TECHNICAL DRAFTING ESSENTIALS

For Vocational and Technical Students

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Architectural Drafting Section by

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PREFACE

This first edition of *Technical Drafting Essentials* cannot be thought of as an entirely new text because a considerable portion of the material has been taken from the author's larger text *Fundamentals of Engineering Drawing* which has been used for a number of years in many Universities, Technical Institutes, and Technical High Schools.

This book has been prepared to fulfill the need for a text in the technical field that will present the basic fundamentals of engineering drafting in accordance with sound pedagogy. Some background material and non-essential handbook tables have been intentionally omitted, so that *Technical Drafting Essentials* will be a student's text and not a reference handbook. Texts of the handbook type often have explanations that are so brief that their content cannot be grasped by the student.

One objective has been to create a nearly self-teaching text that presents all of the essential information covering the theory and the conventions of projection and dimensioning in accordance with present day up-to-date industrial practices. The student has been kept constantly in mind and an attempt has been made to explain fully all of the more common difficulties in understanding theory and practice. Thus, the teacher will not find it necessary to give repeated explanations on some small item that can just as well be presented on a printed page. Other objectives such as simplicity and completeness of presentation determined the choice and construction of the illustrations. In most cases the illustrations have been selected and designed so that they repeat completely the accompanying text in graphic language.

A sufficient number of problems are given at the end of each chapter to allow the instructor a wide selection. For the chapters covering specialized divisions of technical drafting, there are numerous practical industrial problems.

The text material has been made to conform to the latest edition of American Standard Drawings and Drafting Room Practice, ASA Z14.1-1946, as adopted and published by the American Standards Association. The new British-Canadian-American Unified thread form is presented in the chapter covering screw threads and fasteners. The related Unified and American Screw Thread Series Tables as given in the publication ASA B1.1-1949, appear in the appendix.

The author wishes to express his appreciation for the assistance of Dr. Claude Henry Ewing, Director of the Chicago Vocational High School, who took the time from his busy days to edit this text and served as a constant advisor from the very beginning.

Grateful acknowledgment is also made for the text material prepared by Mr. William J. Hornung, Director of Training, National Technical Institute. Mr. Hornung prepared the entire chapter on Architectural Drafting.

The author is indebted to the many teachers of engineering drawing who have expressed an interest in this book and who have offered valued suggestions.

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TABLE OF CONTENTS

1

INTRODUCTION

1. Technical drawing is a graphic language that is used universally by engineers to describe the shape and size of structures and mechanisms. It has developed through the centuries, much as have various spoken and written languages, until at the present time its fundamental principles are understood by trained persons in all civilized nations.

Technical drawing is not, as many students are prone to believe, something a draftsman and engineer alone need understand. The language belongs to all persons concerned with production processes as well as with sales and service.

2. The purpose of this text is to present the grammar and composition of drawing so that those who conscientiously study the basic principles will be able to execute satisfactory drawings and, after some practical experience, be capable of directing the work of others. To facilitate study, the subject matter has been separated into its various component parts: lettering, geometry, multiview drawing, dimensioning, pictorial drawing, sketching, and so forth. Later chapters discuss the preparation of working drawings, both detail and assembly, the preparation of topographic drawings, and the construction of charts and graphs. The major portion of the material presented leads up to the preparation of machine drawings. However, since the methods used in the preparation of machine drawings are the same methods used in the preparation of drawings in other fields of engineering, a thorough understanding of machine drafting assures a good foundation for later study in some specialized field, such as structural drafting. For those interested in specific types of drawing, some material has been presented with the assumption that the student already possesses a working knowledge of projection and dimensioning.

3. Technical drafting offers students an insight into the engineer's methods of attacking design problems. Its lessons teach the principles of accuracy, exactness, and positiveness with regard to the information necessary for the production of a nonexisting structure. Finally, it develops the engineering imagination that is so essential to the creation of successful design.

2

DRAWING INSTRUMENTS AND EQUIPMENT

4. The necessary instruments and materials needed for making ordinary engineering drawings are shown in Fig. 1. The instruments in the plush-lined case should be particularly well made and easy to service,

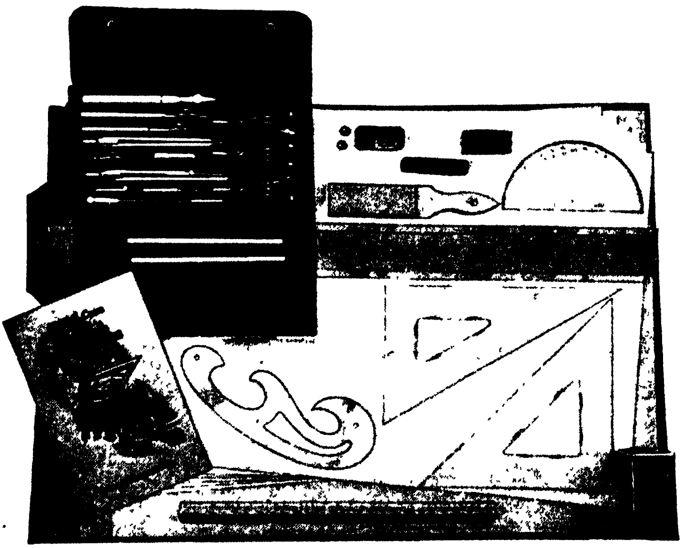


Fig. 1. Essential drafting equipment.

for with cheap, inferior ones, it is often difficult to produce accurate drawings of professional quality.

5. List of equipment and materials. The following list is a practical selection of equipment and materials necessary for making pencil drawings and ink tracings.

(1) Case of drawing instruments.
(2) Drawing board.
(3) T-square.
*(4) 45° triangle.
(5) 10″ 30°–60° triangle.
(6) French curve.
(7) Scale (either one triangular or three flat scales).
(8) Drawing pencils.
(9) Pencil pointer.
(10) Thumb tacks, brad machine, or Scotch tape.
(11) Pencil eraser.
(12) Cleaning eraser.
(13) Erasing shield.
(14) Bottle of black waterproof drawing ink.
(15) Pen wiper.
(16) Penholder.
(17) Lettering device.
(18) Lettering pens.
(19) Protractor.

6. The set of instruments. A standard set of drawing instruments in a velvet-lined case and a small alternative set, which is capable of fulfilling the needs of most draftsmen, are shown in Figs. 1 and 2, respectively.

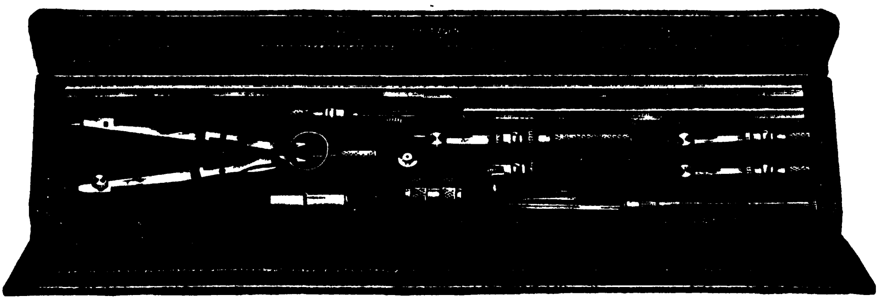


Fig. 2. Drawing instruments—a small set.

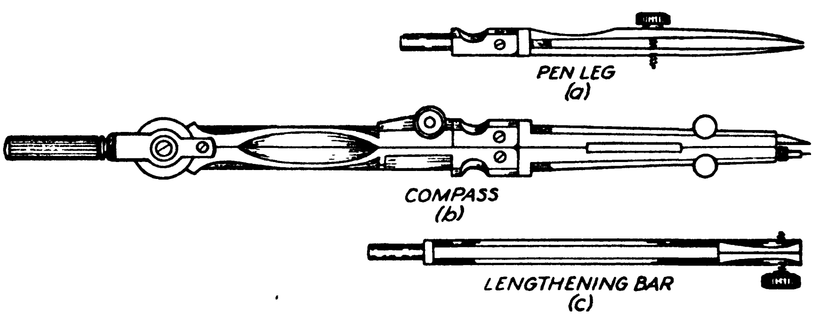


Fig. 3. The compass.

7. Compasses and dividers. One leg of nearly all compasses (Fig. 3) is manufactured with a socket joint, which allows the insertion of either the pen leg for ink work or the lengthening bar for a longer working radius. Both legs of a compass are provided with knee joints. These

* A 6″ 45° Braddock Lettering Triangle, which may be used as either a triangle or a lettering instrument, may be substituted for this item.

allow the legs to be adjusted perpendicular to the paper when a large circle is being drawn.

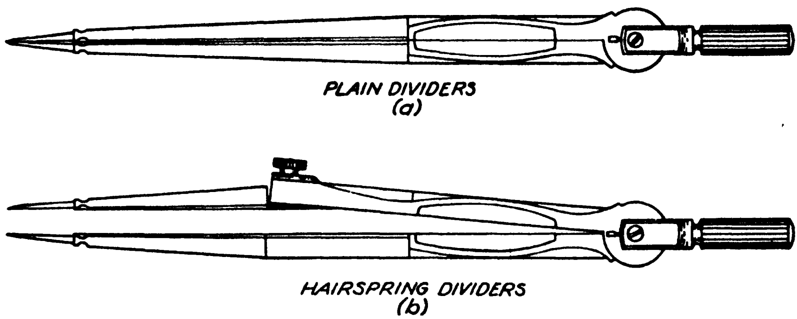


Fig. 4. Dividers.

Since dividers are used to transfer measurements or to divide lines into any number of equal parts, they differ from the compass in that both legs terminate in sharp steel points.

8. Bow instruments. The bow instruments (Fig. 5) include the bow dividers, bow pencil, and bow pen.

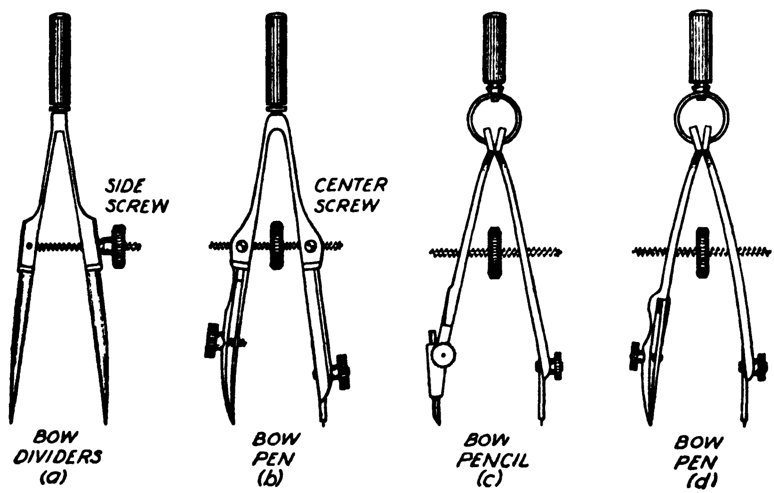


Fig. 5. The bow instruments.

9. Ruling pens. The most satisfactory type of ruling pen consists of two steel blades formed from one solid piece of high-grade steel, a thumb screw for regulating the distance between the ends (nibs) of the blades, and a handle made of wood, ebony, or metal. The best drawing pens have blades of high-speed steel or noncorrosive stainless steel with butt-welded, high-speed steel points.

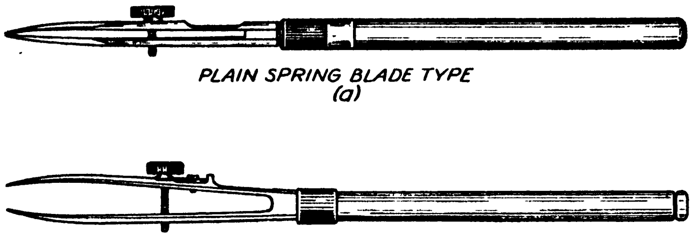


Fig. 6. Ruling pens.

10. The drawing board. Drawing boards should be made of selected straight-grained, soft wood strips which have been thoroughly seasoned. The working surface (top) must be smooth as well as a true plane, and both side edges should be perfectly straight so that either may be used as a working edge. The board shown in Fig. 7 has two working surfaces.

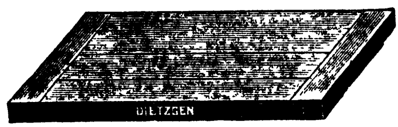


Fig. 7. Drawing board.

11. The T-square. The most popular T-square for ordinary work (Fig. 8*a*) is made with a head of hardwood to which is rigidly fastened a blade lined with transparent material to resist warpage and to permit lines of the drawing to be seen beneath the edge.

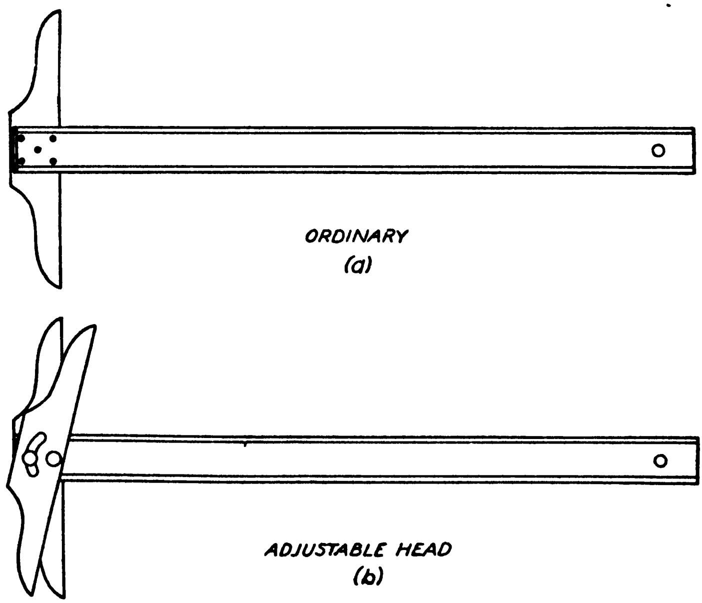
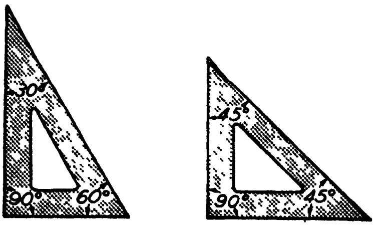


Fig. 8. T-square.

12. The triangles. Triangles are made of various materials, but the transparent amber-colored celluloid ones are to be preferred, for they permit the drawing to be seen beneath them.



30°-60° *45°*

Fig. 9. Triangles.

13. Scales. There are four kinds of scales available for particular types of engineering design. They are classified as mechanical engineers' scales, civil engineers' scales, architects' scales, and metric scales.

The mechanical engineers' scales are generally of the full-divided type which are graduated proportionally to give reductions based on inches. The principal units are divided into fractions of an inch (4, 8, 16, 32 parts) (Fig. 10). The scales are indicated on the stick as $\frac{1}{8}$ size, $\frac{1}{4}$ size, $\frac{1}{2}$ size, and so forth. On some special triangular

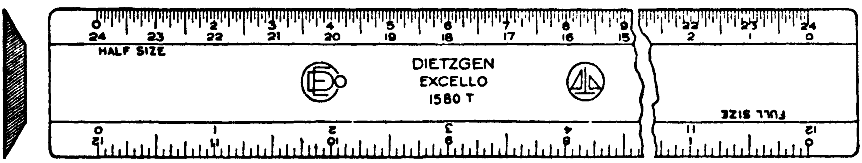


Fig. 10. Mechanical engineers' scale. Full divided.

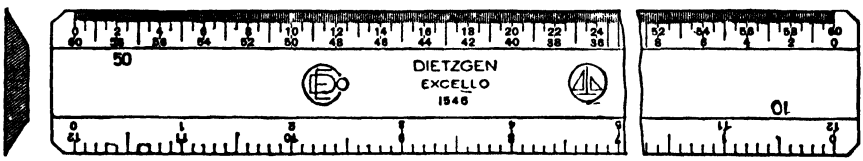


Fig. 11. Civil engineers' scale.

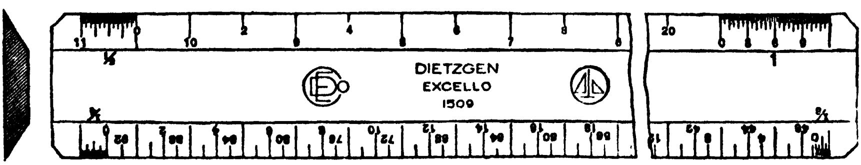


Fig. 12. Architects' scale. Open-divided.

sticks these same scales are given as $\frac{1}{8}''$ equals 1″, $\frac{1}{4}''$ equals 1″, $\frac{1}{2}''$ equals 1″, $\frac{3}{4}''$ equals 1″. Open-divided scales, having only the end divisions subdivided, are used by many industrial draftsmen.

The civil engineers' (chain) scales are full-divided, and are graduated in decimal parts, usually 10, 20, 30, 40, 50, 60, 80, and 100 divisions to the inch.

Architects' scales differ from mechanical engineers' scales in that the divisions represent a foot, and the end units are divided into inches, half inches, quarter inches, and so forth (6, 12, 24, 48, or 96 parts). The usual scales are $\frac{1}{8}''$ equals 1′, $\frac{1}{4}''$ equals 1′, $\frac{3}{8}''$ equals 1′, $\frac{1}{2}''$ equals 1′, 1″ equals 1′, and 3″ equal 1′.

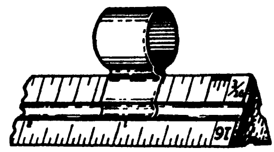
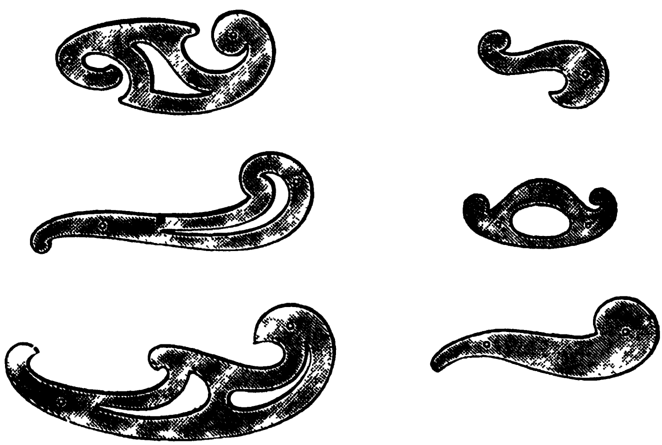


Fig. 13. Scale guard.

14. Curves. Irregular or French curves are used for drawing curves other than circular arcs. Their ruling edges are composed of combinations of spirals, ellipses, and parabolas. Although many commercial draftsmen own a variety of curves or have access to specialized sets of curves which are suitable for their particular type of work, students in technical schools usually find that a curve similar to any of those shown in Fig. 14 is adequate.



Courtesy Keuffel & Esser Co

Fig. 14. Irregular curves.

15. Pencils. The professional draftsman keeps himself equipped with a selection of good, well-sharpened pencils with leads of various degrees of hardness such as: 9*H*, 8*H*, 7*H*, and 6*H* (hard), for layout and design work; 5*H* and 4*H* (medium hard), for light-weight line work such as center lines, dimension lines, and so forth; 3*H* and 2*H* (medium), for ordinary detail and line work; *H* and *F* (medium soft), for lettering; and *HB*, *B*, 2*B*, 3*B*, 4*B*, 5*B*, and 6*B* (soft), for sketching.

16. Pencil pointers. Either a sandpaper pad or an ordinary flat file is satisfactory for sharpening pencil and compass leads.

17. Erasers. A *hard pencil eraser*, only moderately gritty, is the only eraser which should ever be used for erasing pencil and ink lines on drawing paper, tracing paper, or tracing cloth. A large-size pencil eraser with beveled ends, or its equivalent, is favored by many commercial draftsmen.

18. The erasing shield. An erasing shield is a thin sheet of celluloid or metal which is used to prevent any wrinkling of the paper and to protect other lines near a line that is being erased.

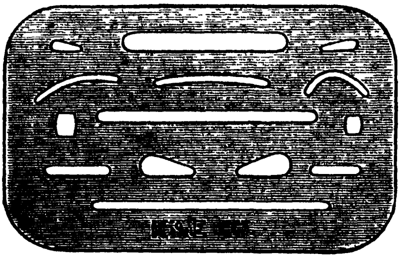


Fig. 15. Erasing shield.

19. Drawing ink. A good waterproof black drawing ink (India ink) is absolutely essential to successful drafting. It must be free-flowing and quick-drying and should make very black opaque lines that will not smudge.

20. Scotch drafting tape—thumb tacks. Some draftsmen use regular Scotch drafting tape instead of thumb tacks, because its smooth surface allows the T-square and triangles to slide easily, and it eliminates the punching of holes in the drawing board.

Fig. 16. Thumb tacks.

21. Pen points and penholders. The selection of penholders and pen points depends so much upon personal preference that individual experience is probably the best guide.

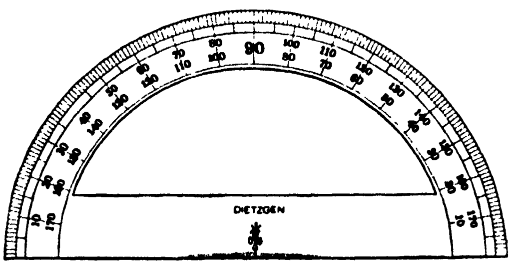


Fig. 17. Inexpensive protractor.

22. The protractor. The protractor, which is used for measuring and laying off angles, is usually semicircular in form.

23. Drawing paper. Drawing papers are available in a variety of types, weights, and colors. For ordinary engineering drawings in pencil (working drawings, design drawings, and so forth), a heavy buff-color detail paper is sometimes preferred.

White light-weight bond paper, on which pencil drawings can be made and from which blueprints can be produced without making tracings, is used in many commercial drafting rooms in order to keep labor costs at a minimum.

24. Tracing papers and cloth. A large variety of natural and specially prepared tracing papers are available for making ink tracings and pencil drawings from which blueprints, ozalid prints, and so forth are made for the shop.

The two general types of cloth available are ink cloth and pencil cloth. The cloth used for ink is a clear translucent cloth which is dull on one side and glossy on the other. Pencil cloth is a white cloth with a surface specially prepared to take pencil readily.

3

USE OF INSTRUMENTS AND EQUIPMENT

25. It is essential that a beginner acquire a knowledge of the proper manipulation and adjustment of drawing instruments and practice the correct technique before attempting even simple engineering drawings. If he concentrates on the right methods of handling at the very start, he will be rewarded later by neat and accurate work of professional quality.

26. Pencils. The grade of pencil to be used for various purposes depends upon the type of line desired, the kind of paper employed, and the humidity, which affects the surface of the paper. Drafting-room standards for line quality usually will govern. Ordinarily, however, a draftsman should have available a 6*H* pencil for the light construction lines in layout work where accuracy is required, a 4*H* for repenciling light finished lines (dimension lines, center lines and invisible object lines), a 2*H* for visible object lines, and an *F* or *H* for all lettering and freehand work.

