of Automotive Engineers (SAE), and other societies, and the government standards as used by the Air Corps (AC) and by the Army and Navy (AN). Books of standards, kept up to date, are used for reference when drawings are made in aircraft drafting rooms.

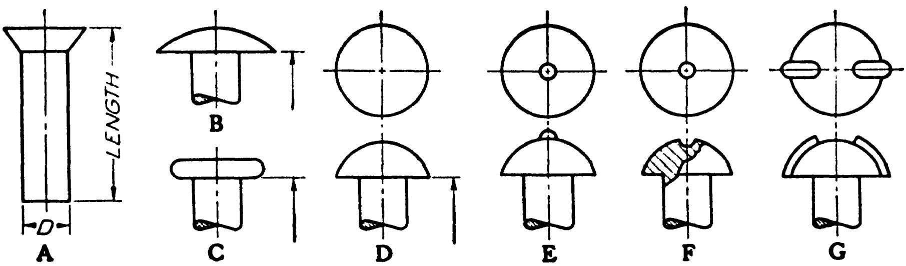
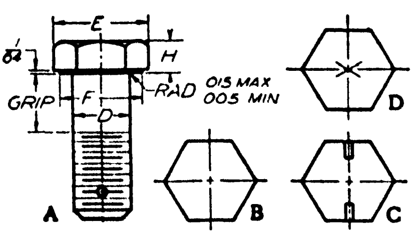


Figure 14·10 Aircraft rivets.

14·11 Aircraft Rivets. Some aircraft rivets are illustrated in Fig. 14·10. For complete dimensions and information, access should be had to AN Standard sheets. A countersunk head (AN425) is shown at A, a brazier head (AN455) at B, a flat head (AN442) at C, and a round head (AN430) at D. Identification markings indicate the material, Type A (aluminum, 3S) without marking is shown at D; Type D (aluminum alloy, 17S) with raised dot is shown at E, Type AD (aluminum alloy, A17S) with depression is shown at F, and Type DD (aluminum alloy, 24S) is shown at G.

Codes are used for calling out rivets as: AN425AD4-8 in which AN425 means Army-Navy standard countersunk head, AD means A17S material, 4 means the diameter in thirty-seconds of an inch, and 8 means the length in sixteenths of an inch.



D	Threads per in.	E	F	D	Threads per in.	E	F
No. 10				1/2	20	7/8	.750
.189	32	7/16	375	9/16	18	1 1/64	.875
1/4	28	1/2	4375	5/8	18	1 3/32	.9375
5/16	24	37/64	.500	3/4	16	1 15/64	1 0625
3/8	24	21/32	.5625	7/8	14	1 7/16	1 250
7/16	20	23/32	.625	1	14	1 21/32	1.4375

For bolthead, $H = \frac{5}{8}D + \frac{1}{32}$". For nut, $H = \frac{7}{8}D$.

Figure 14·11 Aircraft bolts.

14·12 Aircraft Bolts. An AN aircraft bolt is shown in Fig. 14·11 with some dimensions in the table. Sheets of AN standards are used in aircraft plants to give all dimensions and other information for each diameter of bolt. Identification marks, three of which are shown, are used on the heads: for aluminum alloy specification QQ-A-351 head is left unmarked as at B; for aluminum alloy QQ-A-354 head is marked as at C; for steel head is marked as at D.

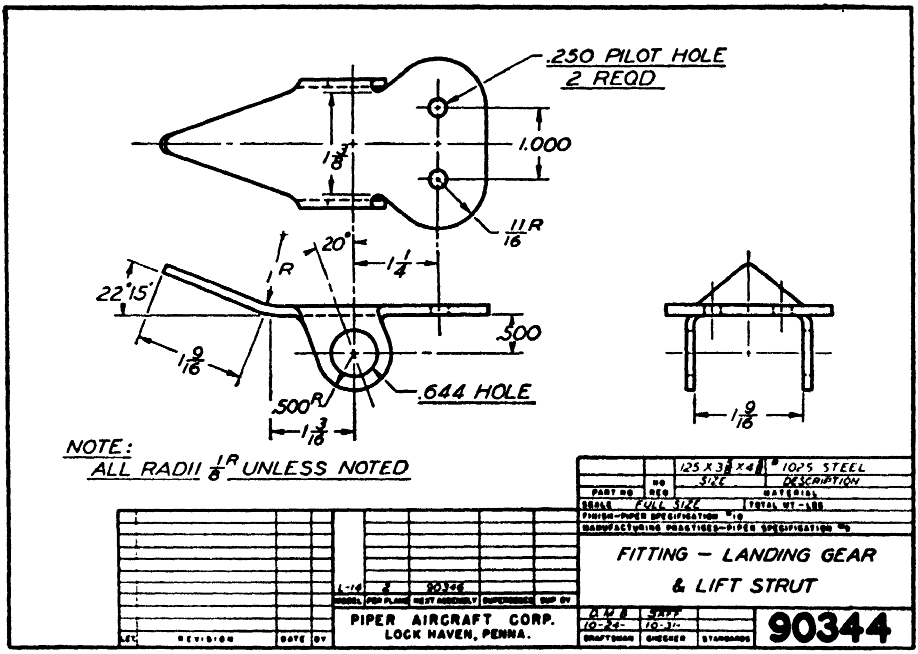


Figure 14·12 Sheet-metal part. (Piper Aircraft Corporation.)

Code symbols are used to "call out" bolts as: AN4-7, in which AN means steel, Army-Navy Standard; 4 means the diameter in sixteenths of an inch or $\frac{4}{16} = 14''$ diameter; 7 means the length in eighths of an inch, or $\frac{7}{8}$ in. long. For aluminum alloy, the dash is replaced by a letter (or letters) to indicate the alloy as: AN4D7. If the pinhole is to be omitted, the letter A is added as AN4D7A.

The length of bolts is given by the number of eighths up to $\frac{7}{8}$ in. in diameter; for 1 in. or more, it is given in inches *and* eighths. Thus 1 in. is given as 10 or 1 in. and no eighths; $1\frac{1}{8}$ in. is given as 11 or 1 in. and one-eighth.

For other aircraft threaded fastenings, clevis bolts, eyebolts, special lock nuts, etc., reference should be made to the latest AN Standard sheets on hand in the company drafting room.

14·13 Sheet-metal drawings are based upon the principles of intersections and developments, as treated in Chap. 18. However, it is necessary to consider the thickness of metal, bend allowances, and other factors when laying out *flat patterns* (developments) or sheet-metal templates. The parts shown in Figs. 14·12 and 14·13 are made of sheet metal.

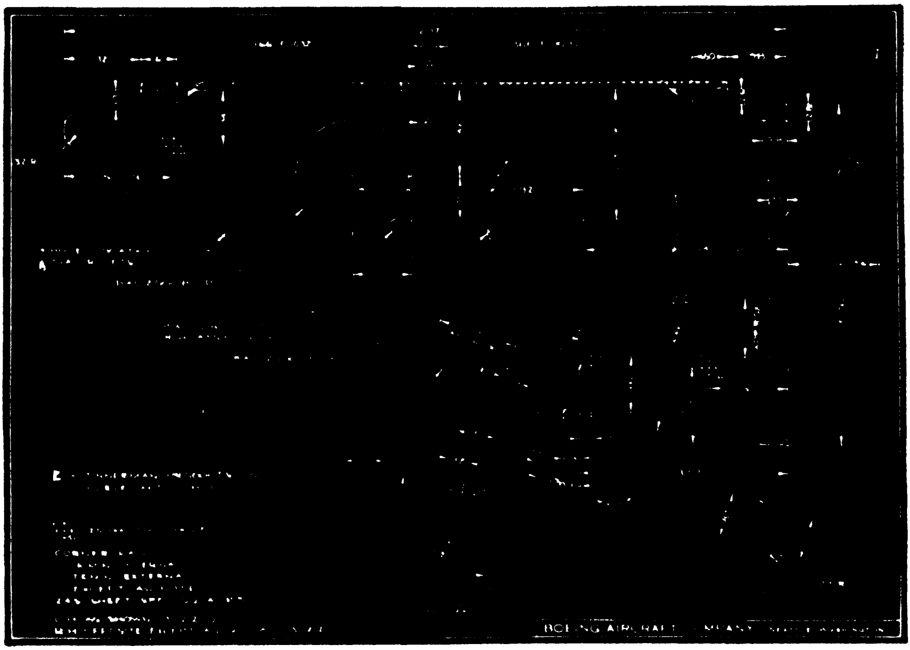


Figure 14·13 Sheet-metal part. (Boeing Aircraft Company.)

Sheet metal is used extensively for forming parts of airplanes as well as for the curved skin covering. Many factors enter into the selection of the proper material, the design, and the forming of such parts. Only a few considerations can be indicated here, as specialized knowledge and experience are necessary for a complete understanding of this part of airplane design.

Bend relief is an allowance made at the corners when plates are bent. A method of bend relief is shown in Fig. 14·14. Allowance must be made for bends (Fig. 14·15). The minimum bend radius depends upon the material and the thickness, and values can be found in the engineering manuals of aircraft companies, or in the Appendix of "Aircraft Drafting" by Carl L. Svensen.

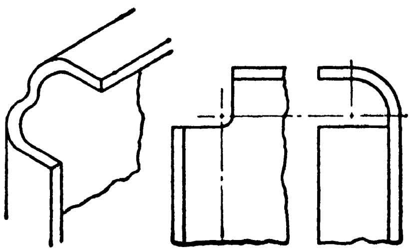


Figure 14·14 Bend relief.

Joggling is used when plates or structural shapes overlap (Fig. 14·16).

14·14 Lofting. Full-size layouts for large projects are made by lofting, a term that comes from the ship loft where the lines or exact shapes of ships are worked out full size. Lofting is an important kind of layout for airplane design, by which accurate full-size contours and sections are developed. Curves are faired to obtain smooth surfaces, and templates are made for use where necessary.

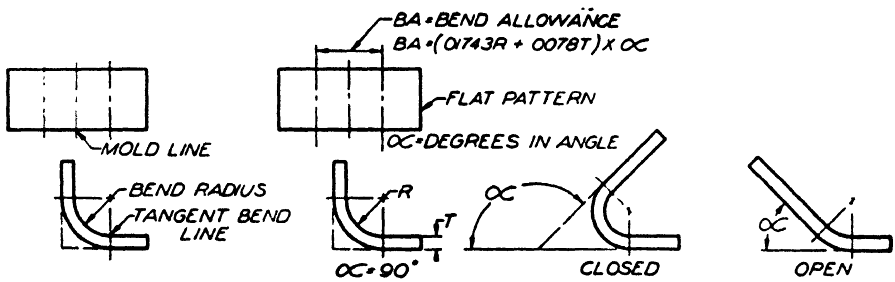


Figure 14·15 Bend allowance.

Specialized knowledge of materials and their properties as well as experience and good judgment is necessary for this work. Such work cannot be done on drawing boards but must be laid out on special loft floors where the required areas are available.

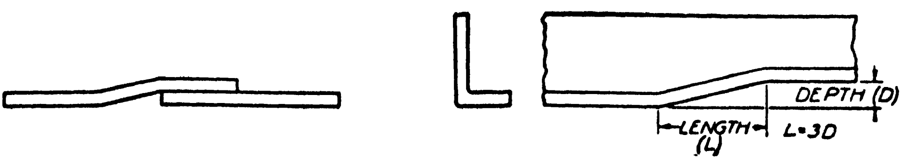


Figure 14·16 Joggling.

Part of a drawing of a master template for wing contours is shown in Fig. 14·17.

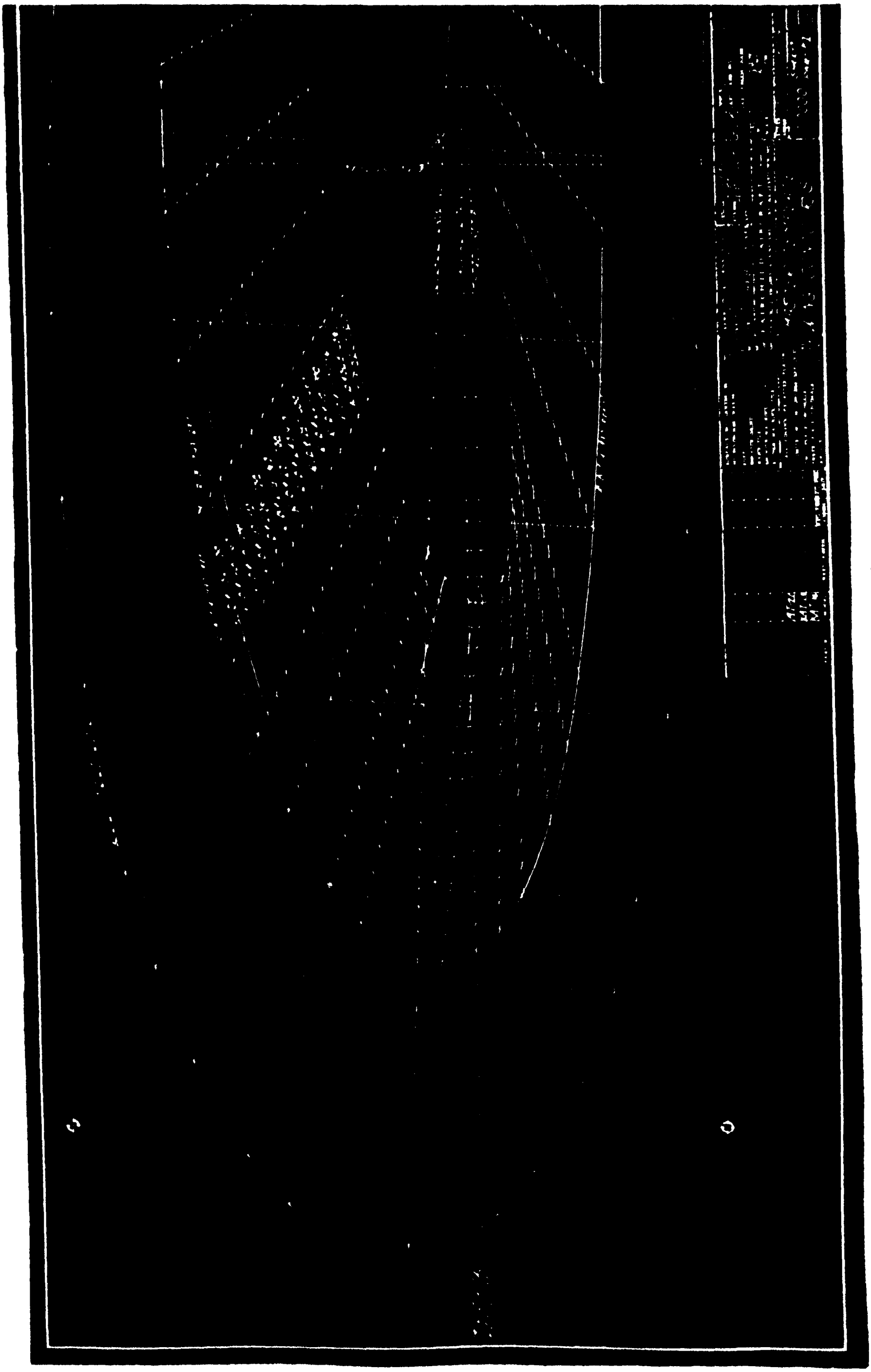


Figure 14·17 Master template.

CHAPTER 15. Welding Drawings

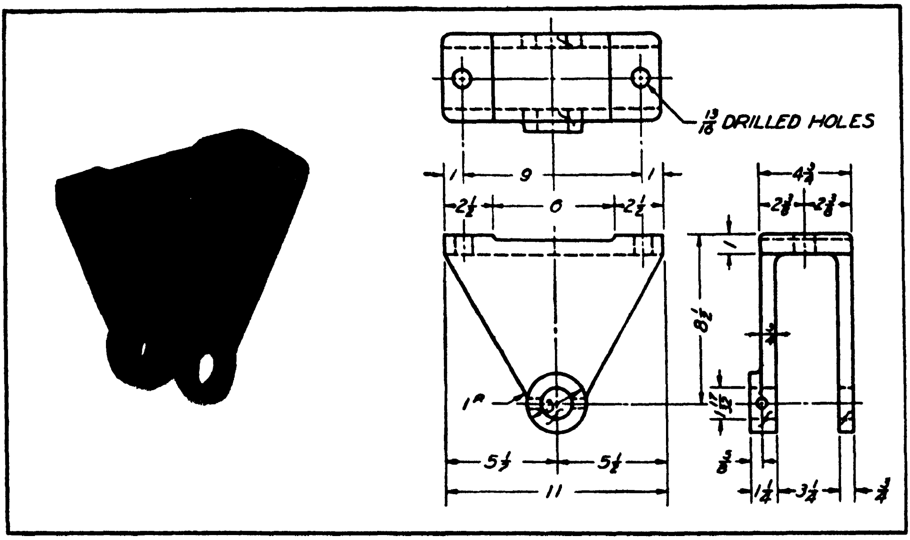


Figure 15·1 Cast sheave housing. **Prob. 422.** (*Wellman Engineering Co. and The Lincoln Electric Co., Cleveland, Ohio.*)

15·1 Welding is being used for an ever-increasing variety of mechanical and structural purposes, such as building up and fastening parts together. Standard steel shapes, plates, and bars may be welded together to make machine frames, bases, jigs and fixtures, etc. The greater strength of steel in tension is often an advantage that permits a design of less weight and complication for parts formerly made of cast iron. Sheet-metal work, such as tanks and other containers, can be simplified by welding instead of riveting the joints.

The aircraft, automotive, and shipbuilding industries have developed welding as a major fabricating method for aluminum and magnesium, as well as for steel.

15·2 Welding Processes. The two basic processes are fusion welding and resistance welding. Fusion welding makes use of filler rods to combine with the metal being welded. It may be either gas welding or carbon-arc welding. Resistance welding uses an electric current to generate welding heat by the resistance of the parts, which are welded by pressure.

15·3 Welding drawings make use of ideographic symbols[1] to give the necessary welding information (Art. 15·5). These symbols have been developed by the American Welding Society and provide

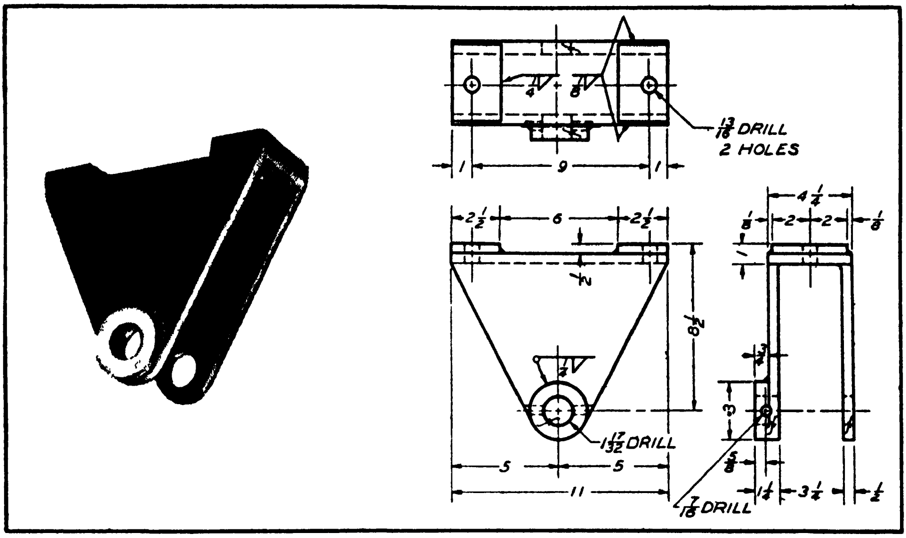


Figure 15·2 Welded sheave housing. **Prob. 423.** (*Wellman Engineering Co. and The Lincoln Electric Co., Cleveland, Ohio.*)

a flexible means of giving specifications, type, location, size of weld, and various combinations to suit any condition. Every drafting room should be provided with one or more copies of the latest edition of[2] "Welding Symbols and Instructions for Their Use." These symbols have been adopted as American Standard.

A photograph and a drawing of a casting for a sheave housing are shown in Fig. 15·1 for comparison with the same part made by welding, as shown in Fig. 15·2.

15·4 Types of joints are shown and named in Fig. 15·3. There are many variations in the kinds of welds used in making these joints. These are further influenced by the preparation of the parts as illustrated for a few joints which are named in Fig. 15·4. The preparation of the groove is shown by the hidden lines at A to I inclusive. The size of the *root opening* is shown by *R* and the amount of the *angle* by *A* at J and K. The *size of weld*, or leg of a fillet weld, is indicated by *S* at L.

[1] Picture-writing symbols.

[2] American Welding Society, New York.

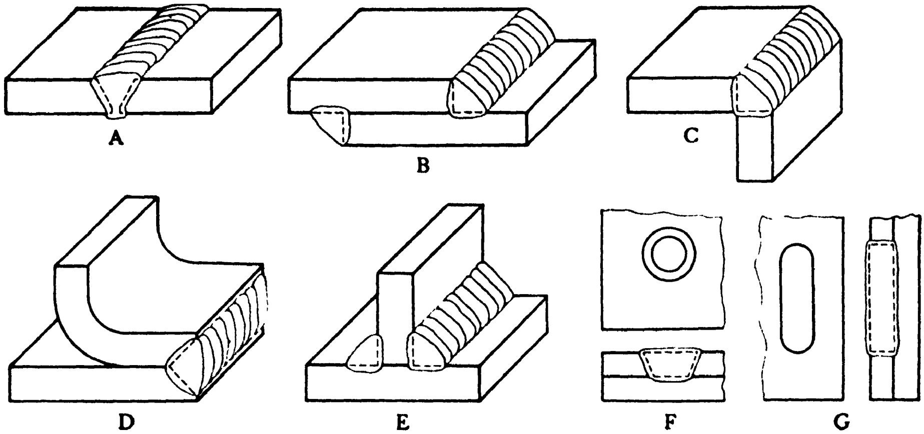


Figure 15·3 Basic types of joints. (A) Butt joint (V-groove weld). (B) Lap joint (fillet weld). (C) Corner joint (fillet weld). (D) Edge joint (V-groove weld). (E) Tee joint (fillet welds). (F) Plug weld. (G) Slot weld. **Prob. 420.**

Many combinations and varieties of joints are used to meet the great number of different conditions that occur in welding practice. Knowledge of conditions together with experience is necessary to make a proper selection of the types and sizes of welds.

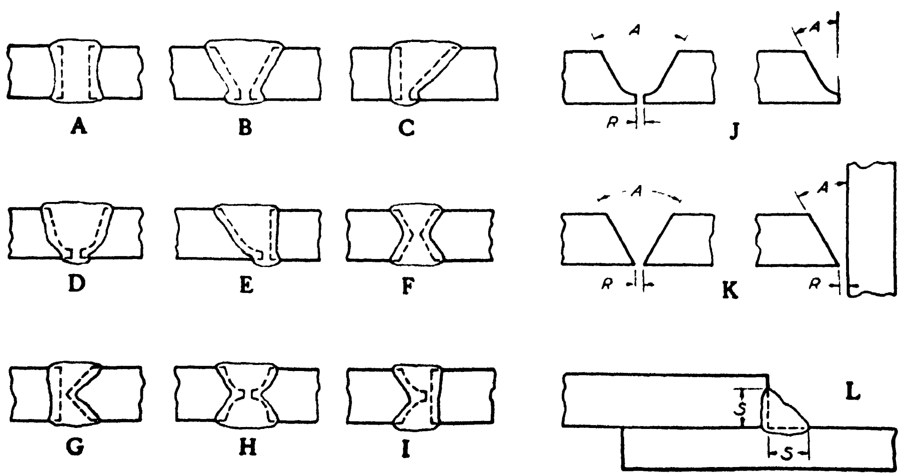


Figure 15·4 Grooved joints. (A) Square groove. (B) Single V-groove. (C) Single bevel groove. (D) Single U-groove. (E) Single J-groove. (F) Double V-groove. (G) Double bevel groove. (H) Double U-groove. (I) Double J-groove. **Prob. 421.**

15·5 Basic arc- and gas- (fusion) welding symbols of the American Welding Society are given in Fig. 15·5 which shows both basic and supplementary symbols. Separate symbols may be selected to describe any desired weld as they may be assembled to describe simple or complicated joints.

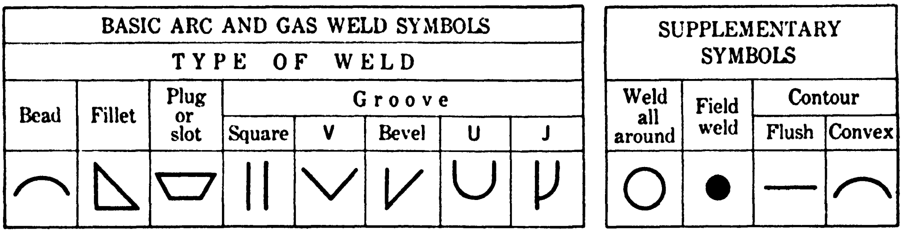


Figure 15·5 Arc- and gas-welding symbols.

The standard location of information on welding symbols is shown on Fig. 15·6. The notes indicate how symbols and data are placed in relation to the reference line. The perpendicular leg of the fillet, bevel- and J-groove weld symbol is always placed to the *left.*

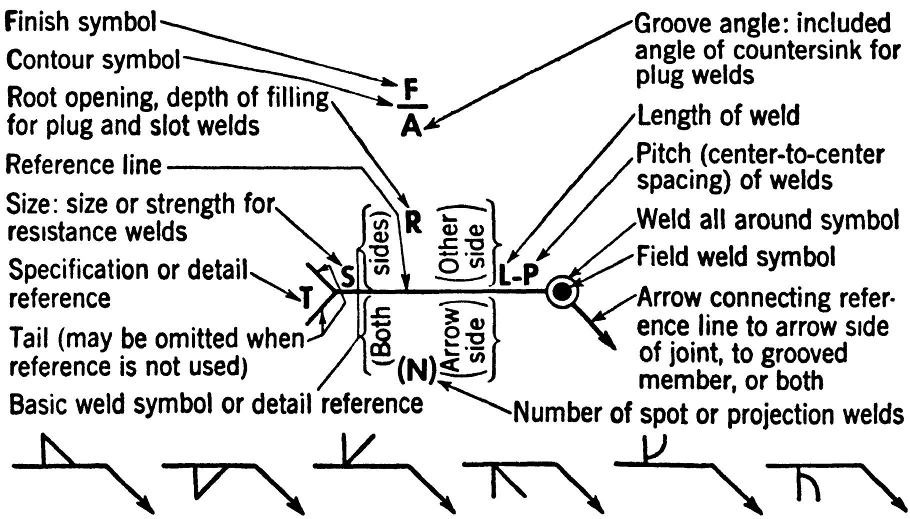


Figure 15·6 Location of welding information on welding symbols.

The words "near side" and "far side," formerly used, have been replaced by the words "arrow side" and "other side" (Fig. 15·7). The symbol is shown at the left and the desired weld at the right at A to E. Note that the weld symbol for arrow side is placed on the side of the reference line toward the reader; for other side it is placed on the side of the reference line away from the reader; for both sides it is

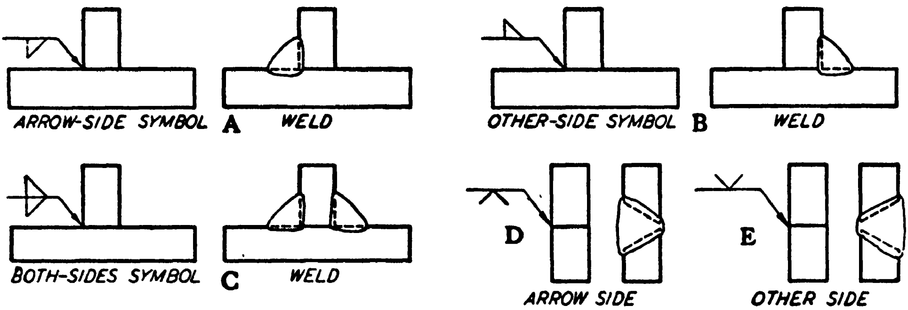


Figure 15·7 Arrow side and other side.

placed on both sides of the reference line. The arrow is drawn to point with *a definite break toward the member to be grooved* when the bevel- or J-groove weld symbol is used (Fig. 15·8). At A, the meaning is not

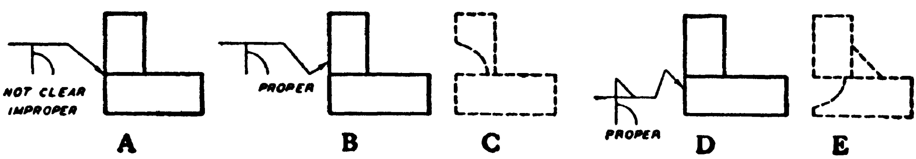


Figure 15·8 Groove indication.

clear. At B, the arrow clearly indicates that the vertical member is to be grooved on the arrow side as at C. At D, the symbol clearly indicates the desired welds as at E.

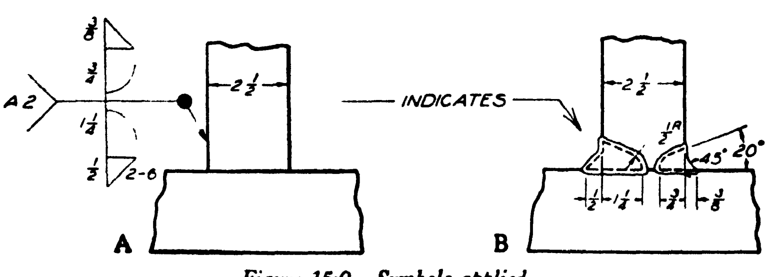


Figure 15·9 Symbols applied.

The tail of the arrow is used for specification reference (see Fig. 15·9) where *A*2 placed in the tail signifies the specification described in connection with that figure. Also see Fig. 15·6, where the letter T is placed in the tail of the arrow to refer to a specification. The tail of the arrow may be omitted when a specification reference is not needed as where standard company specifications are used.

15·6 An example of the way in which the symbols are used to give welding information is illustrated in Fig. 15·9 at A and B. This joint is described as follows:

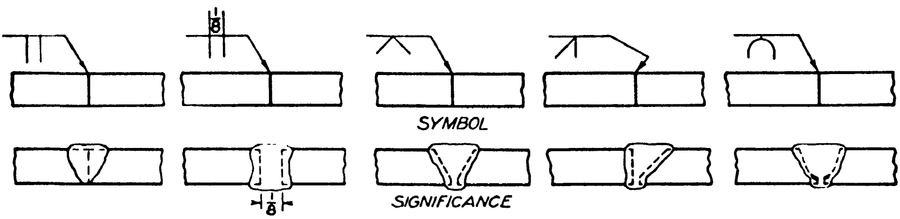


Figure 15·10 Butt joints.

Interpretation of Symbol: Double-filleted-welded, partially grooved, double-J tee joint with incomplete penetration (type of joint shown by the drawing). Grooves of standard proportion (which are, ½ in. *R*, 20° included angle, edges in contact before welding) ¾ in. deep for other (or far) side weld and 1¼ in. deep for arrow (or near) side fillet weld with increments 2 in. long, spaced 6 in. center-to-center. All fillets standard 45° fillets. All welding done in field in accordance with welding specification number *A*2 (which

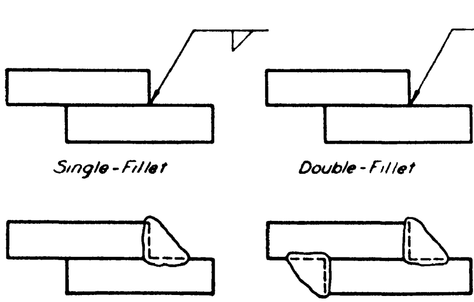


Figure 15·11 Lap joints.

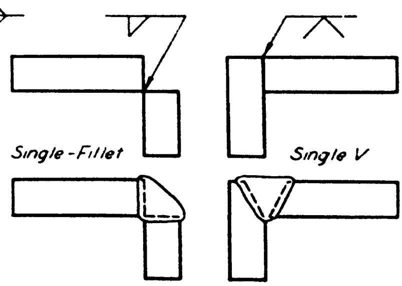


Figure 15·12 Corner joints.

requires that weld be made by manual D.C. shielded metal-arc process using high-grade, covered, mild steel electrode; the root be unchipped and welds unpeened but that joint be preheated before welding.

15·7 Meaning of Symbols. Some symbols used to indicate various welded joints and their meaning are shown in Figs. 15·10 to 15·12. The symbol is shown on the top row, and the preparation of the joint before welding is shown by hidden lines on the bottom row.

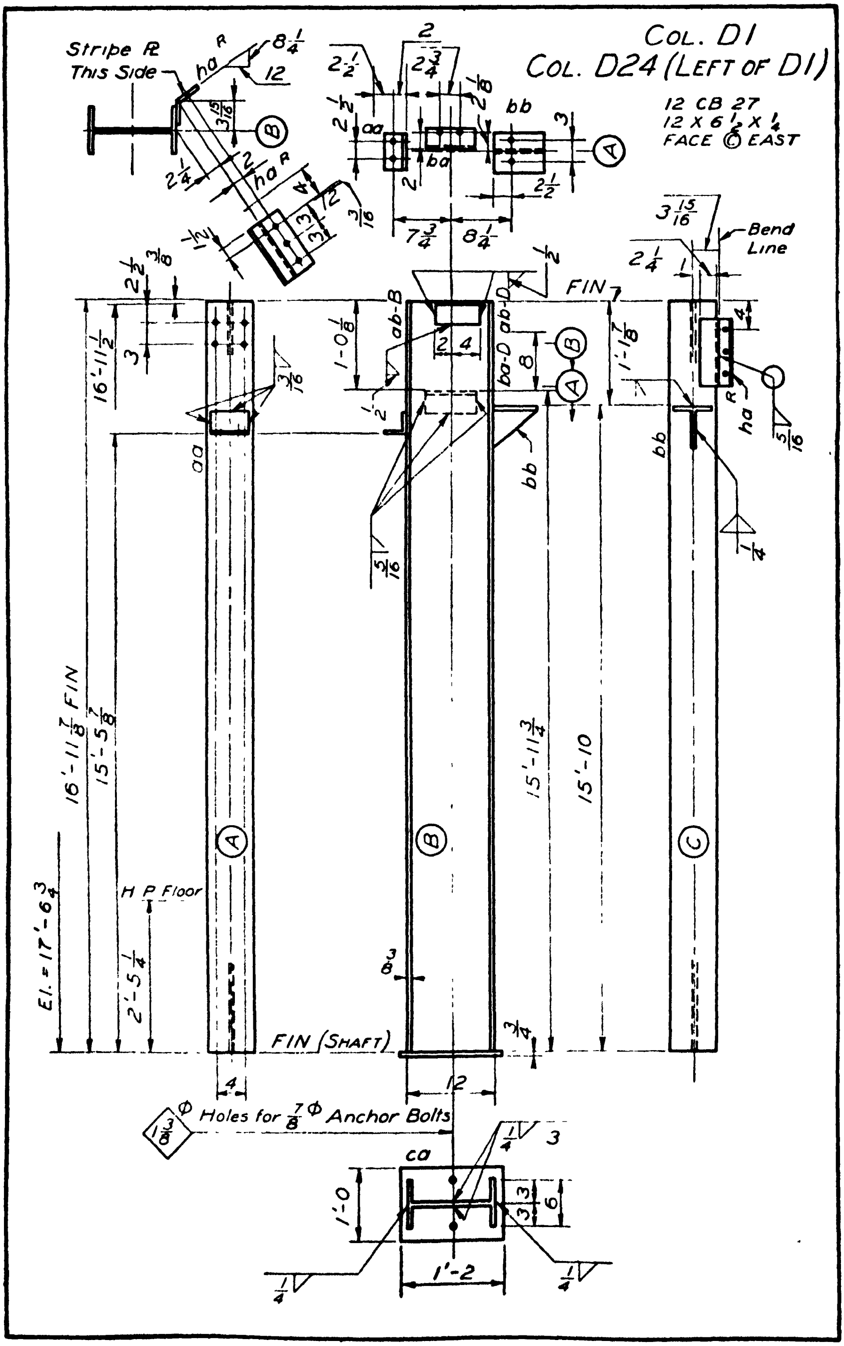


Figure 15·13 Welding symbols on a structural drawing. **Prob. 431.** (*American Bridge Company.*)

Welding symbols are shown on a machine drawing in Fig. 15·2 and on a structural drawing in Fig. 15·13.

15·8 "**Resistance welding**[1] differs from other forms of welding in that no extraneous materials, such as fluxes, filler rods, etc., are used. . . . " The welding heat is generated by the resistance of the parts to the electric current. For contact welding, the parts are placed together, electric current is passed through, and pressure is applied to force the parts together and produce a forge weld. For flash welding,

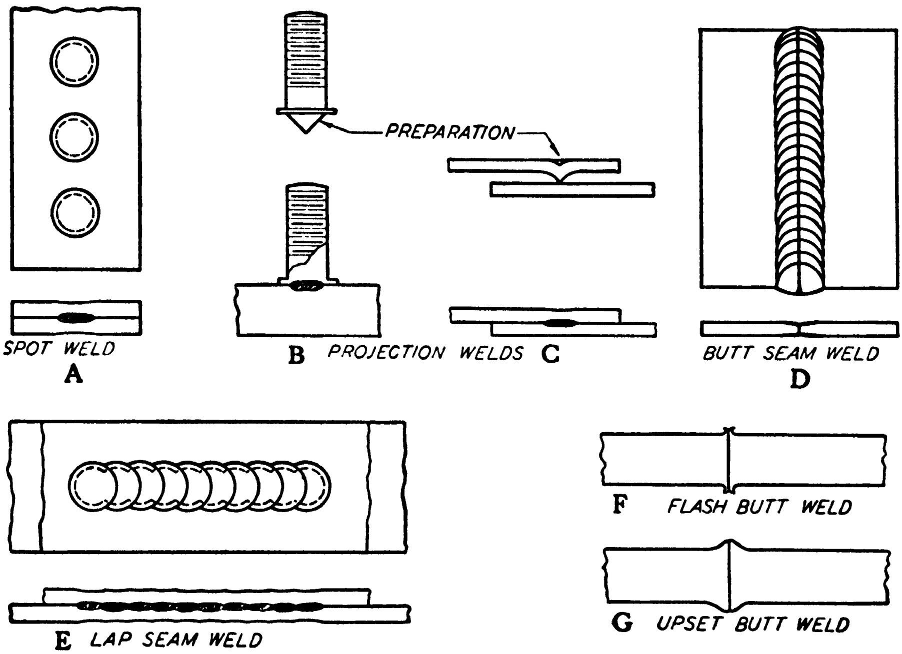


Figure 15·11 Resistance welds.

the parts are placed either in very light contact or with a very small air gap; the electric current "flashes" or arcs and melts the ends of the parts.

15·9 Resistance Welds. There are two major classes of resistance welds: spot welding (including spot, projection, seam, cross-wire, and contact) and butt welding (including butt-flash, push-butt, percussive, and contact).

A few definitions formulated by the Nomenclature Committee of the Resistance Welder Manufacturers' Association are as follows:

[1] "Resistance Welding Manual," Resistance Welder Manufacturers' Association, Philadelphia, Pa.

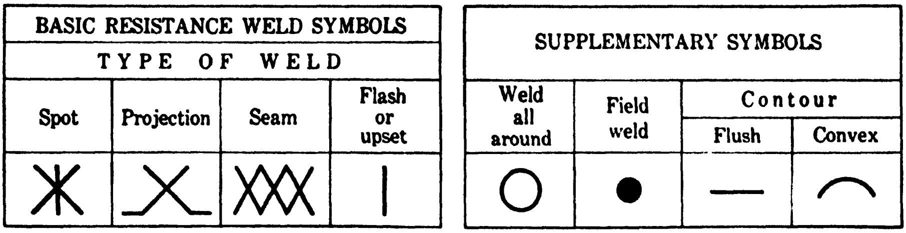


Figure 15·15 Resistance-welding symbols.

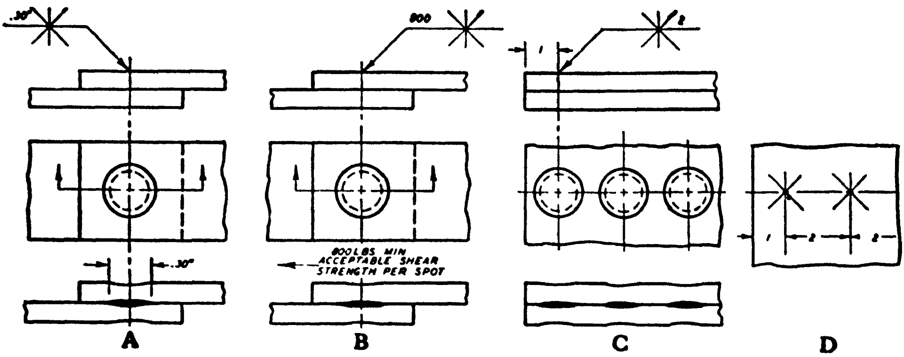


Figure 15·16 Spot-welding symbols.

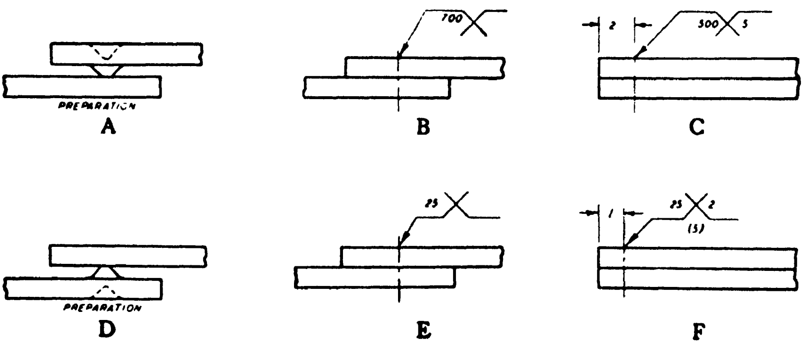


Figure 15·17 Projection-welding symbols.

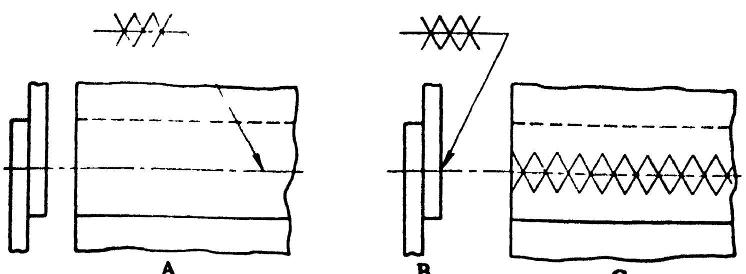


Figure 15·18 Seam-welding symbol.

Spot Welding. A resistance process wherein the fusion is confined to a relatively small portion of the area of the lapped parts to be joined by the shape or contour of one or both welding electrodes (Fig. 15·14 at A).

Projection Welding. A resistance-welding process wherein localization of heat between two or more surfaces or between the end of one member and surface of another is effected by projections (Fig. 15·14 at B and C).

Butt Seam Welding. A welding process with the pieces positioned edge to edge (Fig. 15·14 at D).

Lap Seam Welding. A seam-welding process wherein overlapping or tangent spot welds are made progressively (Fig. 15·14 at E).

Flash Butt Welding. A resistance butt-welding process wherein the necessary heat is derived from an arc or series of arcs established between the parts being welded prior to the application of the weld consummating pressure which is applied when the heat thus obtained has produced proper welding conditions (Fig. 15·14 at F).

Upset Butt Welding. A resistance-welding process wherein the current is applied after the parts to be welded are brought in contact and wherein the heat is derived from the flow of current (Fig. 15·14 at G).

Basic resistance-welding symbols are given in Fig. 15·15. The basic reference line and arrow are used as with arc- and gas-welding symbols, but in general there is no "arrow side" or "other side." Figure 15·6 covers both resistance welds and gas welds.

The spot-welding symbol is shown in Fig. 15·16 in the top row. The second row shows a plan view; the third row shows a section through the weld. At A, the minimum diameter of each weld is specified as 0.30 in. At B, the minimum shearing strength of each weld is specified as 800 lb. At C and D are two methods of specifying the welds to start 1 in. from the left end and spaced 2 in. center to center.

The projection-welding symbol is shown in Fig. 15·17 where the preparation is shown at A when the embossment (projection) is on the "arrow side" member in which case the symbol is placed as at B and C. At B, the "700" means that the acceptable shear strength per weld is to be not less than 700 lb. At C, the minimum shear strength per weld is 500 lb., and the welds are to be spaced 5 in. center to center. At D, the embossment (projection) is on the "other side" member. At E, the minimum diameter of the weld is 0.25 in.; at F the minimum diameter of the weld is 0.25 in., spaced 2 in. center to center. There are five welds. The symbol for seam welding is shown in Fig. 15·18 where the arrow is used at A and B, with the alternative method of placing the symbol on the view shown at C.

CHAPTER 16. Graphic Solutions

16·1 The study of drawing in the previous chapters has had as its main purpose the methods of describing the shape and size of constructions so that they could be built from the drawings. Another important use of drawing is in the graphical solution of problems. For both of these uses, a draftsman should be familiar with geometrical constructions.

16·2 Lines. A line may be divided into two equal parts by measurement with the scale, by trial with the dividers as described in Art. 2·17, or geometrically as in Fig. 16·1. Given the line *AB*: With a radius greater than one-half *AB*, draw arcs with *A* and *B* as centers. A line drawn through the intersections of the arcs will be perpendicular to *AB* and will divide it into two equal parts or bisect it.

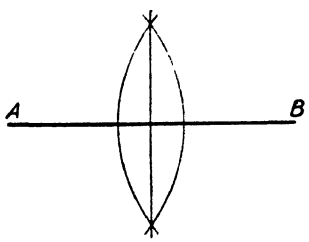


Figure 16·1 To bisect a line.

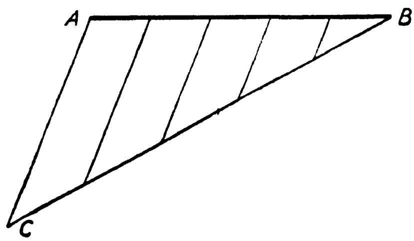


Figure 16·2 To divide a line.

16·3 A line may be divided into any number of equal parts by trial with the dividers, as described in Art. 2·17, or by using the scale as described in Art. 2·18. Another way is by the geometrical method of Fig. 16·2. To divide the line *AB* into five equal parts, from *B* draw another line at any angle. On it step off five equal spaces of any convenient length. Connect the last point *C* with *A*. Through the other points draw lines parallel to *CA*, using a triangle and T-square as shown in Fig. 2·9.

16·4 Sometimes it is necessary to reduce or enlarge linear dimensions from one size to another. A special scale for this purpose may be made geometrically on the well-known theorems of proportional triangles. Draw two parallel lines at a convenient distance apart, one, *AB*, to the given scale and the other, *CD*, to the desired length, either shorter (Fig. 16·3) or longer (Fig. 16·4). Lines through *AC* and *BD* will intersect at point *O*. Draw lines from *O* through each division of the given scale *AB*. These will divide *CD* into proportional spaces, thus making a new scale from which the desired measurements can be taken.

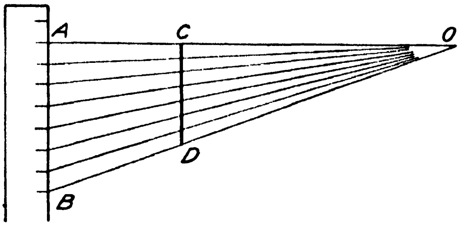


Figure 16·3 Reducing.

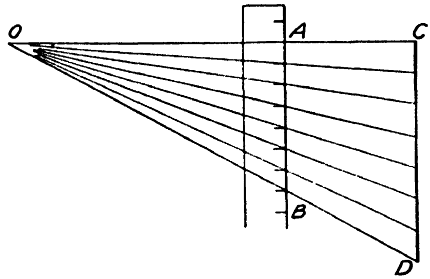


Figure 16·4 Enlarging.

16·5 Angles. The size of the angle between two lines is measured in degrees. As there are 360° in a circle, a right angle would contain 90°. For measuring and laying out angles, an instrument called a "protractor" is used. The usual form is semicircular, as shown in Fig. 16·5, where an angle of 43° is measured.

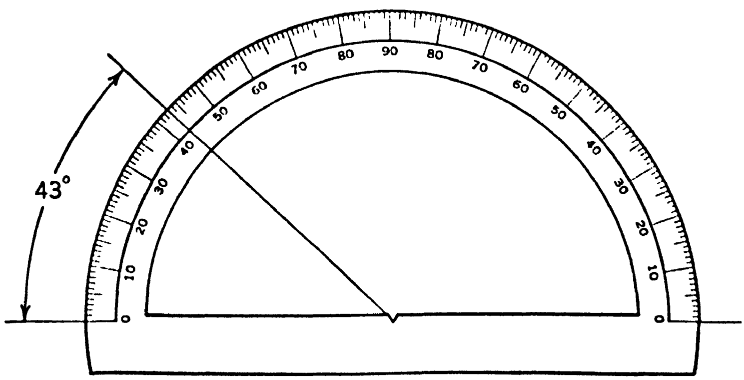


Figure 16·5 A protractor.

In Art. 2·7 (Fig. 2·8) we learned that angles varying by 15° could be constructed with the 30°–60° and 45° triangles. An angle of 90° may be readily bisected with the 45° triangle or trisected with the 30°–60° triangle.

16·6 To Bisect an Angle (Fig. 16·6). With O as a center and any radius, draw an arc cutting the sides at A and B. With A and B as centers and any radius greater than one-half AB, draw intersecting arcs. A line through this intersection and the point O will bisect the angle.

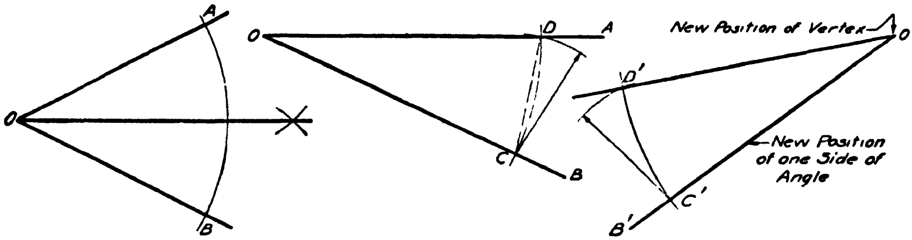


Figure 16·6 To bisect an angle.

Figure 16·7 To copy or transfer an angle.

16·7 To Copy an Angle (Fig. 16·7). Given the angle AOB and line $O'B'$: Draw an arc with O as a center and any convenient radius. With O' as a center and the same radius, draw another arc. With a radius equal to the chord CD, draw an arc with C' as a center intersecting the first arc at D'. Then the angle $D'O'C'$ will be equal to angle AOB.

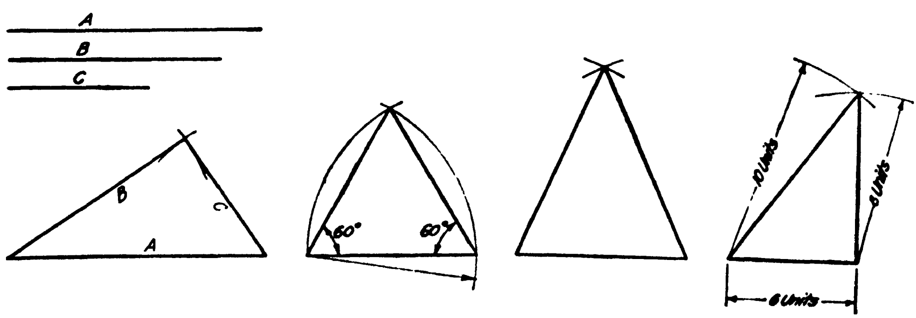


Figure 16·8 To construct a triangle.

Figure 16·9 Equilateral triangle.

Figure 16·10 Isosceles triangle.

Figure 16·11 Right triangle.

16·8 Triangles. To construct a triangle, having given the lengths A, B, and C of the three sides (Fig. 16·8), draw one side, as A, in the desired position. With its ends as centers and radii B and C, draw two intersecting arcs as shown.

An *equilateral* triangle has three equal sides. It may be constructed by drawing one side in the desired position and drawing intersecting arcs with the ends as centers and the length of the side as a radius, or by drawing 60° lines from each end of the base, using the 30°–60° triangle (Fig. 16·9).

An *isosceles* triangle has two equal sides (Fig. 16·10). It may be constructed by locating the base and drawing intersecting arcs from each end, using one of the equal sides as a radius.

A *right* triangle is one with a right angle. It may be constructed geometrically by the "6-8-10 method" when the T-square and triangle cannot be used. Draw the base 6 units long. From one end draw an arc with a radius 10 units long and from the other an arc with a radius 8 units long. Connect their intersections with the ends of the base (Fig. 16·11).

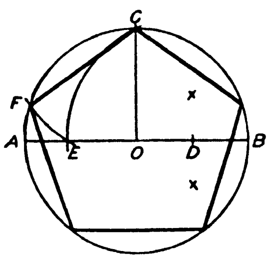


Figure 16·12 Pentagon.

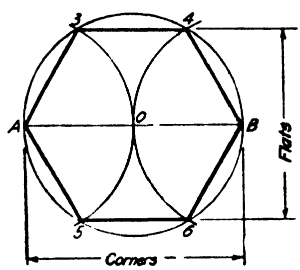


Figure 16·13 Hexagon.

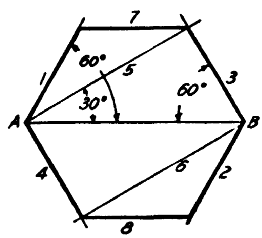


Figure 16·14 Hexagon.

16·9 The Pentagon. To draw a pentagon in a circle (Fig. 16·12), draw a diameter *AB* and a radius *OC* perpendicular to it. Bisect *OB*, and with this point *D* as a center and a radius *DC*, draw the arc *CE*. With *C* as a center and a radius *CE*, draw the arc *EF*. Then *CF* will be one side of the pentagon. With the same radius mark off the remaining three points.

16·10 The Hexagon. A regular hexagon can be drawn in a number of ways and was explained in Art. 10·10. If the distance across corners *AB* (Fig. 16·13) is given, draw a circle with *AB* as a diameter. With *A* and *B* as centers and the same radius, draw arcs and connect the points. A hexagon may be constructed directly on the line *AB*, without using the compasses, by drawing lines with the 30°–60° triangle in the order shown in Fig. 16·14.

16·11 The Octagon. To draw an octagon in a given square (Fig. 16·15), draw the diagonals of the square. With the corners as centers and a radius equal to half a diagonal, draw arcs cutting the sides of the square and connect these points.

16·12 Arcs and Tangents. A circle may be drawn through any three points not in a straight line. Given the points *A*, *B*, and *C* (Fig. 16·16): Draw lines *AB* and *BC*. Using the method of Art. 16·2, bisect these lines. The point *O* where the bisectors cross will be the center of the required circle.

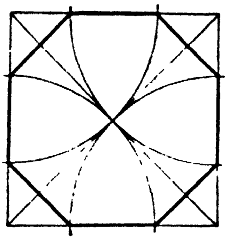


Figure 16·15 Octagon.

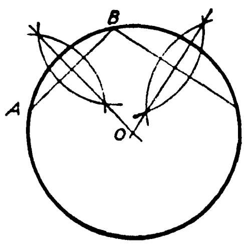


Figure 16·16 Circle.

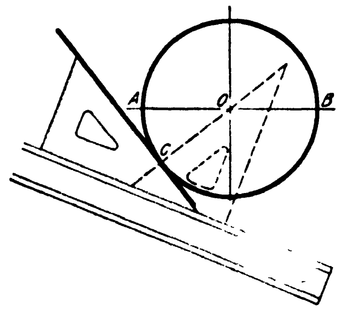


Figure 16·17 To draw a tangent.

16·13 To draw a tangent to a circle, at a given point (draftsman's method, Fig. 16·17), arrange a triangle in combination with the T-square (or another triangle) so that its hypotenuse passes through center *O* and point *C*. Holding the T-square firmly in place, turn the triangle about its square corner, move it until the hypotenuse passes through *C*, and draw the tangent.

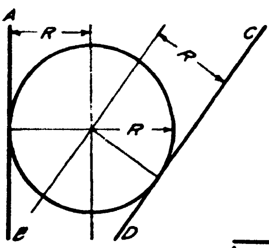


Figure 16·18

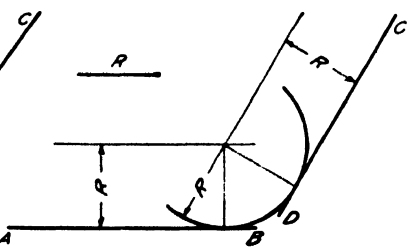


Figure 16·19

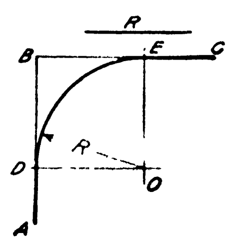


Figure 16·20

Figure 16·18, 16·19, and 16·20 To draw an arc tangent to two lines.

16·14 To Draw an Arc Tangent to Two Lines (Figs. 16·18 and 16·19). Given two lines *AB* and *CD* and radius *R*: Draw lines parallel to *AB* and *CD* at a distance *R* from them. The intersection of these lines will be the center of the required arc. Locate the points of tangency (the stopping points for the curve) by drawing lines through the center of the arc perpendicular to the tangent lines, reversing the method of Fig. 16·17.

16·15 To Draw an Arc in a Right Angle (Fig. 16·20). This is often used in drawing fillets and rounds. It is desired to round the corner *ABC* with an arc of radius *R*. With *B* as a center and radius *R*, cut the two lines at points *D* and *E*. With these points as centers and radius *R*, draw arcs intersecting at *O*. An arc with center *O* and radius *R* will be tangent to the straight lines at points *D* and *E*.

16·16 To draw a noncircular curve approximately with circle arcs, find by trial the center for an arc that will cover a portion of the curve required. Connect the end of the arc with the center. The next center for an arc tangent to the first must lie somewhere on this line. Continue the process as in Fig. 16·21. Remember that, when two arcs are tangent to each other, the two centers and the point of tangency must lie in a straight line. In other words, the line of centers must pass through the point of tangency.

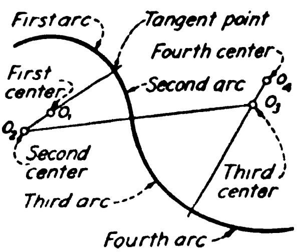


Figure 16·21 To draw tangent arcs.

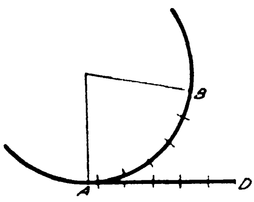


Figure 16·22 Length of an arc.

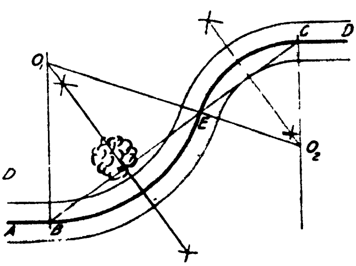


Figure 16·23 An ogee curve.

16·17 To Lay Off on a Straight Line the Approximate Length of a Circle Arc (Fig. 16·22). Given the arc *AB*: At *A* draw the tangent *AD*. Set the dividers to a small space. Starting at *B*, step along the arc to the point nearest *A*, and, without lifting the dividers, step off the same number of spaces on the tangent, as shown.

16·18 To Draw a Reverse or Ogee Curve (Fig. 16·23). To connect two parallel lines *AB* and *CD* by a smooth curve, connect *B* and *C* by a straight line, and select on it a point *E* through which the curve is desired to pass. Bisect *BE* and *CE* (Art. 16·2), and extend the bisectors to meet perpendiculars drawn from *B* and *C*, giving centers for the required arcs.

Proof: Any arc to pass through *B* and *E* must have its center on a perpendicular bisecting the line *BE*. Any arc tangent to *AB* at *B* must have its center on a perpendicular to *AB* from *B*. Therefore the center of an arc tangent to *AB* and containing *E* must lie at the intersection of these perpendiculars. Check by drawing the line of centers, which must pass through *E*.

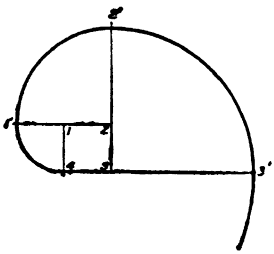


Figure 16·24 Involute of a square.

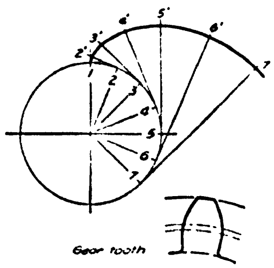


Figure 16·25 Involute of a circle.

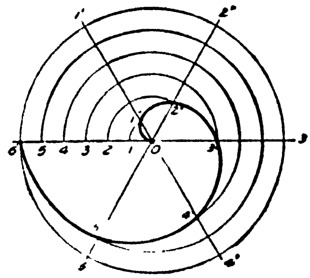


Figure 16·26 Spiral of Archimedes.

16·19 To Draw an Involute. Assume that a string has been wound around the square in Fig. 16·24 in a counterclockwise direction and that the loose end is at point 4. Start unwinding in a clockwise direction, and the end will describe an involute. To draw the involute, take a radius 4-1 with center at 1, and draw the arc 4-1′ ending at 1′

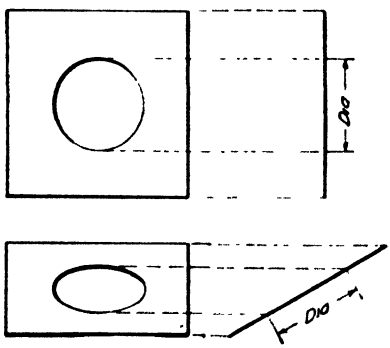


Figure 16·27 Circle projected as an ellipse.

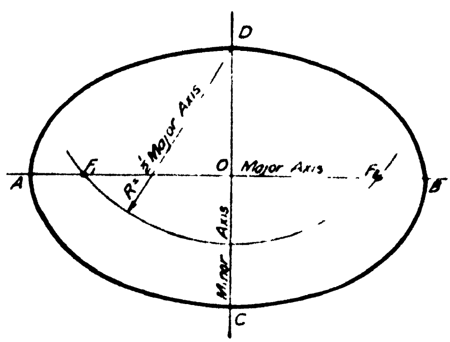


Figure 16·28 Ellipse.

on the side 2-1 produced. With radius 2-1′ and center 2, draw arc 1′-2′. Continue in like manner with the corners of the square as centers, increasing each successive radius by the length of a side. In the same way the involute of any polygon may be drawn.

To draw the involute of a circle (Fig. 16·25), divide the circumference of the circle into a number of equal parts, draw radial lines and tangents at the end of each radial line. Lay off the length of the arc from point 1 to point 2 on the tangent 2-2′ (Art. 16·17). Lay off on each tangent the length of the arc from the point of tangency to point 1. Through the points thus found (2′-3′-4′, etc.), draw the involute as a smooth curve, using the irregular curve. This is the curve of the involute gear tooth.

16·20 To Draw a Spiral of Archimedes (Fig. 16·26). Draw a circle, divide it into a number of equal parts, and divide a radial line into the same number of equal parts. With *O* as a center and radius *O*-1, draw an arc to radial line *O*-1′ to locate point 1″. In like manner, draw arcs with radii *O*-2, *O*-3, etc., to radii to locate points 2″, 3″, etc., as shown. Draw the spiral of Archimedes through the points thus located.

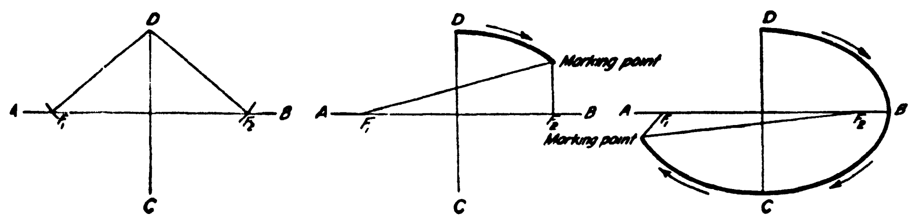


Figure 16·29 To draw an ellipse by pin-and-string method.

16·21 The Ellipse. If a circle is parallel to a plane, its projection on that plane will be a circle. If it is perpendicular to the plane, its projection will be a straight line. If it is at an angle, its projection will be an ellipse. A square card with a circular hole, drawn in different positions, as in Fig. 16·27, illustrates the foregoing statements. An ellipse is defined as "a curve generated by a point moving so that the sum of its distances from two fixed points, called the 'foci,' is constant and is equal to the longest diameter or major axis."

A line through the center perpendicular to the major axis is called the "short diameter" or "minor axis." To find the foci, draw an arc with its center at one end of the minor axis and a radius equal to one-half the major axis. This will cut the major axis at the foci F_1 and F_2 (Fig. 16·28).

16·22 To Draw an Ellipse. The easiest method for large work is the pin-and-string method. Given the major and minor axes (Fig. 16·29), locate the foci as described in the previous paragraph. Drive pins at points F_1, *D*, and F_2, and tie a cord tightly around the three pins. Then remove the pin *D* and move a marking point in the loop, keeping the cord taut. This will draw a true ellipse.

16·23 The trammel method (Fig. 16·30) is convenient and much used. Cut a strip of stiff paper (called a "trammel") and mark distance *oa* equal to one-half the major axis and *od* equal to one-half the minor axis. Move the strip as indicated by the arrows, keeping point

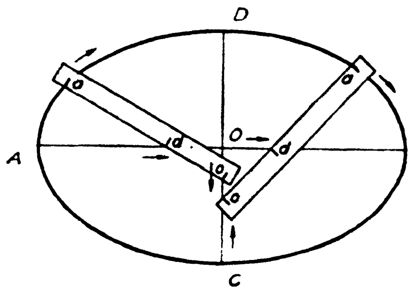


Figure 16·30 Trammel method.

d on the major axis and point *o* on the minor axis. Point *a* will locate points on the ellipse. Make light marks at point *a* for the different positions of the trammel, sketch the curve very lightly, and then draw it using the irregular curve.

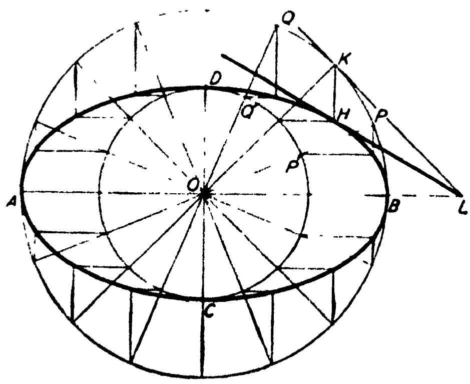


Figure 16·31 Two-circle method.

16·24 The concentric-circle method (Fig. 16·31) is a very accurate method for finding points on a required ellipse. With *O* as center, draw circles on the major and minor diameters. Draw a number of radial lines *OP*, *OQ*, etc., cutting the large circle at *P* and *Q* and the small circle at P' and Q'. From P and Q draw vertical lines and from P' and Q' horizontal lines. Where the lines through P and P' cross, there is one point on the ellipse. The lines through Q and Q' give another point. Find as many points as necessary and through them draw the curve, sketching it in very lightly before using the irregular curve. A tangent at any point H may be found by dropping a perpendicular from the point to the outer circle at K, and drawing an auxiliary tangent KL cutting the major axis produced at L. From L draw the required tangent LH.

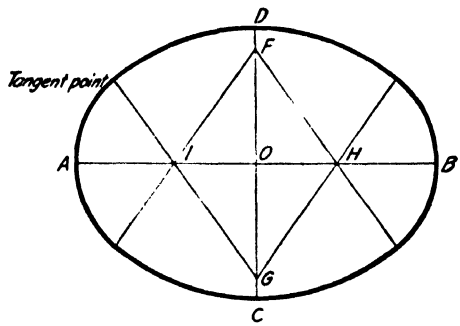


Figure 16·32 Approximate ellipse.

16·25 Approximate ellipses may be drawn with arcs of circles (see Art. 16·16). When the minor axis is at least two-thirds of the major axis, the four-center approximation shown in Fig. 16·32 may be used. Make OF and OG each equal to AB minus CD. Make OH and OI each equal to three-fourths of OF. Draw FH, FI, GH, and GI, extending them as shown. Draw arcs through points D and C with centers at G and F, and through A and B with centers I and H. An approximation is satisfactory when a true ellipse is not required or for the representation of a circle at an angle.

CHAPTER 17. Cams and Gears

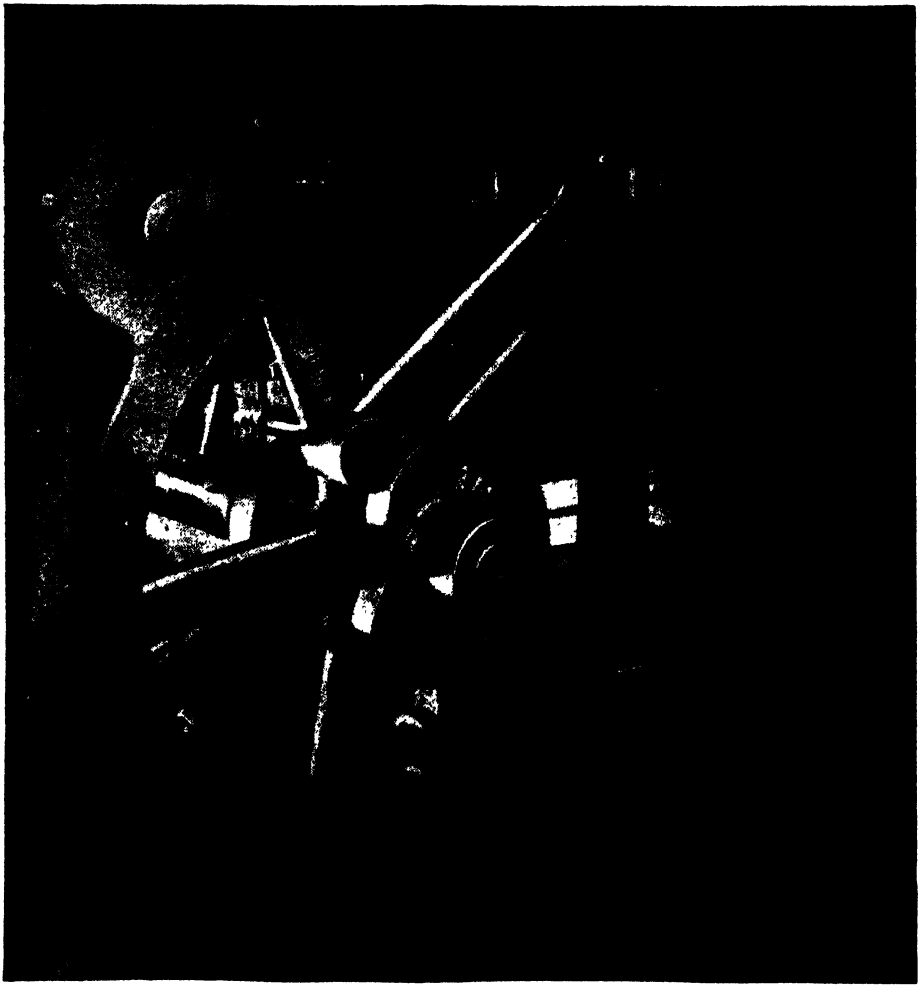


Figure 17·1 Cam installation using the McGill cam follower bearing. The small gear at the lower left-hand corner meshes with a large gear (covered with a guard) secured to a shaft. The cam shown at the center is secured to the same shaft. As the cam revolves, it moves the cam follower (a hollow cylinder) attached to the link and gives it a variable motion. The link is pivoted near the upper right-hand corner in the illustration. (*McGill Manufacturing Company, Inc.*)

17·1 Cams and gears (Fig. 17·1) are machine elements that frequently occur on working drawings. The theory and specification of cams and gears are important divisions of the study of mechanism to which the student is referred. The student should, however, know how to represent them on drawings as indicated in this chapter.

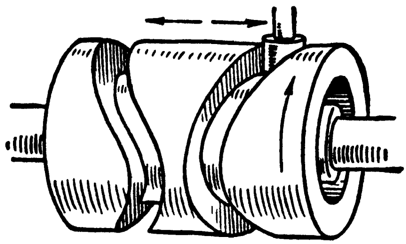


Figure 17·2 A cylindrical cam.

17·2 Cams. A cam is a machine element used to obtain an irregular or special motion not easily obtained by other means. Its shape is derived from the motion required of it. A plate cam is illustrated in

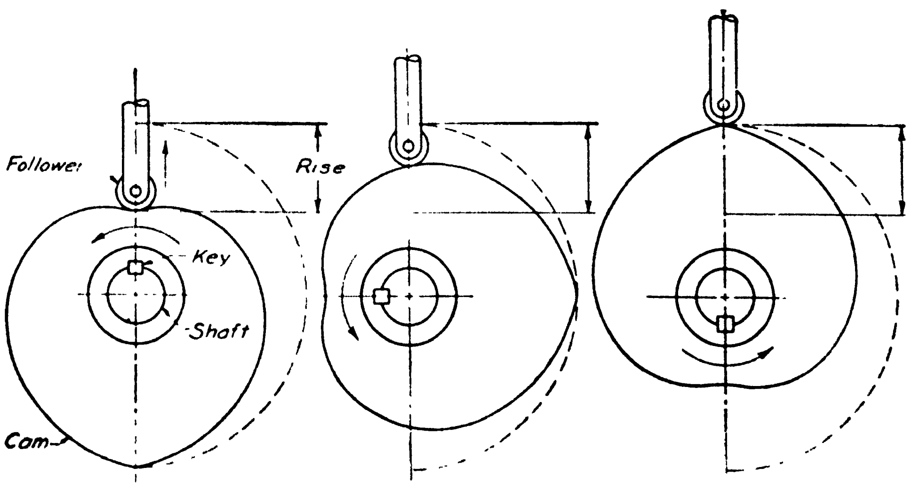


Figure 17·3 Cam terms and action.

Fig. 17·1, and a cylindrical cam in Fig. 17·2. Some cam terms are shown in Fig. 17·3 which also illustrates cam action.

17·3 To find the cam outline (Fig. 17·4), given point C, the center of the shaft, and point A, the lowest position of the center of the roller: It is required to raise the center of the roller with uniform motion during three-eighths of a revolution of the uniformly revolving shaft, to allow it to drop two-thirds of the way down instantly, to remain at rest for one-eighth of a revolution, to drop uniformly during three-eighths of a revolution, and to remain at rest for the remaining one-eighth of a revolution.

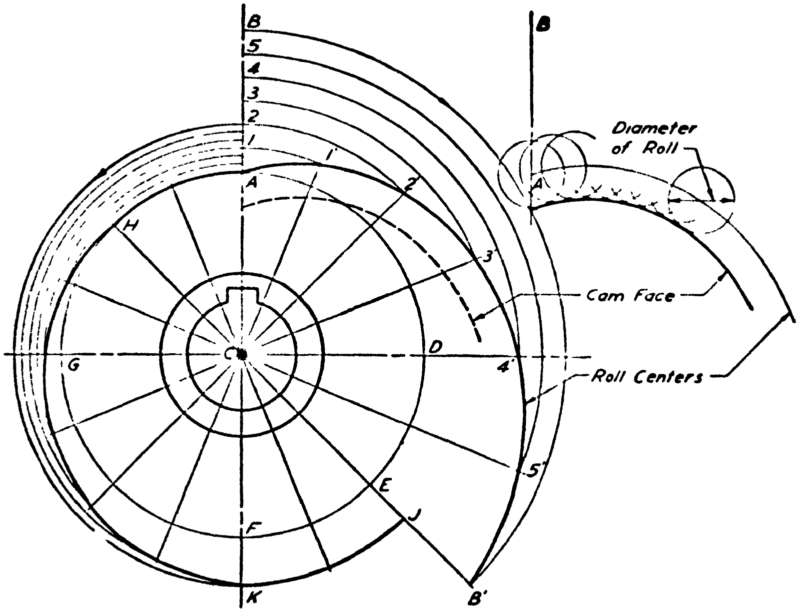


Figure 17·4 Drawing a plate cam.

Divide the rise into a number of equal parts. Divide the arc *ADE* into the same number of equal spaces as there are spaces in the rise, and draw radial lines. With *C* as a center and radius *C*1, draw an arc intersecting the first radial line at 1′. In the same way locate points 2′, 3′, etc., and draw a smooth curve through them. If the cam is revolved in a counterclockwise direction, it will raise the roller with the desired motion. Draw *B′J* equal to two-thirds of *AB*. Draw arc *JK* with radius *CJ*. Divide *A*2 into six equal parts and arc *FGH* into six equal parts. Circle arcs, when drawn as shown, will locate points on the cam outline. Draw arc *HA* with radius *CH* to complete the cam. This outline is for the center of the roller, allowance for which may be made by drawing the roller in its successive positions and then drawing the tangent curve as shown in the auxiliary figure.

17·4 Gears. If two wheels or circular discs are in contact, as in Fig. 17·5, both will revolve if one is turned. If the smaller wheel is two-thirds the diameter of the larger wheel, it will make one and one-

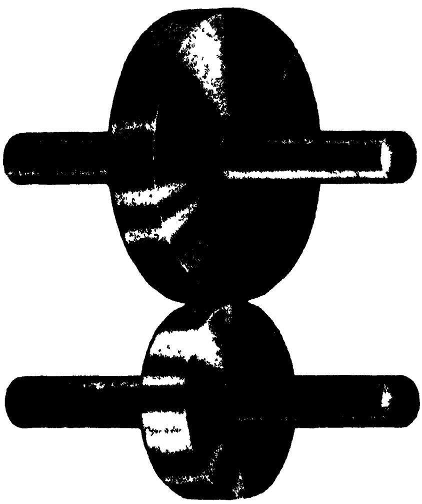


Figure 17·5 Friction wheels.

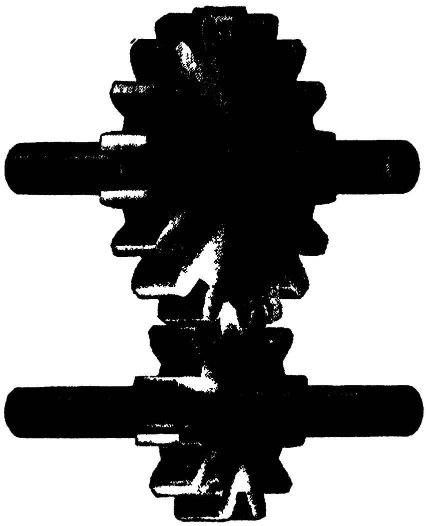


Figure 17·6 Gear and pinion.

half revolutions for one revolution of the larger wheel, provided that no slipping occurs. If the driven wheel is hard to turn, there will be slipping. To prevent this, teeth are added to the wheels, as in Fig.

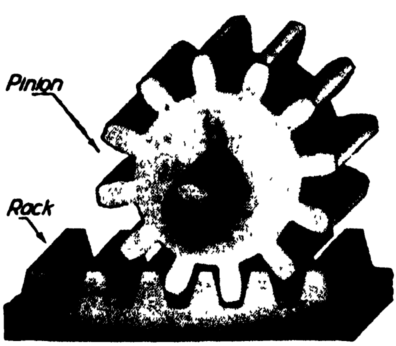


Figure 17·7 Rack and pinion.

17·6. The shape of the teeth is such that the same kind of motion is obtained as with the rolling wheels that did not slip. A *spur gear* and *pinion* are illustrated in Fig. 17·6 where the small gear is the pinion. A *rack* and *pinion* are illustrated in Fig. 17·7.

17·5 The parts of gears have names as illustrated in Fig. 17·8. Note the three diameters: *outside diameter*, *root diameter*, and *pitch diameter*. The pitch diameter corresponds to the diameter of the rolling wheel that is replaced by the gear. There are two kinds of pitch: *circular pitch* and *diametral pitch.* The circular pitch is the distance from a point on one tooth to the same point on the next tooth measured along the pitch circle. The diametral pitch is a ratio, obtained by dividing the number of teeth by the pitch diameter. The *addendum* is the distance that the gear tooth extends above (outside) the pitch circle. The *dedendum* is the distance that the gear tooth extends below (inside) the pitch circle.

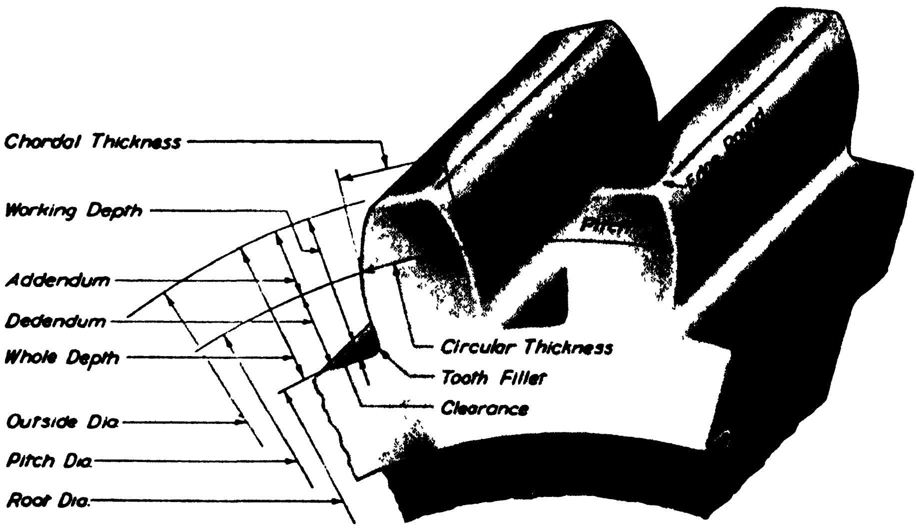


Figure 17·8 Gear terms.

17·6 Gear drawings are illustrated in Figs. 17·9 and 17·10. It is not necessary to draw the teeth on working drawings of gears. The gear *blank* should be drawn with dimensions for making the pattern and for the machining operations, together with notes to give the necessary information for cutting the teeth, the accuracy required, the material, etc. On assembly drawings, the representation shown in Fig. 17·10 may be used which gives the pitch and number of teeth.

17·7 Gear Terms and Abbreviations. The following information and formulas can be used to find required dimensions, etc., for standard gears:

N = number of teeth

A = addendum $= \dfrac{1}{DP}$

D = dedendum $= \dfrac{1.157}{DP}$

C = clearance $= \dfrac{0.157}{DP}$

PD = pitch diameter $= \dfrac{N}{DP}$

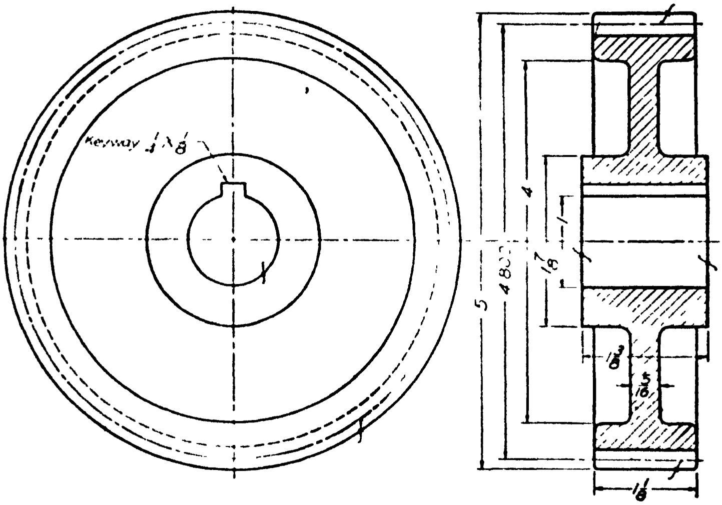
OD = outside diameter $= \dfrac{N+2}{DP} = 2A + PD$

CP = circular pitch $= \dfrac{\pi PD}{N}$

DP = diametral pitch $= \dfrac{N}{PD}$

RD = root diameter $= PD - 2D$

WD = whole depth $= A + D$



No. of teeth	48
Pressure ∡	14½°
Addendum	.10
Whole Depth	.216
Pitch	10
Backlash	.004

Figure 17·9 Working drawing of a cut spur gear.

17·8 Bevel gears (Fig. 17·11) are used when the two gear shafts intersect. In this case the gears may be thought of as replacing rolling cones. When the gears are the same size and the shafts are at right angles, they are called "miter gears." The smaller of two bevel gears is called the "pinion." A working drawing of a cut bevel gear is shown in Fig. 17·12.

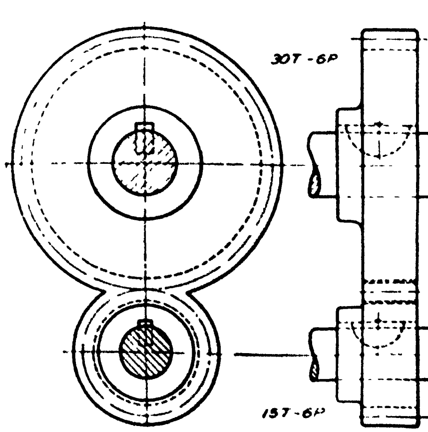


Figure 17·10 Gears in elevation.

17·9 Gear information may be obtained from the published standards of the American Standards Association and by a study of the books devoted to the subject of gearing in its many forms.

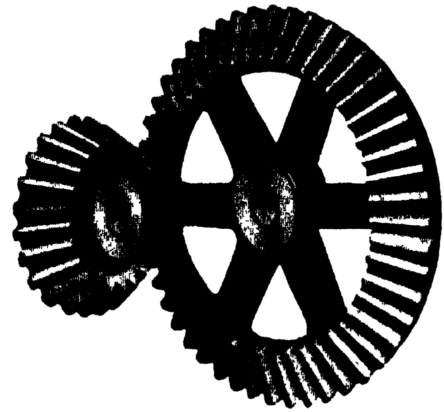


Figure 17·11 Bevel gears.

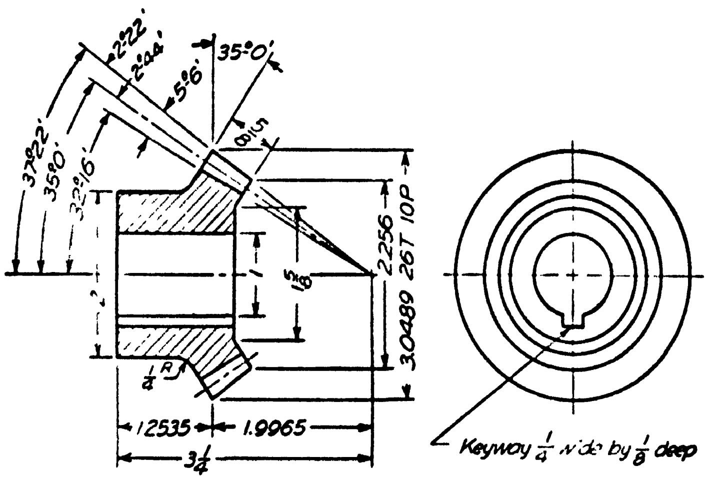


Figure 17·12 Working drawing of a cut bevel gear.

CHAPTER 18. Sheet-metal Drafting

Figure 18·1 Sheet-metal ducts. (*Bethlehem Steel Company.*)

18·1 Sheet-metal Drafting. A large class of metal work is made from thin sheets of metal which are formed into the required shape by bending or folding up and fastening by rivets, seams, soldering, or welding. Figure 18·1 shows an air-conditioning duct installation made up of Bethlehem Steel sheets. For sheet-metal work, the drawings consist of the representation of the finished object and the drawing of the shape of the flat sheet, which, when rolled or folded and fastened, will form the object.[1] This second drawing is called the

[1] A great many thin metal objects are formed without seams by die stamping or by pressing a flat sheet into shape under very heavy presses. Examples range from brass

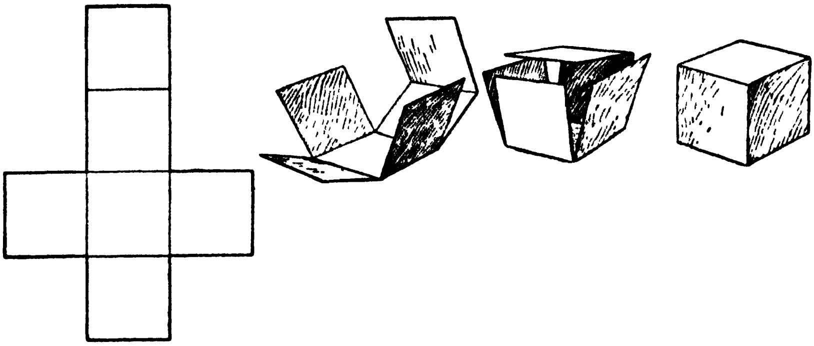


Figure 18·2 Pattern for a cube.

"development" or "pattern" of the piece; making it comes under the term "sheet-metal pattern drafting."

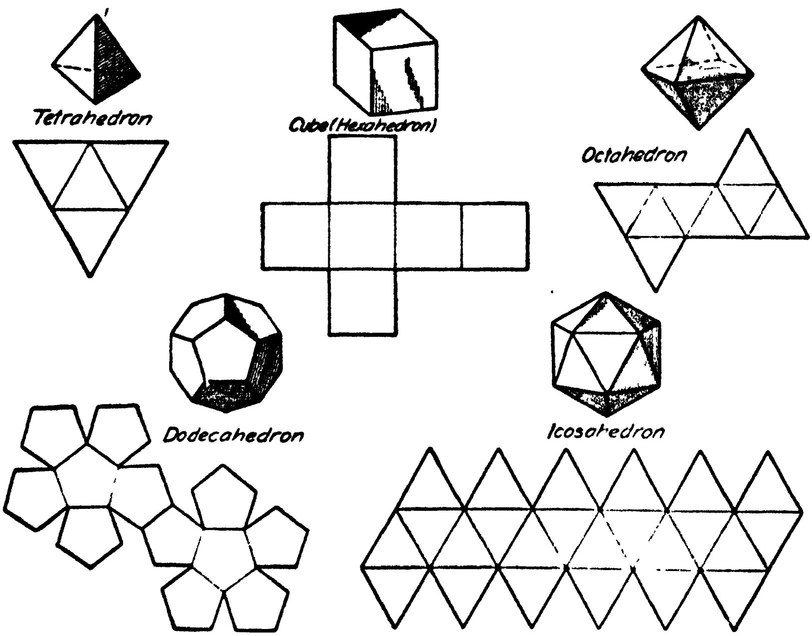


Figure 18·3 The five regular solids.

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cartridge cases to steel wheelbarrows. Still another division is made by spinning, as brass and aluminum ware. In stamped and spun work, the metal is stretched out of its original shape. Making blanks for it depends upon much technical knowledge and experience.

18·2 Development. There are two general classes of surfaces: plane and curved. The six faces of a cube are plane surfaces. The bases of a cylinder are plane surfaces, whereas the lateral surface is curved.

It is possible to cut a piece of paper so as to fold it up into a cube, as in Fig. 18·2. The shape cut out would be the *pattern* of the cube. Those who have studied solid geometry recall that there are five regular solids and that their patterns are made as shown in Fig. 18·3. A good understanding of the nature of developments may be had by laying out the foregoing patterns and folding them to form the figures, using a rather stiff drawing paper. The joints can be easily secured with cellulose tape.

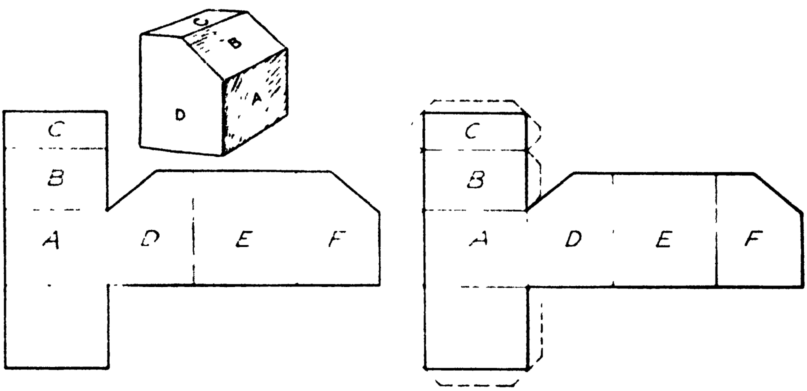


Figure 18·4 A pattern showing lap.

Thus the pattern for any piece that has plane surfaces may be made by first deciding where the seam is to be (usually, for economy of solder or rivets and time, it is taken on the shortest line), then opening up each face in order, showing it in its true size. One example, the development of a prism, is illustrated in Fig. 18·4. The lines inside the pattern are called "folding" or "crease" lines. The dotted lines on the second figure indicate extra material to allow for lap in making joints.

In geometry, we learn that a cylinder may be thought of as a prism with an infinite number of sides. The development of the curved surface of a cylinder, then, might be obtained by opening up each face, in order, and placing it in contact with a plane surface. The result would be a rectangle having a width equal to the height of the cylinder (an element) and a length equal to the distance around the cylinder. The developed surface of a cylinder is illustrated in Fig. 18·5.

The curved surface of a cone may be thought of as being made up of an infinite number of triangles. The development of the curved surface might be obtained by placing each triangle, in order, in contact with a plane surface. The result would be a sector of a circle having a radius equal to an element of the cone and an arc equal in length to the circumference of the base of the cone. The developed surface of a cone is illustrated in Fig. 18·5.

The length of the pattern for a prism is measured on a straight line called the *stretchout line*. This line measures the shortest distance

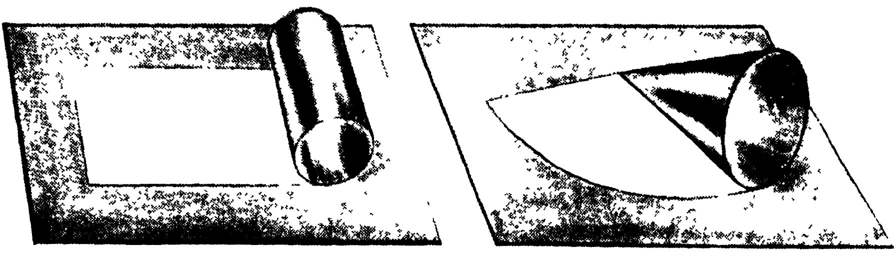


Figure 18·5 Cylinder and cone.

around the prism. When the base is perpendicular to the edges, it will form the stretchout line when the faces of the prism are unfolded in contact with a plane surface. For a cylinder the stretchout line is a straight line equal in length to the circumference of the cylinder. If the base of the cylinder is perpendicular to the axis it will roll out into a straight line and form the stretchout line. If a prism or cylinder does not have a base perpendicular to the axis, a right section must be taken in order to obtain the stretchout line.

18·3 Development of Prisms. To develop the prism in Fig. 18·6, draw the stretchout line *SL*, and on it lay off 1-2, 2-3, 3-4, and 4-1, obtained from the top view. This gives the length of the stretchout and the true distances between the vertical edges. At points 1, 2, 3, 4, and 1 on the stretchout, draw vertical crease lines equal in length to the corresponding edges of the prism. These lengths may be easily projected across from the front view. The true size of the inclined surface is found by the method of auxiliary projection (Chap. 7) and attached to one of the sides in its proper relation. The development of the bottom may be added if desired.

To develop the lateral surface of the triangular prism (Fig. 18·7), draw the stretchout line *SL*, and lay off the distances 1-*a*, *a*-2, 2-3, 3-*b*, *b*-1, taken from the top view. Points *a* and *b* do not locate crease lines but are required to find the line of the cut. Such extra "measuring lines" are often necessary.

18·4 Development of Cylinders. Consider a cylinder as being a many-sided prism. To develop the cylinder (Fig. 18·8), assume the

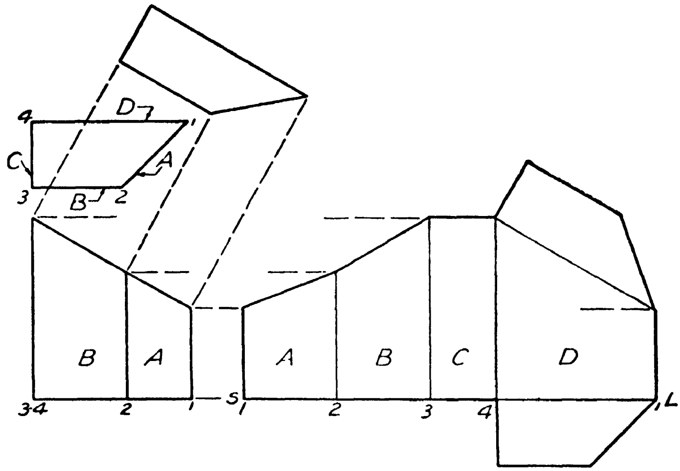


Figure 18·6 Development of a prism.

position of any convenient number of imaginary edges. For ease of working, these are equally spaced. This makes it possible to obtain the length of the stretchout by stepping off as many spaces along *SL* as

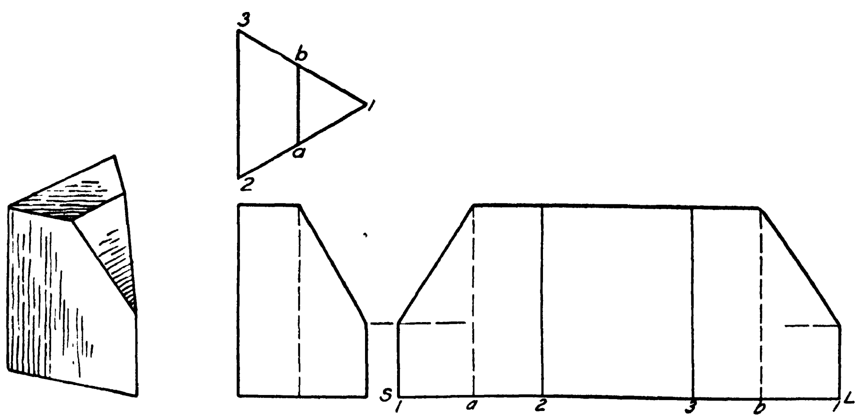


Figure 18·7 Development of a prism.

there are on the top view. At each point on the stretchout, draw a vertical measuring line. Project the length of each imaginary edge across from the front view to the corresponding line of the development, and draw a smooth curve through these points of intersection.

Since the surface is curved, the stretchout as obtained is only approximate. The more edges assumed, the closer will be the approximation. It is seldom necessary to have the points less than ¼ in. apart. The accuracy in length of the stretchout may be tested by measuring

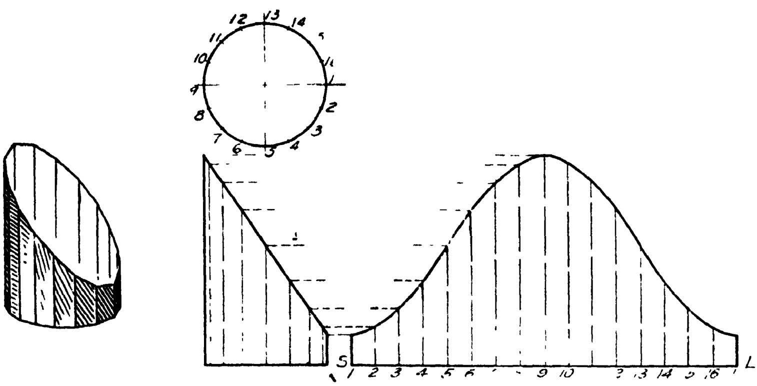


Figure 18·8 Development of a cylinder.

on it the figured length of the circumference, which equals 3.1416 times the diameter, or πd.

18·5 To Draw the Pattern for a Two-piece or Square Elbow (Fig. 18·9). This elbow consists of two cylinders cut off at 45°, so

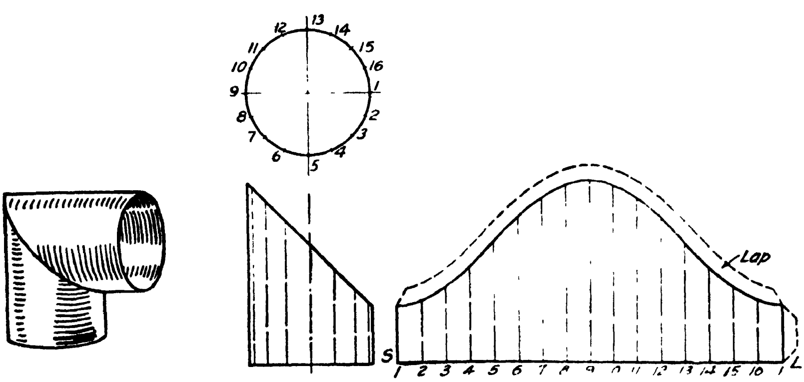


Figure 18·9 Pattern for a square elbow.

only one need be developed. The explanation of Fig. 18·8 applies to this figure. Lap is allowed as indicated.

18·6 The development of a four-piece elbow is illustrated in Fig. 18·10. To draw the elbow, first draw arcs having the desired inner and outer radii as shown at A. Divide the outer quarter circle into six equal parts. Draw radial lines from points 1, 3, and 5 to locate the joints. Draw tangents to the arcs at points 2 and 4 and complete the figure as shown at B, by tangents to the inner quarter circle. With this view completed, we are ready to start development. Draw a circle representing the cross section of the pipe (one-half of this view is sufficient). Divide it into a number of equal parts, and lay out the stretchout line with the same equal parts. From the circle, project to the elevation to locate the imaginary edges. The pattern for the first section is obtained by projecting across from the elevation as shown at C, in the same way as Fig. 18·8.

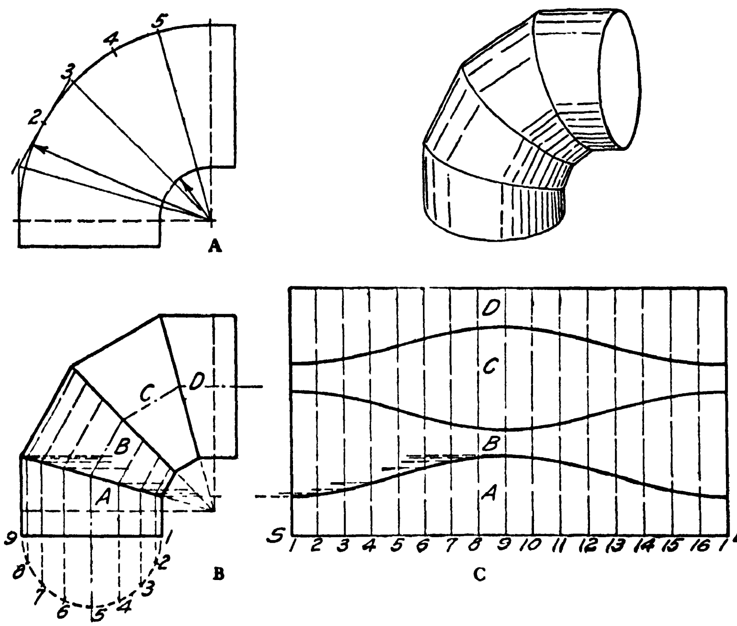


Figure 18·10 Pattern for a four-piece elbow.

The patterns for the four pieces may be cut without waste from a rectangular piece if the seams are made alternately on the inside, or throat line, and the outside line. To draw the pattern for the second section, extend the measuring lines of the first section, and with the dividers take off the lengths of the imaginary edges on the front view, starting with the longest one. The third and fourth sections are made in a similar way. Since the curve is the same for all sections, only one need be plotted.

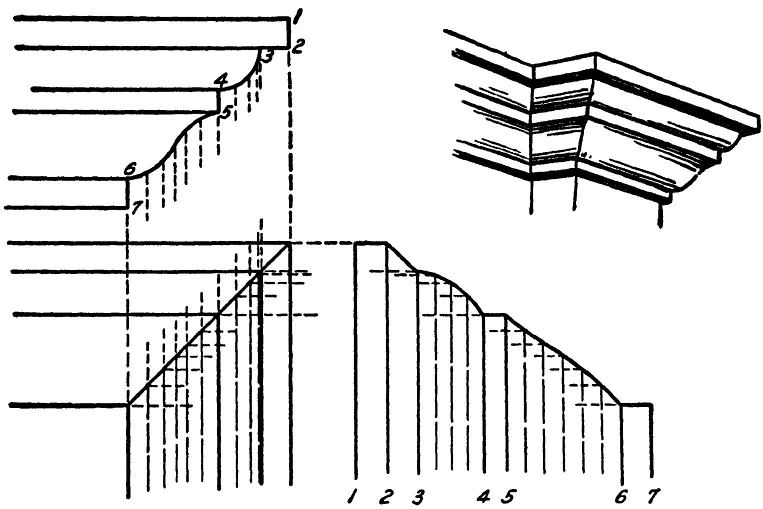


Figure 18·11 Pattern for a return miter.

18·7 Galvanized-iron moldings and cornices are made up of a combination of cylinder and prism parts. A practical problem in developments is making the pattern for a piece mitered to "return" around a corner, as shown in Fig. 18·11. An inspection of the figure shows the method of working to be the same as in Fig. 18·8, the sec-

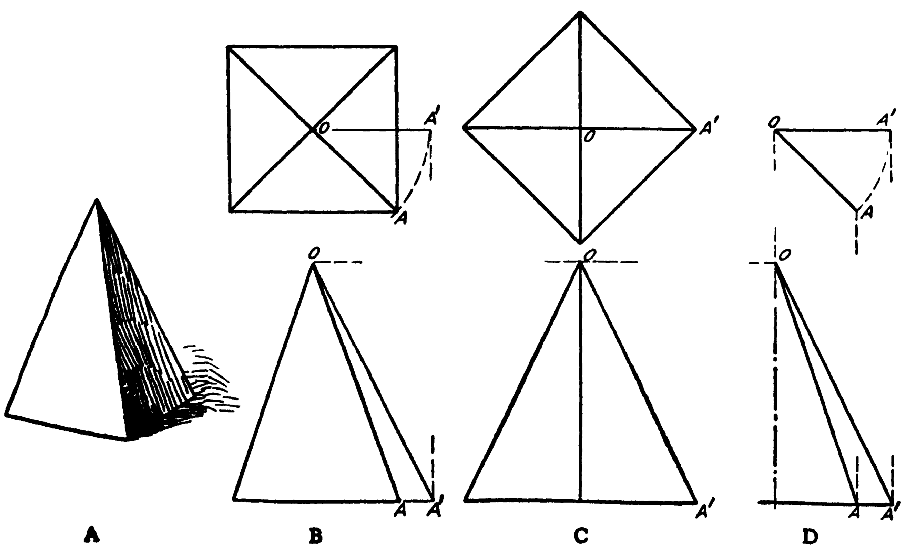


Figure 18·12 True length of a line.

tion of the molding taking the place of the top view and having its length laid out on the stretchout line.

18·8 Development of Pyramids and Cones. In the case of prisms and cylinders, the stretchout was a straight line with the measuring lines perpendicular to it and parallel to each other. As their edges were all parallel to the front plane, their true lengths were always shown in the front view. Pyramids and cones, or any objects larger at one end than at the other, will not roll straight; hence their stretchouts are not straight lines. Since they have sloping sides, their edges will not always show in their true lengths.

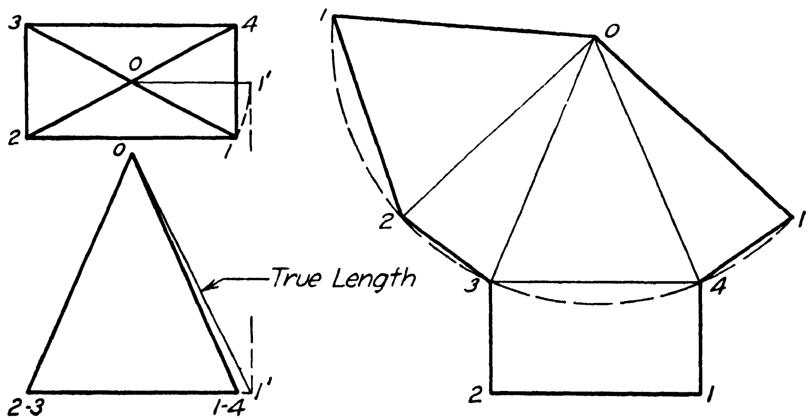


Figure 18·13 Development of a pyramid.

18·9 To find the true length of a line, revolve the line until it is parallel to one of the planes of projection. Its projection on that plane will then be its true length. The pyramid at A in Fig. 18·12 is shown by top and front views at B. The edge *OA* does not show in its true length in either view. However, if we draw the pyramid in the position shown at C, the true length of *OA* is shown in the front view. At C the pyramid has been revolved from the position of B about a vertical axis until the line *OA* is parallel to the vertical plane. At D the line *OA* is shown before and after revolving. Thus the construction for finding the true length of a line is as follows: In the top view, with radius *OA* and center *O*, revolve the top view of *OA* until it is horizontal, project the end of the line down to meet a horizontal line through the front view of *A*. Join this point of intersection with the front view of *O*. The true length is shown at *OA′*.

18·10 To Draw the Pattern for a Rectangular Pyramid (Fig. 18·13). Find the true length of one of the edges by swinging it around as shown. With this true length as a radius, draw an arc of indefinite length for a stretchout line. On this, mark off as chords the four edges of the base 1-2, 2-3, 3-4, 4-1. Connect these points with each other in turn, and draw the crease lines by joining each point with the center.

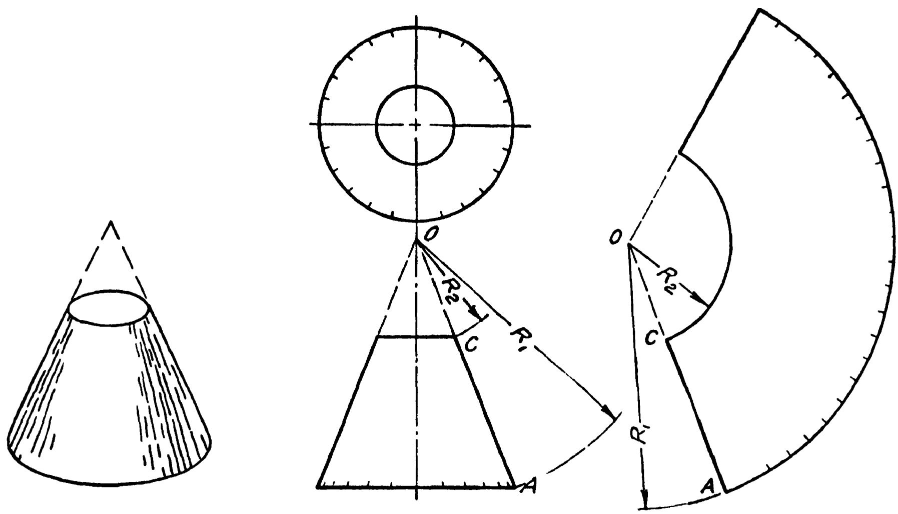


Figure 18·14 Frustum of a cone.

18·11 To Draw the Pattern for a Cone. From Fig. 18·5, it will be seen that the stretchout line for a cone is a circle arc with a radius equal to the slant height of the cone. Considering the cone as a many-sided pyramid, draw on the top view a convenient number of imaginary edges (elements), using equal spacing for convenience. With the slant height taken from the front view as a radius (*OA* in Fig. 18·14), draw an arc of indefinite length as a stretchout. On this, step off as many spaces as were assumed in the top view and at the same distances apart. Connect end points with the center. The resulting sector is the developed surface. If the cone is cut off straight across, as in Fig. 18·14, draw another arc with *OC* as a radius after developing the full cone.

18·12 If the cone is cut off at an angle, as in Fig. 18·15, first develop the full cone, drawing the developed position of each element and numbering them to avoid mistakes. Then find the true length of each element from the base to the cut surface by revolving it around the axis until it is parallel to the front plane or, in other words, by projecting it across to the outside line in the front view. Lay off these true lengths on the corresponding lines on the pattern and connect the points. The elements and lines have been stopped at the cut surface to preserve clearness.

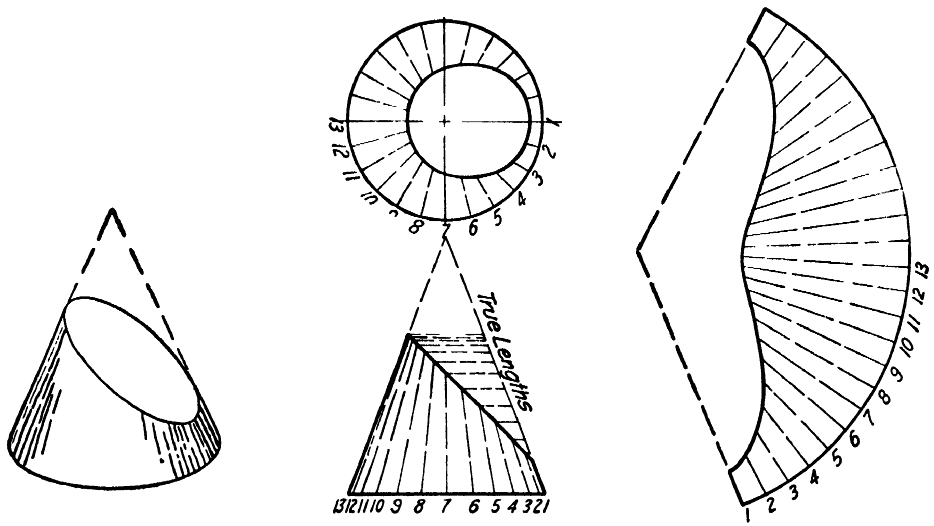


Figure 18·15 Truncated cone.

18·13 Development of a Transition Piece. A transition piece is used to connect a pipe of one shape with another of a different shape. Transition pieces are made up of parts of different kinds of surfaces and are developed by triangulation. The example shown in Fig. 18·16 connects a round pipe with a rectangular one. From the picture, it is seen that this piece is formed of four triangles, between which are four conical parts, with apexes at the corners of the rectangular opening and bases each one-quarter of the round opening.

Starting with the cone whose apex is at *A*, divide its base 1-5 into a number of equal parts as 2, 3, 4, and draw the lines *A*2, *A*3, *A*4, giving triangles approximating the cone. Find the true length of each of these lines. This is done in practical work by constructing a separate diagram, as at I, knowing that the true length of each line is the hypotenuse of an imaginary triangle whose altitude is the altitude of the cone and whose base is the length of the top view of the line.

On the front view, draw the vertical line AE as the altitude of the cone. On the base EF lay off the distances $A1$, $A2$, etc. This is done

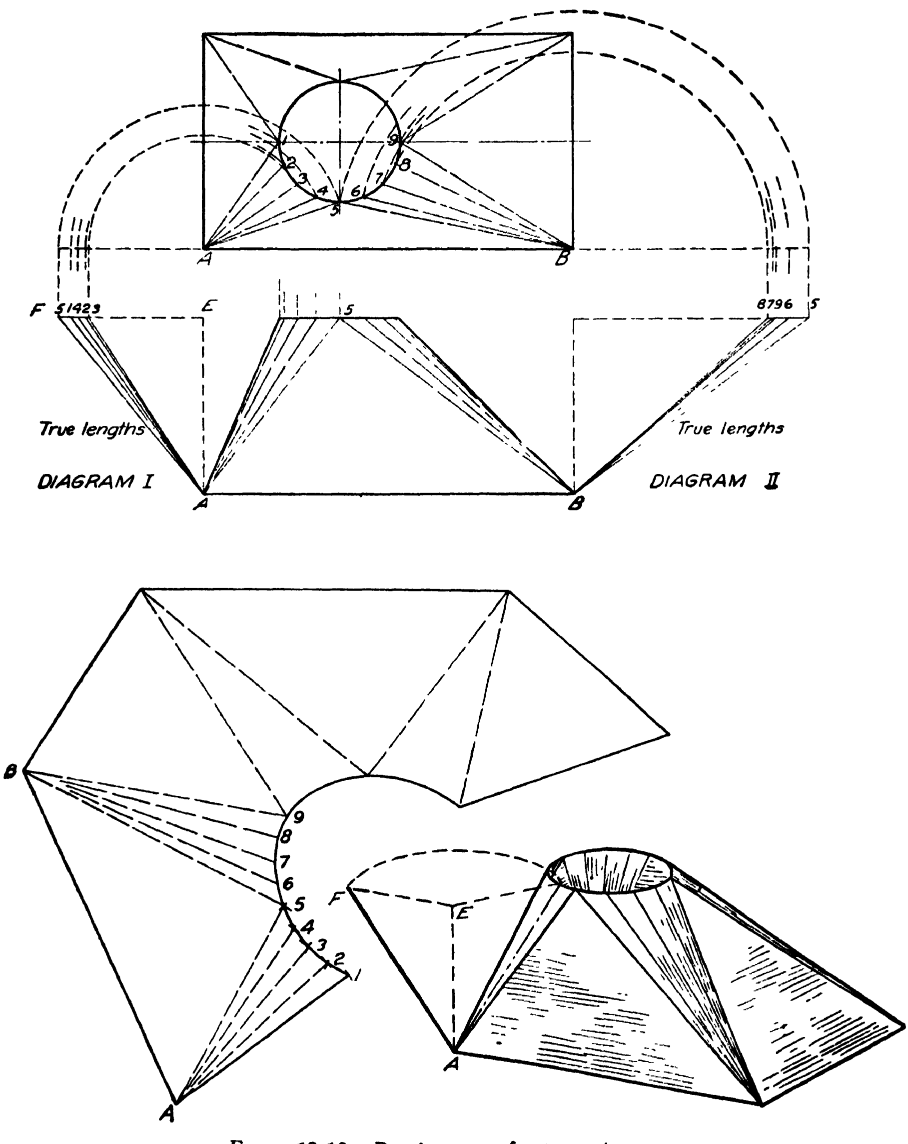


Figure 18·16 Development of a transition piece.

in the figure by swinging each distance about the point A in the top view and dropping perpendiculars to EF. Connect the points thus found with the point A in diagram I, thus obtaining the desired true lengths. Diagram II, constructed in the same way, gives the true lengths of lines $B5$, $B6$, etc., of the cone whose apex is at B. After the true-length diagrams are constructed, start the development, with the seam at $A1$. Draw a line $A1$ equal to the true length of $A1$. With 1 as a center and radius 1-2 taken from the top view, draw an arc. Intersect this arc with an arc from center A and radius equal to the true length of $A2$, thus locating the point 2 on the development. With 2 as center

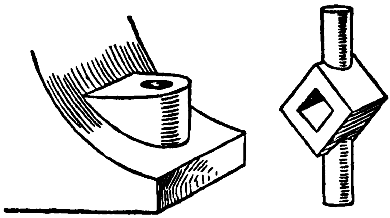


Figure 18·17 Intersections.

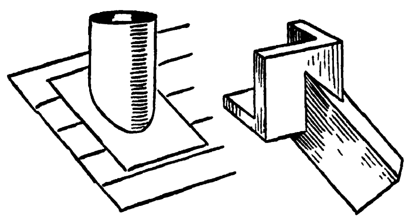


Figure 18·18 Intersections.

and radius 2-3, draw an arc and intersect it by an arc with center A and radius of the true length of $A3$. Proceed similarly with points 4 and 5 and draw a smooth curve through the points 1, 2, 3, 4, and 5, thus found. Then attach the true size of the triangle $A5B$, locating point B on the development by intersecting arcs from A with radius AB taken from the top view, and from 5 with radius the true length of $B5$. Continue until the piece is completed.

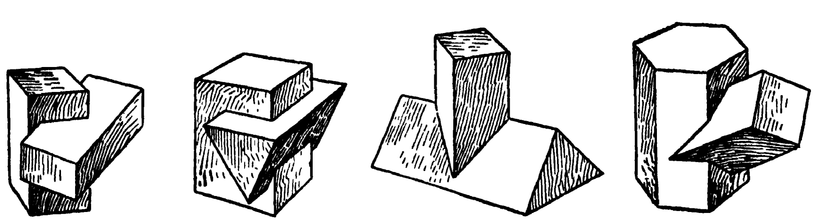


Figure 18·19 Intersecting prisms.

18·14 Intersections. Whenever surfaces come together, there is a line common to both, called the "line of intersection." In Figs. 18·17 and 18·18 a number of lines of intersection are shown. It is necessary for both the machine designer and the sheet-metal worker to be able to locate a line of intersection when one occurs.

18·15 Intersecting Prisms. Several examples of intersecting prisms are illustrated in Fig. 18·19.

To draw the intersection of two prisms, first start the orthographic

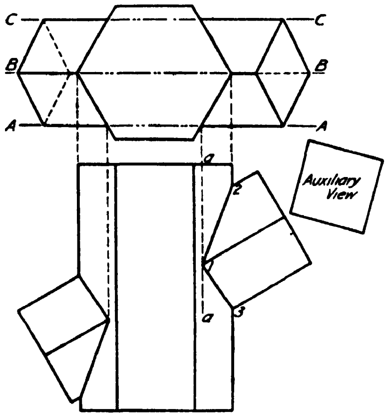


Figure 18·20 Intersecting prisms.

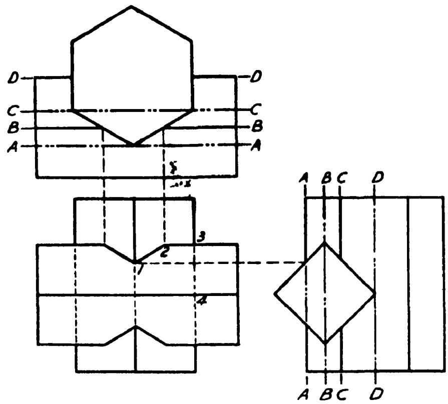


Figure 18·21 Intersecting prisms.

views. In Fig. 18·20 a square prism passes through a hexagonal prism. Through the front edge of the square prism pass a plane parallel to the vertical plane. The top view of this plane appears as a line *AA*.

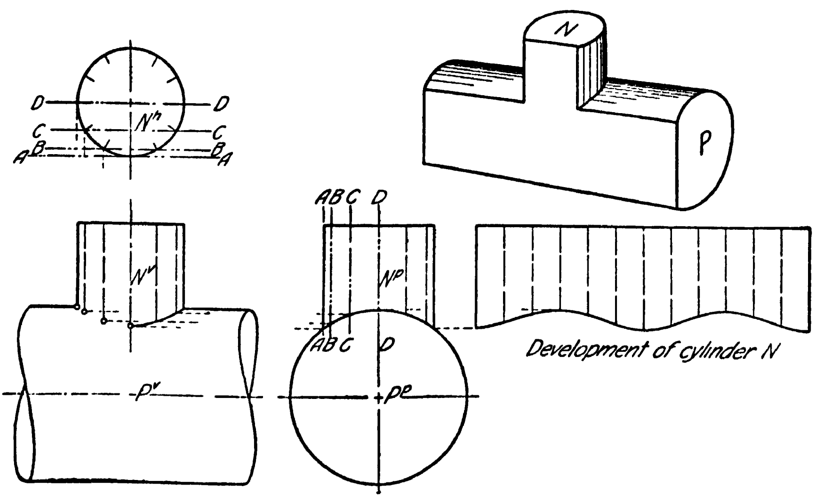


Figure 18·22 Intersecting cylinders.

The intersection of the plane *AA* with one of the faces of the vertical prism shows in the front view as line *aa* and is crossed by the front edge of the square prism at point 1, which is a point on both prisms and, therefore, a point in the desired line of intersection. Plane *BB* is parallel to plane *AA* and contains an edge of the vertical prism and an edge of the inclined prism, which meet at point 2 in the front view. Plane *BB* also determines point 3.

These planes are called "cutting planes," and they may be used for the solution of most problems in intersections. For intersecting prisms, pass planes through all the edges of both prisms within the limits of the line of intersection. Where the lines that are cut from both prisms by the same plane cross, there is a point on the required line of intersection. In Fig. 18·21 four cutting planes are required. The limiting planes are *AA* and *DD*, as a plane in front of *AA* or back of *DD* would cut only one of the prisms.

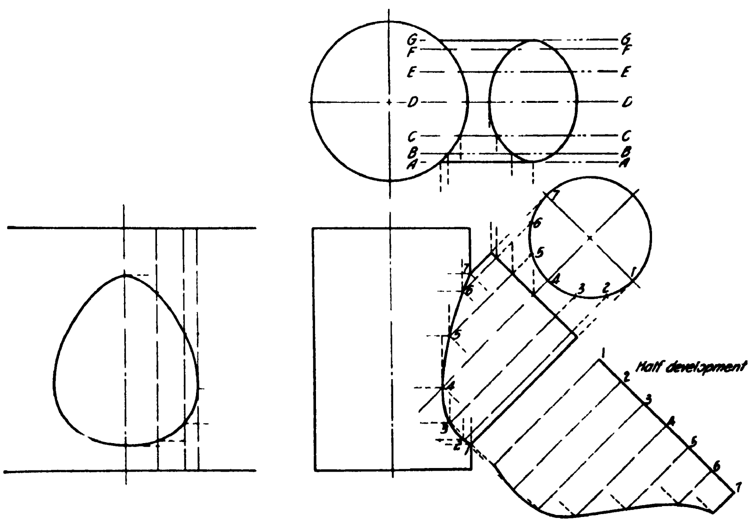


Figure 18·23 Intersecting cylinders.

18·16 Intersecting Cylinders. To draw the line of intersection of two cylinders (Fig. 18·22). Since there are no edges on the cylinders, it will be necessary to assume positions for the cutting planes. Plane *AA* contains the front line of the vertical cylinder and cuts a line from the horizontal cylinder. Where these two lines intersect in the front view, there is a point on the required curve. Each plane cuts lines from both cylinders, which intersect at points common to both cylinders. The development of the vertical cylinder, obtained by the method of Art. 18·4, is shown in the figure.

The solution for an inclined cylinder is given in Fig. 18·23, where the positions of the cutting planes are located by an auxiliary view. To develop the inclined cylinder, the auxiliary view is used to get the length of the stretchout. If the cutting planes have been chosen so that the circumference of the auxiliary view is divided into equal parts, the measuring lines will be equally spaced along the stretchout.

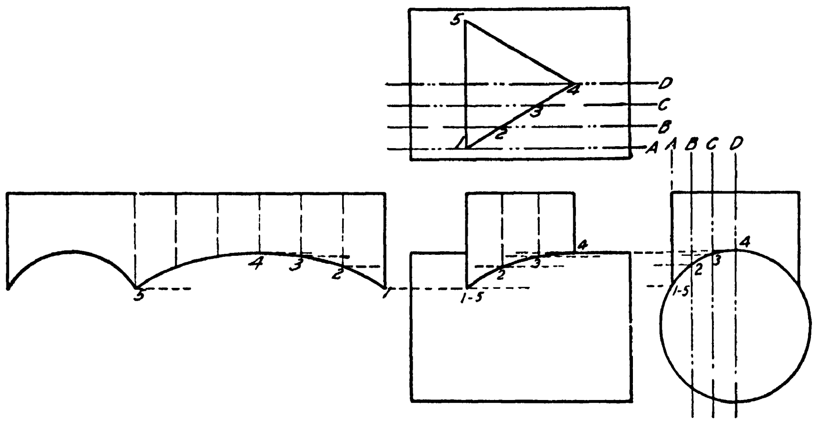


Figure 18·24 Intersection and development of a cylinder and a prism.

To develop the portion of the vertical cylinder having the hole for the inclined cylinder, lay out a portion of the stretchout and project from the front view to the measuring lines as shown.

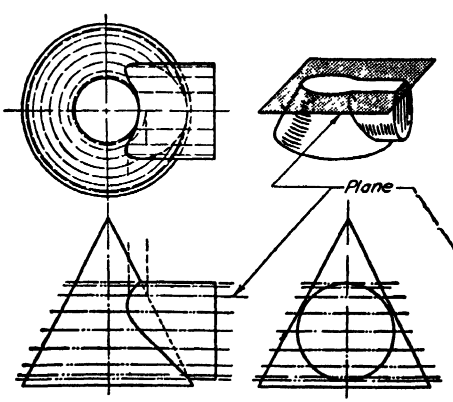


Figure 18·25 Cylinder and cone.

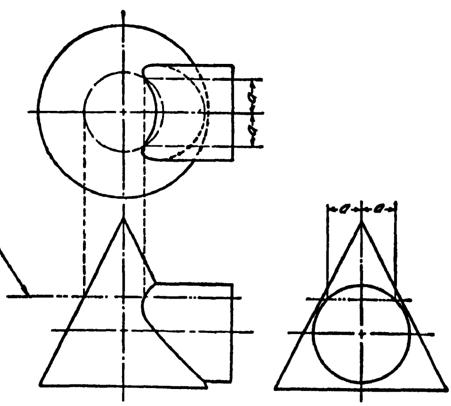


Figure 18·26 A cutting plane.

18·17 Intersecting Cylinders and Prisms. The intersection of a cylinder and a prism is found by the use of cutting planes as already described. In Fig. 18·24 a triangular prism intersects a cylinder. The planes *A*, *B*, *C*, and *D* cut lines from the prism and lines from the cylinder which cross in the front view and determine the curve of intersection, as shown. The development of the triangular prism is found by taking the length of the stretchout line from the top view and the lengths of the measuring lines from the front view. Since one plane of the triangular prism is perpendicular to the axis of the cylinder, the curve of intersection on that face is the radius of the cylinder.

18·18 Intersection of Cylinders and Cones. The intersection of a cylinder and a cone may be found by passing planes parallel to the horizontal plane, as shown in Fig. 18·25. Each plane will cut a circle from the cone and two straight lines from the cylinder. The straight lines of the cylinder cross the circle of the cone in the top view at points on the curve of intersection, which are then projected to the front view, as in Fig. 18·26, where the construction is shown for a single plane. Use as many planes as are necessary to obtain a smooth curve.

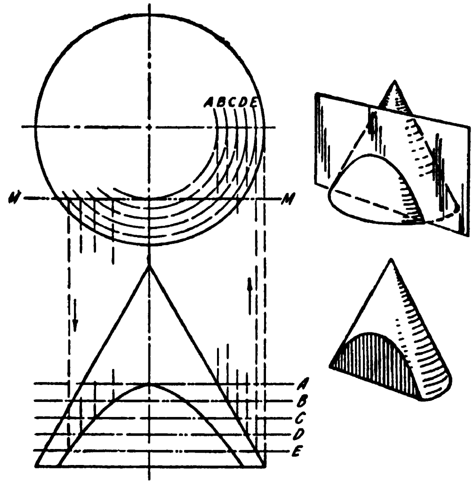


Figure 18·27 Cone and plane.

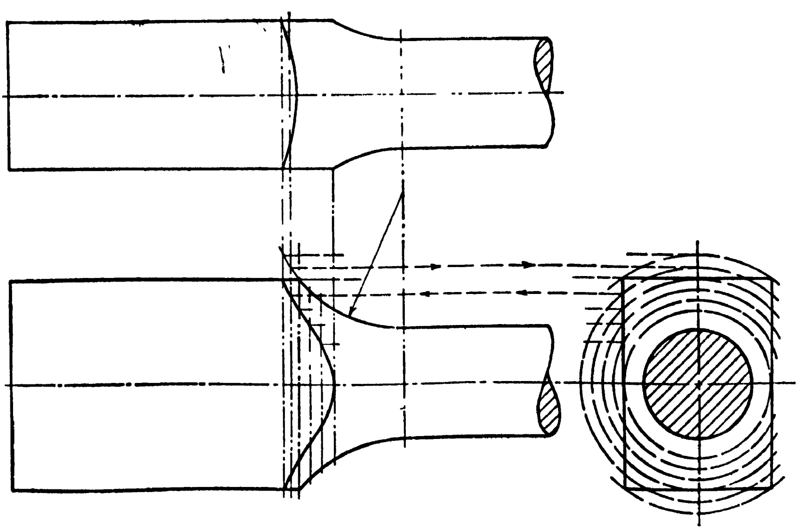


Figure 18·28 Intersection of plane and turned surface.

Figure 18·29 A measure.

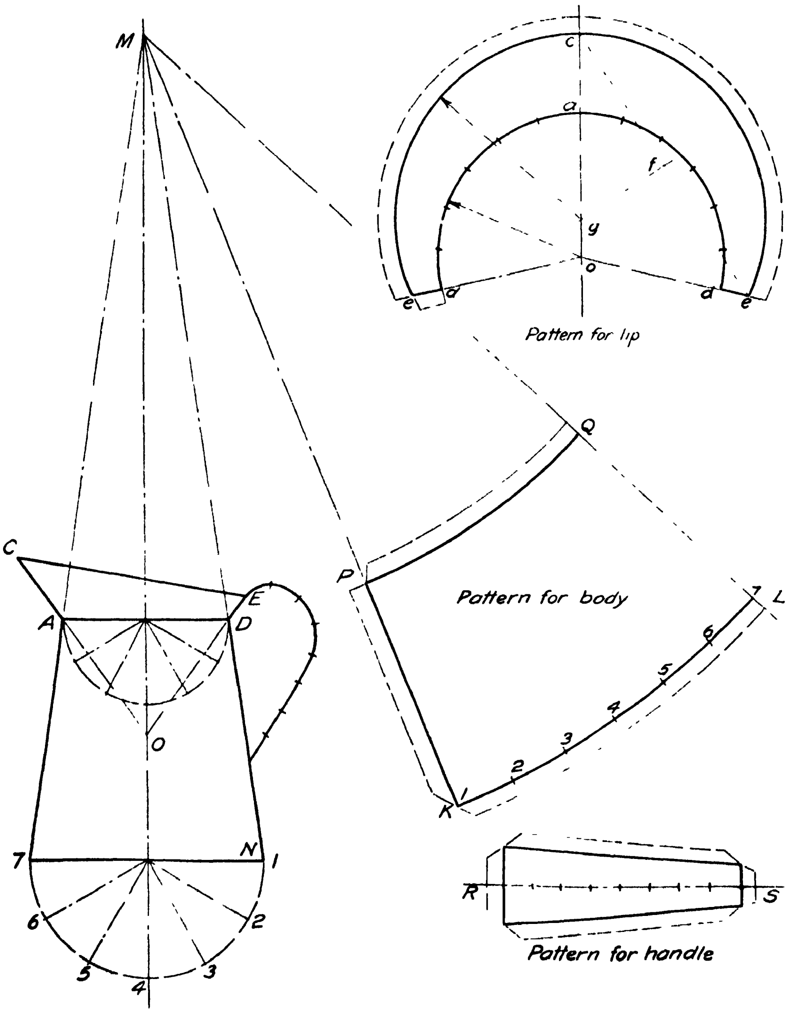


Figure 18·30 Pattern for a measure. *

18·19 Intersection of Planes and Curved Surfaces. The line of intersection of a cone cut by a plane *MM*, as in Fig. 18·27, may be found by horizontal cutting planes *A*, *B*, *C*, *D*. Each plane cuts a circle from the cone and a straight line from the plane *MM*, thus locating points common to both the plane *MM* and the cone, as shown in the top view. These points, when projected to the front view, give the curve of intersection.

The intersection at the end of a connecting rod is found by passing planes perpendicular to the axis, which cut circles as shown in the end view of Fig. 18·28. The points at which these circles cut the "flat" are projected back as points on the curve.

18·20 Development of a Measure. To draw the development of a measure (Fig. 18·29), draw the view shown with the half circles at top and bottom in Fig. 18·30. Observe that the body is a frustum of a cone. Extend the outline to complete the cone. With *MN* as a radius, draw an arc. Step off one-half the circumference of the base on this arc, and draw the radial lines *MK* and *ML*. With *M* as a center and *MD* as a radius, draw arc *PQ*, completing the development of the body. Add the necessary allowance for lap.

To develop the handle, divide it into a number of spaces and step them off on the stretchout *RS*. At *R* lay off one-half the width of the upper end of the handle on each side and at *S* one-half the width of the lower end of the handle on each side of the stretchout. Add allowance for laps and hems. The true development of the lip would require the drawing of lines through each point and finding the length of each line as described for the truncated cone (Fig. 18·15). The usual practical method is as follows: On a center line *oa* draw an arc with *OA* as a radius, and space one-half the circumference of the top of the body on each side, as shown by *dad*. Draw the radii *od*. Increase *OA* by $ac = AC$, and increase *od* by $de = DE$, as obtained from the elevation. Draw *ce* and the perpendicular bisector of *ce* intersecting the center line at *g*. With *g* as a center and *gc* as a radius, draw arc *ece* to complete the pattern. Add the necessary material for seams and hems.

18·21 Seams and Laps. The basis of sheet-metal pattern drafting is development. For practical work, it is necessary to know the processes of wiring, seaming, and hemming and the allowances of material to be made. Open ends of articles are usually reinforced by enclosing a wire in the edge, as shown at A in Fig. 18·31. The amount added to the pattern may be taken as 2½ times the diameter of the wire. Edges are also stiffened by hemming. Single- and double-hemmed edges are shown at B and C. Edges are fastened by soldering on lap seams D, folded seams E or, the commonest way, by

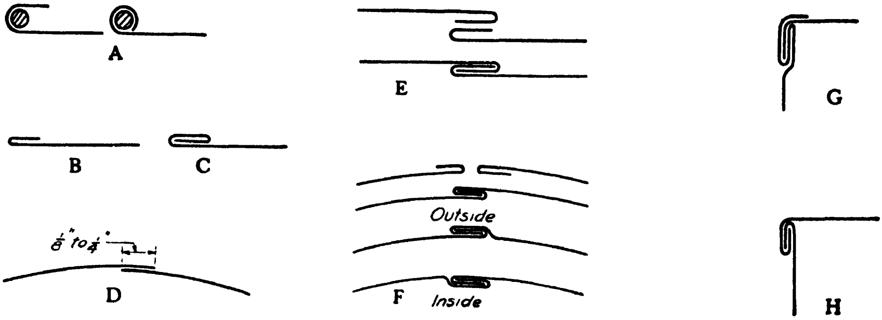


Figure 18·31 Wiring, seaming, and hemming.

grooved seams, shown in three stages, both inside and outside, at F. The Pittsburgh corner lock joint is shown at G and the cup joint at H. An important consideration in allowing lap on patterns is the shape of the space left at the corners to prevent thick places in the seam. This is called "notching" and is illustrated on Fig. 18·30.

CHAPTER 19. Architectural Drafting

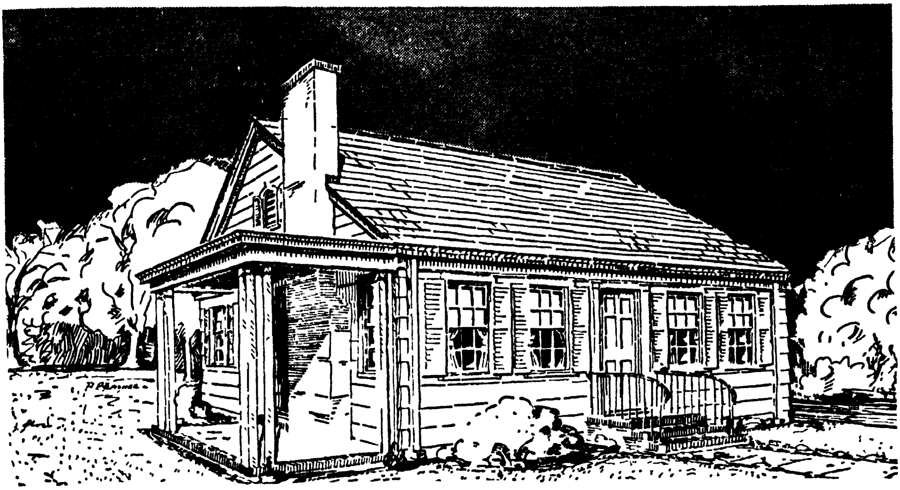


Figure 19·1 Pen-and-ink perspective of house.

19·1 Architectural drawings are concerned with the representation and specification of buildings and structures of various kinds. Although the general principles are the same as for other technical drawings, there are certain methods of representation, conventional symbols, and practices that are necessary because of the relatively small scale used for architectural plans.

In addition to regular working drawings, pictorial drawings are much used to show how the completed structure will look, such as the perspective drawing in Fig. 19·1.

19·2 House styles have developed from the materials available, the climate conditions, and the needs of the occupants. From simple shelters, houses have progressed in convenience and appearance with the growth of civilization. Present-day equipment and utilities have removed the restrictions of climate and made it possible to have a comfortable home of any style in almost any part of the country. Electricity provides for conveniences from lighting and making the breakfast toast to refrigeration or heating the house. Gas provides for both heating and refrigeration. The lastest information on both

Figure 19·2 Cape Cod house. **Prob. 559.**

Figure 19·3 Traditional Tudor house. **Prob. 560.**

Figure 19·4 Modern functional house. **Prob. 561.**

Above drawings by William Allen, courtesy *Science Illustrated.*

electrical and gas conveniences can always be obtained from catalogs and descriptive literature of the manufacturers. Many other kinds of equipment and materials should be investigated and understood regardless of the style of house that is being considered.

The following brief notes about Figs. 19·2 to 19·9 (described in *Science Illustrated*) give sufficient information to enable the student to understand and identify the different styles illustrated.

The Cape Cod house shown in Fig. 19·2 is a much-favored type of architecture and is a fundamentally American design. It has come down from colonial times and is a favorite in the eastern part of the country. It is identified by its clapboard or shingle sides, central chimney, small-sash windows with side shutters, and dormers. The drawing in Fig. 22·319 (Chap. 22, Prob. 567) shows a method of enlarging the basic plan by the addition of a wing.

The traditional Tudor house shown in Fig. 19·3 is basically English. It is identified by its half-timbered exterior, separated chimney stacks, arched recessed doorway, and small-paned windows. It presents a certain seventeenth-century feudal air. The same type of architecture may be used for houses with large central halls and with one or two projecting wings as suggested in Fig. 22·322 (Chap. 22, Prob. 570).

The modern functional house shown in Fig. 19·4 is built without a basement and is very different from traditional designs. It is identified by its simplicity, large windows, flat roofs, and the precedence given to functional capacity rather than architectural style. Insulation against heat or cold provides comfortable living. Wings or extra stories may be added as suggested in Fig. 22·321 (Chap. 22, Prob. 569).

The Dutch colonial house shown in Fig. 19·5 is a much-favored modification of early designs. It is identified by the slightly over-hanging upper story and contrasting brick or fieldstone lower story. Enlargement by an addition is suggested in Fig. 22·322 (Chap. 22, Prob. 570).

The ranch house shown in Fig. 19·6 is a modern type of one-story construction. It may be enlarged by additions as suggested in Fig. 22·323 (Chap. 22, Prob. 571).

The Georgian house shown in Fig. 19·7 is another design that came from England. It is identified by the simple bold cornice line and the arched doorway with fanlight above. A larger house would be symmetrical as suggested in Fig. 22·324 (Chap. 22, Prob. 572).

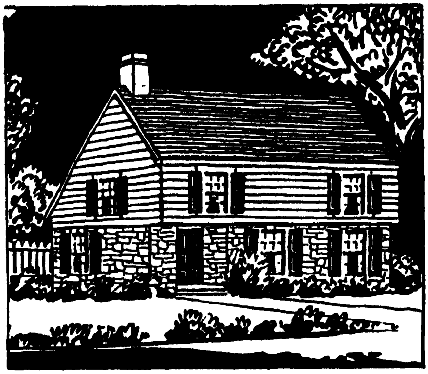


Figure 19·5 Dutch colonial house. **Prob. 562.**

Figure 19·6 Ranch house. **Prob. 563.**

Figure 19·7 Georgian house. **Prob. 564.**

Above drawings by William Allen, courtesy *Science Illustrated.*

The Monterey house shown in Fig. 19·8 is of Spanish origin and was developed on the West coast. It is identified by the upper porch, which should be faced in a southerly direction, and its graceful lines. The addition of a wing to join with a garage is suggested in Fig. 22·325 (Chap. 22, Prob. 573).

The bungalow shown in Fig. 19·9 is a popular one-story house which does not present any particular type of architecture. It may be a single unit design as shown or with wings attached as suggested in Fig. 22·326 (Chap. 22, Prob. 574).

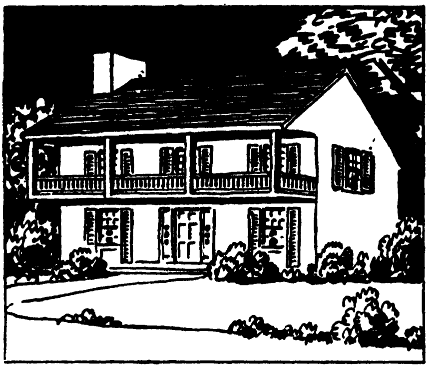


Figure 19·8 Monterey house. **Prob. 565.**

Figure 19·9 Bungalow. **Prob. 566.**

Above drawings by William Allen, courtesy *Science Illustrated.*

19·3 Classes of Drawings. There are three general classes of architectural drawings: (1) preliminary sketches, (2) display and competitive drawings, and (3) working drawings.

19·4 Preliminary Sketches. These are freehand studies of the arrangement of rooms, general appearance of elevations, and other matters for study and consideration. Very small thumbnail sketches are made at first, somewhat in proportion but without using the scale. Schemes that promise a satisfactory solution are then worked up in larger freehand sketches to approximate scale. Squared paper is convenient for this purpose. Tracing paper is often used to work out and preserve different arrangements by making one sketch over another.

19·5 Display and Competitive Drawings. These are more or less elaborate preliminary drawings of a proposed building. Plans and elevations, often including a perspective, are used but without working information. They are rendered in water color, pen and ink, pencil, or crayon to make them legible and attractive. A pen-and-ink perspective of a house is shown in Fig. 19·1.

19·6 Working Drawings. These form the most important class of drawings and include plans, elevations, sections, and detail drawings which, when read with the specifications for details of materials, finish, etc., give the working information for the erection of the building. (Working drawings for the house shown in Fig. 19·1 are given in Figs. 19·31 to 19·35.)

19·7 Scales. The architects' scale is described in Arts. 2·10 and 2·11. Ordinary house plans and plans for small buildings are drawn to the scale of $\frac{1}{4}'' = 1'$. The usual scale for larger buildings is $\frac{1}{8}'' = 1'$.

Figure 19·10 A Roman alphabet.

Plot plans (Art. 19·18), may be drawn at $\frac{1}{16}'' = 1'$ or $\frac{1}{32}'' = 1'$. Larger scales are used for drawings of parts that cannot be shown with sufficient detail on the small-scale drawings. Wall sections may be drawn at $1'' = 1'$ or $1\frac{1}{2}'' = 1'$. Other scales used for details include $\frac{1}{2}'' = 1'$, $\frac{3}{4}'' = 1'$, $3'' = 1'$, $6'' = 1'$, and full size.

19·8 Lettering and Titles. The traditional lettering used by architects is based on the Old Roman alphabet. A Roman alphabet is shown in Fig. 19·10. The letters may be "solid" or in "outline". For architectural working drawings the lettering is usually done in light single-stroke Roman, as shown in Fig. 19·11, or with plain terminals.

Figure 19·11 Single-stroke Roman. **Probs. 493 to 496.**

However, some architects use the single-stroke letters of Figs. 3·6 and 3·9 or Figs. 3·11 and 3·15, for office lettering on working drawings.

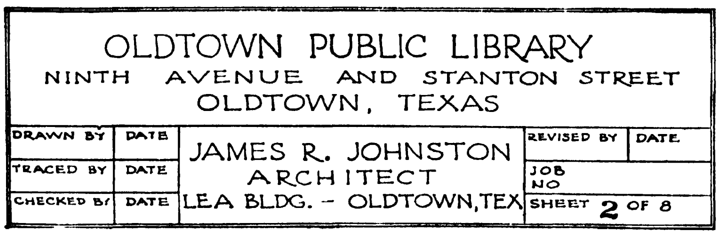


Figure 19·12 Title.

Titles may be designed with single-stroke Roman letters or with the Roman letters of Fig. 19·10. The titles shown in Figs. 19·12 and 19·13

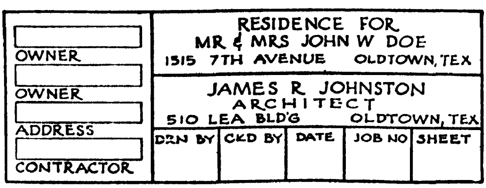


Figure 19·13 Title.

indicate the usual content and treatment of titles for architectural drawings.

19·9 House Framing. The framework of a building must be strong and rigid to ensure low maintenance costs over a long period of years. For residences, *light frame construction* is used, which varies somewhat with different builders and in different parts of the country but is generally classed as (1) *balloon framing*, (2) *braced framing*, or (3) *western* or *platform framing*.

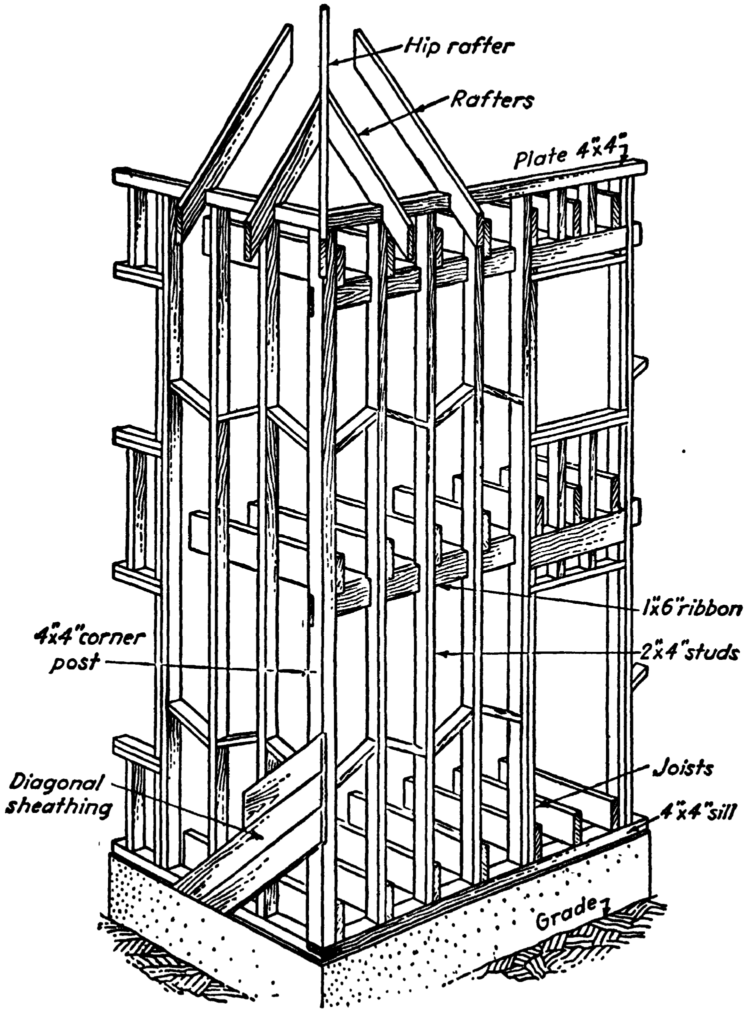


Figure 19·14 Balloon framing. **Prob. 502.** (*From George H. Cooper's "Building Construction Estimating," McGraw-Hill Book Company, Inc., New York.*)

The most prevalent method is, perhaps, balloon framing, illustrated in Fig. 19·14 where the *studs* extend from the foundation to the roof with the *second-floor beams* (joists) supported by a *ribbon* or *ledger board.* This is a satisfactory construction especially when diagonal *sheathing* is used.

The braced frame illustrated in Fig. 19·15 is an older type and a modification of early colonial heavy timber construction.

Western or platform framing differs from balloon framing by having each floor separately framed as a platform. The studs are made one

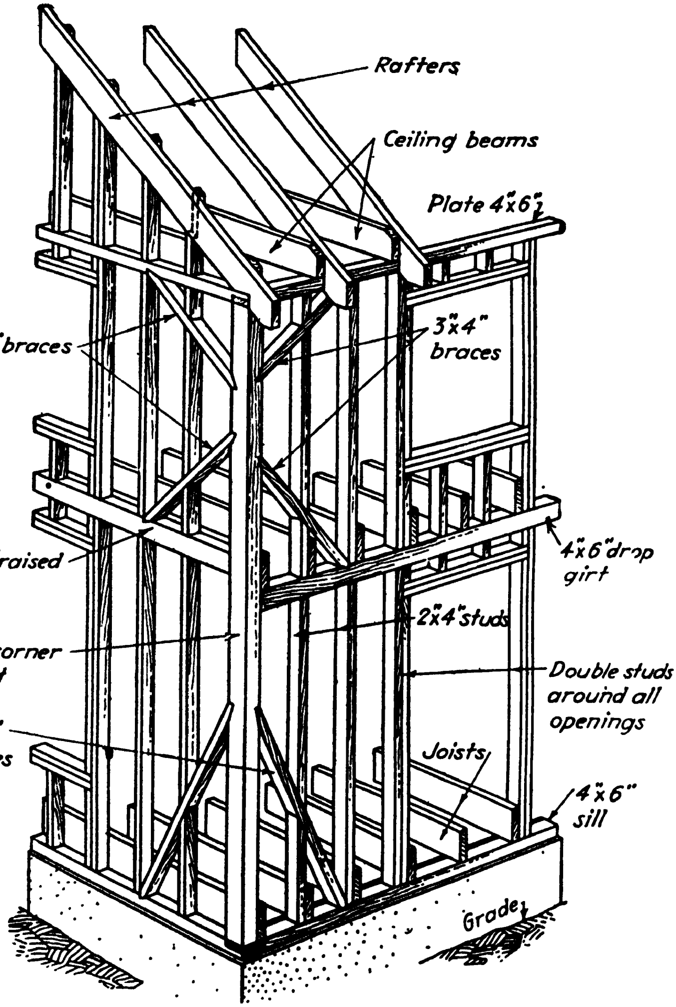


Figure 19·15 Braced framing. **Prob. 503.** (*From George H. Cooper's "Building Construction Estimating," McGraw-Hill Book Company, Inc., New York.*)

story in height to support the floor above.

19·10 Sill Details. Sill construction for braced framing is shown in Fig. 19·16, and box-sill construction for western framing is shown in Fig. 19·17. Note the metal shield for protection against termites.

Where brick veneering is used, the foundation wall must be increased in thickness as shown in Fig. 19·18.

19·11 Corner Studs and Sheathing. The arrangement of corner studs shown in Fig. 19·19 is simple and satisfactory. Another arrangement, shown in Fig. 19·20, requires greater care in making up. Diagonal sheathing and subflooring are shown in Fig. 19·19 and horizontal sheathing and subflooring in Fig. 19·20. Anchor bolts (Fig. 19·20) are used to anchor the building to the foundation. They should be $\frac{5}{8}$ to $\frac{3}{4}$ in. in diameter, spaced about 8 ft. apart, and extend through the sill and about 18 in. into the foundation.

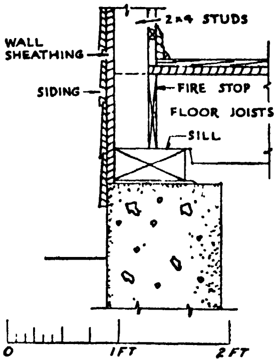


Figure 19·16 Braced frame sill. **Prob. 504.**

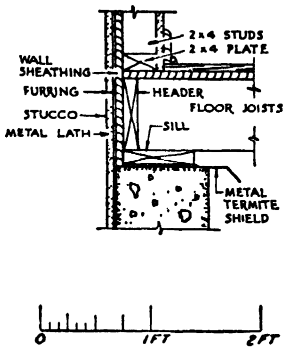


Figure 19·17 Box sill for western framing. **Prob. 504.**

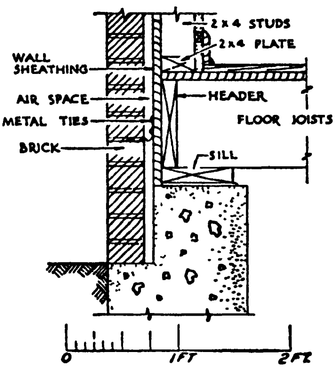


Figure 19·18 Box sill for brick veneer.

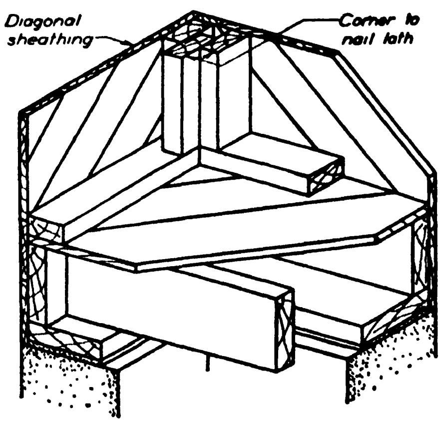


Figure 19·19 Diagonal sheathing. **Prob. 505.**

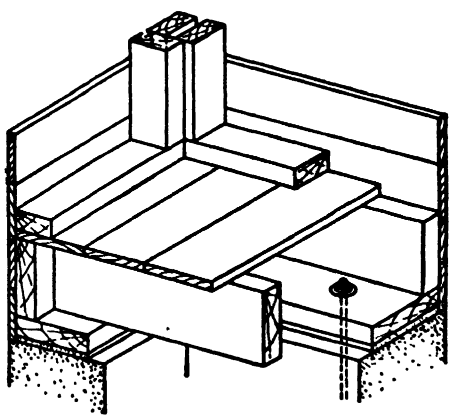


Figure 19·20 Horizontal sheathing. **Prob. 506.**

19·12 Cornice Details and Roof Framing. The usual roof framing members are shown and named in Fig. 19·21. The joints between the walls and roofs of houses are finished by cornices. An open

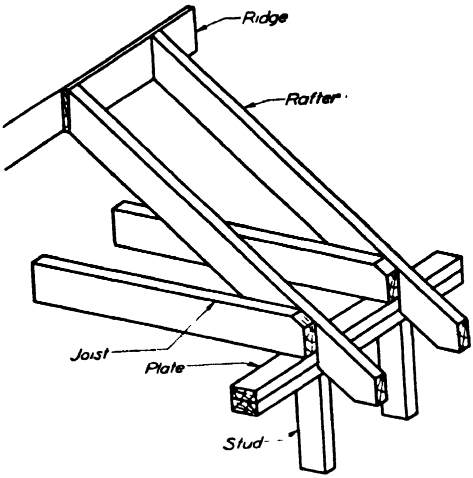


Figure 19·21 Roof framing. **Prob. 508.**

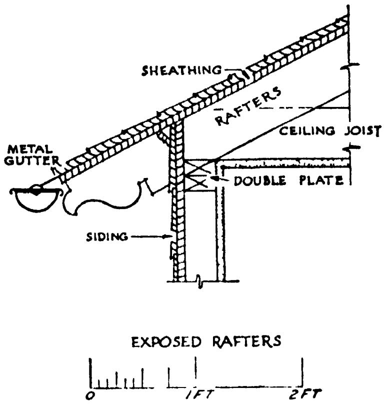


Figure 19·22 Open cornice. **Prob. 507.**

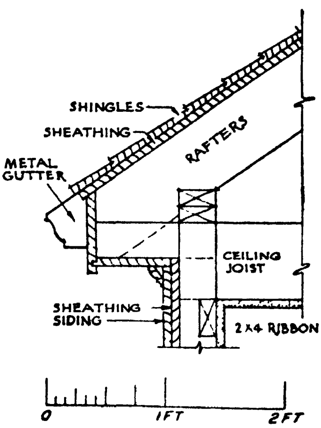


Figure 19·23 Box cornice. **Prob. 507.**

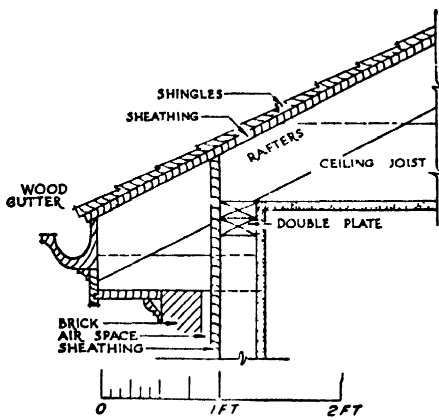


Figure 19·24 Box cornice for brick veneer. **Prob. 507.**

cornice, which exposes the rafters, is shown in Fig. 19·22. Box cornices, which conceal the rafters, are shown in Figs. 19·23 and 19·24. The gutters may be either metal or wood. A box cornice with concealed gutter is shown in Fig. 19·34.

19·13 Stairways. In drawing a stairway (Fig. 19·25), first make a diagram to find the number of steps and the space required. The riser, or height from one step to the next, is generally about 6½ to 7½ in. and the width of the tread is such that the sum of riser and tread is about 17½ in. On the plan the lines represent the edges of the risers and are drawn as far apart as the width of the tread, as shown in the illustration. Note the use of the scale to divide the floor-to-floor height into the number of risers. On working drawings, the entire flight is not drawn but is broken so as to show what is on the floor under it. The other end is shown on the floor above.

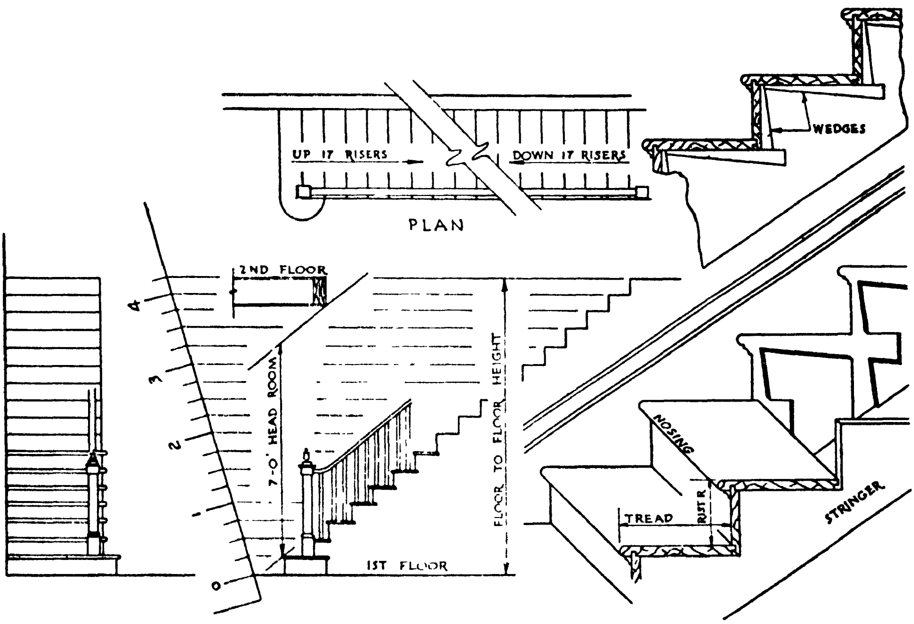


Figure 19·25 Stairs.

19·14 Symbols. The small scale used on general plans makes it necessary to use symbols. Symbols for walls consist of lines drawn to represent the thickness as in Fig. 19·26, which also shows the conventional methods of representing doors and windows. Symbols for building materials are shown in Fig. 19·27, electrical symbols in Fig. 19·28, and plumbing fixtures in Fig. 19·29.

19·15 Plans. A plan is a drawing of a horizontal section taken above the floor represented and at such places as will show the walls, doors, windows, and other structural features. It is drawn to include all details relating to the story, such as built-in construction, cabinets,

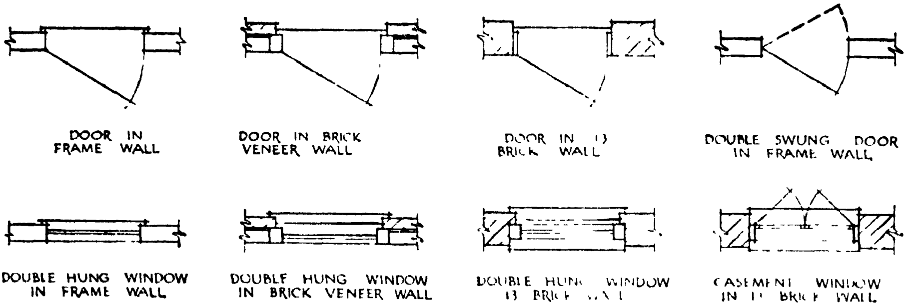


Figure 19·26 Symbols for doors and windows.

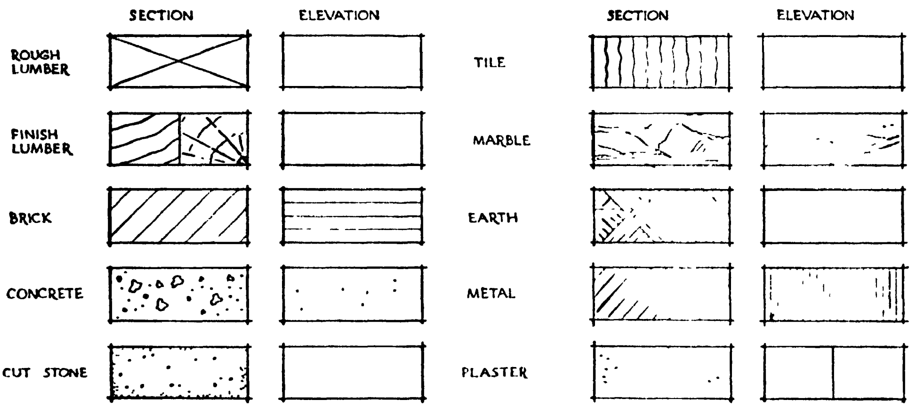


Figure 19·27 Symbols for building materials.

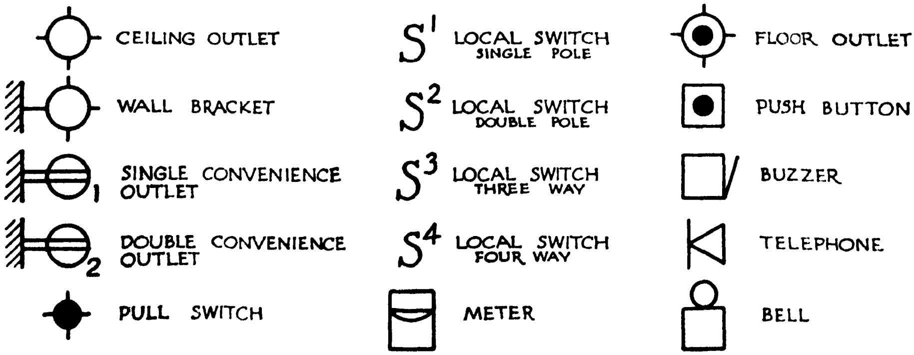


Figure 19·28 Electrical symbols.

stairways, heating, plumbing, and lighting outlets in walls and ceiling. Ordinary house plans are drawn to the scale of $\frac{1}{4}'' = 1'$.

A set of working drawings for a house is generally called a "set of plans" and includes a basement plan, plot plan, wall section, floor plan, elevations, details, etc. Such a set of plans for the house illustrated in Fig. 19·1 is shown in Figs. 19·31 to 19·35.

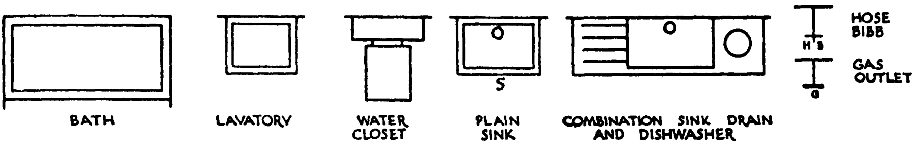


Figure 19·29 Plumbing symbols.

19·16 Floor Plan. The sketch plan of a house is shown in Fig. 19·30. The floor plan developed from this sketch is shown in Fig. 19·31. The procedure is to draw a horizontal line representing the outside face of the front of the house; then draw the interior walls and the interior partitions. Frame walls are drawn 6 in. thick. Locate the doors and windows and draw them with conventional symbols. For sizes of doors and windows refer to the schedules of Fig. 19·33.

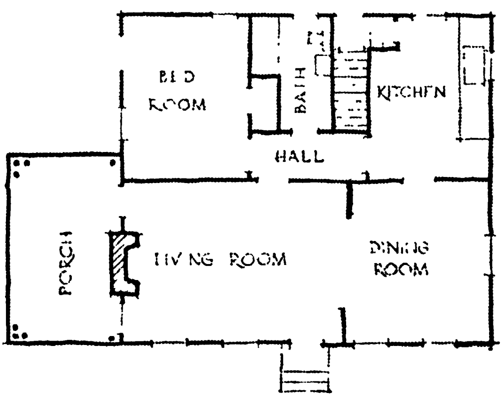


Figure 19·30 Sketch plan.

The stairway shown can be laid out as described for Fig. 19·25. Note that a landing is used in place of one of the treads.

Only one floor plan is required for the house shown. When a second floor is to be drawn for a two-story house, it is best planned by laying a piece of tracing paper over the first-floor plan. Trace the exterior walls, and locate stairways and chimney flues. The interior partitions need not be continuous with the first floor. Closets should be provided in the bedrooms and elsewhere as required.

19·17 Basement Plan. The basement plan or foundation layout (Fig. 19·32) must be completely dimensioned because the house is started with this plan. It should be checked with the first-floor plan and may be traced from it. Note the foundations for the chimney, porches, etc., and other details. Windows should be under the first-floor windows.

19·18 Plot Plan. This is a plan of the site showing the location of the house and accessory buildings on the lot. It should give complete and accurate dimensions, indicate all driveways and walks, show the location of electric, gas, water, sewer, and telephone lines, and should give all other pertinent information. A plot plan is shown as a part of Fig. 19·32.

19·19 Elevations. A front elevation is shown in Fig. 19·33 and a side elevation in Fig. 19·34. Four elevations (front, back, and both sides) are included in a complete set of plans and are required for Federal Housing Administration (F.H.A.) loans. The elevations show the exterior appearance of the house, floor and ceiling heights, openings for windows and doors, roof pitch, etc. To draw an elevation, start with the grade line, locate the floor levels and the vertical dimensions of other features. Horizontal dimensions can be obtained by placing a plan above the elevation, or underneath if tracing paper is used.

19·20 Details. A wall section to a larger scale is shown at the left in Fig. 19·34. Other larger scale drawings are made of such parts as cannot be shown with sufficient detail on the ¼-in. scale drawings. A typical sheet of such details is shown in Fig. 19·35. As the building progresses, the architect furnishes full-size drawings, made with a soft pencil, for millwork, moldings, and any special details.

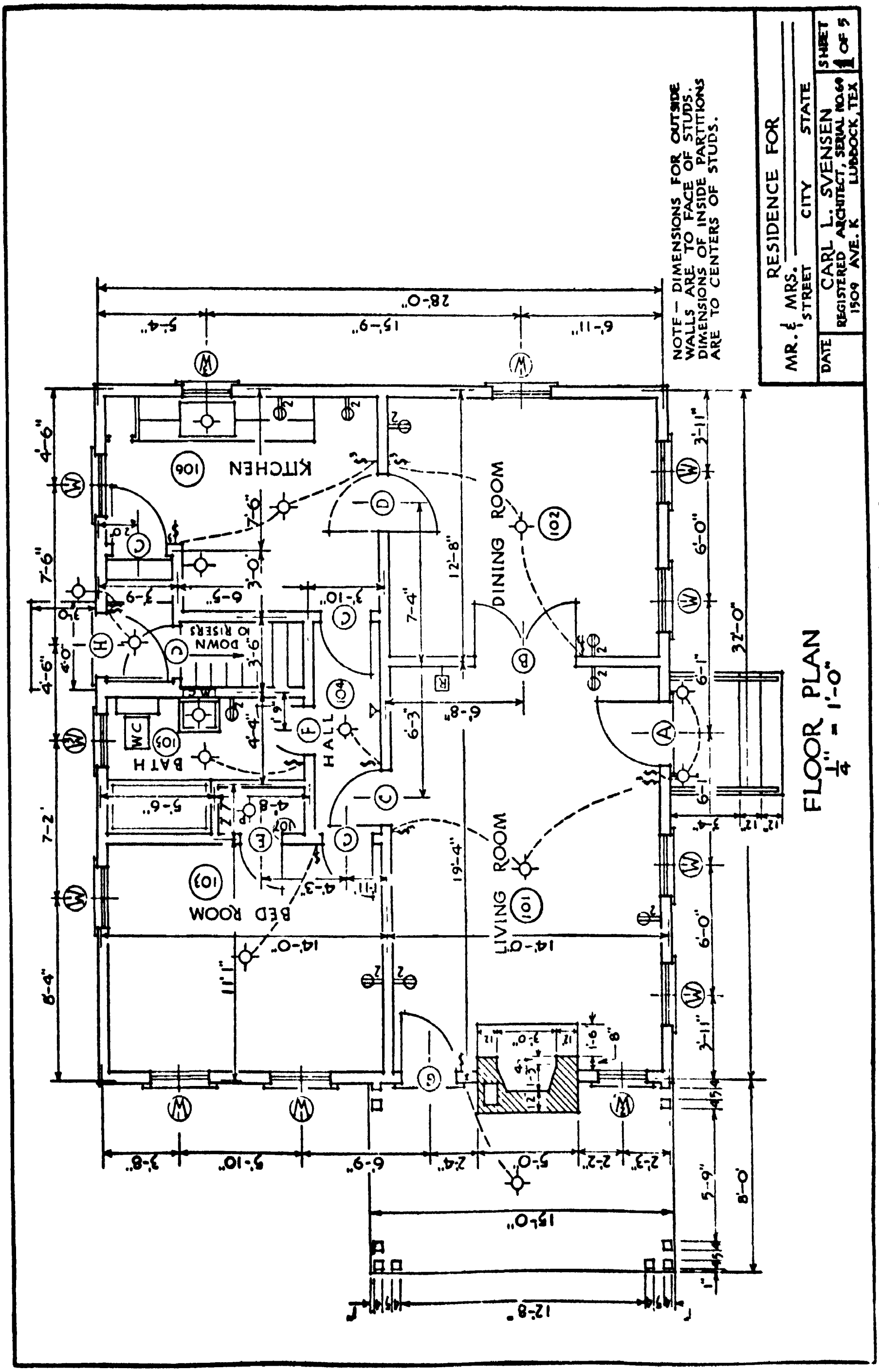


Figure 19·31 Floor plan. **Prob. 545.**

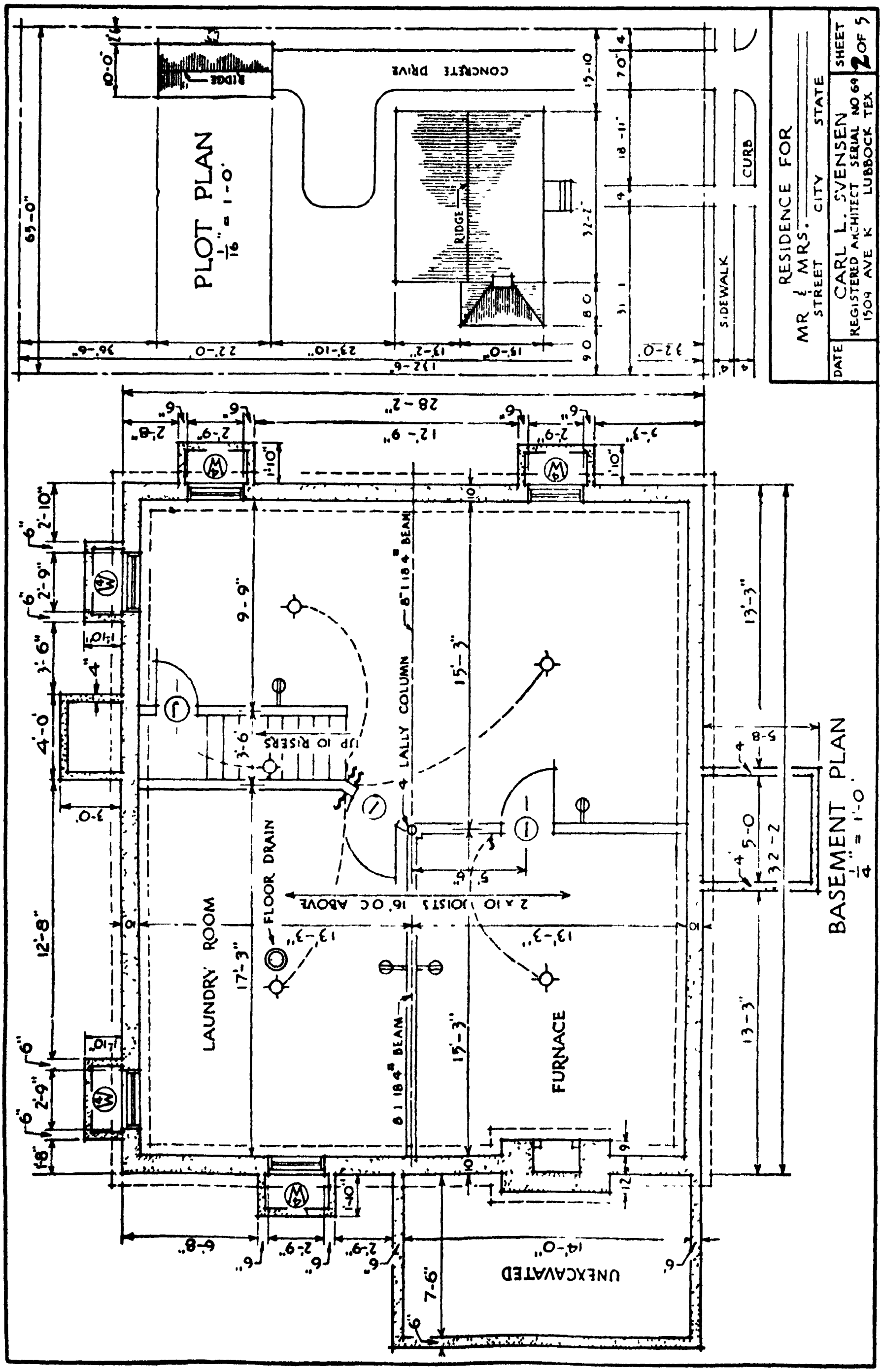
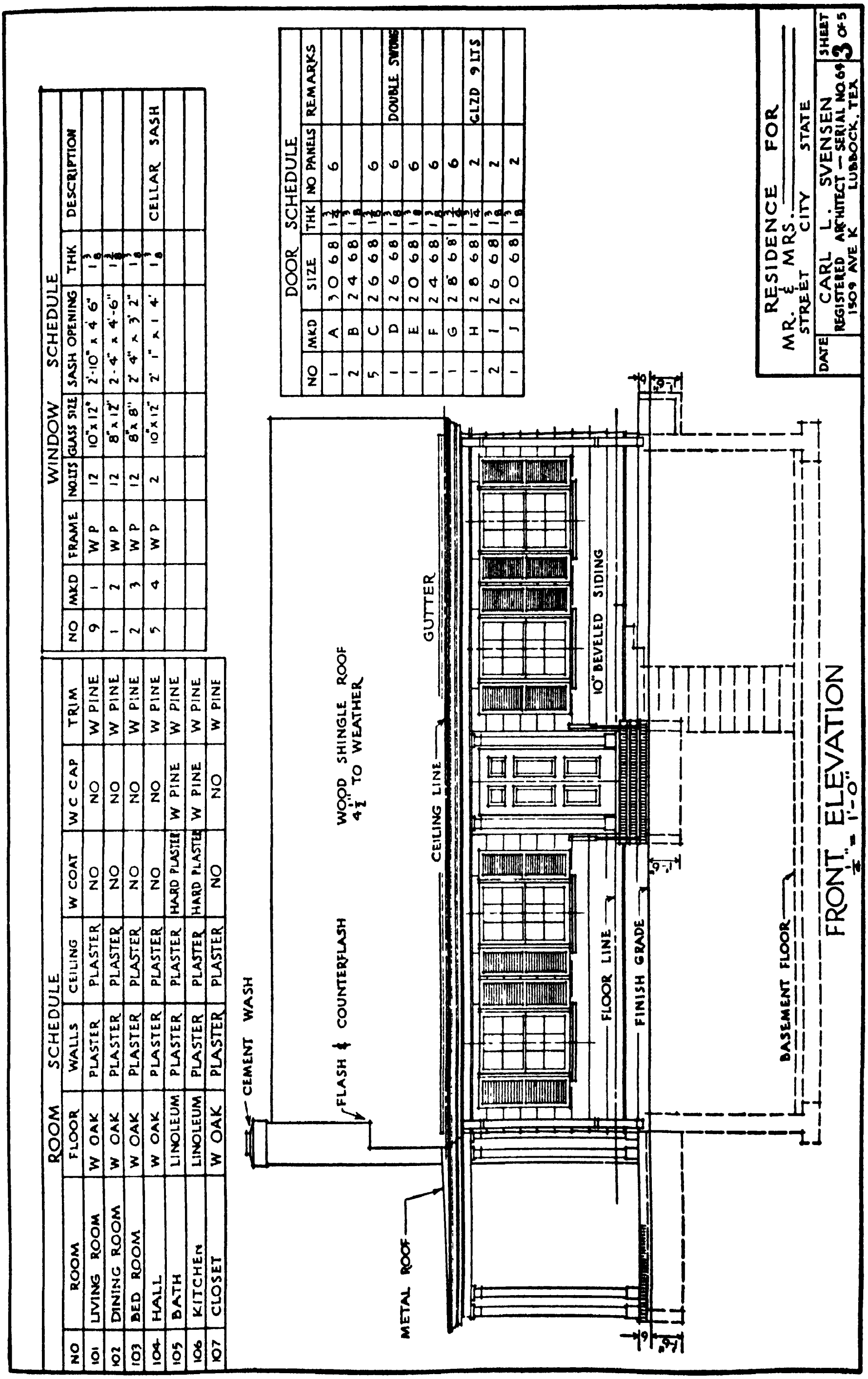


Figure 19·32 Basement plan and plot plan. **Prob. 545.**



ROOM SCHEDULE

NO	ROOM	FLOOR	WALLS	CEILING	W COAT	W C CAP	TRIM
101	LIVING ROOM	W OAK	PLASTER	PLASTER	NO	NO	W PINE
102	DINING ROOM	W OAK	PLASTER	PLASTER	NO	NO	W PINE
103	BED ROOM	W OAK	PLASTER	PLASTER	NO	NO	W PINE
104	HALL	W OAK	PLASTER	PLASTER	NO	NO	W PINE
105	BATH	LINOLEUM	PLASTER	PLASTER	HARD PLASTER	W PINE	W PINE
106	KITCHEN	LINOLEUM	PLASTER	PLASTER	HARD PLASTER	W PINE	W PINE
107	CLOSET	W OAK	PLASTER	PLASTER	NO	NO	W PINE

WINDOW SCHEDULE

NO	MKD	FRAME	NO. LTS	GLASS SIZE	SASH OPENING	THK	DESCRIPTION
9	1	W P	12	10" x 12"	2'-10" x 4' 6"	$1\frac{3}{8}$	
1	2	W P	12	8" x 12"	2'-4" x 4'-6"	$1\frac{3}{8}$	
2	3	W P	12	8" x 8"	2' 4" x 3' 2"	$1\frac{3}{8}$	
5	4	W P	2	10" x 12"	2' 1" x 1' 4'	$1\frac{3}{8}$	CELLAR SASH

DOOR SCHEDULE

NO	MKD	SIZE	THK	NO PANELS	REMARKS
1	A	3 0 6 8	$1\frac{3}{4}$	6	
2	B	2 4 6 8	$1\frac{3}{8}$		
5	C	2 6 6 8	$1\frac{3}{4}$	6	
1	D	2 6 6 8	$1\frac{3}{8}$	6	DOUBLE SWING
1	E	2 0 6 8	$1\frac{3}{8}$	6	
1	F	2 4 6 8	$1\frac{3}{8}$	6	
1	G	2 8 6 8	$1\frac{3}{4}$	6	
1	H	2 8 6 8	$1\frac{3}{4}$	2	GLZD 9 LTS
2	I	2 6 6 8	$1\frac{3}{8}$	2	
1	J	2 0 6 8	$1\frac{3}{8}$	2	

Figure 19·33 Front elevation. **Prob. 545.**

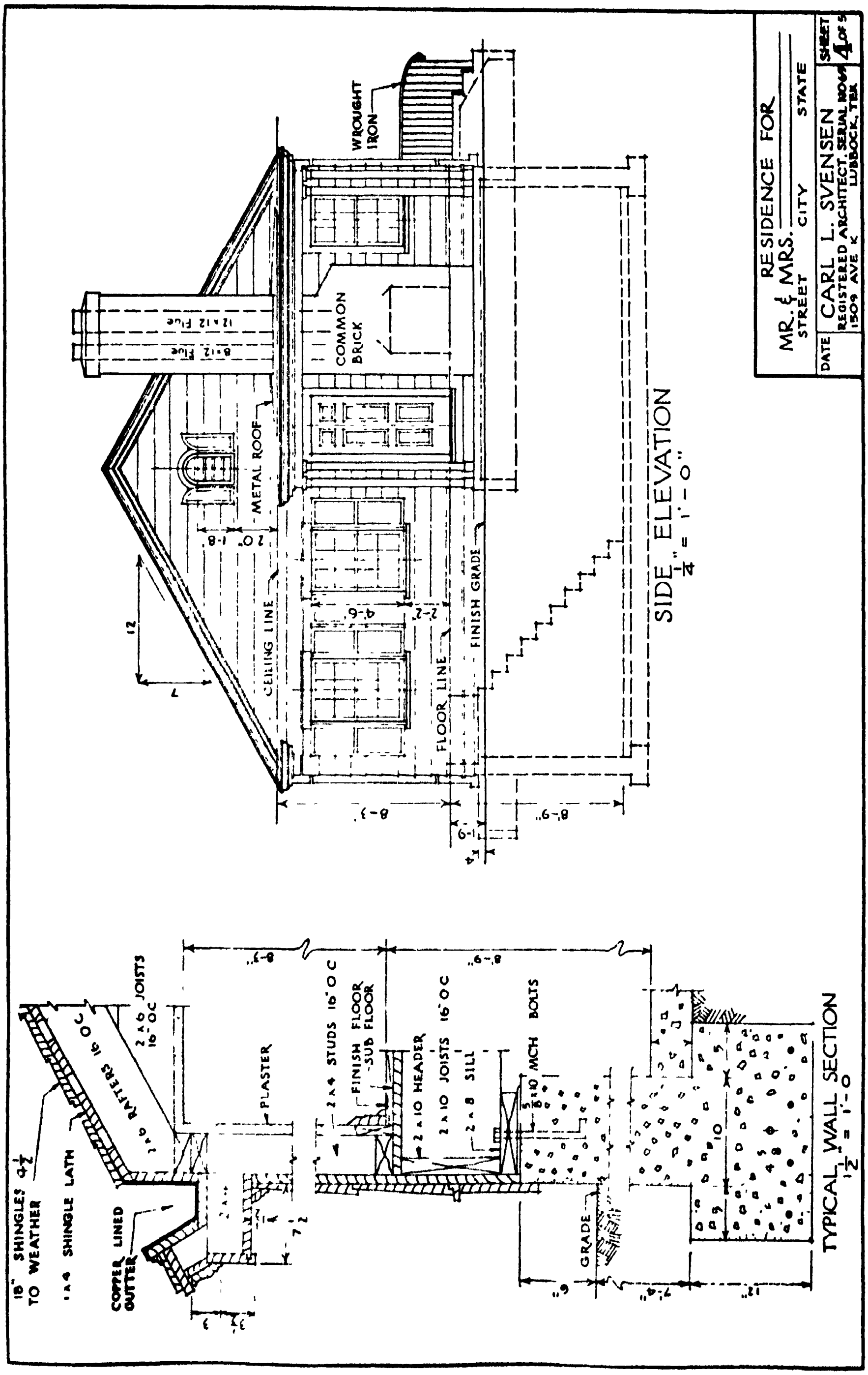


Figure 19·34 *Side elevation.* **Prob. 545.**

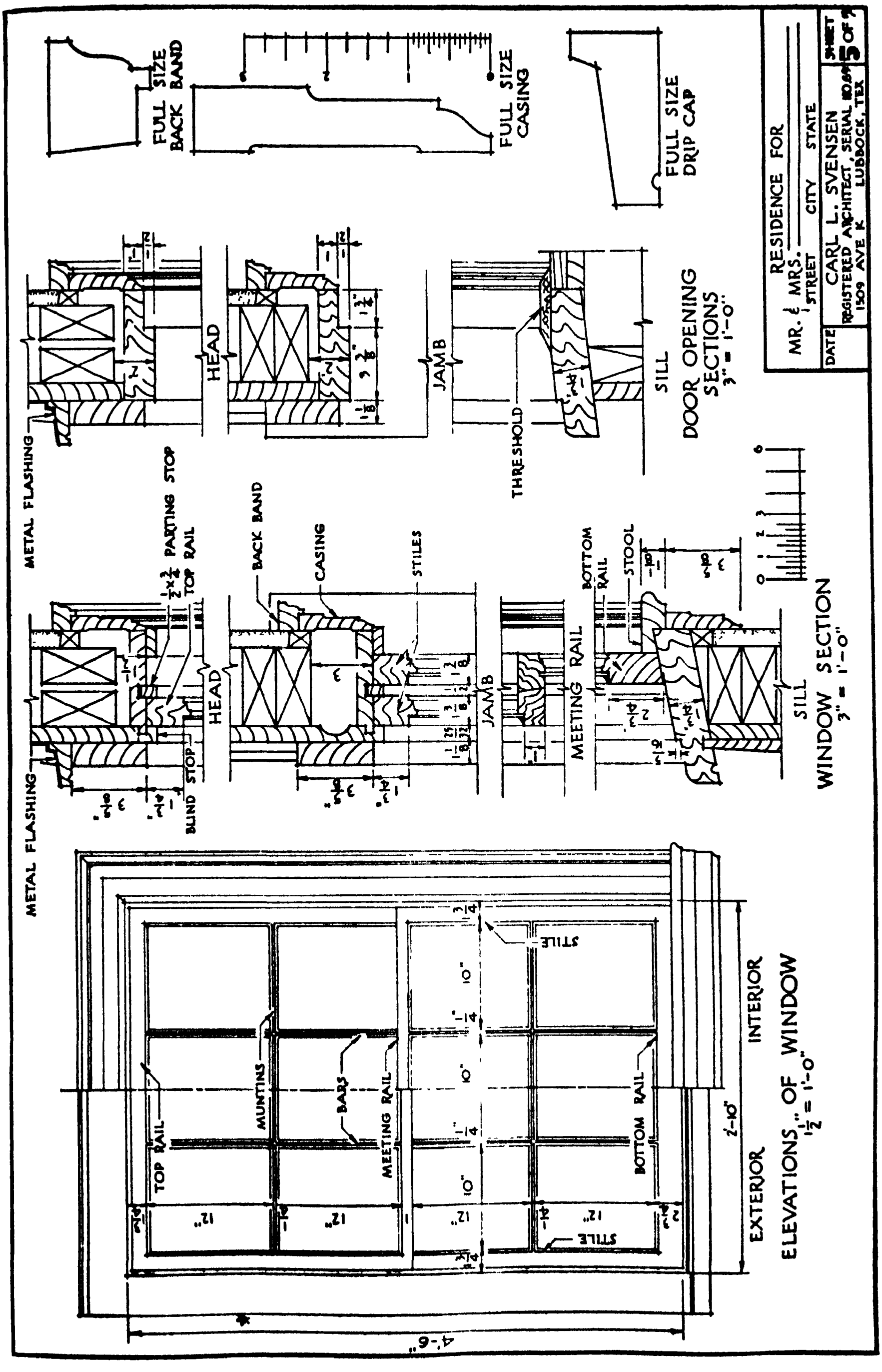


Figure 19·35 Details. Prob. 545.