27. Pointing the pencil. Many draftsmen prefer the conical point for general use (Fig. 18), while others find the wedge point more suitable for straight-line work, as it requires less sharpening and makes a denser line (Fig. 19).

When sharpening a pencil, the wood should be cut away (on the unlettered end) with a knife or a pencil sharpener equipped with draftsman's cutters. About $\frac{3}{8}$ inch of the lead should be exposed and should form a cut, including the wood, about $1\frac{1}{2}$ inches long. The lead then should be shaped to a conical point on the pointer (file or sandpaper pad). This is done by holding the file stationary in the left hand and drawing the lead toward the handle while rotating the pencil against the movement (Fig. 18). All strokes should be made in the same manner, a new grip being taken each time so that each stroke starts with the pencil in the same rotated position as at the end of the preceding stroke.

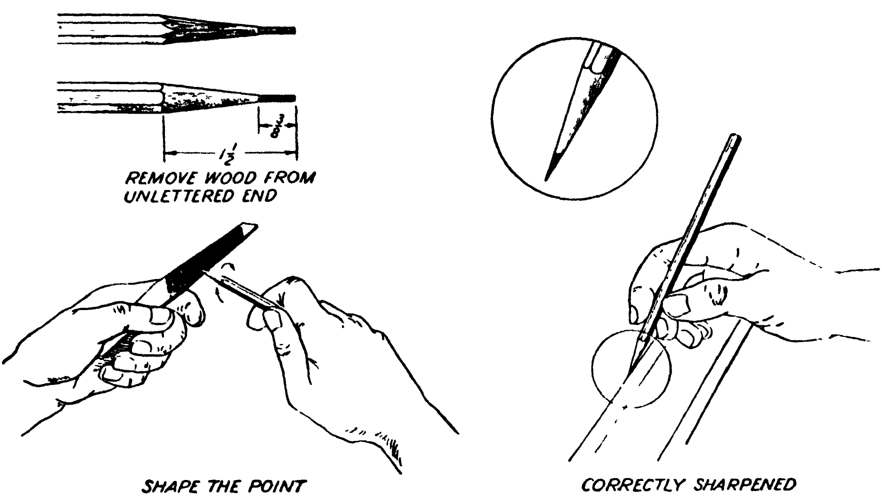


Fig. 18. Conical point.

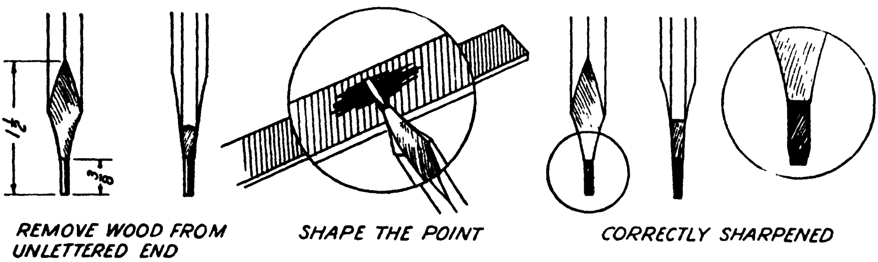


Fig. 19. Wedge point.

28. Drawing pencil lines. Pencil lines should be sharp and uniform along their entire length, and sufficiently distinct to fulfill their ultimate purposes. Construction lines (preliminary lines) should be drawn *very* lightly so that they may be easily erased. Finished lines should be made boldly and distinctly, so that there will be definite contrast between visible and invisible object lines and auxiliary lines, such as dimension lines, center lines, and section lines. To give this contrast, which is necessary for clearness and ease in reading, object lines should be sharp and very black,

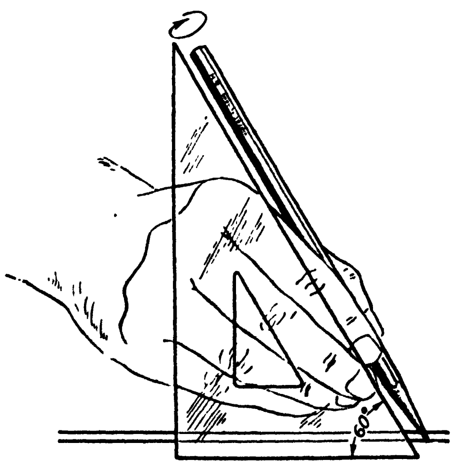


Fig. 20. Using the pencil.

invisible lines sharp and not so black, and auxiliary lines light and fine.

When drawing a line, the pencil should be inclined slightly (about 60 degrees) in the direction in which the line is being drawn. The pencil should be "pulled" (never pushed) at the same inclination for the full length of the line. If it is rotated (twirled) slowly between the fingers as the line is drawn, a symmetrical point will be maintained and a straight uniform line will be insured.

29. Placing and fastening the paper. For accuracy and ease in manipulating the T-square, the drawing paper should be located well up on the board and near the left-hand edge. The lower edge of the sheet (if plain) or the lower border line (if printed) should be aligned along the working edge of the T-square before the sheet is fastened down at all four corners with thumb tacks, Scotch tape, or staples.

30. The T-square. The T-square is used primarily for drawing horizontal lines and for guiding the triangles when drawing vertical and

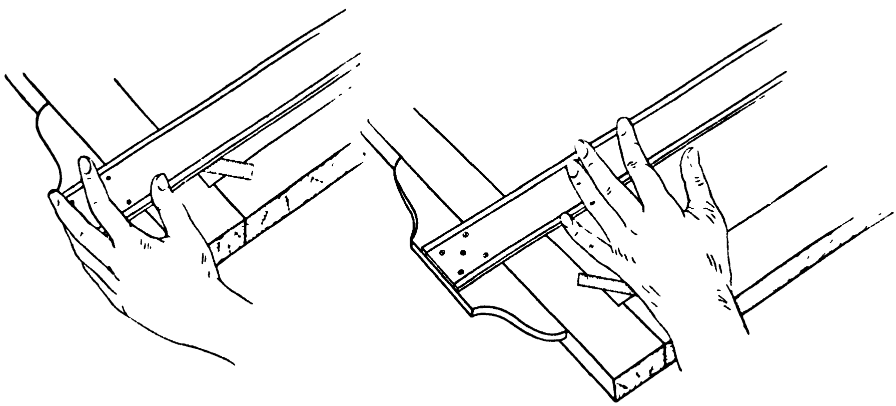


Fig. 21. Manipulating the T-square.

inclined lines. It is manipulated by sliding the working edge (inner face) of the head along the left edge of the board until the blade is in the required position. The left hand then should be shifted to a position near the center of the blade to hold it in place and to prevent its deflection while drawing the line. Experienced draftsmen hold the T-square, as shown in Fig. 21(*b*), with the fingers pressing on the blade and the thumb on the paper. Small adjustments may be made with the hand in this position by sliding the blade with the fingers.

Horizontal lines are drawn from left to right along the upper edge of the T-square. (*Exception:* left-handed persons should use the T-square head at the right side of the board and draw from right to left.) While drawing the line, the ruling hand should slide along the blade on the little finger.

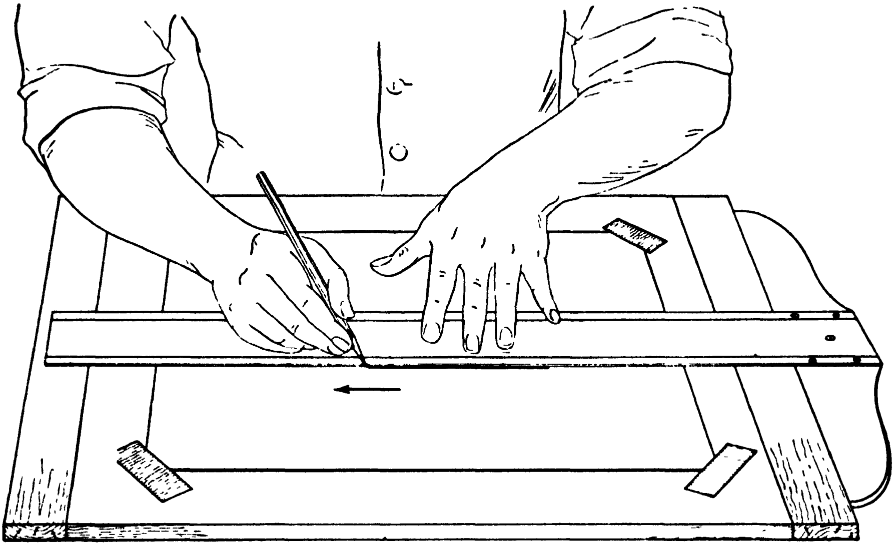


Fig. 22. Drawing horizontal lines.

31. Vertical lines. Vertical lines are drawn upward along the vertical leg of a triangle whose other (horizontal) leg is supported and guided by

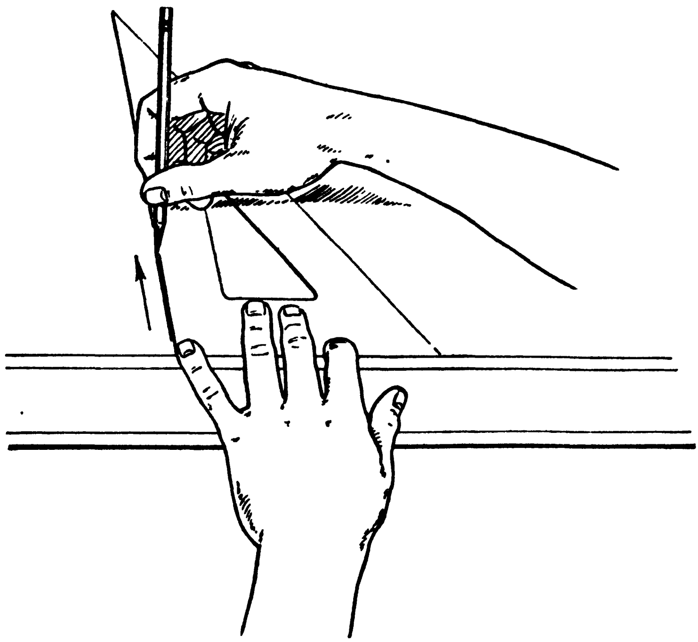


Fig. 23. Drawing vertical lines.

the T-square blade. In the case of a right-handed person, the triangle should be to the right of the line to be drawn.

32. Inclined lines. Triangles also are used for drawing inclined lines. Lines which make angles of 30 degrees, 45 degrees, or 60 degrees with the horizontal may be drawn with the 30 degree × 60 degree or the 45 degree triangle in combination with the T-square, as shown in Fig. 25. If the two triangles are combined, lines which make 15 degrees or a multiple of 15 degrees may be drawn with the horizontal. Several possible arrangements and the angles which result are shown in Fig. 26.

33. Parallel lines. The triangles are used in combination to draw a line parallel to a given line. To draw such a line, place a ruling edge

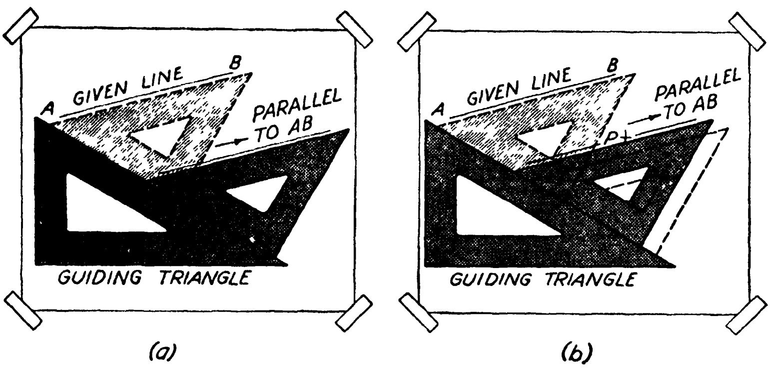


Fig. 24. To draw a line parallel to a given line.

of a triangle, supported by a T-square or another triangle, along the given line; then, slip the triangle, as shown in Fig. 24, to the required position and draw the parallel line along the same ruling edge which previously coincided with the given line.

34. Perpendicular lines. Either the sliding triangle method (Fig. 27*a*) or the revolved triangle method (Fig. 27*b*) may be used to draw a line perpendicular to a given line. When using the former method, adjust to the given line, a side which is adjacent to the right angle; then slide the triangle along a guiding edge, as shown in Fig. 27(*a*), until it is in the required position for drawing the perpendicular along the other working edge adjacent to the right angle.

Although the revolved triangle method is not so quickly done, it is widely used. To draw a perpendicular using this method, align along the given line the hypotenuse of a triangle, one leg of which is guided by the T-square or another triangle, then hold the guiding member in position and revolve the triangle about the right angle until the other leg is against the guiding edge. The new position of the hypotenuse will be perpendicular to its previous location along the given line and, when

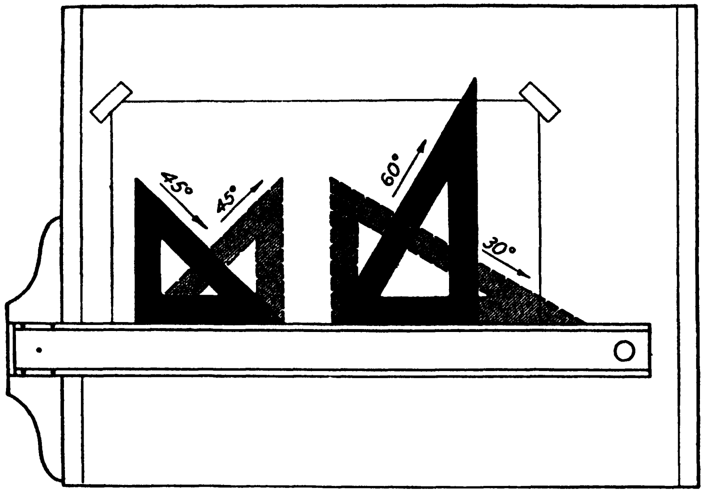


Fig. 25. Inclined lines.

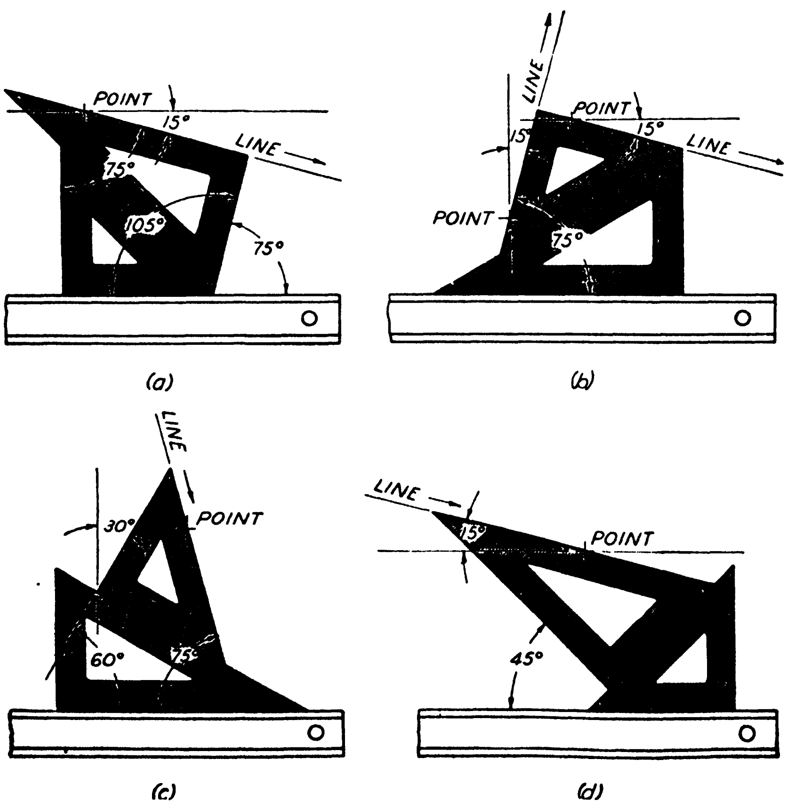


Fig. 26. Drawing inclined lines with triangles.

moved to the required position, may be used as a ruling edge for the desired perpendicular.

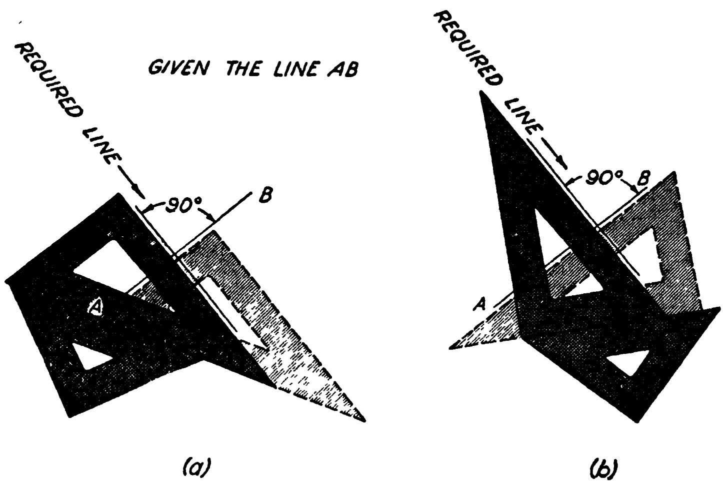


Fig. 27. To draw a line perpendicular to another line.

35. Inclined lines making 15 degrees, 30 degrees, 45 degrees, 60 degrees, or 75 degrees with an oblique line. A line making with an oblique line an angle equal to any angle of a triangle may be drawn with the triangles. The two methods, previously discussed for drawing per-

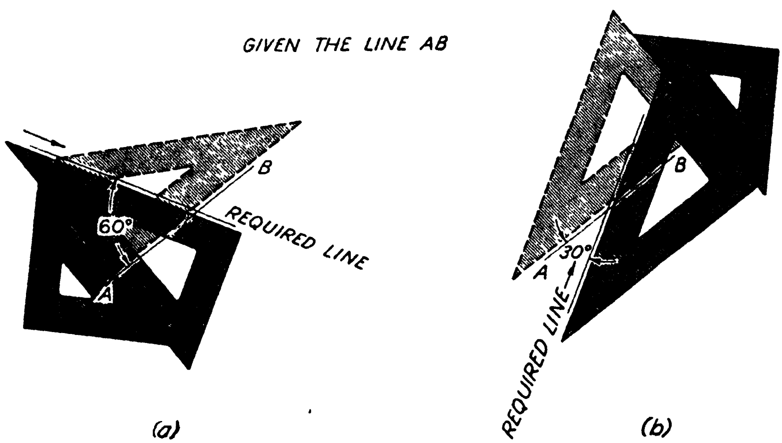


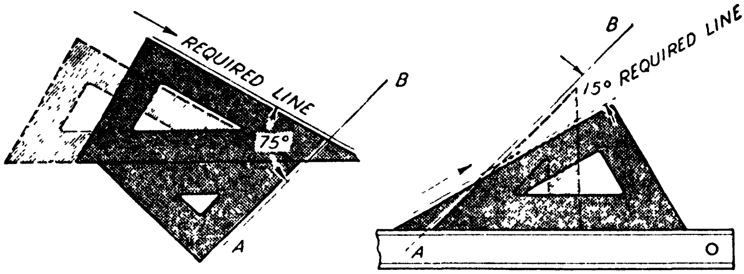
Fig. 28. To draw lines making 30°, 45°, or 60° with a given line.

pendicular lines, are applicable with slight modifications. To draw an oblique line using the revolved triangle method (Fig. 28*a*), adjust along the given line the edge that is opposite the required angle, then revolve the triangle about the required angle, slide it into position, and draw the required line along the side opposite the required angle.

To use the sliding triangle method, illustrated in Fig. 28(*b*), adjust to the given line one of the edges adjacent to the required angle, and guide the side opposite the required angle with a straight edge; then slide the triangle into position and draw the required line along the other adjacent side.

To draw a line making 75 degrees with a given line, place the triangles together so that the sum of a pair of adjacent angles equals 75 degrees, and adjust one side of the angle thus formed to the given line; then slide the triangle, whose leg forms the other side of the angle, across the given line into position, and draw the required line, as shown in Fig. 29(*a*).

GIVEN THE LINE AB



(*a*) (*b*)

Fig. 29. To draw lines making 15° or 75° with a given line.

To draw a line making 15 degrees with a given line, select any two angles whose difference is 15 degrees. Adjust to the given line a side adjacent to one of these angles, and guide the side adjacent with a straight edge. Remove the first triangle and substitute the other so that one adjacent side of the angle to be subtracted is along the guiding edge, as shown in Fig. 29(*b*); then slide it into position and draw along the other adjacent side.

36. The scale. The sole purpose of the scale is to reproduce the dimensions of an object full size on a drawing or to reduce or enlarge them to some regular proportion such as eighth size, quarter size, half size, or double size. The scales of reduction most frequently used in commercial practice are as follows:

Full Size (12″ = 1′ or 1″ = 1″)
Half Size (6″ = 1′ or $\frac{1}{2}$″ = 1″)
Quarter Size (3″ = 1′ or $\frac{1}{4}$″ = 1″)
Eighth Size ($1\frac{1}{2}$″ = 1′ or $\frac{1}{8}$″ = 1″)

1″ = 1′	$\frac{1}{4}$″ = 1′
$\frac{3}{4}$″ = 1′	$\frac{3}{16}$″ = 1′
$\frac{1}{2}$″ = 1′	$\frac{1}{8}$″ = 1′
$\frac{3}{8}$″ = 1′	$\frac{3}{32}$″ = 1′

It is essential that a draftsman always think and speak of each dimension as full size when scaling measurements, because the dimension figures given on the finished drawing indicate full-size measurements of the finished piece, regardless of the scale used.

The reading of the open-divided scale, as illustrated in Fig. 30, is very simple. The dimension can be read directly as 21 inches, the nine inches

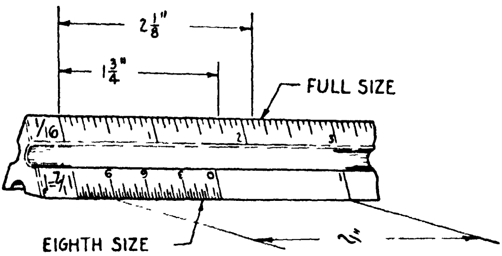


Fig. 30. Reading a scale.

being read in the divided end division. Each long open division represents twelve inches (one foot).

To lay off a measurement, using a scale starting at the left of the stick, align the scale in the direction of the measurement with the zero of the scale being used toward the left. After it has been adjusted to the correct location, make short marks opposite the divisions on the scale which establish the desired distance.