CHAPTER 20. Structural Drafting

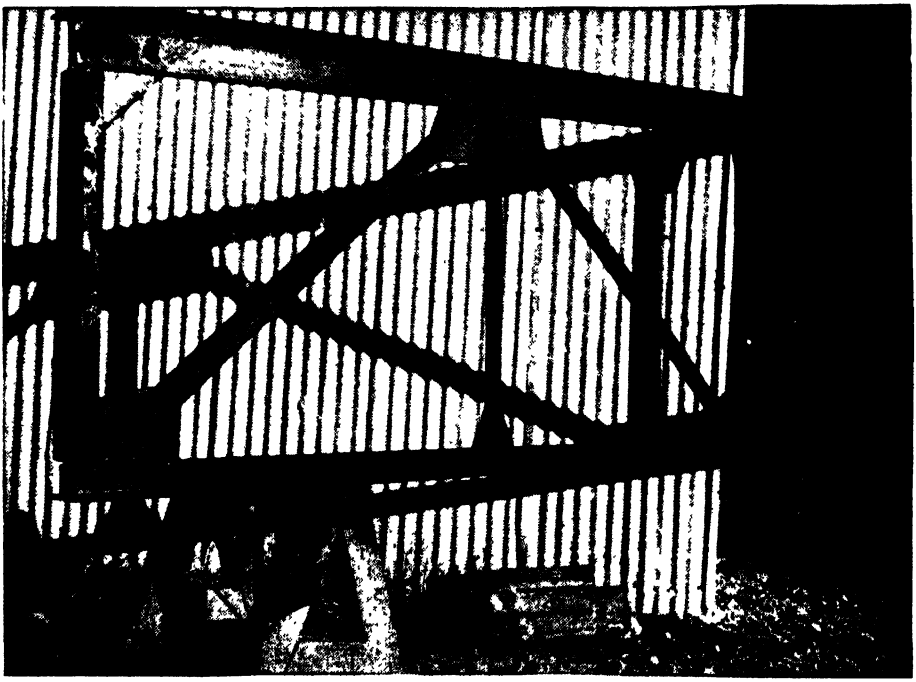


Figure 20·1 Riveted joints in steel construction.

20·1 Structural drafting has to do with the drawings made for the framework and supporting members of structures, such as columns, floor members, roof trusses, and bridge trusses.

The picture of a part of a flat steel truss for a building is presented in Fig. 20·1. It has been made up or "fabricated" in the shop and, as shown, is ready for shipment to the site of the building. The top horizontal member or "top chord" is made of two "angles" (Fig. 20·3). The "bottom chord" is made of smaller "angles" and the "diagonals" of single "angles." Notice how the various members are connected by riveting to steel "gusset plates." The design of structures requires a knowledge of the many subjects included in structural engineering, such as mathematics, stresses, mechanics, properties of materials, methods of fabricating, and methods of erection. However, the student should know some of the characteristics of drawings made for such purposes and how they differ from other drawings.

20·2 Structural Drawings. Assembly or part-assembly working drawings form a large class of structural drawings. These include the

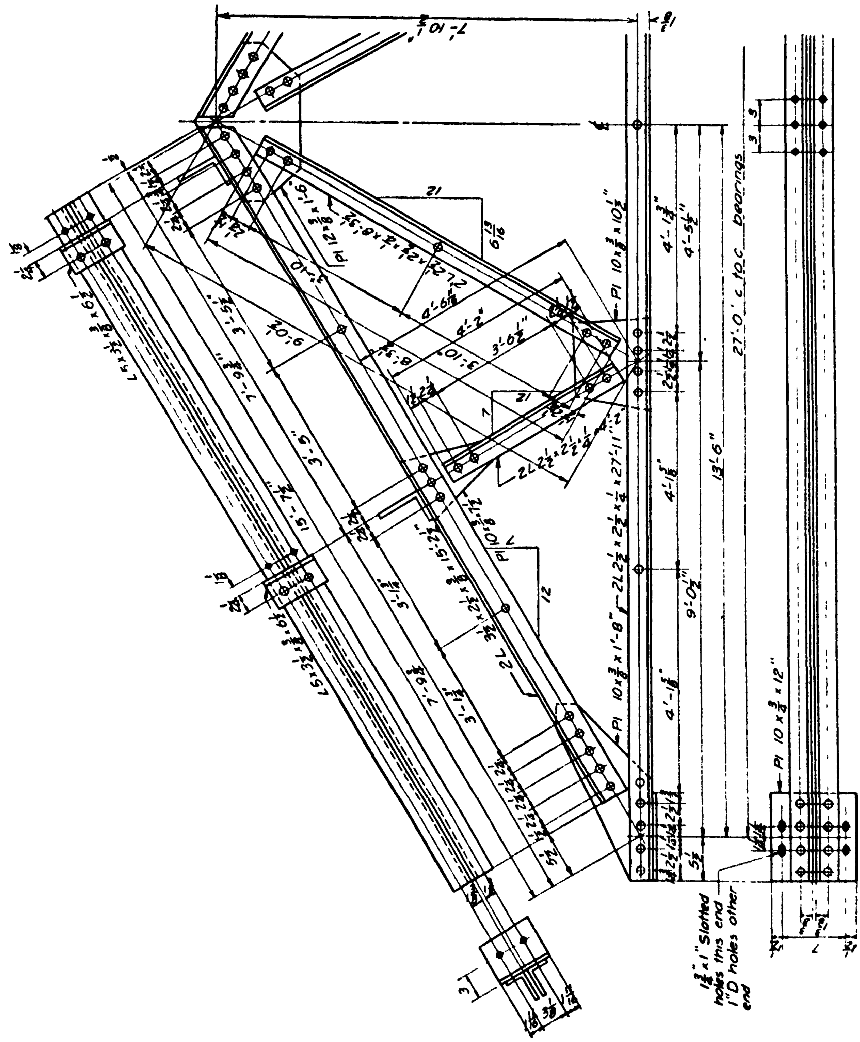


Figure 20·2 A structural drawing. **Prob. 578.**

"skeleton" or basic and center lines to locate the "working points," the structural members, gage lines, location dimensions, notes, and other necessary information. Such a general working drawing is shown in Fig. 20·2 for a small steel roof truss. Since the truss is symmetrical about a vertical center line, it is necessary to show only one-half of it in the drawing. Notice the lines upon which the design is built and the notes used to designate the various features. The sizes of the gusset plates are given in notes as are the number and sizes of angles (∟s). The slope or inclination is indicated by a right triangle, one leg of

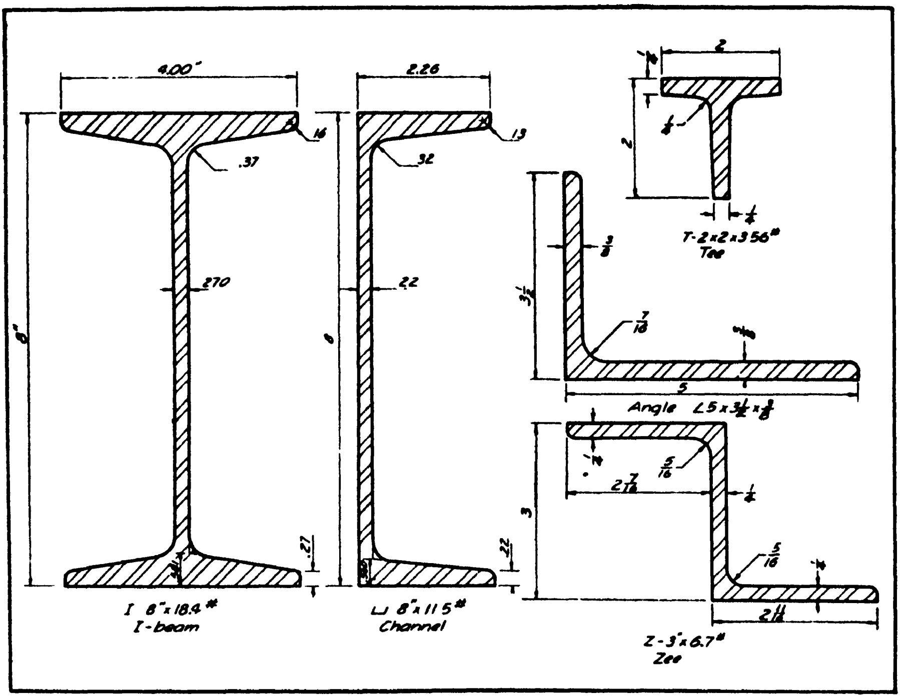


Figure 20·3 Rolled steel shapes. **Prob. 575.**

which is 12 in. A study of the drawing will show that each member is completely dimensioned or described and that dimensions are given to fix the location of each member.

Separate shop drawings are made for complicated or special details and for repeated details.

20·3 Structural Shapes. Structural members are built up of standard rolled shapes, some of which are shown in section in Fig. 20·3. Such shapes are made in a great variety of sizes and weights, lists of which may be found in the handbook, "Steel Construction," published by the American Institute of Steel Construction, or in the handbooks published by the various steel companies. The A.I.S.C. handbook contains tables of the properties of the various shapes and of many combinations of shapes, beam and column data, details of standard beam connections, specifications for the design, fabrication and erection of structural steel for buildings, and a large amount of related information. Dimensions of steel plates are specified by giving the width, thickness, and length; thus: Pl. 12 × 3/8 × 24. Angles are

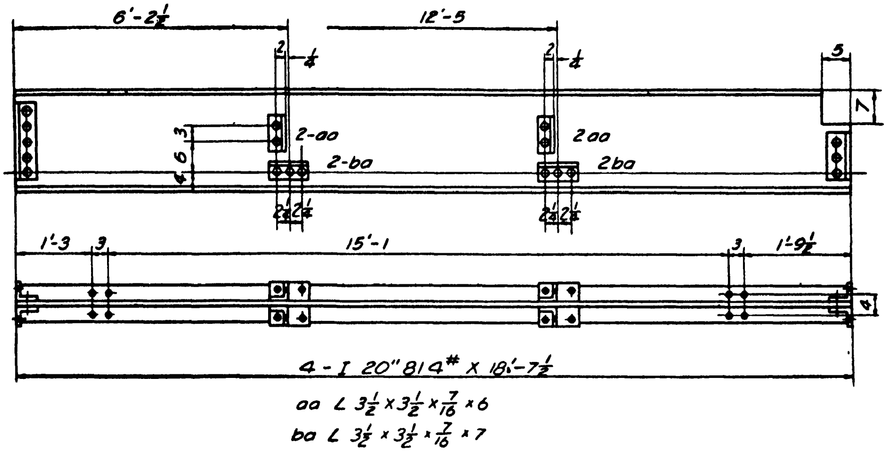


Figure 20·4 A structural detail. **Prob. 577.**

specified by dimensions, as the length of the legs and thickness of material: thus: L 5 × 3½ × 3/8. Other shapes are specified by the main dimension and weight per foot:

18 WF 64 means 18″ wide flange I-beam, 64 lb. per ft.

Bar 2 ⏀ means 2″ square bar.

Bar 1 ϕ means 1″ diameter round bar.

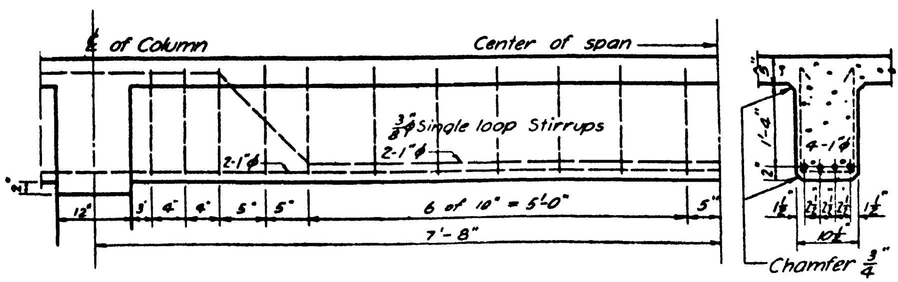


Figure 20·5 Reinforced concrete. **Prob. 579.**

20·4 Detail Drawings. Shop detail drawings give all the dimensions and information necessary to fabricate (or make) the parts. The location and kind of rivets are shown with everything drawn to scale. The simple beam detail of Fig. 20·4 shows the general characteristics of such drawings. Notice that the dimensions are placed above the

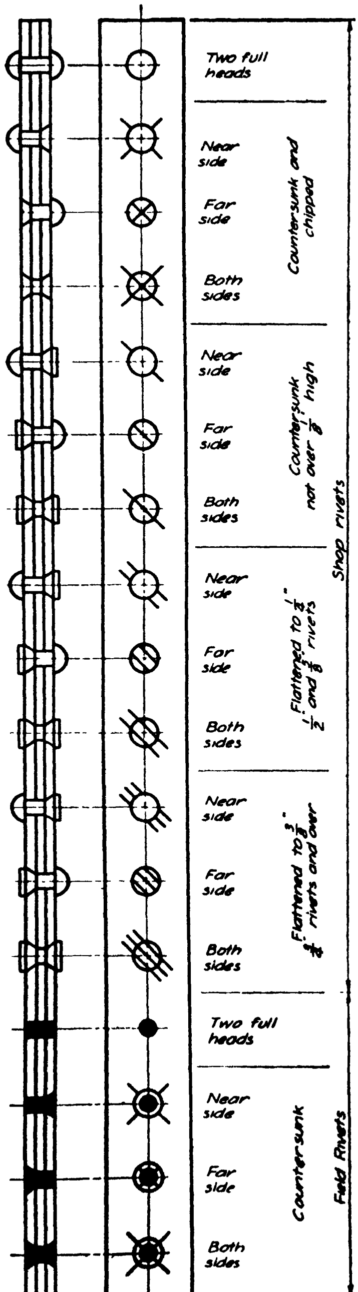


Figure 20·6 Rivet symbols.
Prob. 576.

dimension lines. The lower view is a section and, on structural drawings, is shown as seen from above.

The connections or angles at the ends of the beam are "Standard Beam Connections," and it is not necessary to dimension them. At the left end a "B5" connection is used, and at the right end, a "B3" connection. For the sizes of angles and dimensions, see a steel handbook (the rivets are $3/4$ in. in diameter).

20·5 Reinforced Concrete. Drawings made for reinforced-concrete structures show the dimensions of the concrete members, sections, and give the sizes and locations of the steel reinforcing material. A part of such a drawing is shown in Fig. 20·5. Notice the symbol for the diameter of the steel rods and the representation of the rods by long dashes and blacked-in circles. The rods are drawn as though on different levels on the elevation in order to show how two of them are bent. The section shows them on the same level along the bottom of the beam. The symbol for concrete is shown in Fig. 9·8. Reinforced-concrete design requires a good knowledge of mathematics, mechanics, and materials and is a specialized field of structural engineering.

The proportions of the materials to be used to give the required strength must be understood—the amounts of cement, sand, gravel or crushed rock, and water—as well as the computation of the size and amount of steel and the placing of the steel.

Many interesting applications of reinforced-concrete construction can be found in the pages of *Engineering News-Record* and similar magazines, such as dams, retaining walls, bridges, walls, beams, and floors of buildings, and roads.

20·6 Riveting. Structural rivets are shown in Fig. 10·34. The Standard symbols for riveting are given in Fig. 20·6. Riveting done in the shop is called "shop riveting," whereas that done in the field where the work is being erected is called "field riveting" (shown in black on drawings). Lines on which rivets are spaced are called "gage lines," and the distance between centers along these lines is called the "pitch." Welding (Chap. 15) is increasing in use for fabricating structural steel shapes.

Many buildings of steel construction are welded throughout. Others are partly welded and partly riveted.

Sometimes steel construction is put together by bolting, especially in locations that are remote from facilities for welding or riveting.

CHAPTER 21. Map Drafting

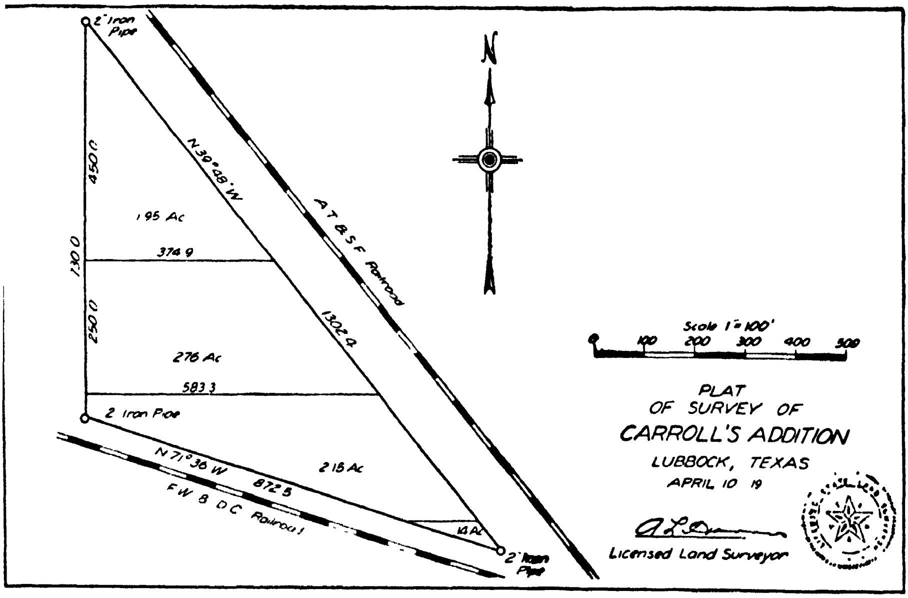


Figure 21·1 Plat of a survey. **Prob. 580.**

21·1 Maps are essentially one-view drawings of parts of the earth's surface. There are so many features to be represented and so many uses for maps that they are made in great variety. Some maps, such as city plats, must be extremely accurate and made to a relatively large scale (50 to 200 ft. to the inch), whereas geographic maps of states or countries, which show boundary lines, streams, lakes, coast lines, and relative locations, may use a scale of several miles to the inch. (See the maps in your geography and history books.)

21·2 Plats of a Survey. A map to record the boundaries of a tract of land and to identify it is called a "plat." The amount and kind of information will depend upon the purpose for which the map is required. The plat of a plane survey is shown in Fig. 21·1 which was made to record the legal description of the property.

21·3 City Plat. Maps of cities are made for many purposes, such as to maintain a record of street improvements, location of utilities, and sizes and location of property for tax assessments. A part of such a city plat is shown in Fig. 21·2. Notice the numbering of the lots, location of streets and alleys, sidewalks, etc.

21·4 Contours. Since maps are one-view drawings, vertical distances or variations in ground levels do not show. They can,

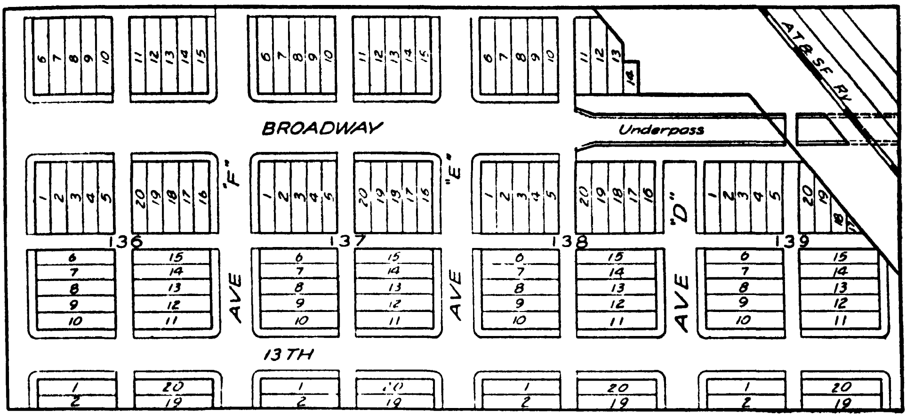


Figure 21·2 A city map. **Prob. 581.**

however, be indicated by lines of constant level called "contours." This is illustrated in Fig. 21·3 where the contours show the location of lines on the ground, which are at stated heights above the ocean (sea level). Contour lines close together indicate a steeper slope than

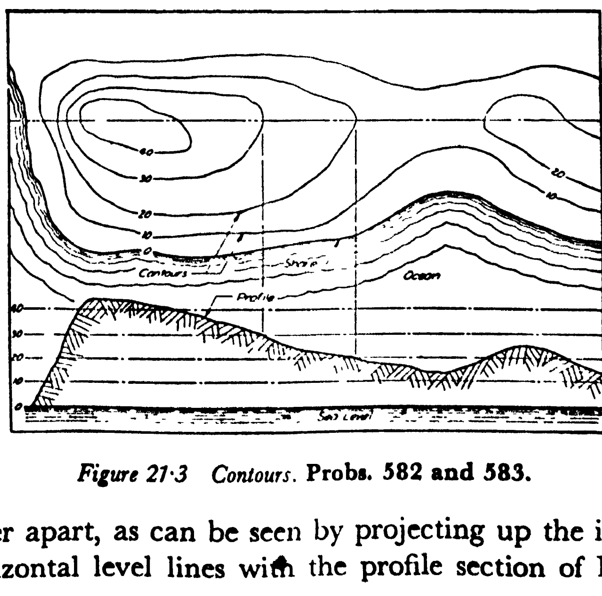


Figure 21·3 Contours. **Probs. 582 and 583.**

lines farther apart, as can be seen by projecting up the intersections of the horizontal level lines with the profile section of Fig. 21·3 as indicated.

It will be observed that the contour map and the profile correspond to the plan and section of an ordinary drawing. Note the horizontal line or cutting plane on the contour map, which shows the position or line on which the profile is taken. Notice how the profile would change if the cutting plane was moved toward the ocean or to some other new position.

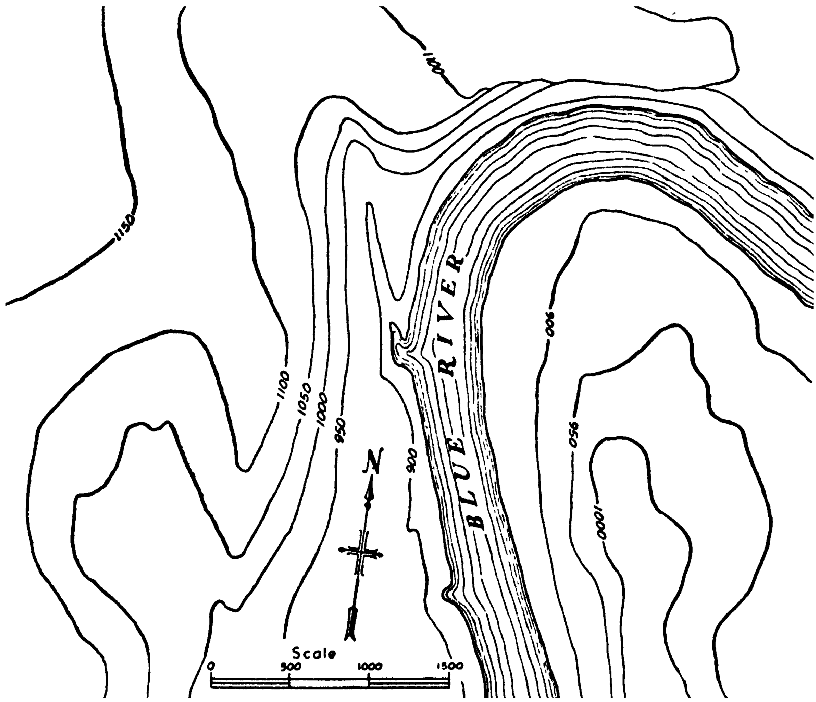


Figure 21·4 Contour map. **Prob. 584.**

21·5 A contour map is shown in Fig. 21·4 with contour intervals of 50 ft. (distance between contour levels). When there are many contour lines, every fifth one is drawn heavier to make them easier to follow. The elevation in feet is marked in a break in the line. Notice the "water lining" used on the representation of the river.

21·6 Topographic maps are made to give rather complete descriptions of the areas shown. This includes such information as boundaries, natural features, the works of man, vegetation, and relief (elevations and depressions). Symbols are used for many of the features shown on topographic maps, some of which are given in Fig. 21·5. Maps using topographic symbols can be obtained at nominal cost from the Director, U.S. Geological Survey, Department of the Interior, Washington, D.C., and represent the highest type of topographic drawing.

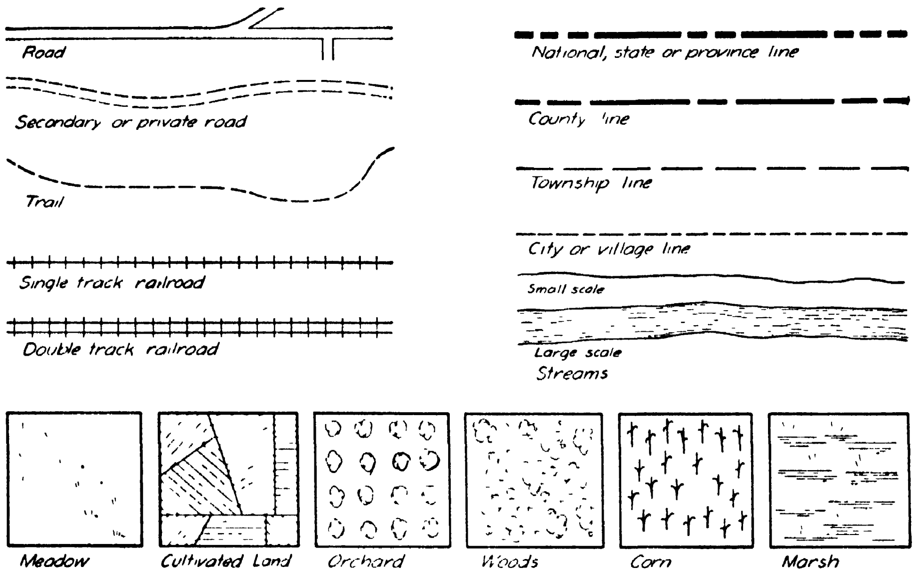


Figure 21·5 Conventional symbols. **Prob. 585.**

The making of maps is an important part of civil engineering and requires thorough training. Books on surveying and mapping and United States government bulletins should be studied before undertaking work on any important maps.

CHAPTER 22 Problems

22·1 The important part of any course in mechanical drawing consists of the working of a large number of properly selected and graded problems. The problems that follow are arranged somewhat in the order of difficulty in each of the divisions of the subject, and the methods of presentation are varied to suit the objectives and requirements of the problems. Graphic layouts are given when practicable, as they are definite and save time for both teacher and pupil. It is not necessary or intended that all the problems be worked; a selection to fit the course should be made by the teacher. A large number of references to text matter are given with the problems and should be studied before asking for asisstance from the teacher.

Any or all of the drawings may be inked, but the best results are generally obtained by delaying this until the ability to make a good pencil drawing has been acquired.

22·2 General Instructions. The trim sizes of sheets recommended by the American Standards Association, as given in Art. 2·3, are in almost universal use in industry and are advised for use in drawing courses. It is, of course, easily possible to use other sizes and arrangements where necessary and desired by the instructor. To assist in such cases, Fig. 22·1 is given with letters to indicate the dimensions. The desired numerical values can be filled in after the equality signs (=) on the figure.

Most of the problems in this book are designed for use on the American Standard Size "B" sheet with the layout shown on Figs. 22·2 and 22·3. Other layouts are suggested on Fig. 22·4.

On the following figures the numbers enclosed in circles are for locating the starting lines and are always measured full size regardless of the scale of the views of the drawing. When such dimensions are given, the lines that they locate should be drawn first. (These dimensions are not to be put on the completed drawing as they are simply to locate the lines upon which the drawing is built.) Use light, sharp pencil lines and work very accurately, as errors in starting often are not evident until the drawing is nearly completed. The title for each sheet is given in italics.

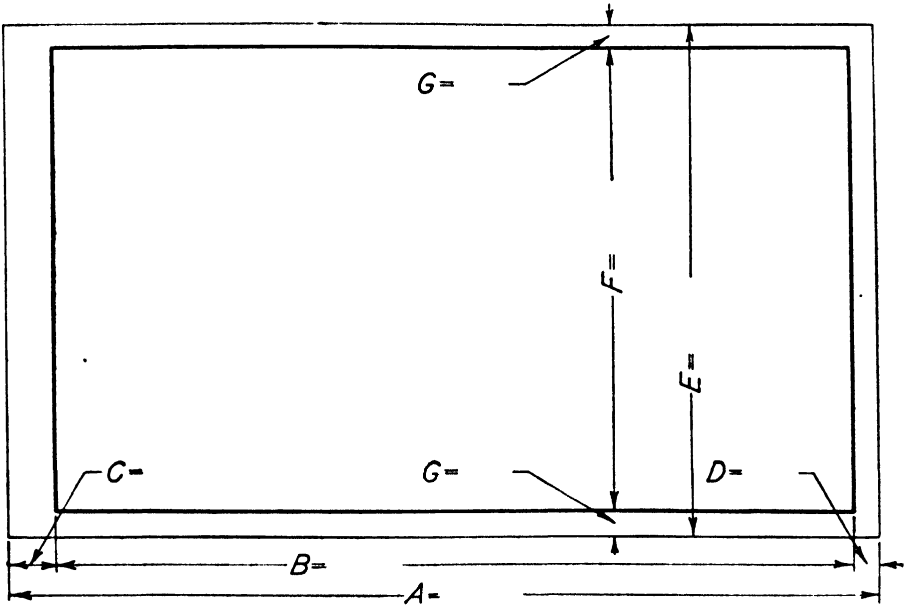


Figure 22·1 Adjustable layout for any size sheet.

If a different size of sheet is used, the figures in the circles should be adjusted to allow more or less space. This had best be done by the instructor at first, but the students can learn how to locate the views after a little practice.

Since most drawings are now finished in pencil, careful attention should be given to developing the ability to make bright contrasty drawings on either drawing paper or tracing paper. This requires firm black pencil lines for the view lines and thin sharp pencil lines for dimension lines, extension lines, etc.

A minimum amount of erasing is essential if clean, professional appearing drawings are to be obtained. A great deal depends upon the care that is given to keeping the pencil point in proper condition at all times.

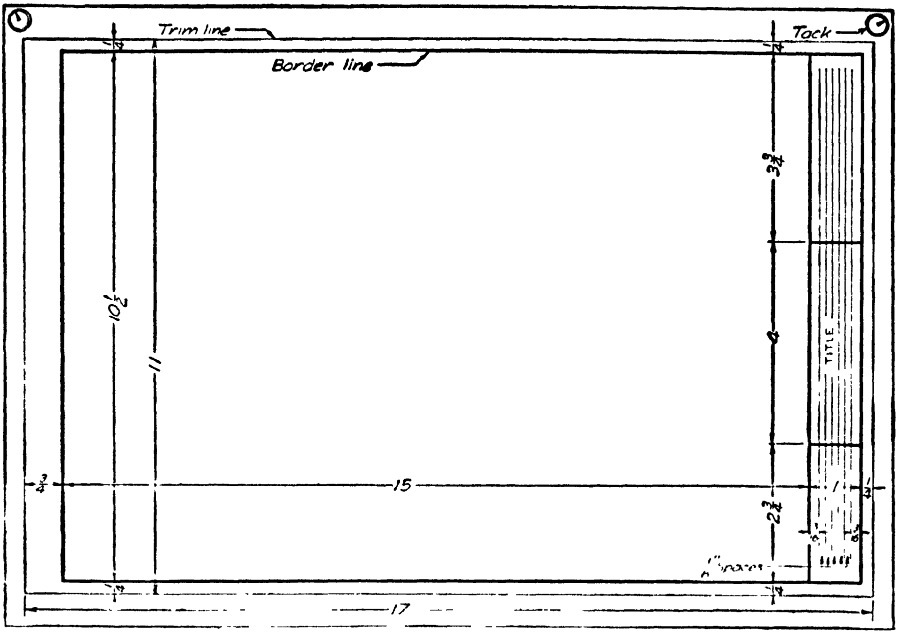


Figure 22·2 Standard layout of sheet.

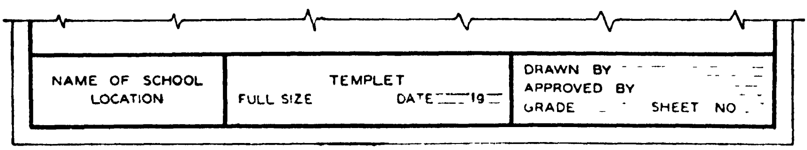


Figure 22·3 Record strip.

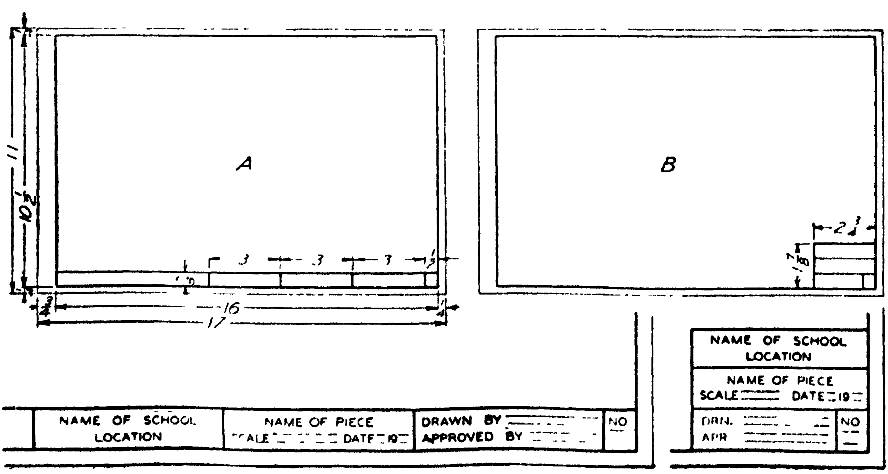


Figure 22·4 Alternate layouts.

22·3 Layout of the Sheet. Read Arts. 2·1 to 2·6. Fasten the paper to the board as described in Art. 2·2. The outside dimensions to which the finished sheet will be trimmed are 11″ × 17″, with border line and record strip as shown in Fig. 22·2. (The guide lines for lettering in the record strip, Fig. 22·3, are not to be put in until the drawing is finished ready for the title.) By following the method illustrated in progressive steps, the layout of a sheet should not take more than two minutes.

Two-minute Method (Fig. 22·5). With the scale measure 17″ near the bottom of the sheet, making short vertical marks, not dots. Measure and mark ¾″ in from the left-hand mark and ¼″ in from the right-hand mark (Fig. 22·5, Space 1). From this last mark measure 1″ toward the left and mark. Lay the scale vertically near the left of the paper and make short horizontal marks 11″ apart. Make short marks ¼″ down from the top mark and ¼″ up from the bottom mark. Now with the T-square draw horizontal lines through the four marks last made (Space 2). Next draw vertical lines through the five vertical marks (Space 3). Then brighten up the border lines and the sheet will appear as in Space 4; it is now ready to be used for a drawing.

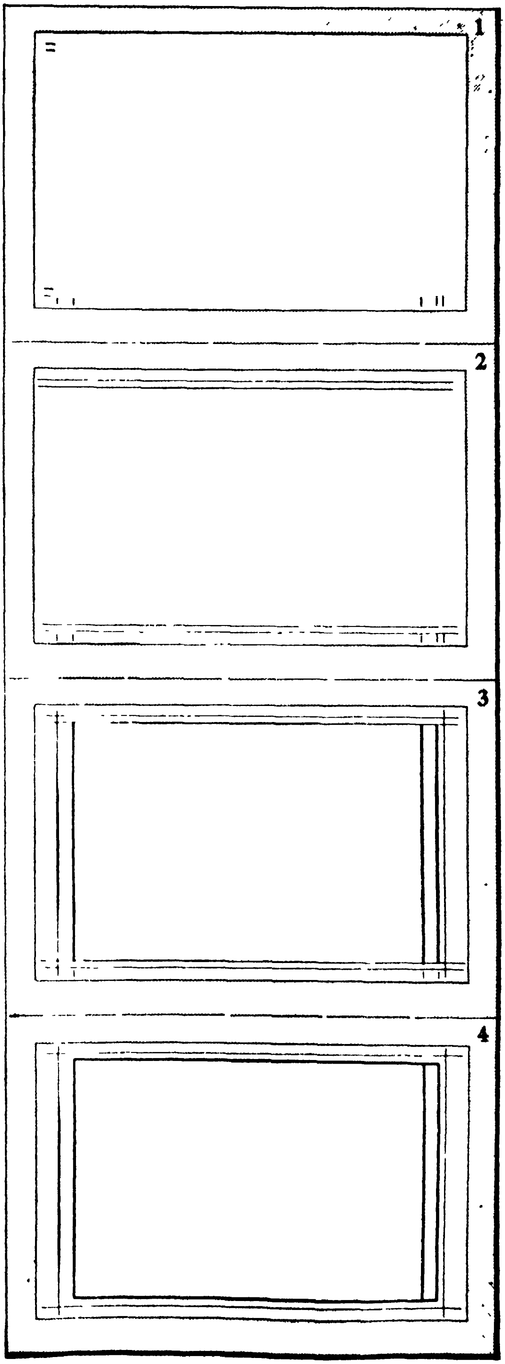


Figure 22·5 Order of working.

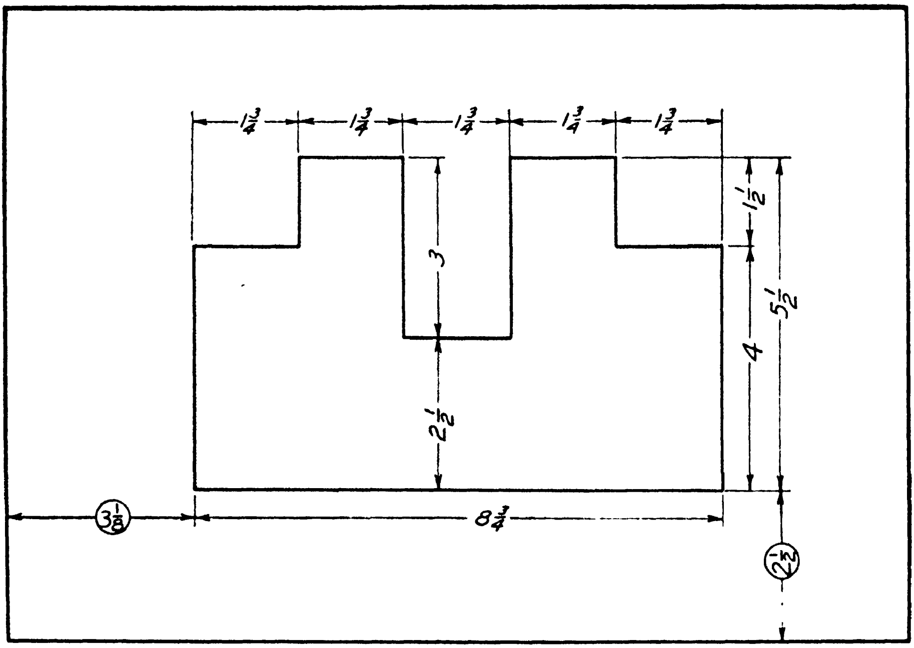


Figure 22·6 Templet. **Prob. 1.**

GROUP 1. USE OF INSTRUMENTS

Problem 1 The first sheet (Fig. 22·6) is a one-view drawing of a *templet.* Complete specifications would include the thickness and kind of material.

In this and the following one-view problems the order of making the drawing is shown in progressive stages. These stages should be followed carefully as they represent the draftsman's procedure in making drawings.

It is necessary for the beginner to learn to draw in good form, and the most important feature in this regard is the order of working. Do not simply follow the explanations as being directions for the particular problem, but try to understand the system and the reasons for it. This system, thoroughly mastered at the start, will apply to all drawings and will develop the two requirements in execution: accuracy and speed.

Order of Working (Fig. 22·7).

1. Lay out the sheet as described on the preceding page.
2. Measure 3⅛" from left border line and from this mark measure 8¾" toward the right.
3. Lay the scale on the paper vertically near the left edge, make a mark 2½" up and from this measure 5½" more. The sheet will appear as in Fig. 22·7, Space 1.
4. Draw horizontal lines *1* and *2* with the T-square, and vertical lines *3* and *4* with T-square and triangle (Space 2), being careful to hold the instruments as illustrated in Fig. 2·4. These four lines "block in" the figure.

5. Lay the scale along the bottom line of the figure with the measuring edge on the upper side and make marks 1¾″ apart. Then with the scale on line *3*, with its measuring edge to the left, measure from the bottom line two successive distances vertically, 2½″ and 1½″ (Space 3).

6. Through the two marks draw horizontal lines lightly across the figure.

7. Draw the vertical lines with T-square and triangle, setting the pencil on the marks on the bottom line and starting and stopping the lines on the proper horizontal lines (Space 4).

8. Erase the lines not wanted and brighten the lines of the figure to obtain the finished drawing (Space 5).

9. Write your name, sheet number, and date lightly in the record strip. The record strip is to be lettered in later.

10. Trim sheet to finished size.

Problems 2 and 3 Alternates with same layout as in Fig. 22·6.

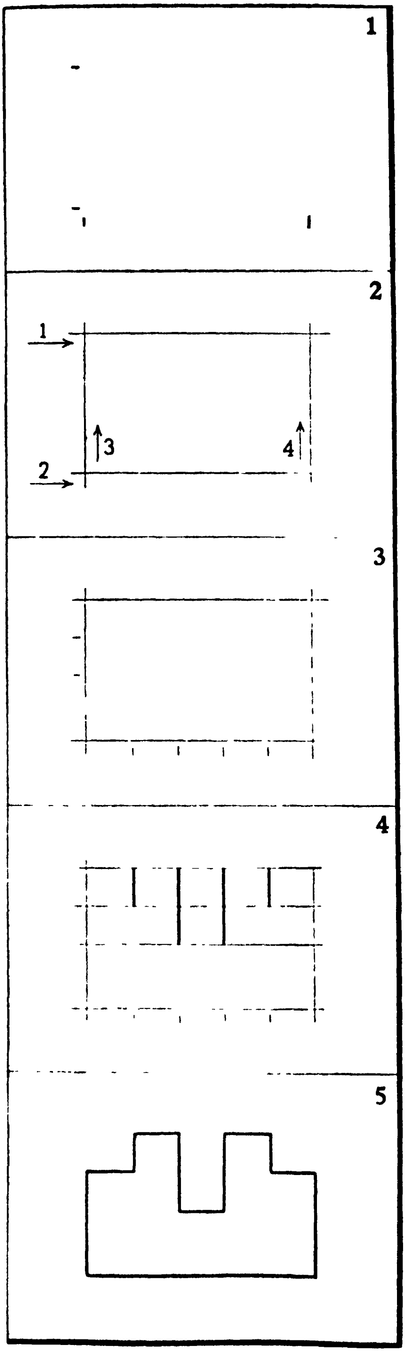


Figure 22·7 Order of working.

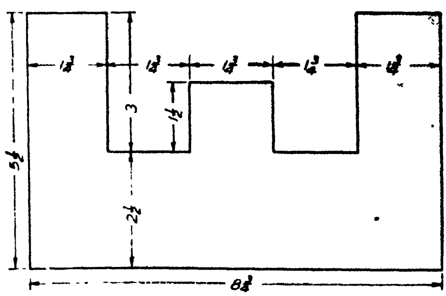


Figure 22·8 Templet No. 2. **Prob. 2.**

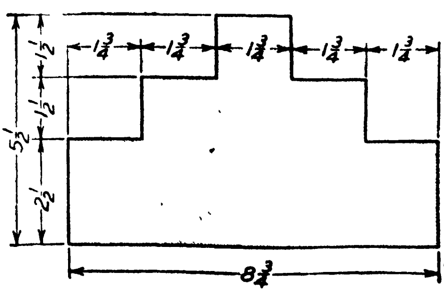


Figure 22·9 Gage. **Prob. 3.**

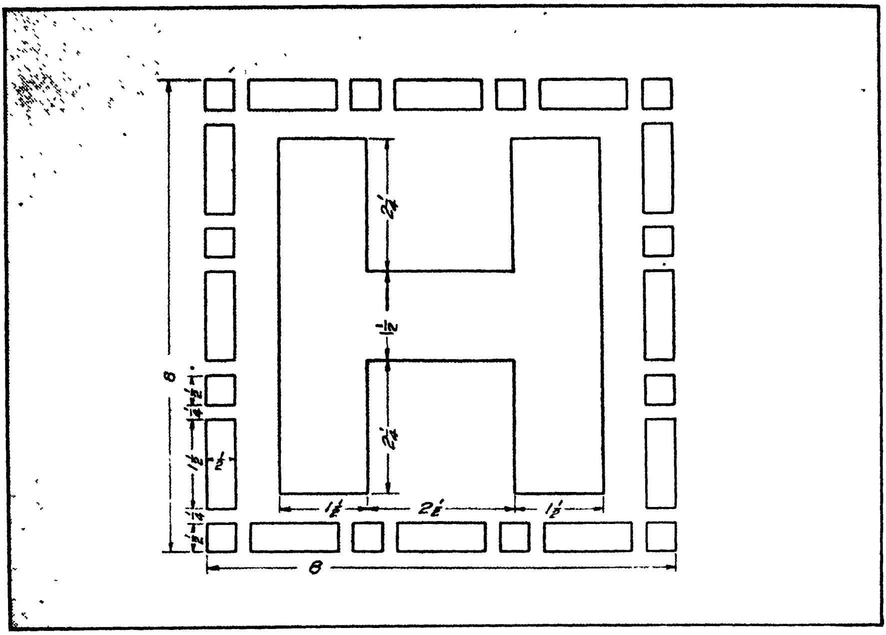


Figure 22·10 *Stencil.* **Prob. 4.**

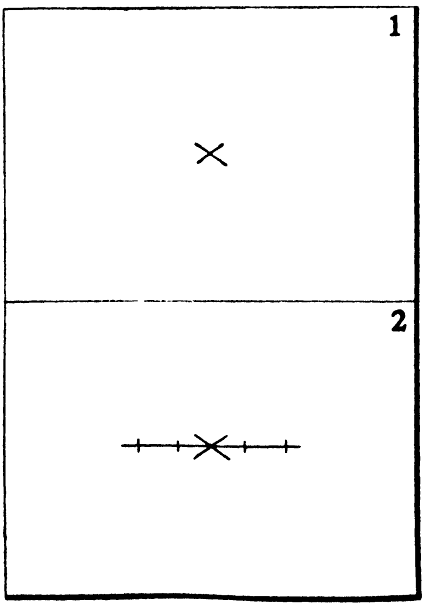


Figure 22·11 *Order of working.*

Problem 4 To make a drawing of the *stencil* (Fig. 22·10). This drawing gives practice in accurate measuring with the scale and making careful corners with short lines. The construction lines shown in Fig. 22·11 should be drawn very lightly and with a well-sharpened pencil. All measurements must be made very carefully and accurately.

Order of Working (Figs. 22·11 and 22·11 (*Continued*).

1. Find the center of the sheet inside the border by laying the T-square blade face down across the corners and drawing short pieces of the diagonals where they intersect (Fig. 22·11, Space 1).

2. Through the center draw a horizontal center line and on it

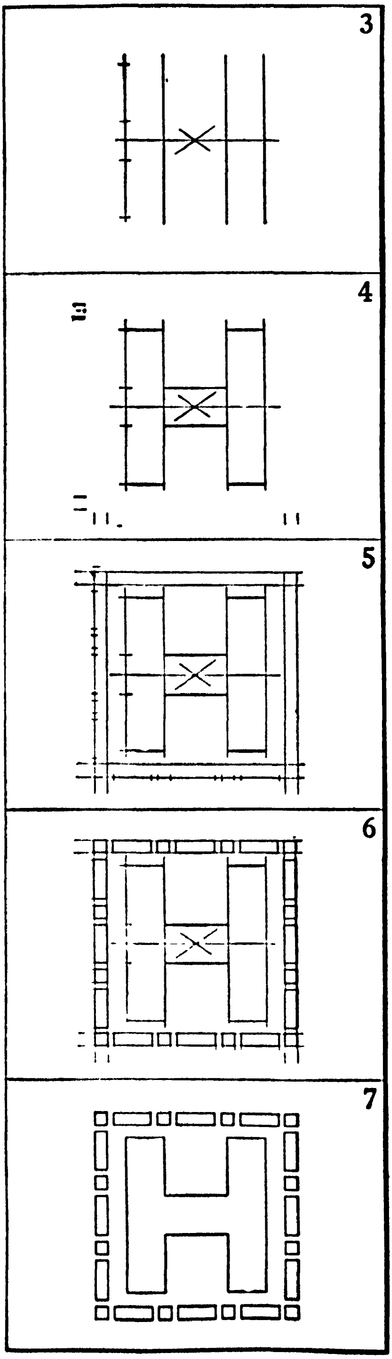


Figure 22·11 Continued.

measure and mark off points for the four vertical lines. The drawing will appear as in Space 2.

3. Draw the vertical lines lightly with T-square and triangle. On the first vertical line, at the extreme left, measure and mark off points for all horizontal lines. The drawing will now appear as in Space 3.

4. Draw the horizontal lines as finished lines, and measure points for the stencil border lines on the left side and bottom. The drawing will now appear as in Space 4.

5. Draw the border lines. On the lower and left-hand border lines, measure the points for the ties. The drawing will now appear as in Space 5.

6. Complete the border by drawing the cross lines as finished lines and brightening the other lines (Space 6).

7. Brighten the vertical lines and finish as in Space 7.

8. Write name, sheet number, and date in the record strip and trim the sheet to finished size.

Problem 5 To make a drawing of the *tile pattern* (Fig. 22·12). This is an alternate problem, using the same measurements as in Fig. 22·10 with additional $1\frac{1}{2}''$ measurements for the top and bottom strips and for the middle vertical strip.

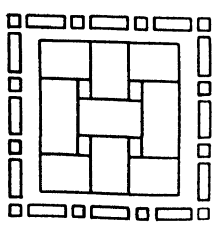


Figure 22·12 Tile pattern. **Prob. 5.**

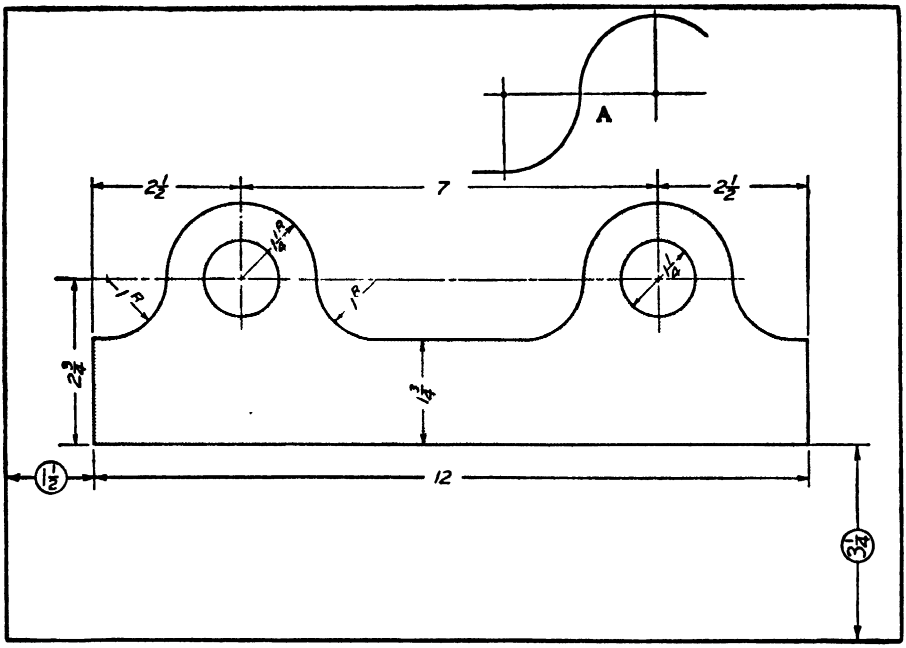


Figure 22·13 Shim. **Prob. 6.**

Problem 6 To make a drawing of the *shim* (Fig. 22·13). For practice with compasses. Read Art. 2·13. When circles and circle arcs occur on a drawing, the first step is to locate the centers, the second to mark off the radii, the third to locate the points of tangency and make sure of smooth joints.

Be sure that the lead in the compasses is carefully sharpened and adjusted with the needle point as shown in Fig. 2·19. Draw intersecting center lines on a separate sheet, and practice handling both the compasses and bow pencil in drawing circles, carefully observing the operations illustrated in Figs. 2·17 and 2·20. The needle point may be placed at the exact crossing of the two center lines by guiding it with the little finger of the left hand, resting the other fingers on the paper.

Tangents occur constantly on all machine drawings and must be drawn neatly and quickly. Accuracy in setting the compasses to a required radius should be practiced, as any error is doubled when the diameter is measured.

Note that when two circle arcs are tangent to each other the point of tangency must lie on a line joining the centers of the arcs (Fig. 22·13 at A).

Order of Working (Fig. 22·14).

1. Draw the base line 2½″ from the bottom. On it measure in 1½″ from the left border, then the distances 2½″, 7″, and 2½″ (Space 1).
2. Measure the vertical distances 1¾″ and 2¾″ (Space 1).
3. Draw the horizontal lines, then the vertical lines (Space 1).

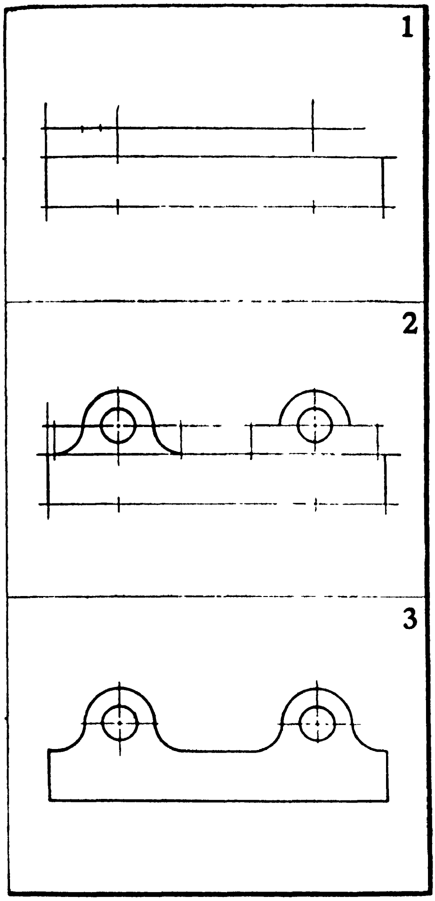


Figure 22·14 Order of working.

4. On the horizontal center line mark points for the radii and draw the two circles, then the two semicircles, then the fillets. Be sure to stop at the tangent points (Space 2).

5. Brighten the lines of the figure, leaving the center lines lighter than the outlines, as in Space 3.

6. Write name, sheet number, and date lightly in the record strip, and trim the sheet.

Problem 7 Make a drawing of a *brace* (Fig. 22·15). Plan a systematic order of working before starting the drawing.

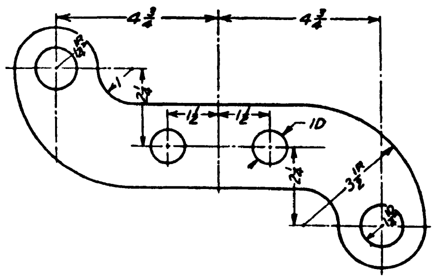


Figure 22·15 Brace. **Prob. 7.**

Problem 8 Make a drawing to show the layout for a *basketball floor* (Fig. 22·16). Use a scale of ⅛″ = 1′ (Art. 2·8). Distance *A* to be at least 3′.

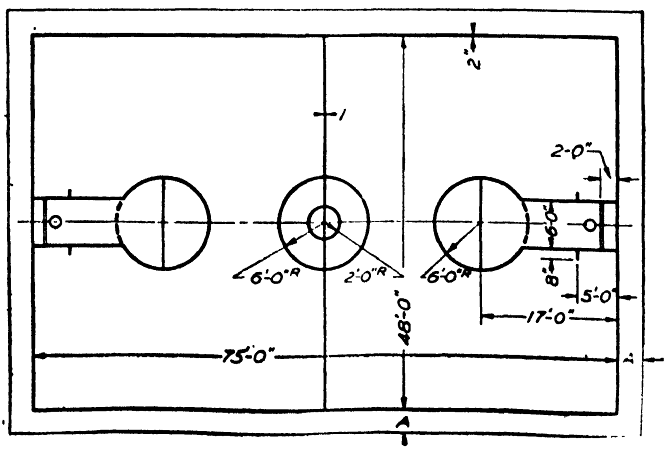


Figure 22·16 Basketball floor. **Prob. 8.**

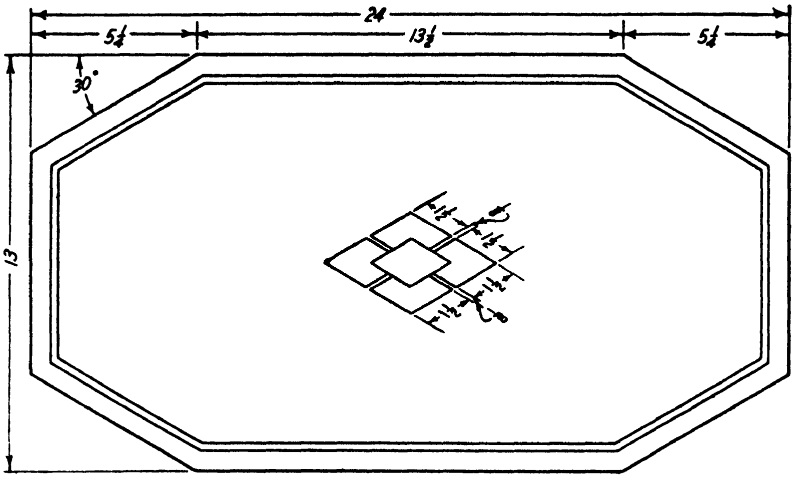


Figure 22·17 Inlaid table top. **Prob. 9.**

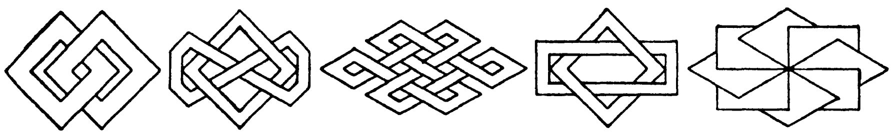


Figure 22·18 Alternate centers for table top.

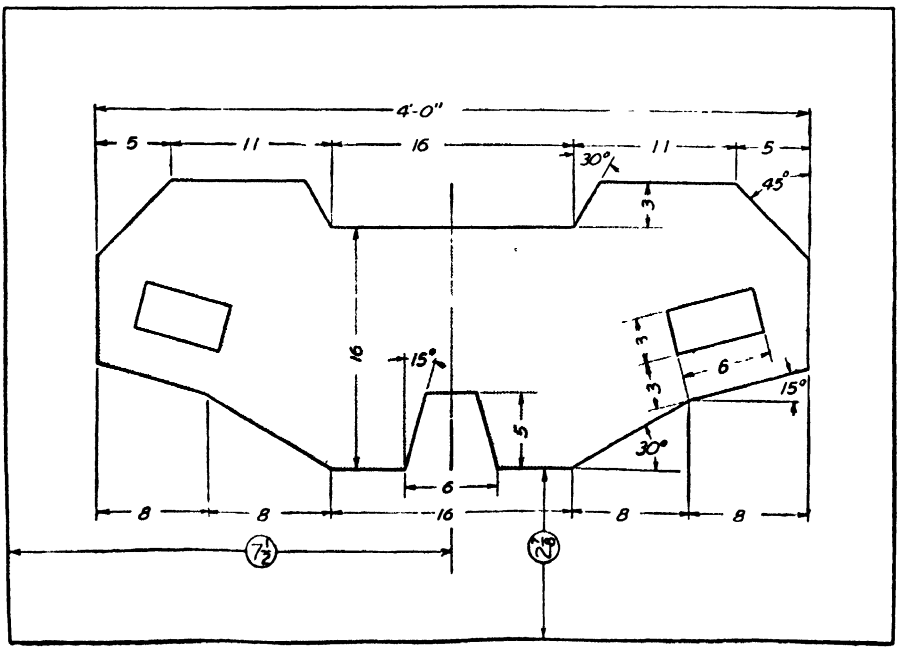


Figure 22·19 Shearing blank. **Prob. 10.**

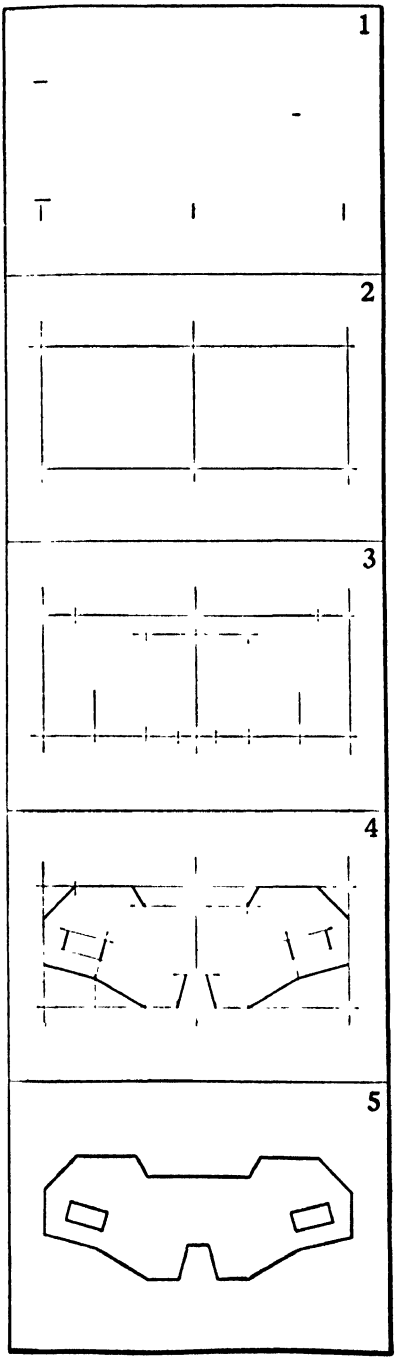


Figure 22·20 Order of working.

Problem 9 To draw an *inlaid table top* (Fig. 22·17). Draw horizontal and vertical center lines. Plan a systematic order of working. The central inlay may be varied, using one of the suggestions of Fig. 22·18 or the student's own original design.

Problem 10 To make a drawing of the *shearing blank* (Fig. 22·19). When a view has inclined lines, it should first be "blocked in" with square corners. Angles of 15°, 30°, 45°, 60°, and 75° are drawn with the triangles after locating one end of the line. See Fig. 2·13.

Order of Working (Fig. 22·20).

1. Locate vertical center line and measure 2′ on each side (Space 1). Note that this drawing must be made to the scale of 3″ = 1′ (Art. 2·8).
2. Locate vertical distances for top and bottom lines.
3. Draw main blocking-in lines as in Space 2.
4. Make measurements for starting points of inclined lines (Space 3).
5. Draw inclined lines with T-square and triangles (Space 4).
6. Finish as in Space 5.
7. Write name, sheet number, and date in record strip, and trim to size.

Problem 11 Make a drawing of a *T-square head* (Fig. 22·21). Plan a systematic order of working before starting the drawing. Note tangent points *A*, *B*, and *C*, and that *BC* is a straight line.

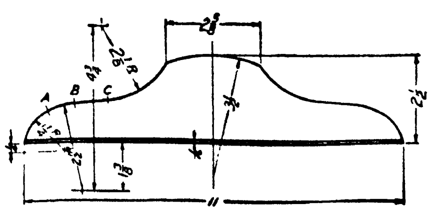


Figure 22·21 T-square head. **Prob. 11.**

Problem 12 To make a drawing of the *cushioning base* (Fig. 22·22). For practice with triangles, compasses, and scale. Centers of arcs and tangent points must be carefully located.

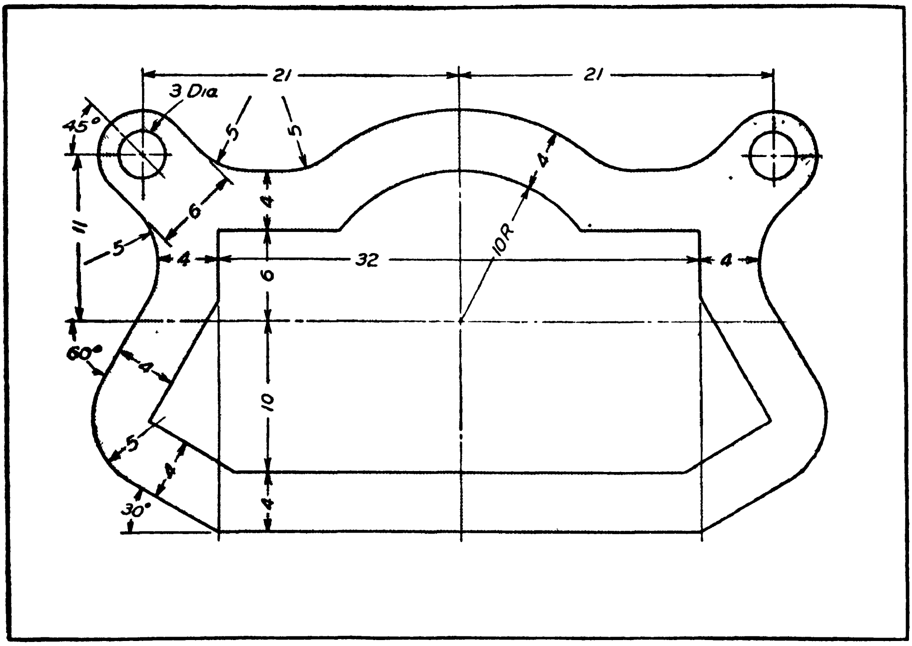


Figure 22·22 Cushioning base. **Prob. 12.**

Order of Working (Fig. 22·23).

1. Through the center of the working space draw horizontal and vertical center lines. Measure horizontal and vertical distances. This drawing must be made to the scale of 3″ = 1′. Then draw horizontal and vertical lines (Space 1).

2. Draw inclined lines with 45° and 30°–60° triangles. Then draw large arcs and two semicircles with tangents at 45° (Space 2).

3. Locate centers and tangent points for the 5″ radius tangent arcs. To do this, measure 5″ perpendicularly from each tangent line and draw lines parallel to the tangent lines. The intersection of these lines will be the required centers. To find the points of tangency, draw lines from the centers perpendicular to the tangent lines. To find the centers for the 5″ arcs tangent to the middle arc, proceed as follows: Increase the radius of the larger arc by 5″ and draw two short arcs cutting lines parallel to and 5″ above the top horizontal tangent line. These points will be the centers. Lines joining these centers with the center of the large arc will locate the points of tangency of the arcs (Space 3).

Draw all the 5″ tangent arcs above the horizontal center line. Locate points of tangency and draw the two 60° tangent lines. Locate centers and draw the 5″ tangent arcs below the center line.

4. Complete the view by drawing the lines for the opening. Brighten the lines and finish (Space 4).

GROUP 2. GEOMETRICAL CONSTRUCTIONS

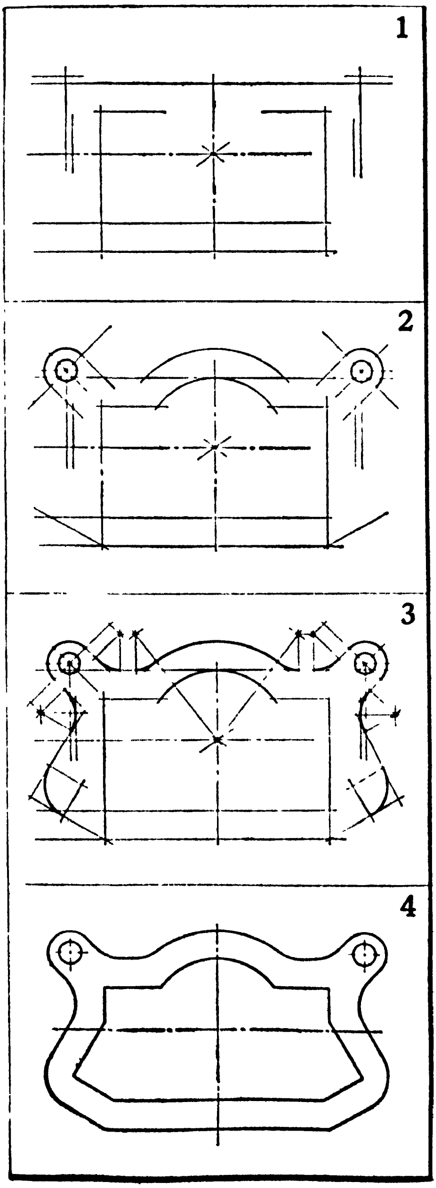


Figure 22·23 Order of working.

22·4 The working of a limited number of geometrical exercises is valuable both for the practice in the use of instruments and for the gaining of familiarity with the constructions that occur most frequently in drafting. Such problems must be worked very accurately, with a very sharp pencil and comparatively light lines. A point should be located by two intersecting lines and the length of a line by two short dashes crossing the given line.

The following problems (13 to 43) are designed to be drawn in one-quarter of the working space of an 11″ × 17″ sheet. Lay out the sheets as in Fig. 22·2 and draw horizontal and vertical lines to divide the space into four equal parts as shown in Fig. 22·24.

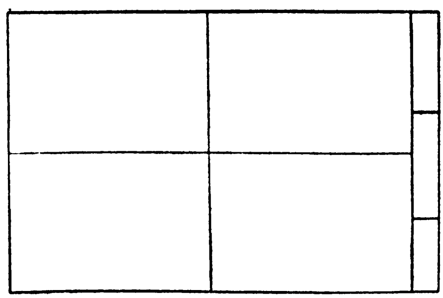


Figure 22·24 Sheet layout.

Problem 13 Art. 16·2. Near the center of the space draw a line $3\frac{11}{16}$″ long and bisect it.

Problem 14 Art. 16·2. Near the center of the space draw a line $3\frac{7}{16}$″ long and bisect it.

Problem 15 Art. 16·3. Above the center of the space draw a horizontal line $5\frac{13}{16}''$ long. Divide it into seven equal parts geometrically.

Problem 16 Art. 16·3. To the left of the center draw a vertical line $3\frac{7}{16}''$ long and divide it into five equal parts geometrically.

Problem 17 Art. 16·6. Locate a point $\frac{3}{4}''$ above lower line of space and $1''$ from left side. Draw lines joining the middle points of the upper and right-hand sides of the space. Bisect the angle between these lines.

Problem 18 Art. 16·6. Locate a point $\frac{3}{4}''$ below the middle of the upper line of the space. Draw lines joining this point with the lower right-hand corner and with the middle of left side of space. Bisect the angle.

Problem 19 Art. 16·7. Draw a vertical line $\frac{3}{4}''$ from left edge of space. From a point on this line $\frac{3}{4}''$ below top of space draw another line making any angle. Copy this angle so that one side is $\frac{3}{4}''$ from right side of space and vertex is $\frac{3}{4}''$ from bottom of space.

Problem 20 Art. 16·7. From the middle of left side of space draw lines to upper and lower right-hand corners. Copy this angle so that one side is horizontal and $\frac{1}{2}''$ above bottom of space.

Problem 21 Art. 16·8. Draw a horizontal line $4\frac{3}{4}''$ long and $1''$ above bottom of space. On it as a base construct a triangle having sides of $4\frac{1}{8}''$ and $3\frac{1}{4}''$.

Problem 22 Art. 16·8. Draw a vertical line $2\frac{7}{8}''$ long and $1\frac{1}{2}''$ from left side of space. On it construct a triangle having sides of $5\frac{1}{8}''$ and $4\frac{3}{4}''$.

Problem 23 Art. 16·8. Draw a horizontal line $4\frac{1}{2}''$ long and $1''$ above bottom of space. Using this as the longer of two sides, construct a right triangle by the 6-8-10 method.

Problem 24 Art. 16·9. Draw a regular pentagon in a circle whose diameter is $3\frac{3}{4}''$.

Problem 25 Art. 16·10. Draw a regular hexagon $3\frac{3}{4}''$ across corners.

Problem 26 Art. 16·11. Draw a regular octagon in a $3\frac{1}{2}''$ square.

Problem 27 Art. 16·12. Locate three points as follows: point *A* $3\frac{3}{4}''$ from left edge of space and $4\frac{1}{4}''$ above bottom of space; *B* $5\frac{1}{4}''$ from left edge and $2\frac{5}{8}''$ from bottom; *C* $2''$ from left edge and $1\frac{3}{4}''$ from bottom. Draw a circle through *A*, *B*, and *C*.

Problem 28 Art. 16·14. Locate a point $\frac{1}{2}''$ from bottom of space and $\frac{1}{2}''$ from left edge. Draw lines from this point to middle of top of space and to lower right-hand corner. Draw an arc tangent to these two lines with a radius of $1\frac{1}{2}''$.

Problem 29 Art. 16·17. Draw an arc having a radius of $3\frac{1}{2}''$, with its center $\frac{3}{4}''$ from top of space and $1\frac{3}{4}''$ from left edge. Find the length of an arc of 60°.

Problem 30 Art. 16·18. From the left edge of the space draw a horizontal line 1½″ long and 1¼″ below top of space. From right edge draw a horizontal line 1½″ long and 1¼″ above bottom of space. Join these two lines by an ogee curve. Point *E* to be one-third the distance from *B* to *C* (Fig. 16·23).

Problem 31 Art. 16·19. Draw an equilateral triangle in the center of the space, sides ¾″ long. Draw one turn of an involute of the triangle.

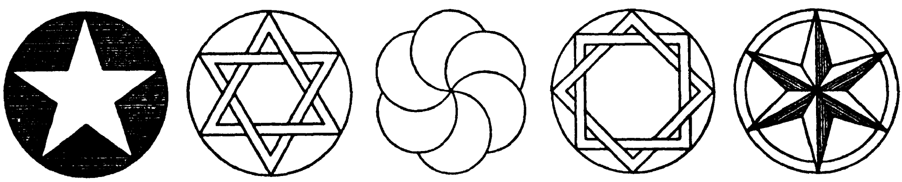
Problem 32 Art. 16·19. Locate a point 2¾″ below top of space and 2″ from left side of space. With this point as a center draw a circle having a diameter of 3″. Draw an involute of the right half of the circle.

Problem 33 Art. 16·20. Draw horizontal and vertical lines through the center of the space. Draw one turn of a spiral of Archimedes in a 4″ diameter circle.

Problem 34 Art. 16·24. Draw an ellipse having a major axis of 4″ and a minor axis of 2½″. Use concentric-circle method.

Problem 35 Art. 16·23. Draw an ellipse having a major axis of 4″ and a minor axis of 1″. Use trammel method.

Problem 36 Art. 16·25. Draw an approximate ellipse having a major axis of 4½″ and a minor axis of 3¼″.



A *B* *C* *D* *E*

Figure 22·25 **Probs. 37 to 43.**

Problem 37 Divide a 4″ circle into 5 equal parts and draw a five-pointed star by connecting opposite points (Fig. 22·25*A*).

Problem 38 In a 4″ circle draw interlaced equilateral triangles (Fig. 22·25*B*). The bands are ¼″ wide.

Problem 39 Draw a 4″ circle. With six equally spaced radii as diameters draw circle arcs as in Fig. 22·25*C*.

Problem 40 Variation of Prob. 39 using 5, 8, or 12 radii.

Problem 41 Variation of Probs. 39 or 40, adding a concentric-circle arc one-half the radius of first arc.

Problem 42 In a 4″ circle draw interlaced squares (Fig. 22·25*D*), making the bands ¼″ wide.

Problem 43 With 30°–60° and 45° triangles together draw the six-pointed star of Fig. 22·25*E*. Refer to Fig. 2·13.

GROUP 3. LETTERING

22·5 Lettering can best be taught using short practice periods. For such a purpose, lettering practice books, ready ruled and with directions, are available and are inexpensive. Book I, "Lessons in Lettering," by French and Turnbull is for vertical letters, and Book II is for inclined letters.

The exercises that follow can be done in one-quarter of the working space of a regular sheet (Fig. 22·24).

For pencil letters use a long conical point. Rotate the pencil in the fingers after each few strokes to keep the point symmetrical.

For ink letters use a penholder with a cork grip and set the pen well into the holder. Always use drawing ink for lettering. To get clean-cut letters, it is necessary to wipe the pen frequently with a cloth penwiper.

Problems are given for both vertical and inclined letters, but only one kind should be taught beginners.

Vertical Lettering.

Problems 44 to 47 Fig. 22·26. Single-stroke vertical capitals in pencil. Layout sheet as in Fig. 22·24. Rule guidelines 3/8" apart, starting 1/2" over and 9/16" down. Letter as indicated in each space, making a careful study of the letters with the order and direction of the strokes as given in Fig. 3·6. Complete each line. Prob. 44, Space 1. Prob. 45, Space 2. Prob. 46, Space 3. Prob. 47, Space 4 (see Figs. 3·6 and 3·8). Use an F pencil.

Problem 48 Fig. 22·27, Space 1. Rule guidelines 3/16" apart, starting 1 1/4" over and 1 3/16" down. Make first two lines in pencil. Make next two lines very lightly in pencil and go over them with pen and ink. Use Gillott 404 pen. Make fifth and sixth lines in ink without first penciling. Seventh line in pencil. Eighth line in ink.

Problem 49 Fig. 22·27, Space 2. Single-stroke vertical lower case in pencil. Rule guidelines as shown in lower left-hand space. Start 1 1/4" over and 1 3/16" down. The bodies of the letters are 1/8" high. The first space is 1/16" down, the next 1/8" and the next 3/16". Repeat until there are guidelines for eight lines of letters. Complete each line. Study Fig. 3·9.

Problem 50 Fig. 22·27, Space 3. Same as Prob. 49, except that the lettering is to be done directly in ink.

Problem 51 Fig. 22·27, Space 4. Rule as for Prob. 49. Letter the sentence first in pencil, then below, directly in ink.

Inclined Lettering.

Problems 52 to 55 Fig. 22·28. Single-stroke inclined capitals in pencil. Lay out sheet as in Fig. 22·24. Rule guidelines 3/8" apart, starting 1/2" over and 9/16" down. Letter as indicated in each space, making a careful study of the letters with the order and direction of strokes as given in Fig. 3·11. Complete each line. Prob. 52, Space 1. Prob. 53, Space 2. Prob. 54, Space 3. Prob. 55, Space 4.

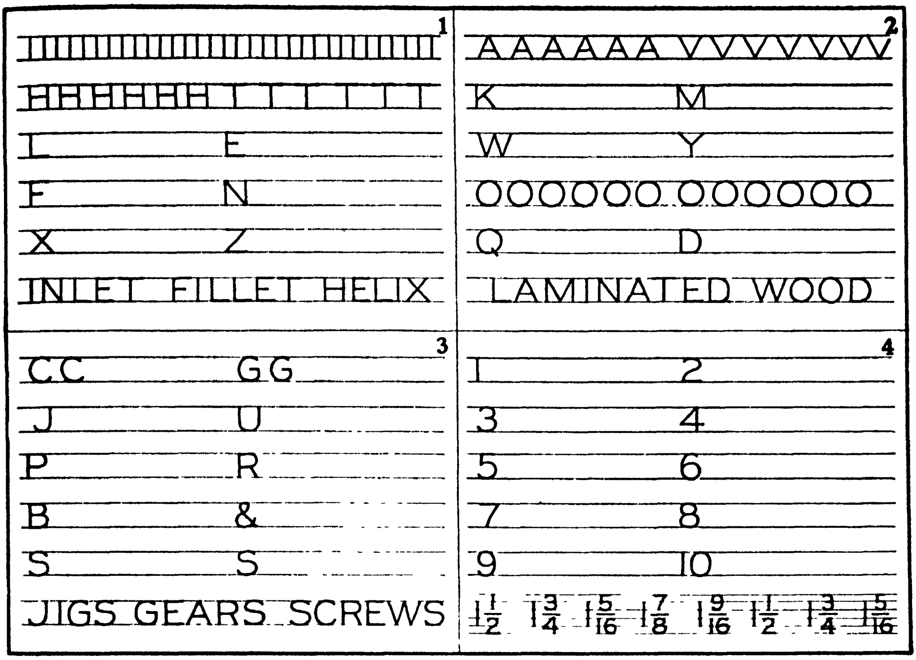


Figure 22·26 **Probs. 44 to 47.**

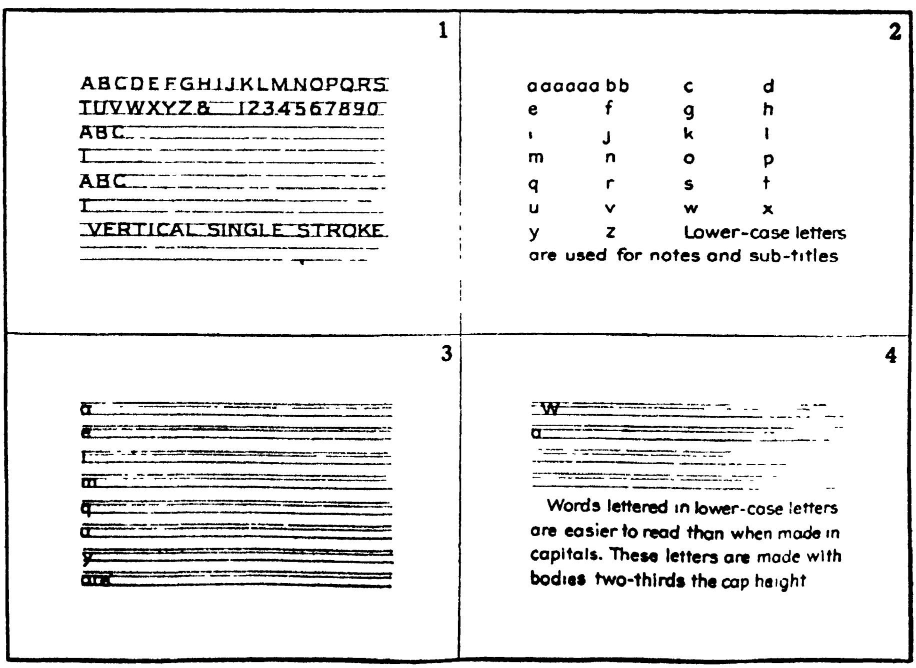


Figure 22·27 **Probs. 48 to 51.**

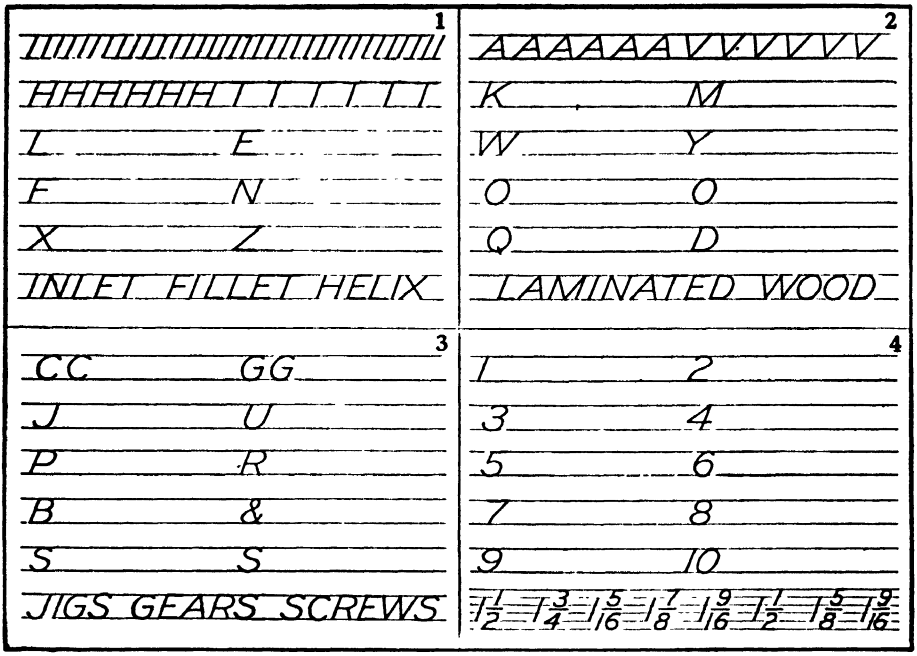


Figure 22·28 **Probs. 52 to 55.**

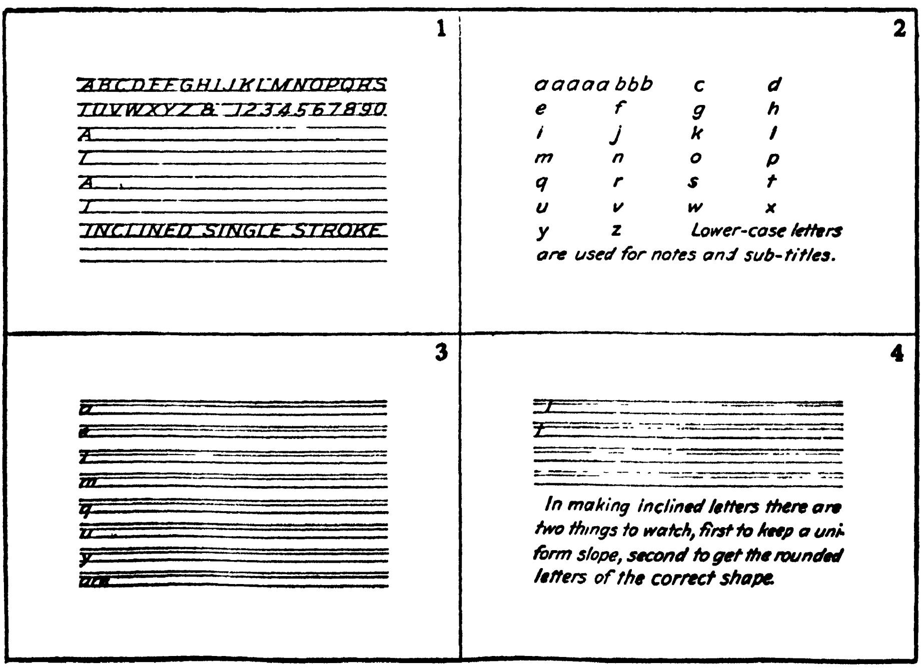


Figure 22·29 **Probs. 56 to 59.**

Problem 56 Fig. 22·29, Space 1. Rule guidelines $3/16''$ apart, starting $1\frac{1}{4}''$ over and $1\frac{3}{16}''$ down. Make first two lines in pencil. Make next two lines very lightly in pencil and go over them with pen and ink. Use Gillott 404 pen. Make fifth and sixth lines in ink without first penciling. Seventh line in pencil. Eighth line in ink.

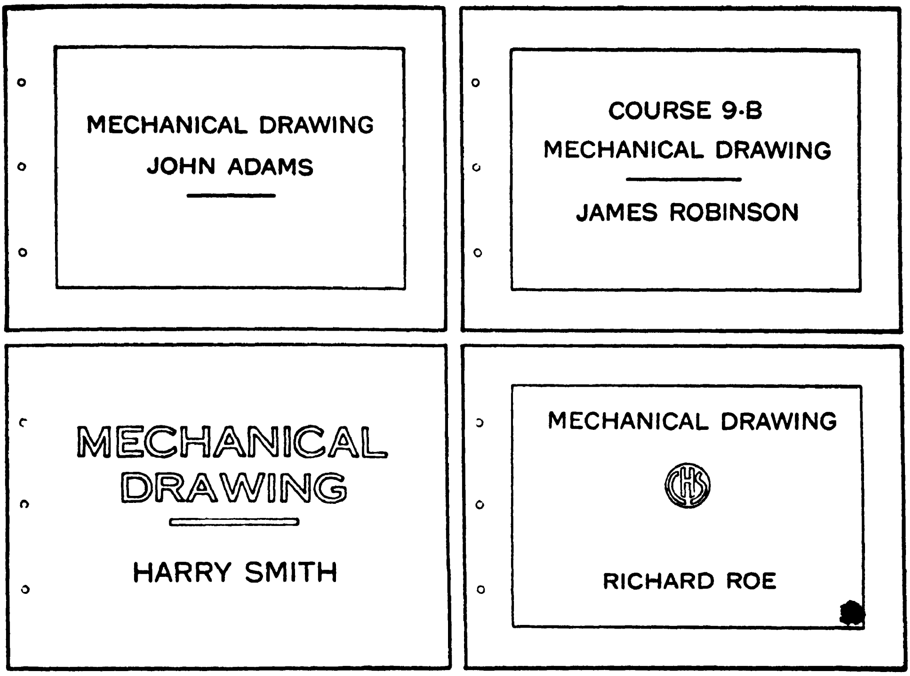


Figure 22·30 Title page. **Prob. 60.**

Problem 57 Fig. 22·29. Space 2. Single-stroke inclined lower case in pencil. Rule guidelines as shown in lower left-hand space. Start $1\frac{1}{4}''$ over and $1\frac{3}{16}''$ down. The bodies of the letters are $1/8''$ high. The first space is $1/16''$ down, the next $1/8''$ and the next $3/16''$. Repeat until there are guidelines for eight lines of letters. Complete each line. Study Fig. 3·15.

Problem 58 Fig. 22·29. Space 3. Same as Prob. 57, except that the lettering is to be done directly in ink.

Problem 59 Fig. 22·29. Space 4. Rule as for Prob. 57. Letter the sentence first in pencil, then below, directly in ink.

Title Page.

Problem 60 Design a *title page.* Suggestions for composition are shown in Fig. 22·30.

GROUP 4. SHAPE DESCRIPTION

22·6 The problems in this group are for practice in representing objects by views in order to gain a thorough understanding of the theory of shape description. Chapter 4 should be studied carefully first. Views and pictures are given for some of the problems to assist the student in visualizing the object. In others two views are given, from which the student is to work out the third view. In still others pictures are given from which the student is required to determine what views are necessary, the plan and arrangement of the views in the working space, and then to work out the views.