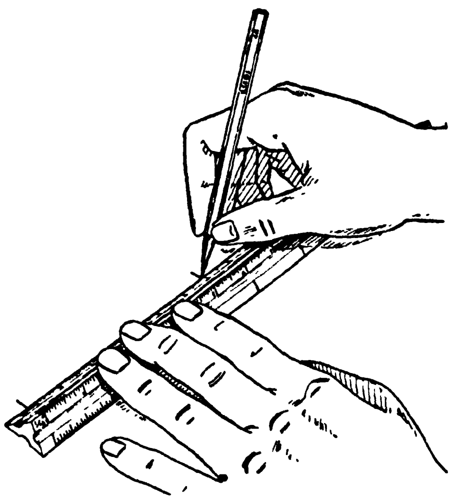


Fig. 31. To lay off a measurement.

To set off a measurement (say 2′-9″) to half scale, the scale indicated either as $\frac{1}{2}$ (Fig. 32) or $\frac{1}{2}'' = 1'$ should be used. If the measurement is to be made from left to right, place the 9-inch fractional division mark (counted toward the left from the cipher) on the given line, and make an indentation (or mark) opposite the 2-foot division point. (See Fig. 32*a*.) The distance from the line to the point represents 2′-9″, although it is actually $1\frac{3}{8}$ inches. To set off the same measurement from right to left, place the 2-foot mark on the given line, and make an indentation opposite the 9-inch fractional division mark. (See Fig. 32*b*.)

The procedure for setting off a distance to full size is illustrated in Fig. 33. The scale that is full divided into inches and sixteenths is best suited for this purpose.

To set off a measurement (say $1\frac{9}{16}$ inches) from left to right, place the initial mark at the start of the scale on the given line, and make an indentation opposite the $1\frac{9}{16}$-inch mark (Fig. 33*a*). To set off the same measurement from right to left, place the $1\frac{9}{16}$-inch mark on the given line, and make an indentation opposite the initial division mark at the start of the scale.

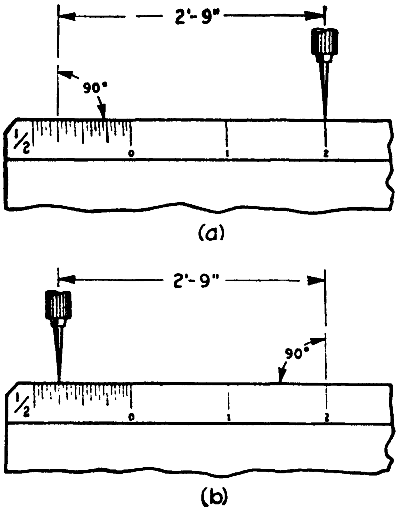


Fig. 32. To lay off a measurement.

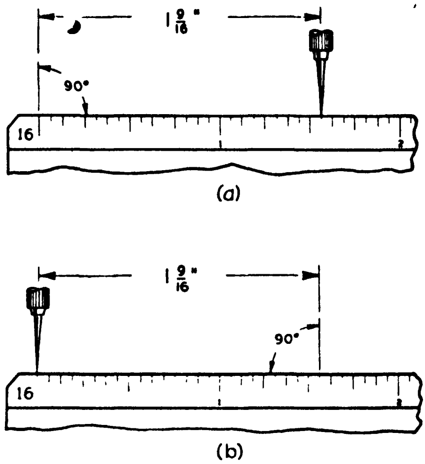


Fig. 33. To lay off a measurement (full size).

37. The compass. The compass is used principally for drawing circles and circle arcs having radii beyond the working range of the bow pencil and bow pen. For drawing pencil circles, the style of point illustrated in Fig. 35(*c*) should be used, as it gives more accurate results and is easier to maintain than most other styles. This style of point is formed by first sharpening the outside of the lead to a long flat bevel approximately $\frac{1}{4}$ of an inch long (see Fig. 35*a*), and then finishing it (see Fig. 35*b*) with a slight rocking motion to reduce the width of the point. Some draftsmen have found that a 2*H* lead is a satisfactory compromise for ordinary working drawings. However, for design drawings, layout work, and graphical solutions, a harder lead will give better results.

The needle point should have the shouldered end out, and should be adjusted (approximately $\frac{3}{8}$ of an inch beyond the end of the split sleeve) so that it is slightly longer than the pen point. When the pencil leg is used, the lead should be adjusted slightly shorter and, as it is resharpened, should be readjusted.

38. Using the compass. To draw a circle, it is first necessary to draw two intersecting center lines at right angles and mark off the radius as previously explained. The pivot point may be guided accurately into position at the center with the little finger of the left hand. After the pencil point has been adjusted to the radius mark, the circle is drawn in a clockwise direction by holding the compass as shown in Fig. 36, and rotating the handle between the thumb and forefinger. While drawing

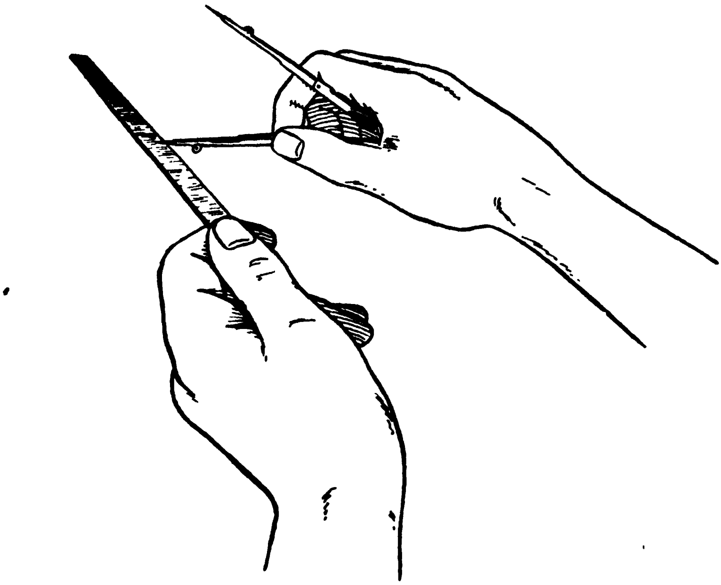
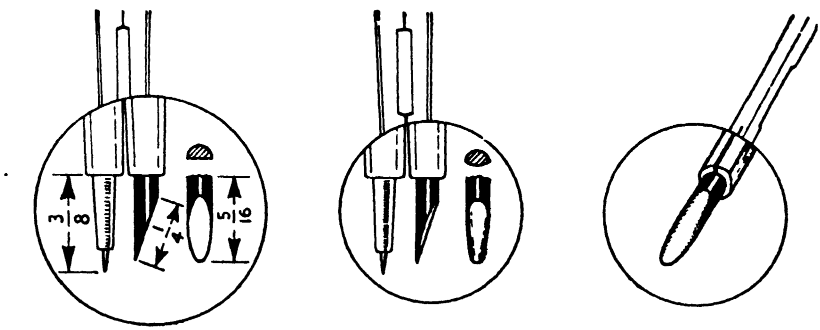


Fig. 34. Sharpening the compass lead.



(a) (b) (c)

Fig. 35. Shaping the compass lead.

the circle, the compass should be inclined slightly forward. If the pencil line is not dark enough, it may be brightened by drawing around it again.

For a radius larger than two inches, the legs should be bent at the knee joints so as to stand approximately perpendicular to the paper. For circles whose radii exceed five inches, the lengthening bar should be used to increase the capacity. In this case the instrument is manipulated by steadying the pivot leg with one hand, and rotating the marking leg with the other (Fig. 38).

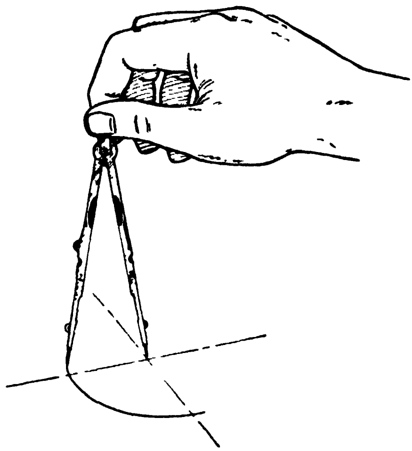


Fig. 36. Using the compass.

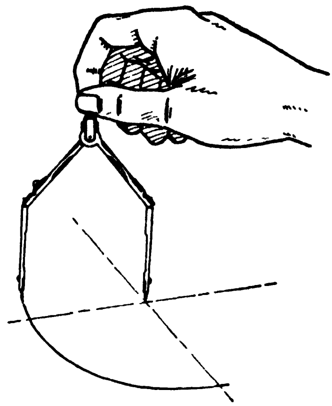


Fig. 37. Using the compass (legs bent).

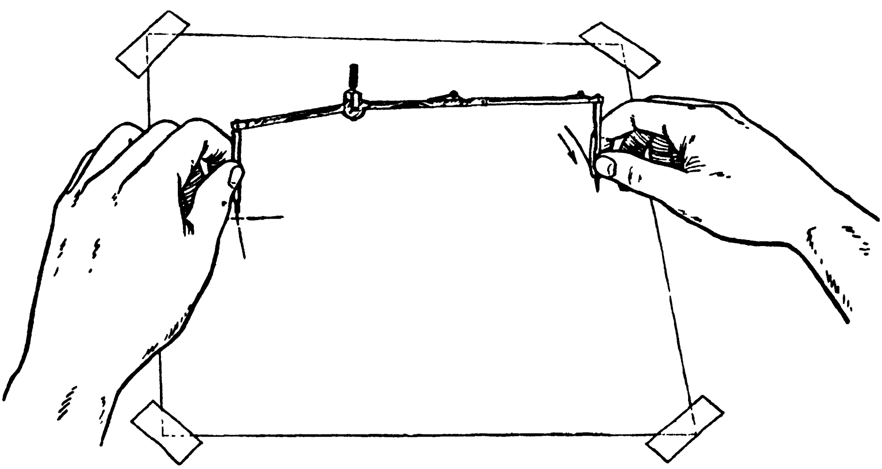


Fig. 38. Drawing large circles.

39. The dividers. The dividers are used principally for dividing curved and straight lines into any number of equal parts, and for transferring measurements. If the instrument is held with one leg between the forefinger and second finger, and the other leg between the thumb and third fingers, as illustrated in Fig. 39, an adjustment may be quickly and easily made with one hand. The second and third fingers are used to "open out" the legs, and the thumb and forefinger to close them.

40. Use of the dividers. The trial method is used to divide a line into a given number of equal parts. (See Fig. 40.) To divide a line into a desired number of equal parts, open the dividers until the distance

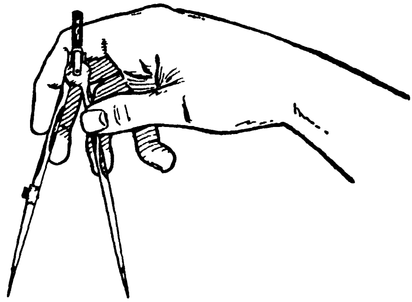


Fig. 39. To adjust the large dividers.

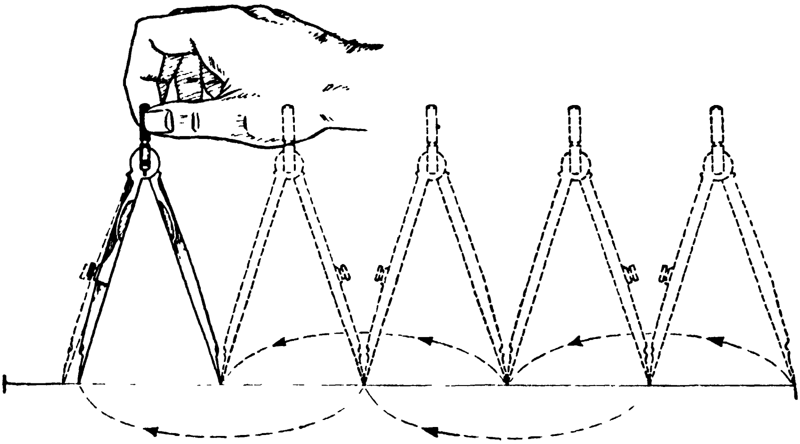


Fig. 40. Use of the dividers.

between the points is estimated to be equal to the length of a division, and step off the line *lightly*. If the last prick mark misses the end point, increase or decrease the setting by an amount estimated to be equal to the error divided by the number of divisions, before lifting the dividers from the paper. Step off the line again. Repeat this procedure until the dividers are correctly set, then space the line again and indent the division points. When stepping off a line, the dividers are rotated alternately in an opposite direction on either side of the line, each half revolution, as shown in Fig. 40.

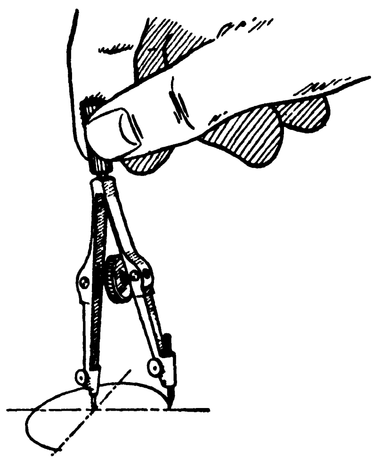


Fig. 41. Use of the bow pencil.

41. Use of the bow instruments. The bow pen and bow pencil are convenient for drawing small circles having a radius of one inch or less. The needle points should be adjusted slightly longer than the marking points, as in the case of the compass.

The bow dividers are used for the same purposes and in the same manner as the large dividers. However, since they hold a setting better, they are more suited for very accurate or small work.

42. Conventional line symbols. Symbolic lines of various weights are used in making technical drawings. The American Standards Association suggests:

> Three weights of lines, heavy, medium, and light are considered desirable on finished drawings in ink, both for legibility and appearance, although in rapid practice and in particular on penciled drawings from which blueprints are to be made this may be simplified to two weights, medium and light. For pencil drawings the lines should be in proportion to the ink lines, *medium* for outlines, hidden, cutting plane, short breaks, adjacent part and alternate position lines and *light* for section, center, dimension, long break, and ditto lines.

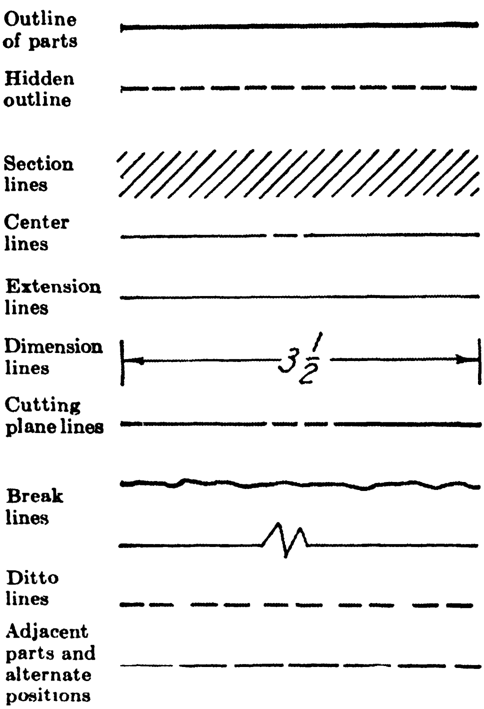


Fig. 42. Conventional lines—pencil.

The lines illustrated in Fig. 42 are shown full size. When these symbolic lines are used on a pencil drawing, they should vary in color as well as in width to give the necessary contrast which makes a drawing easy to read. Object lines and hidden lines should be sharp and dark. Center lines, dimension lines, extension lines, and section lines must be fine and light, yet distinct. Construction lines should be drawn *very* fine so as to be unnoticeable on the finished drawing.

Fig. 43. Using the irregular curve.

43. Use of the French curve. A French curve is used for drawing irregular curves which are not circle arcs. After sufficient points have been located, the French curve is applied so that a portion of its ruling edge passes through at least three points, as shown in Fig. 43. It should be so placed that the increasing curvature of the section of the ruling edge being used follows the direction of that part of the curve which is

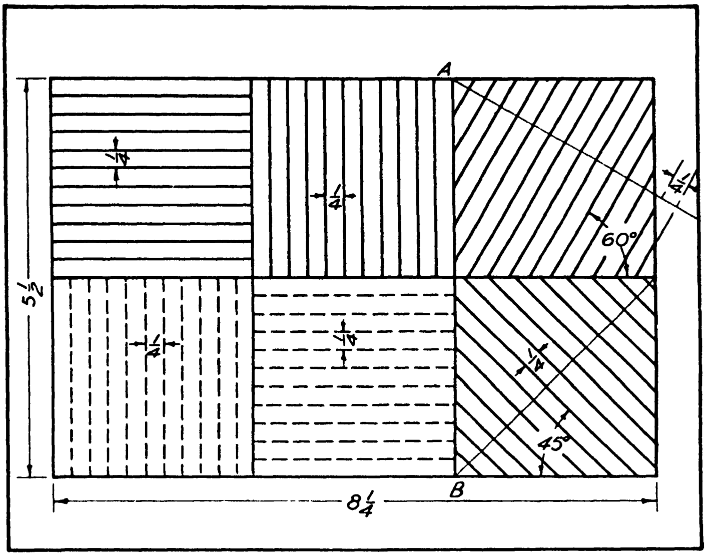


Fig. 44.

changing most rapidly. To insure that the finished curve will be free of humps and sharp breaks, the first line drawn should start and stop short of the first and last points to which the French curve has been fitted. Then the curve is adjusted in a new position with the ruling edge coinciding with a section of the line previously drawn. Each successive segment should stop short of the last point matched by the curve. When inking a curve, overlapping should be avoided, as sharp changes in the thickness or the color of the line may result. In Fig. 43, the curve fits the three points, *A*, 1, and 2. A line is drawn from between point *A* and point 1 to between point 1 and point 2. Then, the curve is shifted, as shown, to again fit points 1 and 2 with an additional point 3, and the line is extended to between point 2 and point 3.

Draftsmen sketch a smooth continuous curve through the points in pencil before drawing the mechanical line. This procedure makes the task of drawing the curve less difficult, as it is easier to adjust the ruling edge to segments of the free-hand curve than to the points.

44. Use of the erasing shield and eraser. An erasure is made on a drawing by placing an opening in the erasing shield over the work to be erased and rubbing with a pencil eraser (never an ink eraser) until it is removed. The fingers holding the erasing shield should rest partly on the drawing paper to prevent the shield from slipping.

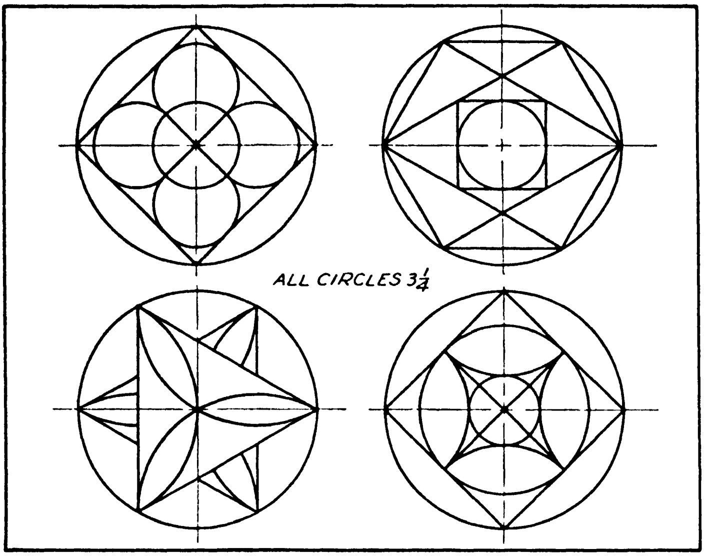


Fig. 45.

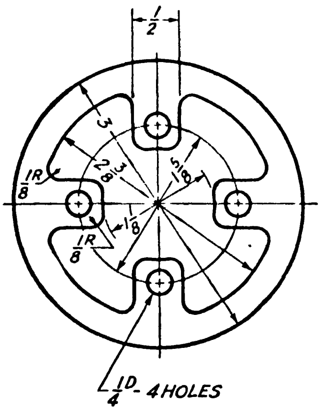


Fig. 46.

45. Exercises in instrumental drawing. The following elementary exercises have been designed to offer experience in the use of the drafting instruments.

1. (Fig. 44.) On a sheet of drawing paper reproduce the line formations shown. If the principal border lines have not been printed on the sheet, they may be drawn first so that the large $5\frac{1}{2}'' \times 8\frac{1}{4}''$ rectangle can be balanced horizontally and vertically within the border. To draw the inclined lines, first draw the indicated measuring lines through the lettered points at the correct angle, and mark off $\frac{1}{4}''$ distances. These division points establish the locations of the required lines of the formation. The six squares of the formation are equal in size.

2. (Fig. 45.) This exercise is designed to give the student practice with the bow pencil and compass through the drawing of some simple geometrical figures. The line work within each large circle may be reproduced with the knowledge only that the diameter is $3\frac{1}{4}''$. All circles and circle arcs are to be made finished weight when they are first drawn, since retracing often produces a double line.

3. (Fig. 46.) Reproduce the contour view of the stamping.

4, 5. (Figs. 47, 48.) Reproduce the designs following the instructions given for problem 2, making the dashes of the arcs approximately $\frac{1}{8}''$ long.

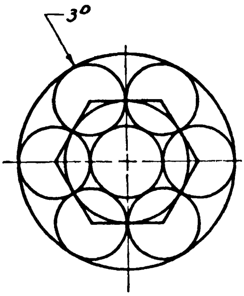


Fig. 47.

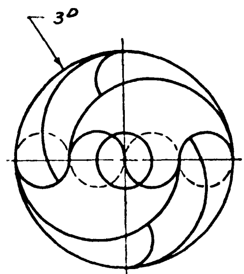


Fig. 48.

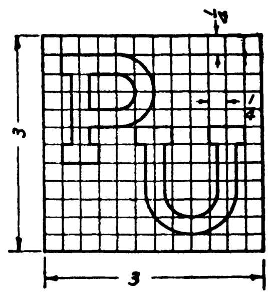


Fig. 49.

6. (Fig. 49.) Reproduce the line work and letters using the dimensions given.

4

ENGINEERING GEOMETRY

46. Introduction. The simplified geometrical constructions presented in this chapter are those with which a draftsman should be familiar, for they frequently occur in engineering drawing. The methods are applications of the principles found in textbooks on plane geometry.

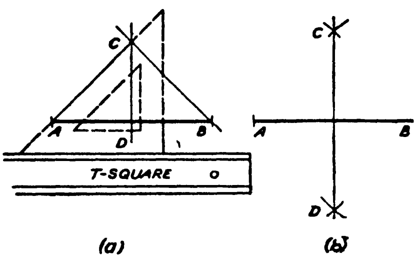


Fig. 50. To bisect a straight line.

47. To bisect a straight line (Fig. 50). Given the line AB.

(*a*) Draw 45 degree lines through A and B. Through their intersection draw the perpendicular DC, which will bisect AB.

(*b*) With A and B as centers, strike the intersecting arcs as shown using any radius greater than one-half of AB. A straight line through points C and D bisects AB.