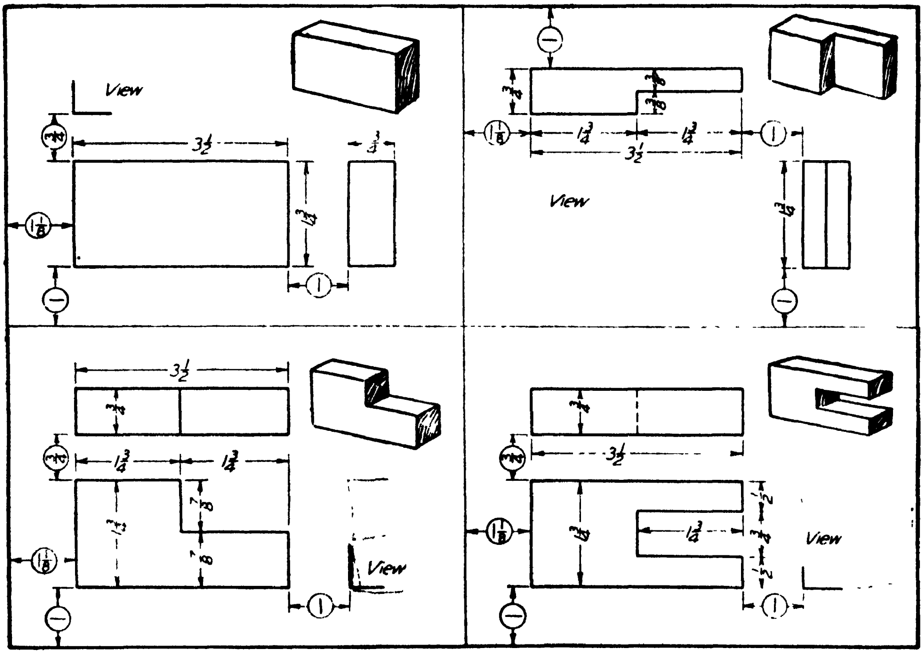


Figure 22·31 Shape description blocks. **Probs. 61 to 64.**

Problems 61 to 64 Fig. 22·31. Lay out an 11″ × 17″ sheet, as in Fig. 22·2, and divide the working space into four equal parts. In each of the spaces draw three views of the block as shown. A picture of each block is given and two of the three views with dimensions. Complete the three views using full-size scale, and letter the record strip. When the sheet is finished, it will appear as shown in Fig. 22·32. The record strip will contain the title *Shape Description Blocks*, the scale "Full Size," and the date. See Figs. 22·2 and 22·3.

Problems 65 to 68 Fig. 22·33. Draw three complete views of each of the *adjusting blocks.* Do not copy the pictures.

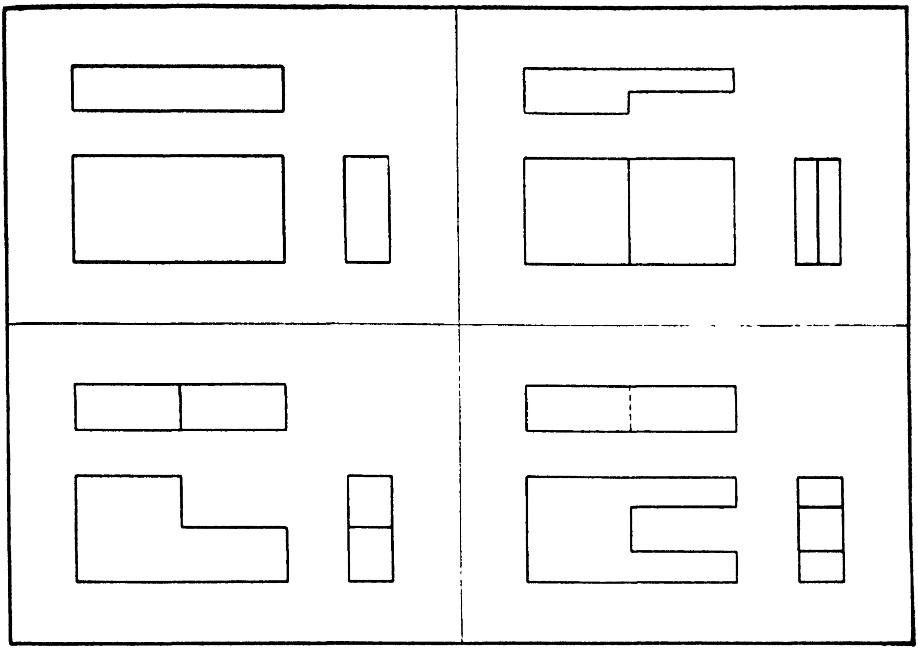


Figure 22-32.

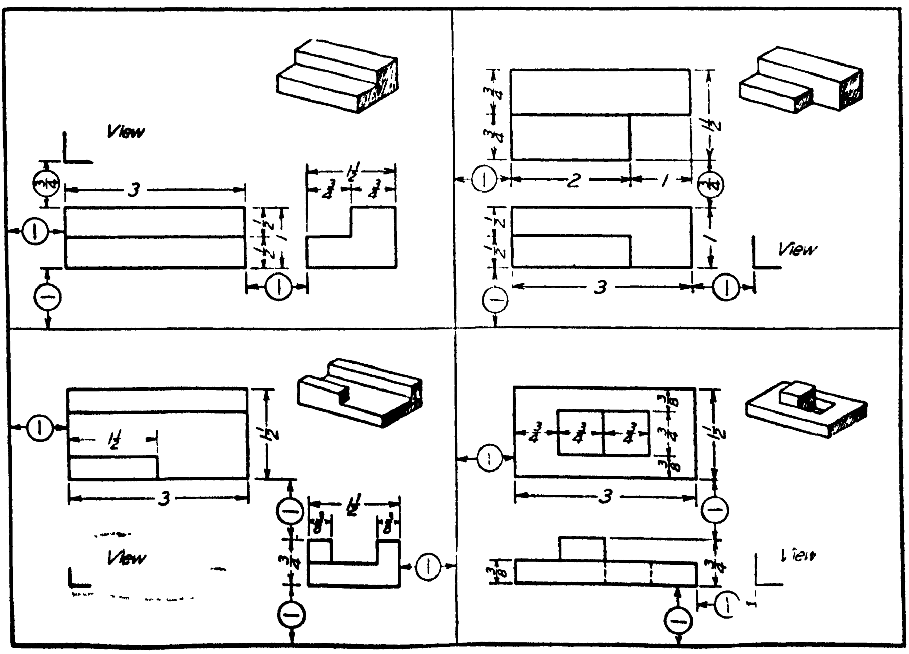


Figure 22-33 Adjusting blocks. **Probs. 65 to 68.**

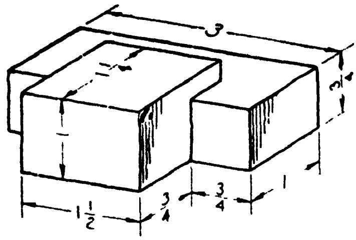


Figure 22·34 Base. **Prob. 69.**

Problem 69 Fig. 22·34. Draw three views of the *base.*

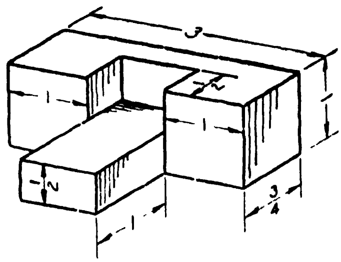


Figure 22·35 Anchor. **Prob. 70.**

Problem 70 Fig. 22·35. Draw three views of the *anchor.*

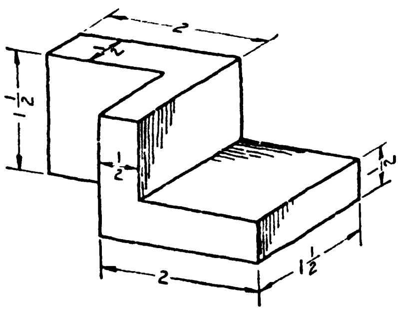


Figure 22·36 Spacer. **Prob. 71.**

Problem 71 Fig. 22·36. Draw three views of the *spacer.*

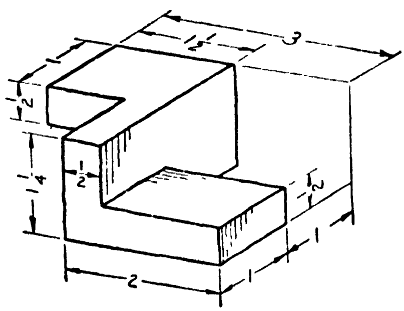


Figure 22·37 Stop. **Prob. 72.**

Problem 72 Fig. 22·37. Draw three views of the *stop.*

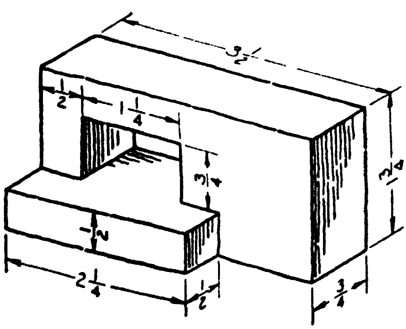


Figure 22·38 Guide. **Prob. 73.**

Problem 73 Fig. 22·38. Draw three views of the *guide.*

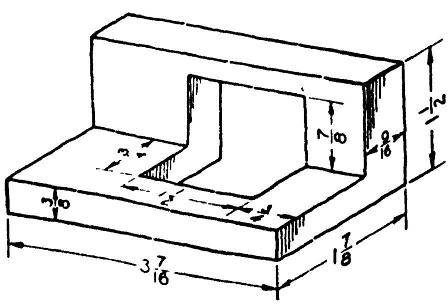


Figure 22·39 Angle. **Prob. 74.**

Problem 74 Fig. 22·39. Draw three views of the *angle.*

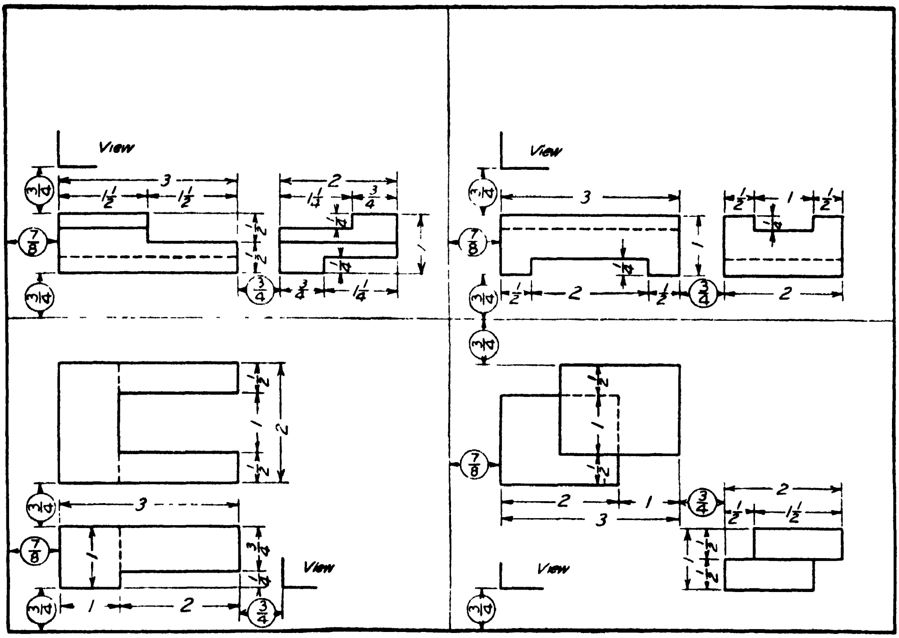


Figure 22·40 **Probs. 75 to 78.** Draw three complete views of each *slide block.*

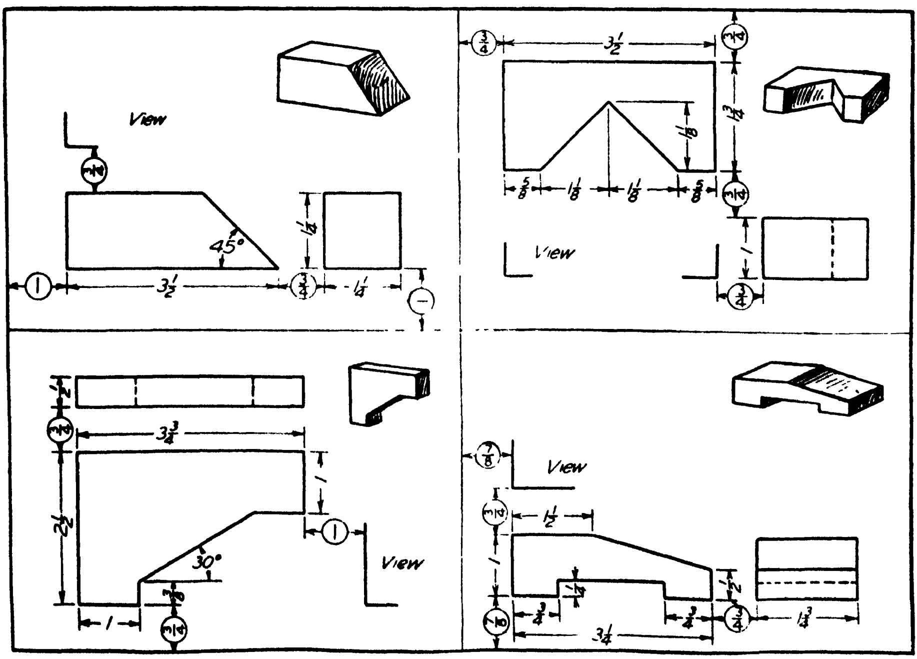


Figure 22·41 **Probs. 79 to 82.** Draw three complete views of each *support block.*

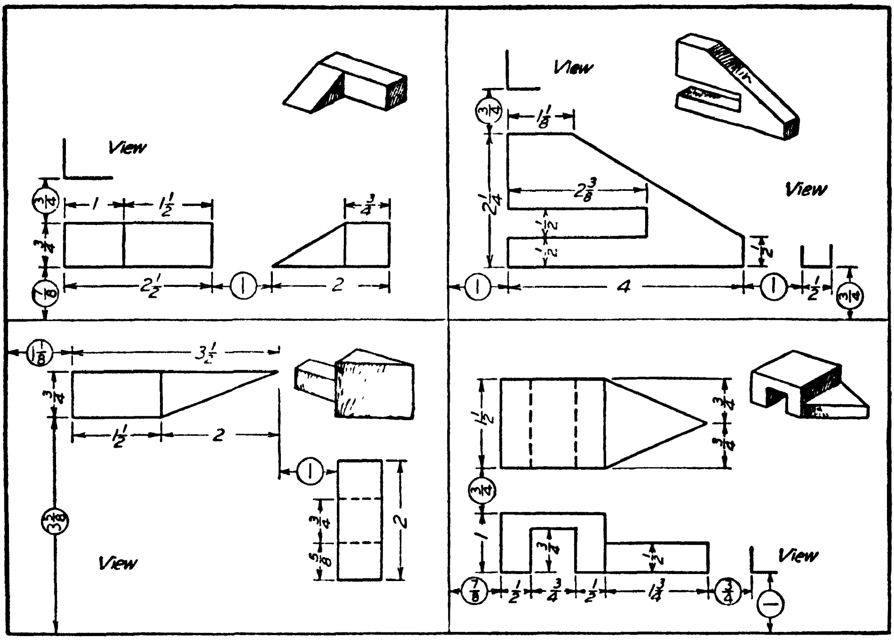


Figure 22·42 **Probs. 83 to 86.** Draw three complete views of each *adjusting block.*

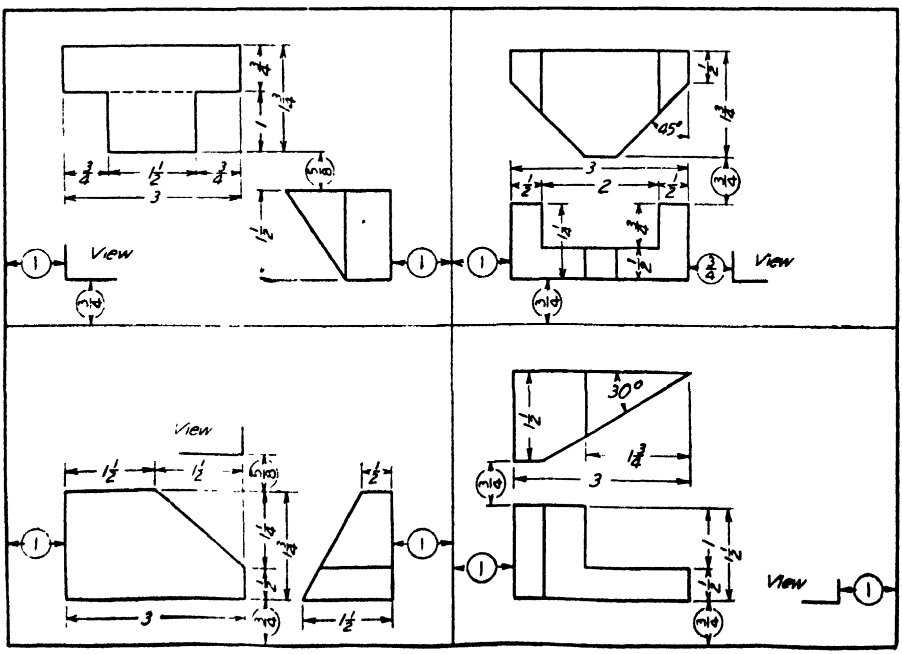


Figure 22·43 **Probs. 87 to 90.** Draw three complete views of each *angle block.*

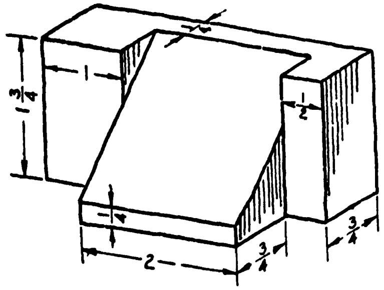


Figure 22·44 End stop. **Prob. 91.**

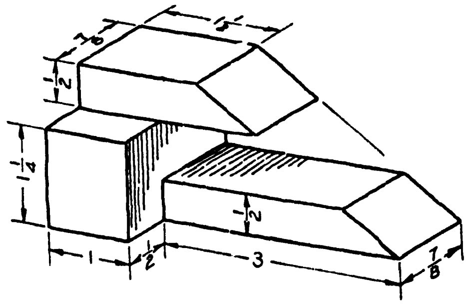


Figure 22·45 Latch. **Prob. 92.**

Problem 91 Fig. 22·44. Draw three views of the *end stop.*

Problem 92 Fig. 22·45. Draw three views of the *latch.*

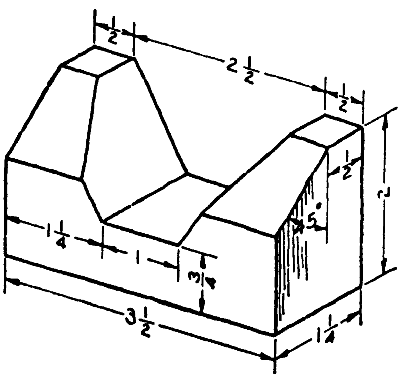


Figure 22·46 Y-block. **Prob. 93.**

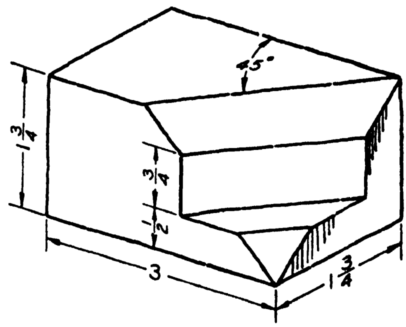


Figure 22·47 Corner lock. **Prob. 94.**

Problem 93 Fig. 22·46. Draw three views of the *Y-block.*

Problem 94 Fig. 22·47. Draw three views of the *corner lock.*

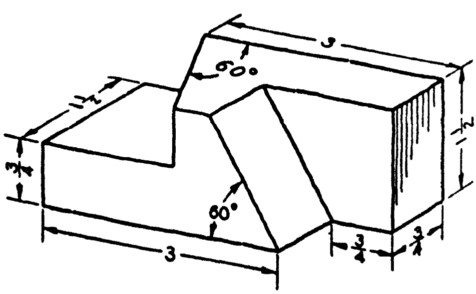


Figure 22·48 Wedge spacer. **Prob. 95.**

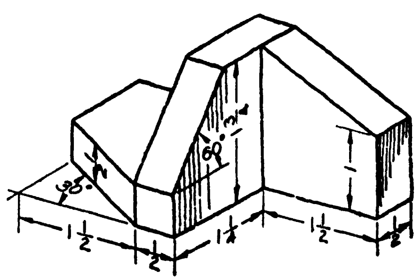


Figure 22·49 Double angle. **Prob. 96.**

Problem 95 Fig. 22·48. Draw three views of the *wedge spacer.*

Problem 96 Fig. 22·49. Draw three views of the *double angle.*

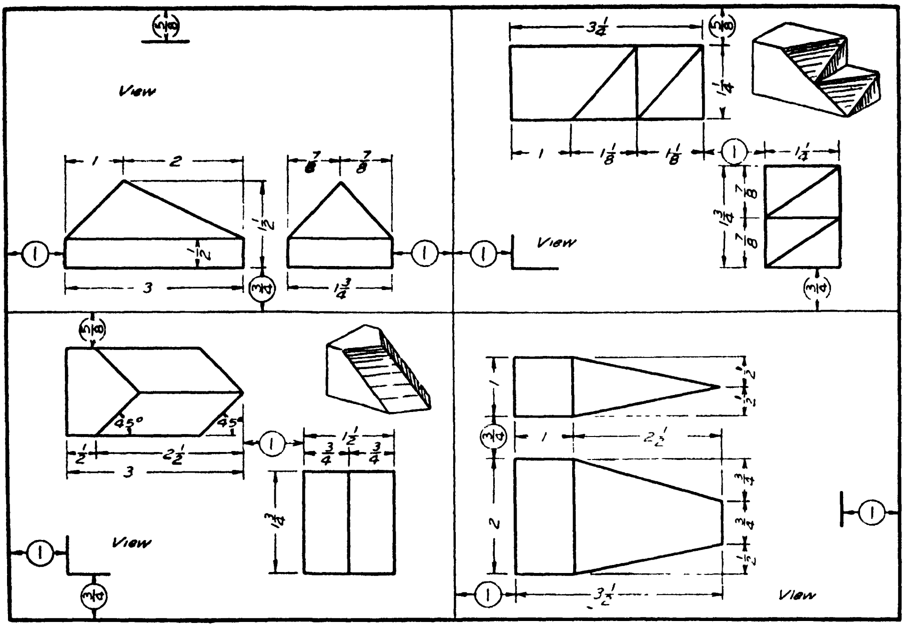


Figure 22·50 Angle block. **Probs. 97 to 100.**

Problems 97 to 100 Fig. 22·50. Draw three views of each *angle block.*

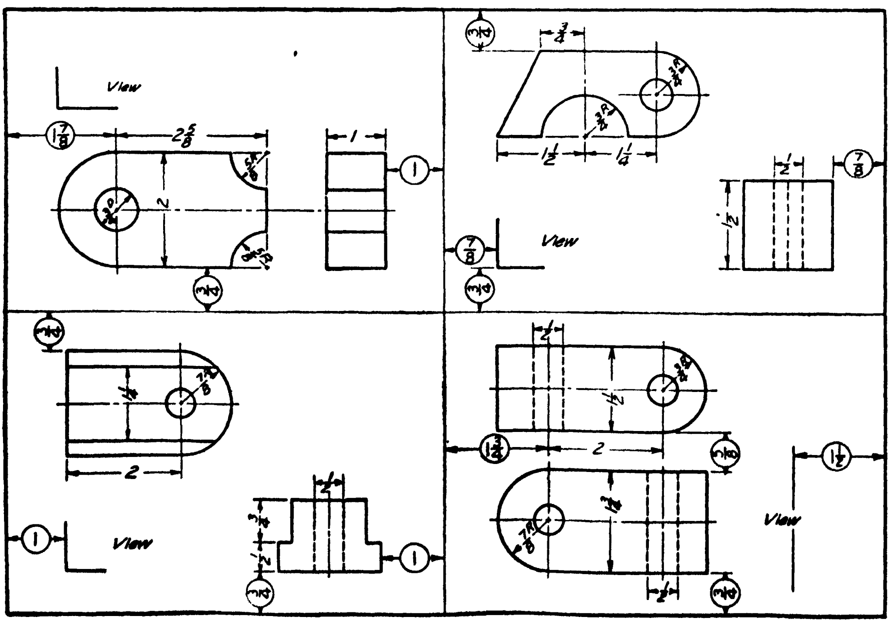


Figure 22·51 Link. **Probs. 101 to 104.**

Problems 101 to 104 Fig. 22·51. Draw three views of each *link.*

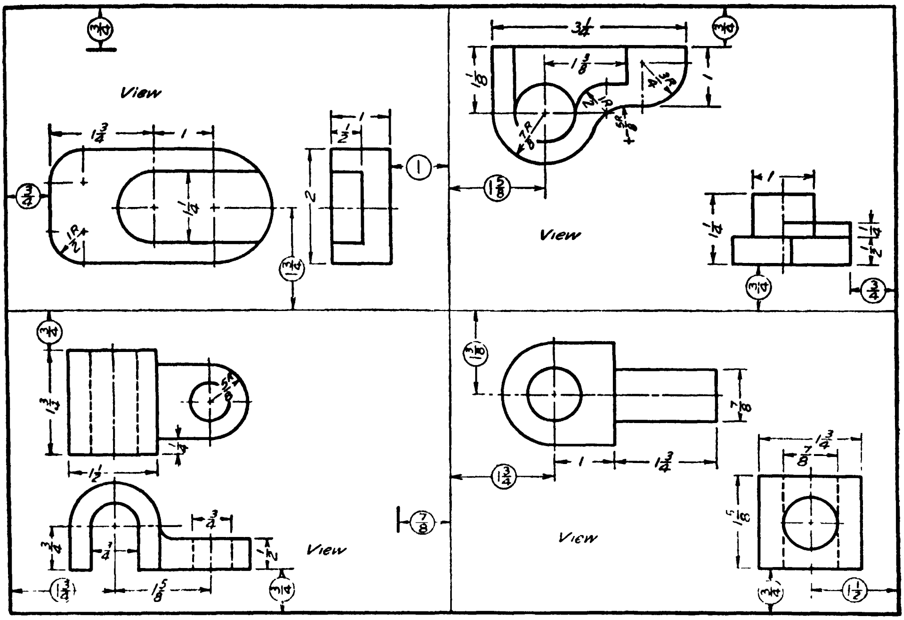


Figure 22·52 Holders. **Probs. 105 to 108.**

Problems 105 to 108 Fig. 22·52. Draw three complete views of each *holder.*

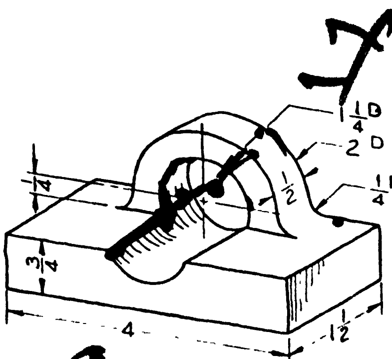


Figure 22·53 Base guide. **Prob. 109.**

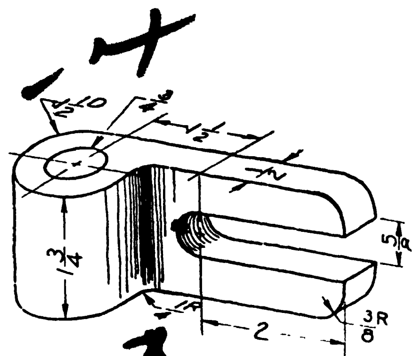


Figure 22·54 Vertical stop. **Prob. 110.**

Problem 109 Fig. 22·53. Draw three complete views of the *base guide.*

Problem 110 Fig. 22·54. Draw three complete views of the *vertical stop.*

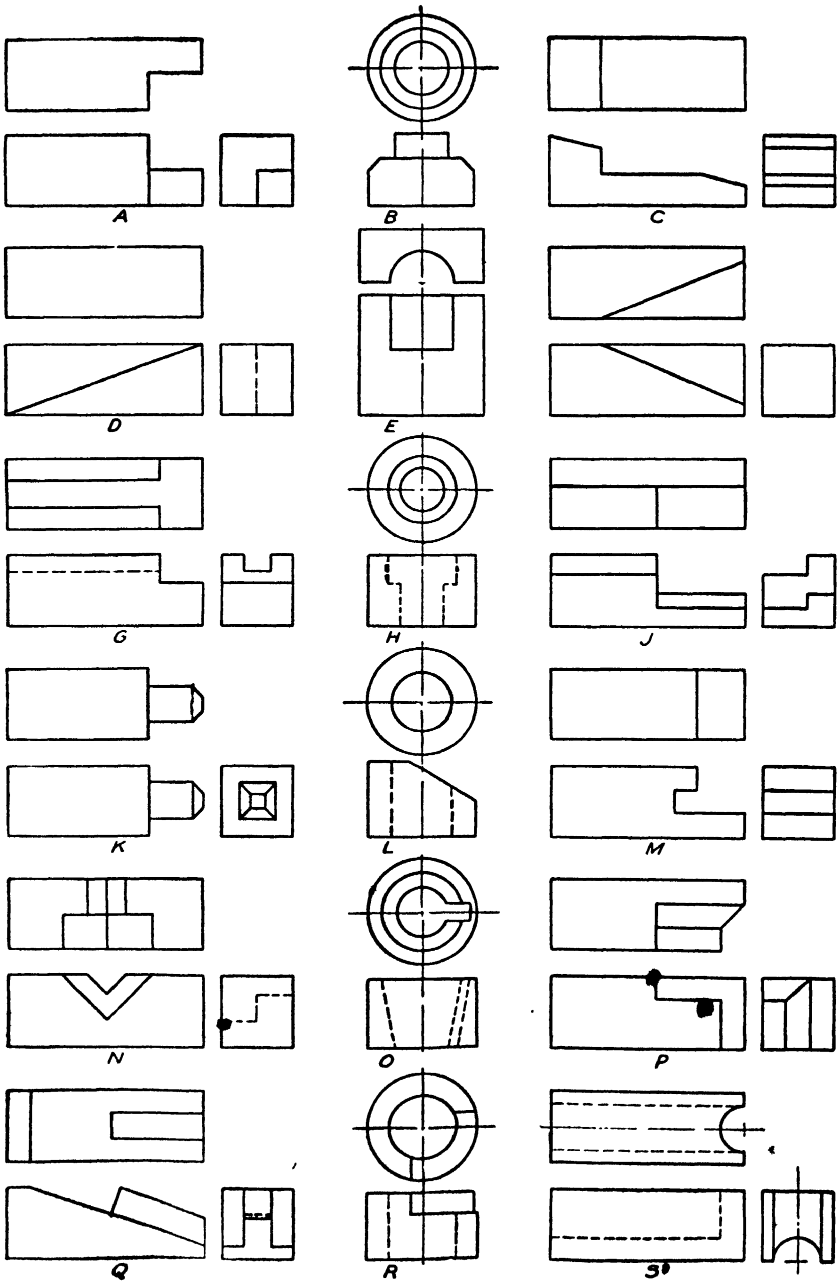


Figure 22·55 **Prob. 111.**

Problem 111 Fig. 22·55. On one of the views of each of the objects, A to S, a line is missing. Make a freehand sketch (enlarged) of the views and supply the missing line.

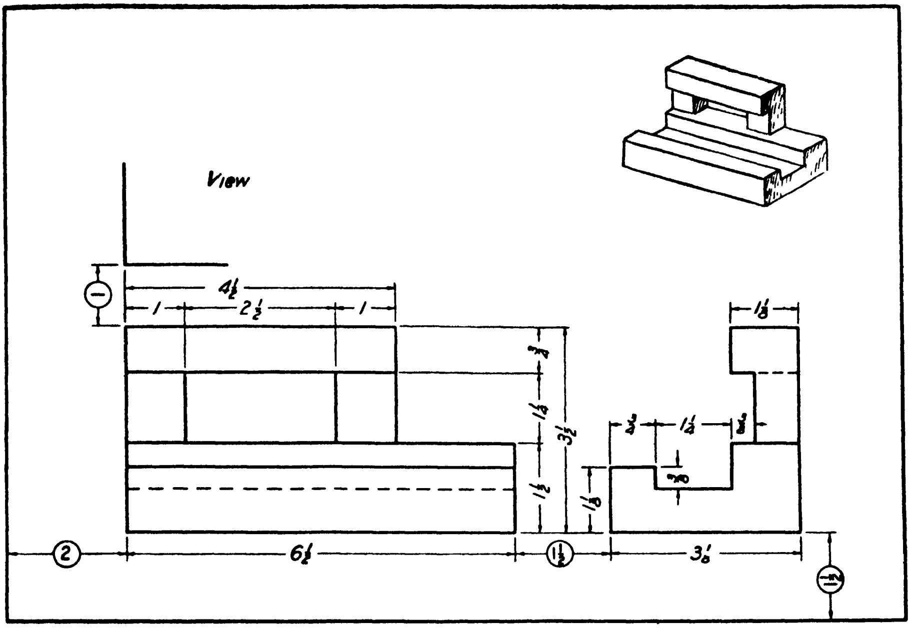


Figure 22·56 **Prob. 112.** Draw three complete views of the *support guide.*

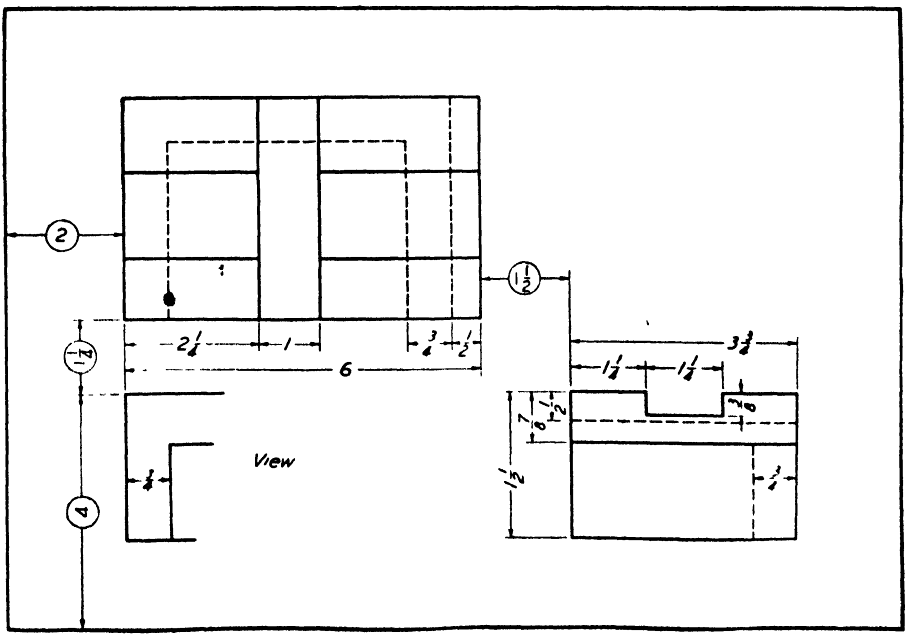


Figure 22·57 **Prob. 113. Draw three complete views of the** ***slotted bracket.***

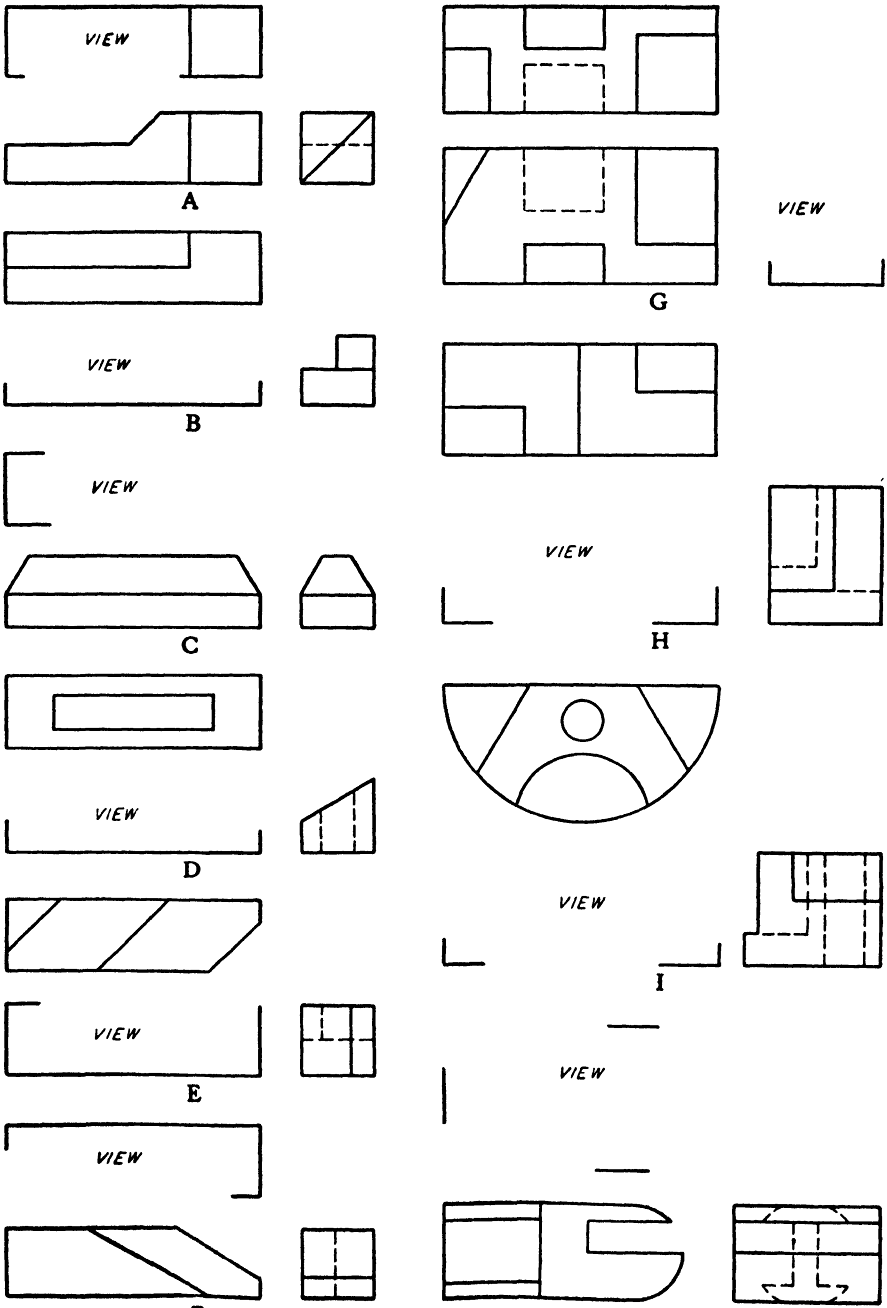


Figure 22·58 **Prob. 114.** One view is missing from each of the objects, A to J. Make a freehand sketch (enlarged) showing three complete views of each object.

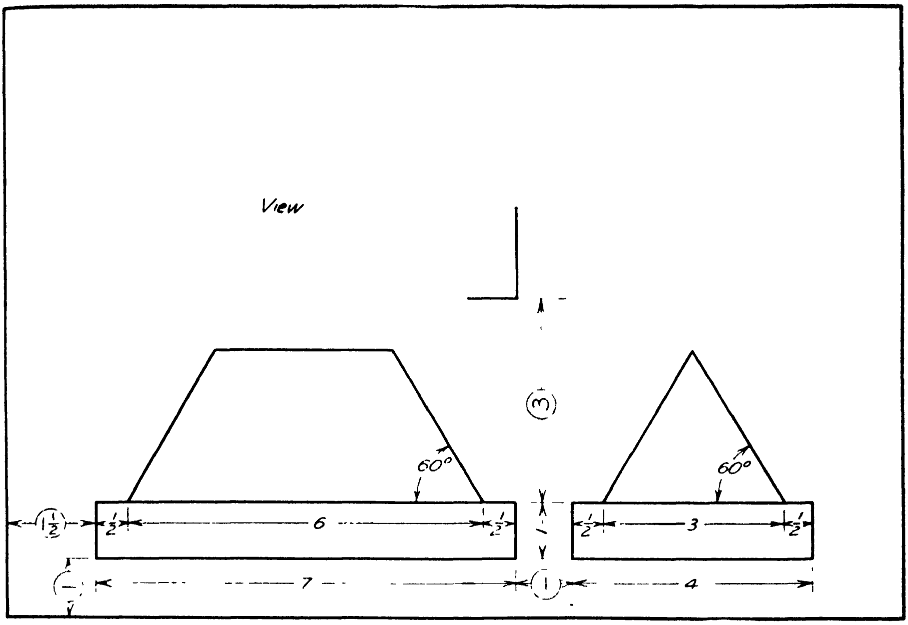


Figure 22·59 **Prob. 115.** Draw three complete views of the *fulcrum*. Height is found in the side view where the 60° lines cross.

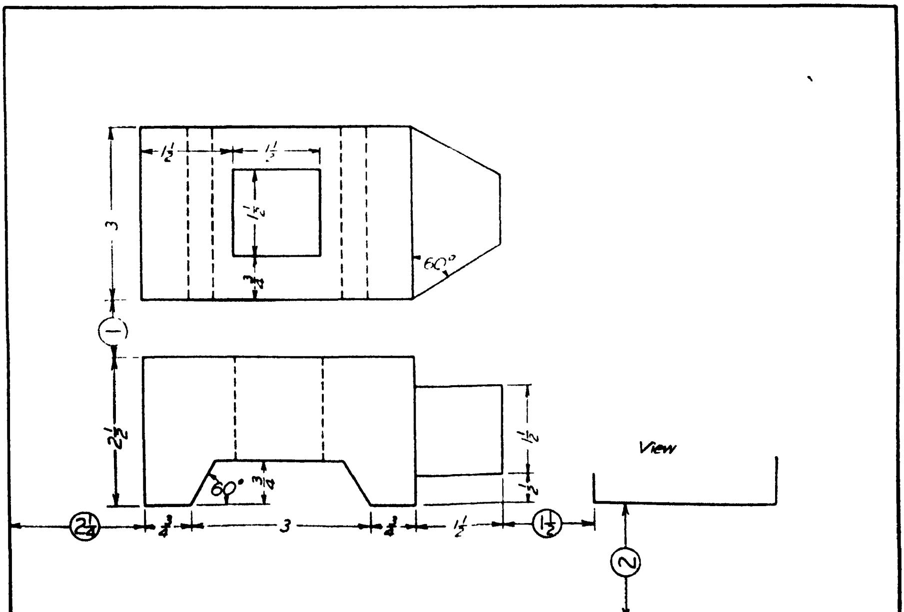


Figure 22·60 **Prob. 116.** Draw three views of the *locating support*.

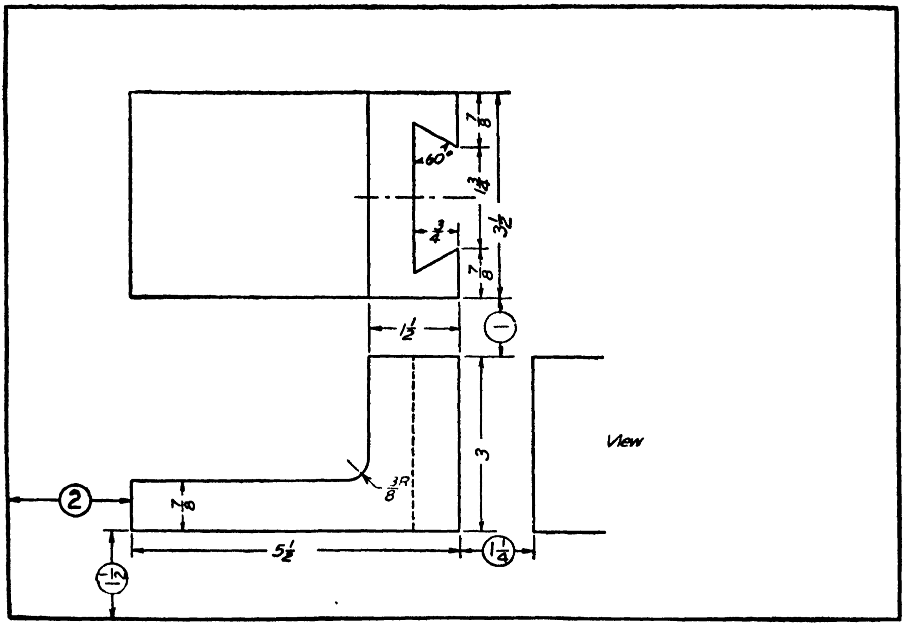


Figure 22·61 **Prob. 117.** Draw three complete views of the cast-iron *dovetail*. Lay off one-half of 1¾″ on each side of the center line in the top view and draw 60° lines to intersect the ¾″ depth line.

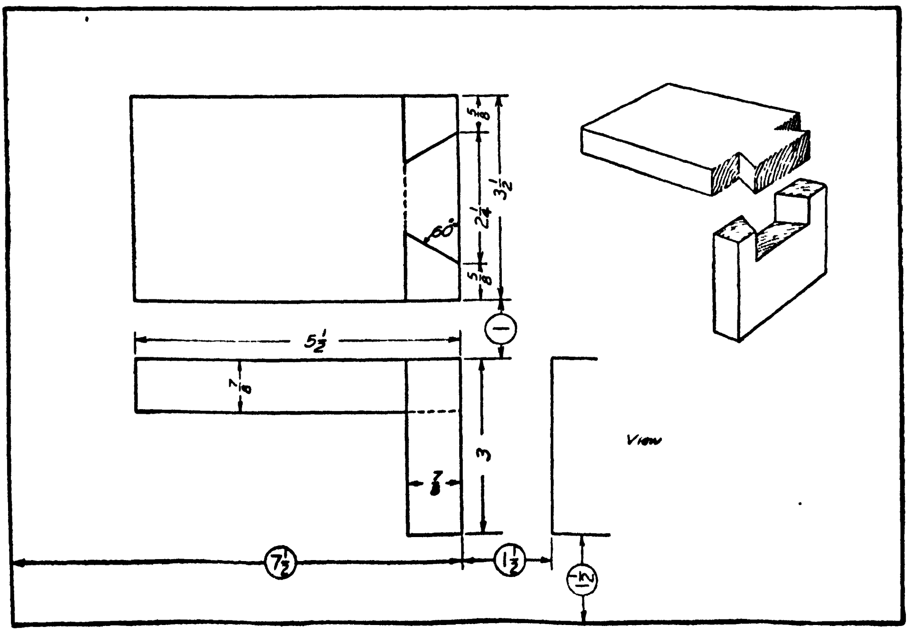


Figure 22·62 **Prob. 118. Draw three complete views of the *dovetail joint*.**

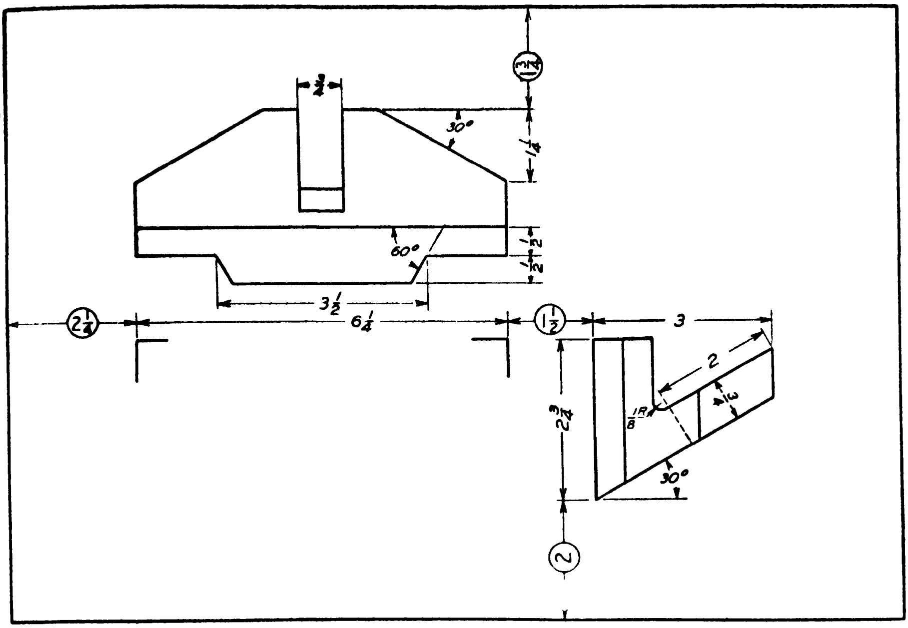


Figure 22·63 **Prob. 119.** Draw three views of the *secondary guide lug.*

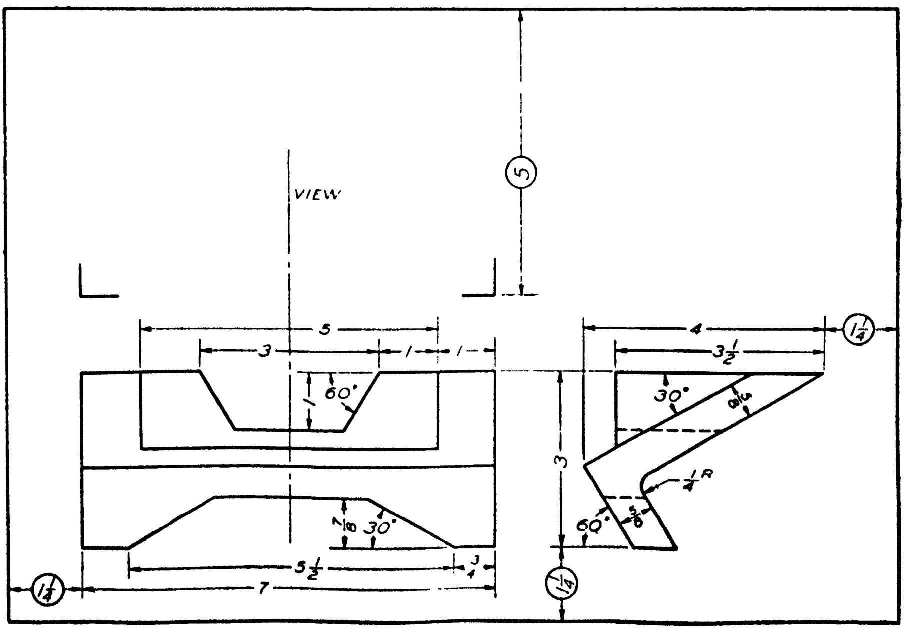


Figure 22·64 **Prob. 120.** Draw three complete views of the *separator.*

22·7 Placing Views. The location of the views for the preceding problems has been given. When drawings are made from objects or for things that have not been made, it is necessary for the draftsman to be able to place the views so that they will go in the space to advantage. This is done by considering the space necessary for each view and comparing the total room required with the size of the sheet.

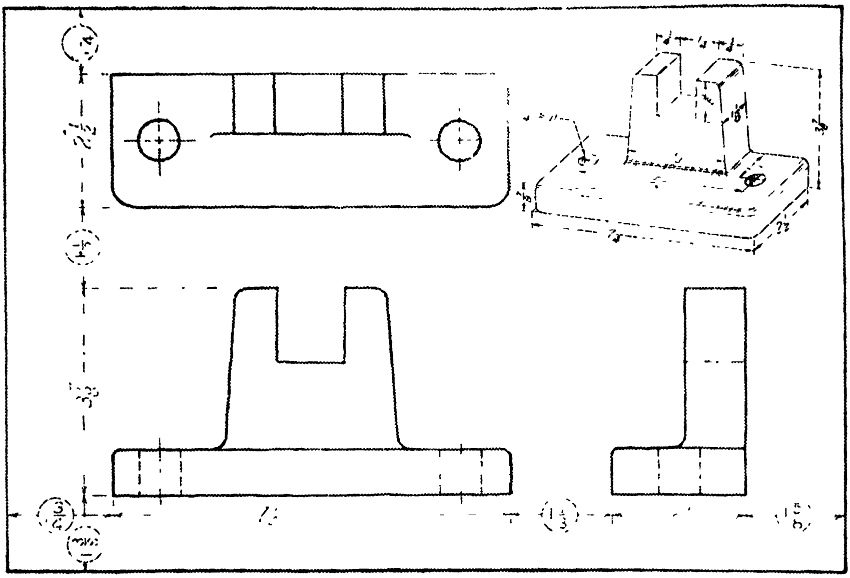


Figure 22·65 Guide yoke. **Prob. 121.**

Note the object of Fig. 22·65. Working space on sheet is 10½" × 15". The top view will require 2½" in a vertical direction and the front view 3⅞". Allowing (say) 1½" between views, the total is 7⅞". Subtracting 7⅞" from 10½" (the height of the space), we have left 2⅝" to be divided between top and bottom. In the layout sketch (Fig. 22·65) the base line of the front view has been placed 1⅜" up, which leaves 1¼" above the top line of the top view. The sum of the horizontal dimensions of the front and side views is 9¾". Allowing 1⅞" between views, there is left 3⅜" for the two side spaces. In Fig. 22·65 the left space is 1¾" and the right is 1⅝". It is not necessary to have the spaces exactly alike either between the views or around them.

Problem 121 Fig. 22·65. Draw three complete views of the *guide yoke.* Make a sketch similar to the one illustrated above in Fig. 22·65 and check the computations for the spacing of the views before beginning the problem.

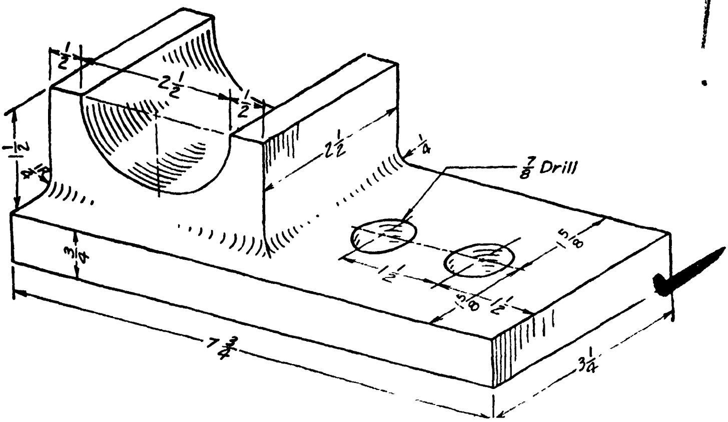


Figure 22·66 **Prob. 122.** Draw three views of the *horizontal guide.*

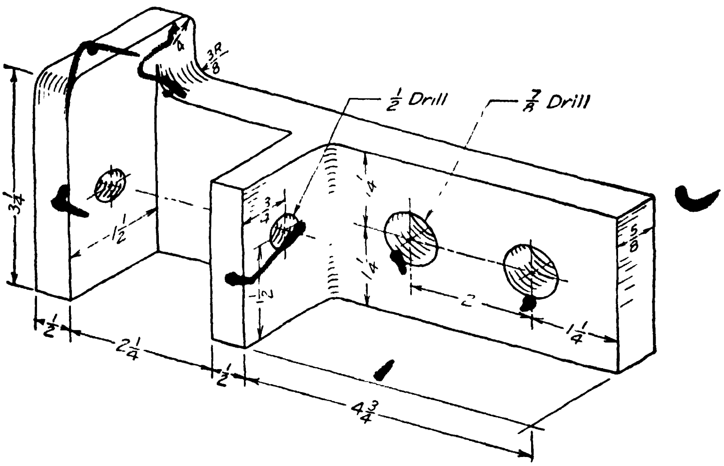


Figure 22·67 **Prob. 123.** Draw three views of the *vertical guide.*

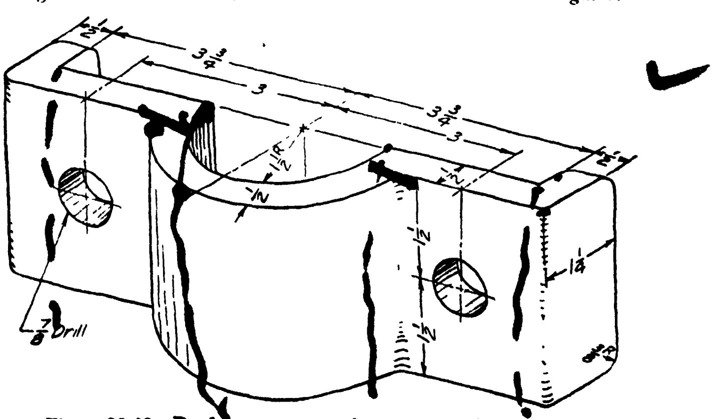


Figure 22·68 **Prob. 124.** Draw three views of the *side cap.*

Problem 125 Fig. 22·69. Draw two complete views of the *cast-iron collar.* Divide the regular working space (10½″ × 15″) into two parts by drawing a vertical line through the center to provide a space 7½″ wide by 10½″ high in which to draw the views.

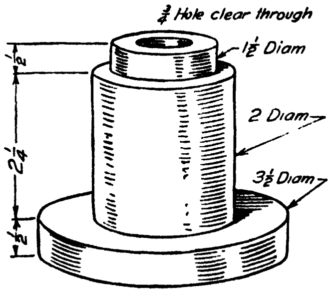


Figure 22·69 Cast-iron collar. **Prob. 125.**

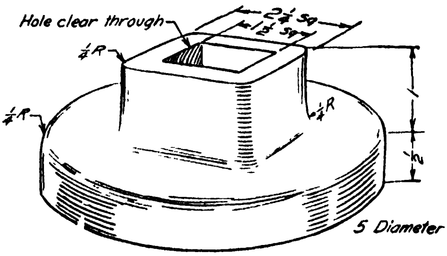


Figure 22·70 Socket. **Prob. 126.**

Problem 126 Fig. 22·70. Draw two complete views of the *socket.* Divide the regular working space (10½″ × 15″) into two parts by drawing a vertical line through the center to provide a space 7½″ wide by 10½″ high in which to draw the views.

Suggested Spacing. For a sheet containing Probs. 125 and 126, or 127 and 128, the views required for each of these pieces would obviously be a top view and a front view. Draw a vertical center line for the left-hand figure about 3¾″ from the left border. Draw a base line about 1½″ from the bottom and a horizontal center line for the top view 6″ above the base line. For the right-hand figure draw a vertical center line about 3¾″ from the right border, base line 1½″ from bottom border and center line for top view 5¼″ above base line of front views.

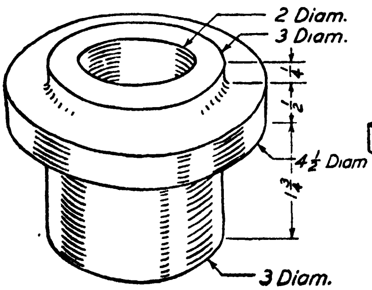


Figure 22·71 Stud bushing. **Prob. 127.**

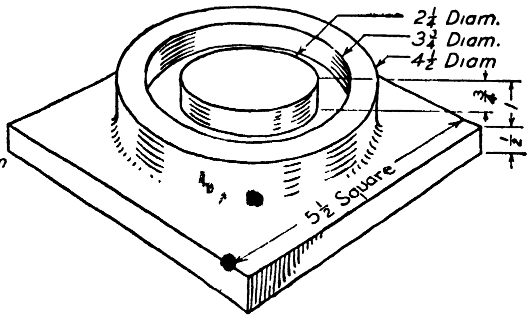


Figure 22·72 Swivel base. **Prob. 128.**

Problem 127 Fig. 22·71. Draw two complete views of the *stud bushing.* Use half the regular working space. 7½″ wide by 10½″ high.

Problem 128 Fig. 22·72. Draw two complete views of the *swivel base.* Use half the regular working space. 7½″ wide by 10½″ high.

Problem 129 Fig. 22·73. Draw two complete views of the *centering plate.* Four holes are to be drilled and countersunk in plate for ½″ cap screws (see Appendix, page 422, for dimensions).

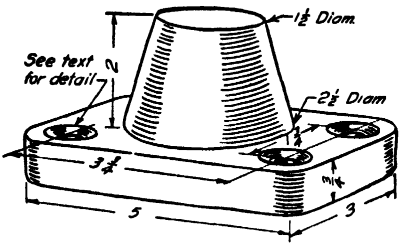


Figure 22·73 Centering plate. **Prob. 129.**

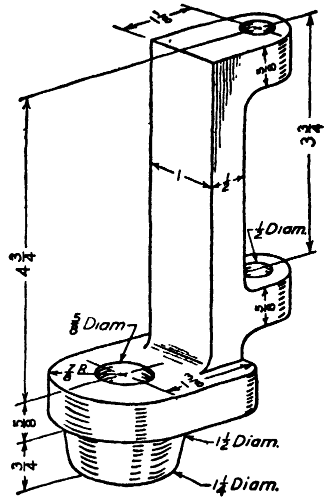


Figure 22·74 Bearing. **Prob. 130.**

Problem 130 Fig. 22·74. Draw front and side views of the *bearing.*

Suggested Spacing. For a sheet containing Probs. 129 and 130, or 131 and 132, draw a vertical center line for the left-hand figure about 4″ from the left border. Then work out the spacing in a vertical direction on the center line as explained in Art. 22·7 on Placing Views. In a similar manner work out the placing of the views for the right-hand figure in the remaining space.

Problem 131 Fig. 22·75. Draw two complete views of the *rocker block.* The ½″ holes extend through the piece.

Problem 132 Fig. 22·76. Draw three complete views of the *vertical bracket.*

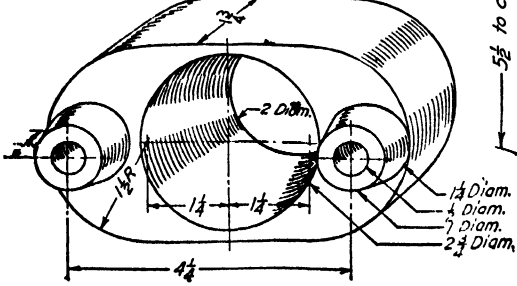


Figure 22·75 Rocker block. **Prob. 131.**

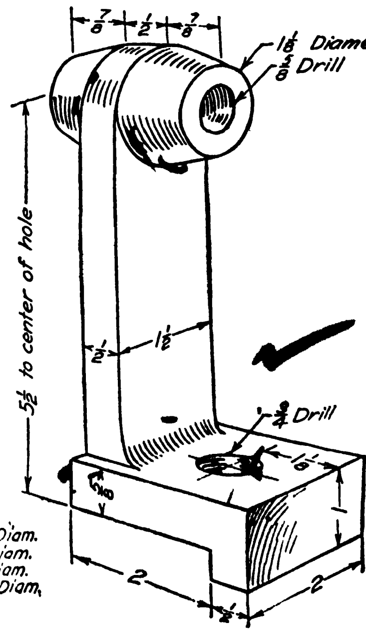


Figure 22·76 Vertical bracket. **Prob. 132.**

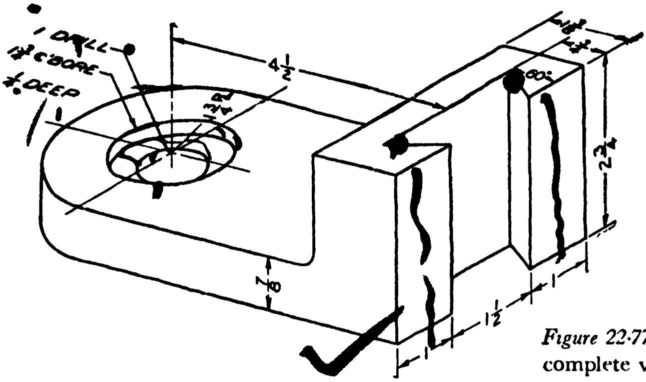


Figure 22·77 **Prob. 13.** Draw three complete views of the ***dovetail base.***

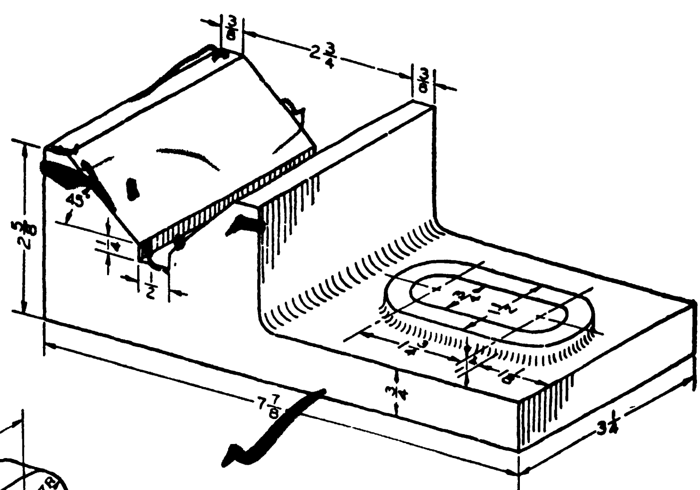


Figure 22.78 **Prob. 134.** Draw three complete views of the ***V-block base.***

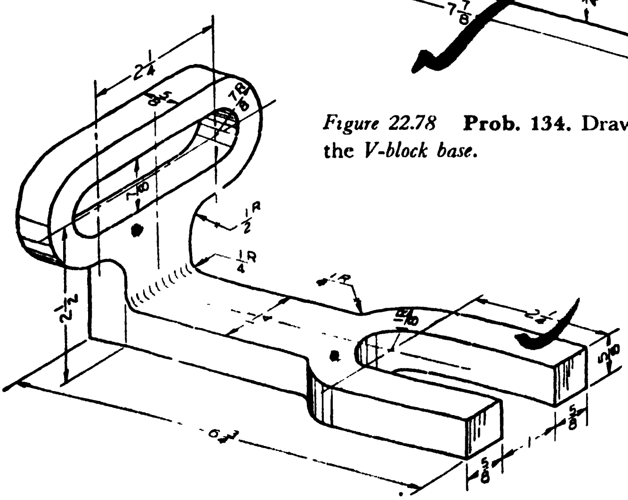


Figure 22·79 **Prob. 135.** Draw three complete views of the ***adjustable fork.***

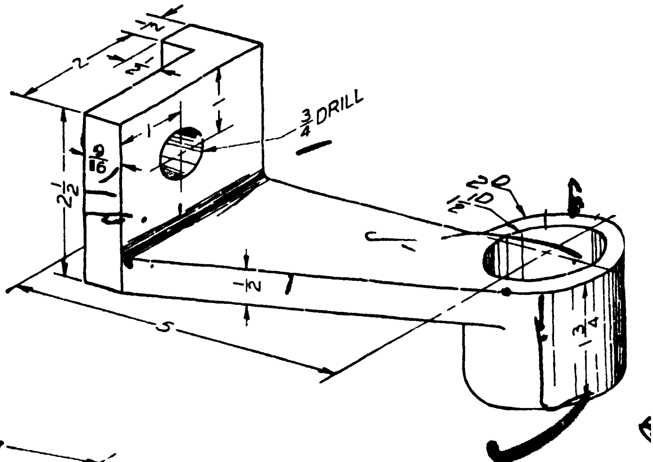


Figure 22·80 **Prob. 136.** Draw three complete views of the *bracket.*

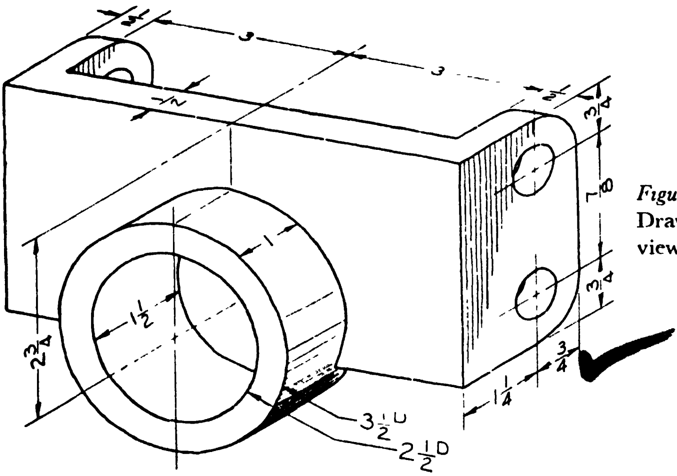


Figure 22·81 **Prob. 137.** Draw three complete views of the *post bearing.*

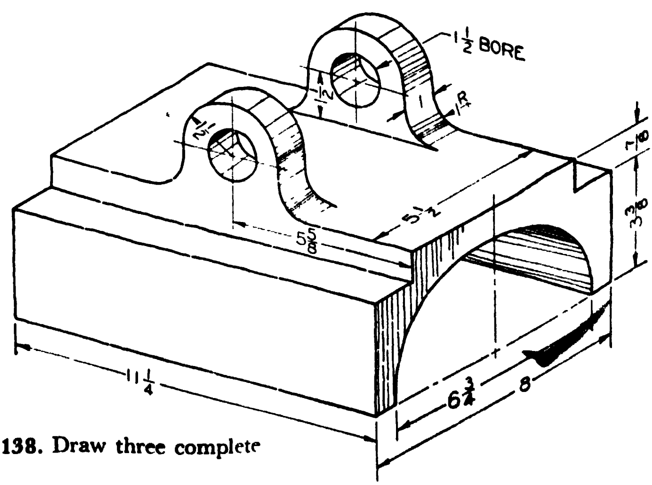


Figure 22·82 **Prob. 138.** Draw three complete views of the *keeper.*

GROUP 5. SECTIONS

22·8 Study carefully Chap. 6. The cut surface is indicated by section lining with fine uniformly spaced lines at 45°; about $\frac{1}{16}''$ apart.

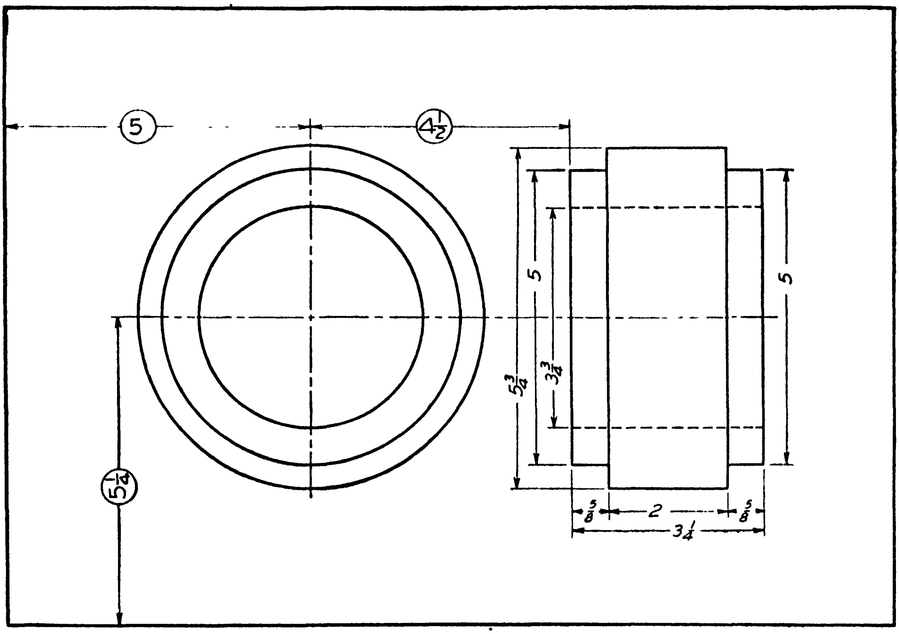


Figure 22·83 **Prob. 139. Make a two-view drawing of the *cylindrical spacer*, the right-hand view to be a full section.**

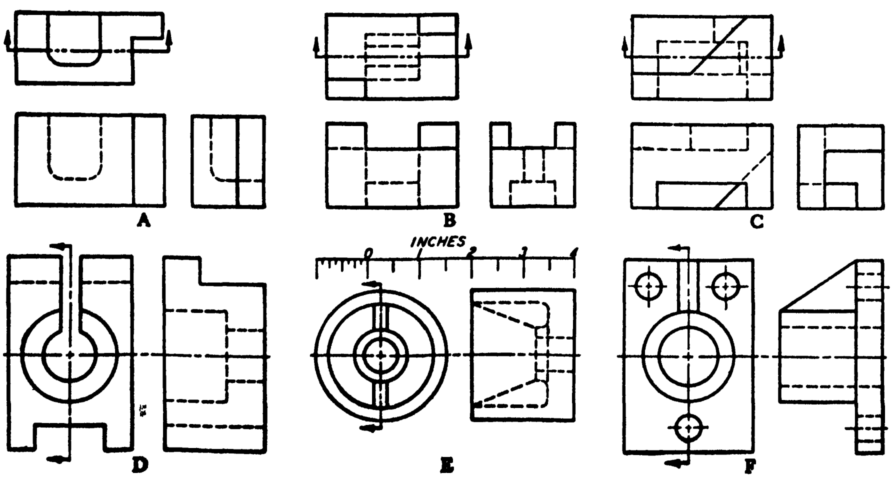


Figure 22·84 **Prob. 140. Copy the views freehand (enlarged). Show a view in section on the plane indicated.**

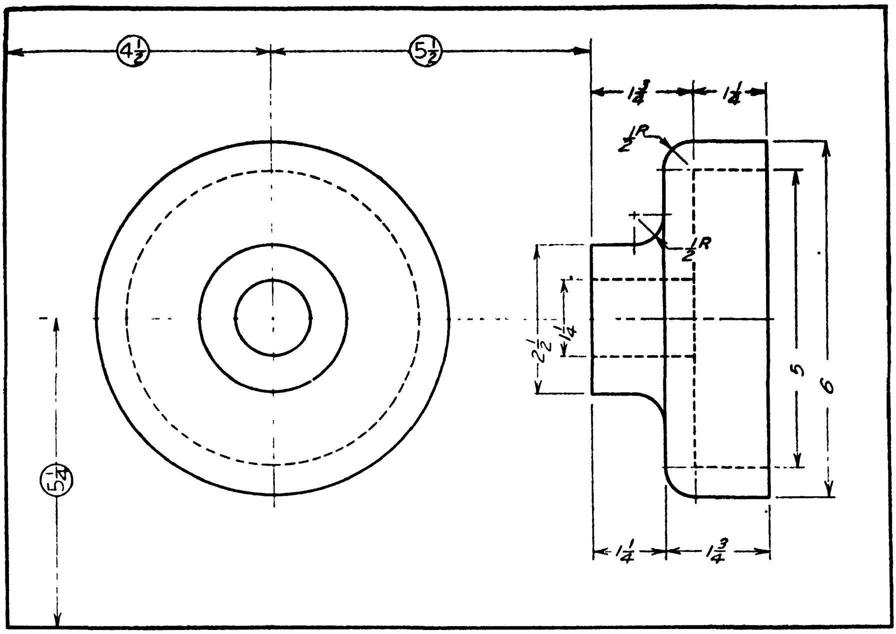


Figure 22·85 **Prob. 141.** Make a two-view drawing of the *clamping disc*, the right-hand view to be a full section.

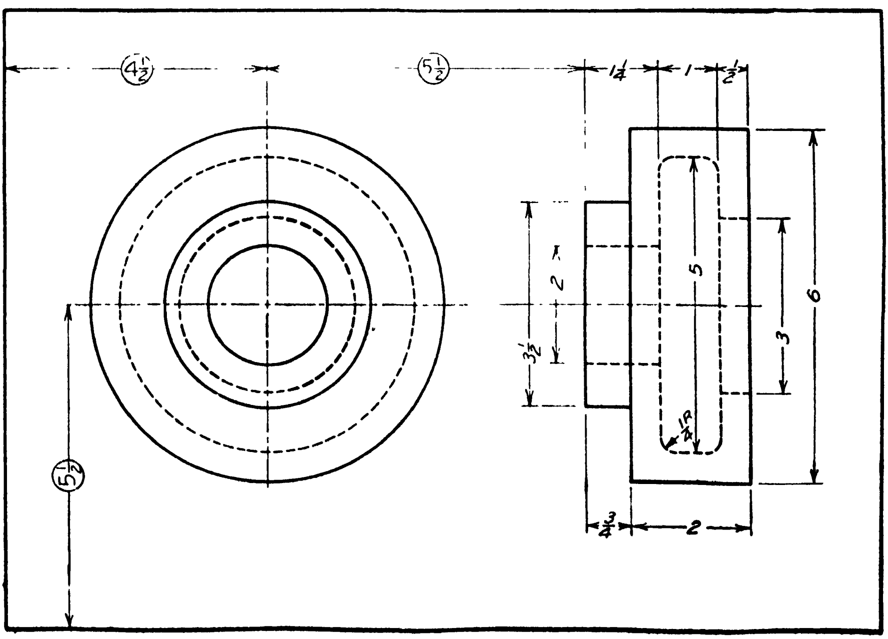


Figure 22·86 **Prob. 142.** Make a two-view drawing of the *reducing spacer*, the right-hand view to be a full section.

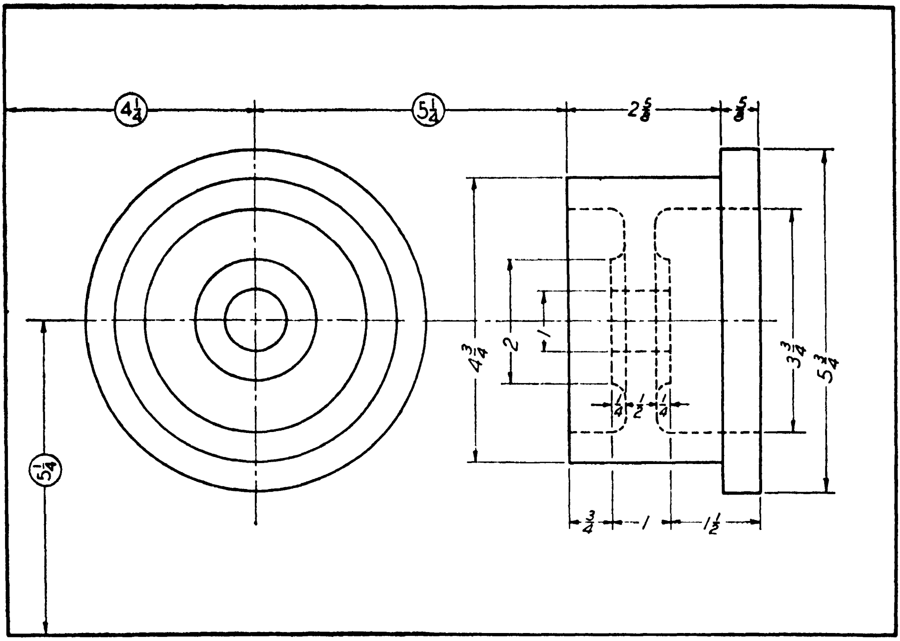


Figure 22·87 **Prob. 143.** Make a two-view drawing of the *water piston body*, showing the right-hand view as a half-section. Read Art. 6·4.

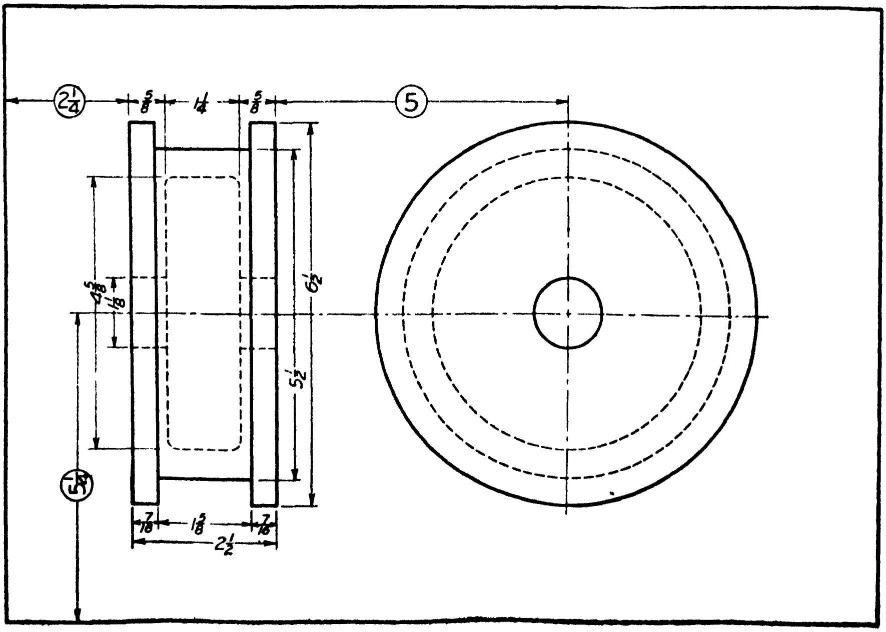


Figure 22·88 **Prob. 144.** Make a two-view drawing of the *steam piston*, the left-hand view to be a full section.

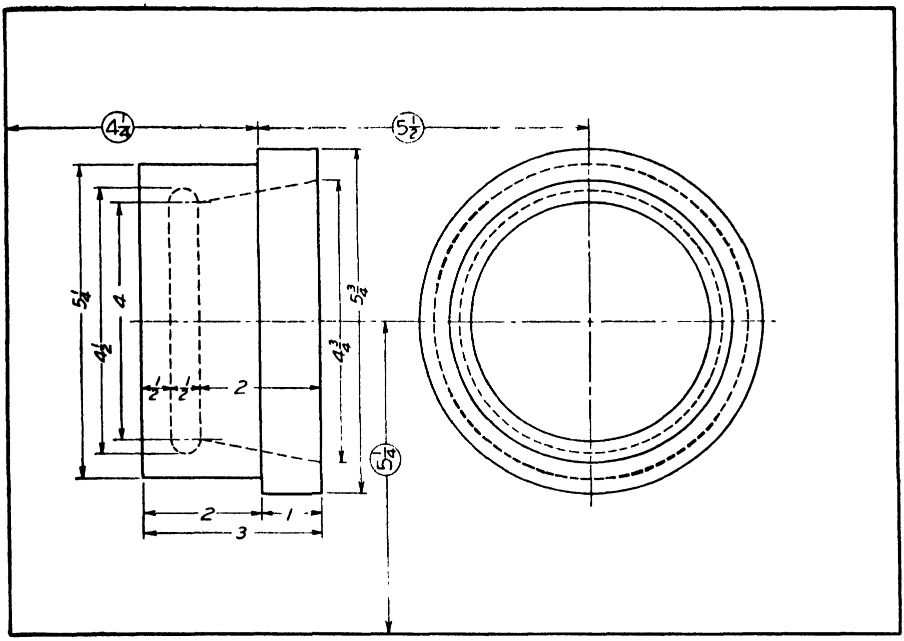


Figure 22·89 **Prob. 145.** Make a two-view drawing of the *shaft cap*, the left-hand view to be a full section.

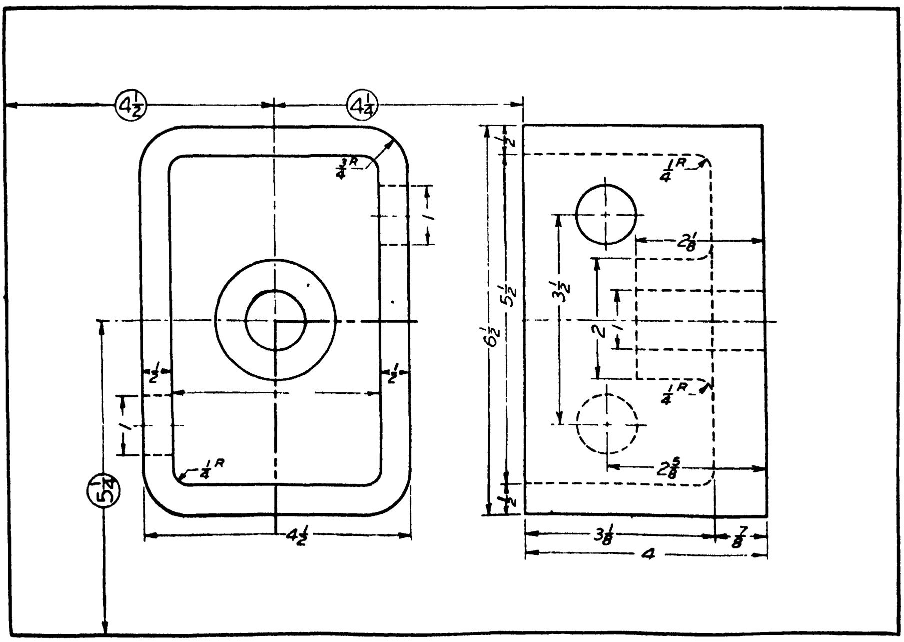


Figure 22·90 **Prob. 146.** Make a two-view drawing of the *protected bearing*, showing the right-hand view as a half section. Read Art. 6·4.

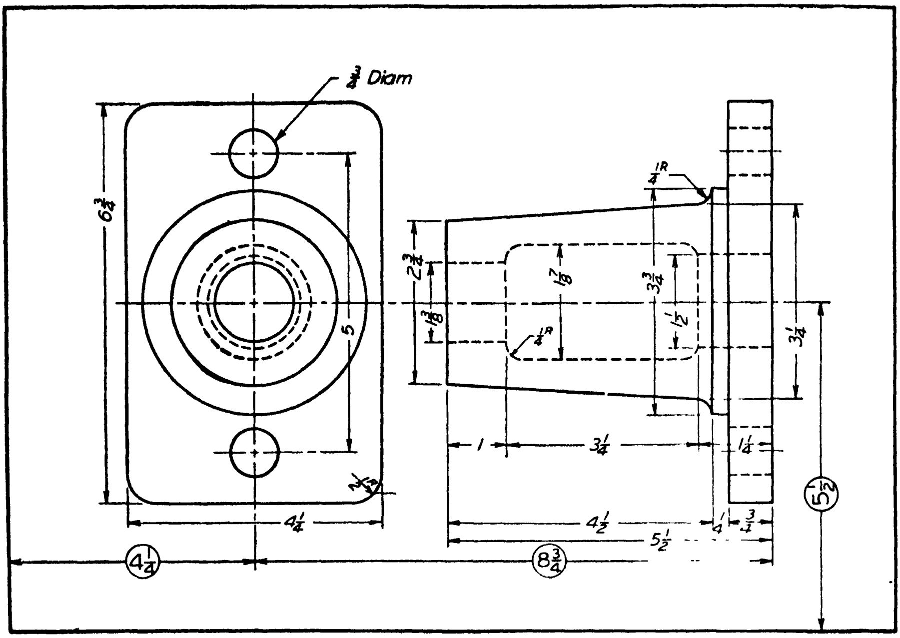


Figure 22·91 **Prob. 147.** Make a two-view drawing of the *hood bearing*, showing the right-hand view in section.

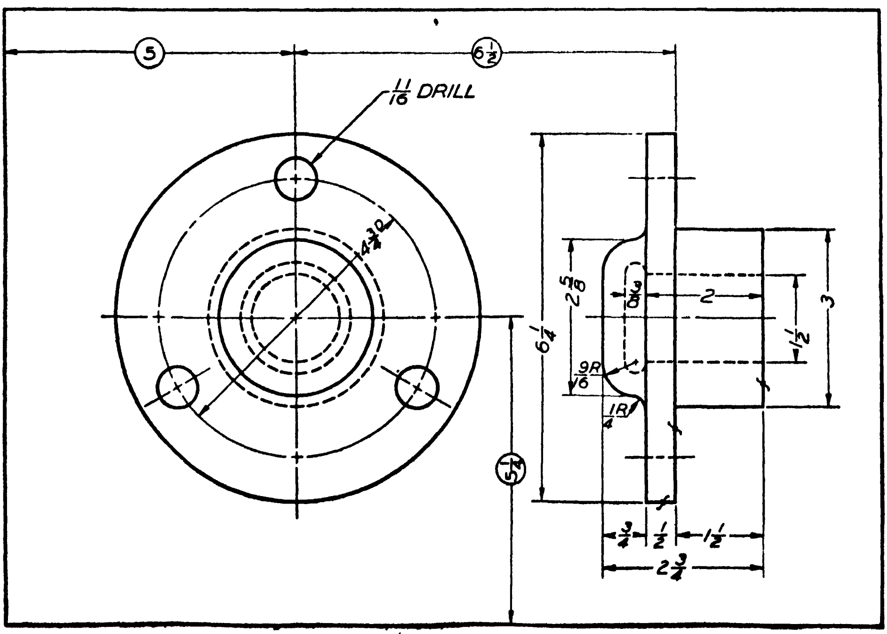


Figure 22·92 **Prob. 148.** Make a two-view drawing of the *end cap* showing the right-hand view in section.

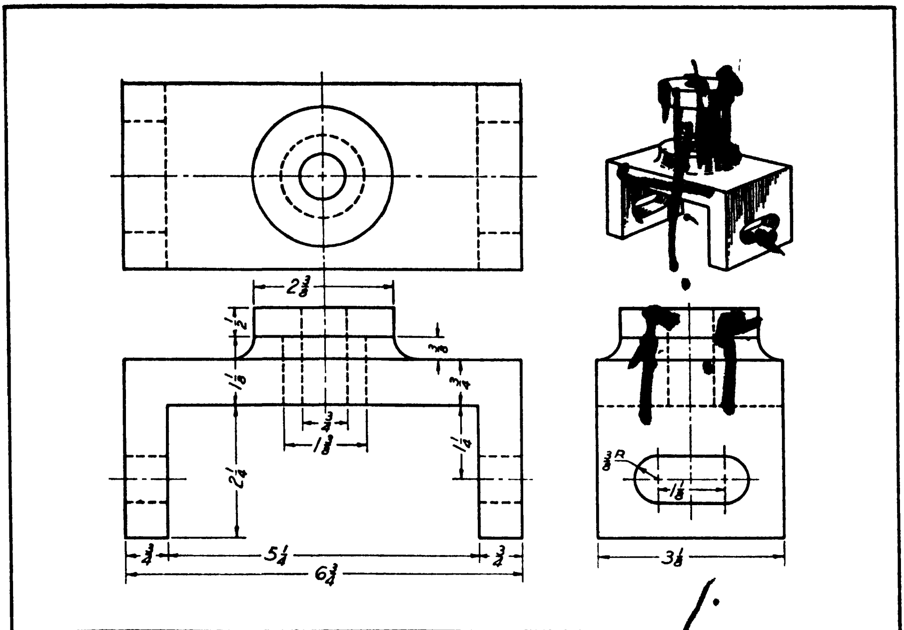


Figure 22·93 **Prob. 149.** Draw three views of the *yoke,* the front view in section. There are two pieces, the yoke and the bushing. Do not copy the picture.

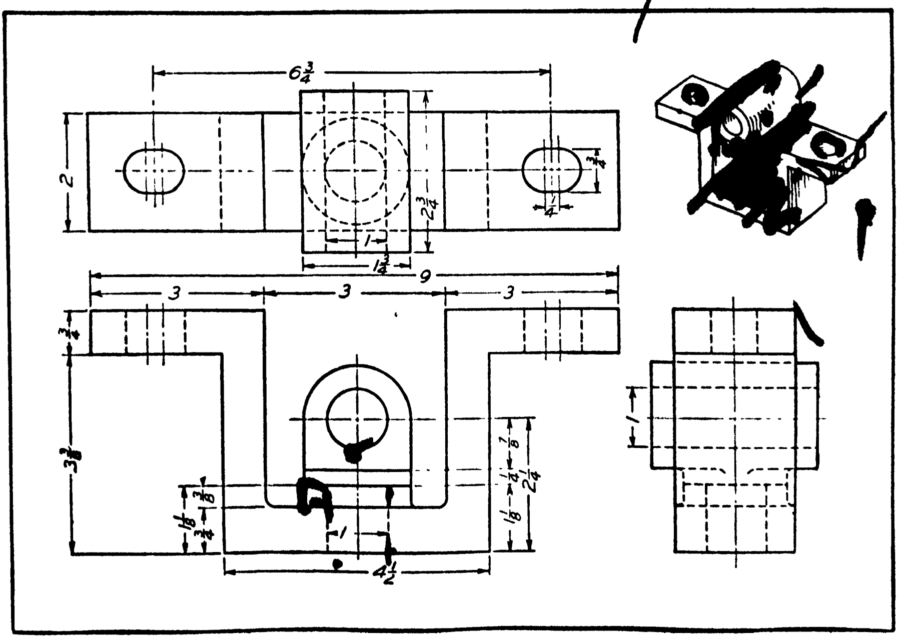


Figure 22·94 **Prob. 150.** Draw three views of the *swivel hanger*, the side view to be a section. There are two pieces, the hanger and the bearing.

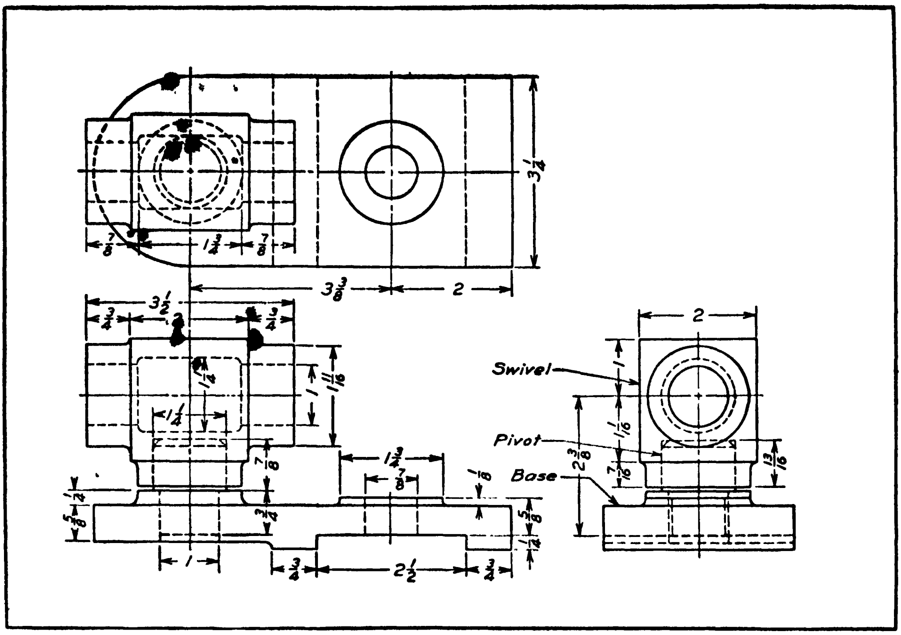


Figure 22·95 **Prob. 151.** Draw three views of the *swivel base*. The front view to be in section.