The use of the dividers to divide or bisect a line by the trial method is explained in Sec. 40.

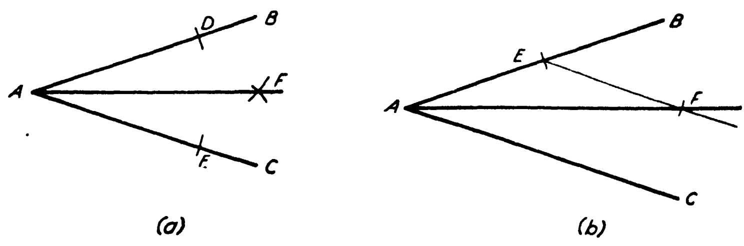


Fig. 51. To bisect an angle.

48. To bisect an angle (Fig. 51). Given the angle BAC.

(*a*) Use any radius with the vertex A as a center, and strike an arc that intersects the sides of the angle at D and E. With D and E as centers and a radius larger than one-half of DE, draw the intersecting arcs locating point F. Draw AF. Angle BAF equals angle FAC.

(*b*) Lay off along AB any convenient distance AE. Through point E draw a line parallel to AC, and set off EF equal to AE. Angle BAF equals angle FAC.

49. To divide a straight line into a given number of equal parts (Fig. 52). Given the line LM which is to be divided into five equal parts.

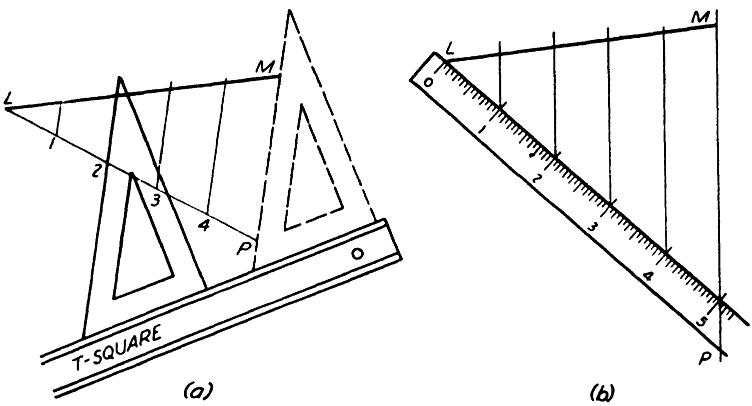


Fig. 52. To divide a straight line into a number of equal parts.

(*a*) Step off, with the dividers, five equal divisions along a line making any convenient angle with LM. Connect the last point P with M, and through the remaining points draw lines parallel to MP intersecting the given line. These lines divide LM into five equal parts.

(*b*) Some commercial draftsmen prefer a modification of this construction known as the scale method. For the first step, draw a vertical PM through point M. Place the scale so that the first mark of five equal divisions is at L and the last mark falls on PM. Locate the four intervening division points, and through these draw verticals intersecting the given line. The verticals will divide LM into five equal parts.

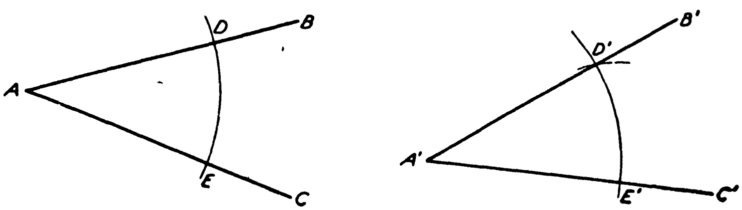


Fig. 53. To construct an angle equal to a given angle.

50. To construct an angle equal to a given angle (Fig. 53). Given the angle BAC and the line $A'C'$ which forms one side of the transferred angle. Use any convenient radius with the vertex A as a center, and strike the arc which intersects the sides of the angle at D and E. With A' as a center, strike the arc intersecting $A'C'$ at E'. With E' as a center and the chord distance DE as a radius, strike a short intersecting arc to locate D'. $A'B'$ drawn through D' makes angle $B'A'C'$ equal angle BAC.

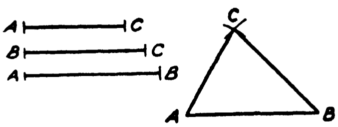
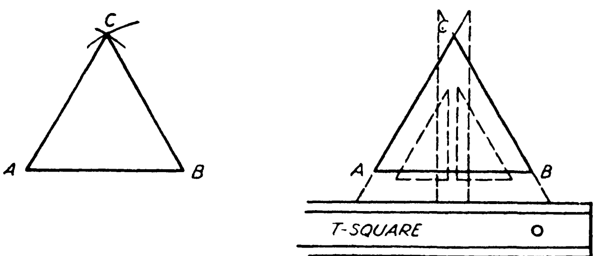


Fig. 54. To construct a triangle with three sides given.

51. To construct a triangle having its three sides given (Fig. 54). Given the three sides AB, AC, and BC. Draw the side AB in its correct location. Using its end points A and B as centers and radii equal to AC and BC, respectively, strike the two intersecting arcs locating point C. ABC is the required triangle. This construction is particularly useful for developing the surface of a transition piece by triangulation, or for transferring a triangle or polygon to a new location.

52. To construct an equilateral triangle (Fig. 55). Given the side AB.

(*a*) Using the end points A and B as centers and a radius equal to the



(a) (b)

Fig. 55. To construct an equilateral triangle

length of AB, strike two intersecting arcs to locate C. Draw lines from A to C and C to B to complete the required equilateral triangle.

(*b*) Using a 30-60 degree triangle, draw through A and B lines that make 60 degrees with the given line.

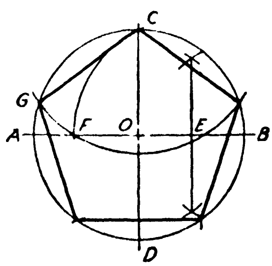


Fig. 56. To construct a regular pentagon.

53. To construct a regular pentagon (Fig. 56). Given the circumscribing circle. Draw the perpendicular diameters AB and CD. Bisect OB and, with its mid-point E as a center and EC as a radius, draw the arc CF. Using C as a center and CF as a radius, draw the arc FG. The line CG is one of the equal sides of the required pentagon. Locate the remaining vertices by striking off this distance around the circumference.

If the length of one side of a pentagon is given, the construction shown in Fig. 58 should be used.

54. To construct a regular hexagon (Fig. 57).

(*a*) Given the distance *AB* across corners. Draw a circle having *AB* as a diameter. Using the same radius and with points *A* and *B* as

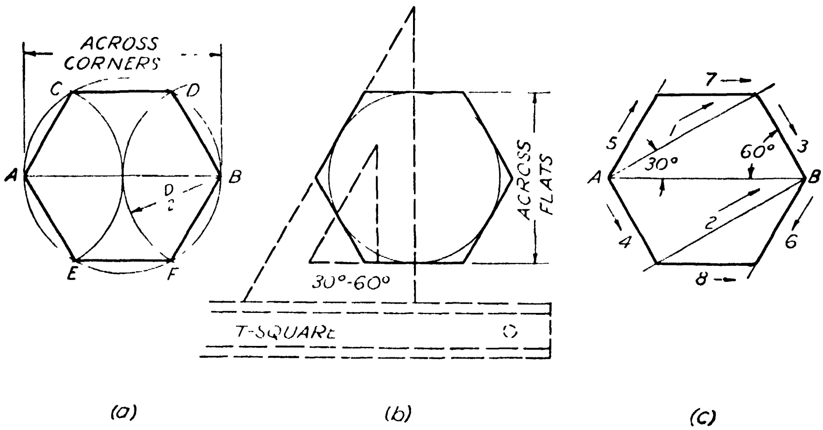


Fig. 57. To construct a regular hexagon.

centers, strike arcs intersecting the circumference. Join these points to complete the construction.

(*b*) Given the distance across flats. Draw a circle whose diameter equals the distance across flats. Using a 30 degree to 60 degree triangle and a T-square, as shown, draw the tangents which establish the sides and vertices of the required hexagon.

This construction is used in drawing hexagonal bolt heads and nuts.

(*c*) Given the distance *AB* across corners. Using a 30–60 degree triangle and a T-square, draw the lines in the order indicated by the numbers on the figure.

55. To construct any regular polygon having one side given (Fig. 58). Given the side *LM*. With *LM* as a radius, draw a semicircle and divide it into the same number of equal parts as the number of sides needed for the polygon. Suppose the polygon is to be seven-sided. Draw radial lines through points 2, 3, and so forth. Point 2 (the second division point) is always one of the vertices of the polygon, and line *L*2 is a side. Using point *M* as a center and *LM* as a radius, strike an arc across the radial line *L*6 to locate point *N*. Using the same radius with *N* as a center, strike another

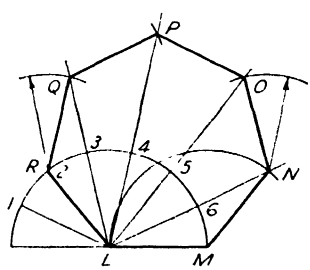


Fig. 58. To construct any regular polygon, having one side given.

arc across $L5$ to establish O on $L5$. Although this procedure may be continued with point O as the next center, more accurate results will be obtained if point R is used as a center for the arc to locate Q, and Q as a center for P.

56. To find the center for a circle through three given points not in a straight line (Fig. 59). Given the three points A, B, and C. Join the points with straight lines (which will be chords of the required circle), and draw the perpendicular bisectors. The point of intersection O of the bisectors is the center of the required circle, and OA, OB, or OC is its radius.

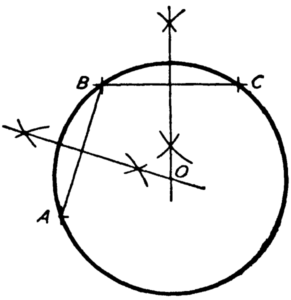


Fig. 59. To find the center of a circle through three points.

57. To draw a circular arc of radius R tangent to two lines (Fig. 60).

(*a*) Given the two lines AB and CD at right angles to each other, and the radius of the required arc R. Using their point of intersection I as a center and R as a radius, strike an arc cutting the given lines at T_1 and T_2 (tangent points). With T_1 and T_2 as centers and the same radius, strike the intersecting arcs locating the center O of the required arc.

(*b*) Given the two lines AB and CD, not at right angles, and the radius R. Draw lines EF and GH parallel to the given lines at a distance R. Since the point of intersection of these lines is distance R from both given lines, it will be the center O of the required arc. Mark the tangent points T_1 and T_2 which lie along perpendiculars to the given lines through O.

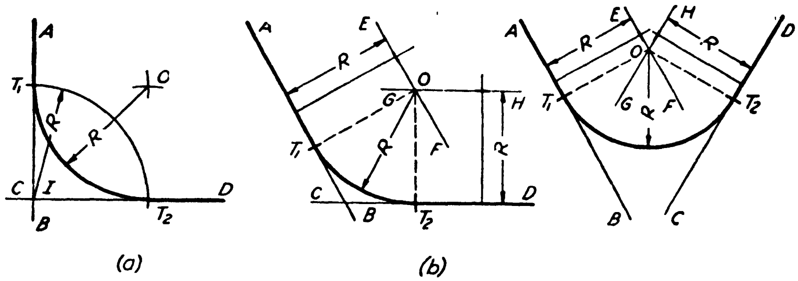


Fig. 60. To draw a circular arc tangent to two lines.

These constructions are useful for drawing fillets and rounds on views of machine parts.

58. To draw a circular arc of radius R_1 tangent to a given circular arc and a given straight line (Fig. 61). Given the line AB and the circular arc with center O.

(*a*) and (*b*) Let R_1 be the radius of the required arc. Draw line CD

parallel to AB at a distance R_1. Using the center O of the given arc and a radius equal to its radius plus or minus the radius of the required arc (R_2 plus or minus R_1), swing a parallel arc intersecting CD. Since the line CD and the intersecting arc will be the loci of centers for all circles of

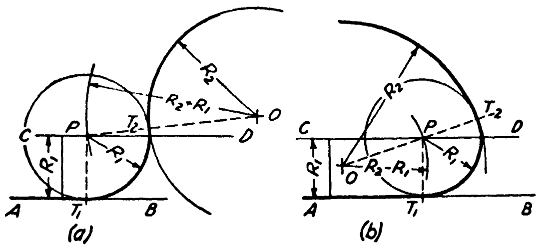


Fig. 61. To draw a circular arc tangent to a given circular arc and a line.

radius R_1, tangent respectively to the given line AB and the given arc, their point of intersection P will be the center of the required arc. Mark the points of tangency T_1 and T_2. T_1 lies along a perpendicular to AB through the center P, and T_2 along a line joining the centers of the two arcs.

This construction is useful for drawing fillets and rounds on views of machine parts.

59. To draw a circular arc of a given radius R_1 tangent to two given circular arcs (Fig. 62). Given the circular arcs AB and CD with centers

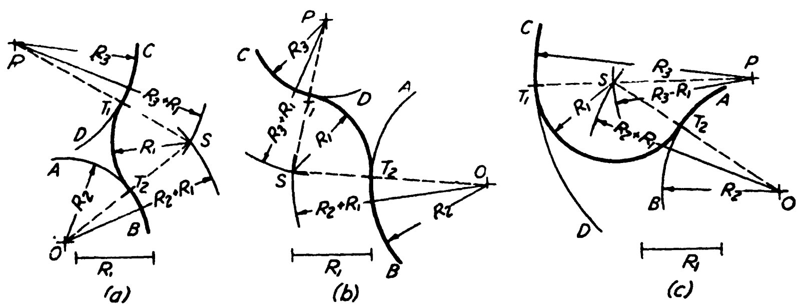


Fig. 62. To draw a circular arc tangent to two given arcs.

O and P, and radii R_2 and R_3, respectively. Let R_1 be the radius of the required arc.

(*a*) and (*b*) Using O as a center and R_2 plus R_1 as a radius, strike an arc parallel to AB. Using P as a center and R_3 plus R_1 as a radius, strike an intersecting arc parallel to CD. Since each of these intersecting arcs is the locus of centers for all circular arcs of radius R_1 tangent to the given arc to which it is parallel, their point of intersection S will be the center for the required arc which is tangent to both. Mark the points of tangency T_1 and T_2 which lie on the lines of centers PS and OS.

(*c*) Using O as a center and R_2 plus R_1 as a radius, strike an arc parallel to AB. Using P as a center and R_3 minus R_1 as a radius, strike an intersecting arc parallel to CD. The point of intersection of these arcs is the center for the required arc.

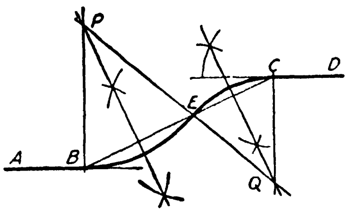


Fig. 63. To draw a reverse curve.

60. To draw a reverse (ogee) curve (Fig. 63). Given the two parallel lines AB and CD. At points B and C, the termini and tangent points of the reverse curve, erect perpendiculars. Join B and C with a straight line and assume a point E which will be the point at which the curves will be tangent to each other. Draw the perpendicular bisectors of BE and EC. Since an arc tangent to AB at B must have its center on the perpendicular BP, point of intersection P of the bisector and the perpendicular is the center for the required arc which is to be tangent to the line at B and the other required arc at point E. For the same reason, point Q is the center for the other required arc.

This construction is useful to architects in drawing mouldings, and to engineers in laying out center lines for railroad tracks, pipe lines, and so forth.

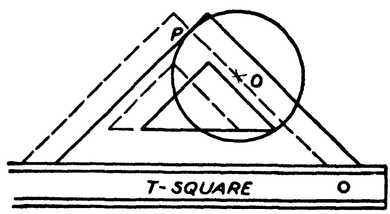


Fig. 64. To draw a line tangent to a circle at a point on the circumference.

61. To draw a line tangent to a circle at a given point on the circumference (Fig. 64). Given a circle with center O and point P on its circumference. Place a triangle supported by a T-square or another triangle in such a position that one leg passes through the center O and point P. Holding the supporting T-square in place, slide the triangle along the guiding edge until the required tangent can be drawn through P. This construction satisfies the geometrical requirement that a tangent must be perpendicular to a radial line which is drawn to the point of tangency.

62. To draw a line tangent to a circle through a given point outside the circle (Fig. 65). Given a circle with center O, and an external point P.

(*a*) Join the point P and the center O with a straight line, and bisect it to locate point S. Using S as a center and SO (one-half PO) as a radius, strike an arc intersecting the circle at point T (point of tangency). Line PT is the required tangent.

(*b*) Place a triangle supported by a T-square or another triangle in such a position that one leg passes through point P tangent to the circle, and draw the tangent. Slide the triangle along the guiding edge until the other leg coincides with the center O, and mark the point of tangency.

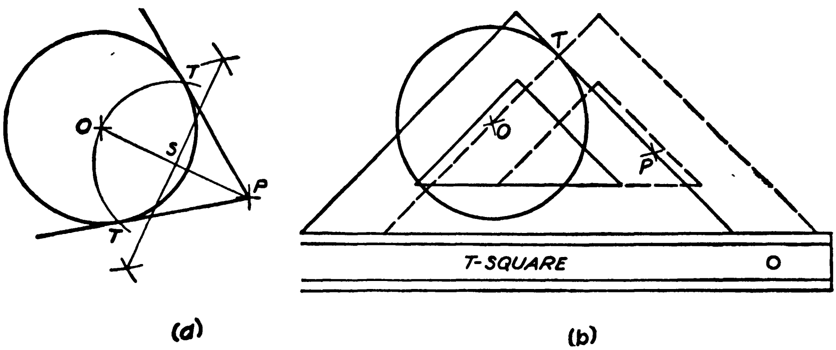


Fig. 65. To draw a line tangent to a circle through a given point outside.

63. To lay off the approximate length of a circular arc on its tangent (Fig. 66). Given the arc AB.

(a) Draw the tangent through A, and extend the chord BA. Locate point C by laying off AC equal to one-half the length of the chord AB. With C as a center and a radius equal to CB, strike an arc intersecting the tangent at D. The length AD along the tangent is slightly shorter than the true length of the arc AB by an amount that may be disregarded, for, when the angle between the chord and the tangent is less than 60°, the

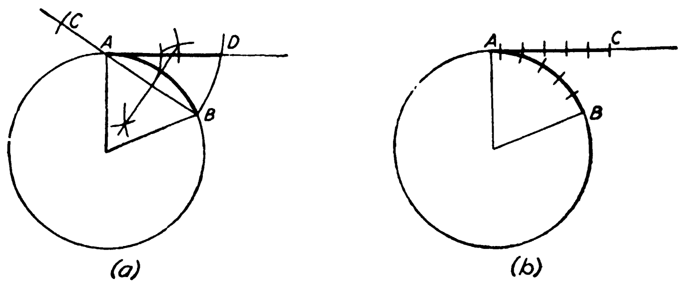


Fig. 66. To lay off the approximate length of a circular arc on its tangent.

length of AD differs from the true length of the arc AB by less than 6′ in one mile; when 30°, the error is $4\frac{1}{2}''$ in one mile.

(b) Draw the tangent through A. Using the small dividers, start at B and step off equal chord distances around the arc until the point nearest A is reached. From this point (without raising the dividers) step off along the tangent an equal number of distances to locate point C. If the point nearest A is indented into the tangent instead of the arc, the almost negligible error in the length of AC will be still less.

64. The ellipse. The curved line of intersection formed by a plane cutting a cone or cylinder without cutting the base is an ellipse.

65. To construct an ellipse, trammel method (Fig. 67). Given the major axis AB and the minor axis CD. Along the straight edge of a strip of paper or cardboard, locate the points O, C, and A, so that the distance

OA is equal to one-half the length of the major axis and the distance OC is equal to one-half the length of the minor axis. Place the marked edge across the axes so that point A is on the minor axis and point C is on the major axis. *Point O will fall on the circumference of the ellipse.* Move the strip, keeping A on the minor axis and C on the major axis, and mark at least five other positions of O on the ellipse in each quadrant. Using a French curve, complete the ellipse by drawing a smooth curve through the points.

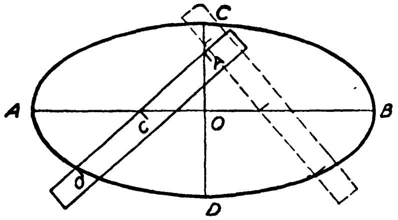


Fig. 67. To construct an ellipse, trammel method.

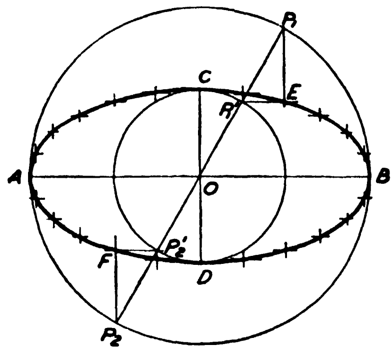


Fig. 68. To construct an ellipse, concentric circle method.

66. To construct an ellipse, concentric circle method (Fig. 68). Given the major axis AB and the minor axis CD. Using the center of the ellipse (point O) as a center, describe circles having the major and minor axes as diameters. Divide the circles into equal central angles and draw diametrical lines such as P_1P_2. From point P_1 on the circumference of the larger circle, draw a line parallel to CD, the minor axis, and from point P_1' at which the diameter P_1P_2 intersects the inner circle, draw a line parallel to AB, the major axis. The point of intersection of these lines, point E, is on the required ellipse. At points P_2 and P_2' repeat the same procedure and locate point F. Thus, two points are established by the line P_1P_2. Locate at least five points in each of the four quadrants. The ellipse is completed by drawing a smooth curve through the points.

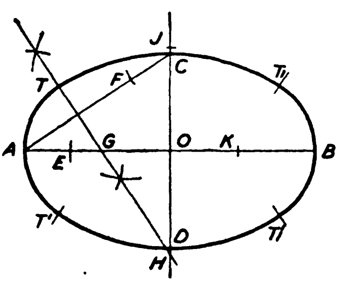


Fig. 69. To construct an ellipse, center method.

This is one of the most accurate methods used to form ellipses.

67. To construct an ellipse, four-center method (Fig. 69). Given the major axis AB and the minor axis CD. Draw the line AC. Using the center of the ellipse O as a center and OC as a radius, strike an arc intersecting OA at point E. Using C as a center and EA as a radius, strike an arc intersecting the line AC at F. Draw the perpendicular bisector of the line AF. The points G and H, at which the perpendicular bisector intersects the axes AB and CD (extended) are the centers of two of the arcs forming the ellipse. Locate the other two centers, J and K, by laying off OJ equal to OH and OK equal to OG. To determine the junction points (tangent points) T, T', T_1, and T_1' for the arcs, draw lines through the centers of the tangent arcs. The figure thus formed by the four circle arcs approximates a true ellipse.

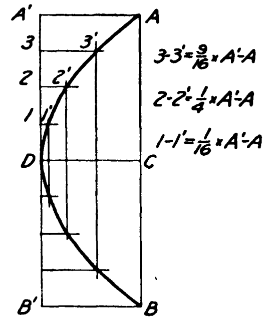


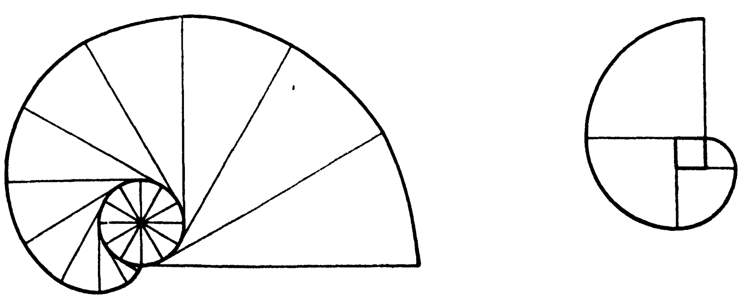
Fig. 70. To construct a parabola, offset method.

68. To construct a parabola, offset method (Fig. 70). Given the enclosing rectangle $A'ABB'$. Divide DA' into any number of equal parts (say four), and draw from the division points the perpendiculars parallel to DC, along which the offset distances are to be measured off. The offsets vary as the square of their distances from D. For example, since $D1$ is one-fourth of the distance from A' to D, 1-1′ will be $(\frac{1}{4})^2$, or one-sixteenth of $A'A$. Similarly, 2-2′ will be $(\frac{1}{2})^2$, or $\frac{1}{4}$ of $A'A$; and 3-3′ will be $\frac{9}{16}$ of $A'A$. To complete the parabola, lay off the computed offset values along the perpendiculars and form the figure with a French curve.

This method is preferred by civil engineers for laying out parabolic arches and computing vertical curves for highways.

69. An involute. The spiral curve traced by a point on a chord as it unwinds from around a circle or a polygon is an involute curve. Fig. 71(*a*) shows an involute of a circle, while (*b*) shows that of a square. The involute of a polygon is obtained by extending the sides and drawing arcs using the corners, in order, as centers. The circle in (*a*) may be considered to be a polygon having an infinite number of sides.

70. To draw an involute of a circle (Fig. 71*a*). Divide the circumference into a number of equal parts. Draw tangents through the divi-



(*a*) (*b*)

Fig. 71. The involute.

sion points. Then, along each tangent, lay off the rectified length of the corresponding circular arc, from the starting point to the point of tangency. The involute curve is a smooth curve through these points.

71. To draw the involute of a polygon (Fig. 71*b*). Extend the sides of the polygon as shown in (*b*). With the corners as centers, in order around the polygon, draw arcs terminating on the extended sides. The first radius is equal to the length of one side of the polygon. The radius of each successive arc is the distance from the center to the terminating point of the previous arc.

72. Problems. The following exercises not only require the student to study and use certain common geometrical constructions, but also furnish additional practice in applying good line technique to the drawing of instrumental figures and practical designs. All work should be very accurately done. Tangent points should be indicated by a light short dash across the line.

1. Draw a horizontal line $4\frac{3}{8}''$ long. Bisect it by the method shown in Fig. 50(*a*).

2. Draw a line $3\frac{3}{4}''$ long, inclined at 30° to the horizontal. Divide it into five equal parts. Use the method illustrated in Fig. 52(*a*).

3. Using a line $3\frac{1}{4}''$ long as the base line, construct a triangle having sides $2\frac{1}{2}''$, $3\frac{1}{4}''$, and $3\frac{3}{4}''$ long, respectively. Study the method that is illustrated in Fig. 54.

4. Construct a regular hexagon having a $2\frac{1}{2}''$ distance across flats. Select the most practical procedure.

5. Construct a regular hexagon having a $3\frac{1}{4}''$ distance across corners. Select the most practical method.

6. Construct a regular pentagon having $1\frac{1}{4}''$ sides. Use the method illustrated in Fig. 58.

7. Draw a $2\frac{1}{2}''$ circle. Select a point $2''$ from the center and draw a line tangent to it, using the method illustrated in Fig. 65(*a*).

8. Draw a $2\frac{3}{4}''$ circle, and draw tangent to it a line which makes 15° with the horizontal. Draw a $1\frac{1}{2}''$ circle tangent to the line and the $2\frac{3}{4}''$ circle. Use the method illustrated in Fig. 61.

9. Draw a $3''$ circle. Inside this circle, and tangent to it, draw a $1\frac{3}{4}''$ circle. See that the centers of both circles are on the same vertical center line. Draw two $1''$ circles tangent to the $3''$ and the $1\frac{3}{4}''$ circles. Use the method illustrated in Fig. 62.

10. Construct an ellipse having a major diameter of $4\frac{1}{4}''$ and a minor diameter of $2\frac{3}{4}''$. Use the trammel method illustrated in Fig. 67.

11. Construct an ellipse having a major diameter of $4''$ and a minor diameter of $2\frac{3}{4}''$. Use the concentric circle method illustrated in Fig. 68. Find a sufficient number of points to obtain a smooth curve.

12. Construct the ellipse required in problem 11, using the four-center method. Study Sec. 67 and Fig. 69.

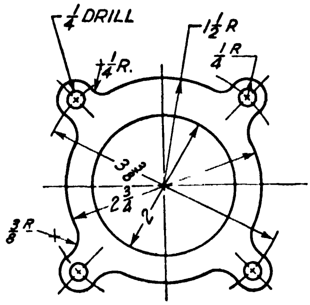


Fig. 72. Gasket.

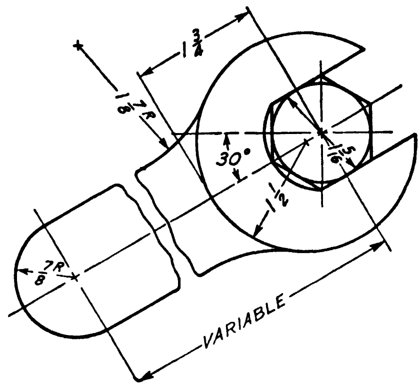


Fig. 73. Wrench.

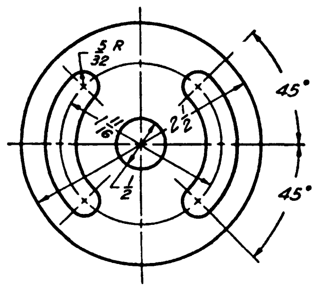


Fig. 75. Guide.

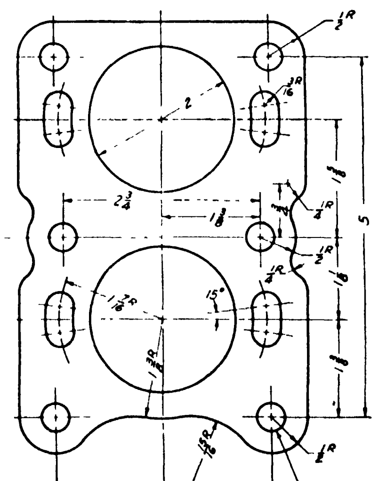


Fig. 74. Gasket.

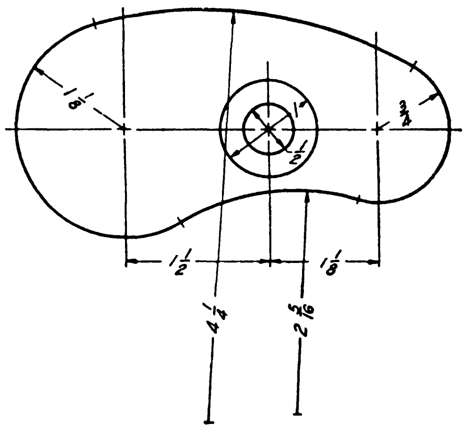


Fig. 76. Cam.

13. Construct the involute of an equilateral triangle with 1″ sides. Study Sec. 71.

14. Construct the involute of a circle $\frac{7}{8}''$ in diameter. Study Sec. 70 and Fig. 71(*a*).

15. Reconstruct the view of the gasket shown in Fig. 72 to full scale. Mark all of the tangent points with short lines. Study Fig. 62. Do not place dimensions on the finished drawing.

16. Reconstruct the view of the wrench shown in Fig. 73. Mark all tangent points with short lines.

17. Reconstruct the view of the gasket shown in Fig. 74. Mark all tangent points with short marks across tangent lines.

18. Reconstruct the view of the guide shown in Fig. 75.

19. Reconstruct the view of the cam shown in Fig. 76. Mark all tangent points.

20. Construct the shape of the slotted guide shown in Fig. 77. Show all construction for locating centers and mark points of tangency.

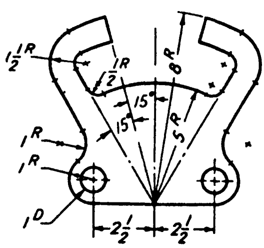


Fig. 77. Slotted guide.

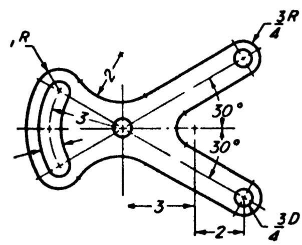


Fig. 78. Adjustable Y-clamp.

21. Construct the adjustable Y-clamp shown in Fig. 78. Show all construction for locating centers and mark points of tangency.

5

TECHNICAL LETTERING

73. To impart to the men in the shops all of the necessary information for the complete construction of a machine or structure, the shape description, which is conveyed graphically by the views, must be accompanied by size description and instructive specifications in the form of figured dimensions and notes.

74. Freehand lettering. All dimensions and notes should be lettered freehand in a plain legible style which can be rapidly executed. Poor lettering detracts from the appearance of a drawing, and often impairs its usefulness, regardless of the quality of the line work.

75. Single-stroke Gothic letters (Reinhardt). The simplified single-stroke Gothic letters developed by Charles W. Reinhardt are now used universally for working drawings. This style is particularly suitable for most technical purposes because it possesses the qualifications necessary for legibility and speed.

The expression "single-stroke" means that the width of the straight and curved lines which form the letters are the same width as the stroke of the pen or pencil.

76. The general proportions of letters. Although there is no fixed standard for the proportions of the letters, certain definite rules in their design must be observed by a draftsman if he wishes to have his lettering appear neat and pleasing to the eye.

It is advisable for the beginner, instead of relying on his untrained eye for proportions, to follow the fixed proportions given in this chapter. Otherwise, his lettering most likely will be displeasing to the trained eye of a professional engineer or draftsman. Later, after he has thoroughly mastered the art of lettering, his individuality will be revealed naturally by slight variations in the shapes and proportions of some of the letters.

It is often desirable to increase or decrease the width of letters in order to make a word or group of words fill a certain space. Letters narrower than normal letters of the same height are called *compressed letters;* those that are wider are called *extended letters.* (See Fig. 79.)

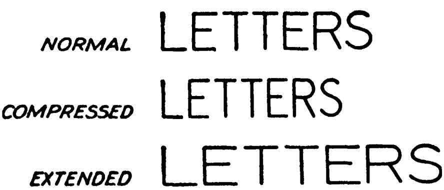


Fig. 79. Compressed and extended letters.

77. Lettering pencils, pens, and equipment. Pencil lettering is usually done with either an *F* or 2*H* pencil. In order to obtain satisfactory lines, the pencil should be sharpened to a long conical point and then rounded slightly on a piece of scratch paper. To keep the point symmetrical while lettering, the pencil should be rotated a partial revolution before each new letter is started.

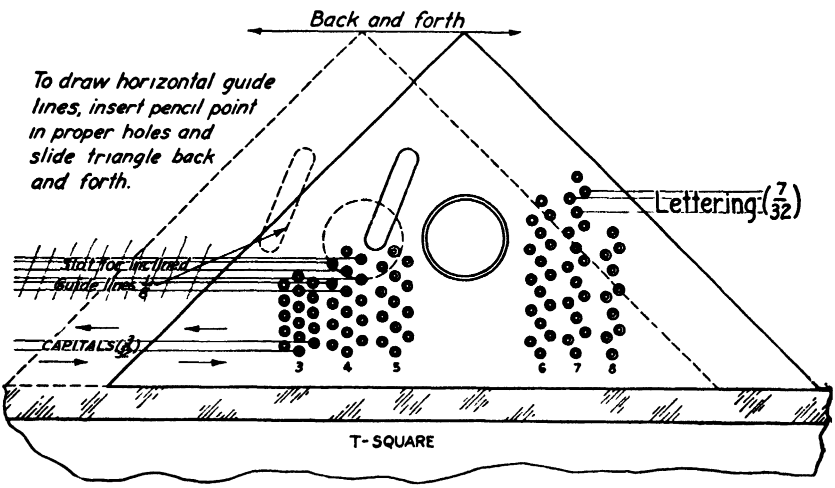


Fig. 80. Braddock lettering triangle.

A pen that makes a heavy stroke should be used for the bold letters in titles and so forth, while a light-stroke pen is required for the lighter letters in figures and notes.

A very flexible point never should be used for lettering. Such a point is apt to shade the downward stem strokes as well as the downward portions of curved strokes. A good point is one which has enough resistance to normal pressure to permit the drawing of curved and stem strokes of uniform width.

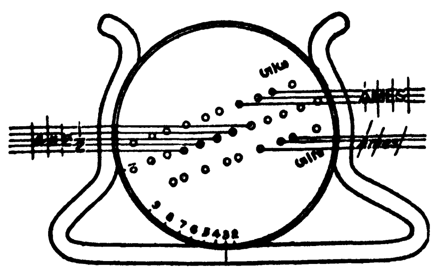


Fig. 81. Ames lettering instrument.

78. Devices for drawing guide lines and slope lines. Devices for drawing guide lines are available in a variety of forms. The two devices which are the most popular are the *Braddock Lettering Triangle* (Fig. 80), and the *Ames Lettering Instrument* (Fig. 81).

The Braddock Lettering Triangle is provided with sets of grouped countersunk holes which may be used to draw guide lines by inserting a

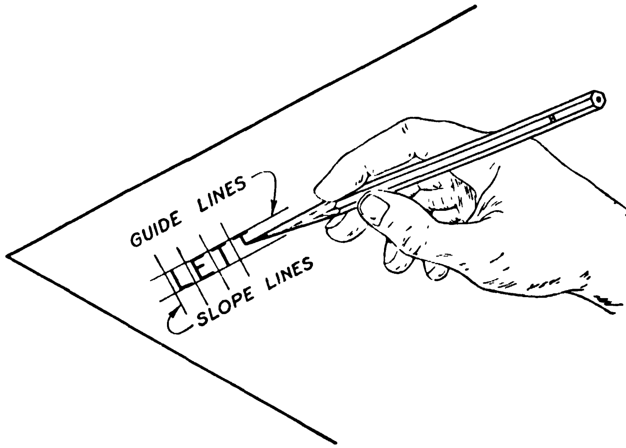


Fig. 82. Guide lines and slope lines.

sharp-pointed pencil (*4H* or *6H*) into the holes and sliding the triangle back and forth along the guiding edge of a T-square or a triangle supported by a T-square. The holes are grouped to give guide lines for capitals and lower-case letters. The numbers below each set indicate the height of the capitals in thirty-seconds of an inch.

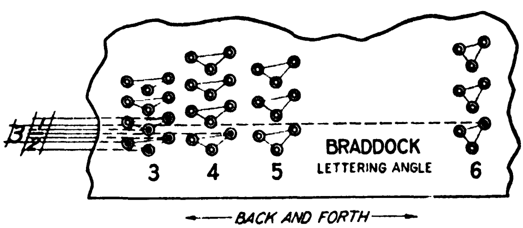


Fig. 83. Guide lines for fractions.

The following practice is recommended for drawing guide lines on drawings of ordinary size.

Notes and detail titles. To draw guide lines for notes and detail titles, use the top and bottom holes of the lower group in size No. 4.

Sheet titles. To draw guide lines for single-line sheet titles, use the top and bottom holes of the lower group in size No. 6. For two-line titles use the top and bottom holes of the two lower groups in size No. 4.

Combined whole numbers and fractions. To draw the seven guide lines required for a whole number and a fraction, use the countersunk holes indicated with black centers in Fig. 83.

These lines are produced by inserting a sharp *6H* pencil in the indicated holes and moving the triangle, guided by a T-square held in a fixed position, back and forth with the pencil point. The height of a fraction numeral will be three-fourths the height of the whole number, and the total height of the fraction will be twice that of the whole number.

79. Uniformity in lettering. Uniformity in height, inclination, spacing, and strength of line is essential for good lettering. Professional appearance depends as much upon uniformity as upon the correctness of the proportion and shape of the individual letters. Uniformity in height and inclination is assured by the use of guide lines and slope lines; uniformity in weight and color, by the skillful use of the pencil and proper control of the pressure of its point on the paper. The ability to space letters correctly becomes easy after continued thoughtful practice.

80. Composition. In combining letters into words, the spaces for the various combinations of letters are arranged so that the areas appear to be equal. For standard lettering, this area should be about equal to one-half the area of the letter *M*. If the adjacent sides be stems, this area is obtained by making the distance between the letters slightly greater than one-half the height of a letter, and a smaller amount depending on the contours, for other combinations.

The space between words should be equal to or greater than the height of a letter, but not more than twice the height. The space between sentences should be somewhat greater. The distance between lines of lettering may vary from one-half the height of the capitals to one and one-half times their height.

81. Stability. If the areas of the upper and lower portions of certain letters are made equal, an optical illusion will cause them to appear to be unstable and top-heavy. To overcome this effect, the upper portions of the letters *B*, *E*, *F*, *H*, *K*, *S*, *X*, and *Z* and the figures *2*, *3*, and *8* must be reduced slightly in size.

An associated form of illusion is the phenomenon that a horizontal line drawn across a rectangle at the vertical center will appear to be below the center. Since the letters *B*, *E*, *F*, and *H* are particularly subject to this illusion, their central horizontal strokes must be drawn slightly above the vertical center in order to give them a more balanced and pleasing appearance.

The letters *K*, *X*, *S*, *Z* and the figures *2*, *3*, and *8* are stabilized by making the width of the upper portion less than the width of the lower portion.

82. The technique of freehand lettering. Any prospective draftsman or engineer can learn to letter if he practices intelligently and is persistent in his desire to improve.

Pencil letters should be formed with strokes that are dark and sharp; never with strokes that are gray and indistinct. Beginners should avoid the tendency to form letters by sketching, as strokes made in this manner vary in color and width.

When lettering with ink, the results obtained depend largely upon the manner in which the pen is used. Many draftsmen blunder along with incorrect habits, then complain that the execution of good freehand lettering is impossible with an ordinary pen point. The most common result of these habits is an inability to make strokes of uniform width. This may be due to one of four causes: (1) excessive pressure on the pen point; (2) an accumulation of lint, dirt, or dried ink on the point; (3) tilting the point while forming a stroke; or (4) fresh ink on the point. The latter cause requires some explanation, since very few draftsmen know the proper method of "inking" the pen. The pen should be wiped thoroughly clean, and the ink should be deposited on the under side over the slot, as shown in Fig. 84. When the pen is filled in this manner, the ink feeds down the slit in an even flow, making possible the drawing of uniform curved and straight lines. If ink is placed on the point or allowed to run to the point, an excessive amount of ink will be deposited on the first letters made, and the width of the strokes will be somewhat wider than the strokes of, say, the sixth or seventh letter. (See Fig. 85.)

Fig. 84. "Inking" the pen.

When lettering, the pen is held as shown in Fig. 86. It should rest so loosely between the fingers that it can be slid up and down with the other hand.

Fig. 85.

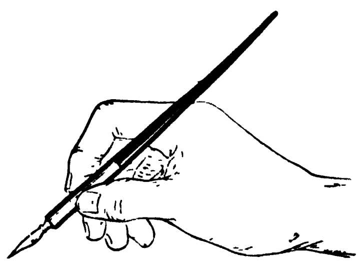


Fig. 86. Holding the pen.

The thin film of oil on a new point must be removed by wiping before it is used.

Inclined Straight-Line Letters

83. The I, T, L, E, and F (Fig. 87). The letter *I* is the basic or stem stroke. The horizontal stroke of the *T* is drawn first, and the stem starts at the exact center of the bar. The *L* is 5 units wide, but it is often desirable to reduce this width when an *L* is used in combination with such letters as *A* and *T*. The middle bar of the *E* is 3½ units long and is placed slightly above the center for stability. The top bar is one-half unit shorter than the bottom bar. The letter *F* is the *E* with the bottom bar omitted.

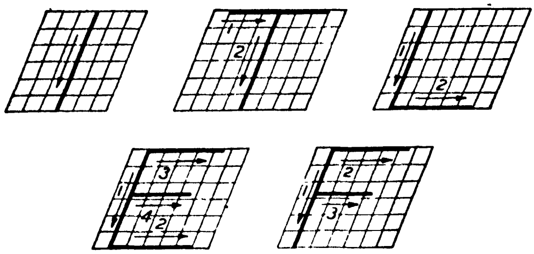


Fig. 87.

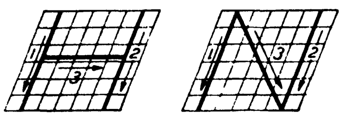


Fig. 88.

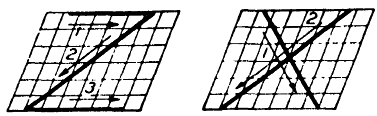


Fig. 89.

84. The H and N (Fig. 88). Stroke 3 of the *H* should be slightly above the center, for stability. The outside parallel strokes of the *N* are drawn first to permit an accurate estimate of its width.

85. The Z and X (Fig. 89). The top of both the letters *X* and *Z* should be one unit narrower than the bottom, for stability.

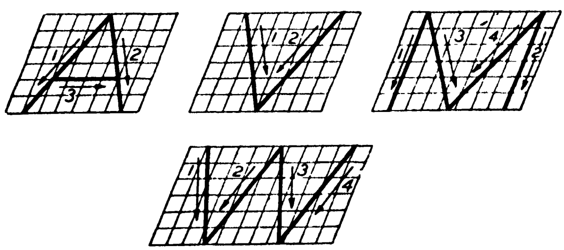


Fig. 90.

86. The A, V, M, and W (Fig. 90). The horizontal bar of the *A* is located up from the bottom a distance equal to one-third of the height of the letter. It should be noted that the bisector of the enclosing parallelogram passes through the vertex, and that the inclined strokes are not parallel to the slope lines. The *V* is the letter *A* inverted without the crossbar, and is the same width. The letters *M* and *W* are the widest letters of the alphabet. The outside strokes of the *M* are drawn first, so that its width may be judged accurately. The outside strokes of this letter are parallel, and the inside strokes meet at the center of the base.

The *W* is formed by two modified *V*'s. Strokes 1 and 3 are practically vertical. Alternate strokes are parallel.

87. The K and Y (Fig. 91). The top of the letter *K* should be one unit narrower than the bottom, for stability. Stroke 2 intersects the stem one-third up from the bottom. Stroke 3 is approximately perpendicular to stroke 2, and, if extended, would touch the stem at the top. The strokes of the *Y* meet at the center of the enclosing parallelogram.