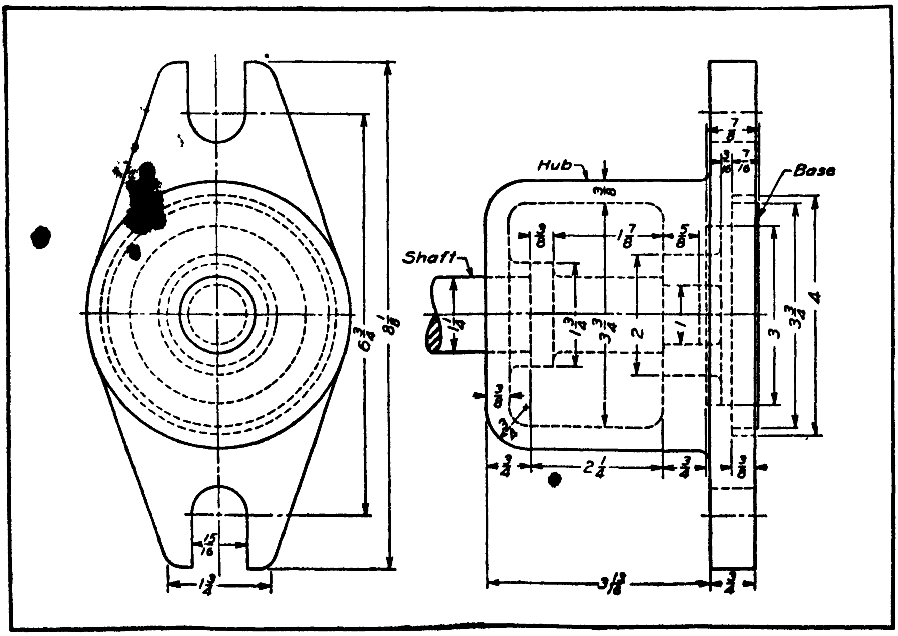


Figure 22·96 **Prob. 152. Draw two views of the *thrust bearing*, the right-hand view to be a section. There are three parts, the shaft, hub, and base.**

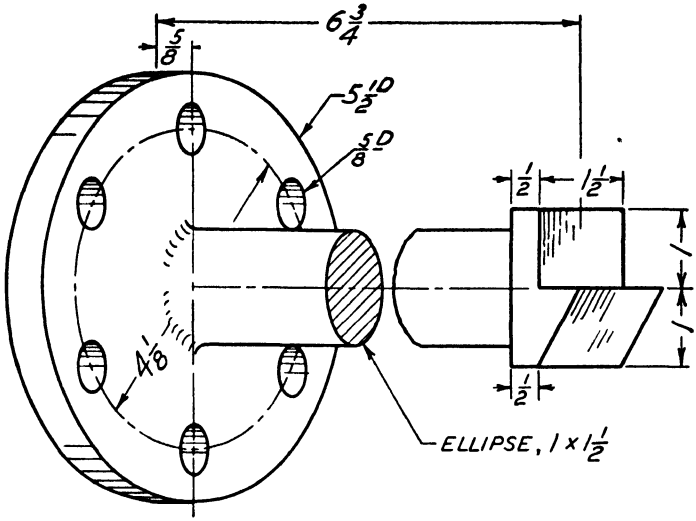


Figure 22·97 **Prob. 153.** Draw the necessary views of the *flanged latch.* Show a revolved section.

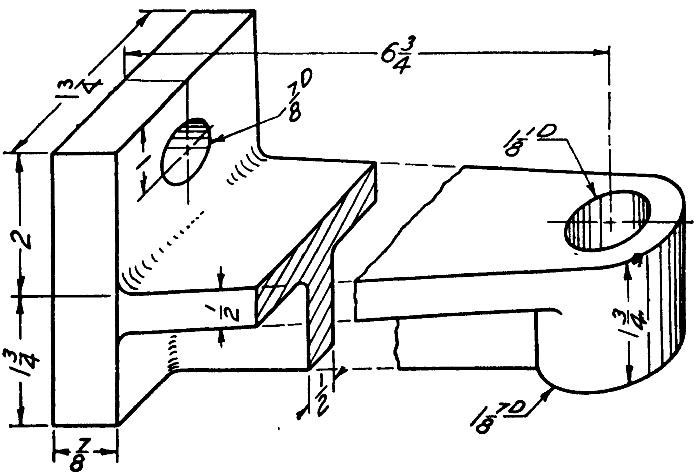


Figure 22·98 **Prob. 154.** Draw the necessary views of the *bracket.* Show a revolved section.

The problems in this group have all been section lined as if made of cast iron. Occasionally it is desirable, as an aid in reading a drawing, to use one or more of the symbols for other materials, as stated in Art. 9·9. The following exercise is given for practice with symbolic section lining.

Problem 155 Symbolic Section Lining. Fig. 9·8. Lay off sixteen $1\frac{1}{2}'' \times 2\frac{1}{2}''$ rectangles equally spaced. In these draw the first 12 and a choice of 4 other symbols from Fig. 9·8. Make the cast-iron section lines about $\frac{1}{8}''$ apart and the others in proportion. Letter names of materials under the rectangles.

GROUP 6. AUXILIARY VIEWS

22·9 Study Chap. 7 on auxiliary views before beginning the problems. In the layouts of the problems the location is given for the center line or reference line, parallel to the slanting surface, on which the auxiliary view is to be constructed. In the case of symmetrical figures the center line corresponds to the horizontal center line of the top view, as in Prob. 156. For unsymmetrical figures the reference line is usually taken at the back on the top view as in Prob. 157. The projection lines from the front view of the object to the auxiliary view are shown in the layouts to aid in starting the problems. If drawn by the student, they should be extremely light so as not to confuse the result. The title for sheets with Probs. 156 to 162 is *auxiliary views.*

Problem 156 Fig. 22·99. The figure gives the layout for two problems. Draw the top, front, and the complete auxiliary view of the *rectangular prism* as shown.

Problem 157 Fig. 22·99. Draw the views given and the complete auxiliary view of the *triangular prism.*

Problems 158 to 162 Figures 22·100 to 22·104 are alternate problems similar to Probs. 156 and 157.

Problem 163 Fig. 22·105. Use half a regular working space. Make a drawing of the *anchor lug* including a complete auxiliary view. The hole and rounded end need not be shown in the top view.

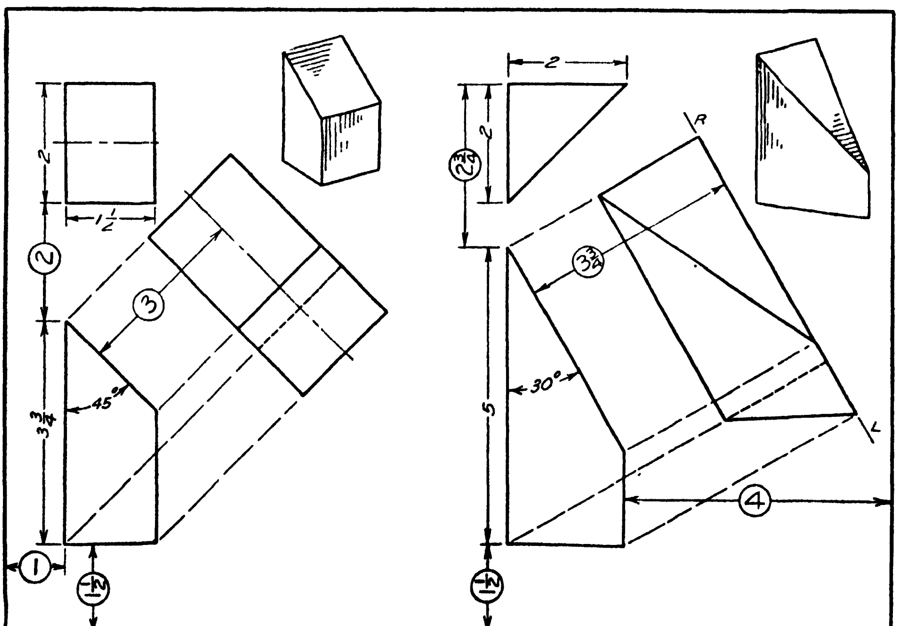


Figure 22·99 Auxiliary views. **Probs. 156 and 157.**

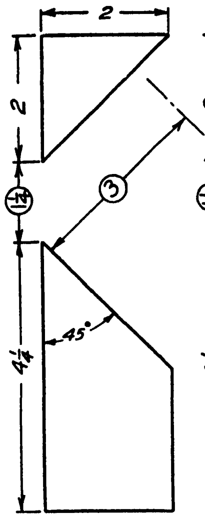


Figure 22·100
Prob. 158.

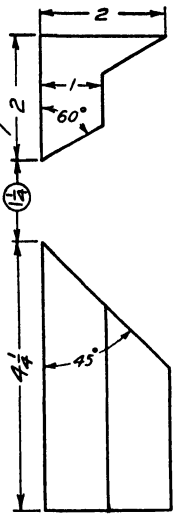


Figure 22·101
Prob. 159.

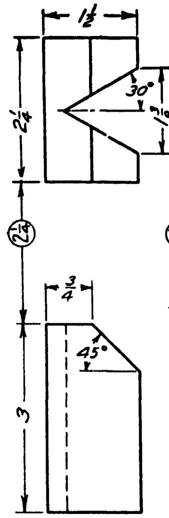


Figure 22·102
Prob. 160.

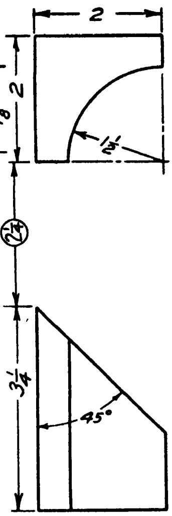


Figure 22·103
Prob. 161.

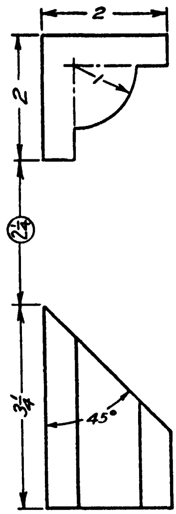


Figure 22·104
Prob. 162.

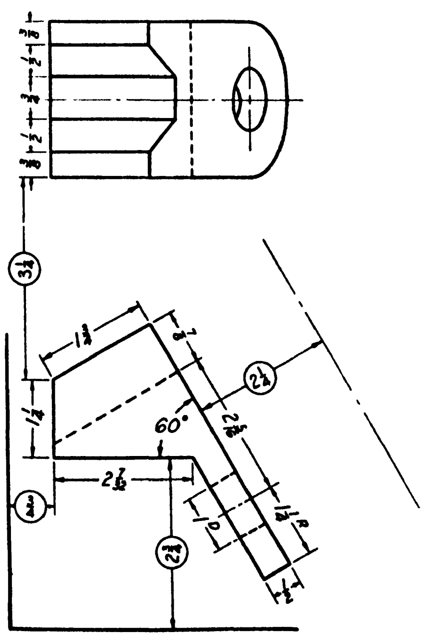


Figure 22·105 Anchor lug. **Prob. 163.**

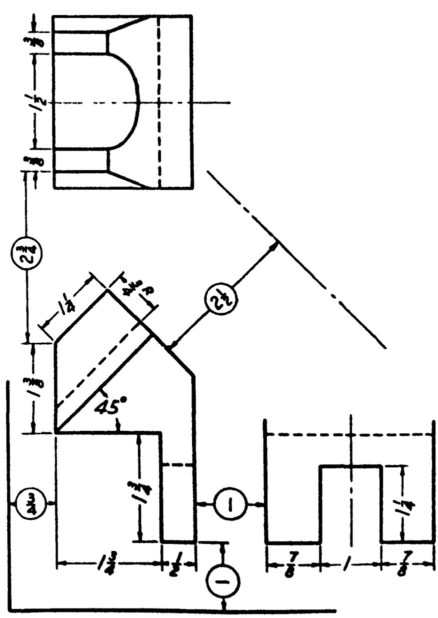


Figure 22·106 Inclined bearing. **Prob. 164.**

Problem 164 Fig. 22·106. Use half a regular working space. Make a drawing of the *inclined bearing* including an auxiliary view.

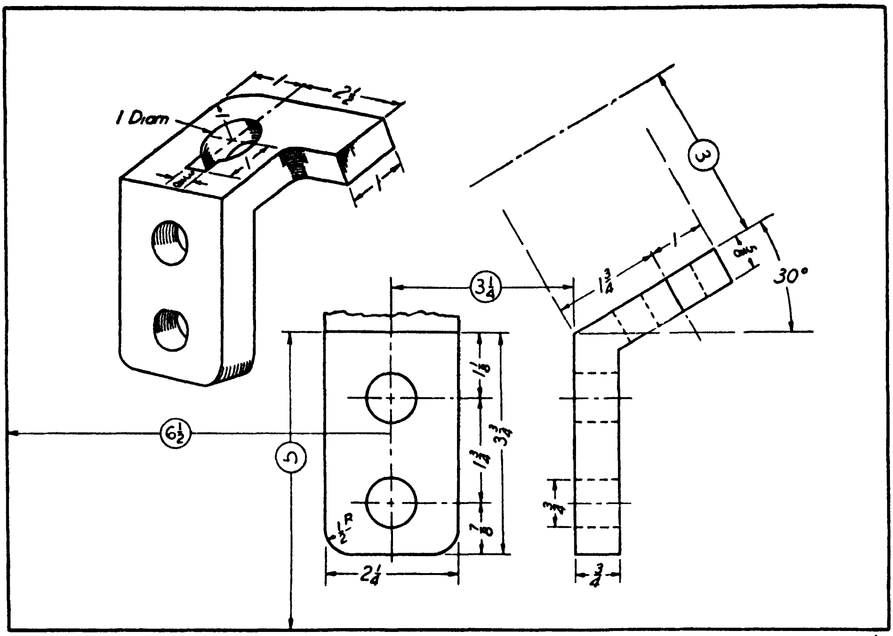


Figure 22·107 **Prob. 165.** Draw the two views as given and a part auxiliary view for the *angle stop.*

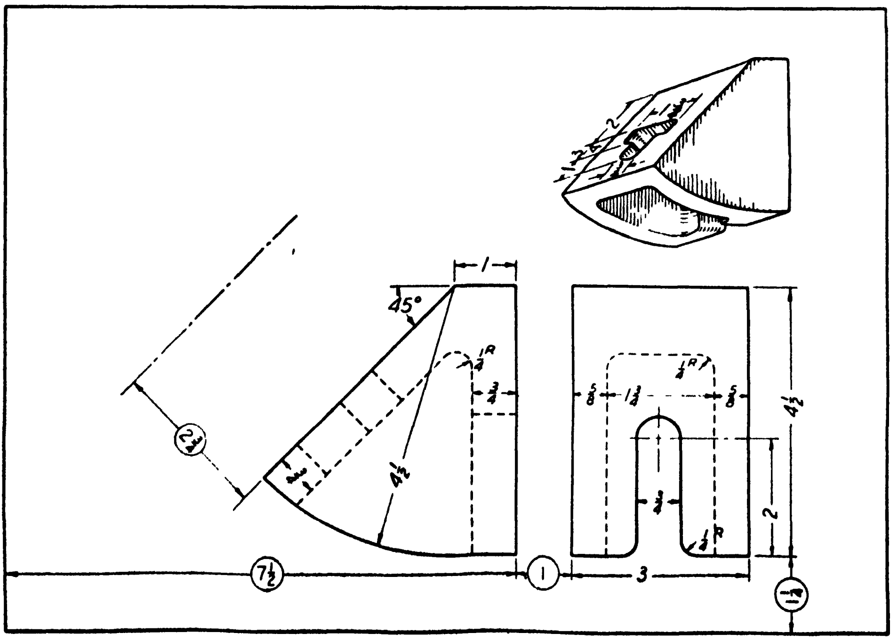


Figure 22·108 **Prob. 166.** Draw the two views given and an auxiliary view of the slanting face of the *angle support.*

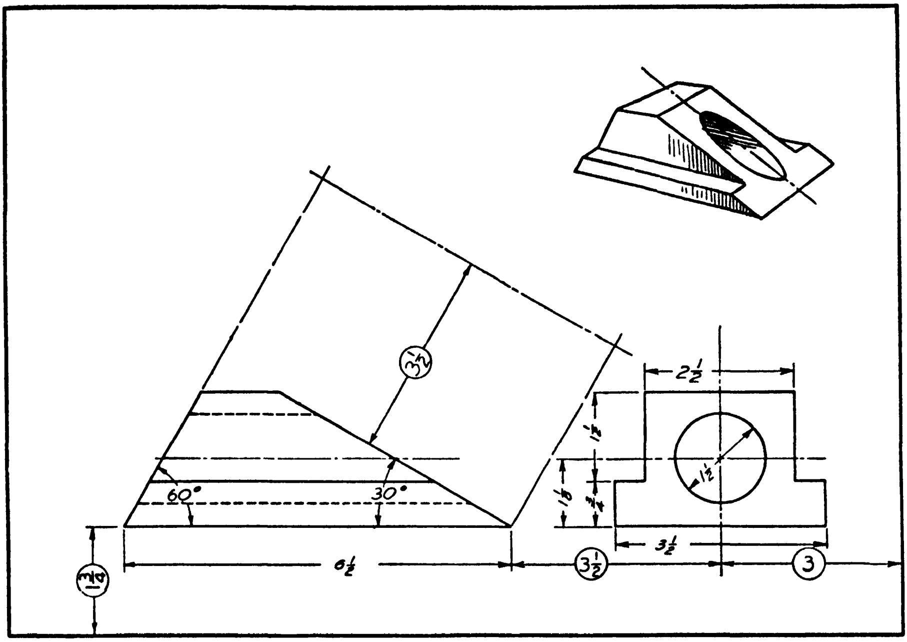


Figure 22·109 Hollow molding. **Prob. 167.**

Problem 167 Fig. 22·109. A picture and a layout for a piece of *hollow molding* are shown in the figure. Consider the left-hand view to be the front view. Draw the front and side views as shown. Draw a complete auxiliary view on a plane parallel to the cut face. Refer to Art. 7·3. Note that this will be a right-auxiliary view made on a plane perpendicular to the vertical plane. See Fig. 7·5 and compare with your solution of this problem. Do not copy the picture.

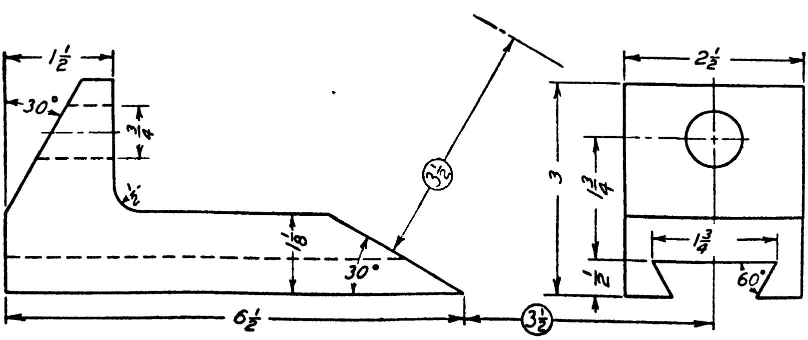


Figure 22·110 Sloping dovetail. **Prob. 168.**

Problem 168 Fig. 22·110. Using a layout similar to Fig. 22·109, draw the two views given and from these draw the complete auxiliary view of the *sloping dovetail.*

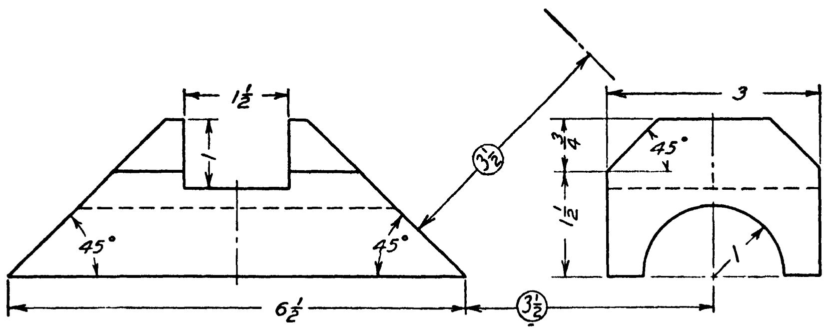


Figure 22·111 Shaft holder. **Prob. 169.**

Problem 169 Fig. 22·111. Draw views given and a complete auxiliary view of the *shaft holder*. Use layout similar to Fig. 22·109.

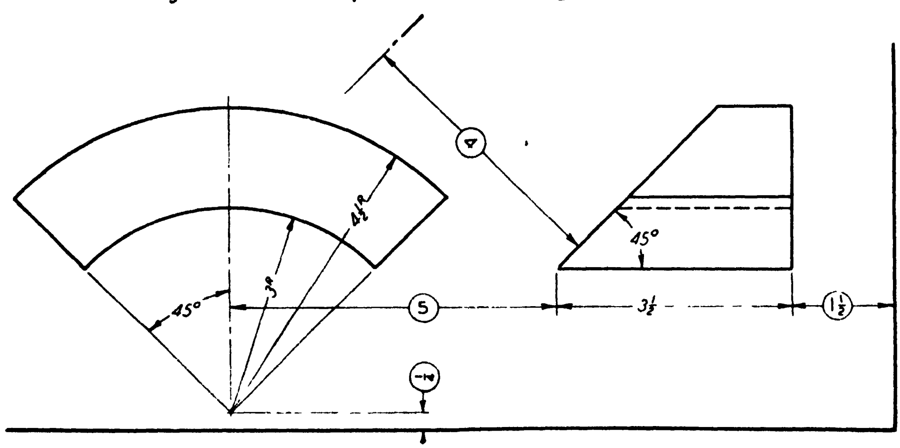


Figure 22·112 Saddle. **Prob. 170.**

Problem 170 Fig. 22·112. Draw views given and a complete auxiliary view of the *saddle*. Use layout similar to Fig. 22·109.

Problem 171 Figure 22·113 shows a picture and a layout for an *inclined stop*. The complete view in the middle of the space is the right-side view. Draw this side view. Draw the part front view shown in the upper left-hand part of the space. Draw a part rear view on both sides of the vertical center line in the lower right-hand part of the space. Draw an auxiliary view of the inclined part. Refer to Art. 7·3. Note that this will be a front auxiliary view.

Problem 172 Fig. 22·114. A top view, a left-side view, and an incomplete front view of an *angle spacer* are shown on the layout in the figure. Draw the top view, finish the incomplete front view, and draw the side view. The invisible parts of the holes that show as ellipses in the front and side views need not be drawn. Draw a part auxiliary view where indicated in the upper right-hand part of the space. Art. 7·3. Note that this will be an auxiliary elevation as it is made on a plane perpendicular to the horizontal.

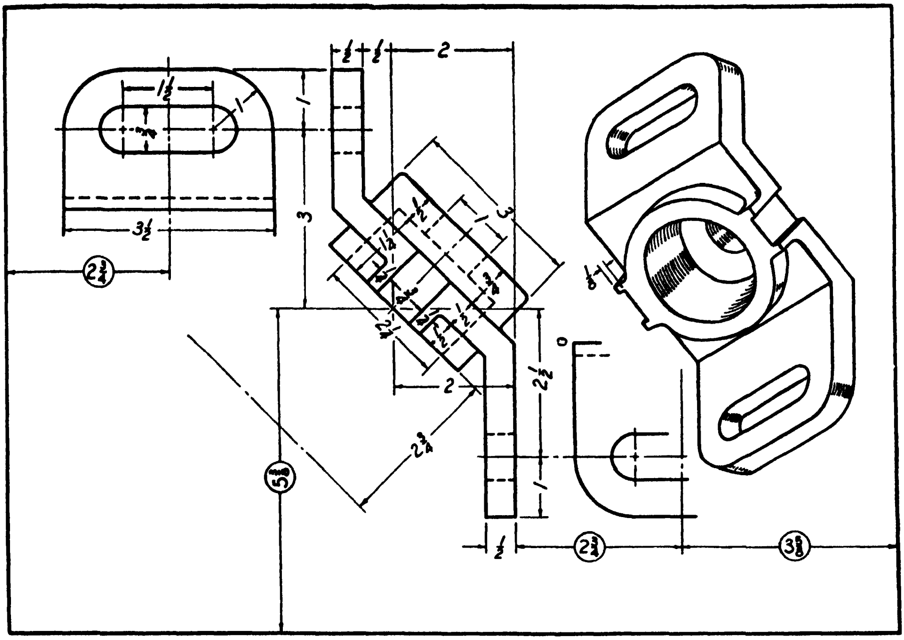


Figure 22·113 Inclined stop. **Prob. 171.**

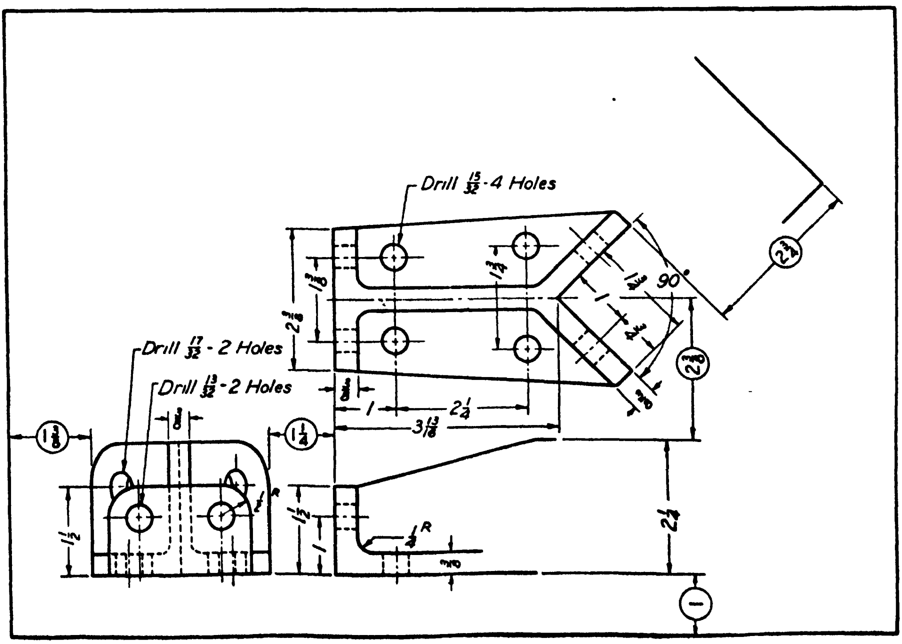


Figure 22·114 Angle spacer. **Prob. 172.**

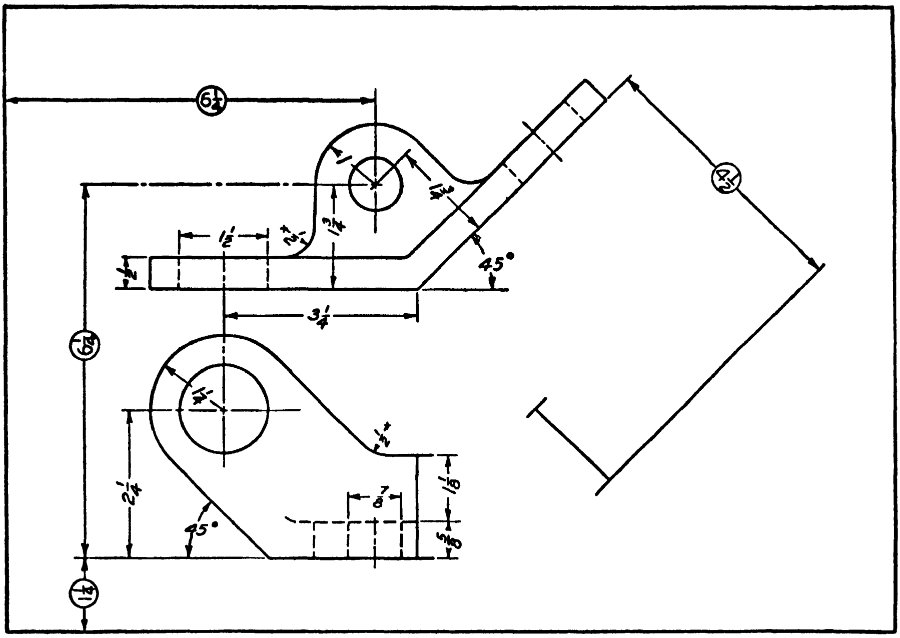


Figure 22·115 Angle rail support. **Prob. 173.**

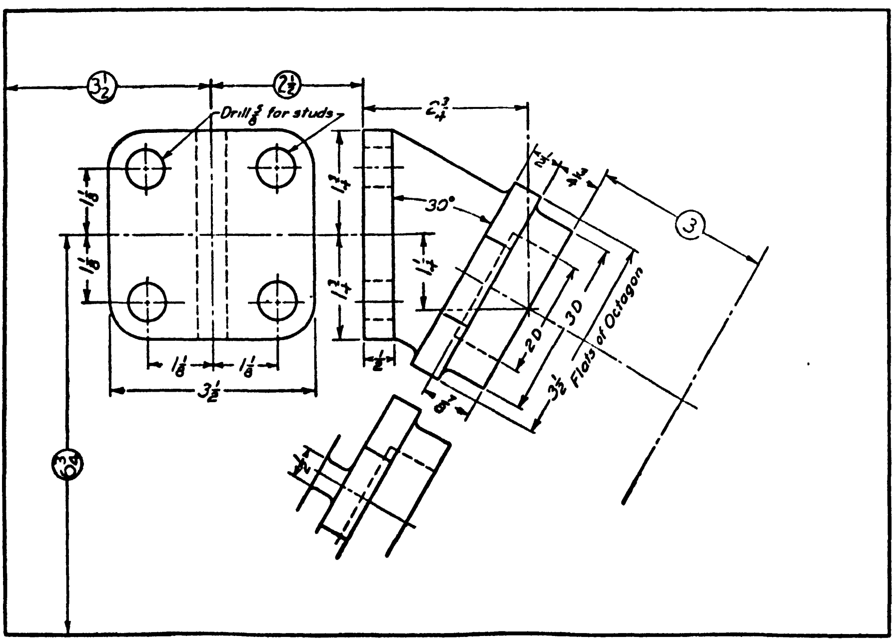


Figure 22·116 Angle cap. **Prob. 174.**

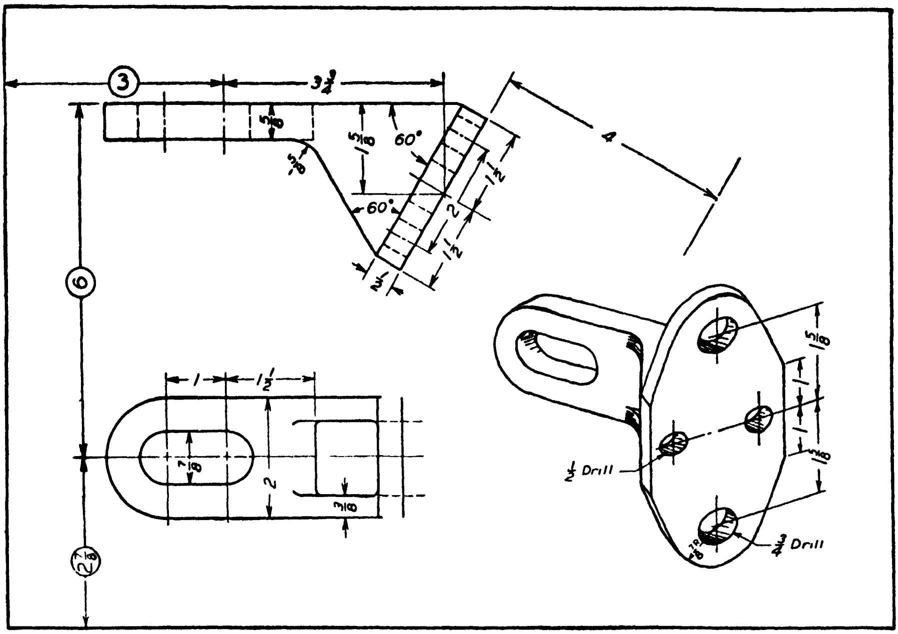


Figure 22·117 Angle plate. **Prob. 175.**

Problem 173 Fig. 22·115. A top view and part front view of an *angle rail support* are shown in the layout in the figure. Draw the top view and the part front view as shown. Draw a part auxiliary view where indicated on the layout. Refer to Art. 7·3. Note that this will be an auxiliary elevation as it is made on a plane perpendicular to the horizontal plane. See Fig. 7 4 and compare with the solution of your problem. Dimensicn if required by the instructor.

Problem 174 Fig. 22·116. A part front view, a right-side view, and a part auxiliary view of an *angle cap* are shown on the layout in the figure. Draw the views given and another part auxiliary view where indicated on the layout. Refer to Art. 7·3. Note that this last auxiliary view is a rear auxiliary view and that the one shown on the layout is a front auxiliary view. See Fig. 7·6 and compare with the solution of your problem. Dimension if required by the instructor.

Problem 175 Fig. 22·117. A picture and a layout for an *angle plate* are shown in the figure. Draw the top view and the part front view as shown. Draw a part auxiliary view where indicated on the layout. Refer to Art. 7·3. Note that this is an auxiliary elevation as it is made on a plane perpendicular to the horizontal plane. See Fig. 7·4 and compare with the solution of your problem. Do not copy the picture. Dimension if required by the instructor.

GROUP 7. REVOLUTIONS

22·10 Study Arts. 7·6 to 7·12 and understand the rule of revolution as there explained before beginning the problems in this group. The object of including one or two problems in revolution in a course in drawing, when time permits, is to give further training in the relationship of views.

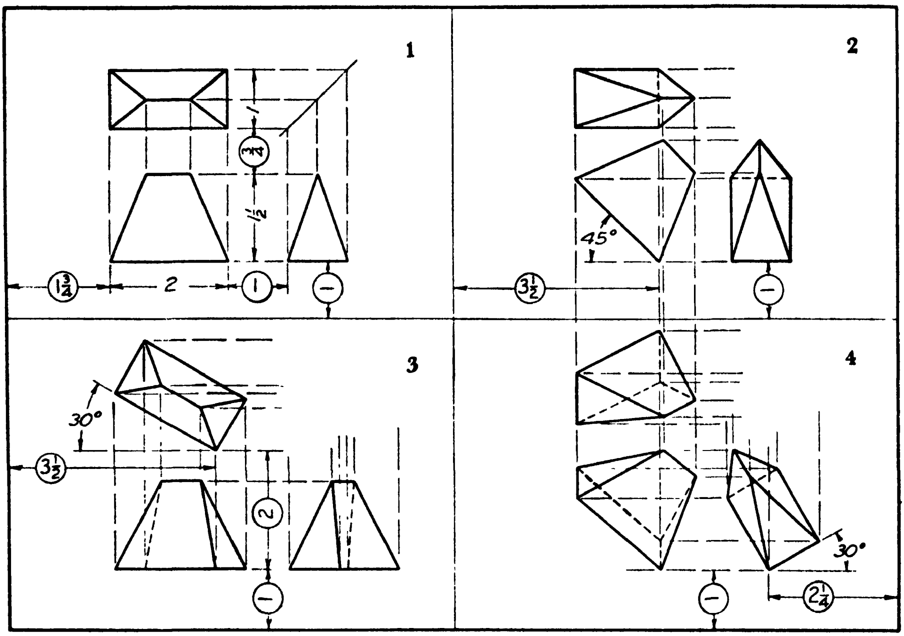


Figure 22·118 Revolution. **Prob. 176.**

Problem 176 Fig. 22·118. The figure shows the completed problem. It is given for comparison and is not to be copied. Divide the standard sheet into four equal parts. In Space 1 is a three-view drawing of a block in its simplest position. In Space 2 (upper right-hand) the block is shown after being revolved from the position in Space 1, through 45°, about an axis perpendicular to the vertical plane. The front view was drawn first, copying the front view of Space 1, and the top view obtained by projecting up from the front view and across from the top view in Space 1.

In Space 3 (lower left-hand) the block has been revolved from position one through 30° about an axis perpendicular to the horizontal plane. The top view was drawn first, copied from the top view of Space 1. In Space 4, the block has been tilted forward from position two about an axis perpendicular to the side plane. The side view was drawn first, copied from the side view of Space 2, and the widths of front and top view projected from the front view of Space 2.

A convenient method of obtaining the widths of the side views by "mitering" from the top view is shown in Fig. 22·118.

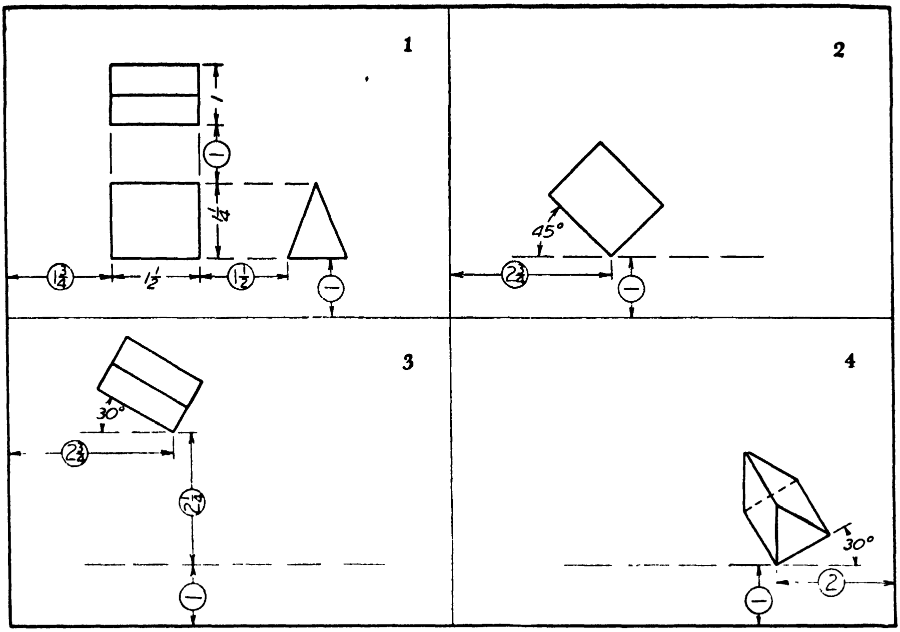


Figure 22·119 Revolutions. **Prob. 177.**

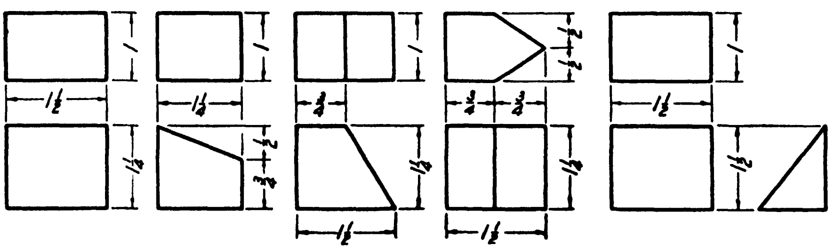


Figure 22·120 **Probs. 178 to 182.**

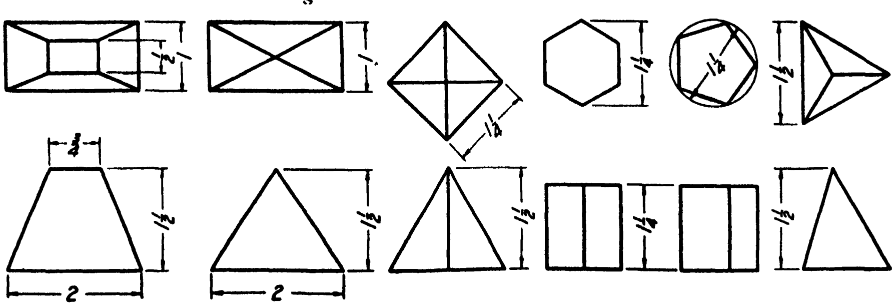


Figure 22·121 **Probs. 183 to 188.**

Problem 177 Fig. 22·119. Follow the directions for Prob. 176 and work out views of the wedge.

Problems 178 to 188 Figs. 22·120 and 22·121. Follow directions for Probs. 176 and 177 and work out the required views.

GROUP 8. SIZE DESCRIPTION

22.11 Size description, or dimensioning, is a very important part of mechanical drawing. Study Chap. 8 carefully and apply the principles described in it to the solutions of the following problems. First draw the complete views for shape description, then put on all dimension lines for size dimensions and for location dimensions. When certain that all dimensions are indicated, fill in the dimensions and add notes where necessary.

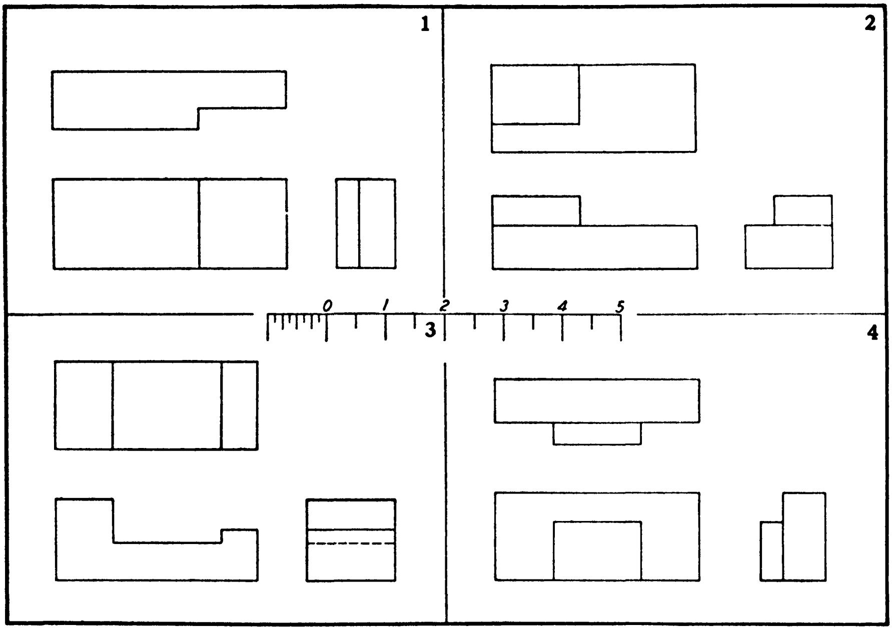


Figure 22·122 Dimensioning studies. **Probs. 189 to 192.**

Problems 189 to 192 Fig. 22·122. Lay out an 11″ × 17″ sheet and divide the working space into four parts. The printed scale was full size before the drawing was reduced. Use the dividers to take off the distances from the scale, and draw the views full size. Put on the *size dimensions* as scaled from the views.

Problems 193 to 196 Fig. 22·123. Draw the views as described for Fig. 22·122. Put on the *size dimensions* as scaled from the views.

Problems 197 to 200 Fig. 22·124. Draw the views as described for Fig. 22·122. Put on the *size dimensions* as scaled from the views.

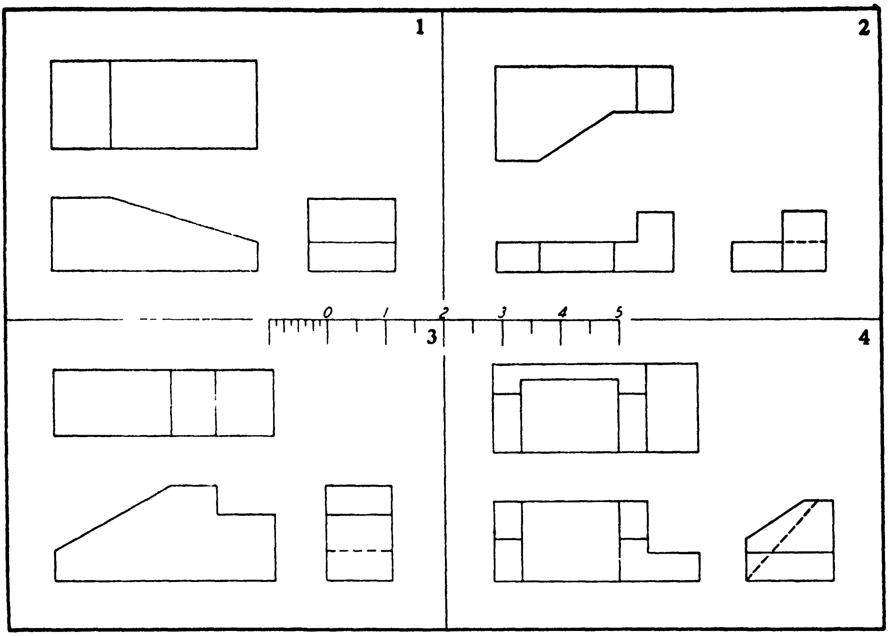


Figure 22·123 Dimensioning studies. **Probs. 193 to 196.**

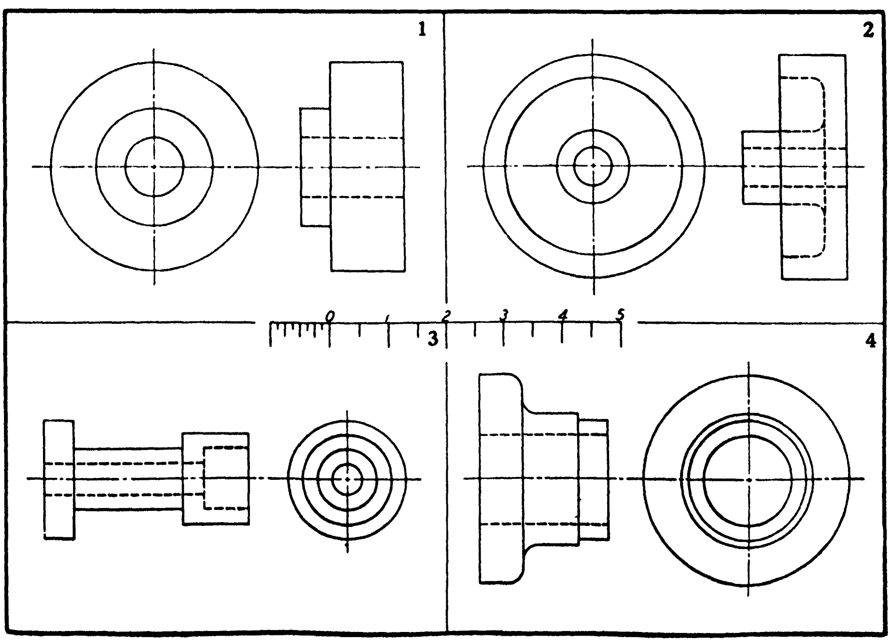


Figure 22·124 Dimensioning studies. **Probs. 197 to 200.**

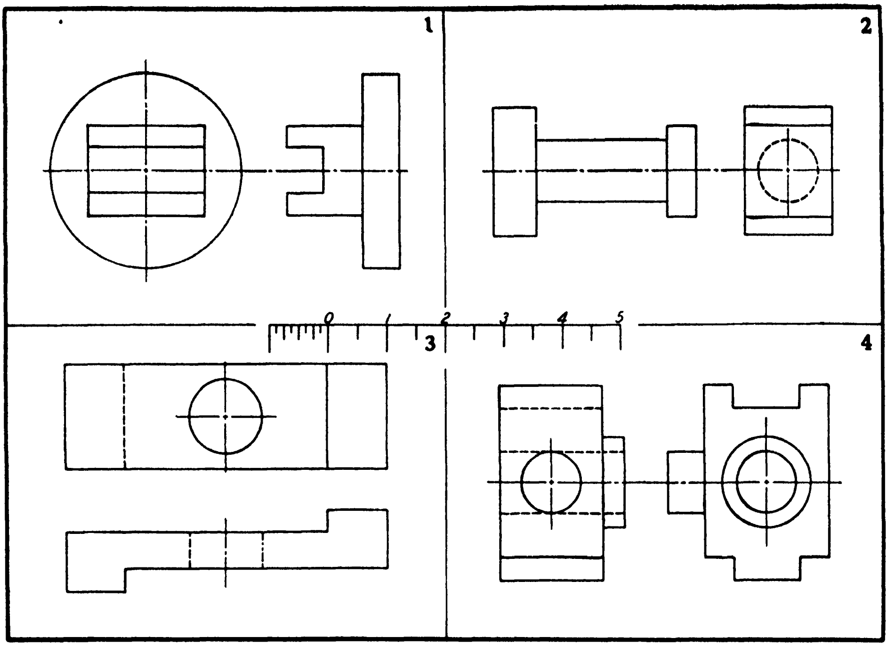


Figure 22·125 Dimensioning studies. **Probs. 201 to 204.**

Problems 201 to 204 Fig. 22·125. Lay out an 11″ × 17″ sheet and divide the working space into four parts. The printed scale was full size before the drawing was reduced. Use the dividers to take off the distances from the scale, and draw the views full size. Put on the size dimensions as scaled from the views.

Problems 205 to 208 Fig. 22·126. Lay out an 11″ × 17″ sheet and divide the working space into four parts. The printed scale was full size before the drawing was reduced. Use the dividers to take off the distances from the scale, and draw the views full size. Put on the location dimensions as scaled from the views.

Problems 209 to 212 Fig. 22·127. Lay out an 11″ × 17″ sheet and divide the working space into four parts. The printed scale was full size before the drawing was reduced. Use the dividers to take off the distances from the scale, and draw the views full size. Put on the location dimensions as scaled from the views.

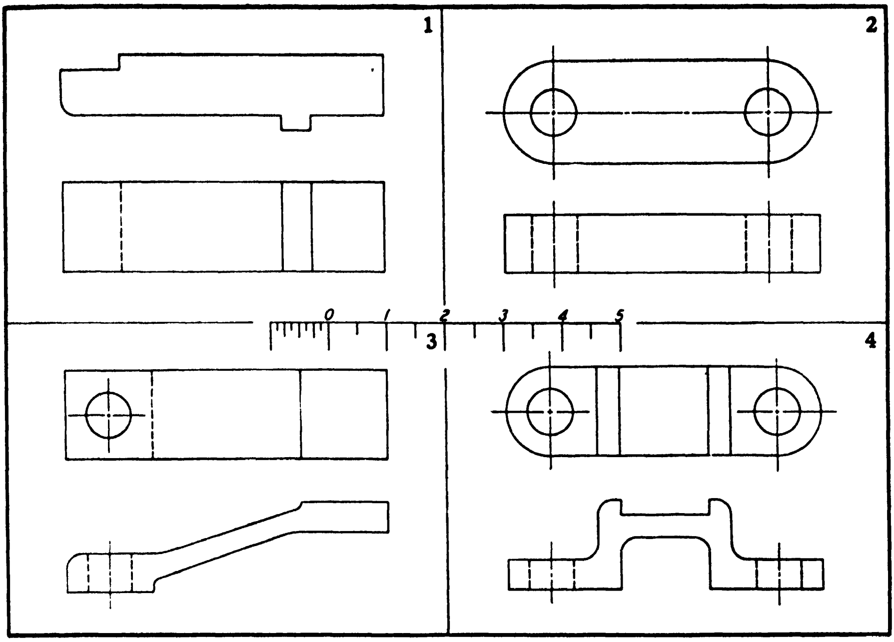


Figure 22·126 Dimensioning studies. **Probs. 205 to 208.**

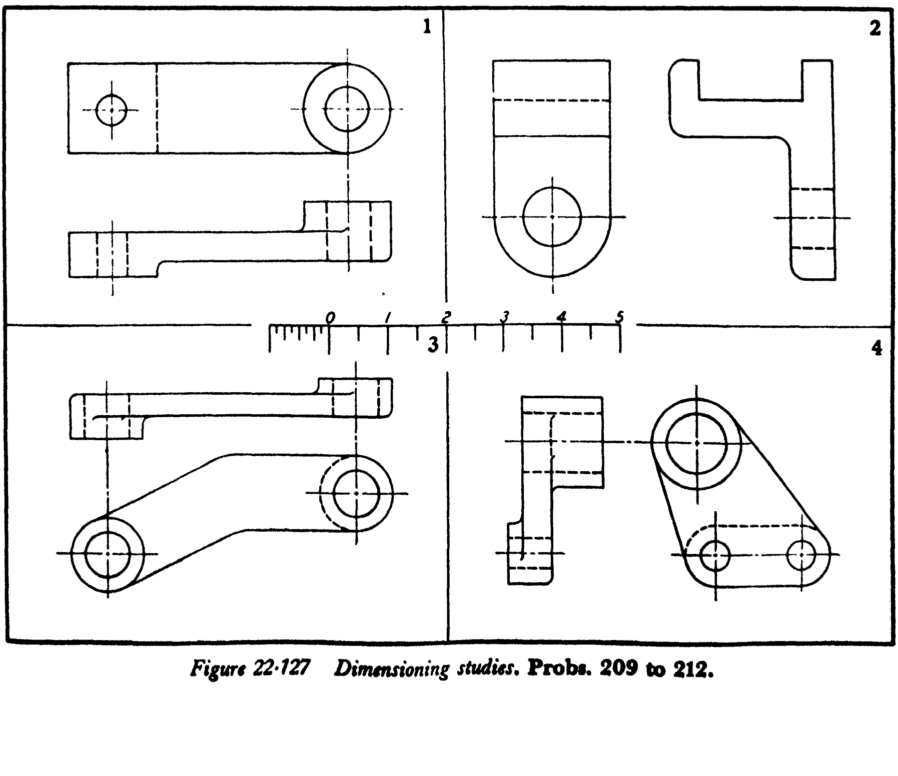


Figure 22·127 Dimensioning studies. **Probs. 209 to 212.**

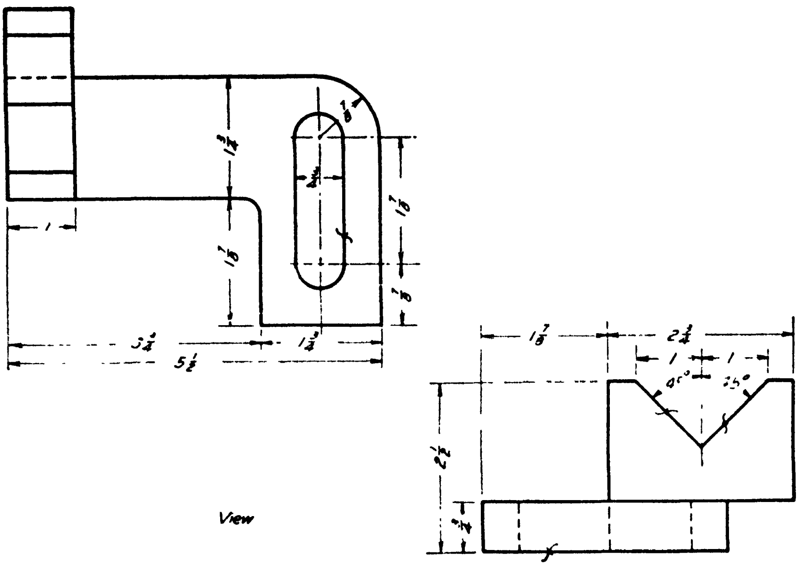


Figure 22·128 Adjustable center. **Prob. 213.**

Problem 213 Fig. 22·128. Make a working drawing of the *adjustable center,* with complete dimensions. Locate views to allow for dimensions.

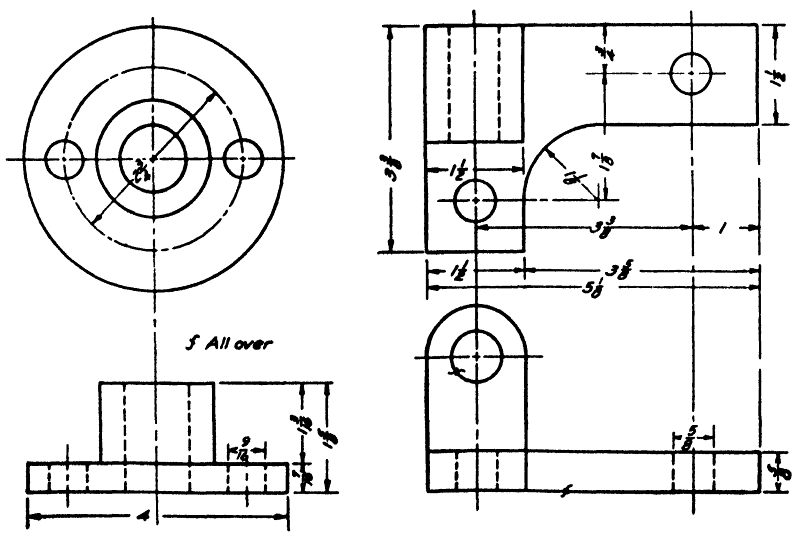


Figure 22·129 Gland and bearing. **Prob. 214.**

Problem 214 Fig. 22·129. Make working drawings of the *gland* and *bearing,* with complete dimensions. The diameter of the hole (1″) and of the hub (1¾″) should be added to the gland. For the bearing the distance from the underside of the base up to the center of the hole is 2″. The length of the hole is 1¾″ and its diameter is ¾″. The thickness of the base is ⅝″.

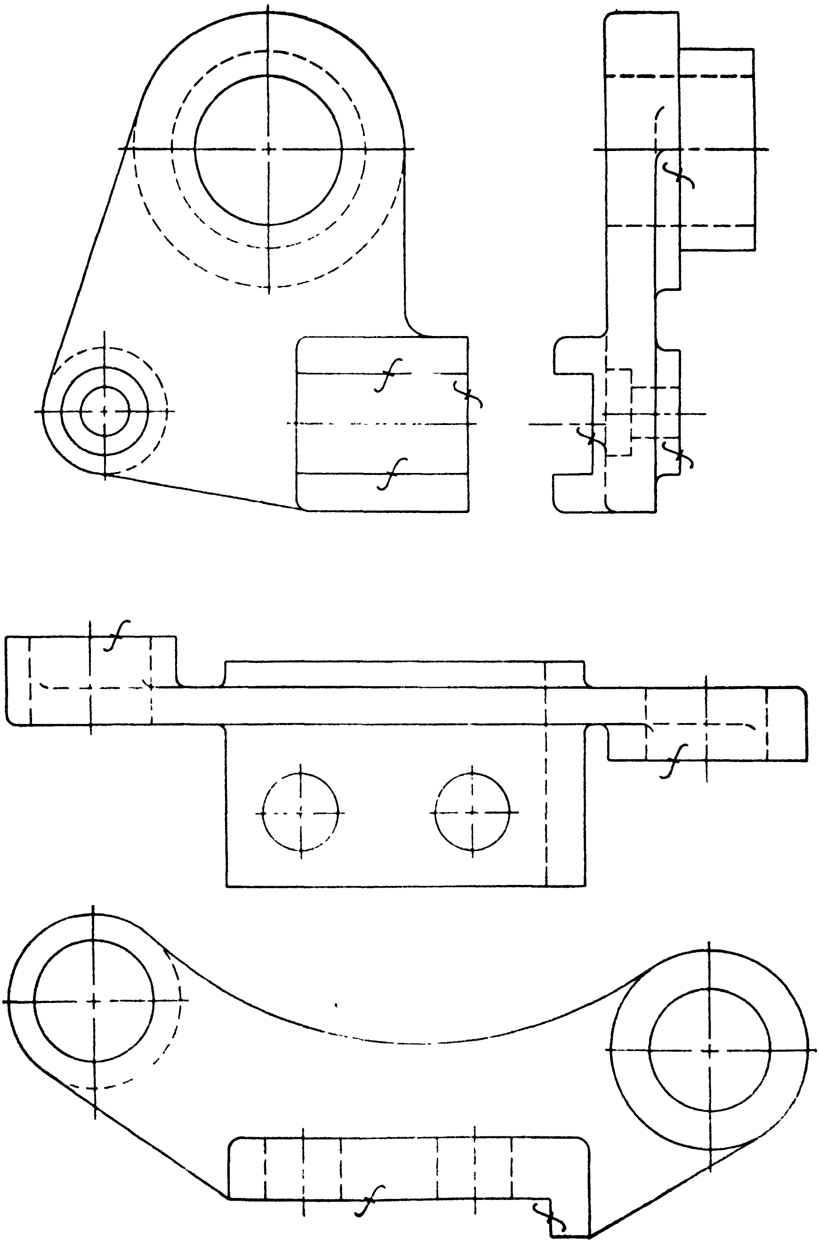


Figure 22·130 Dimensioning studies. **Prob. 215.**

Problem 215 Fig. 22·130. Copy the views to twice the size in the book. Use the right-hand side of the figure as the bottom of the sheet. Completely dimension the pieces, obtaining dimensions by scaling your drawing.

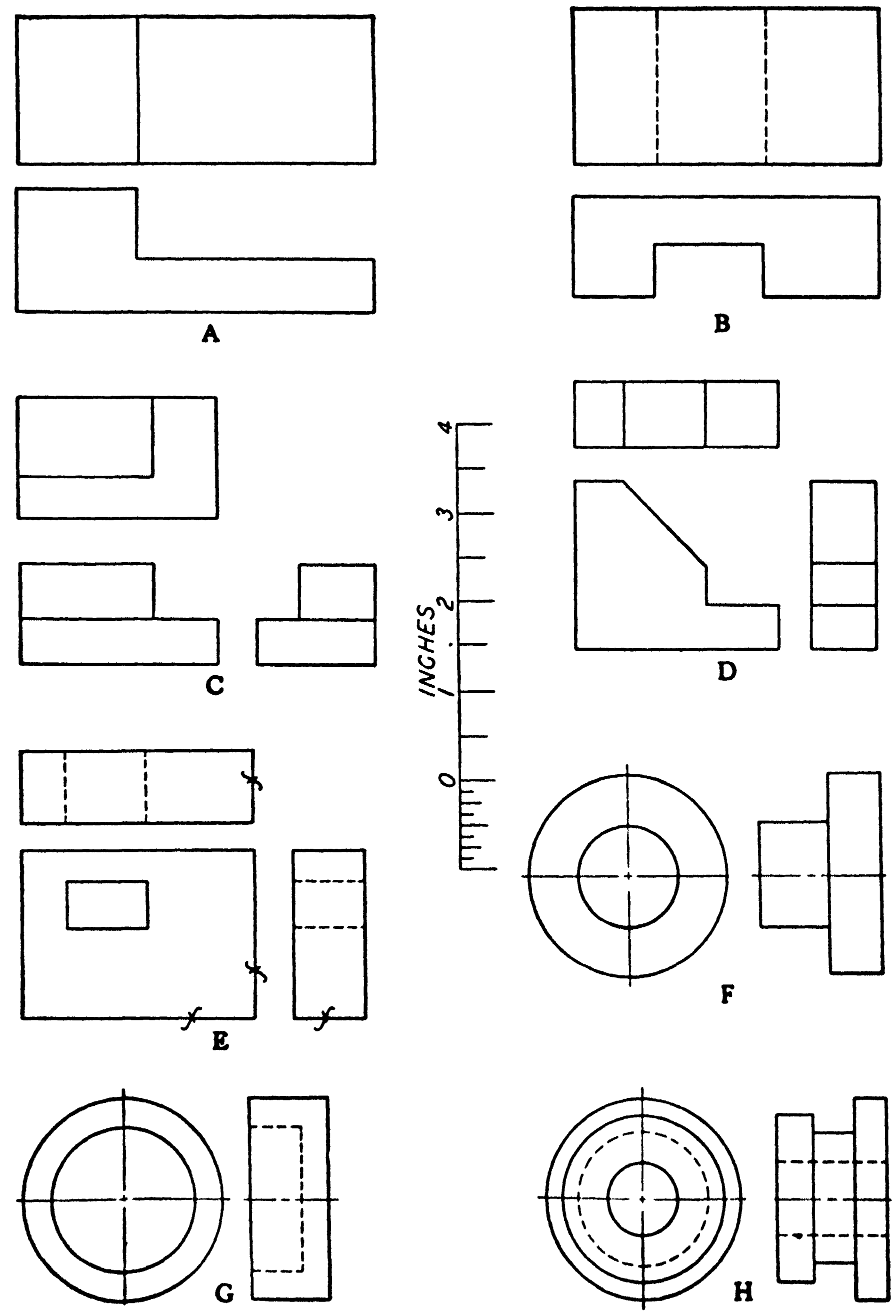


Figure 22·131 **Prob. 216.**

Problem 216 Fig. 22·131. Copy the views freehand, enlarged. Add dimensions using *S* for size dimensions.

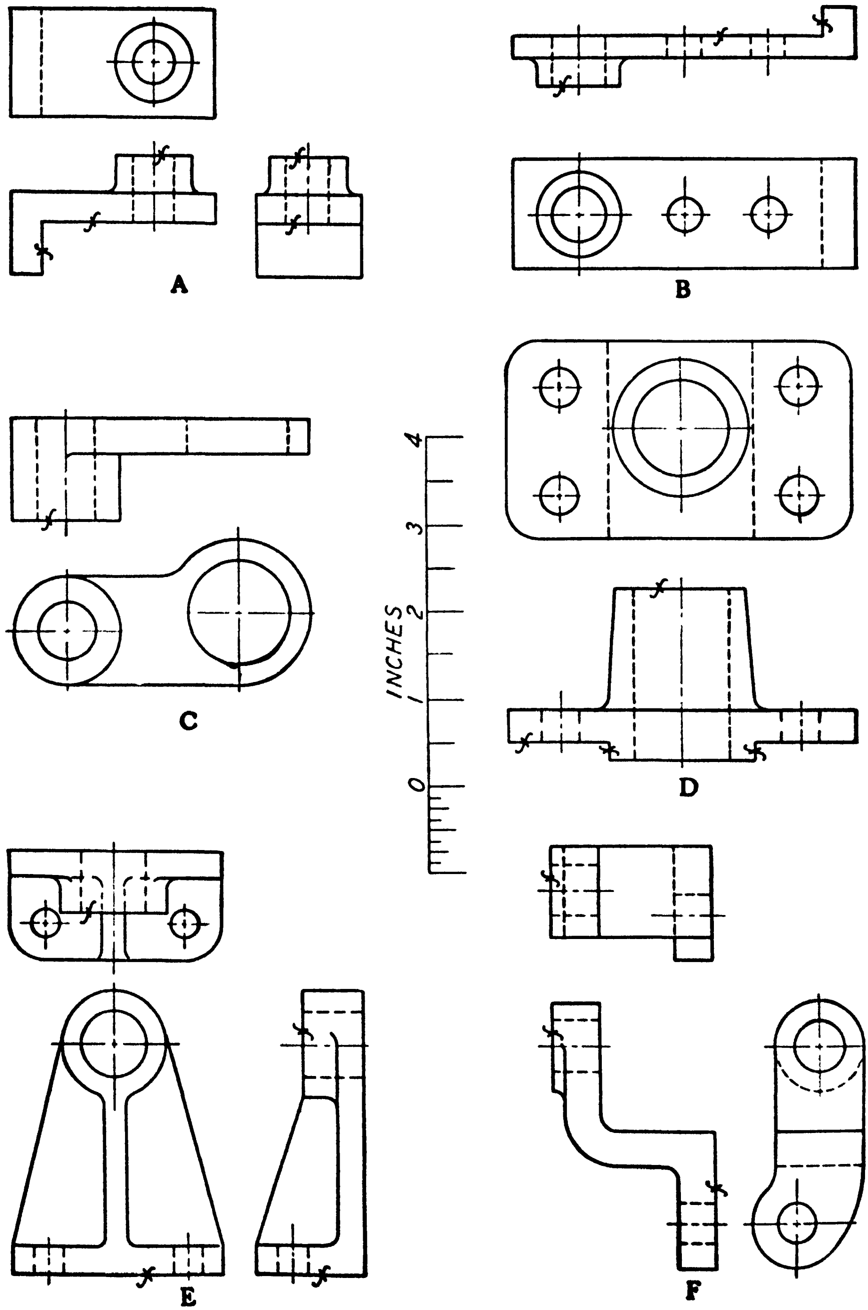


Figure 22·132 **Prob. 217.**

Problem 217 Fig. 22·132. Copy the views freehand, enlarged. Add dimensions using *S* for size dimensions and *L* for location dimensions.

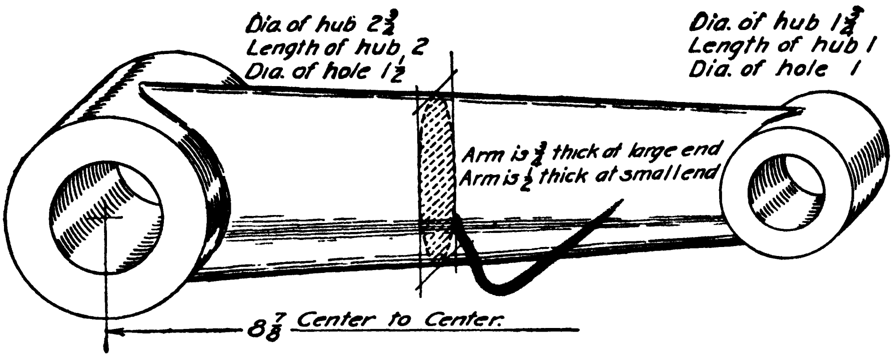


Figure 22·133 *Link.* **Prob. 218.**

Problem 218 Fig. 22·133. Make a complete working drawing of the *link*, with dimension lines, extension lines and dimensions correctly placed. Do not copy the notes or dimensions as given in the picture. Figure 22·134 gives the layout for the problem.

Problem 219 Fig. 22·135. Make a complete working drawing of the *bell crank* with dimensions placed correctly. Do not copy the notes from the picture. Figure 22·136 gives the layout for the problem.

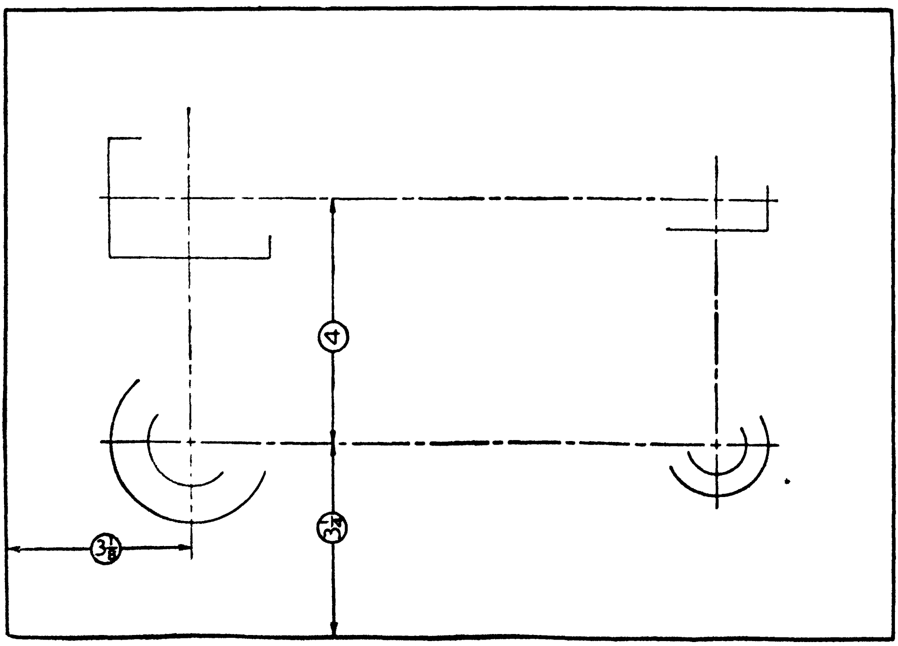


Figure 22·134 *Layout for Prob. 218.*

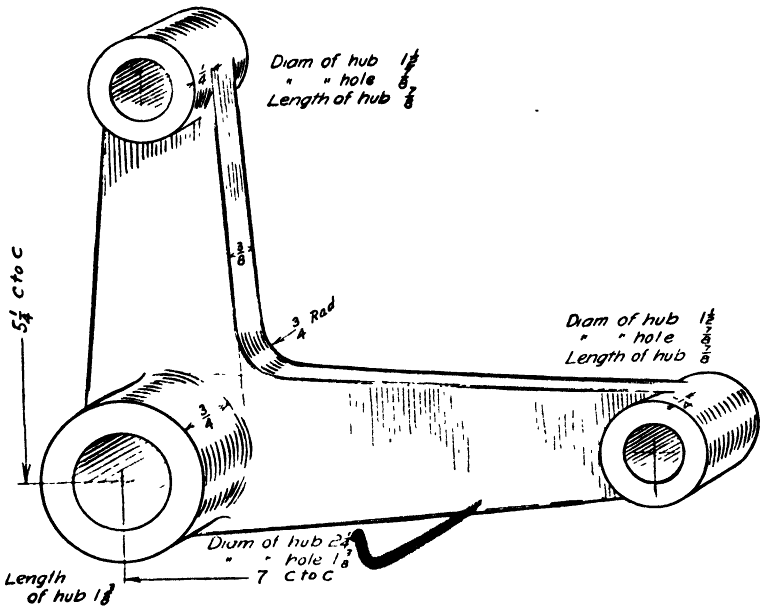


Figure 22·135 Bell crank. **Prob. 219.**

In the layout of Fig. 22·136 note that a complete front view is suggested with a view at the left to show the vertical arm, and a part top view of the horizontal arm.

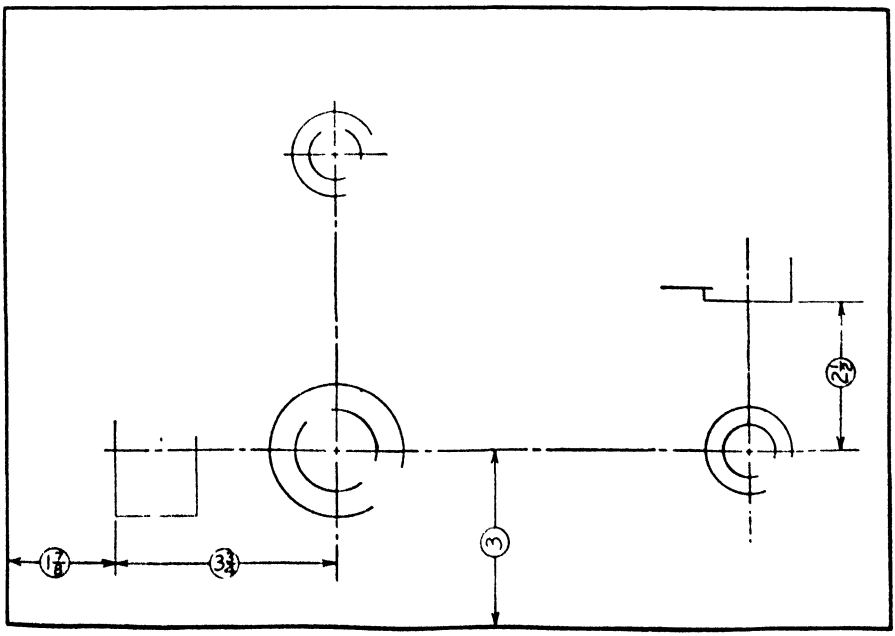


Figure 22·136 Layout for Prob. 219.

GROUP 9. BOLTS AND SCREWS

22·12 It is necessary for a draftsman to know the forms of screw threads and the conventional methods of drawing bolts and screws. Read Chap. 10 carefully before starting the problems in this group. Threads are always understood to be single and right-hand unless otherwise specified. A right-hand thread enters when turned clockwise. A left-hand thread enters when turned counterclockwise and is always marked L.H. on a drawing. When the American Standard form and number of threads per inch are used, it is not necessary to specify except by a note. See Appendix for screw-thread information.

Problem 220 Fig. 22·137. In the left half of the sheet construct two complete turns of a right-hand helix whose diameter is 4″ and pitch 1½″ (Arts. 10·2 and 10·3). In the right half of the sheet draw, as shown in the layout, the forms of the V-thread, American Standard thread and square thread, each with 1″ pitch. Letter the name of each form under the drawing of it.

Sometimes in drawing a helix, a templet is made by laying out the curve on a piece of cardboard, celluloid, or thin wood and cutting out with a sharp knife.

Problem 221 An alternate for Prob. 220. In the left half of the sheet construct two complete turns of a right-hand helix whose diameter is 3″ and pitch 2″. In the right half draw the forms of the American Standard thread, Acme thread, and knuckle thread, each with 1″ pitch. Letter the name of each form under the drawing of it.

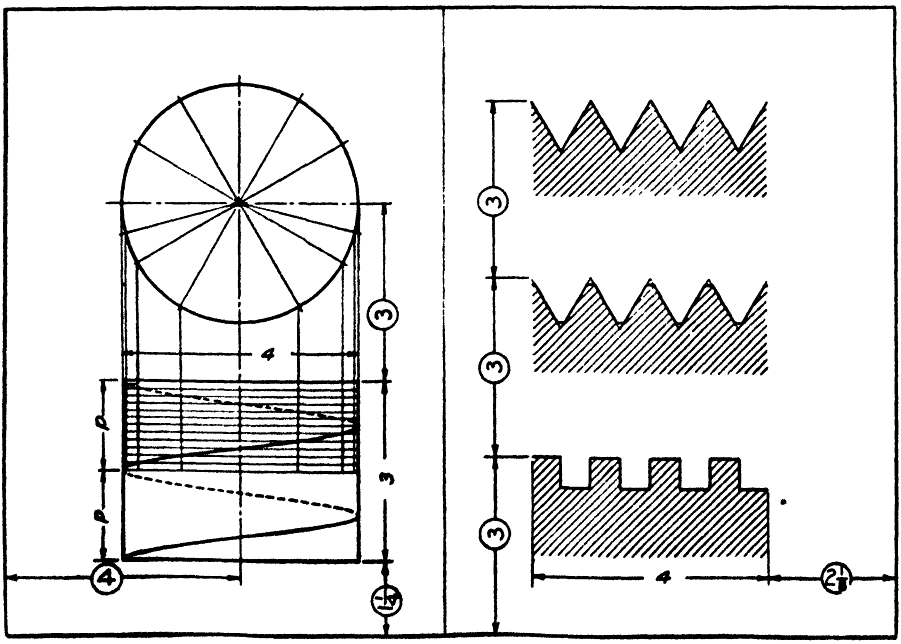


Figure 22·137 Helix and thread forms. **Prob. 220.**

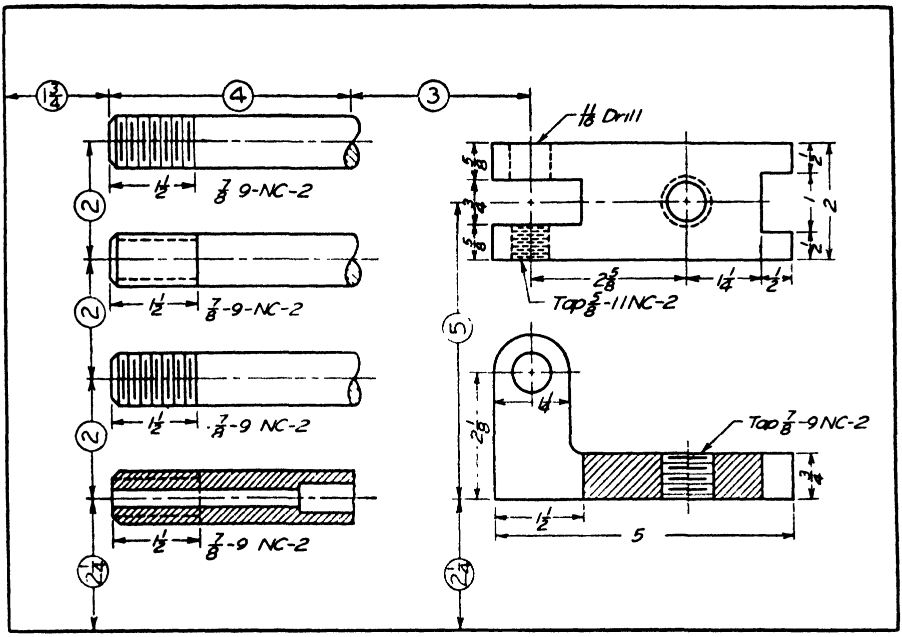


Figure 22·138 **Prob. 222.** Draw the conventional thread representations as specified on the layout.

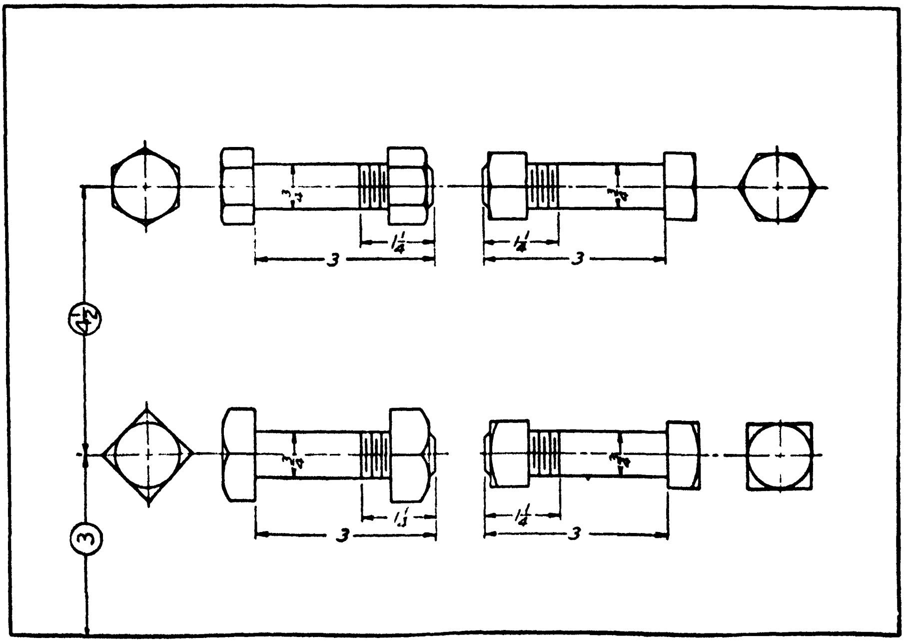


Figure 22·139 **Prob. 223. Draw the American Standard bolts and nuts in the positions indicated.**

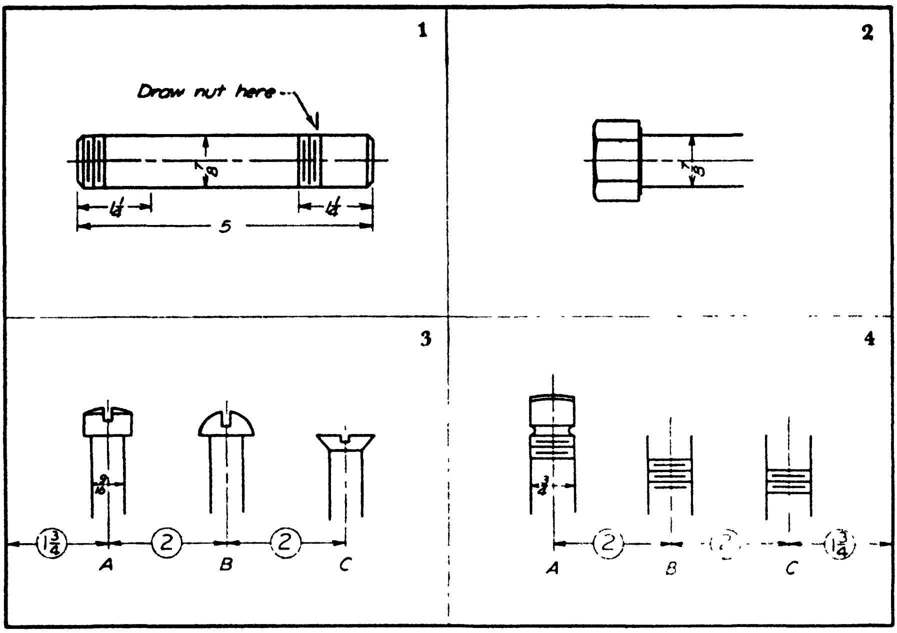


Figure 22·140 Fastenings. **Prob. 224.**

Problem 224 Fig. 22·140. Divide working space into four spaces as shown. In the upper left-hand space draw a stud and American Standard nut. Diameter, 7/8″; length 5″; length of thread on each end 1 1/4″. In the upper right-hand space draw an American Standard hexagonal-head cap screw. Diameter, 7/8″; length 2 1/4″. In lower left-hand space draw three forms of cap screws, at *A*, *B*, and *C*. Diameter, 9/16″; length 1 1/2″. In lower right-hand space draw three set screws, American Standard square head and two headless set screws. Diameter, 3/4″; length 1 1/2″.

Problems 225 to 234 Fig. 22·141 (Space 1). On the center line shown, draw an American Standard bolt and nut for the flange and head plate. Take dimensions from the table on page 420. Place bolthead at the left and show across flats. Show nut across corners.

Problems 235 to 238 Fig. 22·141 (Space 2). On the center line shown, draw a stud with a hexagonal or square nut, across flats or corners, as directed by the instructor. Take dimensions from table on page 420.

Problem 239 Same as Prob. 235 but for a tap bolt.

Problem 240 Same as Prob. 236 but for a tap bolt.

Problem 241 Same as Prob. 237 but for a tap bolt.

Problem 242 Same as Prob. 238 but for a tap bolt.

Problem 243 Fig. 22·141 (Space 3). On center line *A*, draw 3/4″ fillister head cap screws. On center line at *B*, draw a flat-head cap screw.

Problem 244 Fig. 22·141 (Space 4). At *A* draw a 1/2″ set screw (square head or other as directed by instructor). At *B* draw a 9/16″ hex.-head cap screw.

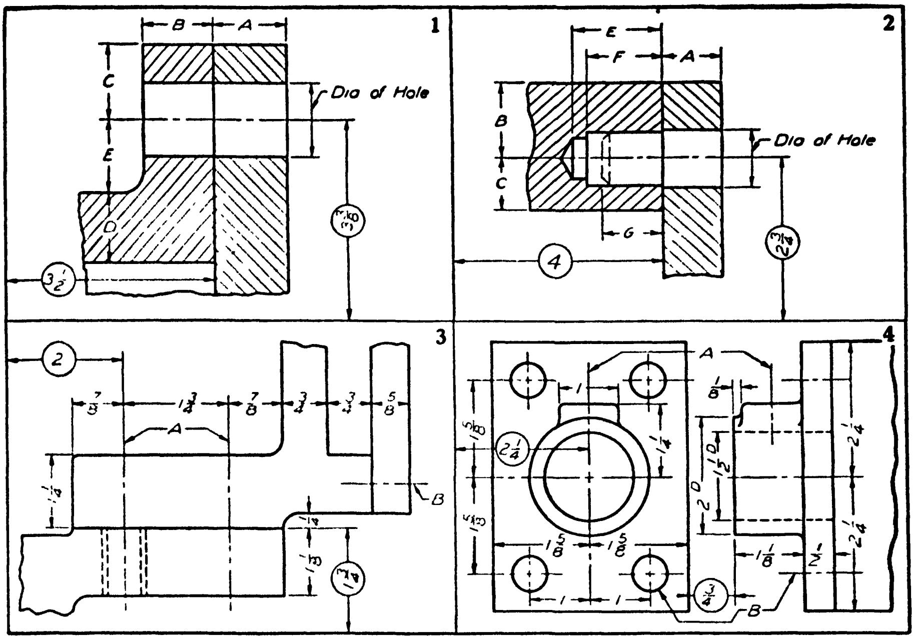


Figure 22·141 Threaded fastenings. **Probs. 225 to 234.**

Prob.	*Diam. bolt*	*Diam. hole*	*Bolt-head*	*Nut*	*A*	*B*	*C*	*E*	*F*	*R*
225	5/8	11/16	Hex.	Hex.	5/8	11/16	3/4	11/16	5/8	1/8
226	3/4	13/16	Sq.	Hex.	3/4	13/16	7/8	13/16	3/4	3/16
227	7/8	15/16	Hex.	Hex.	7/8	1	1 1/16	15/16	7/8	1/4
228	1	1 1/8	Sq.	Hex.	1	1 1/8	1 1/8	1 1/8	1	1/4
229	1 1/8	1 1/4	Hex.	Hex.	1 1/8	1 1/4	1 1/4	1 1/4	1 1/8	5/16
230	5/8	11/16	Sq.	Sq.	11/16	3/4	7/8	11/16	11/16	1/8
231	3/4	13/16	Hex.	Sq.	13/16	7/8	1	13/16	13/16	3/16
232	7/8	15/16	Sq.	Sq.	15/16	1	1 1/8	15/16	15/16	1/4
233	1	1 1/8	Hex.	Sq.	1 1/16	1 1/8	1 1/4	1 1/8	1 1/16	1/4
234	1 1/8	1 1/4	Sq.	Sq.	1 3/16	1 1/4	1 1/2	1 1/4	1 3/16	5/16

Prob.	*Diam. stud*	*Diam. hole*	*Nut*	*A*	*B*	*C*	*E*	*F*	*G*
235	3/4	13/16	Hex.	13/16	1 1/8	3/4	1 3/4	1 3/8	1
236	7/8	15/16	Sq.	15/16	1 3/8	7/8	1 7/8	1 7/8	1 1/8
237	1	1 1/8	Hex.	1 1/8	1 5/8	1	2 1/4	2 1/4	1 1/4
238	1 1/8	1 1/4	Sq.	1 1/4	1 3/4	1 1/8	2 3/4	2 3/4	1 1/2

GROUP 10. WORKING DRAWINGS

22·13 Study Chaps. 8 and 9 very carefully before starting these problems. Use a definite system. Visualize the shape clearly and locate the views carefully to allow proper placing of dimensions. Use your judgment in selecting a proper scale for the drawing. Complete the views before putting on the dimension lines. Then put in all dimension lines and fill in the dimensions. Add any necessary notes and finally check your drawing.

Some problems in Groups 4, 5, and 6, may be used as working drawings.

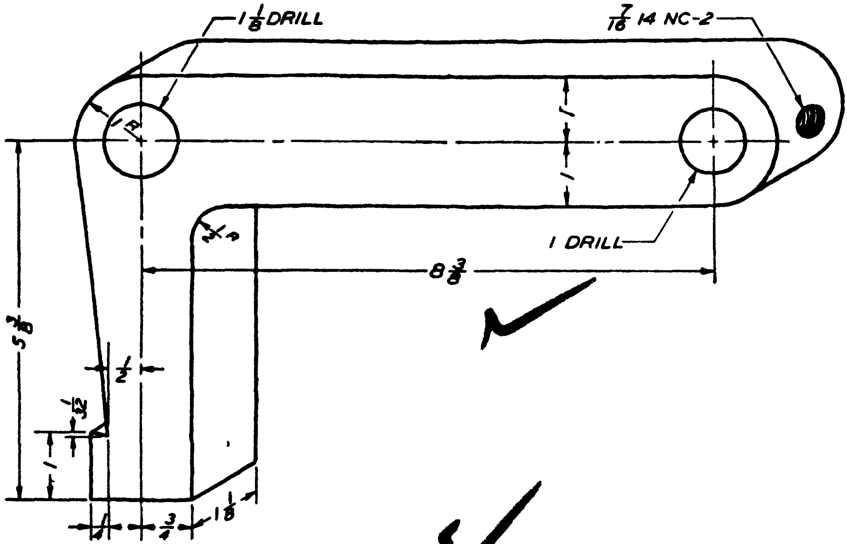


Figure 22·142 *Bell crank.* **Prob. 245.**

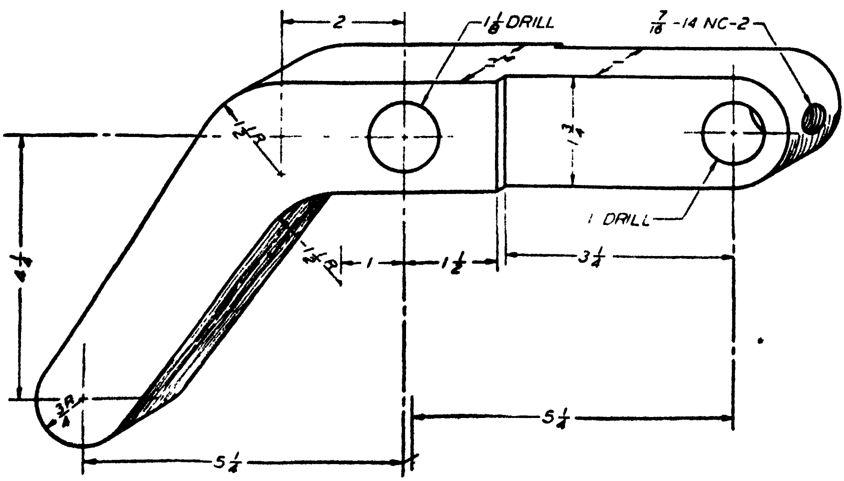


Figure 22·143 *Tripper.* **Prob. 246.**

Problem 245 Fig. 22·142. Make a working drawing of the *bell crank.*

Problem 246 Fig. 22·143. Make a working drawing of the *tripper.*

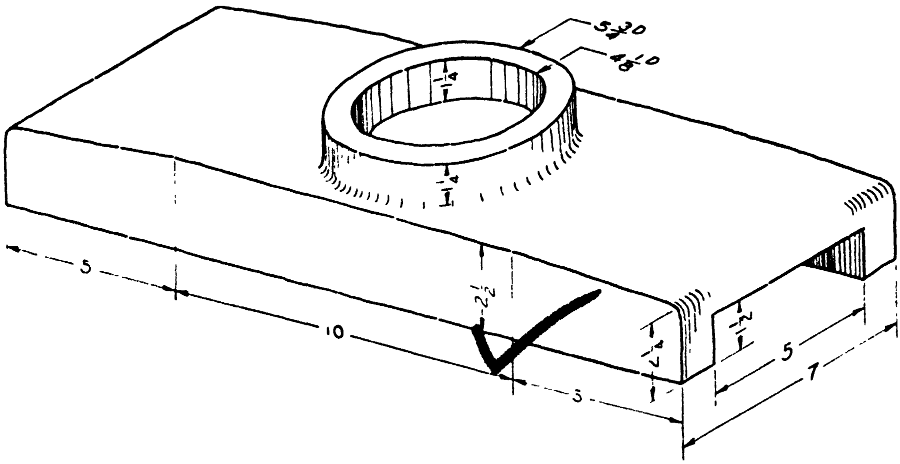


Figure 22·144 Crosshead shoe. **Prob. 247.**

Problem 247 Fig. 22·144. Make a working drawing of the cast-iron *crosshead shoe.*

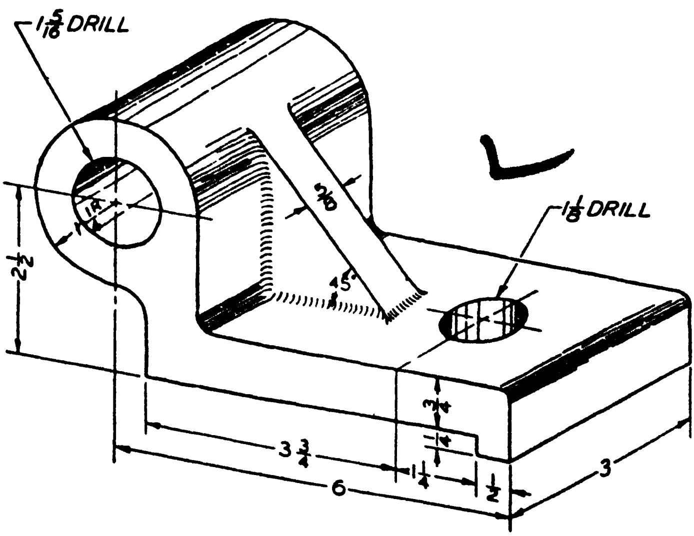


Figure 22·145 Rod bearing. **Prob. 248.**

Problem 248 Fig. 22·145. Make a working drawing of the cast-iron *rod bearing.*

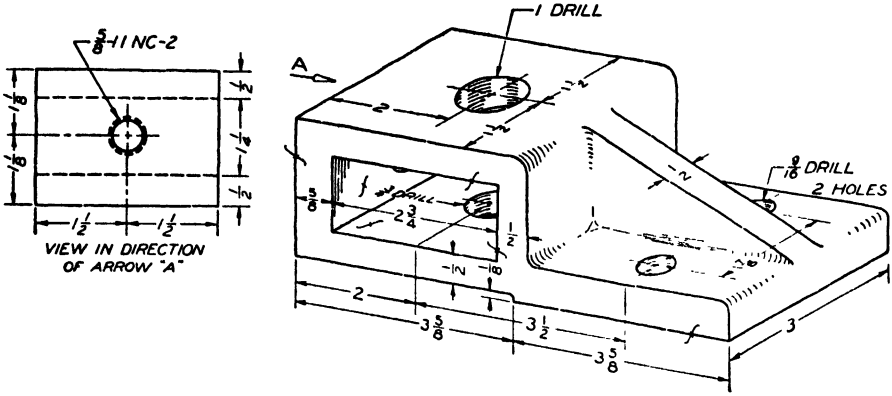


Figure 22·146 Adjustable holder. **Prob. 249.**

Problem 249 Fig. 22·146. Make a working drawing of the cast-iron *adjustable holder.*

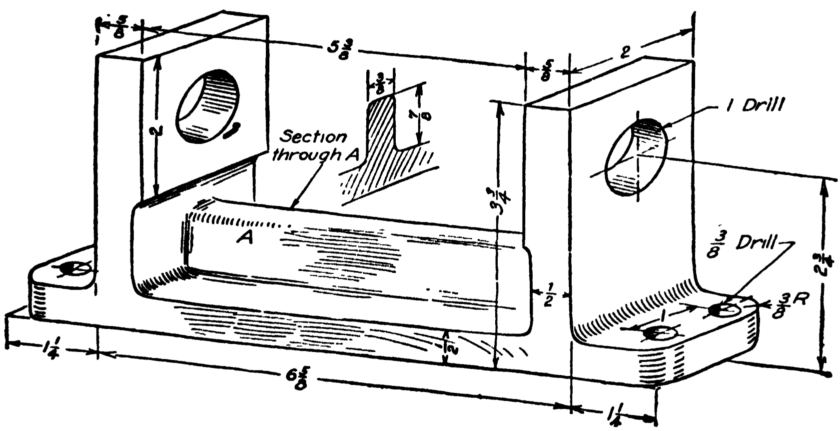


Figure 22·147 Support. **Prob. 250.**

Problem 250 Fig. 22·147. Make a complete working drawing of the *support.* Dimension correctly, supplying missing dimensions. Indicate the surfaces that you assume to be finished. The choice and treatment of views should be considered before starting the drawing. Work out the placing of the views to allow ample room for the dimensions. See Art. 22·7.