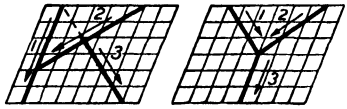


Fig. 91.

Inclined Curved-Line Letters

88. The O, Q, C, and G (Fig. 92). The letters *O*, *Q*, *C*, and *G* are formed by ellipses. Stroke 1 of the letter *O* starts just to the right of the

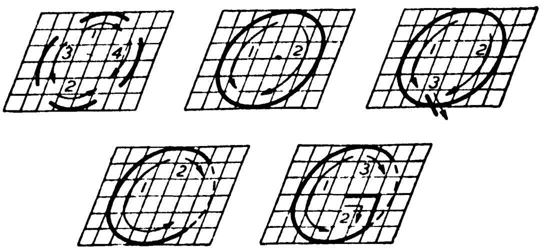


Fig. 92.

top and continues to the left around the side to a point beyond the bottom. The *Q* is the letter *O* with the added kern. The *C* is based on the *O*, but since it is not a complete ellipse, it is narrower than either the *O* or the *Q*. *G* is similar to *C*. The horizontal portion of stroke 2 starts at the center, and the inclined portion is parallel to the side of the parallelogram.

89. The D, U, and J (Fig. 93). The first two strokes of the *D* form an incomplete letter *L*. Stroke 3 starts as a horizontal line, and then forms one-half of a perfect ellipse. The bottom third of the *U* is one-half of an ellipse. *J* is similar to the letter *U*. The bottom third is one-half of a perfect ellipse.

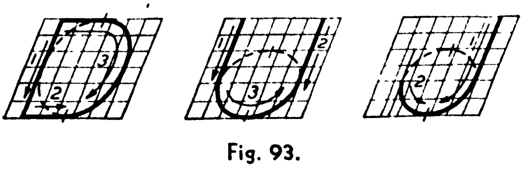


Fig. 93.

90. The P, R, and B (Fig. 94). The middle horizontal bar of the *P* is located at the center of stroke 1. The curved portion of stroke 3 is one-half of a perfect ellipse. The *R* is constructed similarly to the *P*.

The tail joins at the point of tangency of the ellipse and middle bar. To stabilize the letter *B*, the top is made one-half unit narrower than the

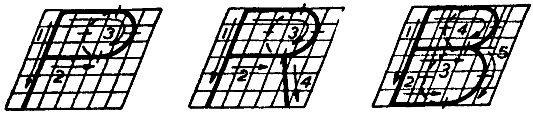


Fig. 94.

bottom and the middle bar is placed slightly above the center. The curves are halves of ellipses.

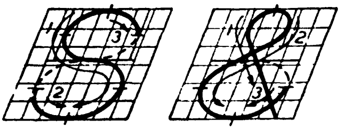


Fig. 95.

91. The S and & (Fig. 95). The upper and lower portions of the *S* are perfect ellipses with one-quarter removed. The top ellipse should be made one-half unit narrower than the lower one, for stability. In the smaller sizes this letter may be made with one or two strokes, depending upon its size. The ampersand is made with three strokes.

Inclined Numerals

92. The 1, 7, and 4 (Fig. 96). These figures are related in that they are composed entirely of straight lines. The stem stroke of the *4* is located one unit in from the right side. The bar is one and one-half units above the base. The stem of the *7* terminates at the center of the base of the parallelogram directly below the left end of the bar.

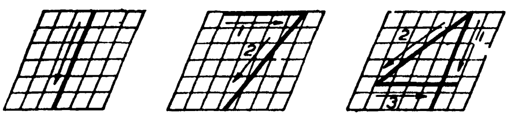


Fig. 96.

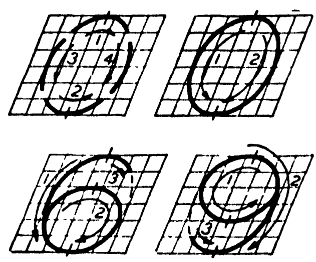


Fig. 97.

93. The 0, 6, and 9 (Fig. 97). The cipher, which is one unit narrower than the letter *O*, is the basic form for this group. In the figure *6*, the right side of the large ellipse ends one unit down from the top, and the left side ends at the center of the base. The small loop is slightly more than three-fourths of a perfect ellipse. The *9* is the *6* inverted.

94. The 8, 3, and 2 (Fig. 98). Each of these figures is related to the letter *S*, and the same rule of stability should be observed in their construction. The top portion of the figure *8* is shorter and one-half unit narrower than the lower portion. The figure *3* is the *8* with the lower left quarter of the upper loop and the upper left quarter of the lower loop omitted. , The *2* is simply three-quarters of the upper loop of the *8* and the upper left quarter of the lower loop of the *8* with straight lines added.

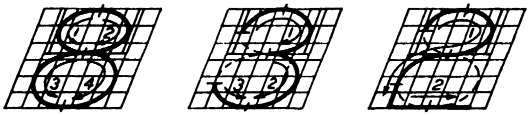


Fig. 98.

95. The 5 (Fig. 99). This figure is a modification of the related groups previously described. The top is one-half unit narrower than the bottom, for stability. The curve is a segment of a perfect ellipse, ending one unit up from the bottom.

96. Single-stroke lower-case letters. Single-stroke lower-case letters, either vertical or inclined, are commonly used on map drawings, topographic drawings, structural drawings, and in survey field books.

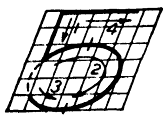


Fig. 99.

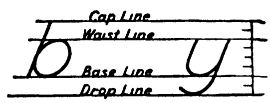


Fig. 100.

97. Inclined lower-case letters. The construction of inclined lower-case letters is based upon the straight line and the ellipse. This basic principle of forming letters is followed more closely for lower-case letters than for capitals. The body portions are two-thirds the height of the related capitals.

98. The i, l, k, and t. All letters of this group are formed by straight lines of standard slope. The *i* is drawn four units high, and the dot is placed half between the waistline and cap line (Fig. 100). Stroke 2 of the *k* starts at the waistline and intersects stroke 1 two units above the base. Stroke 3, extended, should intersect stroke 1 at the top. The *t* is five units high, and the crossbar is on the waistline.

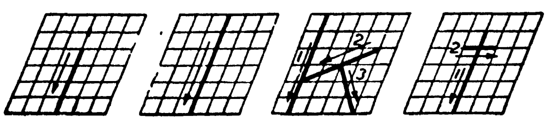


Fig. 101.

99. The v, w, x, and z. Stroke 1 of the *w* is practically vertical, and the alternate strokes are parallel. The width of the top of both the *x* and the *z* is made one-half unit less than the width across the bottom, for stability.

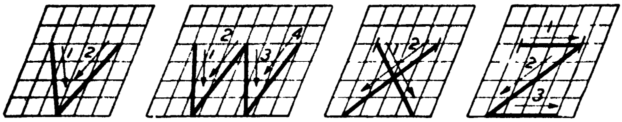


Fig. 102.

100. The o, a, b, d, p, and q. The bodies of the letters in this group are formed by the letter *o*, and they differ only in the position and length

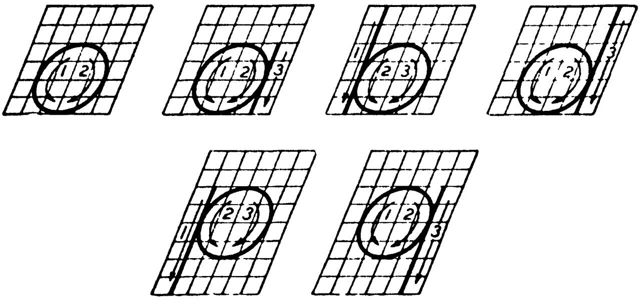


Fig. 103.

of the stem stroke. The *o* is made with two strokes, and the first stroke should form more than half of the ellipse.

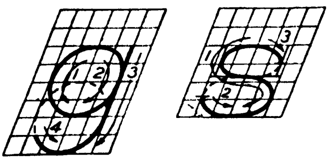


Fig. 104.

101. The g and s. The *g* is related to the letters *o* and *y*. Stroke 3 starts at the waistline and ends slightly beyond the point of tangency of the curve with the drop line. The lower-case *s* is almost identical to the capital *S*.

102. The j and f. The portion of the *j* above the base line is the letter *i*. The elliptical curve is the same as that which forms the tail of the *g*. The body of the *f* without the horizontal bar is two and one-half units wide, stroke 1 starting slightly to the right of the point of tangency with the cap line.

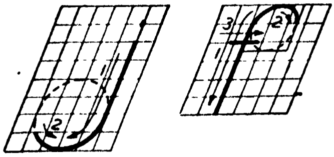


Fig. 105.

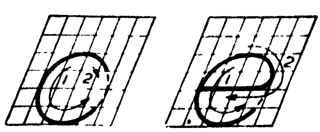


Fig. 106.

103. The c and e. The *c* is a modified letter *o*. It is not a complete ellipse. Therefore, its width is less than its height. Stroke 1 ends one unit up on the right side, stroke 2 one unit down. The *e* is similarly constructed, except for the fact that stroke 2 continues as a curve and finishes as a horizontal line which terminates at the middle of the back.

104. The h, n, r, and m. The curve of the *h* is the upper portion of the letter *o*. Stroke 2 starts 2 units above the bottom of the stem and

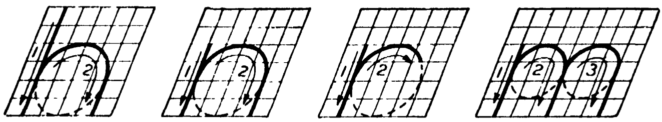


Fig. 107.

finishes parallel to stroke 1. The *n* differs from the *h* in that the stem stroke extends only from the waistline to the base line. The *r* is a portion of the letter *n*, stroke 2 ending one unit down from the top. The *m* consists of two modified letter *n*'s. The straight portions of strokes 2 and 3 are parallel to stroke 1.

105. The u and y. The letter *u* is an inverted *n*, and the curve is a portion of the letter *o*. It should be noted that stroke 2 extends to the base line. The *y* is a partial combination of the letters *u* and *g*.

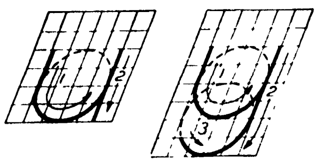


Fig. 108.

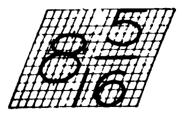


Fig. 109.

106. Fractions. The height of the figures in the numerator and denominator is equal to three-fourths the height of the whole number, and the total height of the fraction is twice the height of the whole number. The division bar should be horizontal and centered between the fraction numerals as shown in Fig. 109.

107. Vertical capitals. Although many commercial draftsmen favor the inclined letters, recent surveys indicate that vertical letters are being more generally used. Since the order and direction of the strokes as well as the general proportions of the vertical letters are the same as previously explained for the inclined form, there is no need for further description. Their general formation is illustrated in Fig. 110.

108. Vertical lower-case. The vertical lower-case letters, illustrated in Fig. 111, are constructed in the same manner as inclined letters. The order and direction of strokes, as well as the proportions, are essentially the same.

109. Vertical numerals. Vertical numerals are made with the same order and direction of stroke and have the same proportions as the inclined numerals (Fig. 112).

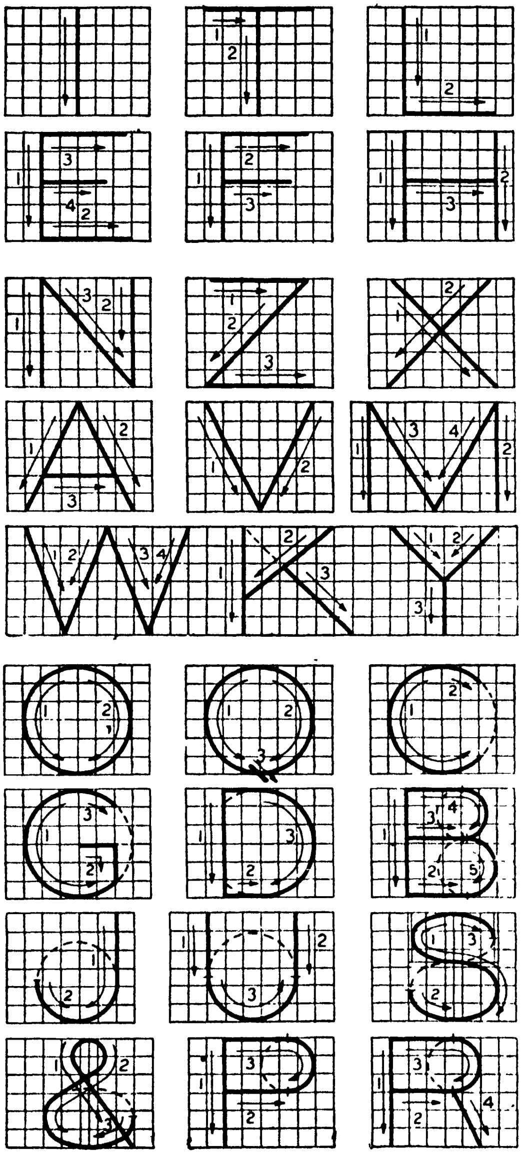


Fig. 110. Vertical capitals.

110. Modern Roman. The Modern Roman letters shown in Fig. 113 are used extensively by engineers for names and titles on maps. These letters must be drawn first in outline, in skeleton form, and then be filled in with a ball-pointed or wide-line pen. The straight lines are usually drawn with a ruling pen. The curved lines, except for the serifs, may be formed either mechanically or freehand. When attempting to construct this type of letter it is wise to bear in mind the following facts: (1) All vertical strokes are heavy except those forming the letters *M*, *N*, and *U*. (2) All horizontal strokes are light. (3) The serif extends about one unit on either side of the body of the stem. (4) The width of the heavy strokes may vary from one-eighth to one-sixth of the height of the letter.

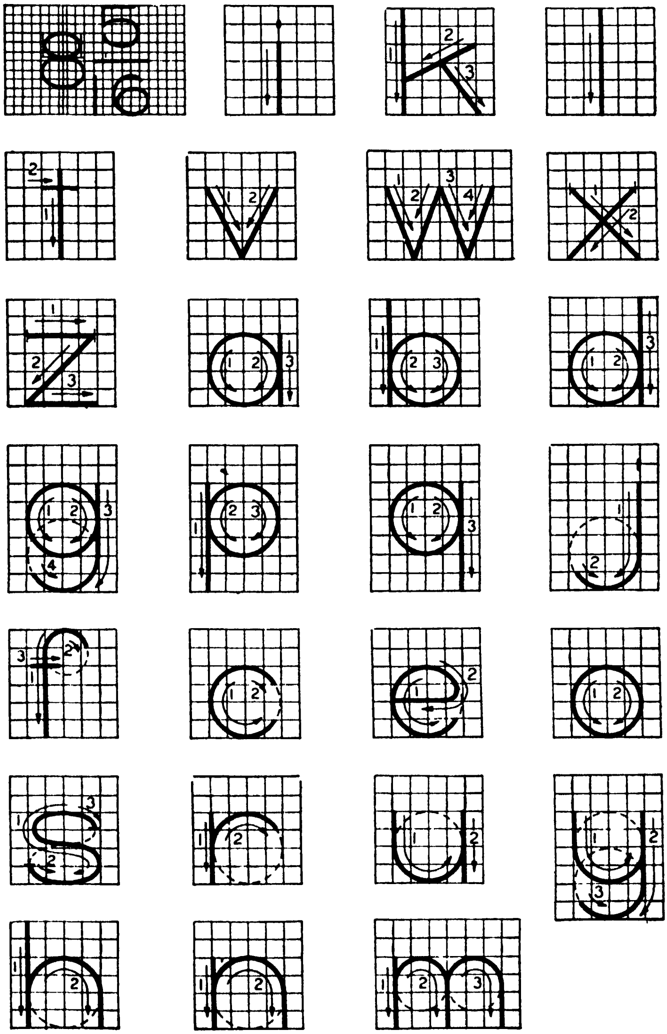


Fig. 111. Vertical lower-case.

111. Problems. It should be noted that while these exercises are offered for the purpose of giving the student practice in letter forms and word composition, they also contain statements of important principles of drawing, shop notes, and titles with which every engineering draftsman should be familiar.

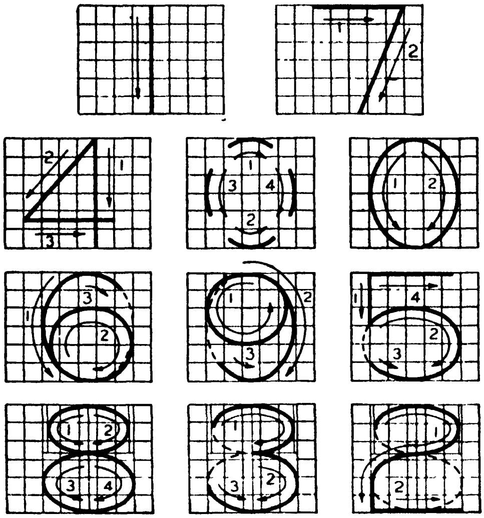


Fig. 112.

1–9. Using a *6H* pencil, draw two or more sets of horizontal and inclined guide lines for $\frac{1}{8}''$ capital letters; then, with pencil, letter the following statements:

(1) A GOOD STUDENT REALIZES THE IMPORTANCE OF NEAT AND ATTRACTIVE LETTERING.

(2) THE CIRCUMFERENCE OF A CIRCLE MAY BE DIVIDED INTO TWENTY-FOUR EQUAL ARCS USING ONLY A T-SQUARE IN COMBINATION WITH THE 30°–60° AND 45° TRIANGLES.

(3) A TRUE ELLIPSE MAY BE CONSTRUCTED BY THE TRAMMEL METHOD.

(4) THE POSITION OF THE VIEWS OF AN ORTHOGRAPHIC DRAWING MUST BE IN STRICT ACCORDANCE WITH THE UNIVERSALLY RECOGNIZED ARRANGEMENT ILLUSTRATED IN FIG. 119.

(5) THE VIEWS OF AN ORTHOGRAPHIC DRAWING SHOULD SHOW THE THREE DIMENSIONS, LENGTH, BREADTH, AND THICKNESS.

(6) INVISIBLE LINES SHOULD START WITH A SPACE WHEN THEY FORM AN EXTENSION OF A SOLID LINE.

(7) THE FRONT VIEW OF AN ORTHOGRAPHIC DRAWING SHOULD BE THE VIEW WHICH SHOWS THE CHARACTERISTIC SHAPE OF THE OBJECT.

(8) AN AUXILIARY VIEW SHOWS THE TRUE SIZE AND SHAPE OF AN INCLINED SURFACE.

(9) A SECTIONAL VIEW SHOWS THE INTERIOR CONSTRUCTION OF AN OBJECT.

10–14. Using a *6H* pencil, draw two or more sets of horizontal and inclined guide lines for $\frac{5}{32}''$ letters, then execute directly with India ink the following exercises in lower-case letters:

Fig. 113. Modern Roman letters.

(10) "The front and top views are always in line vertically."

(11) "The front and side views are in line horizontally."

(12) "The width of the top view is the same as the width of the side view."

(13) "If a line is perpendicular to a plane of projection, its projection will be a point."

(14) "If a line is parallel to a plane of projection, its projection on the plane is exactly the same length as the true length of the line."

15–17. Draw two or more sets of both horizontal and inclined guide lines, and letter the following series of words, whole numbers, and fractions, once in pencil and once in India ink. If a Braddock Lettering triangle is available, draw the seven guide lines shown in Fig. 83.

(15) $1\frac{1}{2}$, $3\frac{3}{4}$, $2\frac{7}{8}$, $1\frac{9}{16}$, $9\frac{17}{32}$, $4\frac{5}{8}$, $9\frac{13}{32}$, $7\frac{13}{64}$, $8\frac{1}{2}$, $\frac{11}{16}$, $5\frac{3}{8}$.

(16) $\frac{1}{2}$″ × $2\frac{3}{4}$″ HEX. HD. CAP SCREW, $\frac{3}{8}$ × $1\frac{1}{4}$ NC HEX. HD. BOLT & HEX. NUT.

(17) $\frac{3}{16}$ DRILL—$\frac{3}{8}$ DEEP, $\frac{1}{4}$ DRILL—4 HOLES, $\frac{1}{8}$ × 45° CHAMFER.

6

MULTIVIEW DRAWING

112. Industrial draftsmen use the orthographic system of projection for describing the shape of machine parts and structures. Practical application of this method of describing an object results in a drawing

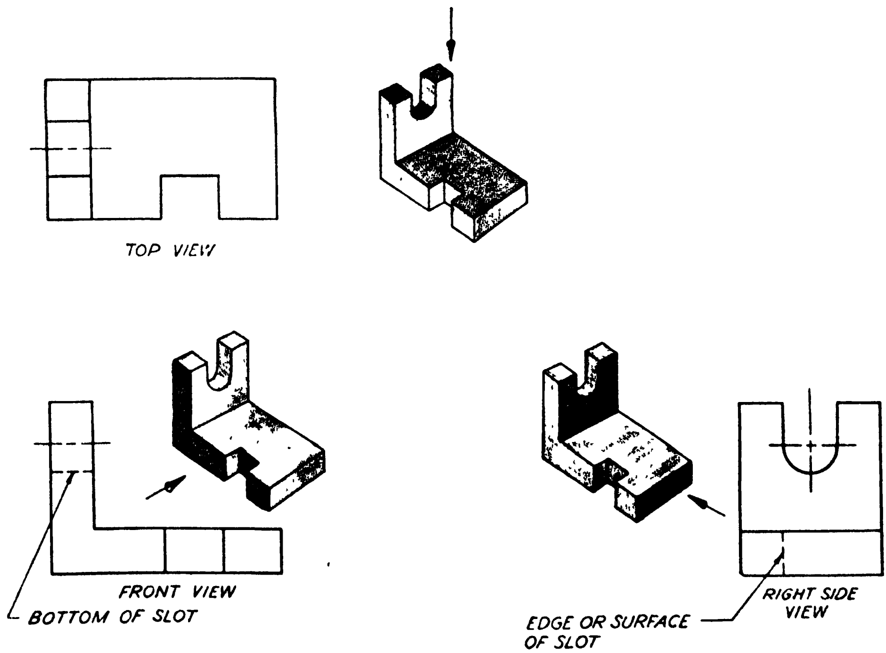


Fig. 114. Three views of an object.

consisting of a number of systematically arranged views which reproduce the object's exact shape. The position of these views, in strict accordance with a universally recognized arrangement, must show the three dimensions, length, height, and depth. Although three views (Fig. 114) are usually required to describe an ordinary object, only two may be needed for a particularly simple one. A very complicated object may require four or more views. Therefore, it is up to the draftsman to determine the number and type of views needed to produce a satisfactory drawing. He will soon develop a knack for this, if he bears in mind that the number of views required depends entirely upon the complexity of the shape to be described.