Problem 251 Fig. 22·148. Make a working drawing of the *adjusting slide.* Consider the choice of views and the scale. Work out the spacing of the views to allow ample room for dimensions and notes. Indicate the surfaces that you assume to be finished. Add a suitable title.

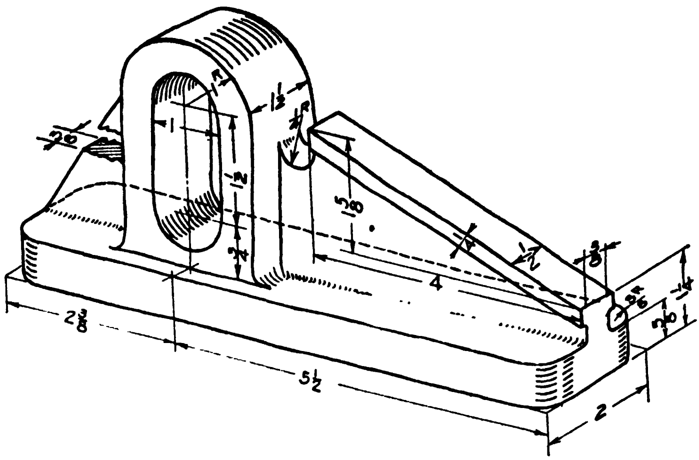


Figure 22·148 Adjusting slide. **Prob 251.**

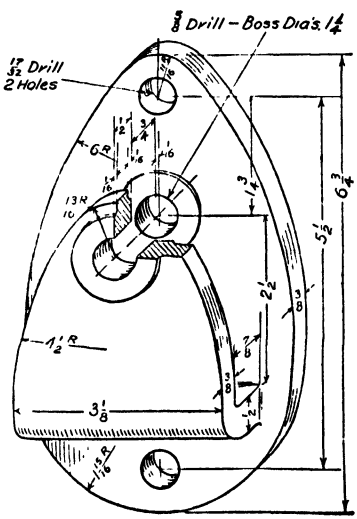


Figure 22·149 Pulley bracket. **Prob. 252.**

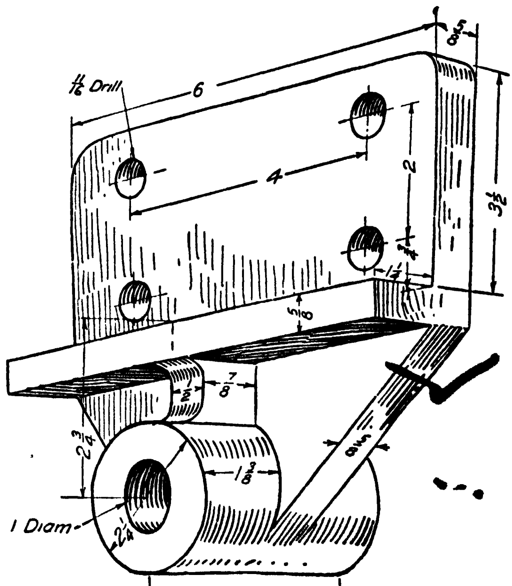
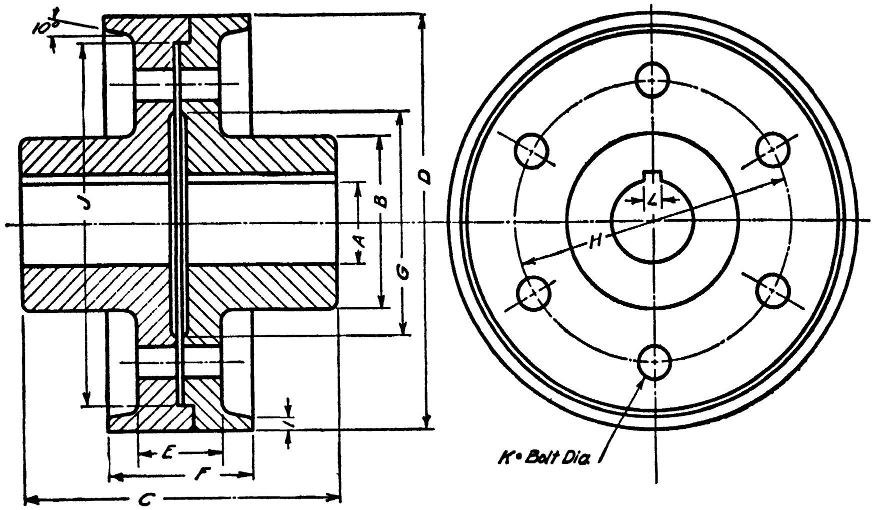


Figure 22·150 Bracket bearing. **Prob. 253.**

Problem 252 Fig. 22·149. Make a two-view working drawing of the *pulley bracket.*

Problem 253 Fig. 22·150. Make a working drawing of the *bracket bearing.*



A	B	C	D	E	F	G	H	I	J	K	L
$1\frac{3}{16}$	$2\frac{1}{2}$	$4\frac{5}{8}$	6	$1\frac{1}{4}$	$2\frac{1}{8}$	$3\frac{1}{4}$	4	$\frac{3}{16}$	$5\frac{1}{4}$	$\frac{7}{16}$	$\frac{1}{4}$
$1\frac{7}{16}$	$2\frac{7}{8}$	$5\frac{1}{8}$	$6\frac{3}{4}$	$1\frac{3}{8}$	$2\frac{1}{4}$	$3\frac{7}{8}$	$4\frac{5}{8}$	$\frac{3}{16}$	$5\frac{3}{4}$	$\frac{1}{2}$	$\frac{5}{16}$
$3\frac{11}{16}$	$6\frac{1}{2}$	10	12	$2\frac{3}{8}$	$4\frac{1}{2}$	$7\frac{1}{4}$	$8\frac{7}{8}$	$\frac{5}{16}$	$10\frac{3}{4}$	1	$\frac{1}{2}$
$3\frac{15}{16}$	7	$10\frac{5}{8}$	$12\frac{1}{2}$	$2\frac{3}{8}$	$4\frac{1}{2}$	$7\frac{1}{2}$	$9\frac{3}{8}$	$\frac{3}{8}$	$11\frac{1}{4}$	1	$\frac{9}{16}$

Figure 22·151 Flange coupling. **Probs. 254 to 257.**

Problems 254 to 257 Fig. 22·151. Make a complete working drawing of one of the sizes of *flange coupling*. Choose a suitable scale. Show the bolts and key in position. The missing dimensions are to be supplied by the student.

Problems 258 to 260 Fig. 22·152. Make a complete working drawing of a *cast-iron pulley*, with one view in section. Taper of arms about $\frac{1}{2}''$ per foot. For dimensions see accompanying table.

Problem	*D*	*F*	*S*	*H*	*L*	*C*	*A*	*E*
258	8	$3\frac{1}{4}$	$1\frac{1}{4}$	$2\frac{3}{8}$	$2\frac{1}{2}$	$\frac{1}{32}$	$\frac{3}{4}$	$\frac{7}{16}$
259	16	$6\frac{1}{2}$	2	$3\frac{1}{4}$	4	$\frac{1}{16}$	$1\frac{1}{8}$	$\frac{9}{16}$
260	30	$8\frac{1}{2}$	$2\frac{3}{4}$	$4\frac{1}{2}$	$5\frac{1}{2}$	$\frac{3}{32}$	$1\frac{1}{2}$	$\frac{13}{16}$

Problems 261 to 264 Fig. 22·153. Make a complete working drawing of a *Babbitted bearing*, with front and side views as half sections. Missing dimensions to be supplied by the student. For dimensions see table at the foot of page 343.

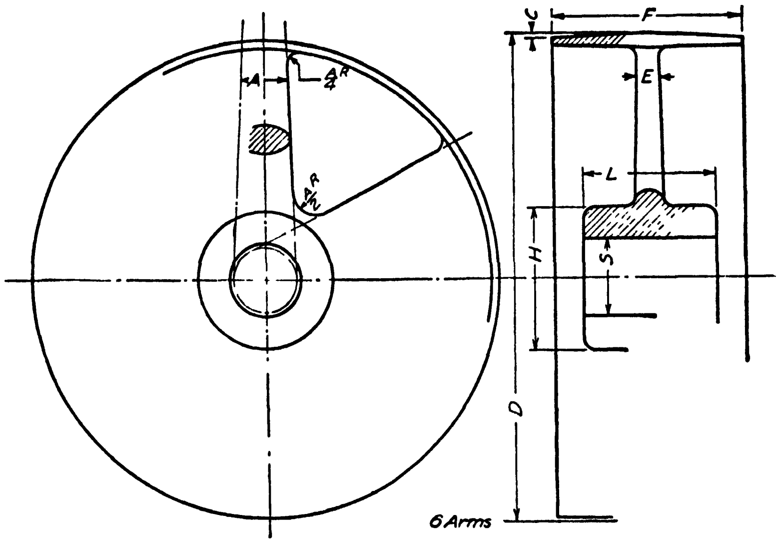


Figure 22·152 Cast-iron pulley. **Probs. 258 to 260.**

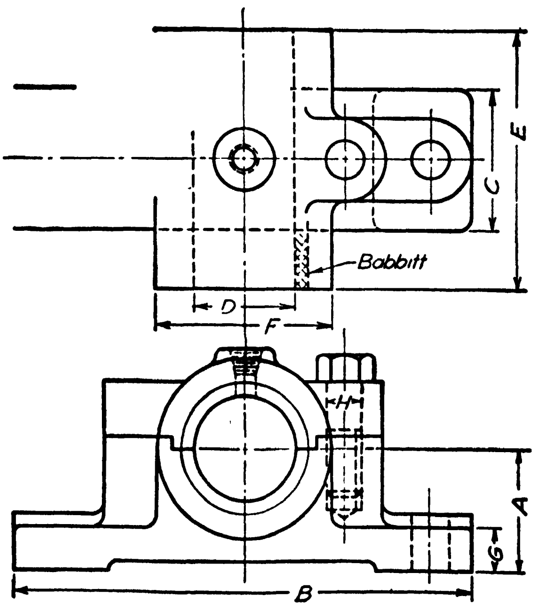


Figure 22·153 Babbitted bearing. **Probs. 261 to 264.**

Problem	*D*	*A*	*B*	*C*	*E*	*F*	*G*	*H*
261	1	1¼	4¾	1⅜	2½	1¾	½	⅜
262	1½	1¾	6¾	2	3¾	2⅝	⅝	½
263	2	2¼	8¾	2½	5	3½	¾	½
264	2½	2¾	10¾	3⅛	6¼	4⅜	⅞	⅝

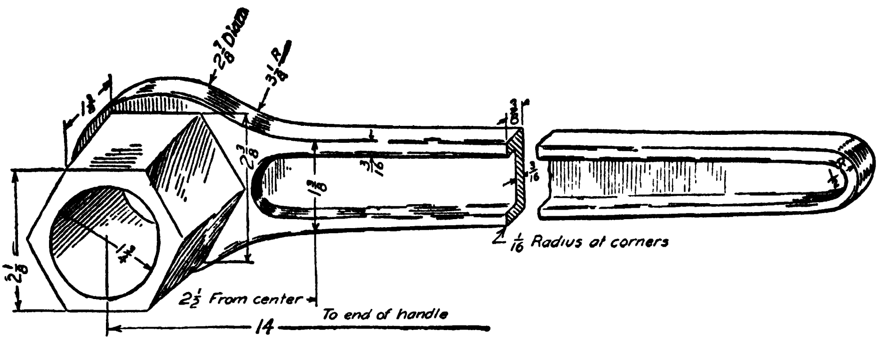


Figure 22·154 Plug wrench. **Prob. 265.**

Problem 265 Fig. 22·154. Make a completely dimensioned two-view working drawing of the *plug wrench.* Show a revolved section through the handle. Consider the choice of views, scale, and placing of views before starting the drawing.

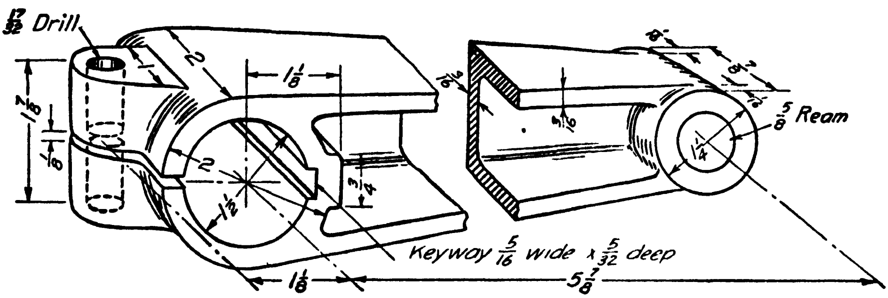


Figure 22·155 Lever. **Prob. 266.**

Problem 266 Fig. 22·155. Make a two-view working drawing of the *lever* with all necessary dimensions. Use your judgment regarding finished surfaces.

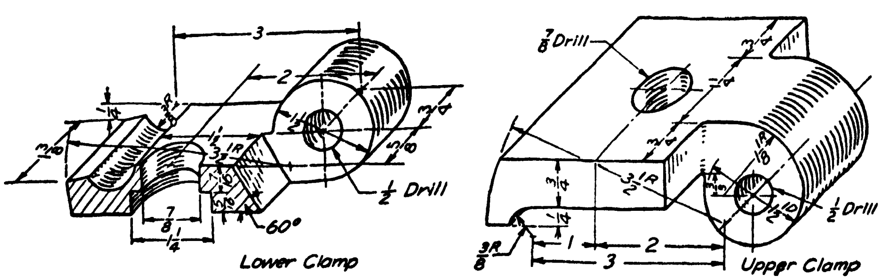


Figure 22·156 Upper and lower clamps. **Prob. 267.**

Problem 267 Fig. 22·156. Make a working drawing showing the proper views of the *upper and lower clamps.* One-half of the lower clamp is shown in the figure. The whole clamp should be drawn. Consider the choice of views, scale, and placing of views before starting the drawing.

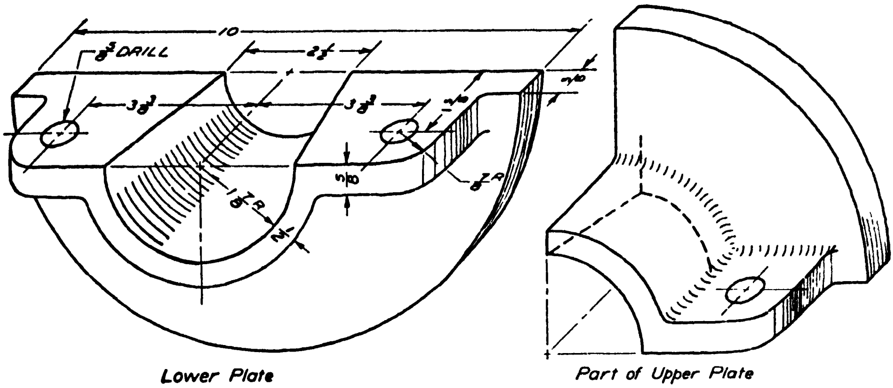


Figure 22·157 Two-part end plate. **Prob. 268.**

Problem 268 Fig. 22·157. Make a working drawing of the *two-part end plate.* Use hex-head bolts and nuts.

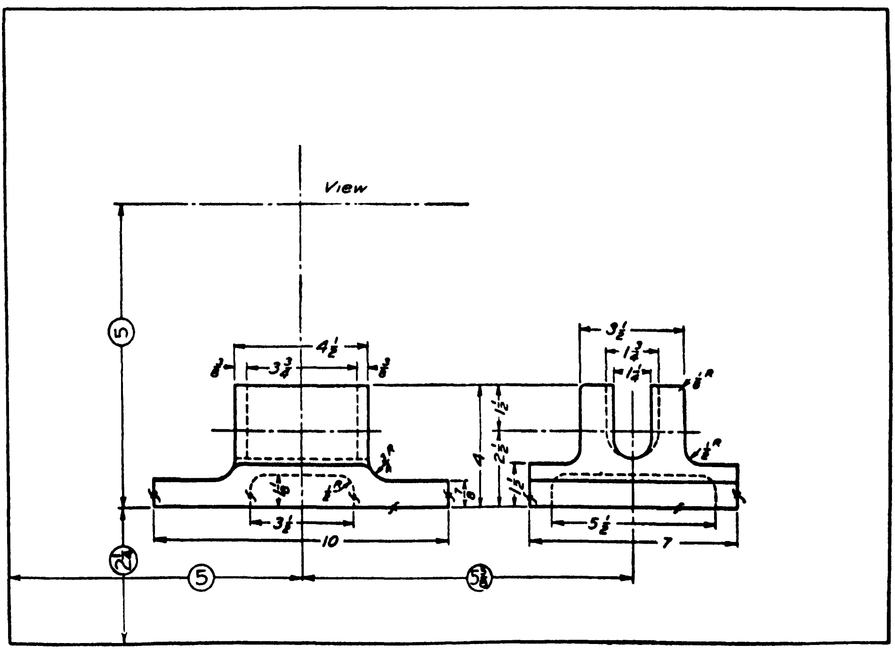


Figure 22·158 Slide valve. **Prob. 269.**

Problem 269 Fig. 22·158. Make a three-view working drawing of the *slide valve,* showing the front view as a section. Completely dimension the drawing. Material is cast iron. Add notes where necessary and a suitable title.

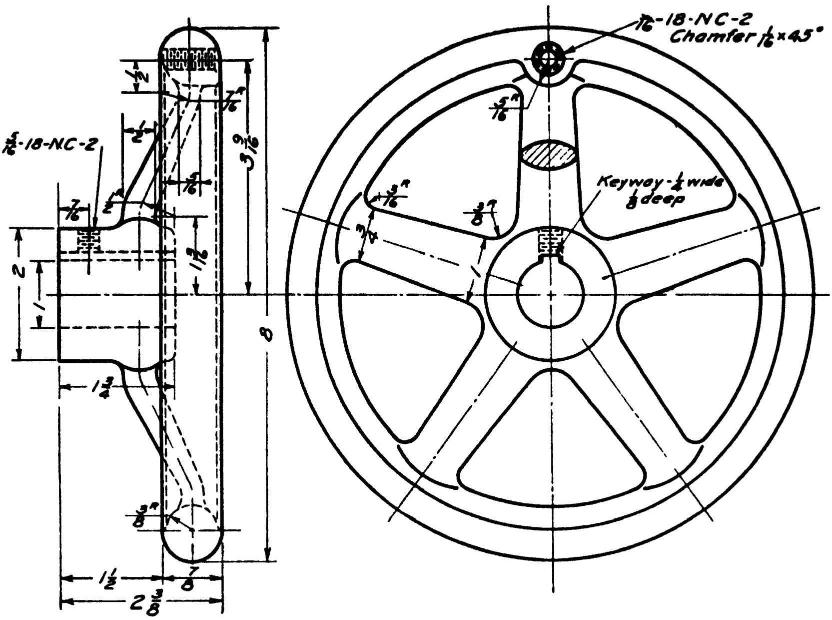


Figure 22·159 Handwheel. **Prob. 270.**

Problem 270 Fig. 22·159. Make a two-view working drawing of the *handwheel*, showing the left view as a section. Read Art. 11·10 regarding arms in section. Consider choice of scale and arrangement of views before starting the drawing. Add a suitable title.

Problem 271 Fig. 22·160. Make a three-view working drawing of the *center plate*, one view to be a section. Consider choice of scale and arrangement of views before starting the drawing. Add a suitable title.

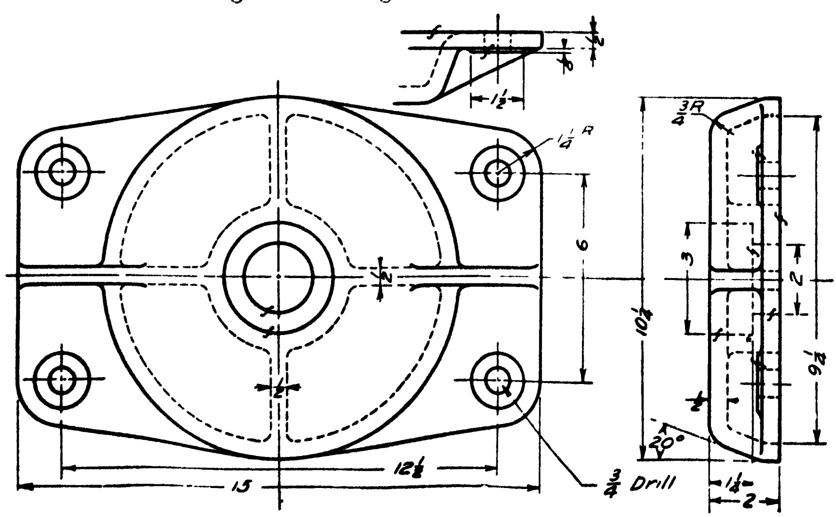


Figure 22·160 Center plate. **Prob. 271.**

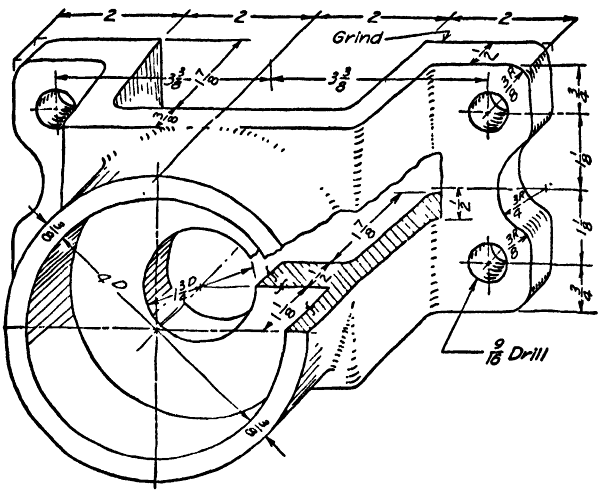


Figure 22·161 Bearing holder. **Prob. 272.**

Problem 272 Fig. 22·161. Make a three-view working drawing, completely dimensioned, of the *bearing holder*. Consider the choice of views, scale, and placing of views before starting the drawing.

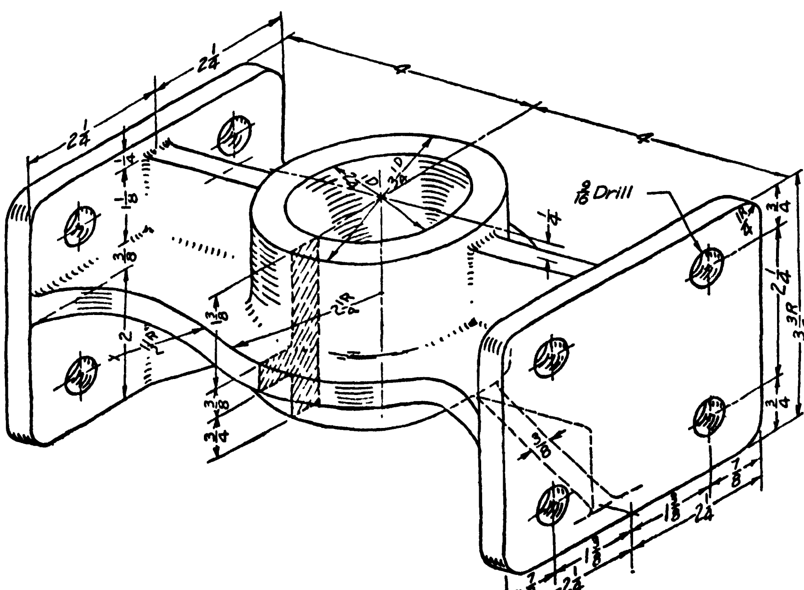


Figure 22·162 Lift-screw bracket. **Prob. 273.**

Problem 273 Fig. 22·162. Make a working drawing of the *lift-screw bracket.*

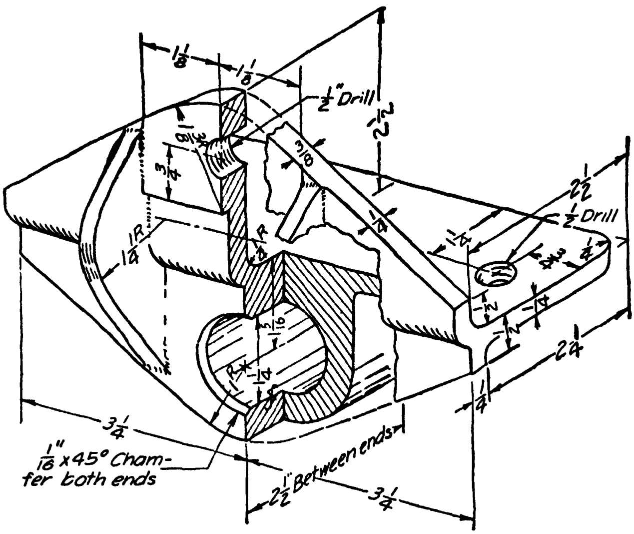


Figure 22·163 Angle bearing. **Prob. 274.**

Problem 274 Fig. 22·163. Make a working drawing of the *angle bearing.* This object is symmetrical, but in the picture a part is broken away to show the interior. Consider choice of views, treatment of views, and scale. Work out the spacing of the views to allow ample room for dimensions and notes. Indicate the surfaces you assume to be finished. Add a suitable title.

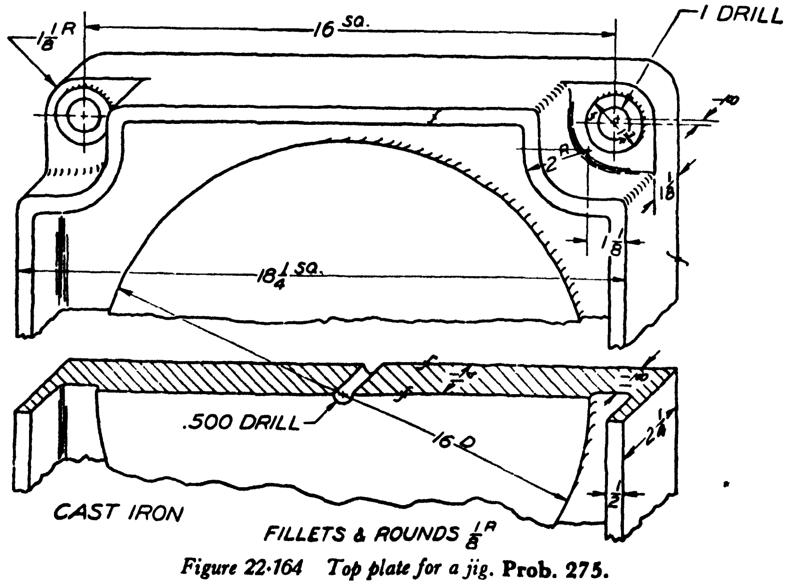


Figure 22·164 Top plate for a jig. **Prob. 275.**

Problem 275 Fig. 22·164. Make a working drawing for the *top plate for a jig,* shown in the broken view. Material is cast iron.

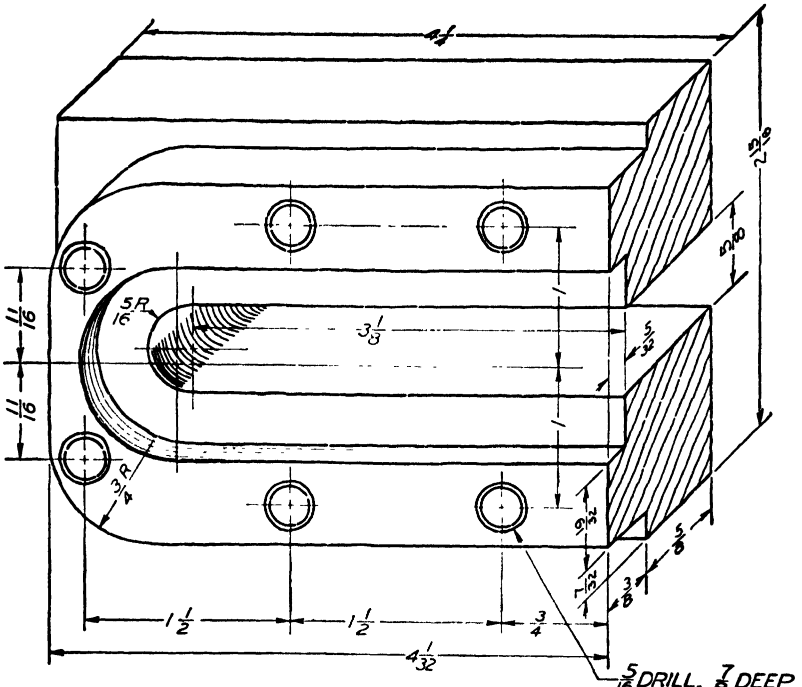


Figure 22·165 Fuel gage block. **Prob. 276.** Make a working drawing of the *fuel gage block,* one-half of which is shown. Material is machine steel. Finish all over.

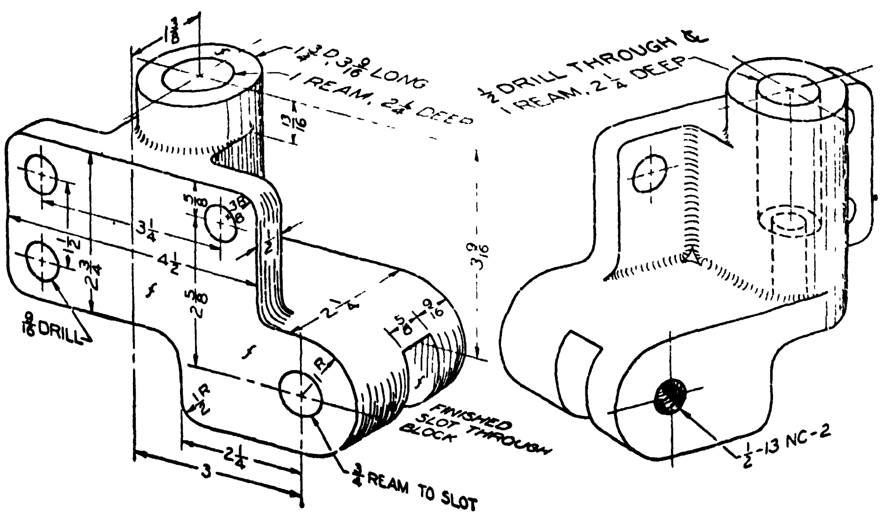


Figure 22·166 **Prob. 277.** Make a working drawing of the *slide arm bracket.* Semisteel casting.

GROUP 11. WOOD CONSTRUCTIONS AND FURNITURE DRAWINGS

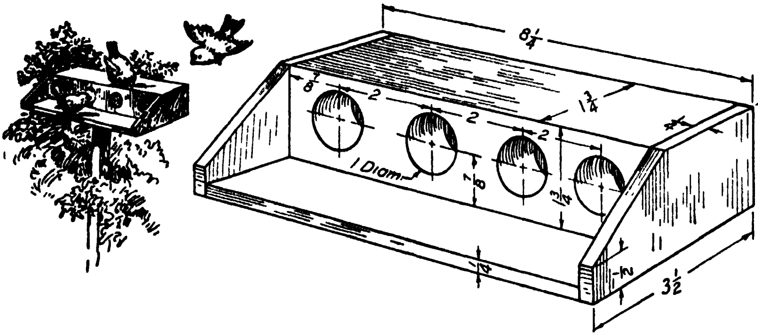


Figure 22·167 Bird feeding stick. **Prob. 278.**

Problem 278 Fig. 22·167. Make a working drawing of the *bird feeding stick.*

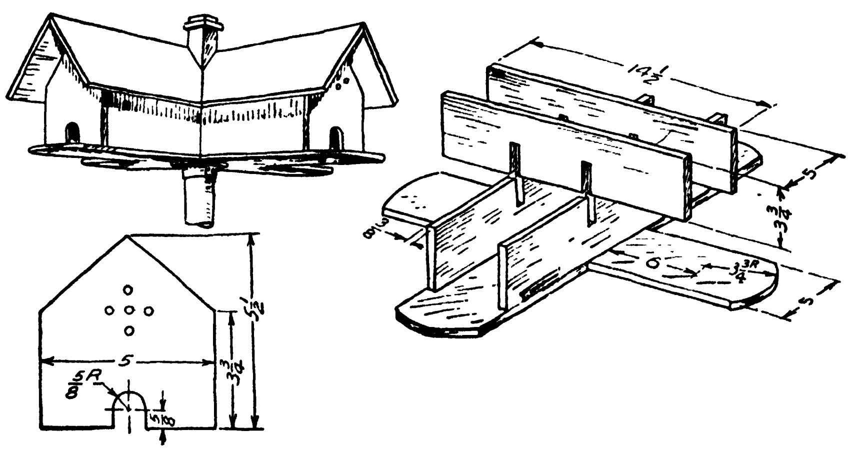


Figure 22·168 Martin house. **Prob. 279.**

Problem 279 Fig. 22·168. Make a working drawing of the *martin house.* Consider the choice and treatment of views and choice of scale. Material is ⅜" white pine. Supply details and dimensions not shown in the pictures.

Problem 280 Fig. 22·169. Make a working drawing of the *radio shelf.* Select views and scale.

Problem 281 Fig. 22·170. Make a working drawing of the *bookrack*. Select views and scale.

Problem 282 Fig. 22·171. Make a working drawing of the *four-compartment bookrack*. Select views and scale.

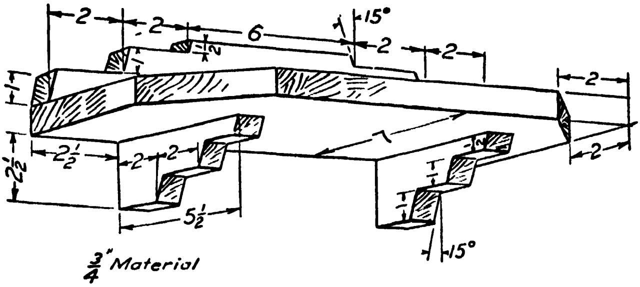


Figure 22·169 Radio shelf. **Prob. 280.**

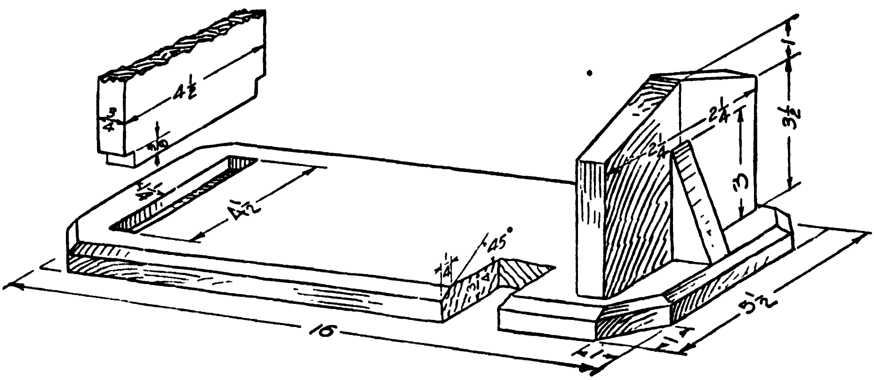


Figure 22·170 Bookrack. **Prob. 281.**

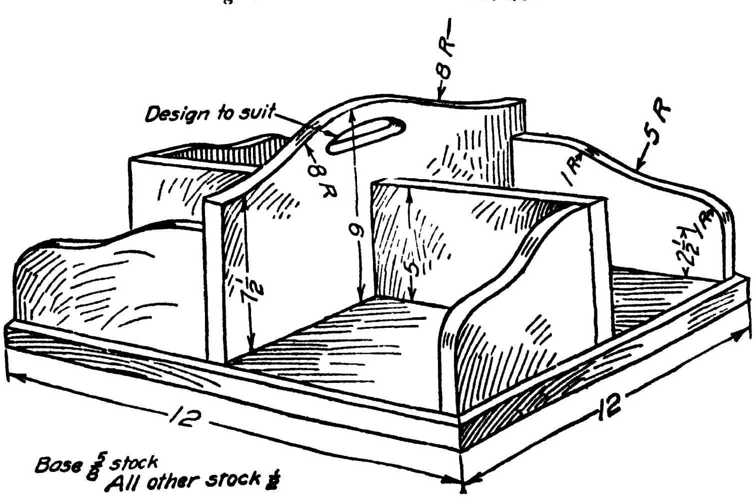


Figure 22·171 Four-compartment bookrack. **Prob. 282.**

Problem 283 Fig. 22·172. Make a working drawing with complete dimensions for the *bench hook.*

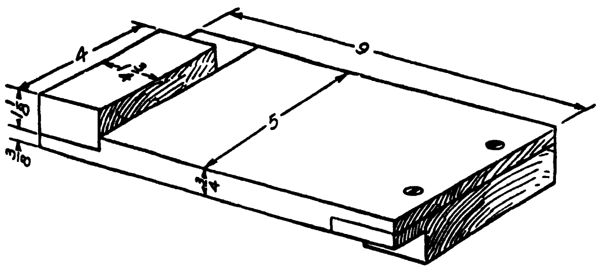


Figure 22·172 Bench hook. **Prob. 283.**

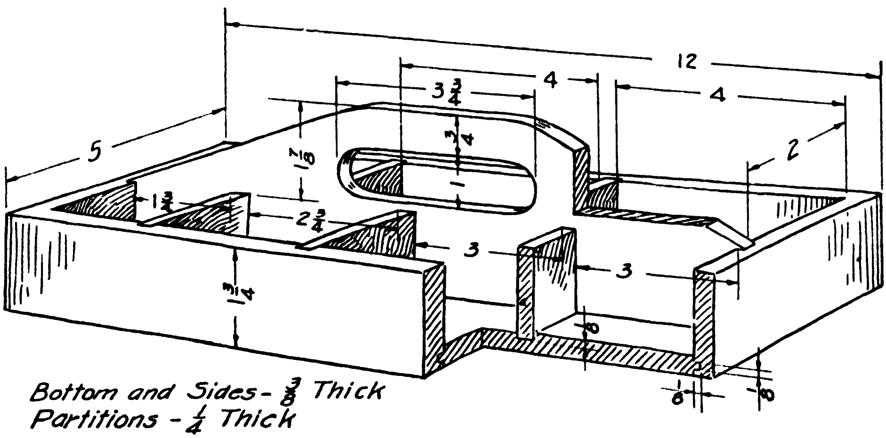


Figure 22·173 Nail box. **Prob. 284.**

Problem 284 Fig. 22·173. Make a working drawing of the *nail box.*
Problem 285 Fig. 22·174. Make a working drawing of the *sawhorse.*

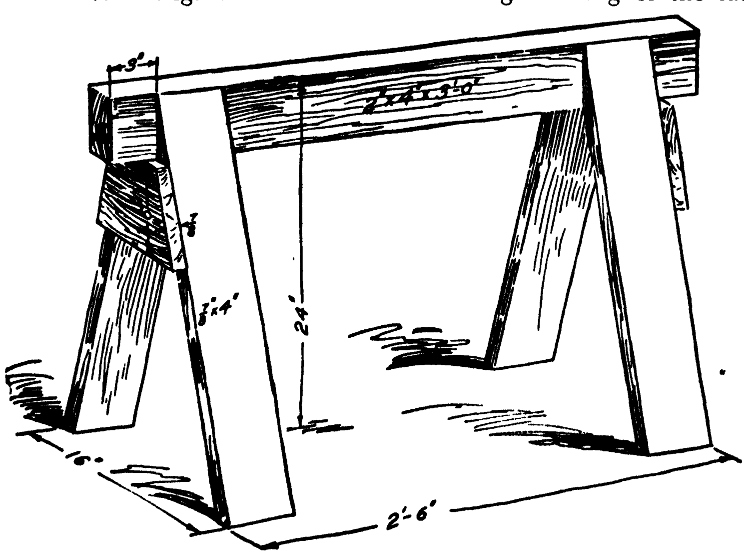


Figure 22·174 Sawhorse. **Prob. 285.**

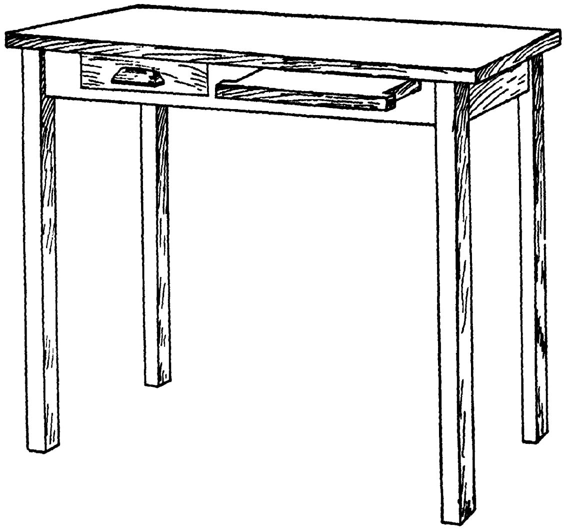


Figure 22·175 Typewriter table. **Prob. 286.**

Problem 286 Fig. 22·175. Make a working drawing of the *typewriter table.* Legs, 1¼″ sq. Top, 18″ × 32″ × 1¼″. Height 26″. Apron 4″ deep. Supply details and dimensions not shown.

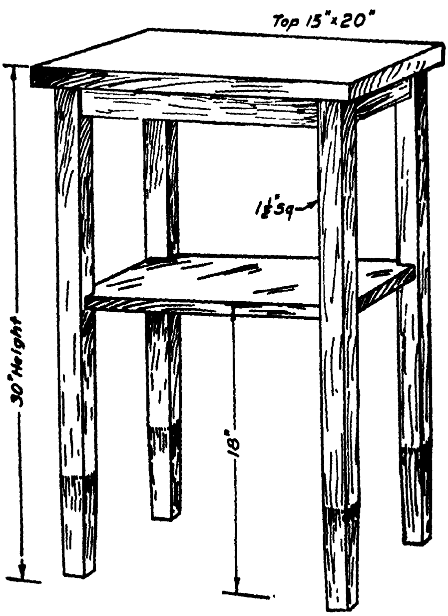


Figure 22·176 **Prob. 287.** Make a working drawing of the *telephone stand.* Supply details and dimensions not shown.

Problem 288 Fig. 22·177. Make a working drawing of the *waste basket.* 12″ sq. at top, 10″ sq. at bottom, 16″ high. Sides of hardboard or similar material.

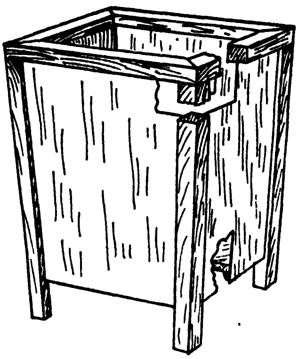


Figure 22·177 Waste basket. **Prob. 288.**

Problem 289 Fig. 22·178. Make a working drawing of the *music cabinet.* Supply missing details and hardware for door.

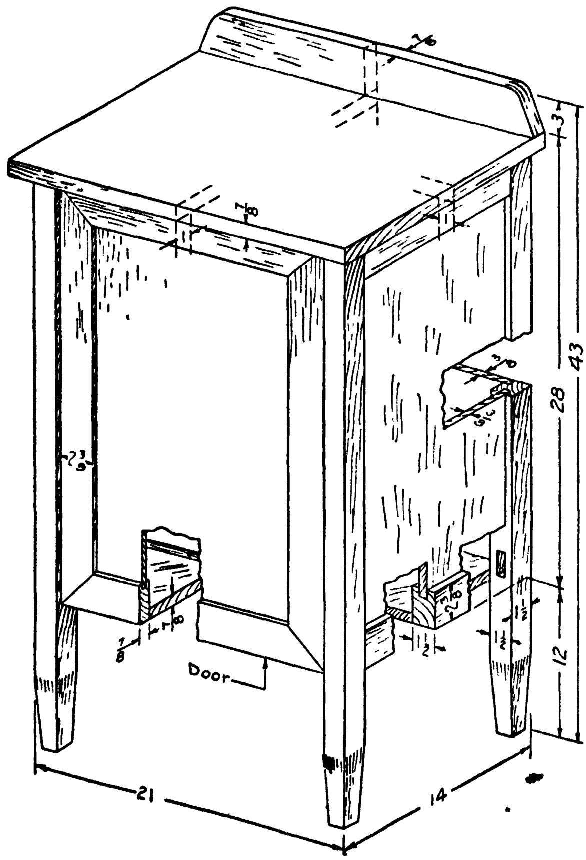


Figure 22·178 Music cabinet. **Prob. 289.**

Problem 290 Fig. 22·179. Make an assembly working drawing, with extra part views if necessary, of the costumer.

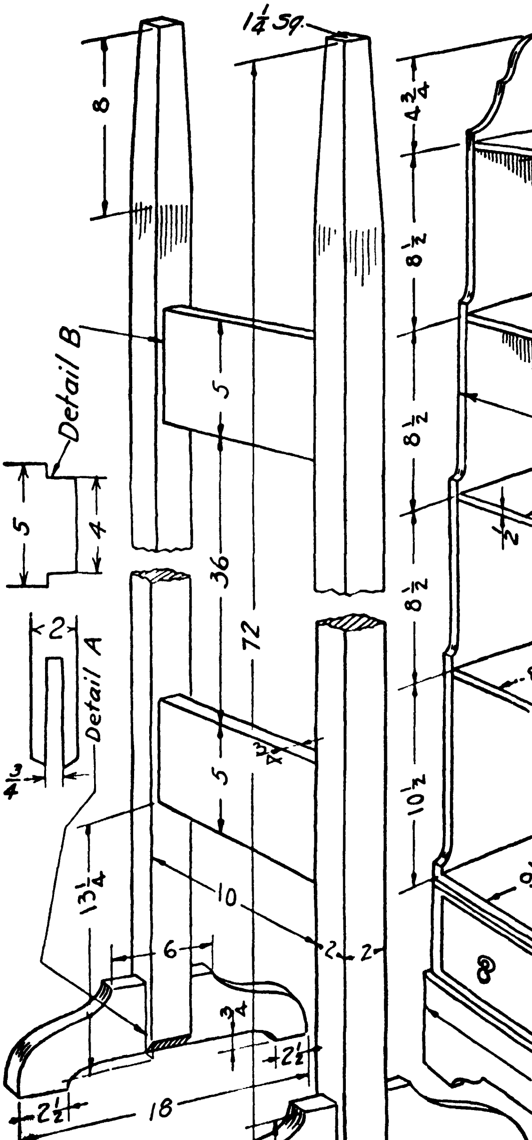


Figure 22·179 Costumer. **Prob. 290.**

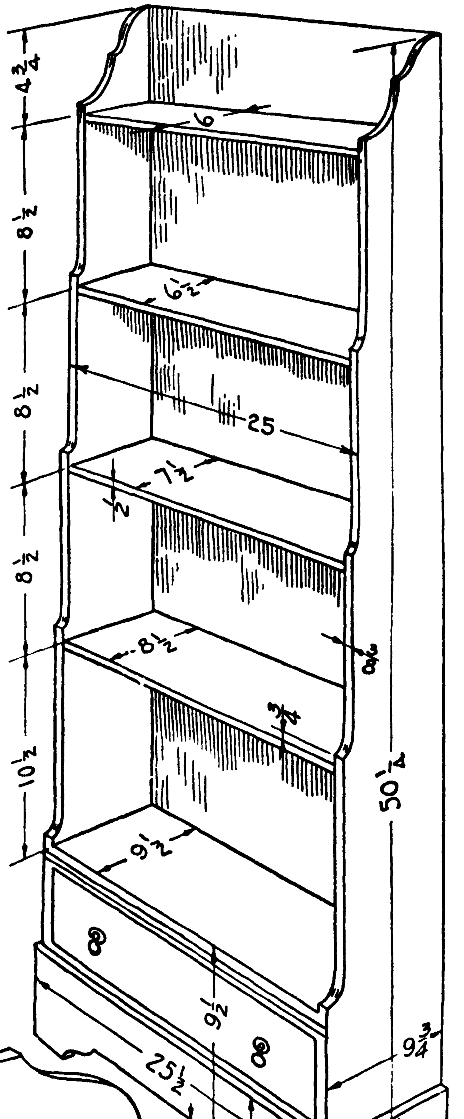


Figure 22·180 Book pier. **Prob. 291.**

Problem 291 Fig. 22·180. Make an assembly working drawing of the *book pier*. Design the construction of the drawer.

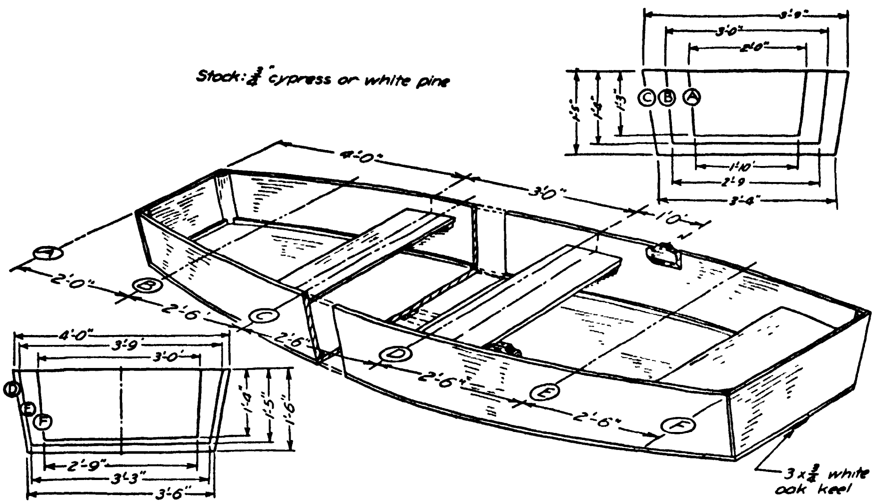


Figure 22·181 Boat. **Prob. 292.**

Problem 292 Fig. 22·181. Make detail and assembly drawings for the *boat*. The shape is defined by the inside dimensions of the bulkheads *A*, *B*, *C*, *D*, *E* and *F*. These shapes may be drawn separate or "stacked." The widths of the seats from bow to stern are 1′-0″, 1′-3″ and 1′-3″. Select views and scale. Use two standard sheets.

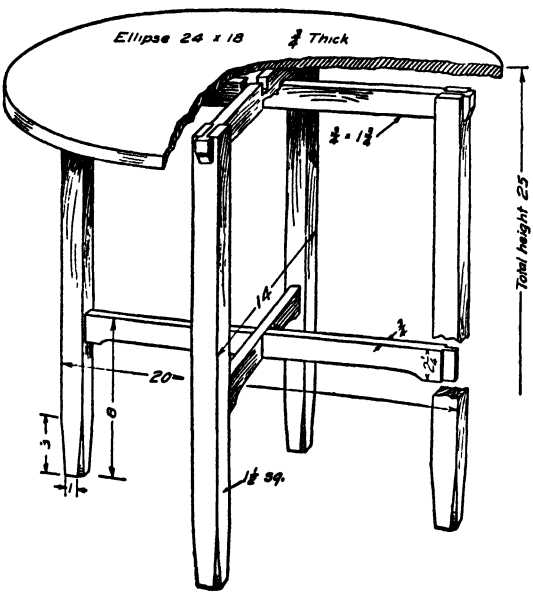


Figure 22·182 Tea table. **Prob. 293.**

Problem 293 Fig. 22·182. Make an assembly working drawing, with extra part views if necessary, for the *tea table*. Supply missing dimensions.

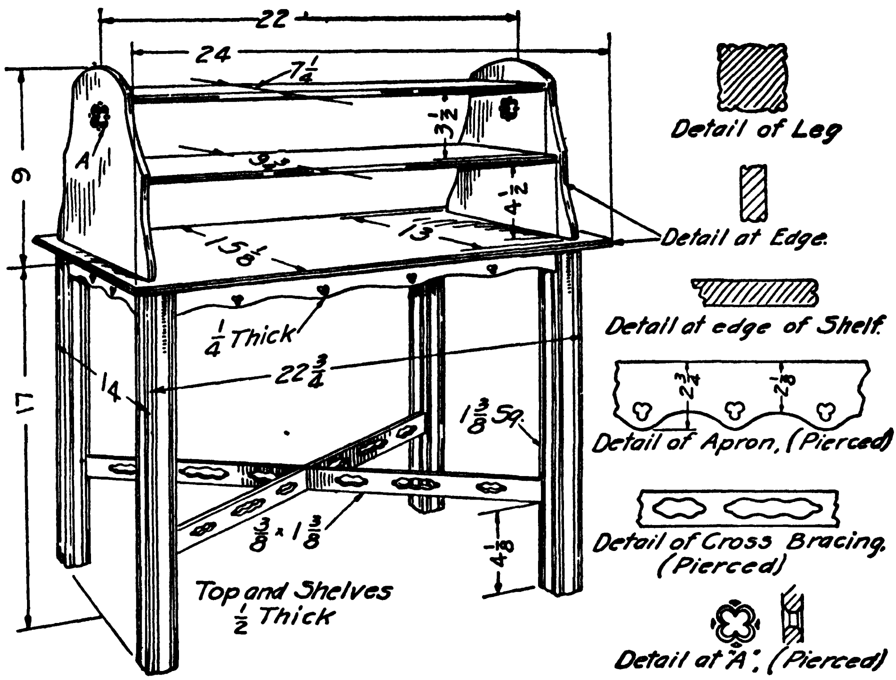


Figure 22·183 **Prob. 294.** Make a drawing of the *magazine table.*

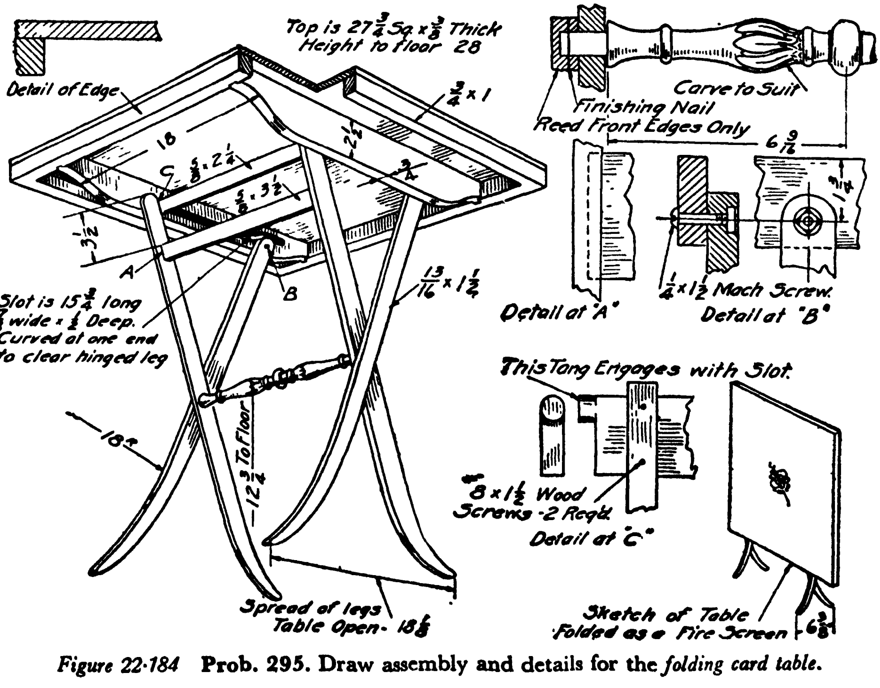


Figure 22·184 **Prob. 295.** Draw assembly and details for the *folding card table.*

GROUP 12. ASSEMBLY AND DETAIL DRAWINGS

22·14 Before starting these problems, study the views given and see just what is required in each case. See how many pieces are to be represented and the best method of showing them. It will be necessary to use judgment to arrange for the spacing of the views for detail drawings of several pieces. Each piece should be completely dimensioned and should be named.

Assembly drawings may have different treatments according to the purpose to be served. They may have no dimensions; they may have dimensions necessary for assembling or erection, for operation, etc.; or they may have all dimensions. If not stated in the problem, consult your instructor.

The chapters on size description, technique of the finished drawing, bolts and screws, and mechanical drafting should be used for study and reference in connection with these assembly and detail drawings.

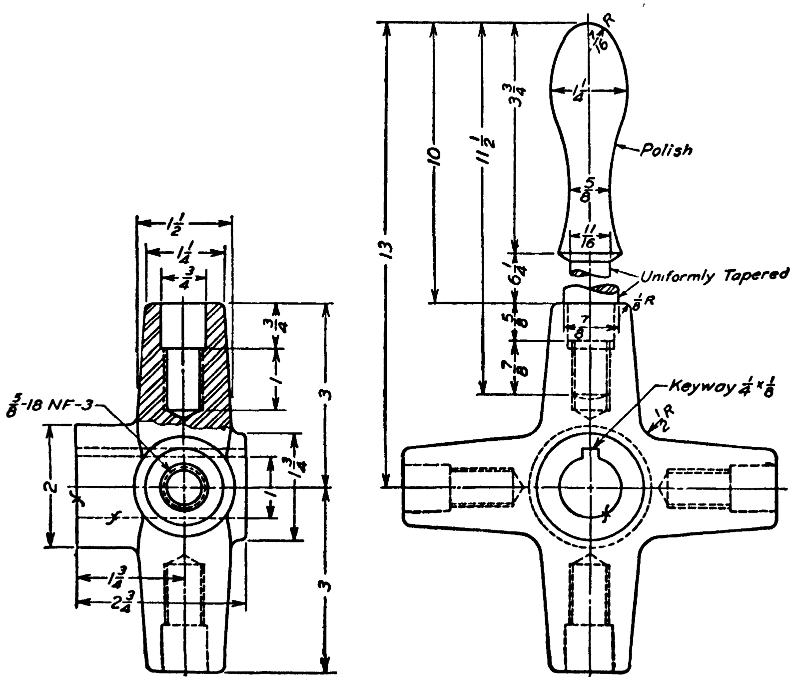


Figure 22·185 Pilot hub. **Prob. 296.**

Problem 296 Fig. 22·185. Make detail drawings of the *pilot hub*, showing each piece fully dimensioned.

Problem 297 Fig. 22·186. Make detail working drawings of the *hung bearing*, showing each piece fully dimensioned. All bolts are 5/8″ in diameter.

Problem 298 Fig. 22·187. Make working detail drawings of base, pulley, bushing, and shaft, with bill of material for complete *pulley and stand* unit. Full size, three sheets. If necessary, the top view of base may be a half plan.

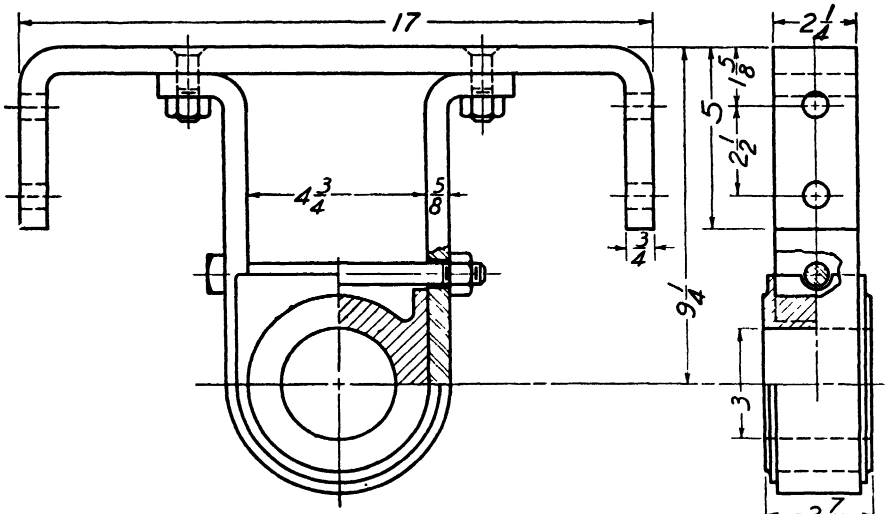


Figure 22·186 Hung bearing. **Prob. 297.**

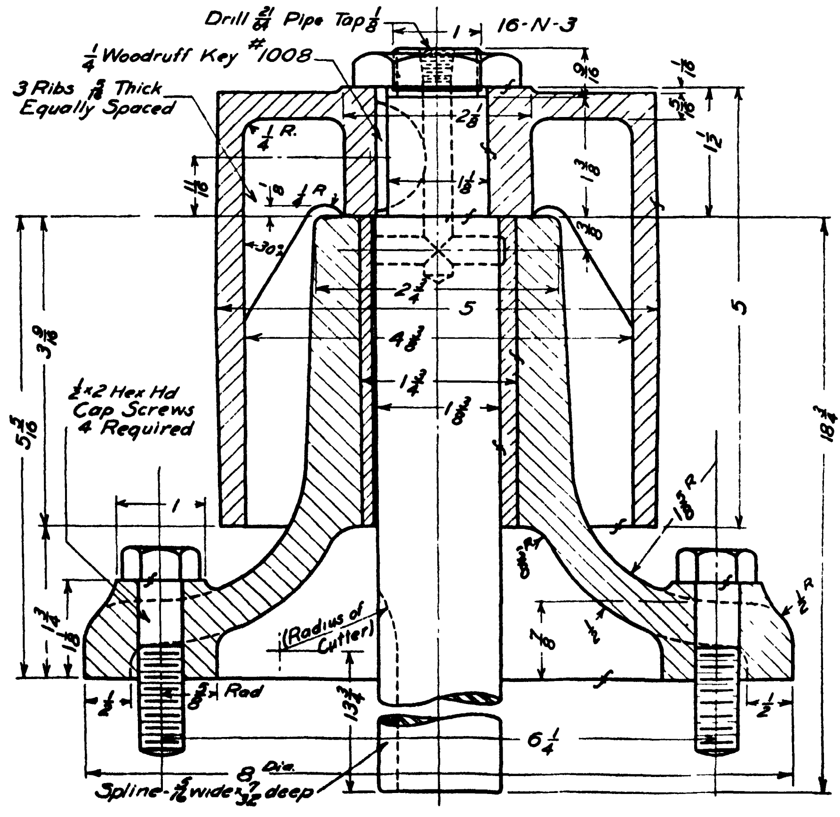
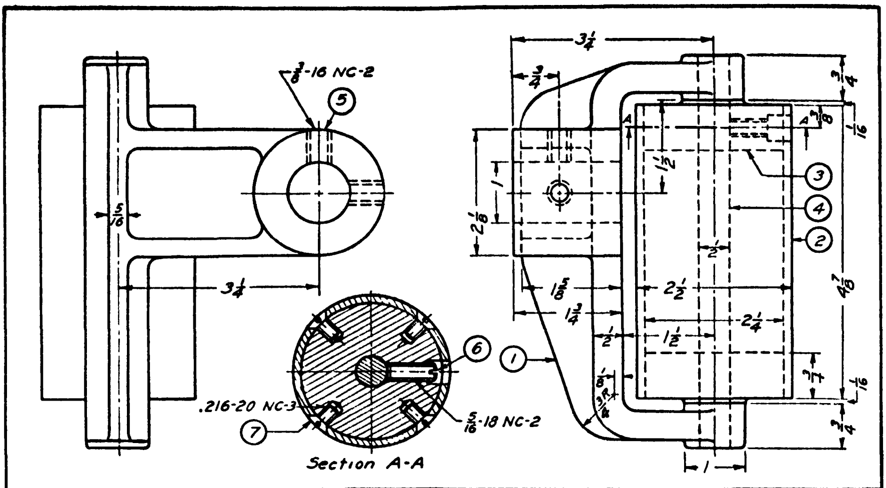


Figure 22·187 Pulley and stand. **Prob. 298.**



No	Part	Mat'l	No Req'd	No	Part	Mat'l	No Req'd
1	Bracket	C I	2	5	Set Screw	Steel	4
2	Tube Roll	Steel Tube	2	6	" "	"	4
3	Bushing	C F S	4	7	Mch Screw	"	8
4	Shaft	C F S.	2				

Figure 22·188 Pivot-guide roll. **Prob. 299.**

Problem 299 Fig. 22·188. Make detail drawings of the *pivot-guide roll.*

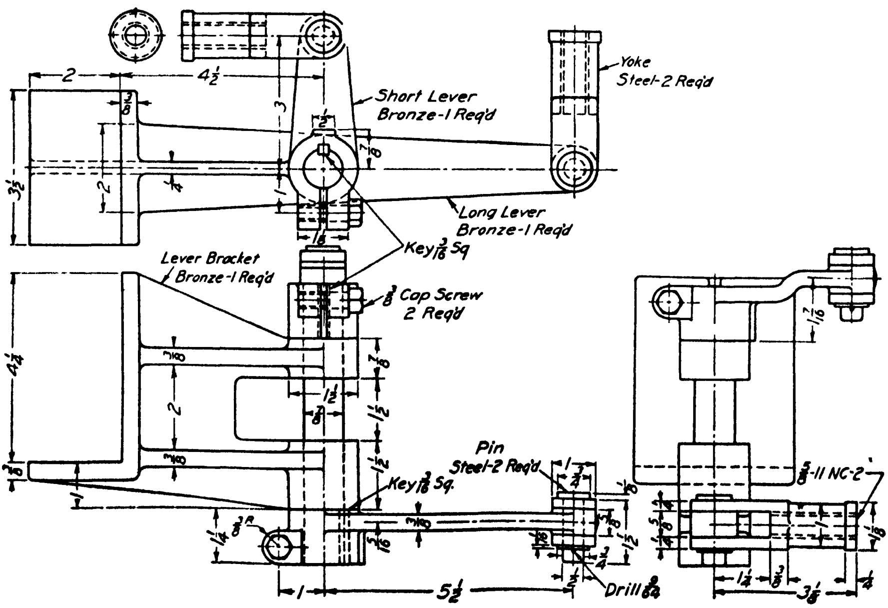


Figure 22·189 Bell-crank reverse. **Prob. 300.**

Problem 300 Fig. 22·189. Make detail drawings of the *bell-crank reverse.*

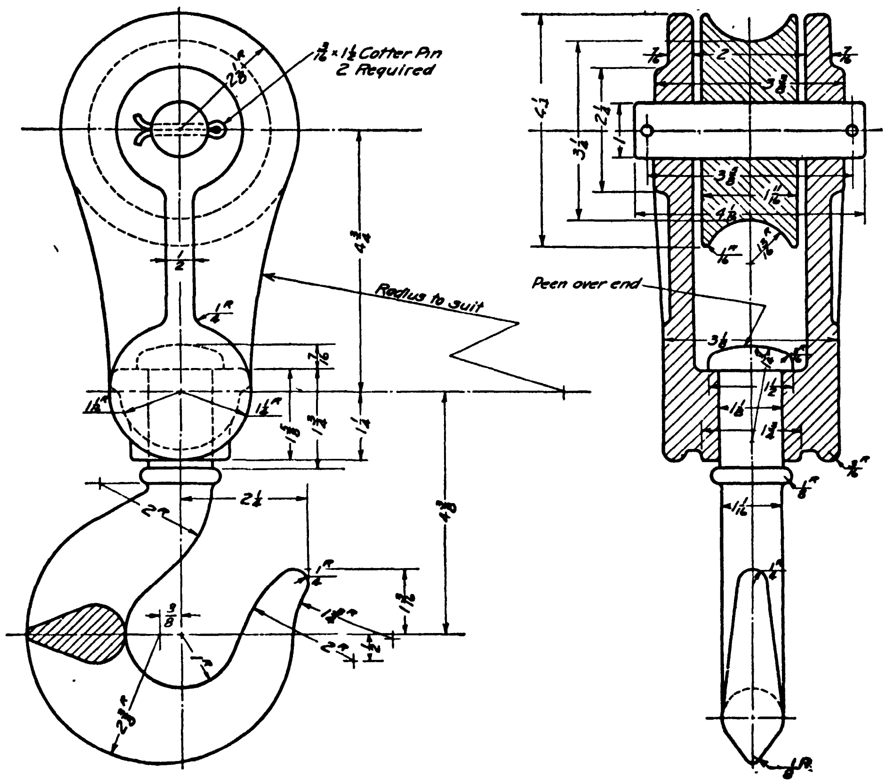


Figure 22·190 **Prob. 301.** Make detail drawings of the *crane hook.*

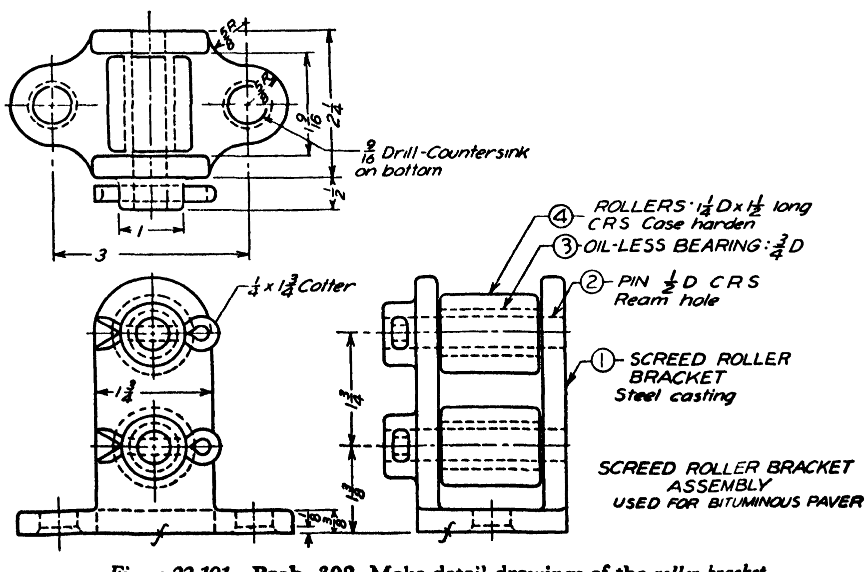
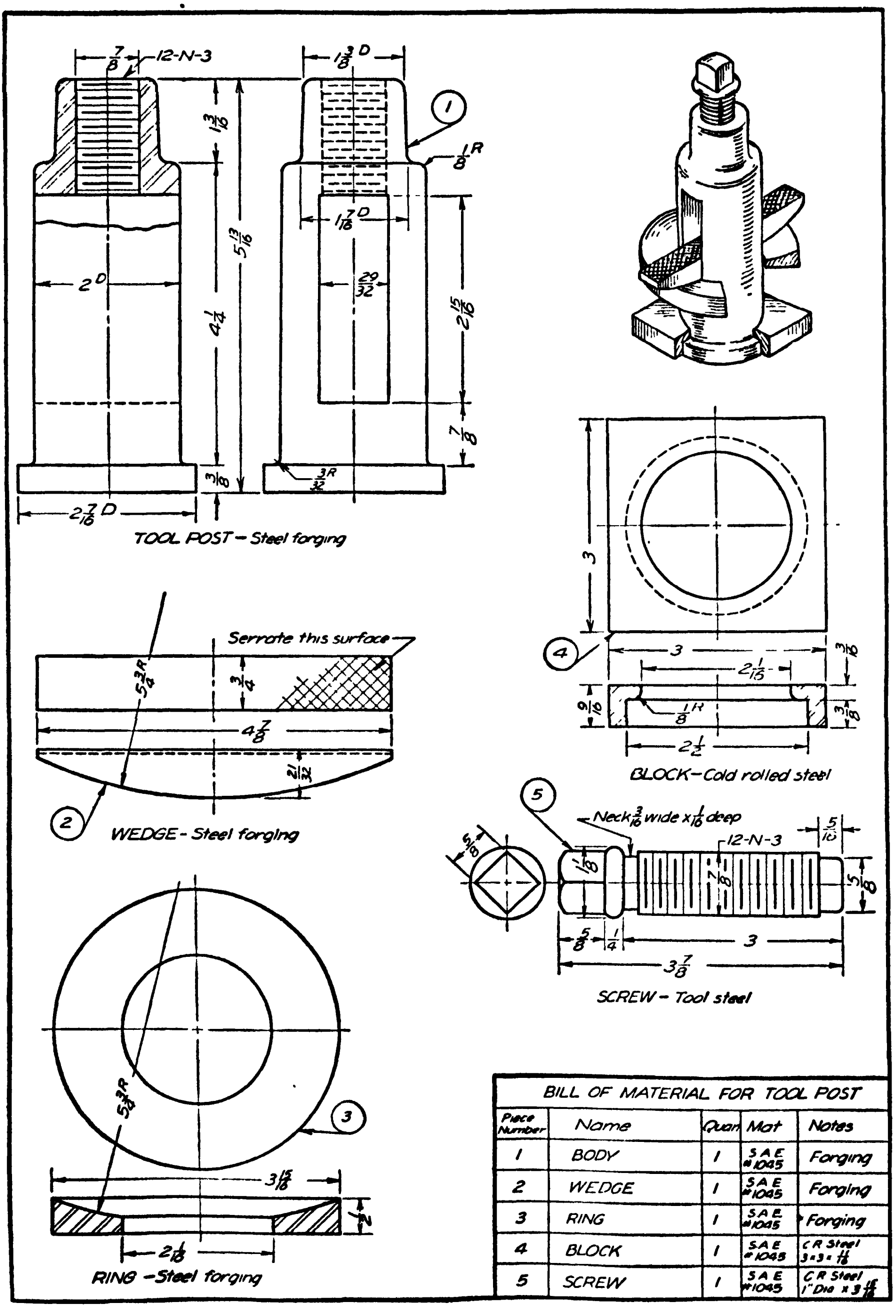


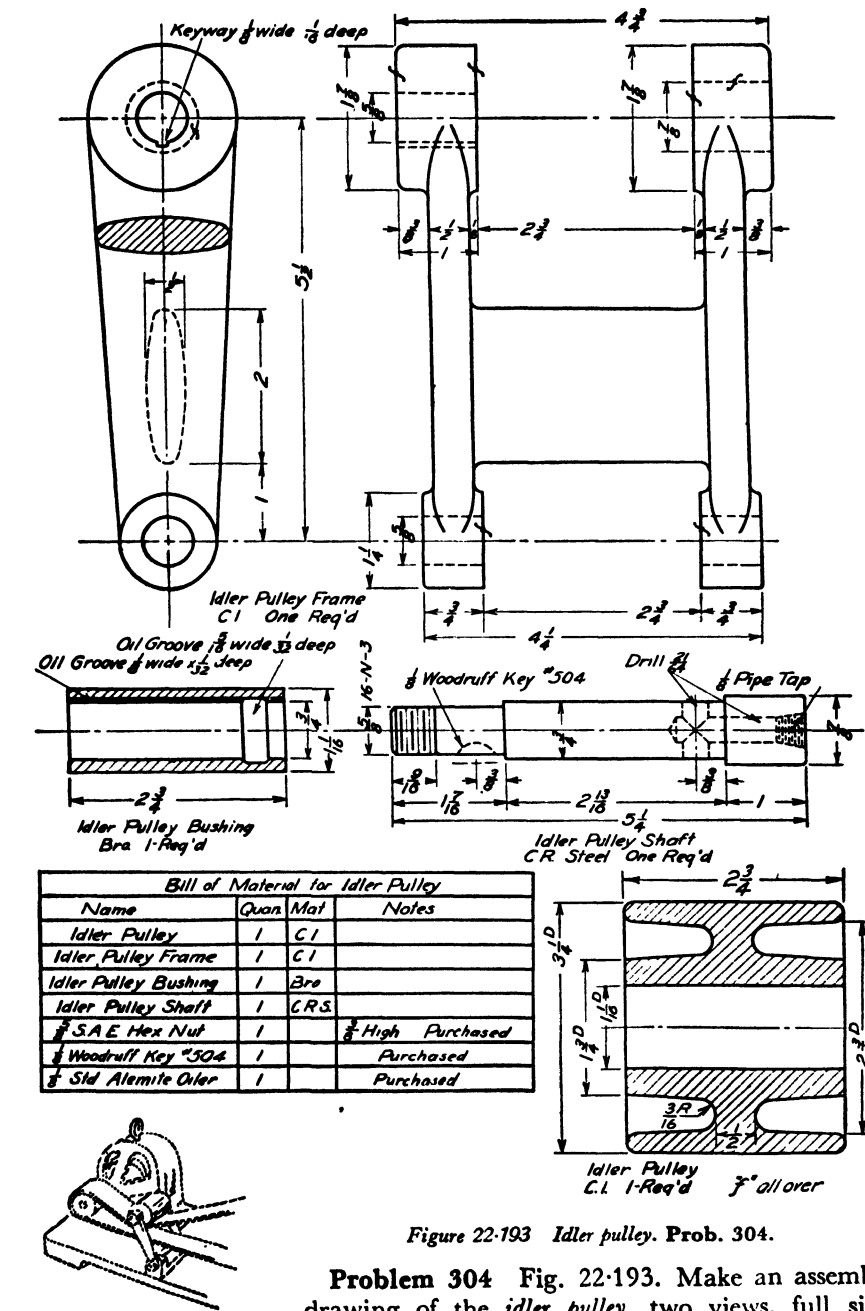
Figure 22·191 **Prob. 302.** Make detail drawings of the *roller bracket.*



BILL OF MATERIAL FOR TOOL POST				
Piece Number	Name	Quan	Mat	Notes
1	BODY	1	SAE #1045	Forging
2	WEDGE	1	SAE #1045	Forging
3	RING	1	SAE #1045	Forging
4	BLOCK	1	SAE #1045	CR Steel 3 x 3 x 11/16
5	SCREW	1	SAE #1045	CR Steel 1" Dia x 3 15/16

Figure 22·192 Tool post. **Prob. 303.**

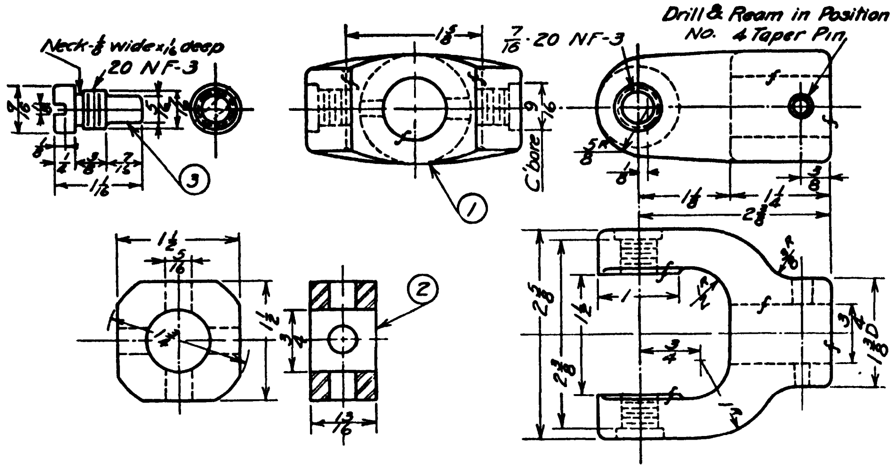
Problem 303 Make a two-view assembly drawing of the *tool-post.*

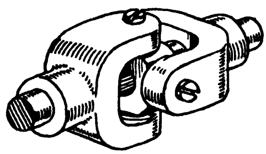


Bill of Material for Idler Pulley			
Name	Quan	Mat	Notes
Idler Pulley	1	CI	
Idler Pulley Frame	1	CI	
Idler Pulley Bushing	1	Bro	
Idler Pulley Shaft	1	CRS	
5/8 SAE Hex Nut	1		3/4 High Purchased
1/8 Woodruff Key #504	1		Purchased
1/8 Std Alemite Oiler	1		Purchased

Figure 22·193 Idler pulley. **Prob. 304.**

Problem 304 Fig. 22·193. Make an assembly drawing of the *idler pulley*, two views, full size, showing pulley, bushing, and upper end of frame in section.





Bill of Material for Universal Joint				
No	Name	Quan	Mat	Notes
1	Fork	2	CI	
2	Ring	1	Steel	
3	Stud	4	Steel	
	No. 4 Taper Pin	2		Purchased

Figure 22·194 Universal joint. **Prob. 305.**

Problem 305 Fig. 22·194. Make a two-view assembly drawing of the *universal joint*, in section.

Problem 306 Fig. 22·195. Make working detail drawings of clutches, driving and driven; clutch cross, muff coupling, collar, bushing and key, with bill of material for complete unit of the *Oldham coupling* (used for connecting the ends of two rotating shafts, not in accurate alignment). Full size. Two sheets.

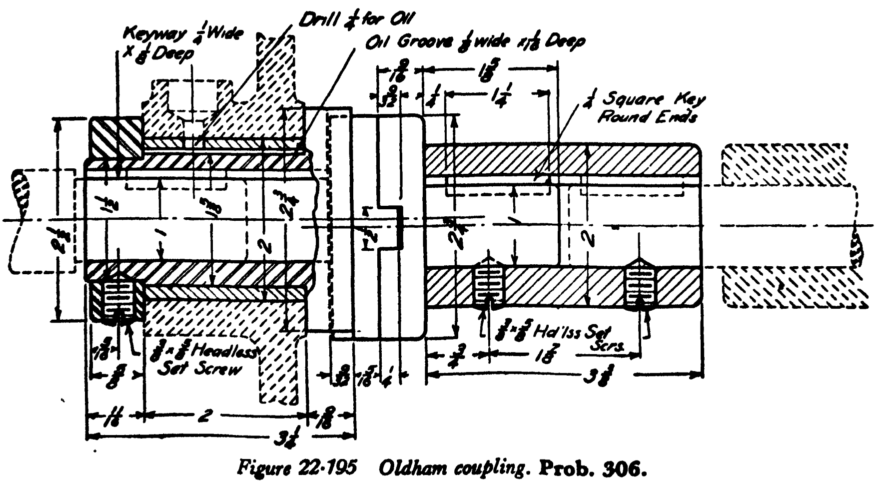
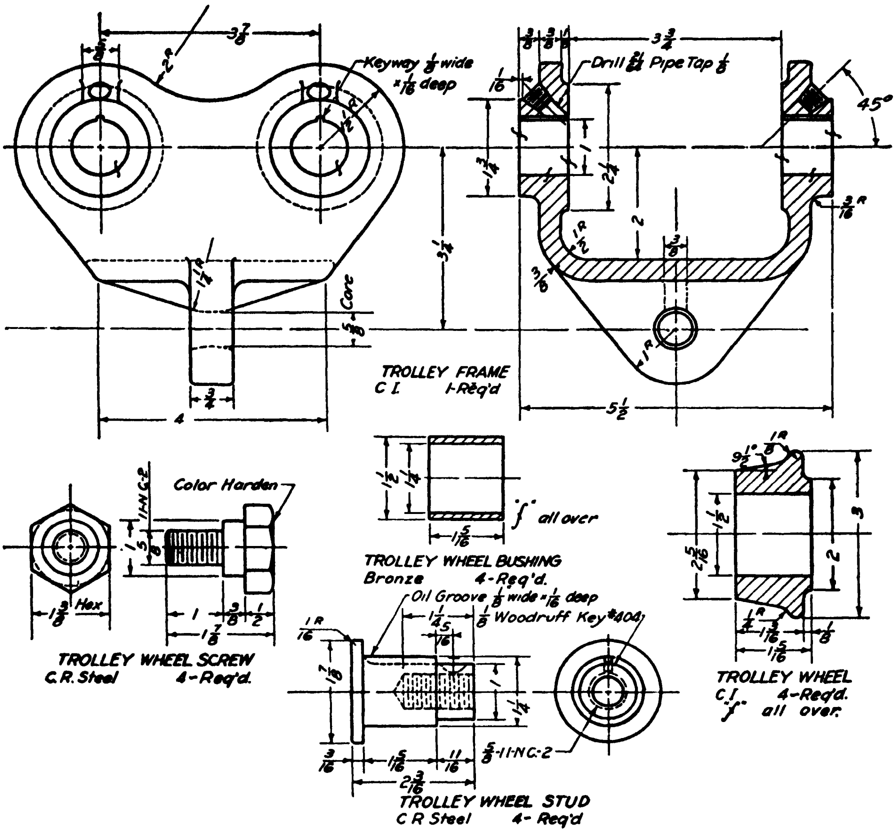


Figure 22·195 Oldham coupling. **Prob. 306.**



BILL OF MATERIAL FOR JIB CRANE TROLLEY

Name	Quan.	Mat'l.	Notes
Trolley Frame	1	C.I.	
Trolley Wheel	4	C.I	
Trolley Wheel Bushing	4	Bro.	
Trolley Wheel Stud	4	C.R.S.	
Trolley Wheel Screw	4	C.R.S	
1/8 Woodruff Key #404	4		Purchased
1/8 Std Alemite Oiler	4		Purchased
1 Lock Washer	4		Purchased

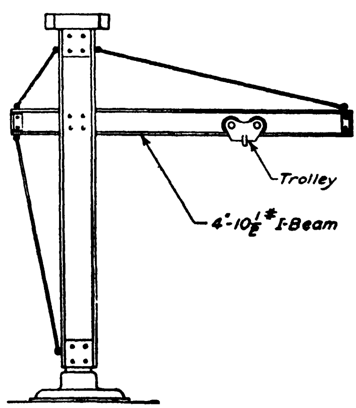


Figure 22·196 Jib crane trolley. **Prob. 307.**

Problem 307 Fig. 22·196. Make an assembly drawing of the *jib crane trolley.* Draw one view in section. The I-beam may be indicated if desired, obtaining dimensions from a structural-steel handbook.

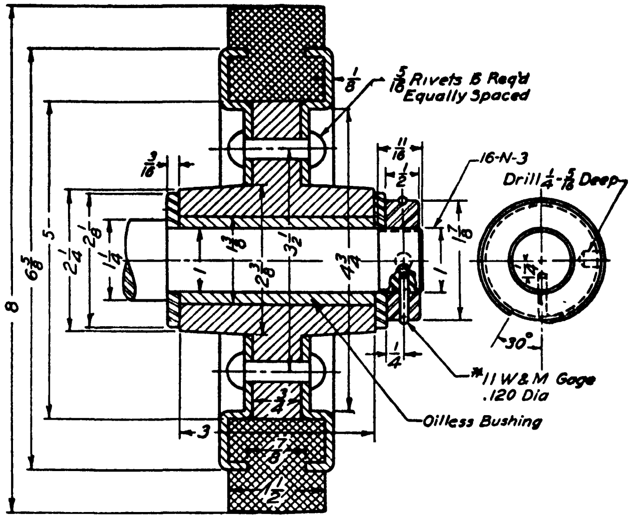


Figure 22·197 Cushion wheel. **Probs. 308 and 309.**

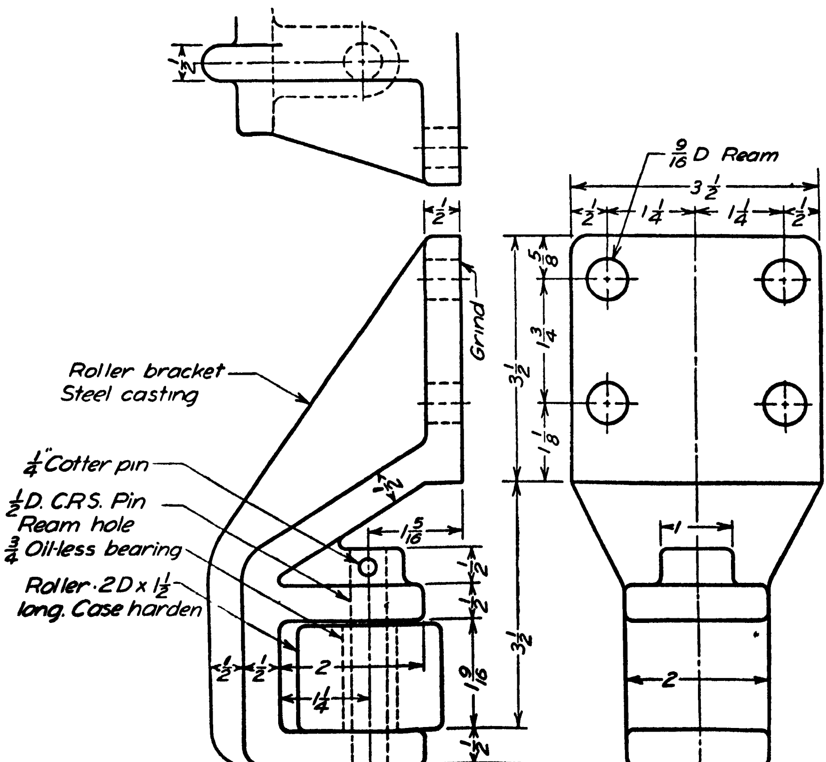


Figure 22·198 Hanger bracket. **Probs. 310 and 311.**

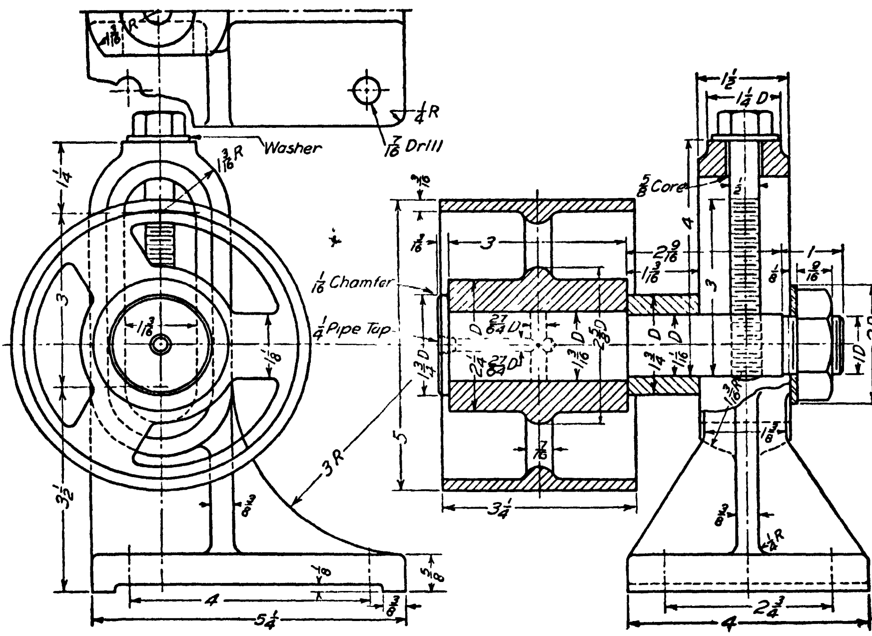


Figure 22·199 Belt tightener. **Probs. 312 and 313.**

Problem 308 Fig. 22·197. Make a front view and section of *cushion wheel,* full size. This type of wheel is used on warehouse or platform trucks to reduce noise and vibration.

Problem 309 Fig. 22·197. Make a complete set of detail drawings, full size, with bill of material, for the *cushion wheel.* Three sheets will be needed. Rivets are purchased and, therefore, would not be detailed but would be specified in the bill of material.

Problem 310 Fig. 22·198. Make a complete assembly drawing of the *hanger bracket.* Place the vertical distances of the figure parallel to the long dimension of the sheet. Supply the missing details.

Problem 311 Fig. 22·198. Make a complete set of detail drawings with bill of material for the *hanger bracket.*

Problem 312 Fig. 22·199. Make an assembly drawing of the *belt tightener.* Show three exterior views.

Problem 313 Fig. 22·199. Make a complete set of detail drawings for the *belt tightener.*

Problems 314 to 316 Figs. 22·200 and 22·201.

The Model KP-186 toggle action clamp, shown in Figs. 22·200 and 22·201, is one of a large variety of clamping fixtures made by Knu-Vise Incorporated, Detroit, Mich. Note the U-shaped toggle bar used to hold work in place. It may be used without the spindle to clamp the work directly. The handle is pivoted on the link and, when raised, it releases the toggle bar. The link and toggle bar are also pivoted on the base. Dimensions not given are to be worked out as the parts are drawn.

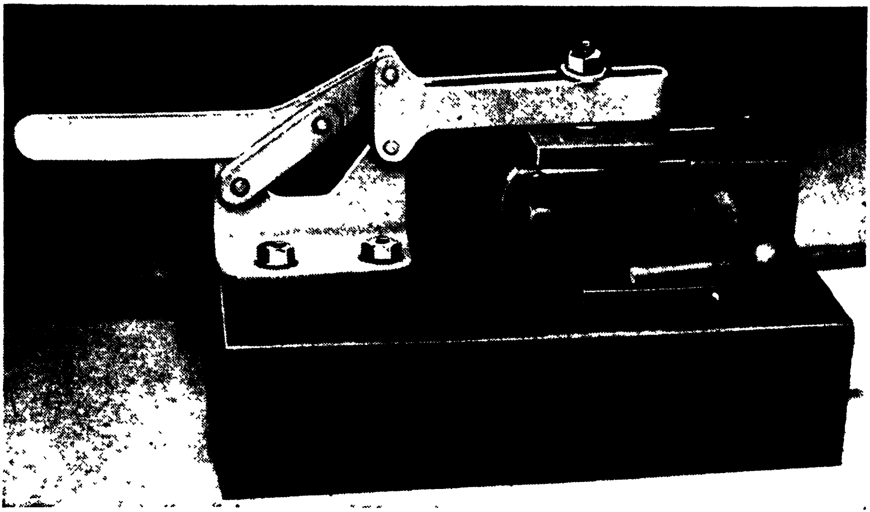


Figure 22·200 Toggle action clamp. **Probs. 314 to 316.**

This low-model clamp allows free overhead movement of operating tools in drilling, routing, or end-mill operations. The parts are made of steel, and all parts, except the toggle bar, are heat-treated. The entire clamp is cadmium-plated. Weight is 19 oz.

Part (1), Base—R.H., made of SAE #1020, C.R.S. (Society of Automotive Engineers, No. 1020, cold-rolled steel), thickness #9, (.1494) U.S.S., GA. (U. S. Standard Gage). Pierce 2 holes $.238 {}^{+.003}_{-.000}$ diameter, ream $.250 {}^{+.001}_{-.000}$. Distance between centers *B* and *C* is 2.470. Spotweld R.H. and L.H. bases together at places marked *X*.

Part (2), Base—R.H. Same as Part (1) but left hand.

Part (3), Toggle bar, made of SAE #1020, C.R.S., thickness #11 (.1196) U.S.S., GA. Pierce 4 holes $.187 {}^{+.001}_{-.000}$ diameter.

Part (4), Handle—R.H. made of SAE #1020, C.R.S., thickness #9 (.1494) U.S.S., GA. Pierce 2 holes $.238 {}^{+.003}_{-.000}$ diameter, ream $.250 {}^{+.001}_{-.000}$ Spotweld R.H. and L.H. handles together at places marked *X*.

Part (5), Handle—L.H. Same as Part (4) but left hand.

Part (6), Link, made of SAE #1020, C.R.S., thickness #11 (.1196)·U.S.S., GA. Pierce 2 holes $.187 {}^{+.001}_{-.000}$.

Distance between centers *C* and *D* is $1.625 {}^{+.001}_{-.001}$.

Part (7), Shoulder rivet, made of SAE #X-1112, screw stock, cyanide harden. Four required. See enlarged view on Fig. 22·201.

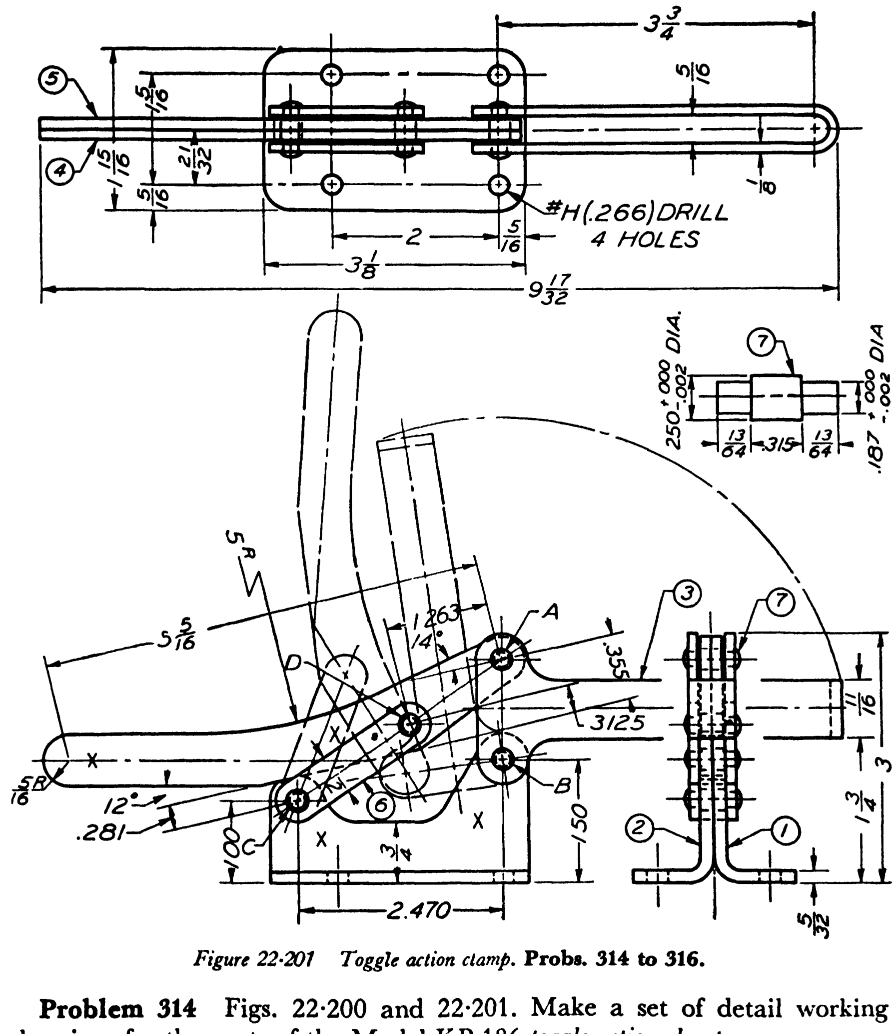


Figure 22·201 Toggle action clamp. **Probs. 314 to 316.**

Problem 314 Figs. 22·200 and 22·201. Make a set of detail working drawings for the parts of the Model KP-186 *toggle action clamp.*

Problem 315 Figs. 22·200 and 22·201. Prepare a complete parts list for the Model KP-186 *toggle action clamp.*

Problem 316 Figs. 22·200 and 22·201. Make an assembly drawing of the Model KP-186 *toggle action clamp.* Work out the open position carefully and draw it in with the proper lines for showing an alternate position. A convenient method is to make tracings of the parts with accurate center distances, place them in the desired position, and punch the centers with a needle point. The parts can then be drawn.

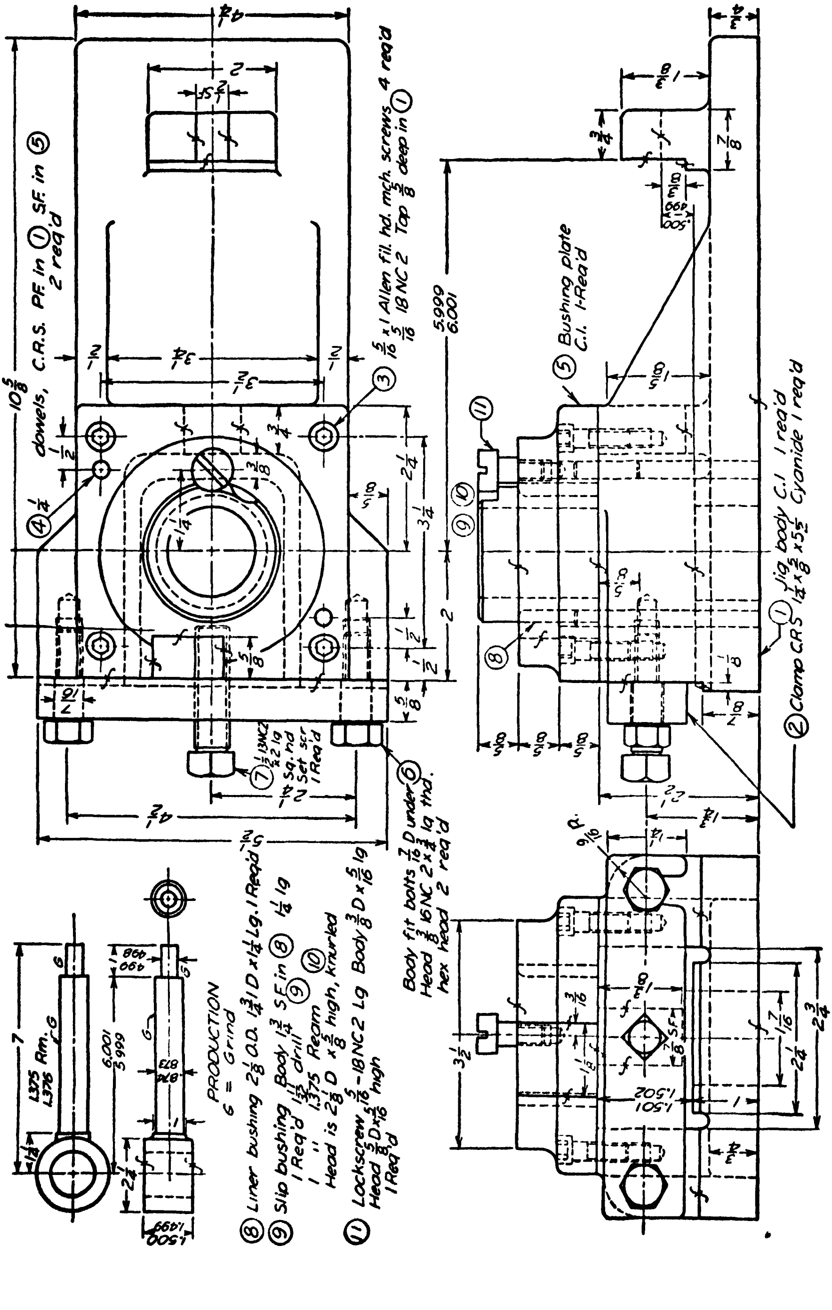


Figure 22·202 Jig. **Probs. 317 to 319.**

A jig is a device used to hold a machine part (called the "work" or "production") while it is being machined or "produced," so that all the parts will be alike within specified limits of accuracy. Note the production shown in the upper left-hand corner of the figure.

Problem 317 Fig. 22·202. Make a detail working drawing of the *jig body*.

Problem 318 Fig. 22·202. Make a complete set of detail drawings for the *jig*, with bill of material. Use as many sheets as necessary or larger sheets.

Problem 319 Fig. 22·202. Make a complete assembly drawing of the *jig*, three views. Give only such dimensions as are necessary for putting the parts together and using the jig.

GROUP 13. PIPING DRAWINGS

22·15 Information about pipe, fittings, etc, is given in the published standards of the American Standards Association, 29 W. 39th St., New York. Obtain dimensions of pipe fittings from the above standards or from a handbook or a piping catalogue. Study Arts. 11·18 to 11·21.

Problem 320 Lay out a standard sheet (Fig. 22·2). Use the representations of Fig. 11·23. In the upper left-hand corner of the sheet draw a ½″ cross, full size. Plug the upper and left-hand outlets with square head and countersunk plugs, respectively. In the right outlet place a 4″ nipple, followed in order by the following fittings: standard ½″ screw union, ½″ nipple, ½″ street ell, ½″ to ⅜″ reducing coupling, ⅜″ nipple, ⅜″ 45° branch, ⅜″ nipple in angle outlet of branch, 45° ell, ⅜″ pipe, ½″ to ⅜″ reducing bushing, ½″ standard ell, and ½″ nipple. This last nipple should screw into the lower outlet of the cross, thus closing the system. The run outlet of the branch should be plugged.

Problem 321 In the upper left-hand corner of the sheet draw, full size, a ½″ standard tee with the run outlets horizontal. Place a countersunk plug in the left-hand outlet. Starting at the right-hand outlet, draw the following fittings in the order mentioned below, the last nipple fitting in the bottom outlet of the tee. Nipple, globe valve, nipple, ell, nipple, 45°—½″ × ½″ × ⅜″ branch, ⅜″ nipple, 45° ell, nipple, R & L coupling, nipple, ½″ to ⅜″ reducing bushing, ½″ screwed union, street ell, nipple, coupling, and nipple. Place a nipple and cap in the run outlet of the branch. Use the representations of Fig. 11·23.

Problem 322 Draw two horizontal center lines 6¾″ apart and between them a third 3″ from the lower one. Draw two vertical center lines 10″ apart. On these center lines draw the following pipe fittings, full size, making two closed systems interconnected. ½″ standard tee, square-head plug, ½″ to ⅜″ reducing coupling, ⅜″ standard coupling, ⅜″ R & L coupling, ⅜″ angle valve, ⅜″—45° branch, ½″ to ⅜″ reducing bushing, ½″ street ell, ½″ gate valve, ½″ screwed union, ½″ ell, ½″ × ½″ × ⅜″ tee, ⅜″ cross, ⅜″ countersunk plug, ⅜″ cap, ⅜″—45° ell. Use nipples to suit. Use the representations of Fig. 11·23.

Problems 323 to 325 Same as Probs. 320 to 322, respectively, but use single-line conventions (see Fig. 11·28).

GROUP 14. PICTORIAL DRAWING

22·16 Study Chap. 12 carefully before beginning the problems.

The isometric cube with the two starting positions for the axes is shown in Figs. 12·5 and 12·6. Remember that all measurements must be taken parallel to the axes. Note the two rules given in Art. 12·12.

Problem 326 Fig. 22·203. Draw the two orthographic views. Construct the *isometric drawing*, using the axes in the second position, as indicated.

Problem 327 Fig. 22·203. Draw the given orthographic views and an isometric drawing of the *notched block*.

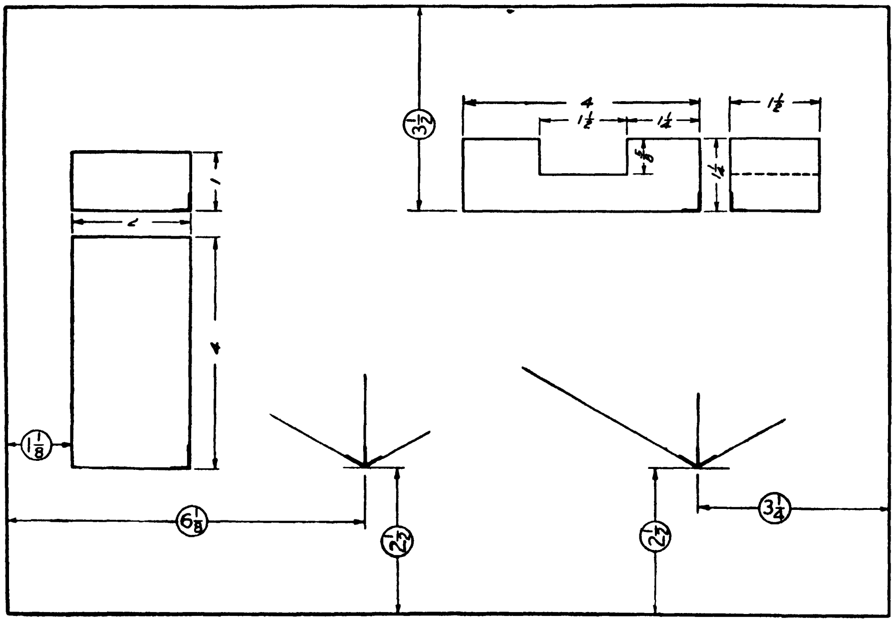


Figure 22·203 Isometric drawing. **Probs. 326 and 327.**

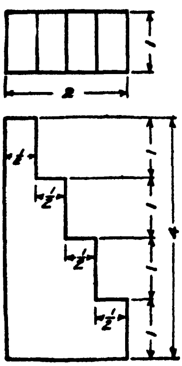


Figure 22·204
Prob. 328.

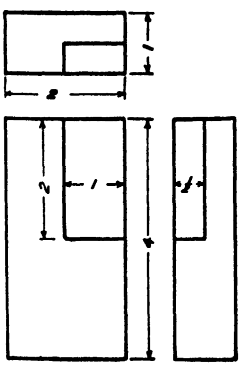


Figure 22·205
Prob. 329.

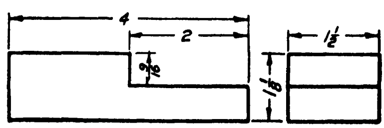


Figure 22·206 **Prob. 330.**

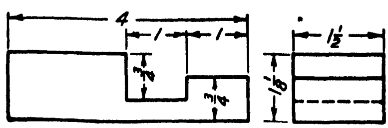


Figure 22·207 **Prob. 331.**

Problems 328 and 329 Figs. 22·204 and 22·205. Alternates for Prob. 326.
Problems 330 and 331 Figs. 22·206 and 22·207. Alternates for Prob. 327.

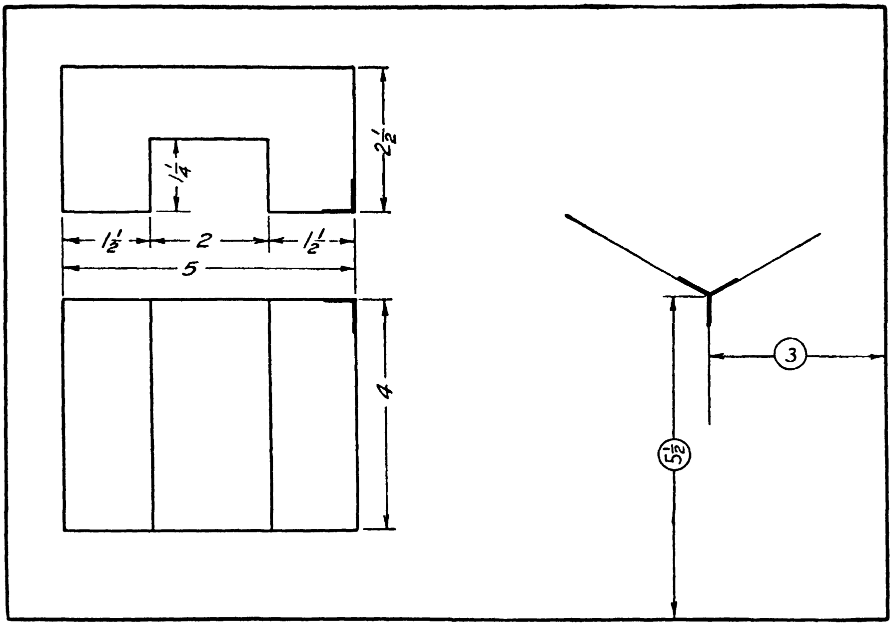


Figure 22·208 Guide. **Prob. 332.**

Problem 332 Fig. 22·208. Draw the orthographic views given, and make an isometric drawing of the guide, using the axes in the position indicated.

Problems 333 to 335 Figs. 22·209 to 22·211. Draw the orthographic views given, and make an isometric drawing of the pieces shown. Use the layout of Fig. 22·208.

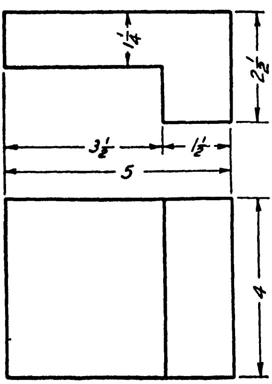


Figure 22·209 Vertical filler. **Prob. 333.**

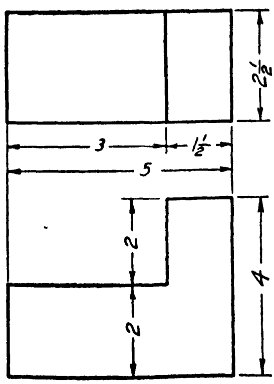


Figure 22·210 Horizontal filler. **Prob. 334.**

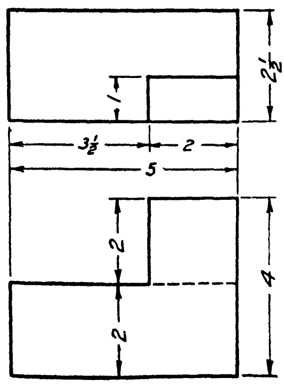


Figure 22·211 Corner filler. **Prob. 335.**

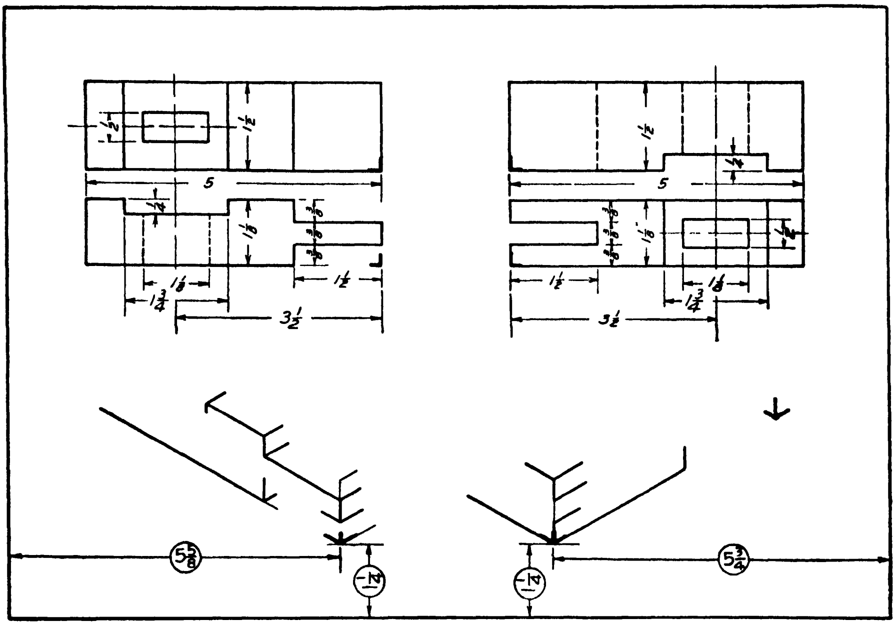


Figure 22·212 Isometric drawing. **Probs. 336 and 337.**

Problem 336 Fig. 22·212. Draw the orthographic views given, and an isometric drawing of the *tenoned block.*

Problem 337 Fig. 22·212. Draw the orthographic views given and an isometric drawing of the *mortised block.*

Problem 338 Fig. 22·213. Alternate problem for Prob. 336.

Problem 339 Fig. 22·214. Alternate problem for Prob. 337.

Problem 340 Fig. 22·215. Alternate problem for Prob. 336.

Problem 341 Fig. 22·216. Alternate problem for Prob. 337.

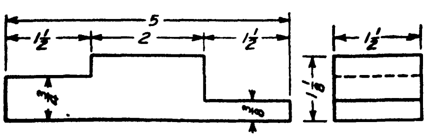


Figure 22·213 **Prob. 338.**

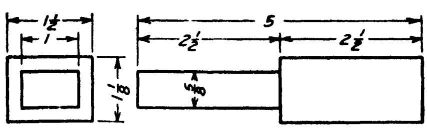


Figure 22·214 **Prob. 339.**

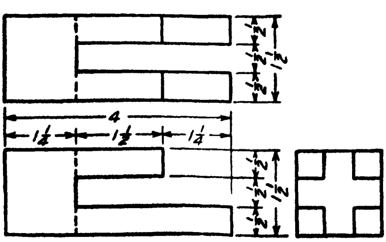


Figure 22·215 **Prob. 340.**

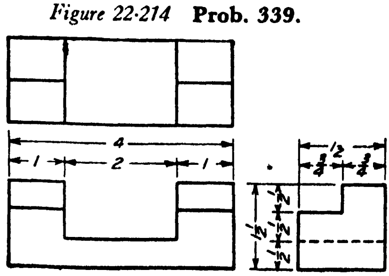


Figure 22·216 **Prob. 341.**

Problem 342 Fig. 22·217. Draw the orthographic views given and make an isometric drawing of the *wedge block* in the left-hand half of the sheet. This problem requires the locating of nonisometric lines. Read Art. 12·5 and observe the construction in Fig. 12·7 before starting this problem. The layout of Fig. 22·212 can be used. The construction lines should be drawn very light and either left on the drawing or not erased until they have been inspected by the instructor. The final lines of an isometric drawing should be brightened with a sharp pencil.

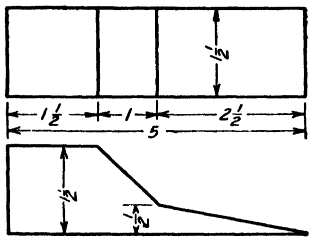


Figure 22·217 Wedge block. **Prob. 342.**

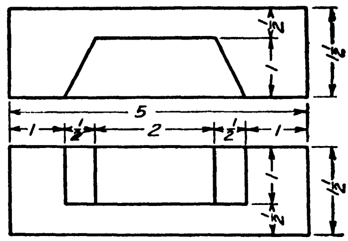


Figure 22·218 Recessed block. **Prob. 343.**

Problem 343 Fig. 22·218. Draw the orthographic views given and make an isometric drawing of the *recessed block* in the right-hand half of the sheet. The same procedure should be followed as in the preceding problem.

Problem 344 Fig. 22·219. Draw the orthographic views given and make an isometric drawing of the *double wedge* in the left-hand half of the sheet. This problem requires the locating of nonisometric lines. Read Art. 12·5 and observe the construction in Fig. 12·7 before starting this problem. The layout of Fig. 22·212 can be used. The construction lines should be drawn very light and either left on the drawing or not erased until they have been inspected by the instructor. The final lines of an isometric drawing should be brightened with a sharp pencil.

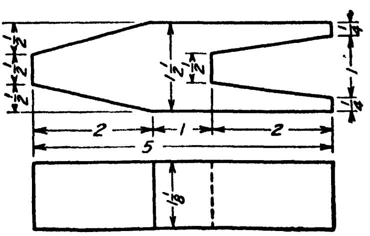


Figure 22·219 Double wedge. **Prob. 344.**

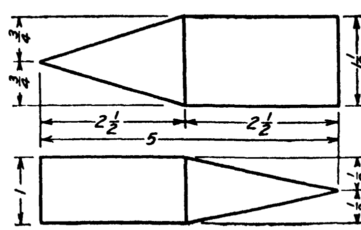


Figure 22·220 Double-end wedge. **Prob. 345.**

Problem 345 Fig. 22·220. Draw the orthographic views given and make an isometric drawing of the *double-end wedge* in the right-hand half of the sheet. The same procedure should be followed as in the preceding problem.

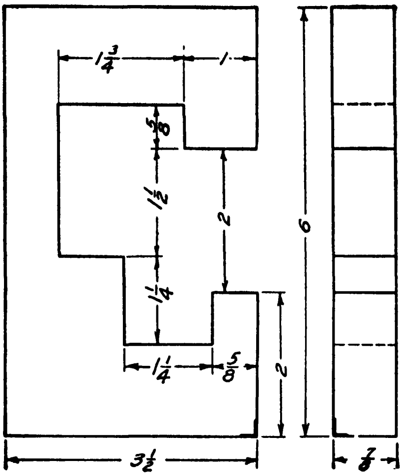


Figure 22·221 Notched block. **Prob. 346.**

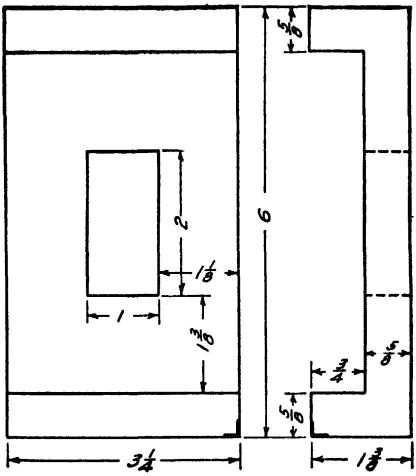


Figure 22·222 Plate. **Prob. 347.**

Problem 346 Fig. 22·221. Make an isometric drawing of the *notched block*. Start with the corner indicated by heavy lines. Locate as in Fig. 22·223.

Problem 347 Fig. 22·222. Make an isometric drawing of the *plate*. Locate as in Fig. 22·223.

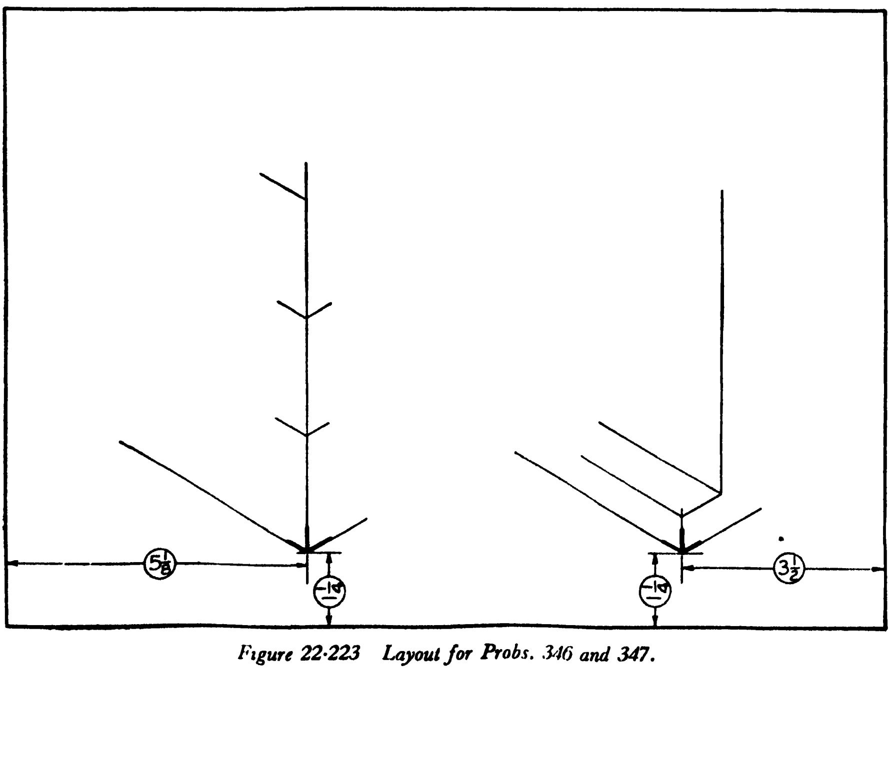


Figure 22·223 Layout for Probs. 346 and 347.

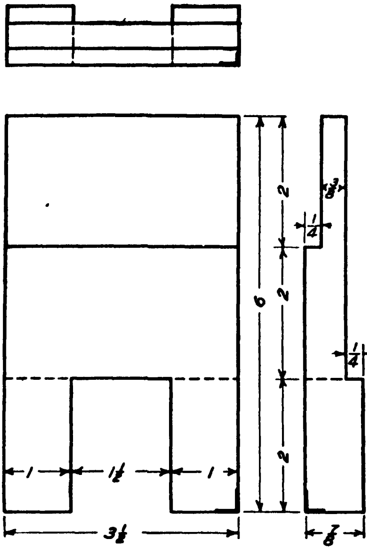


Figure 22·224 Notched plate. **Prob. 348.**

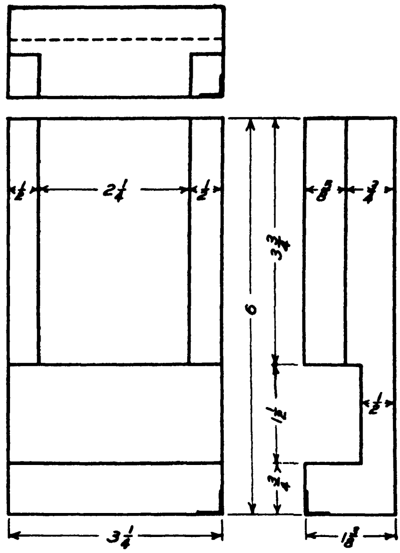


Figure 22·225 Rabbeted stop. **Prob. 349.**

Problem 348 Fig. 22·224. Make an isometric drawing of the *notched plate*, using layout of Fig. 22·223.

Problem 349 Fig. 22·225. Make an isometric drawing of the *rabbeted stop*, using layout of Fig. 22·223.

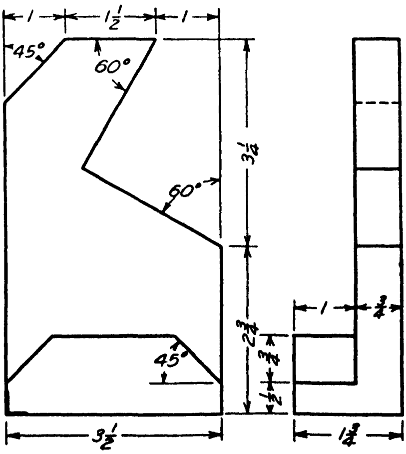


Figure 22·226 Notched slide. **Prob. 350.**

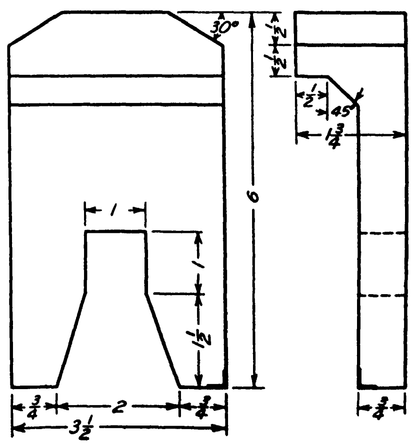


Figure 22·227 Slotted stop. **Prob. 351.**

Problem 350 Fig. 22·226. Make an isometric drawing of the *notched slide*, using layout of Fig. 22·223.

Problem 351 Fig. 22·227. Make an isometric drawing of the *slotted stop*, using layout of Fig. 22·223.

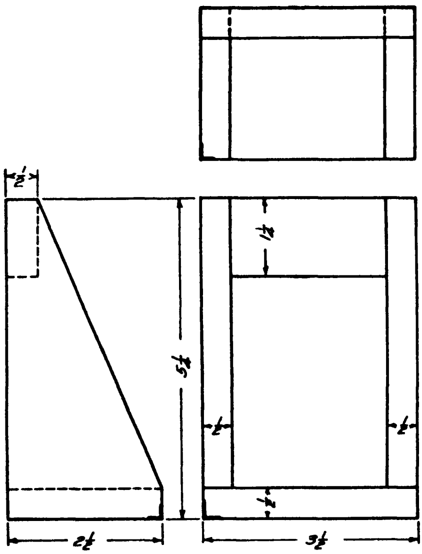


Figure 22·228 Stirrup. **Prob. 352.**

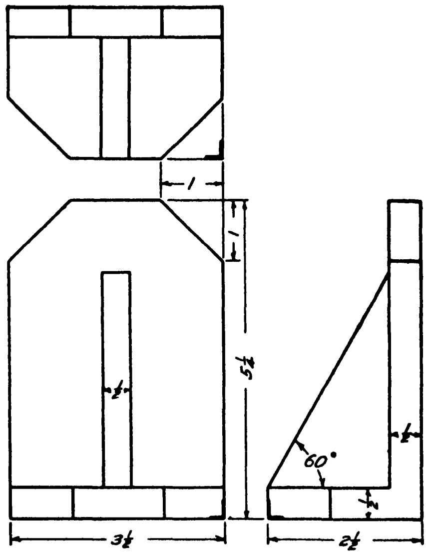


Figure 22·229 Brace. **Prob. 353.**

Problem 352 Fig. 22·228. Make an isometric drawing of the *stirrup*. The drawing is started on the layout (Fig. 22·230). Note the heavy lines for the starting corner. The slant lines are non-isometric (Art. 12·5).

Problem 353 Fig. 22·229. Make an isometric drawing of the *brace*. The drawing is started in Fig. 22·230. Note the 60° angle and read Art. 12·5.

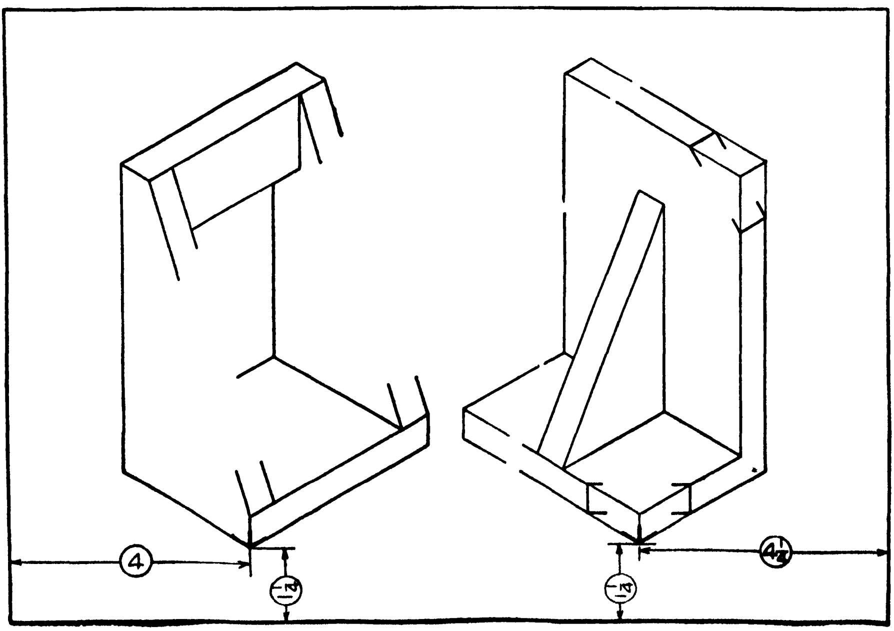


Figure 22·230 Layout for Probs. 352 and 353.

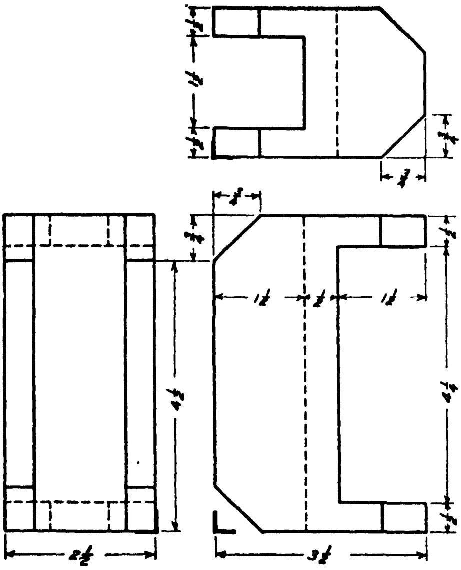


Figure 22·231 *Cross slide.* **Prob. 354.**

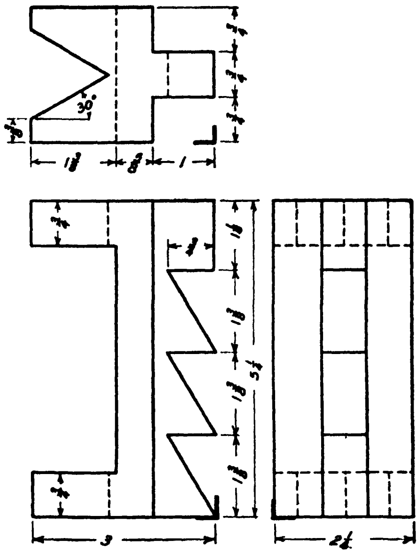


Figure 22·232 *Ratchet.* **Prob. 355.**

Problems 354 and 355 Make isometric drawings. (For Layout, see Fig. 22·230.)

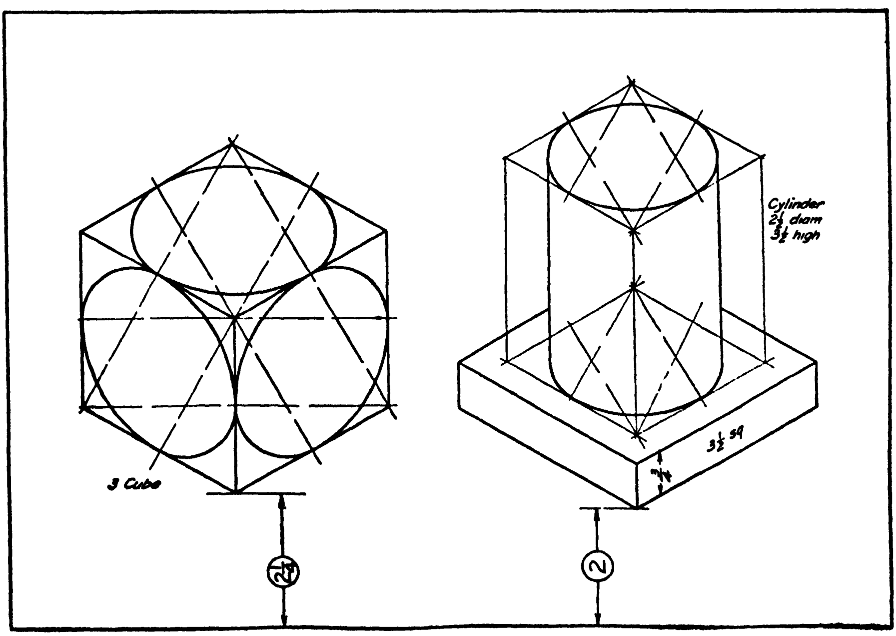


Figure 22·233 **Probs. 356 and 357.**

Problems 356 and 357 Make isometric drawings of a 3″ cube, isometric circle on each face (Art. 12·6) and of a cylinder resting on a square plate.

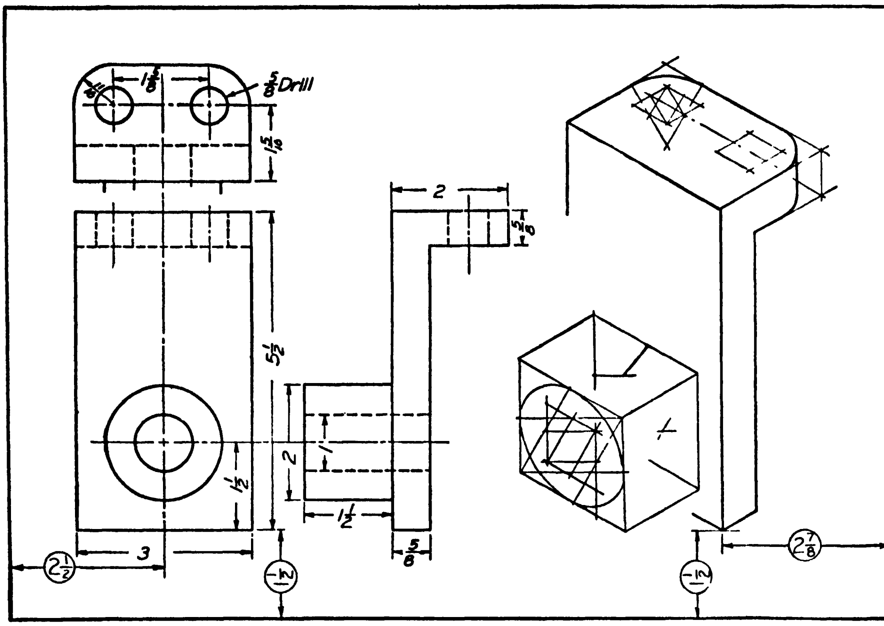


Figure 22·234 Hung bearing. **Prob. 358.**

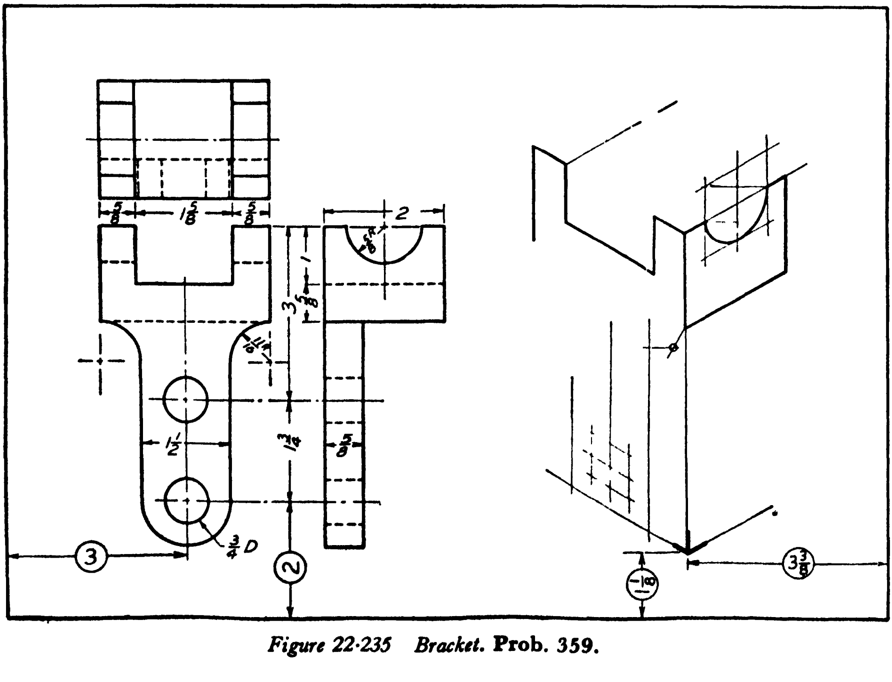


Figure 22·235 Bracket. **Prob. 359.**

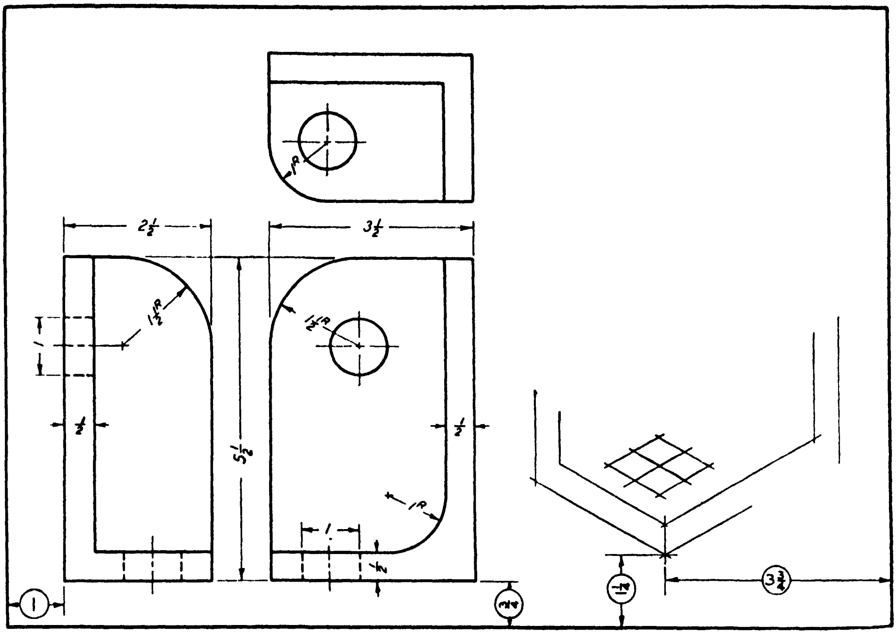


Figure 22·236 Lug. **Prob. 360.**

Problem 358 Fig. 22·234. Draw the three views given and an isometric drawing of the *hung bearing*. Most of the construction is indicated on the layout. Make the drawing as though all corners were square and then construct the curves as described in Art. 12·6.

Problem 359 Fig. 22·235. Draw the three views given, then make an isometric drawing of the *bracket*. Some of the construction is indicated on the layout. Make the drawing as though the corners were square and then construct the curves. Read Art. 12·6. (An alternate for Prob. 358.)

Problem 360 Fig. 22·236. Draw the three views given, then make an isometric drawing of the *lug*. Make the drawing as though the corners were square and then construct the curves. Read Art. 12·6.

22·17 Isometric Sections. The next four problems are sectional views in isometric. As referred to in Art. 12·8, these are often useful in showing interior construction. The cutting planes must be isometric planes, that is, parallel to the faces of the isometric cube. Section lining is done with the 60° triangle. In making a full section, as for Probs. 361 and 363, draw the cut surface first, then add the part of the object behind it. For a half section, as called for in Probs. 362 and 364, it is usually best to draw the full isometric view, very lightly, first, then cut out the front quarter by two isometric planes, as indicated in the layouts (Figs. 22·239 and 22·242) and as shown in Figs. 12·10 and 12·11.

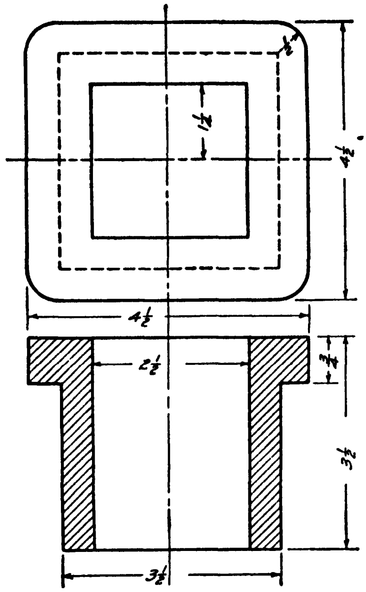


Figure 22·237 Post socket. **Prob. 361.**

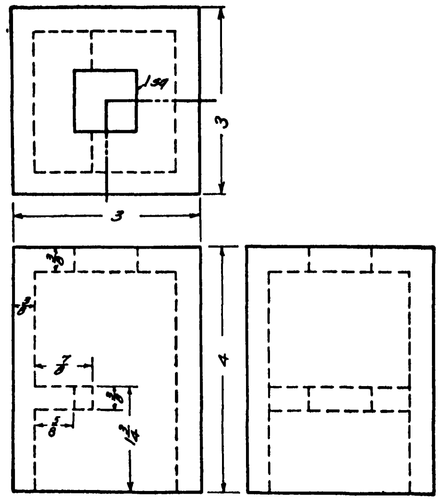


Figure 22·238 Box step. **Prob. 362.**

Problem 361 Fig. 22·237. Make an isometric drawing in section, of the *post socket.* Locate as on Fig. 22·239.

Problem 362 Fig. 22·238. Make an isometric drawing in half section, of the *box step.* Locate as on Fig. 22·239.

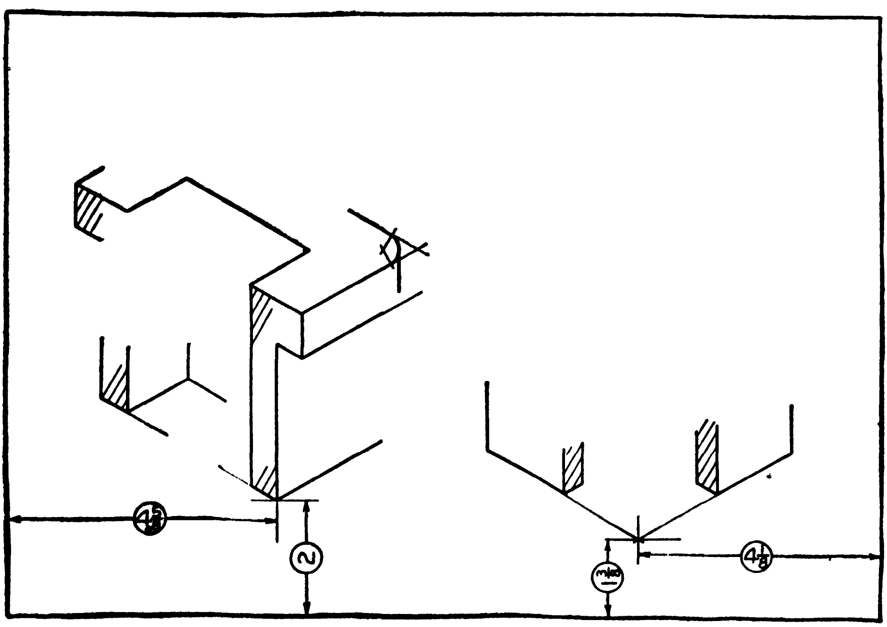


Figure 22·239 Layout for Probs. 361 and 362.

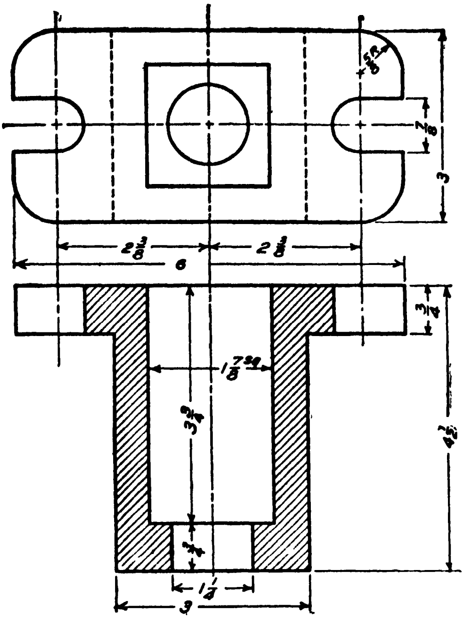


Figure 22·240 Post support. **Prob. 363.**

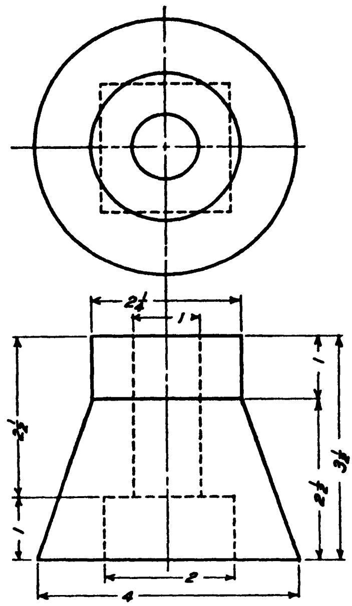


Figure 22·241 Foundation washer. **Prob. 364.**

Problem 363 Fig. 22·240. Isometric section. Layout of Fig. 22·242.
Problem 364 Fig. 22·240. Isometric half section. Layout of Fig. 22·242.

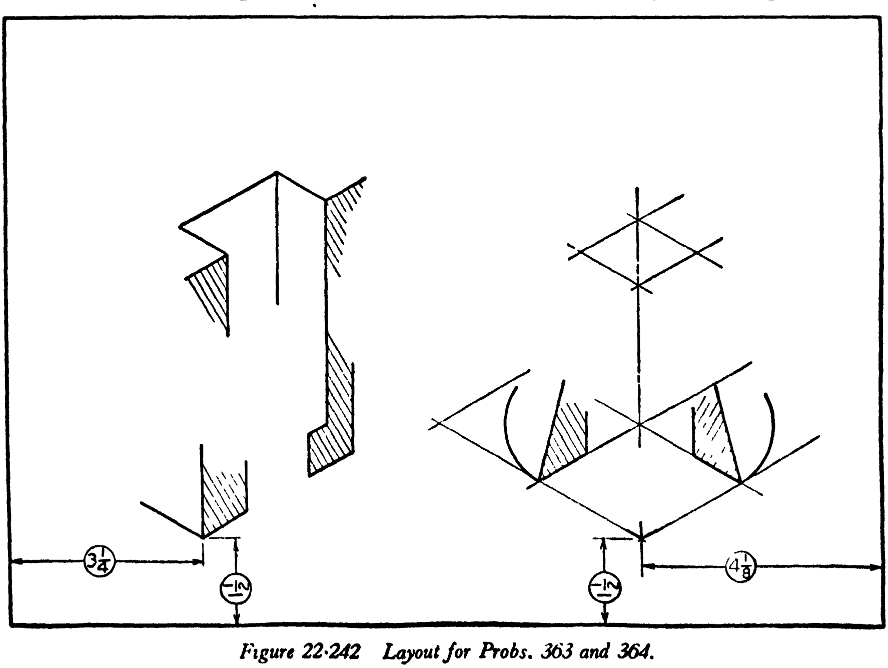


Figure 22·242 Layout for Probs. 363 and 364.

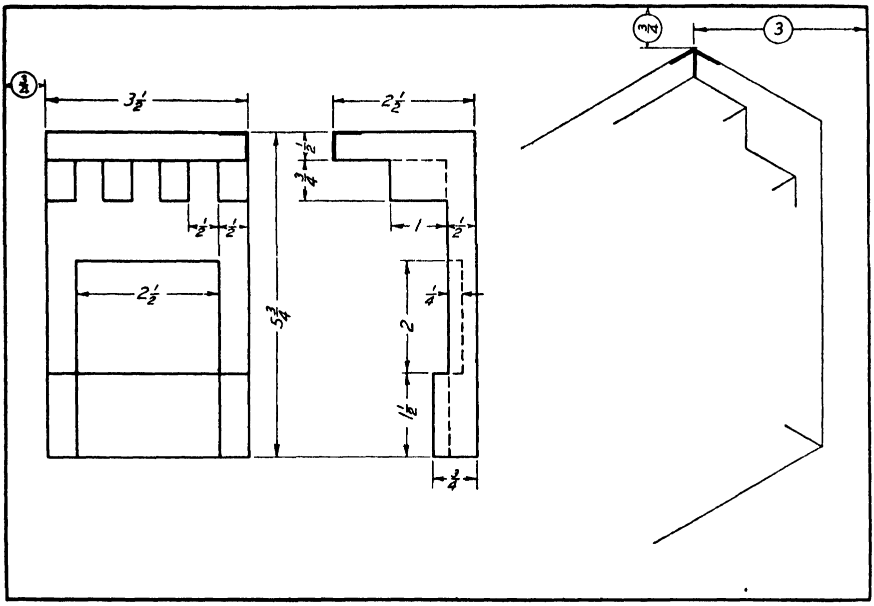


Figure 22·243 **Prob. 365.**

Problem 365 Fig. 22·243. Draw the views given and make an isometric drawing of the *tablet*. Reversed axes, Art. 12·10.

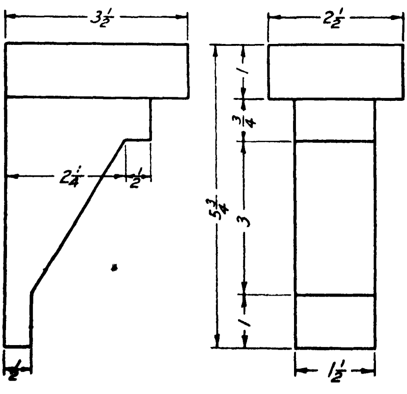


Figure 22·244 **Prob. 366.**

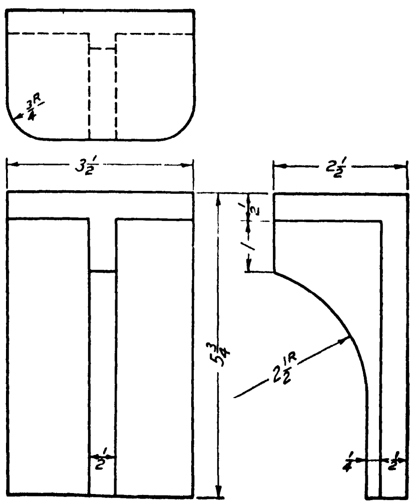


Figure 22·245 **Prob. 367.**

Problem 366 Fig. 22·244. Draw the views given and make an isometric drawing. Reversed axes, Art. 12·10. Locate axes as on Fig. 22·243.

Problem 367 Fig. 22·245. Draw the views given and make an isometric drawing. Reversed axes, Art. 12·10. Locate axes as in Fig. 22·243.

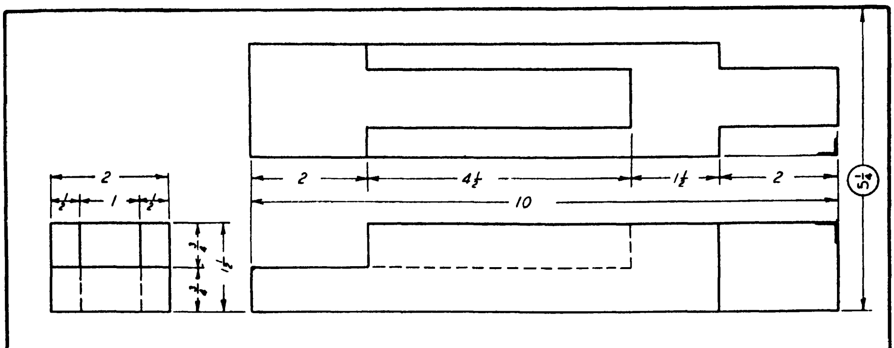
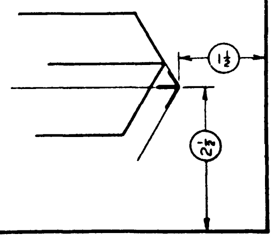


Figure 22·246 **Prob. 368.** Draw the views given and make an isometric drawing of the *extension bar.* Long axis horizontal, Art. 12·11.



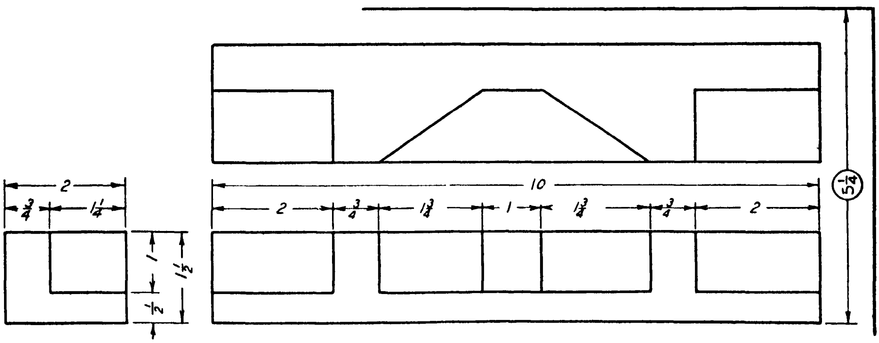


Figure 22·247 **Prob. 369.** Make an isometric drawing of the *spacing bar.*

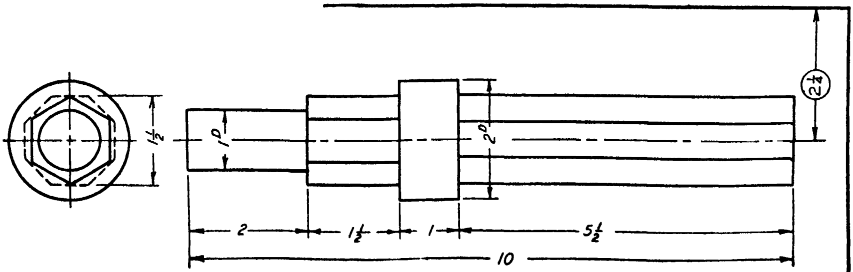


Figure 22·248 **Prob. 370.** Make an isometric drawing of the *special rod.* Use layout of Fig. 22·246 for Probs. 369 and 370.

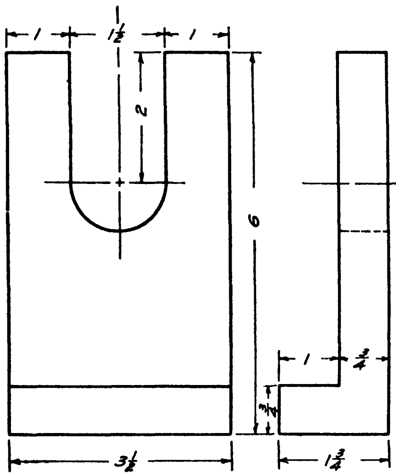


Figure 22·249 Angle piece. **Prob. 371.**

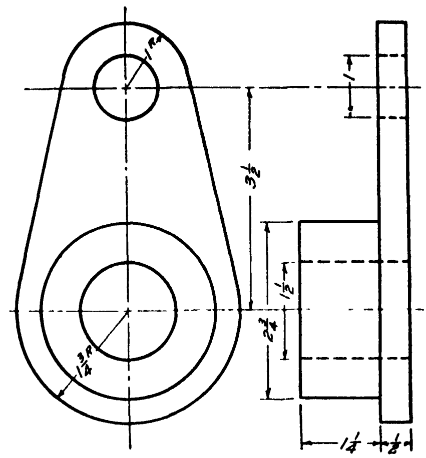


Figure 22·250 Crank. **Prob. 372.**

Problem 371 Fig. 22·249. Make an oblique drawing of the *angle piece*, using layout of Fig. 22·251. Read Arts. 12·12 to 12·14.

Problem 372 Fig. 22·250. Make an oblique drawing of the *crank*, using position and layout of Fig. 22·251.

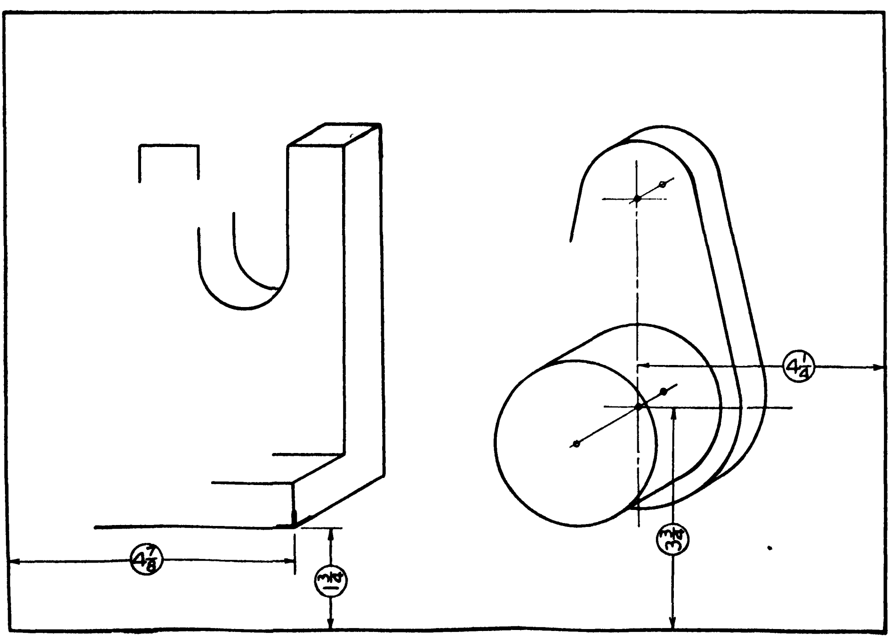


Figure 22·251 Layout for Probs. 371 and 372.

Problem 373 Fig. 22·252. Make an oblique drawing of the *slotted sector.* This drawing can be made in one-half of a sheet (divided by a vertical line through the center). Use an axis of 30° or 45° to the right or left as directed by the instructor.

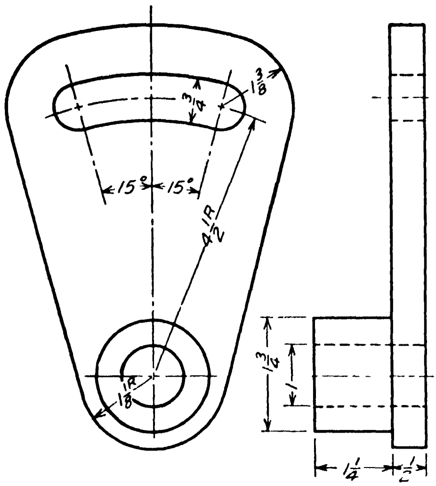


Figure 22·252 Slotted sector. **Prob. 373.**

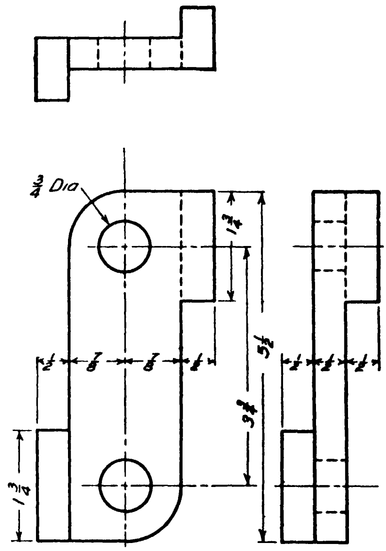


Figure 22·253 Double stop. **Prob. 374.**

Problem 374 Fig. 22·253. Make an oblique drawing of the *double stop.* This drawing can be made in one-half of a sheet (divided by a vertical line through the center). Use an axis of 30° or 45° to the right or left as directed by the instructor.

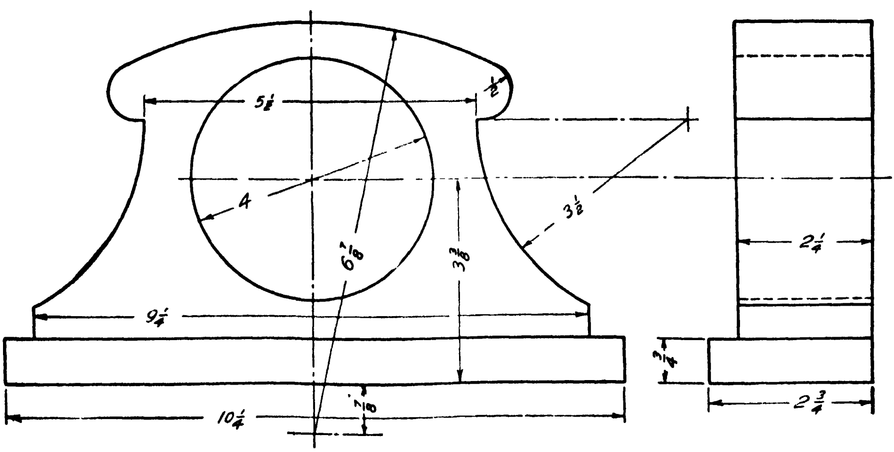
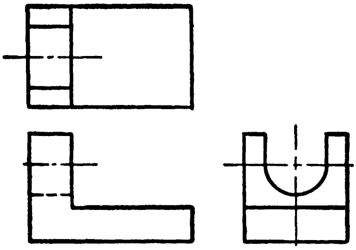


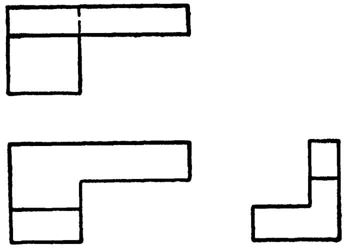
Figure 22·254 Clock case. **Prob. 375.**

Problem 375 Fig. 22·254. Make an oblique drawing of the *clock case.* Use an axis of 30° to the right.

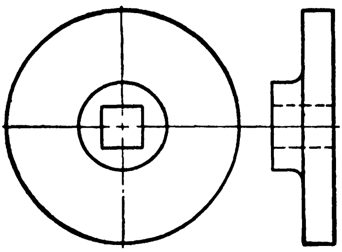
22·18 Pictorial sketching is important for the study of reading drawings and blue prints. The following 24 problems are designed for practice.



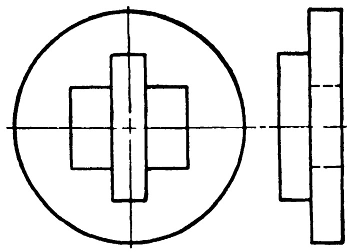
Yoke Bracket



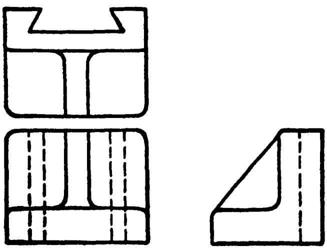
Blank for Tool Rest



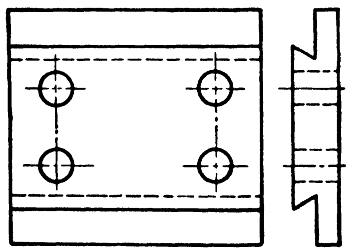
Gear Bracket



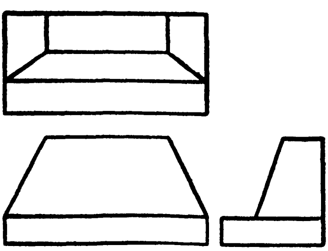
Disc Plate



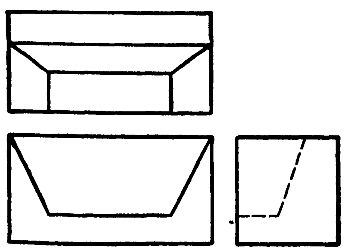
Dovetail Slide



Removable Jaw



Book End



Die Block

Figure 22·255 **Probs.** 376 to 383.

Problems 376 to 383 Fig. 22·255. Problems for pictorial sketching.

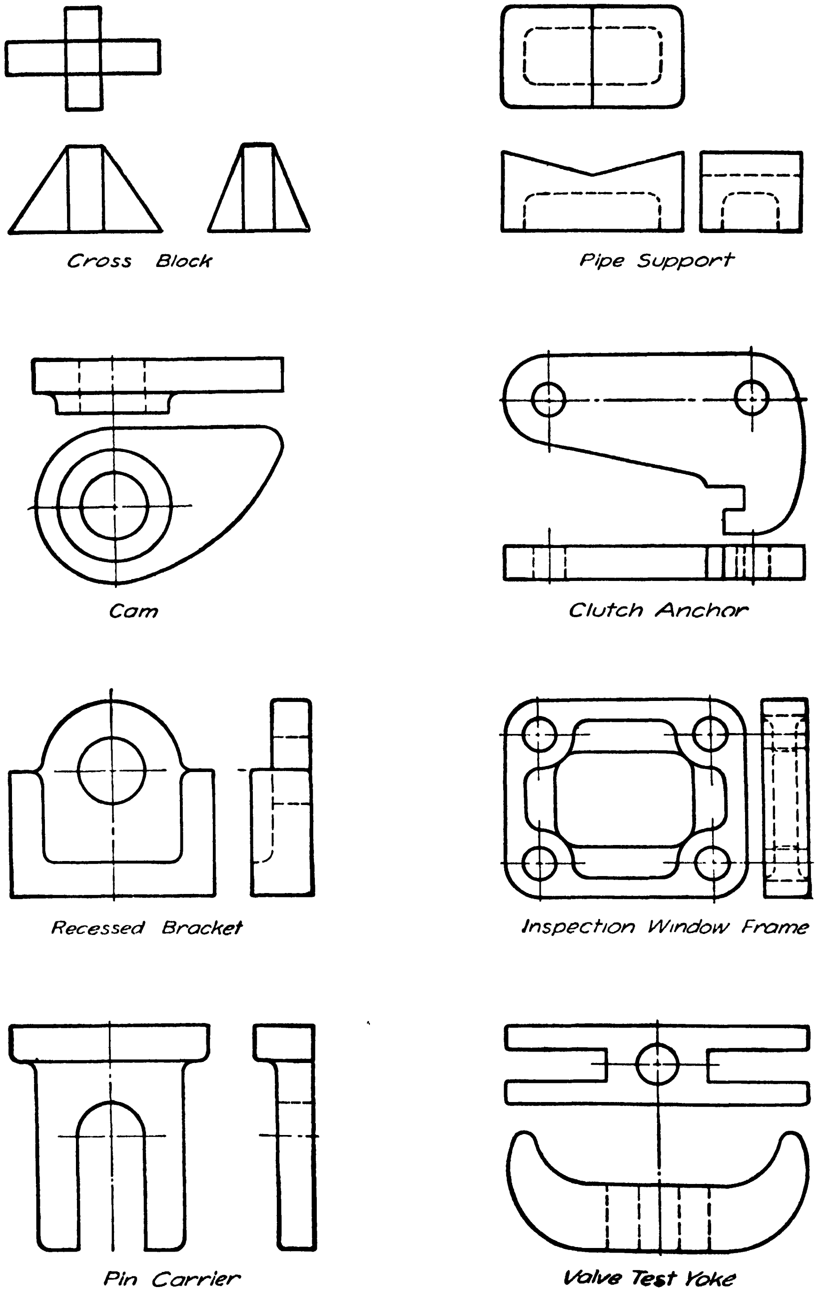


Figure 22·256 **Probs. 384 to 391.**

Problems 384 to 391 Fig. 22·256. Problems for pictorial sketching.

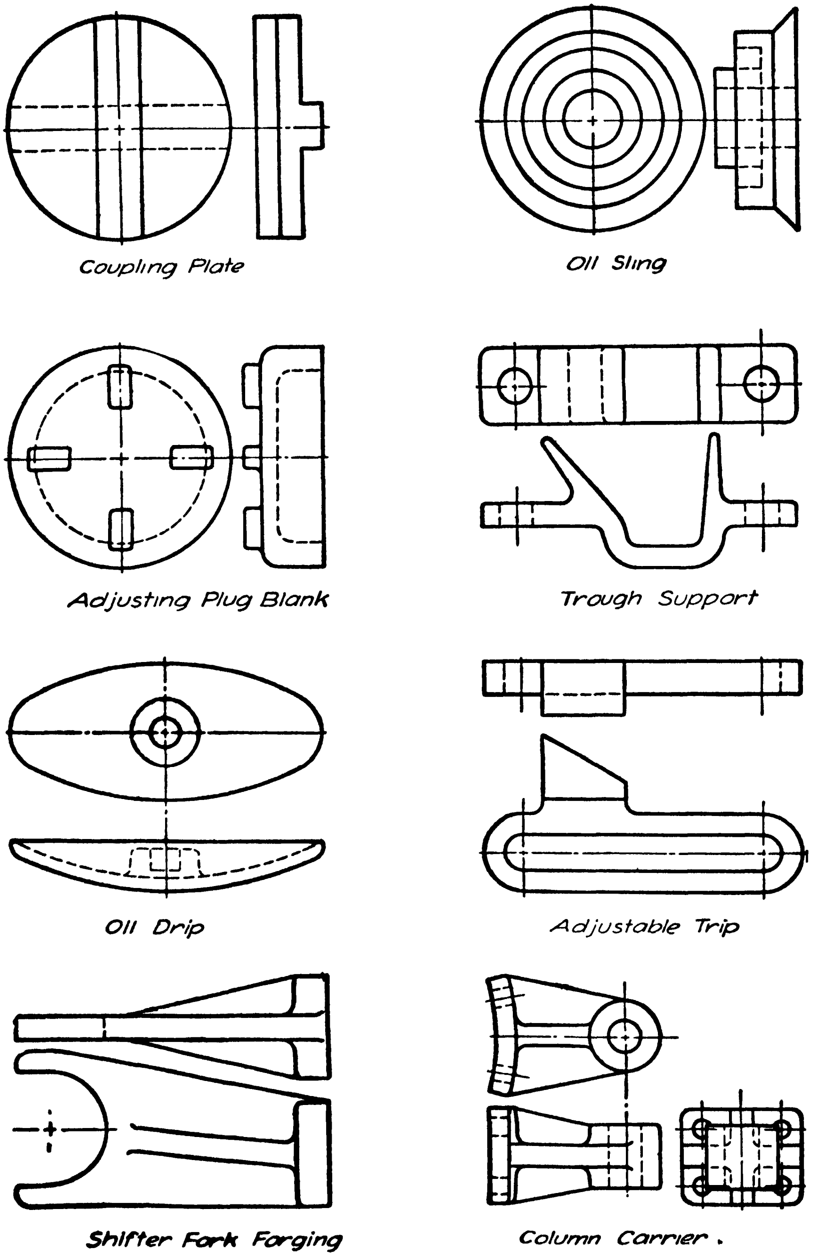


Figure 22·257 **Probs. 392 to 399.**

Problems 392 to 399 Fig. 22·257. Problems for freehand pictorial sketching.

GROUP 15. PRODUCTION ILLUSTRATION DRAWINGS

22·19 Study Chaps. 12 and 13 before beginning these problems.

Any suitable problems may be selected by the instructor to be worked as production drawings. Carefully proportioned freehand pictorial drawings in isometric, oblique, or perspective may be used depending upon the most effective result. A few problems may be drawn with instruments. The amount of rendering should be kept to the least that will serve to bring out the shapes. The following problems indicate the specification of such problems.

Problem 400 Fig. 22·228. Make an exploded-view drawing of the *stirrup*. See Fig. 13·4.

Problem 401 Fig. 22·229. Make an exploded-view drawing of the *brace*. See Fig. 13·4.

Problem 402 Fig. 22·231. Make an exploded-view drawing of the *cross slide*. See Fig. 13·4.

Problem 403 Fig. 22·234. Make an exploded-view drawing of the *hung bearing*. See Fig. 13·4.

Problem 404 Fig. 22·74. Make an exploded-view drawing of the *bearing*. See Fig. 13·4.

Problem 405 Fig. 22·172. Make a production drawing of the *bench hook*.

Problem 406 Fig. 22·173. Make a production drawing of the *nail box*.

Problem 407 Fig. 22·170. Make a production drawing of the *book rack*.

Problem 408 Fig. 22·153. Make a production drawing of the *Babbitted bearing*.

Problem 409 Fig. 22·186. Make an exploded-view drawing of the *hung bearing*.

Problem 410 Fig. 22·198. Make an exploded-view drawing of the *hanger bracket*.

Problem 411 Fig. 22·188. Make an exploded-view drawing of the *pivot guide roll*.

Problem 412 Fig. 22·192. Make an exploded-view drawing of the *tool post*.

Problem 413 Fig. 22·193. Make an exploded-view drawing of the *idler pulley*.

Problem 414 Fig. 22·187. Make an exploded-view drawing of the *pulley and stand*.

Problem 415 Fig. 11·5. Make an exploded-view drawing of the *belt tightener*.

GROUP 16. AIRCRAFT DRAWINGS

22·20 Study Chap. 14 before beginning these problems. It will be helpful to have some special books on hand for reference and additional problems where more study of aircraft drawings is desired. Such books as "Aircraft Detail Drafting" by Norman Meadowcraft, "Aircraft Drafting" by Carl L. Svensen, and "Aircraft Mechanical Drawing" by Davis and Goen are suggested.

Problem 416 Fig. 14·3. Make a drawing of the *tube assembly*.
Problem 417 Fig. 14·4. Make a drawing of the *stabilizer frame*.
Problem 418 Fig. 14·5. Make a drawing of the *flap hinge*.
Problem 419 Fig. 14·6. Make a drawing of the *forge blank*.

GROUP 17. WELDING DRAWINGS

22·21 Study Chap. 15 before beginning these problems.

Problem 420 Fig. 15·3. Make a drawing showing the basic types of joints.

Problem 421 Fig. 15·4. Make a drawing showing the grooved joints illustrated.

Problem 422 Fig. 15·1. Make a drawing of the casting for the *sheave housing*.

Problem 423 Make a welding drawing for the sheave housing of Fig. 15·1 and compare your drawing with Fig. 15·2.

Problem 424 Fig. 22·228. Make a complete welding drawing for the *stirrup*. Show three views with welding symbols.

Problem 425 Fig. 22·229. Make a complete welding drawing for the *brace*. Show three views with welding symbols.

Problem 426 Fig. 22·234. Make a complete welding drawing for the *hung bearing*. Show three views with welding symbols.

Problem 427 Fig. 22·74. Make a complete welding drawing with welding symbols for the *bearing* to replace the casting shown. Use 3/8" steel for all except the hubs.

Problem 428 Fig. 22·117. Same as Prob. 427 for the *angle plate*.

Problem 429 Fig. 22·161. Make a drawing with welding symbols for the *bearing holder* to be of welded steel.

Problem 430 Fig. 22·150. Make a complete welding drawing for the *bracket bearing* to replace the casting shown. Use ½" steel except for the hub.

Problem 431 Fig. 15·13. Make a welding drawing of the structural detail.

GROUP 18. CAM AND GEAR DRAWINGS

22·22 Study Chap. 17 carefully before starting the problems in this group. It will be necessary to make some calculations to obtain dimensions for the gear drawings. Formulas are given in Art. 17·7. The formulas used, the given values, the calculations, and the figured values should be neatly lettered on the drawing or on a separate sheet as directed by your instructor.

Accuracy and neatness are necessary to obtain satisfactory cam drawings. The pencil must be kept very sharp and the lines made fine and light. When the cam outline has been accurately plotted, it should be brightened, using a sharp pencil with the irregular curve.

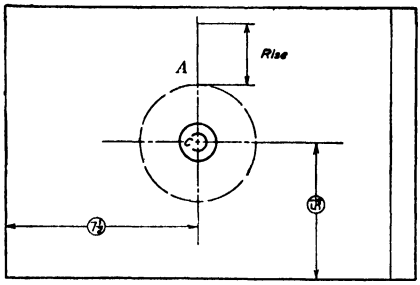


Figure 22·258 Cam plate. **Probs. 432 to 435.**

Problem 432 Fig. 22·258. Design a *plate cam* with point contact. See main drawing in Fig. 17·4. Motion of follower: rise 1½″ with uniform motion during one-half revolution, drop 1½″, at rest during remaining half revolution. Distance *AC* equals 2¼″.

Problem 433 Fig. 22·258. Design a *plate cam* with point contact. Motion of follower: rise 2″ with uniform motion during one-third revolution, at rest during one-sixth revolution, drop 2″ uniformly during one-fourth revolution, at rest during remaining one-fourth revolution. Distance *AC* equals 1¾″.

Problem 434 Fig. 22·258. Design a *plate cam with roller.* Motion of follower: rise 2″ with uniform motion during one-half revolution, drop 1″, remain at rest one-fourth revolution, drop 1″ with uniform motion during remaining one-fourth revolution. Diameter of roller ⅞″. Distance *AC* equals 2¼″.

Problem 435 Fig. 22·258. Design a *plate cam with roller.* Motion of follower: rise 1¾″ with uniform motion during one-third revolution, drop ¾″, drop 1″ with uniform motion during one-third revolution, at rest during remaining one-third revolution. Diameter of roller ⅞″. Distance *AC* equals 2½″.

Problem 436 Make a working drawing for a *cut spur gear* similar to Fig. 17·9, but with 72 teeth, 12 diametral pitch.

Problem 437 Make a working drawing for a *cut spur gear.* Diametral pitch 6; pitch diameter 8″; width of face 1⅝″; diameter of shaft or bore 1⅞″; length of hub 2″.

Problem 438 Make a working drawing for a *cut spur gear and a pinion.* Outside diameter of gear 6½″; width of face 1¼″; length of hub 1½″. Pitch diameter of pinion 1½″. Number of teeth 12 for pinion. Other dimensions to be worked up as views are drawn.

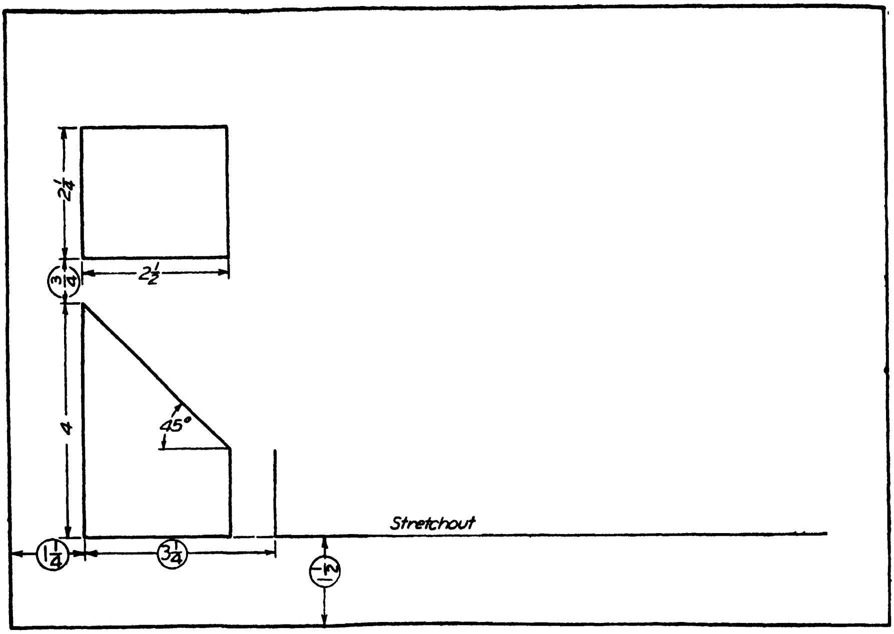


Figure 22·259 Development. **Prob. 439.**

GROUP 19. DEVELOPMENTS AND INTERSECTIONS

Problem 439 Fig. 22·259. Develop the lateral surface of the *truncated prism*, using the layout given. Read Art. 18·3.

Problems 440 to 442 Figs. 22·100 to 22·102. Develop the lateral surface.

Problems 443 to 447 Figs. 22·260 to 22·264. Develop the lateral surface.

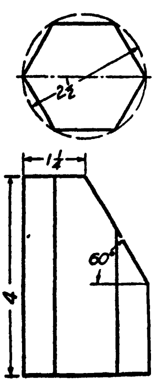


Figure 22·260
Prob. 443.

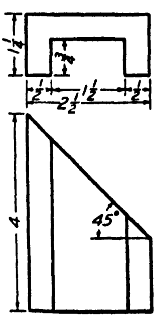


Figure 22·261
Prob. 444.

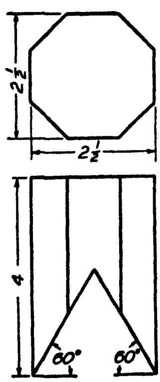


Figure 22·262.
Prob. 445.

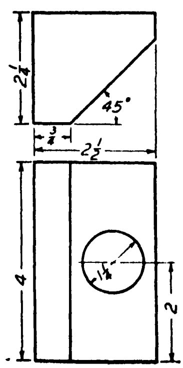


Figure 22·263
Prob. 446.

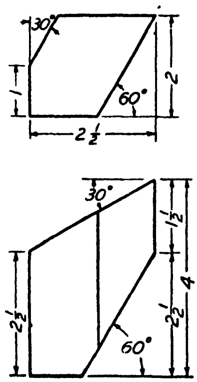


Figure 22·264
Prob. 447.

Problem 448 Fig. 22·265. Develop the lateral surface of the cylinder using the given layout. Read Art. 18·4.

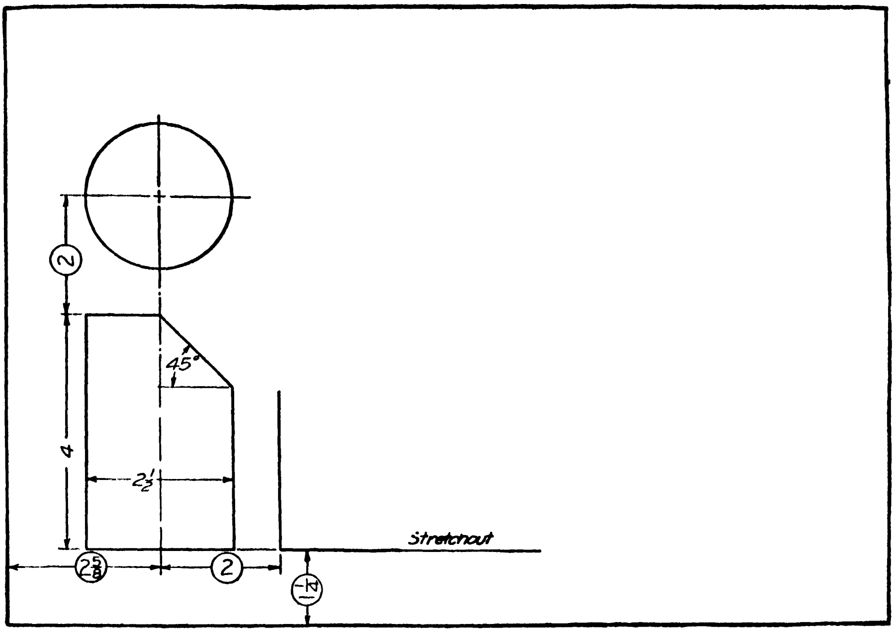


Figure 22·265 Development. **Prob. 448.**

Problems 449 and 450 Figs. 22·103 and 22·104. Develop the lateral surface. They may be worked on a full sheet using the layout of Fig. 22·265.

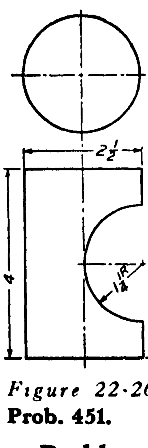


Figure 22·266 **Prob. 451.**

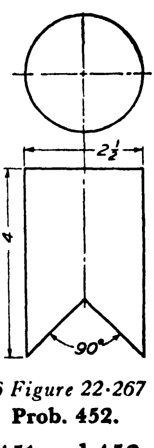


Figure 22·267 **Prob. 452.**

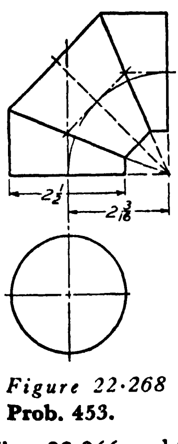


Figure 22·268 **Prob. 453.**

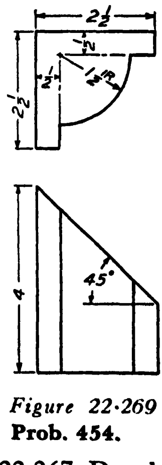


Figure 22·269 **Prob. 454.**

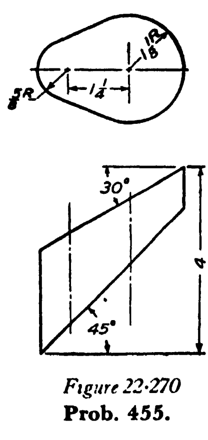


Figure 22·270 **Prob. 455.**

Problems 451 and 452 Figs. 22·266 and 22·267. Develop the lateral surface of the *cylinder* using the layout of Fig. 22·265.

Problem 453 Fig. 22·268. Develop the *three-piece elbow*. Refer to Arts. 18·5 and 18·6. Use a full sheet. Space the views and the pattern carefully.

Problems 454 and 455 Figs. 22·269 and 22·270. Develop the lateral surface. Use the layout of Fig. 22·265.