113. Definition. Multiview (multiplaner) projection is a method by means of which the exact shape of an object can be represented by two or more separate views produced upon projection planes which are usually at right angles to each other.

114. Methods of obtaining the views. The views of an object may be obtained by either of two methods:

(1) The natural method.

(2) The glass box method.

Since the resulting views will be the same in either case, the beginner should adopt the method he finds the easiest to understand. Both methods are explained here in detail.

115. The natural method. This method is commonly used by experienced commercial draftsmen. Each of the necessary views is obtained

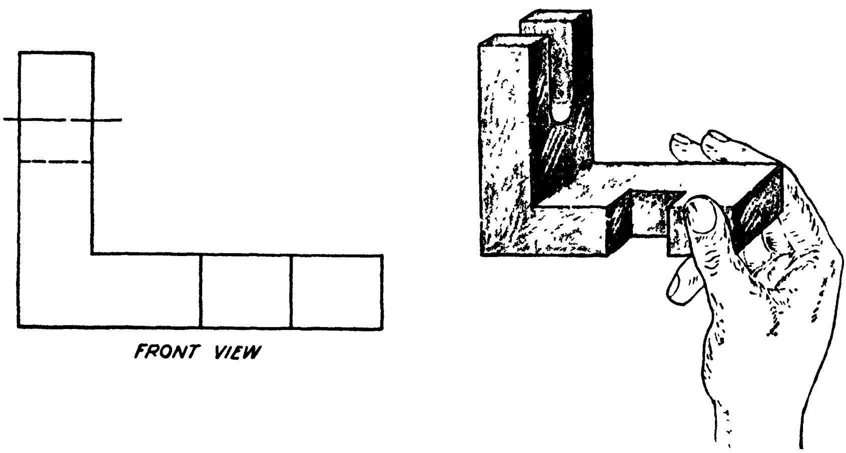


Fig. 115. Viewing an object (natural method).

looking directly at the particular side of the object the view is to represent. The front view in Fig. 115 represents the object as seen by an imaginary observer stationed directly in front of it at an infinite distance away.

Fig. 116 shows three of the principal views of an object, the front, top, and side views. They were obtained by looking directly at the front, top, and right side, respectively. In the application of this method, some draftsmen consider the position of the object as fixed and the position of the observer as shifted for each view; others find it easier to consider the observer's position as fixed and the position of the object as changed (Fig. 116) for each view. Regardless of which procedure is followed, the top and side views must be arranged in their natural positions relative to the front view.

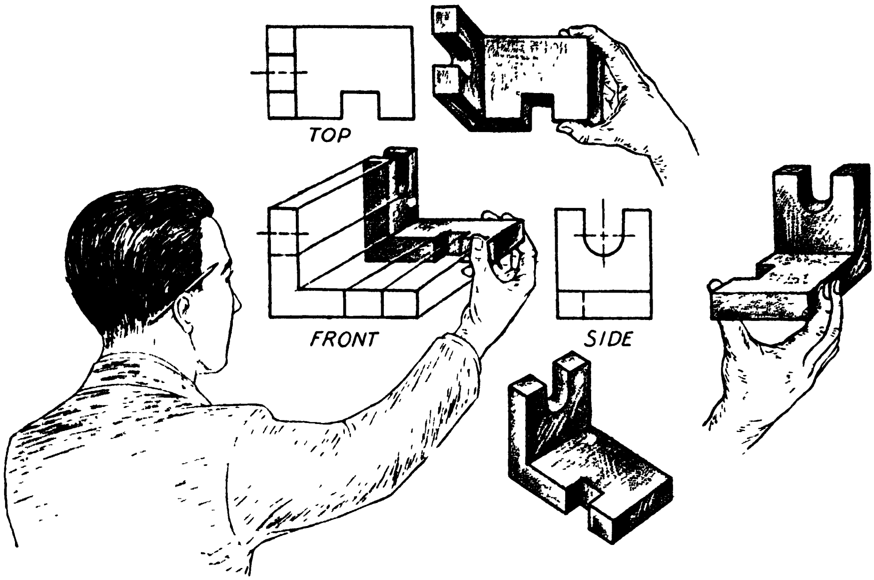


Fig. 116. Obtaining three views of an object.

116. The "glass box" method. An imaginary "glass box" is used widely by drawing instructors to explain the arrangement of orthographic views. It may be considered that planes of projection placed parallel to the six faces of an object form the enclosing "glass box" (see Fig. 117). The observer views the enclosed object from the outside. The views are obtained by running projectors from points on the object to the planes. The front, top, and right side of the box represent the H, V, and P projection planes.

Since the projections on the sides of the three-dimensional transparent box are to appear on a sheet of drawing paper, it must be assumed that the box is hinged (see Fig. 118) so that, when it is opened outward into the plane of the paper, the planes assume the positions illustrated in Figs. 118 and 119. Note that all of the planes, except the back one, are hinged to the front plane. In accordance with this universally recognized assumption, the top projection must take a position directly above the front projection, and the right side projection must lie horizontally to the right of the front projection. To identify the separate projections, draftsmen call the one on the front plane the *front view* or *front elevation*, the one on the horizontal plane the *top view* or *plan*, and the one on the side or

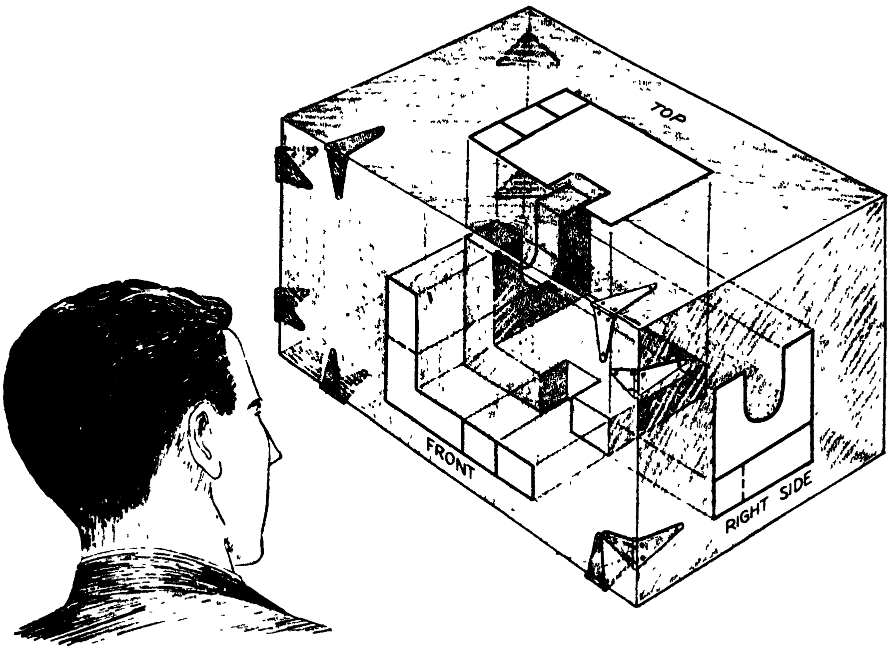


Fig. 117. The glass box.

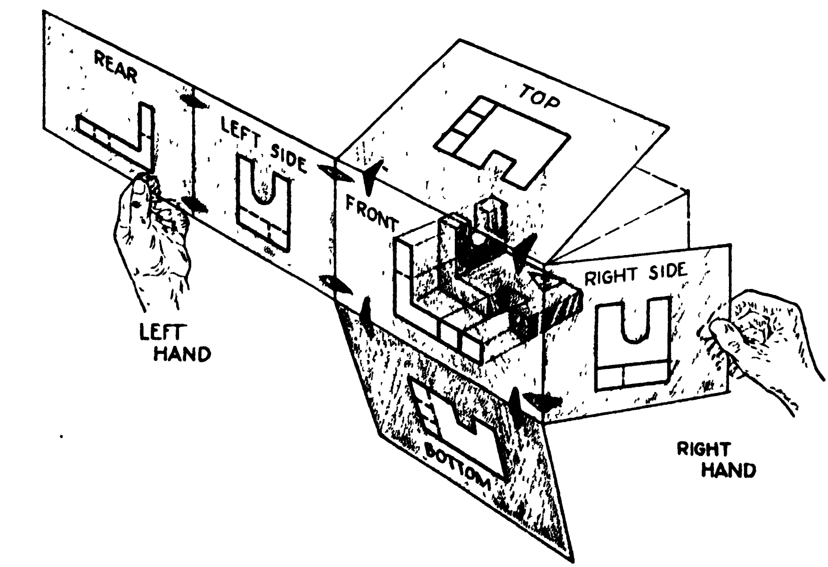


Fig. 118. Opening the glass box.

profile plane the *side view, side elevation,* or *end view.* Fig. 119 shows the six views of the same object as they would appear on a sheet of drawing paper.

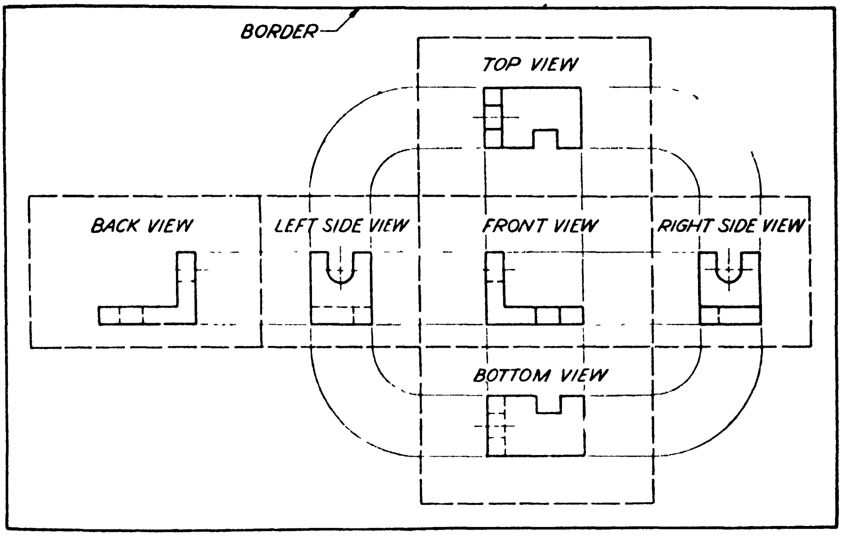


Fig. 119. Six views of an object on a sheet of drawing paper.

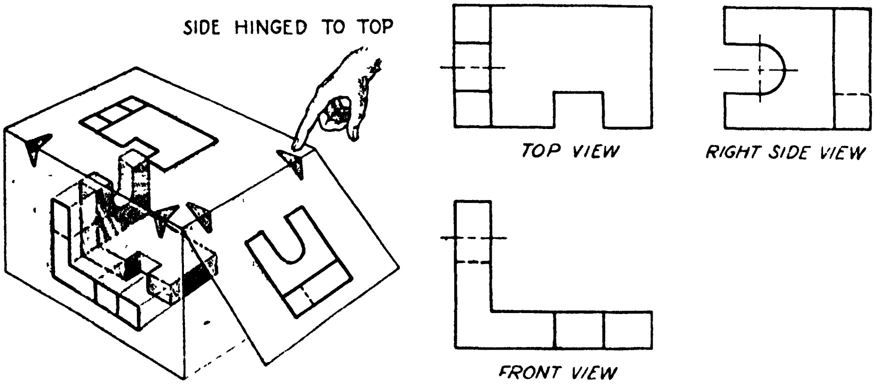


Fig. 120. The "second position" for the side view.

117. The "second position." Sometimes, especially in the case of a broad flat object, it is desirable to hinge the sides of the box to the top plane so that the side view will fall to the right of the top view, as illustrated in Fig. 120. This arrangement conserves space on the paper and gives the views better balance.

118. The principles of multiview drawing. The following principles should be studied carefully and understood thoroughly before any attempt is made to prepare an orthographic drawing.

1. The front and top views are *always* in line vertically.

2. The front and side views are in line horizontally, except when the second position is used.

3. The front of the object in the top view faces the front view.

4. The front of the object in the side view faces the front view.

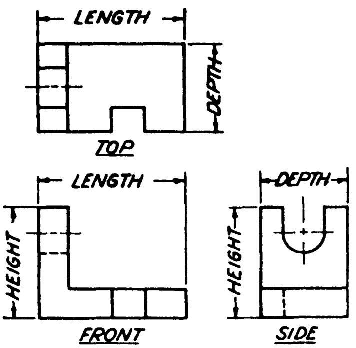


Fig. 121. View terminology.

5. The width of the top view is the same as the width of the side view (or views).

6. The length of the top view is the same as the length of the front view.

7. The height of the side view is the same as the height of the front view.

8. If a line is parallel to a plane of projection, its projection on the plane is exactly the same length as the true length of the line.

9. If a line is inclined to a plane of projection, its projection on the plane will be shorter than the true length of the line.

10. If a line is perpendicular to a plane of projection, its projection will be a point.

11. If a surface is parallel to a plane of projection, its projection on the plane will show its true size and shape.

12. If a surface is inclined to a plane of projection, its projection on the plane will be foreshortened.

13. If a surface is perpendicular to a plane of projection, its projection on the plane will be a line.

119. The selection of views. Careful study should be given to the outline of an object before the views are selected. Otherwise there is no assurance that the object will be described completely from the reader's viewpoint. Only those views that are necessary for a clear and complete description should be selected. Study Figs. 122 and 123.

Often there is a choice between two equally important views, such as between a right-side and left-side view or between a top and bottom view. In such cases, most commercial draftsmen adhere to the following rule: *A right-side view should be used in preference to a left-side view, and a top view in preference to a bottom view.*

Another rule, one that must be considered in selecting the front view, is as follows: *If possible, place the object so as to obtain the smallest number of hidden lines.*

120. The principal (front) view. The principal view is the one which shows the characteristic contour of the object. Good practice dictates that this be used as the front view on a drawing. It should be clearly understood that the view of the natural front of an object is not always the principal view, because frequently it fails to show the object's charac-

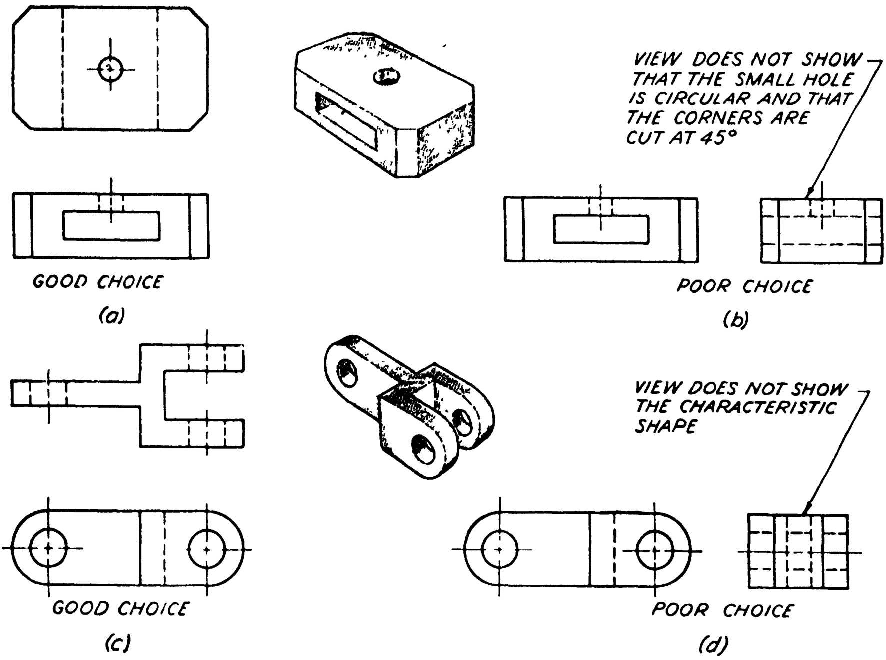


Fig. 122. Choice of views.

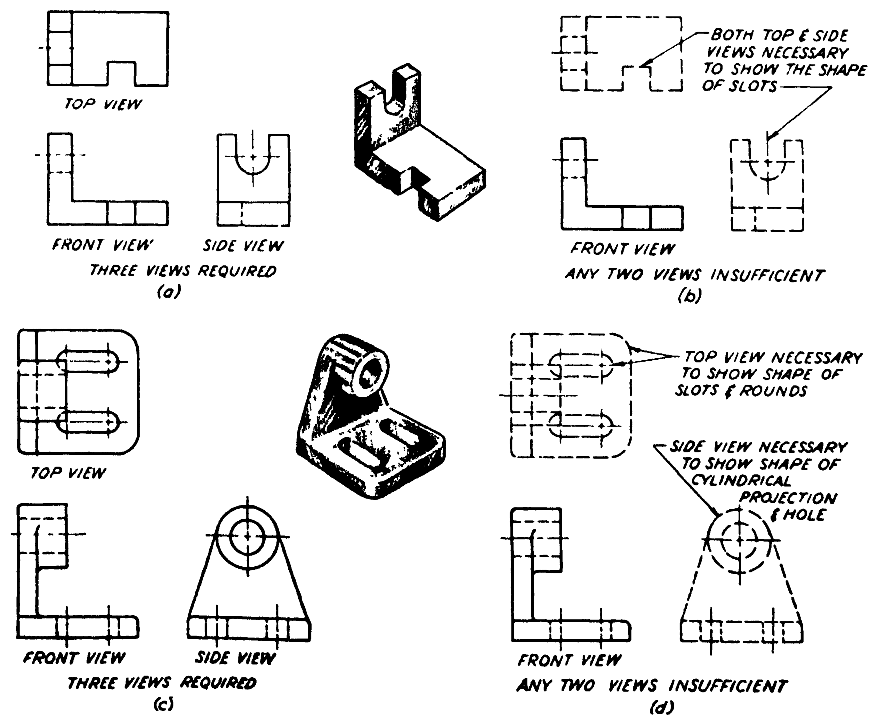


Fig. 123. Choice of views.

teristic shape. Therefore, another rule to be followed is: *Ordinarily, select the view showing the characteristic contour shape as the front view, regardless of the normal or natural front of the object.*

121. Invisible lines. Dotted lines are used on an external view of an object to represent surfaces and intersections invisible at the point from

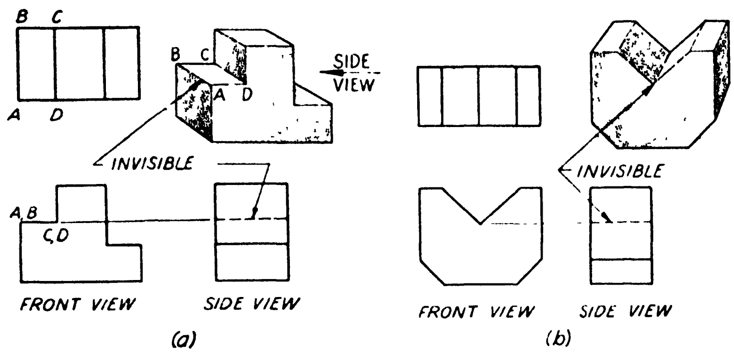


Fig. 124. Invisible lines.

which the view is taken. In Fig. 124(a), the dotted line may be considered to represent the edge AB and the line of intersection CD, or it may represent the entire surface $ABCD$. In Fig. 124(b), the invisible line represents a line of intersection and not a plane.

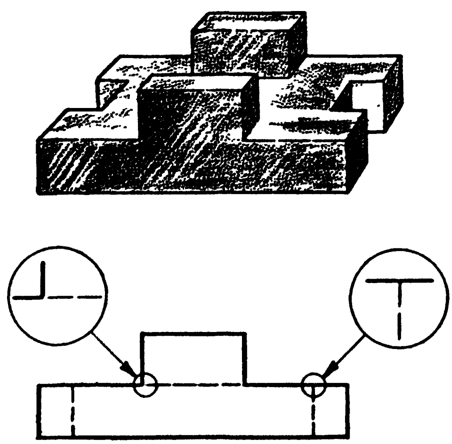


Fig. 125. Treatment of invisible lines.

122. Treatment of invisible lines. The short dashes which form an invisible line should be drawn carefully in accordance with the recommendations in Fig. 129. An invisible line always starts with a dash in contact with the object line from which it starts, unless it forms a continuation of a visible line. In the latter case, it should start with a space, in order to establish at a glance the exact location of the end point of the visible line (see Fig. 125).

Parallel invisible lines should have the breaks staggered for the sake of appearance.

Fig. 126 illustrates correct and incorrect treatment of invisible arcs. Note that an arc should start with a dash at the point of tangency. This treatment enables the reader to determine the exact end points of the curvature.

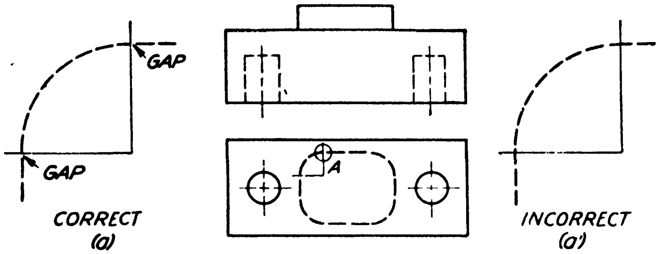


Fig. 126. Invisible (curved) outlines.

123. Omission of invisible lines. Although it is common practice for commercial draftsmen to omit hidden lines when their use tends to further confuse an already overburdened view or when the shape description of a feature is sufficiently clear in another view, it is not advisable for a beginning student to do so. The beginner, until he has developed the discrimination that comes with experience, will be wise to show all hidden lines.

124. Projecting between views. The common geometric methods for projecting from the top view to the side view, and vice versa, are shown in Fig. 127.

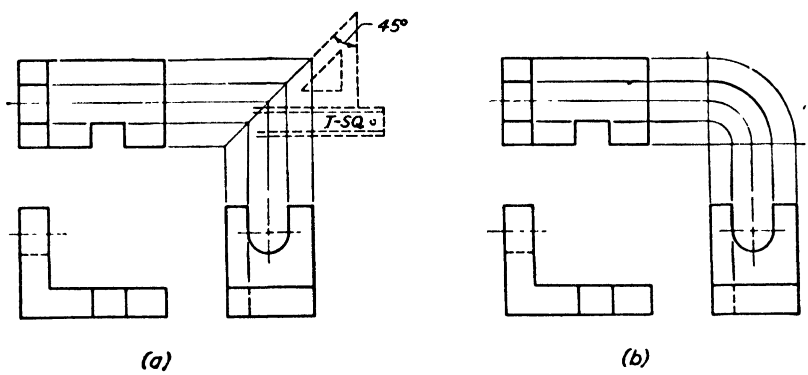


Fig. 127. Methods of projecting from the top view.