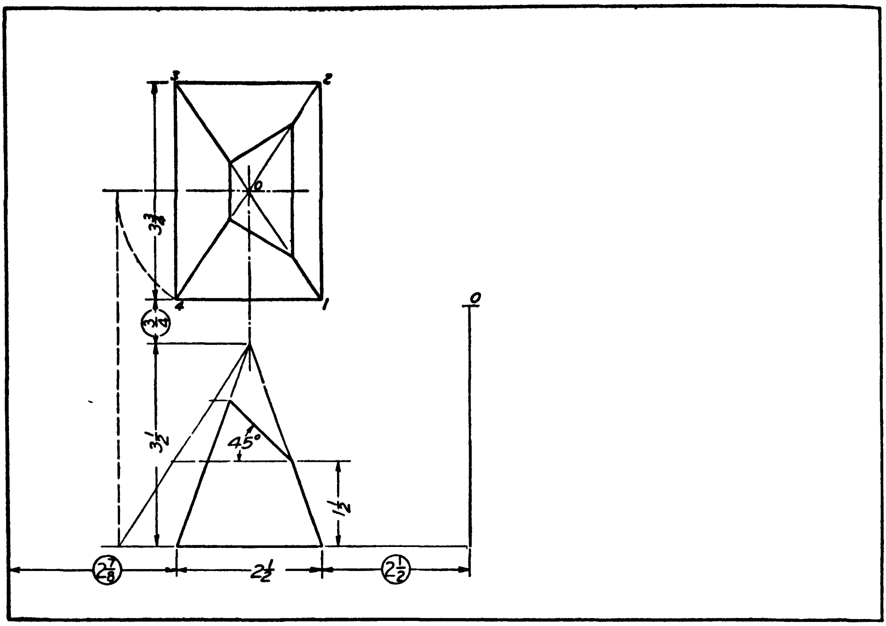
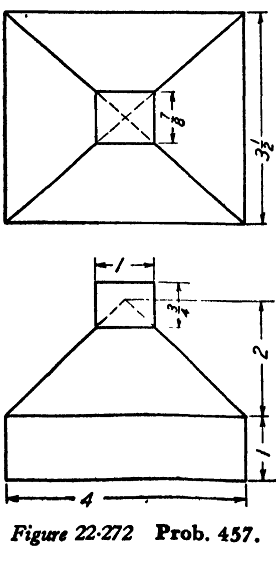
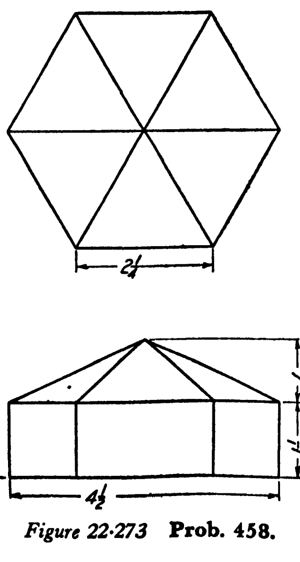


Figure 22·271 Development. **Prob. 456.**

Problem 456 Fig. 22·271. Develop the *truncated rectangular pyramid.* First revolve the edge *O* 4 until its true length shows in the front view. Start with this edge in the position shown to the right of the front view. Read Art. 18·10.

Problems 457 to 459 Figs. 22·272 to 22·274. Develop the surface.





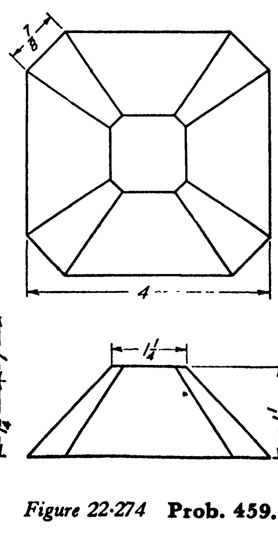


Figure 22·272 **Prob. 457.** *Figure 22·273* **Prob. 458.** *Figure 22·274* **Prob. 459.**

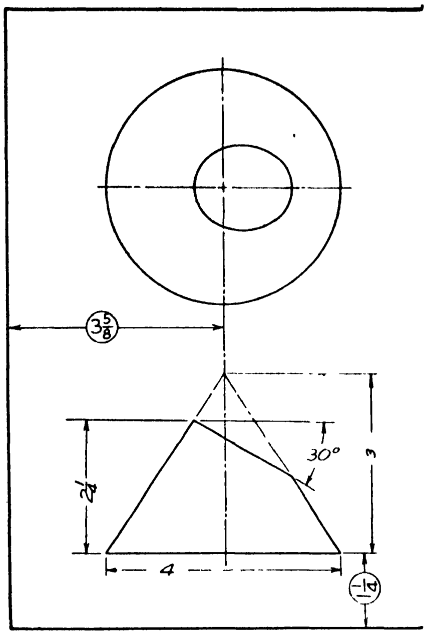


Figure 22·275 Development. **Prob. 460.**

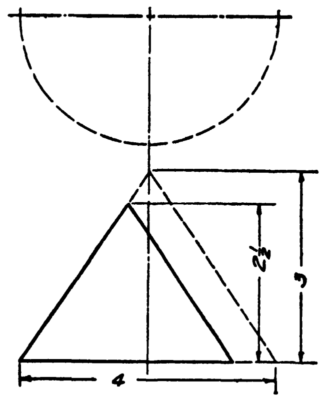


Figure 22·276 **Prob. 461.**

Problem 460 Fig. 22·275. Develop the lateral surface (Arts. 18·2, 18·3).

Problems 461 to 463 Figs. 22·276 to 22·278. Develop the conical surfaces.

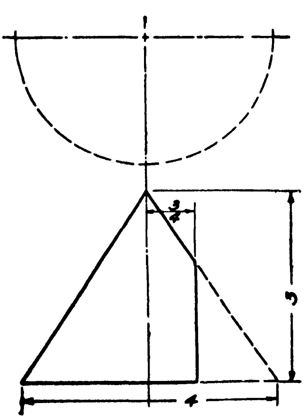


Figure 22·277 **Prob. 462.**

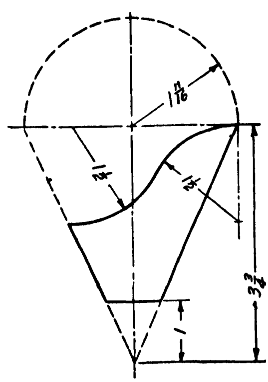


Figure 22·278 **Prob. 463.**

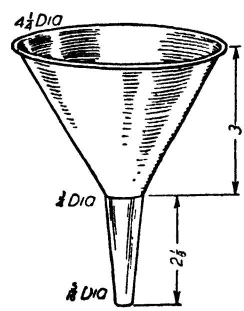


Figure 22·279 Funnel. **Prob. 464.**

Problem 464 Fig. 22·279. Draw a pattern for the *funnel.*

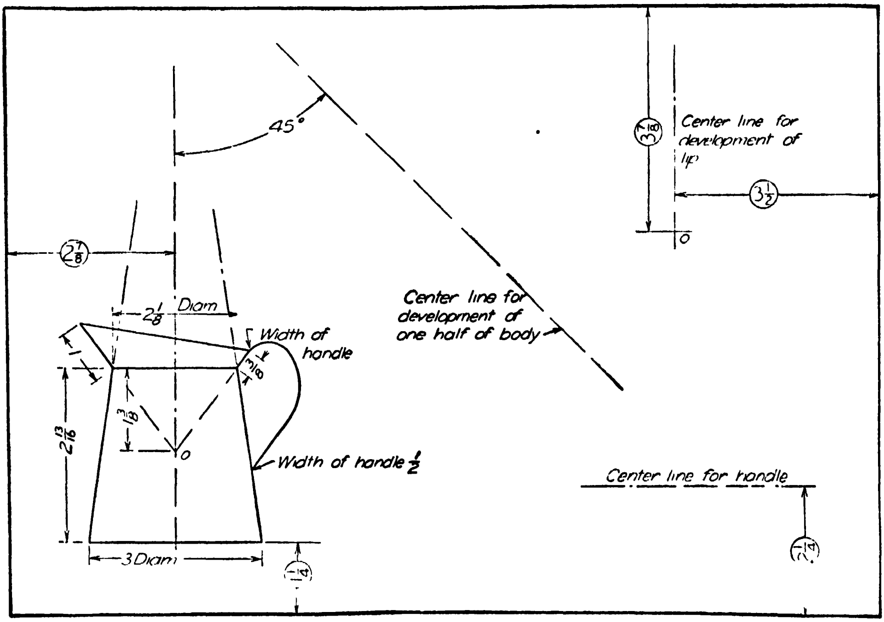


Figure 22·280 Pattern for half-pint measure. **Prob. 465.**

Problem 465 Fig. 22·280. Develop the *half-pint measure.* Arts. 18·20 and 18·21.

Problem 466 Fig. 22·281. Draw patterns for the *scoop.*

Problem 467 Fig. 22·282. Make a working drawing, with patterns for the *bird house.*

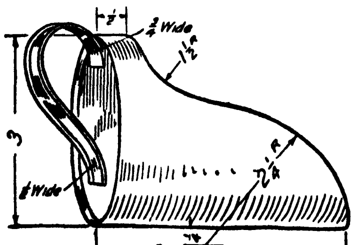


Figure 22·281 Scoop. **Prob. 466.**

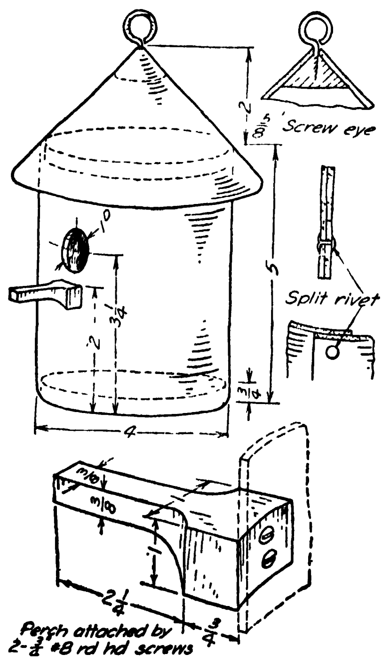


Figure 22·282 Bird house. **Prob. 467.**

Problem 468 Fig. 22·283. Draw a pattern for the *offset funnel* using the layout given. Study Arts. 18·9 and 18·13 for the general method of solution for problems of this type.

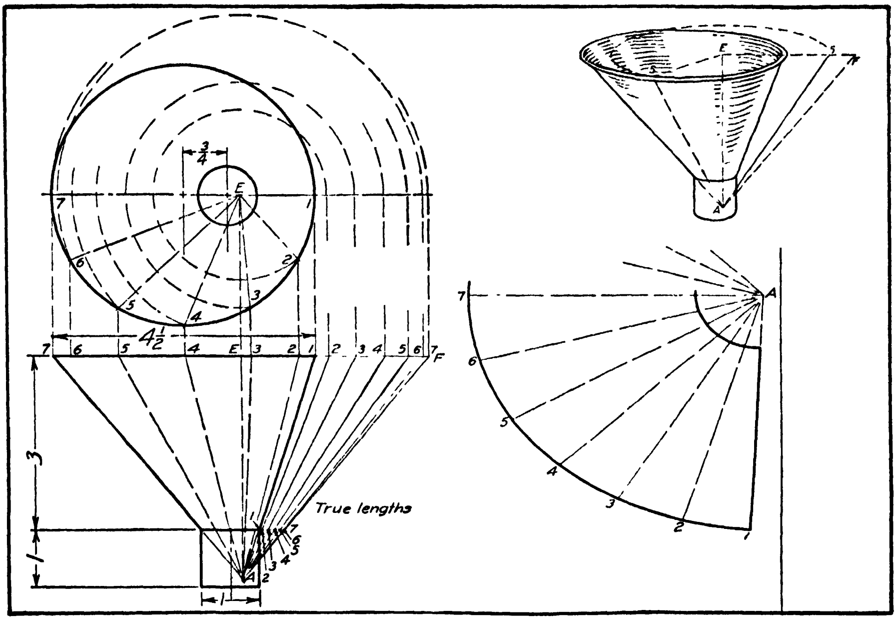
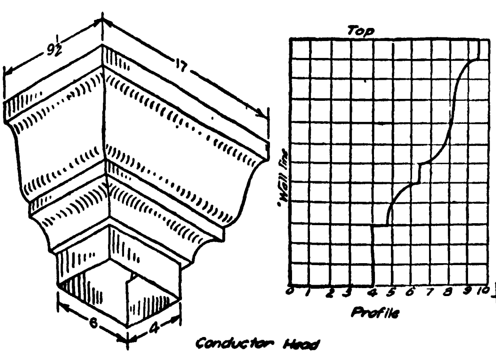


Figure 22·283 Offset funnel. **Prob. 468.**

Problem 469 Fig. 22·284. Draw the orthographic views and the pattern for the *conductor head*. Use a scale that will be suitable for a standard-size sheet. Note that the profile is defined by an outline drawn on squared paper. Each square represents 1″.



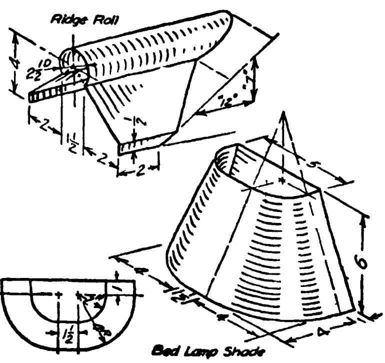


Figure 22·284 Conductor head. **Prob. 469.**

Figure 22·285 Ridge roll and bed-lamp shade. **Probs. 470 and 471.**

Problem 470 Fig. 22·285. Draw a pattern for the *ridge roll*.

Problem 471 Fig. 22·285. Draw a pattern for the *bed-lamp shade*. Use a scale that will be suitable for a standard-sized sheet.

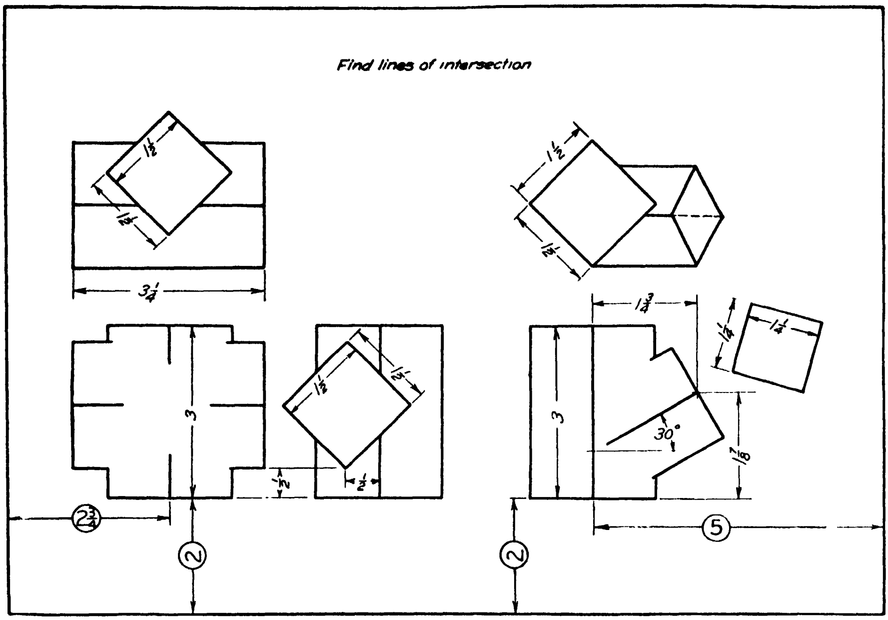


Figure 22·286 Intersections. **Probs. 472 and 473.**

Study Arts. 18·14 to 18·19 on intersections before beginning these problems. First observe the kinds of surfaces and the relative positions. Then see where the limiting planes are to be taken and how many planes are to be needed. Find the lines cut and locate the points on the line of intersection (where the lines cut from both surfaces by the same plane cross each other).

Problem 472 Fig. 22·286. Find the line of intersection between the two prisms (Art. 18·15).

Problem 473 Fig. 22·286. Find the line of intersection between the two prisms (Art. 18·15).

Problem 474 Fig. 22·287. Find the line of intersection between the two prisms (Art. 18·15).

Problem 475 Fig. 22·287. Find the line of intersection between the two prisms (Art. 18·15).

Problem 476 Fig. 22·288. Find the line of intersection between the two cylinders (Art. 18·16).

Problem 477 Fig. 22·288. Find the line of intersection between the two cylinders (Art. 18·16).

Problem 478 Fig. 22·289. Find the line of intersection between the triangular prism and the cylinder (Art. 18·18).

Problem 479 Fig. 22·289. Find the line of intersection between the hexagonal prism and the cylinder (Art. 18·18).

Problems 480 and **481** Fig. 22·290. Find the line of intersection between the hexagonal prism and the cylinder (Art. 18·18).

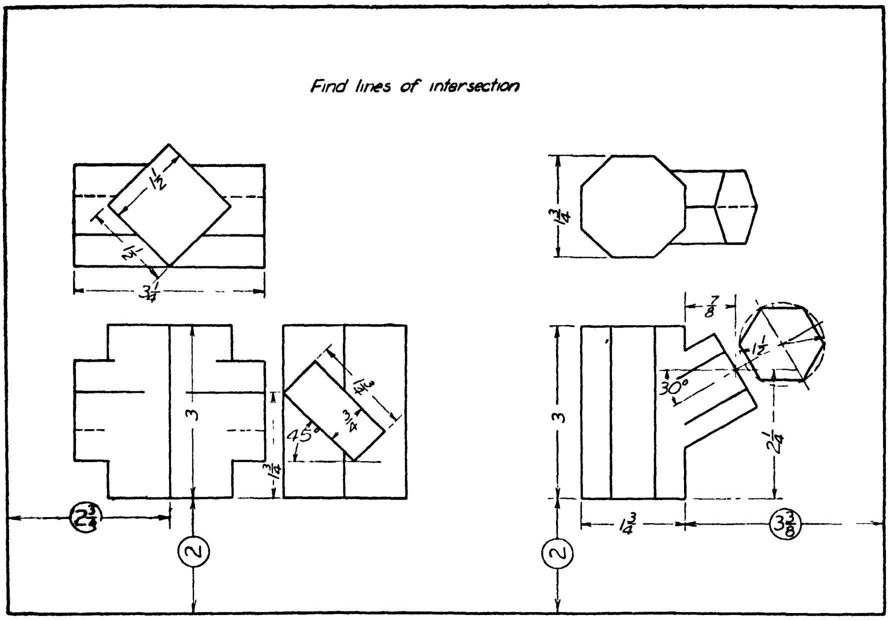


Figure 22·287 Intersections. **Probs. 474 and 475.**

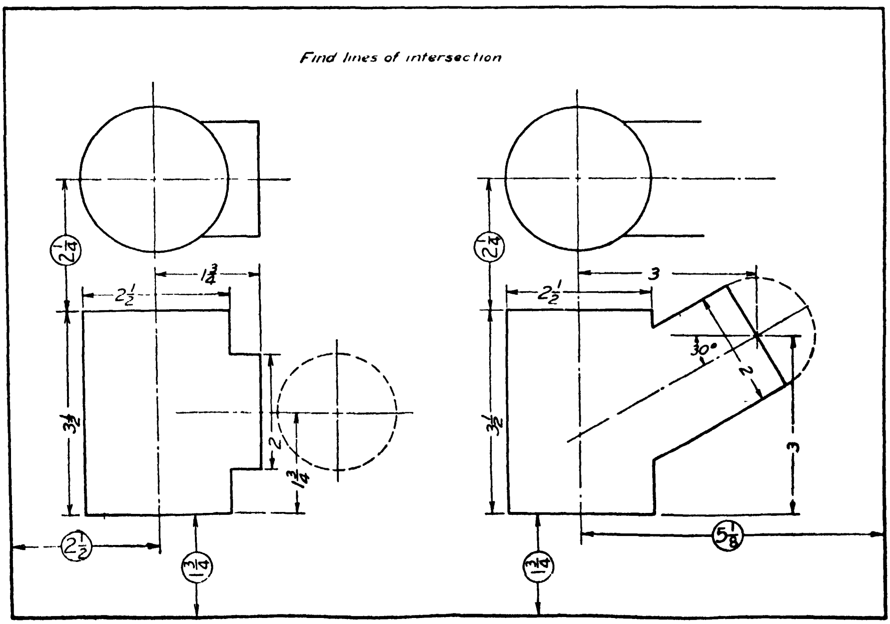


Figure 22·288 Intersections. **Probs. 476 and 477.**

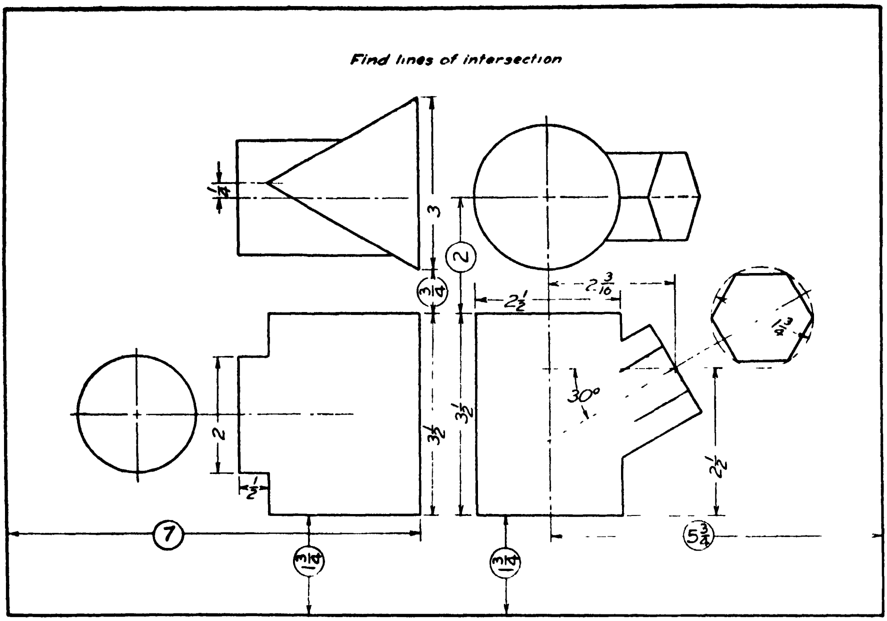


Figure 22·289 Intersections. **Probs. 478 and 479.**

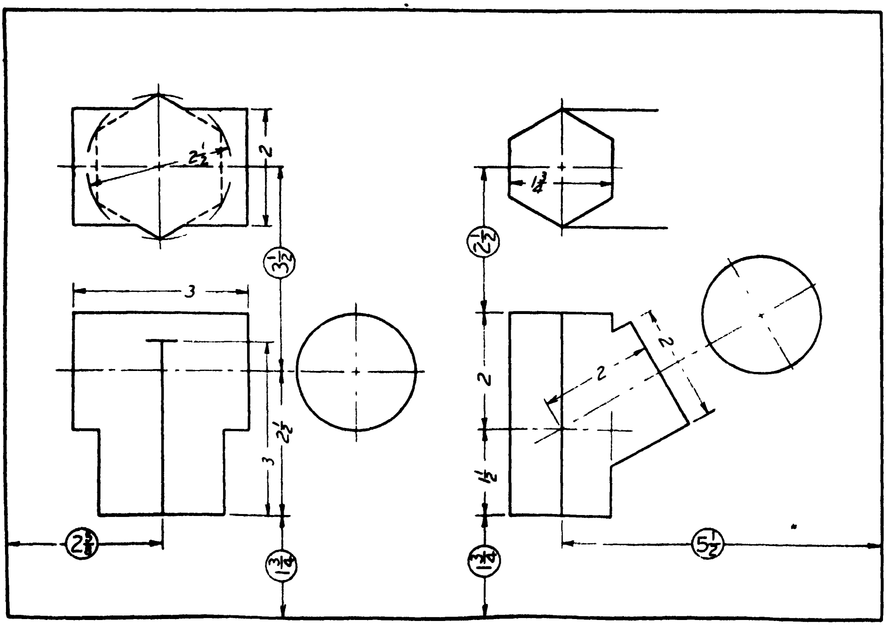


Figure 22·290 Intersections. **Probs. 480 and 481.**

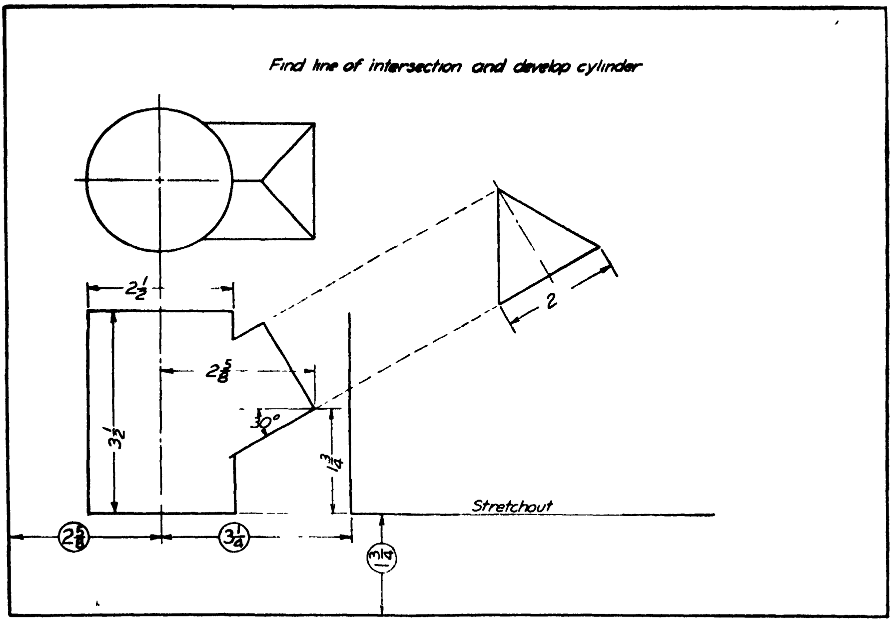


Figure 22·291 Development. **Prob. 482.**

Problem 482 Fig. 22·291. Find line of intersection and develop lateral surface of cylinder.

Problems 483 and 484 Figs. 22·292 and 22·293. Find line of intersection and develop the pyramid.

Problem 485 Fig. 22·294. Find line of intersection and develop the cone.

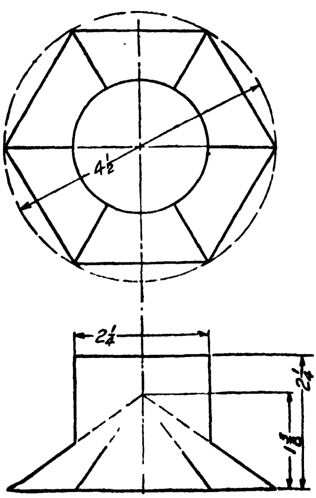


Figure 22·292 **Prob. 483.**

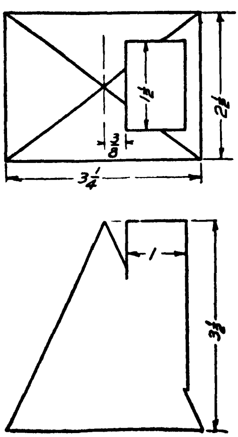


Figure 22·293 **Prob. 484.**

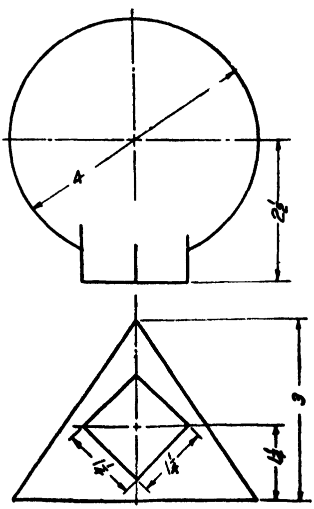


Figure 22·294 **Prob. 485.**

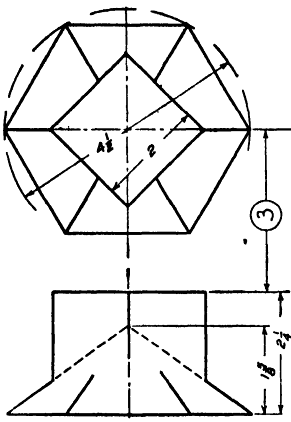


Figure 22·295 Pyramid.
Prob. 486.

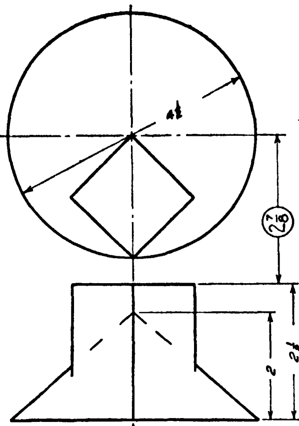


Figure 22·296 Cone.
Prob. 487.

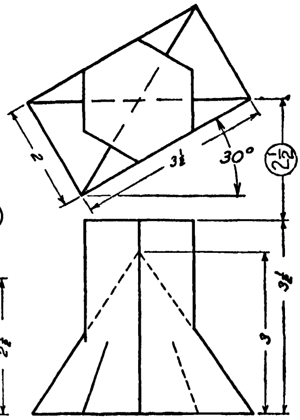


Figure 22·297 Pyramid.
Prob. 488.

Problem 486 Fig. 22·295. Find line of intersection and develop the *pyramid.*

Problem 487 Fig. 22·296. Find line of intersection and develop the *cone.*

Problem 488 Fig. 22·297. Find line of intersection and develop the *pyramid.*

Problem 489 Fig. 22·298. Develop the surface of the *transition piece* (Art. 18·13).

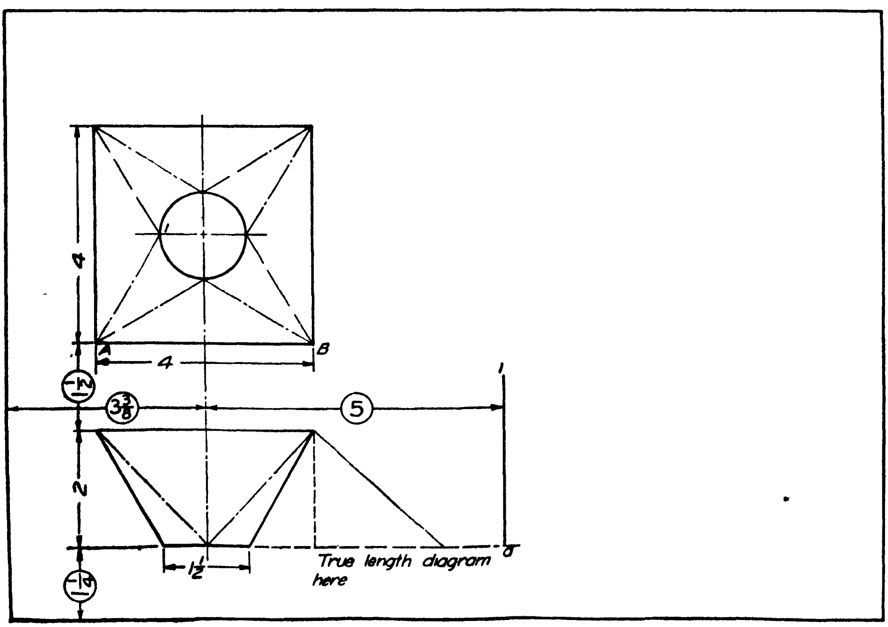


Figure 22·298 Transition piece. **Prob. 489.**

Problems 490 to 492 Figs. 22·299 to 22·301. Develop the surface of the transition piece. Study Art. 18·13 carefully. Any of the intersection problems may be used for development by solving one problem on a sheet.

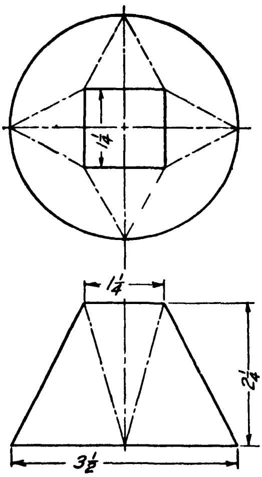


Figure 22·299 **Prob. 490.**

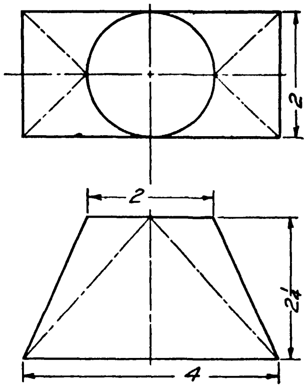


Figure 22·300 **Prob. 491.**

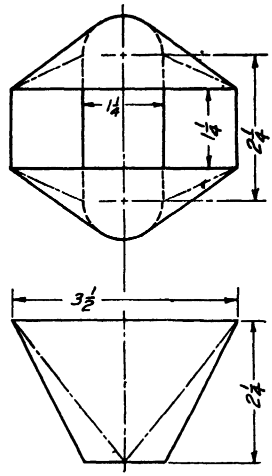


Figure 22·301 **Prob. 492.**

GROUP 20. ARCHITECTURAL LETTERING

22·23 Study Art. 19·8 before starting these exercises. It will be helpful to have some special books on lettering on hand for reference such as "The Essentials of Lettering" by French and Meiklejohn or "The Art of Lettering" by Carl L. Svensen.

Problems 493 to 496 Fig. 19·11. Single-stroke Old Roman capitals in pencil. Lay out a sheet and rule guidelines as directed in Probs. 44 to 47, (Fig. 22·26). Refer to Fig. 19·11 and study the letters carefully. Letter as indicated in each space. Complete each line.

Problem 493 Fig. 19·11, Space 1. Single-stroke Old Roman capitals, upper left-hand space; on last line letter FIX LINTEL "H-Z" instead of INLET FILLET HELIX.

Problem 494 Fig. 19·11, Space 2. Single-stroke Old Roman capitals, upper right-hand space.

Problem 495 Fig. 19·11, Space 3. Single-stroke Old Roman capitals, lower left-hand space; on last line letter BRIDGE SPACE RULE instead of JIGS, GEARS, SCREWS.

Problem 496 Fig. 19·11, Space 4, Numerals from Fig. 19·11, in lower right-hand space.

Problem 497 Fig. 22·302, Space 1, Single-stroke Roman capitals, Fig. 19·11. Start $1\frac{1}{2}''$ over and $\frac{5}{8}''$ down. The first space is $\frac{1}{4}''$ down, the next $\frac{3}{16}''$. Repeat until there are guidelines for nine lines of $\frac{1}{4}''$ high letters. Make the first three lines in pencil. Repeat the same copy on the next three lines very lightly in pencil and go over them in ink. Use a Hunt 512 or Esterbrook 802 pen. Repeat same copy on last three lines, directly in ink.

Problem 498 Fig. 22·302, Space 2. Single-stroke lowercase letters, Fig. 19·11. Start $1\frac{1}{2}''$ over and $\frac{5}{8}''$ down. The bodies of the letters are $\frac{1}{8}''$ high (one-half the cap height). The first space is $\frac{1}{8}''$, the second space is $\frac{1}{8}''$, and the third space $\frac{1}{4}''$. Repeat until there are guidelines as shown. Make the alphabet in pencil on the first two lines. Repeat lightly in pencil on the next two lines and go over them in ink. Use a ball-point pen. Repeat on the next two lines in ink without first penciling. Letter your name in caps and lower case on line 7, in pencil. Repeat on line 8, directly in ink.

Problem 499 Fig. 22·302, Space 3. Rule guidelines as directed for Prob. 498 except start $1''$ over. Letter the sentence shown on Prob. 51 (except change *two-thirds* in last line to *one-half*) first in pencil on the first four lines, then repeat on the last four lines directly in ink.

Problem 500 Fig. 22·302, Space 4. In the middle of the space, lay out a rectangle $5''$ wide and $1\frac{1}{2}''$ high. Letter a title similar to the one shown in Fig. 19·12.

Problem 501 Using the Roman alphabet shown in Fig. 19·10, design a title page similar to one of those shown in Fig. 22·30. (Use ARCHITECTURAL DRAWING instead of MECHANICAL DRAWING.)

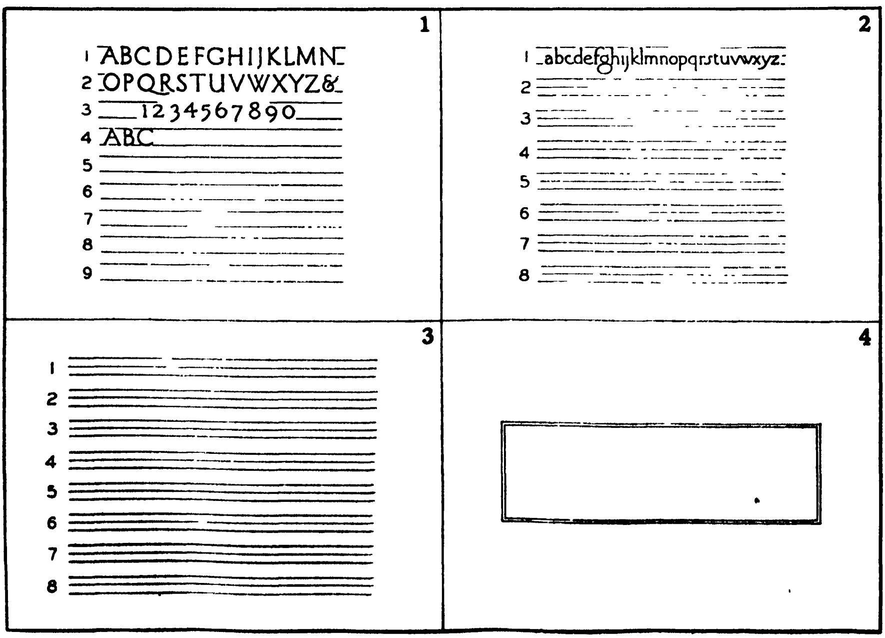


Figure 22·302 **Probs. 497 to 500.**

GROUP 21. ARCHITECTURAL DRAWING

22·24 The reading and making of house plans are important parts of mechanical drawing. Several houses under construction should be visited at different stages of completion and compared with the working drawings. Study Chap. 19 carefully, especially the set of plans in Figs. 19·31 to 19·35 before starting the problems in this group.

Problem 502 Fig. 19·14. Turn the sheet with the long dimension vertical. Make an isometric drawing showing *balloon framing*. Select a suitable scale. Studs and floor joists to be spaced 16″ center to center. Use 2″ × 4″ studs and 2″ × 8″ floor joists.

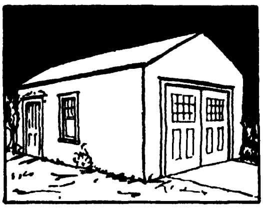


Figure 22·303 **Prob. 509.**

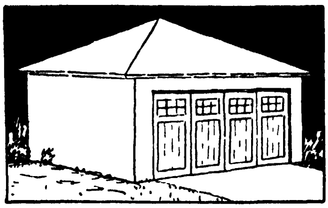


Figure 22·304 **Prob. 510.**

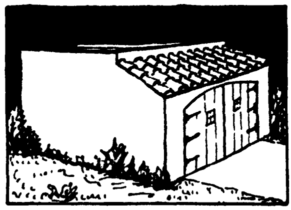


Figure 22·305 **Prob. 511.**

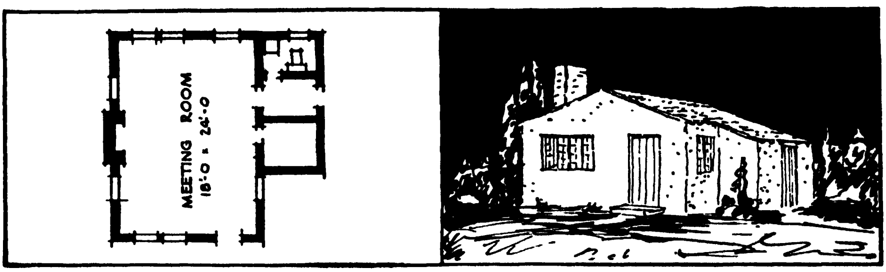


Figure 22·306 **Prob. 546.**

Problem 503 Fig. 19·15. Turn the sheet with the long dimension vertical. Make an isometric drawing showing *braced framing*. Select a suitable scale. Studs and floor joists to be spaced 16″ center to center. Use 2″ × 4″ studs and 2″ × 8″ floor joists.

Problem 504 Figs. 19·16 and 19·18. In the left-hand half of the sheet make a drawing showing a *braced frame sill;* in the right-hand half, a drawing showing a *box sill in brick veneer.*

Problem 505 Fig. 19·19. Make a drawing showing *diagonal sheathing.* Select a suitable scale to show the construction clearly.

Problem 506 Fig. 19·20. Make a drawing showing *horizontal sheathing.* Select a suitable scale to show the construction clearly.

Problem 507 Figs. 19·22 to 19·24. Make a drawing to show two of the three cornices illustrated, one in the left-hand half of the sheet and the other in the right-hand half. Select a scale to show the construction clearly.

Problem 508 Fig. 19·21. Make a pictorial drawing to show the roof framing illustrated. Select a suitable scale to show the construction clearly.

Problems 509 to 511 Figs. 22·303 to 22·305. Draw plan and elevation for one of the garages. Size to be specified by the instructor. Refer to catalogues for over-all dimensions of automobiles.

Problems 512 to 523 Figs. 22·307 to 22·318. Select one of the suggested plans. Make a kitchen plan showing the size and location of both movable and built-in features. Refer to catalogues and trade literature for necessary information.

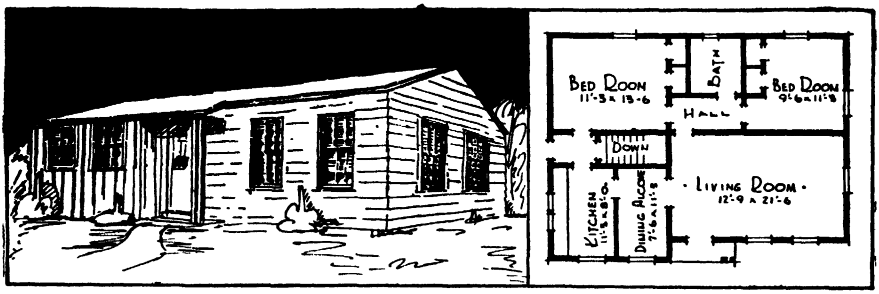


Figure 22·307 **Probs. 512, 524, 547.**

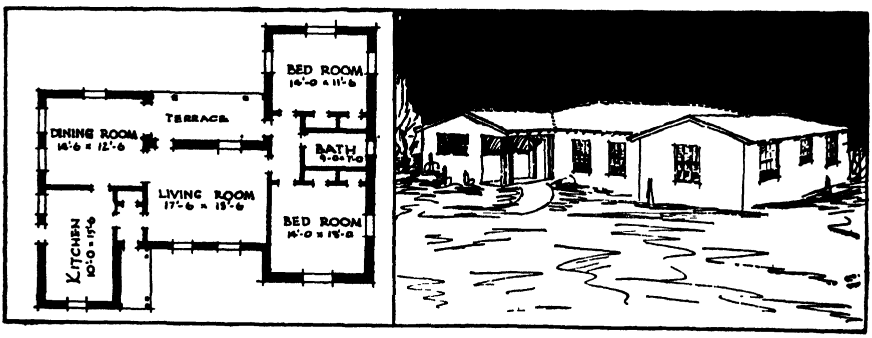


Figure 22·308 **Probs. 513, 525, 548.**

Problems 524 to 535 Figs 22·307 to 22·318. Select one of the suggested plans. Make a bathroom plan showing the sizes and location of the plumbing fixtures. Refer to a manufacturer's catalogue for sizes and styles of the various fixtures.

Problems 536 to 544 Figs. 22·310 to 22·318. Select one of the suggested plans. Make a stairway diagram and draw details for the stairway. Refer to Fig. 19·25.

Problem 545 Figs. 19·31 to 19·35. Make a set of plans for the house illustrated. Draw all four elevations and cabinet details if required by instructor.

Problem 546 Fig. 22·306. Draw a floor plan, foundation plan, and elevations for the club house. The basement is to be omitted, so piers may be

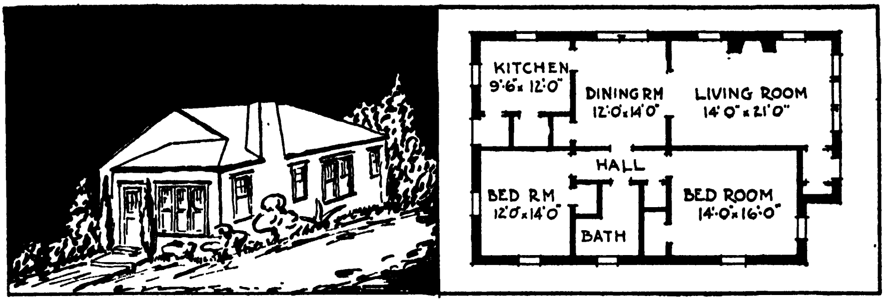


Figure 22·309 **Probs. 514, 526, 549.**

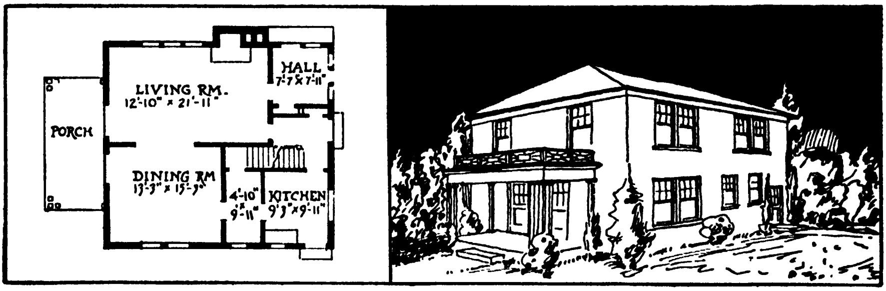


Figure 22·310 **Probs. 515, 527, 536, 550.**

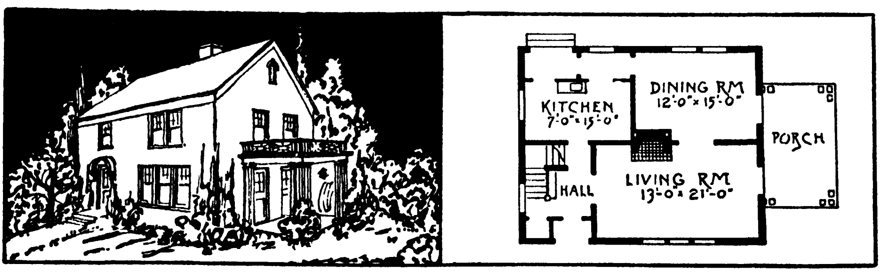


Figure 22·311 **Probs. 516, 528, 537, 551.**

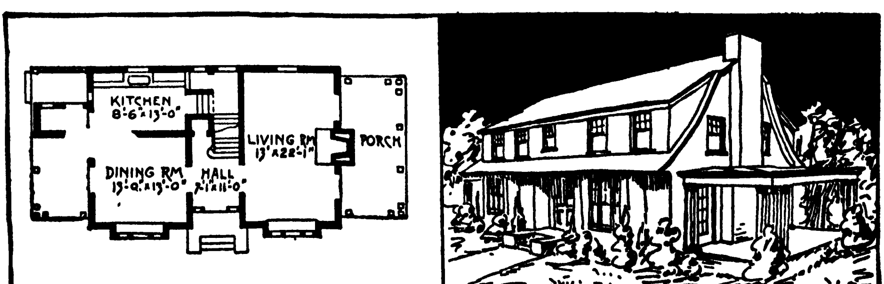


Figure 22·312 **Probs. 517, 529, 538, 552.**

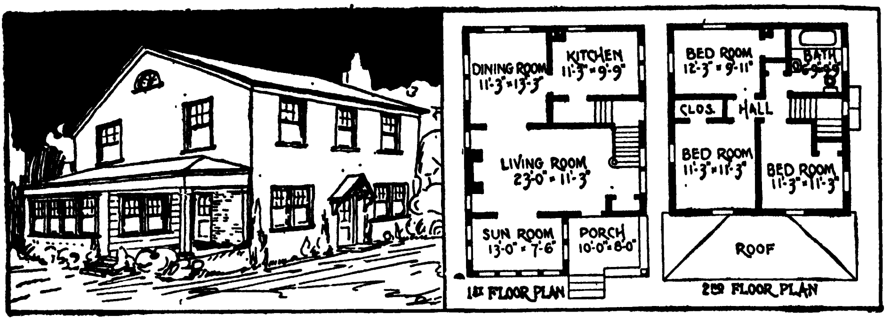


Figure 22·313 **Probs. 518, 530, 539, 553.**

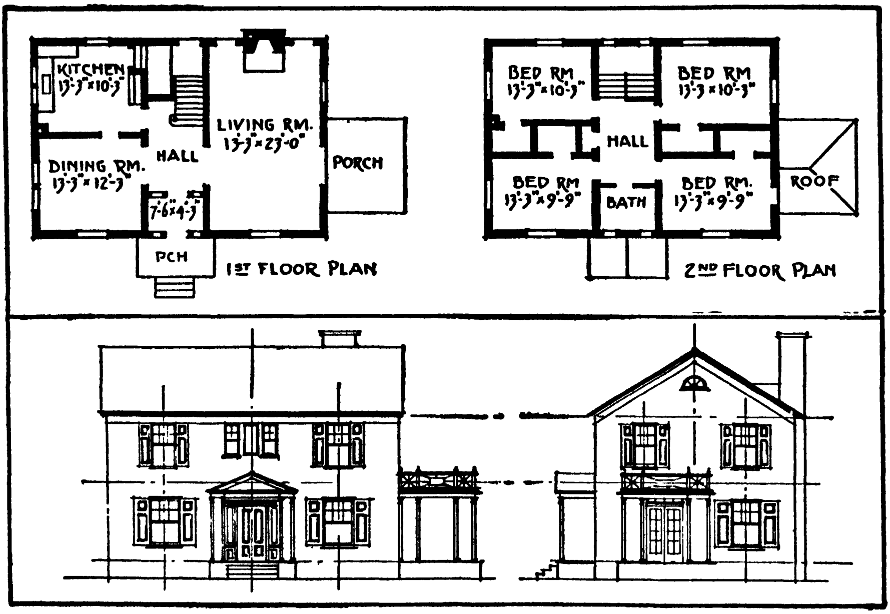


Figure 22·314 **Probs. 519, 531, 540, 554.**

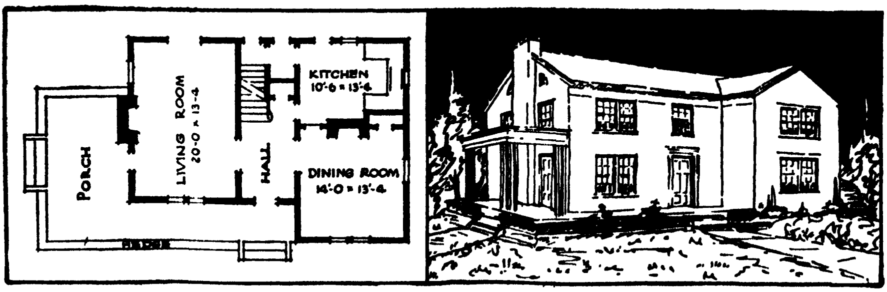


Figure 22·315 **Probs. 520, 532, 541, 555.**

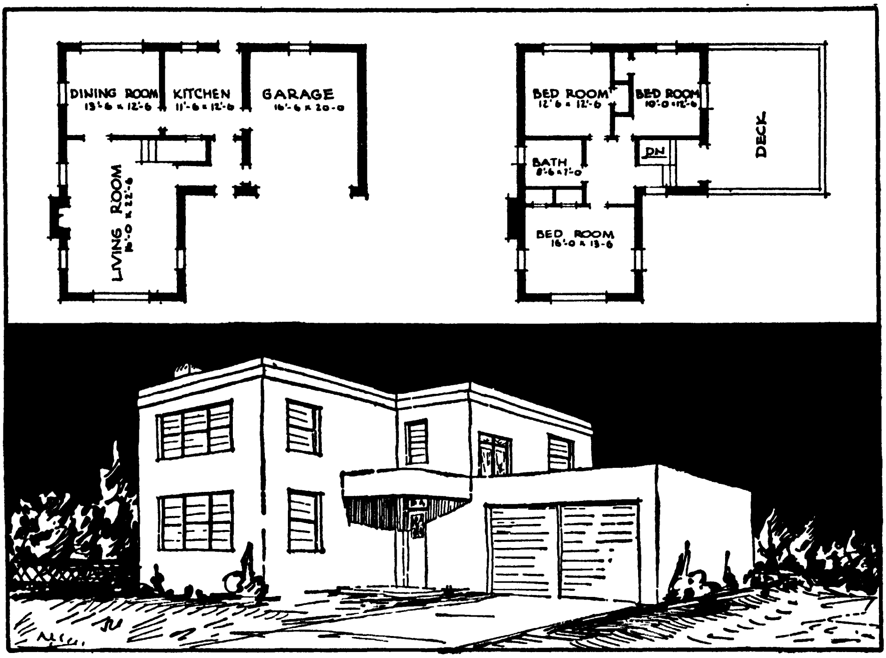


Figure 22·316 **Probs. 521, 533, 542, 556.**

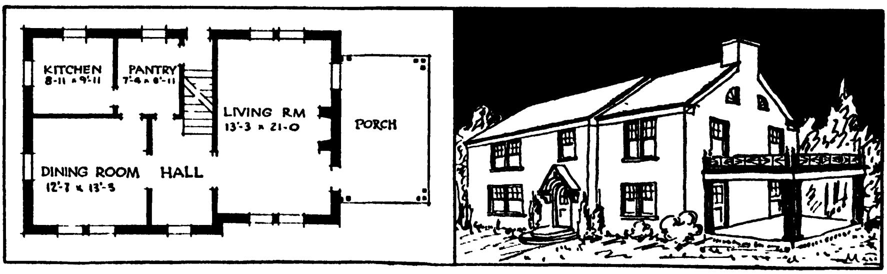


Figure 22·317 **Probs. 522, 534, 543, 557.**

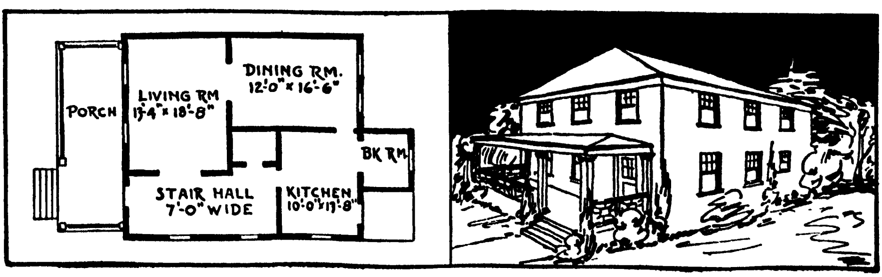


Figure 22·318 **Probs. 523, 535, 544, 558.**

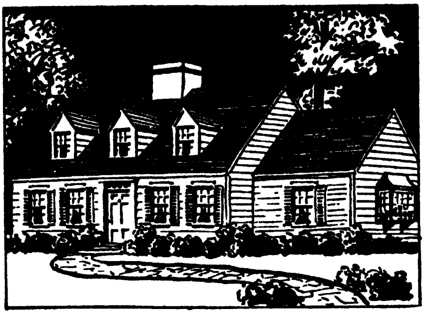


Figure 22·319 **Prob. 567.**

Figure 22·320 **Prob. 568.**

Figure 22·321 **Prob. 569.**

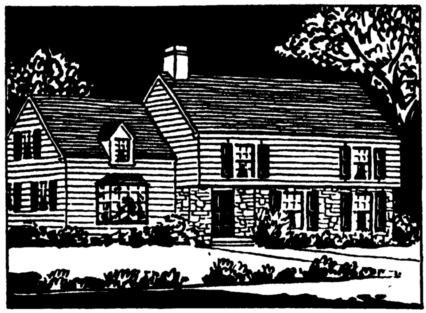


Figure 22·322 **Prob. 570.**

Figure 22·323 **Prob. 571.**

Figure 22·324 **Prob. 572.**

Figure 22·325 **Prob. 573.**

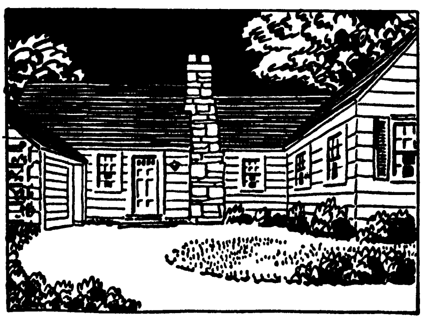


Figure 22·326 **Prob. 574.**

Above drawings by William Allen, Courtesy *Science Illustrated.*

placed inside the foundation where necessary to support a central lengthwise girder on which to rest the floor joists.

Problems 547 to 549 Figs. 22·307 to 22·309. Make drawings for one of the suggested houses as directed by your instructor. (1) Basement plan, (2) floor plan, (3) elevations—four sides, (4) details. In some sections of the country the basement may be omitted. (In such cases draw a foundation plan instead of a basement plan.)

Problems 550 to 558 Figs. 22·310 to 22·318. Select one of the sketch plans and make architectural working drawings as required by your instructor.

1. Basement plan
2. First-floor plan
3. Second-floor plan
4. Front elevation
5. Right-side elevation
6. Left-side elevation
7. Rear elevation
8. Details

Problems 559 to 566 Figs. 19·2 to 19·9. Make floor plans to suit the exterior of one of the houses illustrated, as directed by your instructor.

Problems 567 to 574 Figs. 22·319 to 22·326. Make floor plans to suit the exterior of one of the houses illustrated, as directed by your instructor.

GROUP 22. STRUCTURAL DRAWINGS

22·25 Study Chap. 20 before beginning these problems.

Problem 575 Fig. 20·3. Make a drawing of the structural steel shapes as shown.

Problem 576 Fig. 20·6. Make a drawing showing the rivet symbols. Rearrange to make a good appearing sheet.

Problem 577 Fig. 20·4. Make a drawing of the structural steel detail as shown. Consult a structural steel handbook. Scale: $\frac{3}{4}'' = 1'$.

Problem 578 Fig. 20·2. Make a structural drawing of the truss as shown. Consult a structural steel handbook. Scales: $\frac{3}{4}'' = 1'$ and $1\frac{1}{2}'' = 1'$.

Problem 579 Fig. 20·5. Make a drawing of the reinforced concrete detail as shown. Scale: $1\frac{1}{2}'' = 1'$.

GROUP 23. MAP DRAWINGS

22·26 Study Chap. 21 before beginning these problems.

Problem 580 Fig. 21·1. Make a plat of a survey as shown.

Problem 581 Fig. 21·2. Make a city map as shown, or a part of your town or city. Use dividers to transfer and enlarge the figure.

Problem 582 Fig. 21·3. Make a contour drawing as shown. Use dividers to transfer and enlarge the figure.

Problem 583 Fig. 21·3. Make a contour drawing similar to the figure, but show the profile on a plane closer to the front.

Problem 584 Fig. 21·4. Make a contour map as shown. Use dividers to transfer and enlarge the figure.

Problem 585 Fig. 21·5. Draw the conventional symbols and letter them as indicated. Make the rectangles $2'' \times 1\frac{3}{4}''$.

APPENDIX

Reference Material in Text

Text-films. The McGraw-Hill Text-films listed at the end of Chapters 1, 4, 6, 7, 8, and 11 of this book are of particular value as they are correlated with the text. Certain other films and filmstrips that may be used where they suit the requirements of the course are listed in this Appendix. Other films will come to the instructor's attention from time to time and should be noted for possible use. It is, of course, desirable that all such material be previewed to determine its helpfulness and suitability for the course.

Information in parentheses following the title of the film is as follows: (min) refers to minutes of running time; (si) means silent; (sd) means sound; (MP) means motion picture, 16 mm.; (FS) means filmstrip, 35 mm. All those not listed as color (C) are black and white.

Castle Films, 445 *Park Ave.*, New York 22, *N. Y.*
How to Develop an Intersection: Part 1 (si FS)
How to Develop an Intersection: Part 2 (si FS)
Fabricating Metal Aircraft (14 min sd MP)

Floyd W. Cocking, 4757 *Constance Dr.*, *San Diego*, *Calif.*
Introduction to Mechanical Drawing (20 min si MP)

Frank Knaus, 2113 *Parkside Ave.*, *Los Angeles*, *Calif.*
Industrial Design (10 min si C MP)

Jam Handy Organization, 2821 *South Grand Blvd.*, *Detroit* 11, *Mich.*
T Squares and Triangles, Part 1 (si FS)

T Squares and Triangles, Part 2 (si FS)
Geometric Construction, Part 1 (si FS)
Geometric Construction, Part 2 (si FS)

Purdue University, General Engineering Dept., Lafayette, Ind.

Applied Geometry (16 min si MP)
Orthographic Projection (30 min si MP)
Auxiliary Views (15 min si MP)
Development of Surfaces (15 min si MP)
Intersection of Surfaces (15 min si MP)

U.S. Office of Education (Obtainable from Castle Films, Inc., 445 *Park Ave., New York* 22, *N.Y.)*

The number of U.S. Office of Education films is very large. Only a few are listed here. Silent filmstrips and instructor's manuals are coordinated with the films.

Sectional Views, Projections, Finish Marks (15 min sd MP)
Basic Machines: The Lathe (15 min sd MP)
Basic Machines: The Milling Machine (15 min sd MP)
Basic Machines: The Shaper (15 min sd MP)
Basic Machines: The Drill Press (10 min sd MP)
Principal Dimensions, Reference Surfaces and Tolerances (12 min sd MP)
Visualizing an Object (9 min sd MP)
Reading a Three-view Drawing (10 min sd MP)

Vesco Film Library, Audio-Visual Corp., 116 *Newbury St., Boston* 16, *Mass.*

Airplane Sheet Metal Work (22 min si MP)
The Making of an Airplane Fitting (22 min si MP)

Vocational Guidance Films, 2708 *Beaver Ave., Des Moines* 10, *Iowa.*

The Draftsman (11 min sd MP)

Figure A·1

Models. Machine parts and models of wood or other materials are useful aids in teaching orthographic projection. Plastic models of some of the problems in Group 4 of Chapter 22, devised by Mr. Elmer G. Locke, are made by Teaching Aids Specialty Company, Norman, Okla. The stand for holding models shown in the illustration (Fig. A·1) and the squared sketching paper (Fig. A·2 and A·3) are teaching aids devised by Mr. Frederick J. Bryant of Auburn, Me. Such sheets can be used to advantage in the study of orthographic projection as the views can be sketched, then checked by cutting on the line indicated, and folded to represent the planes of projection.

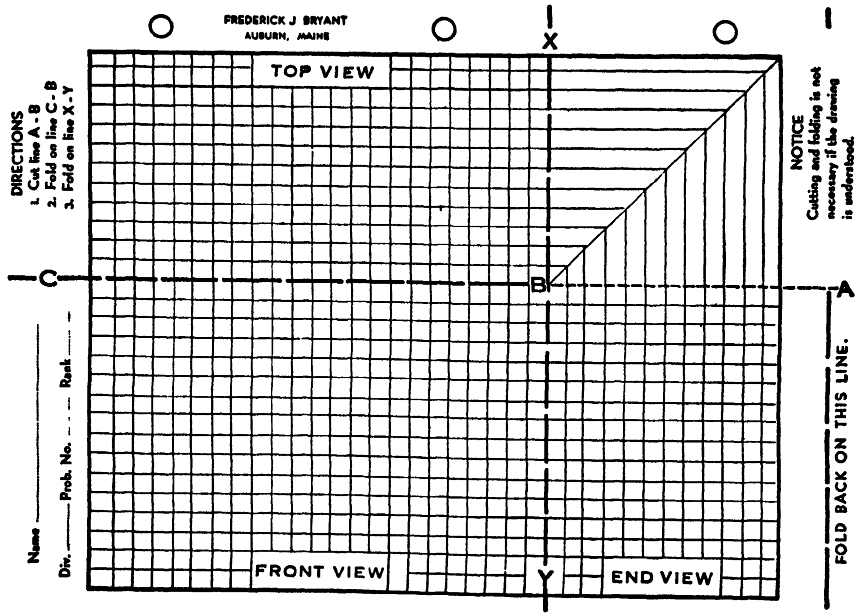


Figure A·2

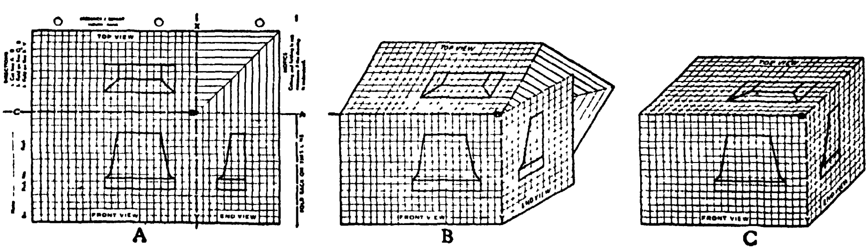


Figure A·3

Wall charts such as the following are useful as teaching aids for reference use in the school drafting room. The instructor should write to the companies named for information about securing copies. "Architectural and Engineering Symbols" (*The Frederick Post Company,* 3635 *N. Hamilton Ave., Chicago, Ill.*). "Basic Standards for Architectural Drawing," "Basic Standards in Mechanical Drawing," and "Standard Woodworking Joints" (*Eberhard Faber Company,* 37 *Greenpoint Ave., Brooklyn* 27, *N.Y.*). A blueprint, "Decimal Equivalents" and a pamphlet "Use and Care of Drawing Instruments" (*Eugene Dietzgen Company,* 2425 *Sheffield Ave., Chicago* 14, *Ill.*).

American Standards, some of which are listed here, are necessary for reference in making working drawings and for other purposes. A complete list of Standards with prices is published by the American Standards Association, 29 W. 39th St., New York, N.Y.

Abbreviations for Use on Drawings	Z32.13
Drawings and Drafting Room Practice	Z14.1
Graphical Symbols for Use on Drawings in Mechanical Engineering	Z32.2
Letter Symbols for Gear Engineering	B6.5
Spur Gear Tooth Form	B6.1
Spring Lock Washers	B27.1
Shaft Couplings	B49
Woodruff Keys, Keyslots, and Cutters	B17f
Machine Tapers	B5.10
Shafting on Stock Keys	B17.1
Screw Threads for Bolts, Nuts, Machine Screws, and Threaded Parts	B1.1
Wrench-head Bolts and Nuts and Wrench Openings	B18.2
Slotted and Recessed Head Screws	B18.6
Socket Head Cap Screws and Socket Head Set Screws	B18.3
Pipe Threads	B2.1
Wrought-iron and Wrought-steel Pipe	B36.10
Steel Pipe Flanges and Flanged Fittings	B16e
C I Screwed Fittings	B16d
Malleable-iron Screwed Fittings, 150 Lb	B16c
Steel Butt-welded Fittings	B16.9
Limits and Fits in Engineering and Manufacturing	B4.1
Plumbing Code	P47.7

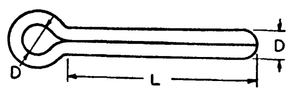
Decimal Equivalents of Common Fractions

1/64	.015625	17/64	265625	33/64	.515625	49/64	.765625
1/32	03125	9/32	28125	17/32	.53125	25/32	.78125
3/64	046875	19/64	.296875	35/64	.546875	51/64	.796875
1/16	.0625	5/16	.3125	9/16	.5625	13/16	.8125
5/64	.078125	21/64	.328125	37/64	.578125	53/64	.828125
3/32	.09375	11/32	.34375	19/32	.59375	27/32	.84375
7/64	.109375	23/64	.359375	39/64	.609375	55/64	.859375
1/8	.1250	3/8	.3750	5/8	.6250	7/8	.8750
9/64	.140625	25/64	.390625	41/64	.640625	57/64	.890625
5/32	.15625	13/32	.40625	21/32	.65625	29/32	.90625
11/64	.171875	27/64	.421875	43/64	.671875	59/64	.921875
3/16	.1875	7/16	.4375	11/16	6875	15/16	.9375
13/64	.203125	29/64	.453125	45/64	.703125	61/64	.953125
7/32	.21875	15/32	.46875	23/32	.71875	31/32	.96875
15/64	.234375	31/64	.484375	47/64	.734375	63/64	.984375
1/4	.2500	1/2	.5000	3/4	.7500	1	1.0000

American Standard Coarse and Fine Threads
With Minor Diameters for Tap-drill Sizes

Diameter	Threads per inch Coarse NC	Threads per inch Fine NF	Tap drill sizes Coarse NC	Tap drill sizes Fine NF	Diameter	Threads per inch Coarse NC	Threads per inch Fine NF	Tap drill sizes Coarse NC	Tap drill sizes Fine NF
1/4	20	28	0.1959	0.2113	1 3/8	6	12	1 1946	1 2848
5/16	18	24	0.2524	0.2674	1 1/2	6	12	1.3196	1.4098
3/8	16	24	0.3073	0 3299	1 3/4	5	..	1.5335	
7/16	14	20	0 3602	0 3834	2	4 1/2	..	1.7594	
1/2	13	20	0.4167	0.4459	2 1/4	4 1/2	..	2.0094	
9/16	12	18	0 4723	0.5024	2 1/2	4	..	2 2294	
5/8	11	18	0 5266	0.5649	2 3/4	4	..	2 4794	
3/4	10	16	0 6417	0.6823	3	4	..	2 7294	
7/8	9	14	0 7547	0.7977	3 1/4	4	..	2 9794	
1	8	14	0 8647	0.9227	3 1/2	4	..	3.2294	
1 1/8	7	12	0 9704	1 0348	3 3/4	4	..	3 4794	
1 1/4	7	12	1 0954	1 1598	4	4	.	3 7294	

SAE Standard Split Cotter Pins
Diameters and Lengths Are Indicated by *X*



Shank length	Shank diameter .061 1/16	.090 3/32	.122 1/8	.150 5/32	Shank length	Shank diameter .122 1/8	.150 5/32	.176 3/16	.207 7/32	225 1/4	280 5/16
5/16	x	..	..	..	1 3/8	x	x				
7/16	x	..	..	..	1 1/2	x	x				
1/2	x	x	..	..	1 5/8	x	x	x			
5/8	x	x	..	..	1 3/4	x	x	x	x		
3/4	x	x	..	..	2	..	x	x	x	x	
7/8	x	x	x	..	2 1/4	..	x	x	x	x	
1	..	x	x	..	2 1/2	..	x	x	x	x	x
1 1/8	..	x	x	..	2 3/4	..	..	..	x	x	x
1 1/4	..	..	x	x	3	..	..	..	x	x	x

American Standard Regular Square and Hexagon Boltheads and Nuts

Nominal Dimensions. Unfinished, Square and Hexagon

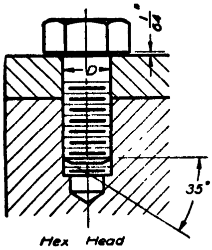
Semifinished, Hexagon Only

Diameter	*Boltheads*				*Nuts*			
	Unfinished		*Semifinished*		*Unfinished*		*Semifinished*	
	Flats	*Height*	*Flats*	*Height*	*Flats*	*Thickness*	*Flats*	*Thickness*
1/4	3/8	11/64	3/8	5/32	7/16	7/32	7/16	13/64
5/16	1/2	13/64	1/2	3/16	9/16	17/64	9/16	1/4
3/8	9/16	1/4	9/16	15/64	5/8	21/64	5/8	5/16
7/16	5/8	19/64	5/8	9/32	3/4	3/8	3/4	23/64
1/2	3/4	21/64	3/4	19/64	13/16	7/16	13/16	27/64
9/16	7/8	3/8	7/8	11/32	7/8	1/2	7/8	31/64
5/8	15/16	27/64	15/16	25/64	1	35/64	1	17/32
3/4	1 1/8	1/2	1 1/8	15/32	1 1/8	21/32	1 1/8	41/64
7/8	1 5/16	19/32	1 5/16	9/16	1 5/16	49/64	1 5/16	3/4
1	1 1/2	21/32	1 1/2	19/32	1 1/2	7/8	1 1/2	55/64
1 1/8	1 11/16	3/4	1 11/16	11/16	1 11/16	1	1 11/16	31/32
1 1/4	1 7/8	27/32	1 7/8	25/32	1 7/8	1 3/32	1 7/8	1 1/16
1 3/8	2 1/16	29/32	2 1/16	27/32	2 1/16	1 13/64	2 1/16	1 11/64
1 1/2	2 1/4	1	2 1/4	15/16	2 1/4	1 5/16	2 1/4	1 9/32
1 5/8	2 7/16	1 3/32	2 7/16	1 1/32	2 7/16	1 27/64	2 7/16	1 25/64
1 3/4	2 5/8	1 5/32	2 5/8	1 3/32	2 5/8	1 17/32	2 5/8	1 1/2
1 7/8	2 13/16	1 1/4	2 13/16	1 3/16	2 13/16	1 41/64	2 13/16	1 39/64
2	3	1 11/32	3	1 7/32	3	1 3/4	3	1 23/32
2 1/4	3 3/8	1 1/2	3 3/8	1 3/8	3 3/8	1 31/32	3 3/8	1 59/64
2 1/2	3 3/4	1 21/32	3 3/4	1 17/32	3 3/4	2 3/16	3 3/4	2 9/64
2 3/4	4 1/8	1 13/16	4 1/8	1 11/16	4 1/8	2 13/32	4 1/8	2 23/64
3	4 1/2	2	4 1/2	1 7/8	4 1/2	2 5/8	4 1/2	2 37/64

American Standard Heavy Square and Hexagon Boltheads and Nuts
Nominal Dimensions. Unfinished, Square and Hexagon
Semifinished, Hexagon Only

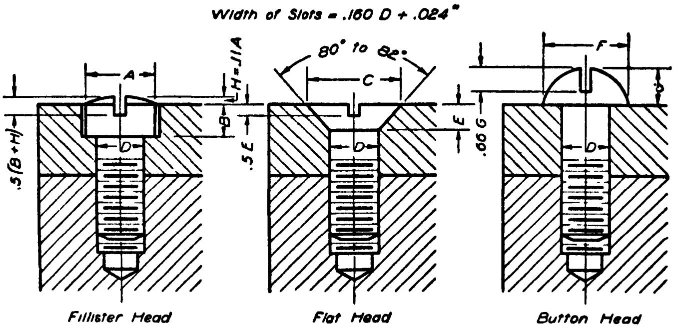
Diameter	*Boltheads*			*Nuts*		
	Flats	*Unfinished height*	*Semifinished height*	*Flats*	*Unfinished thickness*	*Semifinished thickness*
1/2	7/8	7/16	13/32	7/8	1/2	31/64
9/16	15/16	15/32	7/16	15/16	9/16	35/64
5/8	1 1/16	17/32	1/2	1 1/16	5/8	39/64
3/4	1 1/4	5/8	19/32	1 1/4	3/4	47/64
7/8	1 7/16	23/32	11/16	1 7/16	7/8	55/64
1	1 5/8	13/16	3/4	1 5/8	1	63/64
1 1/8	1 13/16	29/32	27/32	1 13/16	1 1/8	1 7/64
1 1/4	2	1	15/16	2	1 1/4	1 7/32
1 3/8	2 3/16	1 3/32	1 1/32	2 3/16	1 3/8	1 11/32
1 1/2	2 3/8	1 3/16	1 1/8	2 3/8	1 1/2	1 15/32
1 5/8	2 9/16	1 9/32	1 7/32	2 9/16	1 5/8	1 19/32
1 3/4	2 3/4	1 3/8	1 5/16	2 3/4	1 3/4	1 23/32
1 7/8	2 15/16	1 15/32	1 13/32	2 15/16	1 7/8	1 27/32
2	3 1/8	1 9/16	1 7/16	3 1/8	2	1 31/32
2 1/4	3 1/2	1 3/4	1 5/8	3 1/2	2 1/4	2 13/64
2 1/2	3 7/8	1 15/16	1 13/16	3 7/8	2 1/2	2 29/64
2 3/4	4 1/4	2 1/8	2	4 1/4	2 3/4	2 45/64
3	4 5/8	2 5/16	2 3/16	4 5/8	3	2 61/64

American Standard Hexagon-head Cap Screws



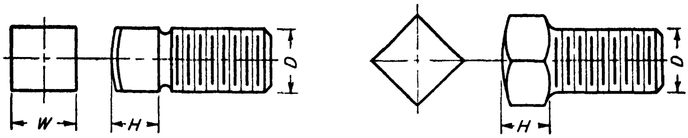
Diameter D	Threads per inch, coarse	Width across flats W	Height of head H
1/4	20	7/16	3/16
5/16	18	1/2	15/64
3/8	16	9/16	9/32
7/16	14	5/8	21/64
1/2	13	3/4	3/8
9/16	12	13/16	27/64
5/8	11	7/8	15/32
3/4	10	1	9/16
7/8	9	1 1/8	21/32
1	8	1 5/16	3/4
1 1/8	7	1 1/2	27/32
1 1/4	7	1 11/16	15/16

American Standard Slotted-head Cap Screws



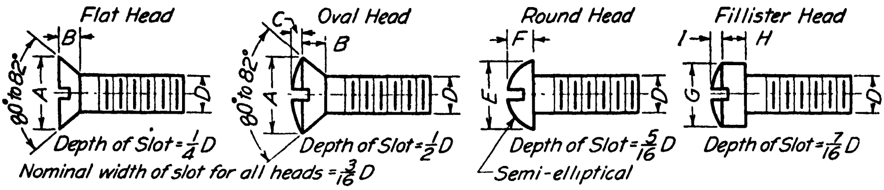
Diameter D	1/4	5/16	3/8	7/16	1/2	9/16	5/8	3/4	7/8	1
A	3/8	7/16	9/16	5/8	3/4	13/16	7/8	1	1 1/8	1 15/16
B	11/64	13/64	1/4	19/64	21/64	3/8	27/64	1/2	19/32	21/32
C	1/2	5/8	3/4	13/16	7/8	1	1 1/8	1 3/8		
E	.146	.183	.220	.220	.220	.256	.293	.366		
F	7/16	9/16	5/8	3/4	13/16	15/16	1	1 1/4		
G	.191	.246	.273	.328	.355	.410	.438	.547		

American Standard Square-head Setscrews



Diameter D	Threads per inch (either coarse or fine)		Width across flats W	Height of head H
	Coarse	Fine		
1/4	20	28	1/4	3/16
5/16	18	24	5/16	15/64
3/8	16	24	3/8	9/32
7/16	14	20	7/16	21/64
1/2	13	20	1/2	3/8
9/16	12	18	9/16	27/64
5/8	11	18	5/8	15/32
3/4	10	16	3/4	9/16
7/8	9	14	7/8	21/32
1	8	14	1	3/4
1 1/8	7	12	1 1/8	27/32
1 1/4	7	12	1 1/4	15/16
1 3/8	6	12	1 3/8	1 1/32
1 1/2	6	12	1 1/2	1 1/8

American Standard Machine Screws
Maximum Dimensions

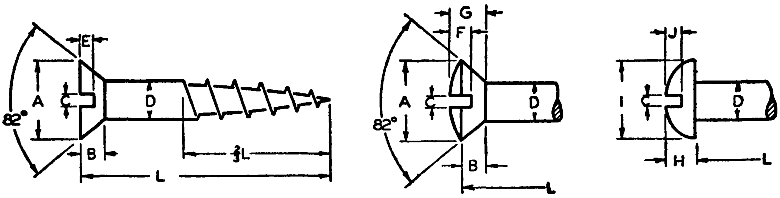


Nominal size	2	3	4	5	6	8	10	12	1/4	5/16	3/8
D = diameter	086	099	112	.125	.138	164	.190	.216	250	.3125	375
Threads per inch (coarse)	56	48	40	40	32	32	24	24	20	18	16
Threads per inch (fine)	64	56	48	44	40	36	32	28	28	24	24
A	172	.199	.225	.252	279	.332	.385	438	.507	636	762
B	.051	059	067	075	.083	.100	.116	132	153	192	.230
C	029	.033	.037	.041	045	053	061	069	079	098	117
E	.162	187	211	236	260	.309	359	408	.472	591	.708
F	.070	078	.086	.095	.103	.119	.136	.152	.174	214	254
G	.140	161	.183	.205	226	270	313	.357	414	519	.622
H	055	063	.072	081	.089	.106	123	.141	163	205	246
I	.028	032	.035	.039	.043	.050	.057	.064	.074	.092	109

SAE Standard Plain Washers

Nominal size	*Inside diam.*	*Outside diam.*	*Thickness*	*Nominal size*	*Inside diam.*	*Outside diam.*	*Thickness*	*Nominal size*	*Inside diam.*	*Outside diam.*	*Thickness*
1/4	9/32	5/8	1/16	9/16	19/32	1 3/16	3/32	1	1 1/16	2	1/8
5/16	11/32	11/16	1/16	5/8	21/32	1 5/16	3/32	1 1/8	1 3/16	2 1/4	1/8
3/8	13/32	13/16	1/16	11/16	23/32	1 3/8	3/32	1 1/4	1 5/16	2 1/2	5/32
7/16	15/32	15/16	1/16	3/4	13/16	1 1/2	1/8	1 3/8	1 7/16	2 3/4	5/32
1/2	17/32	1 1/16	3/32	7/8	15/16	1 3/4	1/8	1 1/2	1 9/16	3	5/32

American Standard Wood Screws
Maximum Dimensions



Nominal size	*D*	*A*	*B*	*C*	*E*	*F*	*G*	*H*	*I*	*J*	*Number threads per inch*
0	0 060	0.119	0 035	0 023	0.015	0.030	0.056	0.053	0.113	0 039	32
1	0.073	0.146	0 043	0 026	0 019	0.038	0.068	0.061	0.138	0.044	28
2	0.086	0.172	0.051	0.031	0 023	0 045	0.080	0.069	0.162	0.048	26
3	0.099	0.199	0 059	0 035	0.027	0.052	0.092	0.078	0.187	0.053	24
4	0.112	0 225	0.067	0.039	0.030	0.059	0.104	0.086	0.211	0.058	22
5	0 125	0.252	0.075	0 043	0.034	0 067	0.116	0.095	0.236	0.063	20
6	0.138	0.279	0.083	0.048	0.038	0.074	0.128	0.103	0.260	0.068	18
7	0.151	0.305	0.091	0 048	0.041	0.081	0.140	0.111	0.285	0.072	16
8	0.164	0.332	0.100	0.054	0.045	0.088	0.152	0.120	0 309	0 077	15
9	0.177	0.358	0.108	0 054	0.049	0.095	0.164	0.128	0.334	0.082	14
10	0.190	0.385	0.116	0.060	0 053	0 103	0.176	0.137	0.359	0.087	13
12	0.216	0.438	0 132	0.067	0.060	0.117	0.200	0.153	0.408	0.096	11
14	0.242	0.491	0.148	0 075	0 068	0.132	0.224	0.170	0.457	0.106	10
16	0.268	0.544	0.164	0 075	0 075	0.146	0.248	0.187	0.506	0.115	9
18	0.294	0 597	0.180	0.084	0.083	0.160	0.272	0 204	0.555	0.125	8
20	0.320	0.650	0.196	0.084	0.090	0.175	0.296	0.220	0.604	0.134	8
24	0.372	0.756	0.228	0.094	0 105	0.204	0.344	0.254	0.702	0.154	7

American Standard Wrought Pipe*

Nominal size	*Threads per inch*	*Outside diameter*	*Actual inside diameter*		
			Standard	*Extra strong*	*Double extra strong*
1/8	27	0 405	0 269	0 215	
1/4	18	0 540	0 364	0 302	
3/8	18	0.675	0 493	0 423	
1/2	14	0.840	0 622	0.546	0.252
3/4	14	1.050	0 824	0 742	0 434
1	11 1/2	1.315	1 049	0 957	0 599
1 1/4	11 1/2	1 660	1 380	1 278	0.896
1 1/2	11 1/2	1 900	1 610	1 500	1 100
2	11 1/2	2 375	2 067	1 939	1 503
2 1/2	8	2 875	2.469	2 323	1.771
3	8	3 500	3 068	2 900	2 300
3 1/2	8	4 000	3 548	3 364	2 728
4	8	4 500	4 026	3 826	3 152
4 1/2	8	5 000	4 506	4 290	3 580
5	8	5 563	5 047	4 813	4 063
6	8	6 625	6 065	5 761	4 897
7	8	7 625	7 023	6 625	5.875
8	8	8 625	8.071	7 625	6 875
8	8	8 625	7.981		
9	8	9 625	8 941	8.625	
10	8	10 750	10.192	9.750	
10	8	10 750	10.136		
10	8	10.750	10.020		
11	8	11 750	11 000	10 750	
12	8	12 750	12.090	11 750	
12	8	12.750	12.000		

* For complete information and data, the American Standard B36.10 for "Wrought-iron and Wrought-steel Pipe" should be consulted. Schedule numbers are used instead of the terms "Standard," "Extra Strong," and "Double Extra Strong." Wall thicknesses are determined according to formulas for the schedule numbers. The usual sizes commercially available which have been known as "Standard" (now Schedule 40), "Extra Strong" (now Schedule 80), and "Double Extra Strong" are included in the above table for convenient reference.

Wire and Sheet-metal Gages

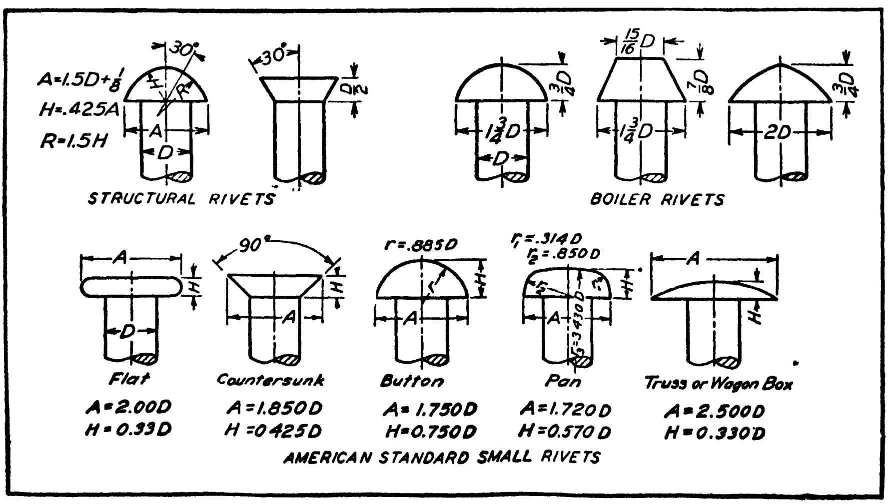
Dimensions in Decimal Parts of an Inch

No. of wire gage	*American, or Brown & Sharpe*	*Birming-ham, or Stubs wire*	*Washburn & Moen or American Steel & Wire Co.*	*W. & M. steel music wire*	*New American S. & W. Co. music wire gage*	*Imperial wire gage*	*U.S. Standard gage for sheet and plate iron and steel*
00000000	..			0083			
0000000	.	..	...	0087			
000000	.... ..	....	. .	0095	.004	.464	.46875
00000	. .	. .		010	.005	.432	4375
0000	460	.454	.3938	011	006	400	40625
000	40964	.425	.3625	012	.007	372	375
00	3648	.380	3310	0133	008	348	34375
0	32486	.340	3065	0144	.009	.324	3125
1	2893	.300	.2830	0156	010	300	28125
2	25763	284	2625	0166	.011	276	265625
3	22942	259	.2437	0178	.012	252	250
4	20431	.238	2253	0188	.013	.232	234375
5	18194	220	.2070	0202	014	.212	21875
6	16202	203	.1920	0215	.016	192	203125
7	14428	.180	.1770	.023	.018	.176	1875
8	12849	.165	1620	.0243	.020	160	.171875
9	11443	.148	.1483	0256	.022	.144	15625
10	10189	.134	1350	027	.024	.128	140625
11	090742	.120	.1205	.0284	.026	.116	.125
12	.080808	.109	1055	0296	.029	.104	109375
13	071961	095	.0915	.0314	031	092	09375
14	064084	083	0800	0326	033	080	078125
15	057068	072	.0720	0345	035	.072	0703125
16	05082	.065	0625	036	037	.064	0625
17	045257	058	0540	0377	.039	.056	05625
18	040303	.049	0475	0395	.041	.048	050
19	03589	042	0410	0414	.043	.040	04375
20	.031961	.035	.0348	.0434	.045	.036	0375
21	028462	032	03175	046	.047	.032	.034375
22	.025347	028	0286	0483	049	.028	03125
23	.022571	025	0258	051	.051	.024	028125
24	.0201	.022	0230	.055	.055	.022	025
25	.0179	.020	.0204	0586	.059	.020	021875
26	01594	.018	0181	.0626	.063	.018	01875
27	014195	016	.0173	.0658	.067	.0164	0171875
28	012641	.014	0162	072	071	.0149	015625
29	011257	.013	0150	.076	.075	.0136	0140625
30	010025	012	0140	080	080	.0124	0125
31	.008928	.010	0132	.....	.085	.0116	0109375
32	.00795	.009	.0128	....	.090	.0108	01015625
33	.00708	.008	.0118	....	.095	.0100	009375
34	.006304	.007	0104	....	....	.0092	00859375
35	.005614	.005	0095	....	....	.0084	0078125
36	.005	.004	.0090	....	....	0076	00703125
37	.004453	. .....	...	....	....	.0068	006640625
38	.003965	.	.	....	. ...	.0060	00625
39	.003531		.	.....	....	0052	
40	.003144		..	.... ..	.....	0048	

Steel-wire Nails

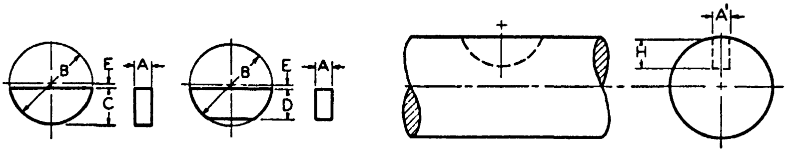
American Steel & Wire Co. Gage

Size	Length	*Common wire nails and brads*		*Casing nails*		*Finishing nails*	
		Gage, diam.	*No. to pound*	*Gage, diam.*	*No. to pound*	*Gage, diam.*	*No. to pound*
2*d*	1	15	876	15½	1010	16½	1351
3*d*	1¼	14	568	14½	635	15½	807
4*d*	1½	12½	316	14	473	15	584
5*d*	1¾	12½	271	14	406	15	500
6*d*	2	11½	181	12½	236	13	309
7*d*	2¼	11½	161	12½	210	13	238
8*d*	2½	10¼	106	11½	145	12½	189
9*d*	2¾	10¼	96	11½	132	12½	172
10*d*	3	9	69	10½	94	11½	121
12*d*	3¼	9	64	10½	87	11½	113
16*d*	3½	8	49	10	71	11	90
20*d*	4	6	31	9	52	10	62
30*d*	4½	5	24	9	46		
40*d*	5	4	18	8	35		
50*d*	5½	3	14				
60*d*	6	2	11				



Woodruff Keys

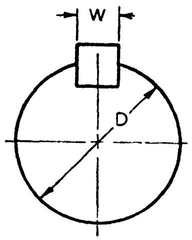
Dimensions in Inches

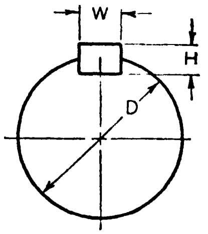


Key No.	*Nominal*			*Maximum*		
	A	*B*	*E*	*C*	*D*	*H*
204	1/16	1/2	3/64	.203	.194	.1718
304	3/32	1/2	3/64	.203	194	.1561
305	3/32	5/8	1/16	.250	240	.2031
404	1/8	1/2	3/64	.203	.194	.1405
405	1/8	5/8	1/16	.250	.240	.1875
406	1/8	3/4	1/16	.313	.303	.2505
505	5/32	5/8	1/16	250	.240	.1719
506	5/32	3/4	1/16	.313	.303	.2349
507	5/32	7/8	1/16	.375	365	.2969
606	3/16	3/4	1/16	313	.303	2193
607	3/16	7/8	1/16	.375	.365	.2813
608	3/16	1	1/16	438	.428	.3443
609	3/16	1 1/8	5/64	.484	.475	.3903
807	1/4	7/8	1/16	375	.365	.2500
808	1/4	1	1/16	.438	428	.3130
809	1/4	1 1/8	5/64	.484	.475	.3590
810	1/4	1 1/4	5/64	.547	.537	.4220
811	1/4	1 3/8	3/32	.594	.584	.4690
812	1/4	1 1/2	7/64	.641	.631	5160
1008	5/16	1	1/16	.438	.428	.2818
1009	5/16	1 1/8	5/64	.484	.475	3278
1010	5/16	1 1/4	5/16	547	.537	3908
1011	5/16	1 3/8	3/32	.594	.584	4378
1012	5/16	1 1/2	7/64	.641	.631	.4848
1210	3/8	1 1/4	5/64	.547	.537	3595
1211	3/8	1 3/8	3/32	.594	.584	.4060
1212	3/8	1 1/2	7/64	.641	.631	.4535

Nominal dimensions are indicated by the key number in which the last two digits give the diameter (*B*) in eighths and the ones in front of them give the width (*A*) in thirty-seconds. For example, No. 809 means B = 9/8 or 1 1/8 and A = 8/32 or 1/4. (*From American Standards.*)

American Standard Square- and Flat-stock Keys and Shaft Diameters
Dimensions in inches





Diameter of shaft D inclusive	*Square keys W*	*Flat keys W × H*
1/2 - 9/16	1/8	1/8 × 3/32
5/8 - 7/8	3/16	3/16 × 1/8
15/16 - 1 1/4	1/4	1/4 × 3/16
1 5/16 - 1 3/8	5/16	5/16 × 1/4
1 7/16 - 1 3/4	3/8	3/8 × 1/4
1 13/16 - 2 1/4	1/2	1/2 × 3/8
2 5/16 - 2 3/4	5/8	5/8 × 7/16
2 7/8 - 3 1/4	3/4	3/4 × 1/2
3 3/8 - 3 3/4	7/8	7/8 × 5/8
3 7/8 - 4 1/2	1	1 × 3/4
4 3/4 - 5 1/2	1 1/4	1 1/4 × 7/8
5 3/4 - 6	1 1/2	1 1/2 × 1

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