125. Penciling a drawing. The correct procedure for making a pencil drawing is shown in Fig. 128. Before any drawing can be done, it is necessary to select the scale to be used, care being taken that the one chosen is large enough to show all details to the best advantage. Ordinarily, the procedure of balancing the views on the sheet (see Fig. 128*a*) can be simplified by a preliminary freehand sketch showing their arrangement. When balancing views, it should be attempted to make the distance D_1 on the left side equal to the distance D_1 on the right side. In the vertical direction, the views should be so located that the shaded area between the top view and the border is approximately equal to the area between the front view and the lower border. The location of each view

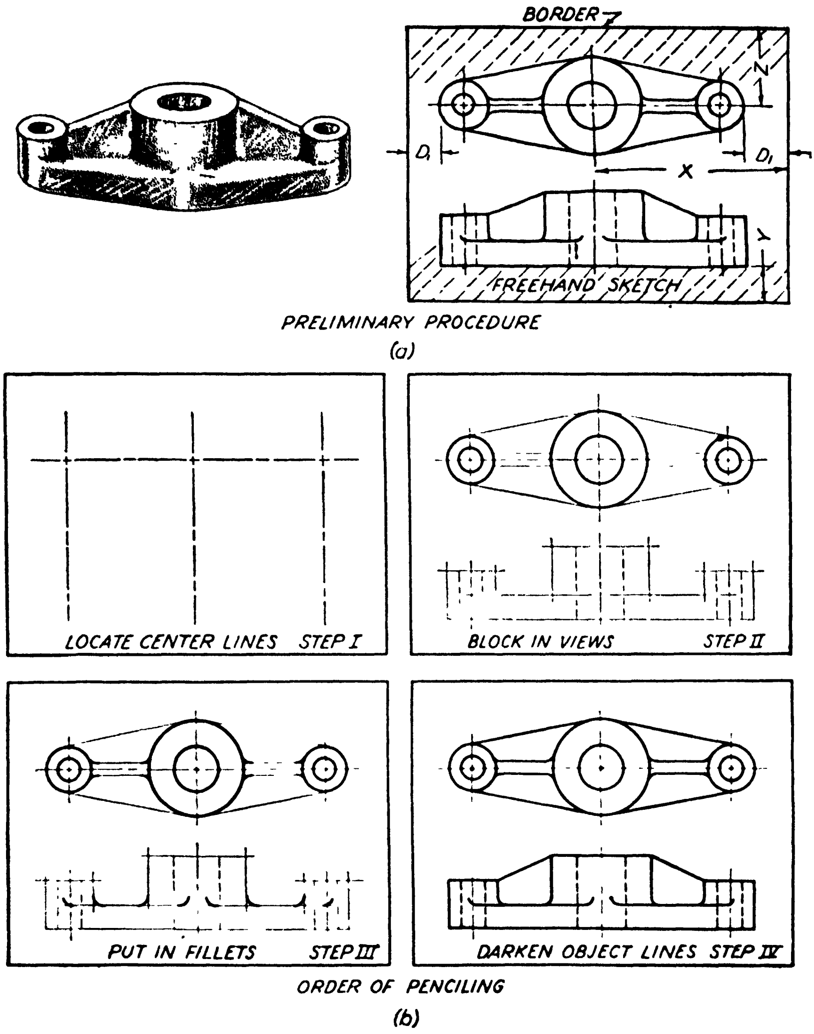


Fig. 128. Procedure in penciling a drawing.

relative to the border and the adjacent views may be calculated and recorded. It is, as every wide-awake student soon discovers, much better to sketch a fully organized plan than to "draw and erase" on a sheet of good drawing paper.

Following the preliminary planning, the views should be penciled in accordance with the following steps.

1. Draw the center lines, using a hard pencil with a sharp, conical point. These lines should be light and continuous at this stage in the development of a drawing.

2. Draw arcs and circles, and block in the views. The arcs and circles should be drawn in their finished weight, if possible.

3. Draw the fillets and rounds in finished weight. These frequently are drawn freehand by commercial draftsmen, but the use of a bow pencil is permissible.

4. Retrace the object lines with the correct grade of pencil. Transform the center lines into symbolic center lines by retracing with a sharp medium hard pencil.

126. The technique of pencil drawing. Since a majority of commercial drawings are executed in pencil on drawing paper or tracing paper, a training course in drafting should include extensive practice in pencil work.

The term "technique," as applied to drawing, may be defined as the style or quality of individual workmanship. Although the style of every good draftsman is characterized by his own individuality, the workmanship of all such draftsmen is distinguished by sharp, snappy lines and well-formed letters.

When penciling, the beginner should endeavor to use the line weights recommended in Sec. 42. The object lines should be made very dark and bright, to give snap to the drawing as well as to create the contrast necessary to cause the shape of the object to stand out. Special care should be taken to gauge the dashes and spaces in invisible object lines. On ordinary drawings, $\frac{1}{8}''$ dashes and $\frac{1}{32}''$ spaces are recommended (Fig. 129).

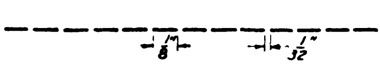


Fig. 129. Invisible lines.

Fig. 130. Center lines.

Center lines consist of alternate long and short dashes. The long dashes are from $\frac{3}{4}''$ to $1\frac{1}{2}''$ long, the short dashes $\frac{1}{8}''$, and the spaces $\frac{1}{32}''$.

The following technique is recommended in drawing center lines.

1. When center lines cross, the short dashes should intersect symmetrically (see Fig. 131*a*). In the case of very small circles, the method shown in (*b*), omitting the breaks, may be used.

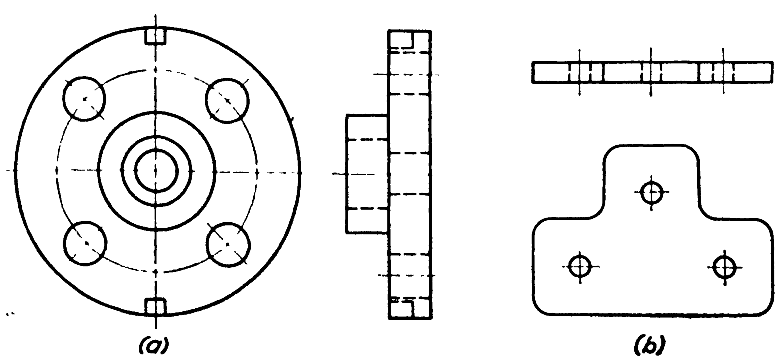


Fig. 131. Intersection of center lines.

2. The breaks should be so located that they will stand out and at the same time allow the center line to be recognized as such.

3. Center lines should extend ⅛" beyond the outline of the part whose symmetry they indicate.

For a finished drawing to be pleasing in appearance, all lines of the same type must be uniform, and each type must have proper contrast with other symbolic types. If the pencils recommended in Sec. 26 are used, each type of line will vary in color as well as width. For example, object lines will be much wider than dimension lines. This is especially evident on commercial drawings, where the usual practice is to "burn in" the object lines by applying heavy pressure.

127. Visualizing an object from given views. Most students in elementary drawing courses find it difficult to visualize an object from two or more views. This trouble is largely due to the lack of systematic procedure for analyzing complex shapes.

The simplest method of determining shape is illustrated pictorially in Fig. 132. This method of "breaking down" may be applied to any

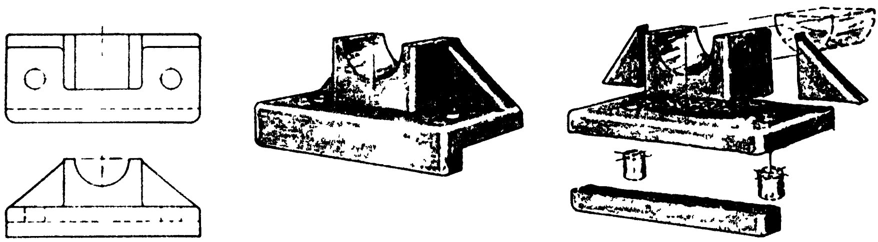


Fig. 132. "Breaking down" method.

object, since all objects may be thought of as consisting of elemental geometrical forms, such as prisms, cylinders, cones, and so on. These imaginary component parts may be additions in the form of projections or subtractions in the form of cavities.

The graphic language is similar to the written language in that neither can be read at a glance. A drawing must be patiently read by referring systematically back and forth from one view to another. The reader at the same time must imagine a three-dimensional object and not a two-dimensional flat projection.

128. Problems. The problems that follow are intended primarily to furnish study in multiview projection through the preparation of sketches and instrumental drawings. Problems 1–13 (Fig. 133) are designed for the sketching of views alone. Many of the other problems of this chapter, however, may be prepared in more complete form. Their views may be dimensioned as are the views of working drawings, if the student will carefully study the early part of the chapter on dimensioning

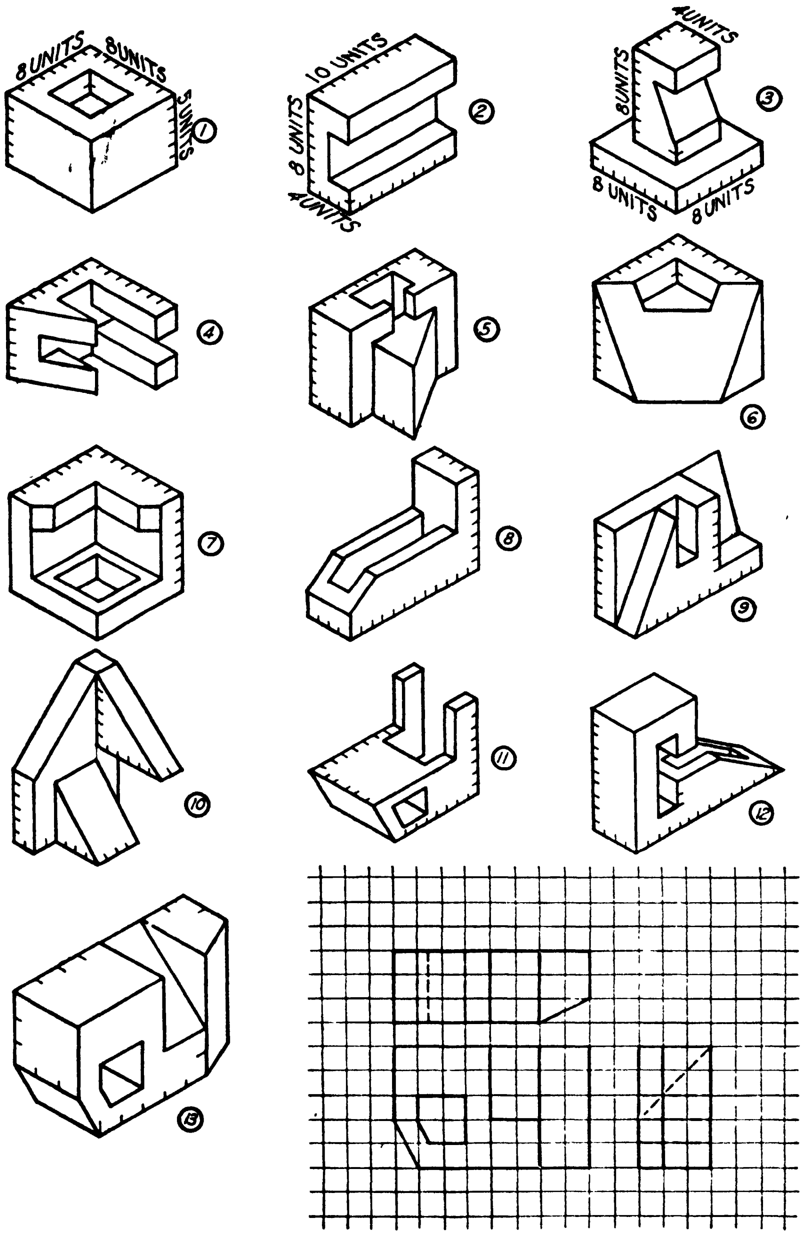


Fig. 133. Objects to be sketched in orthographic projection.

before attempting to record size description. All dimensions should be placed in accordance with the general rules of dimensioning.

All construction work should be done in light lines with a sharp 6*H* pencil. A drawing should be checked by an instructor before the lines are "heavied in," unless the preliminary sketch was checked beforehand.

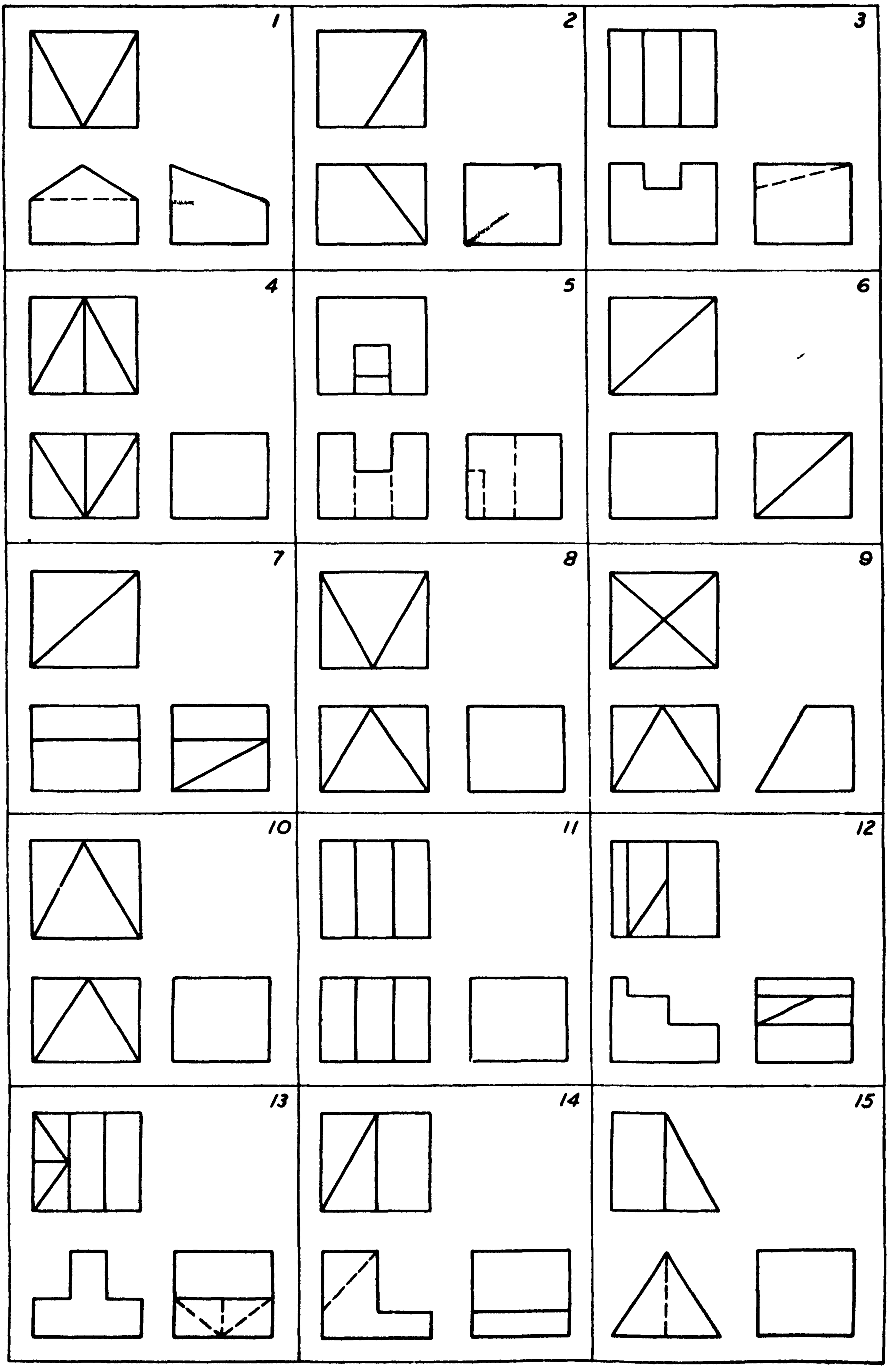


Fig. 134. Missing-line exercises.

1. (Fig. 133.) Sketch, *freehand*, the necessary views of each of the objects shown. Use cross-section paper if it is available. The selected length for the unit will determine the size of the drawing of each object.

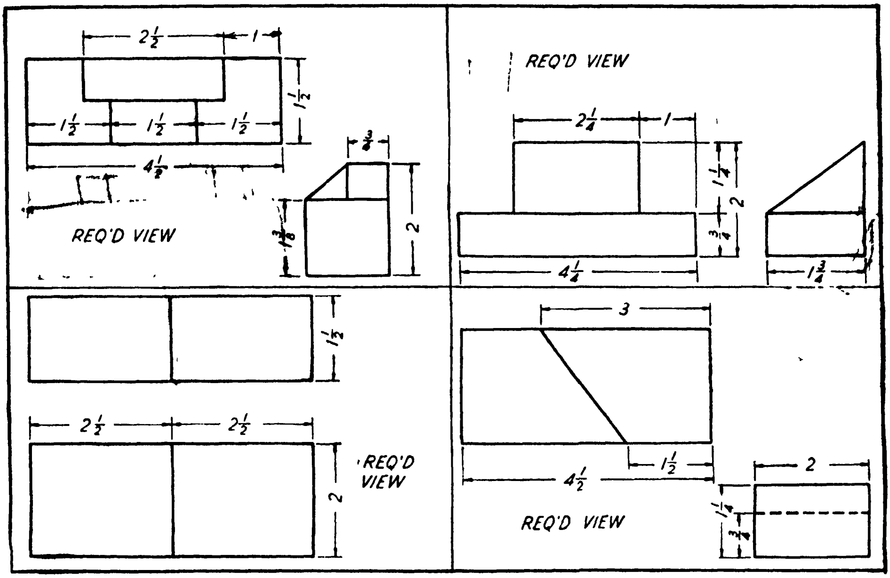


Fig. 135.

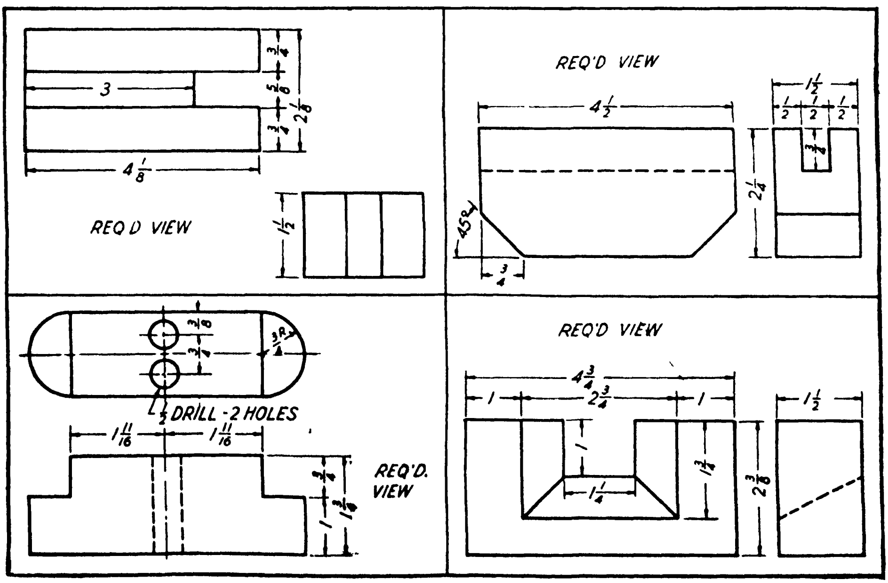


Fig. 136.

2. (Fig. 134.) A line is missing from each of the three-view drawings. When the correct missing line is found, the three views of each object will be consistent with one another.

3–8. (Figs. 135 to 140.) Reproduce the given views and draw the required view. Show all hidden lines.

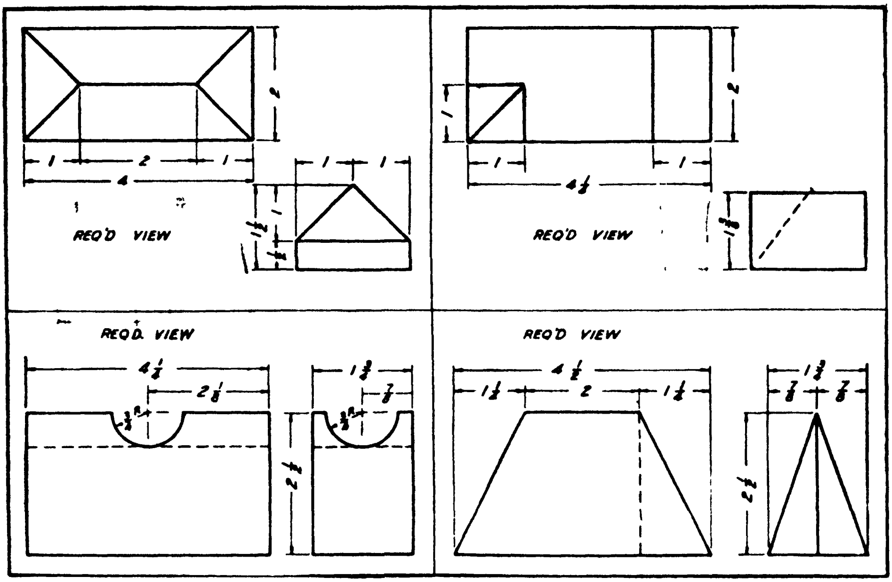


Fig. 137.

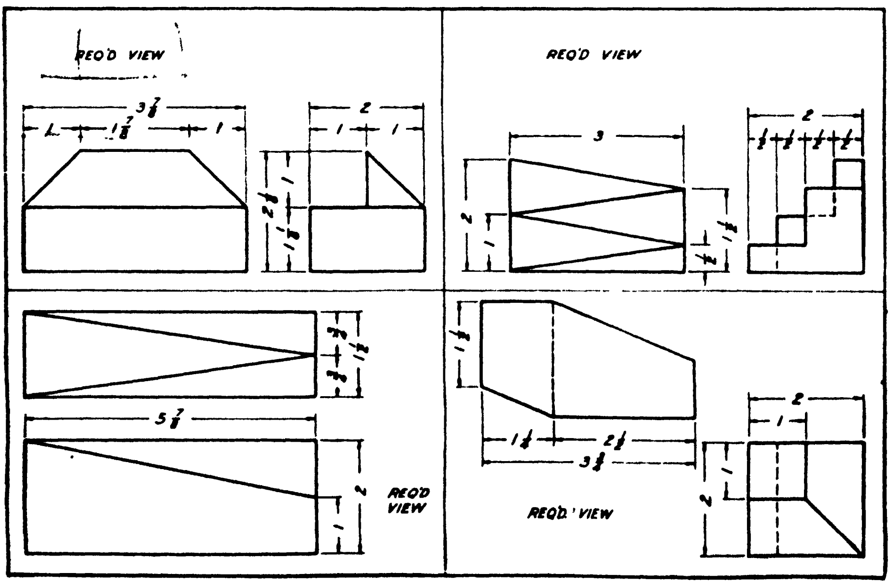


Fig. 138.

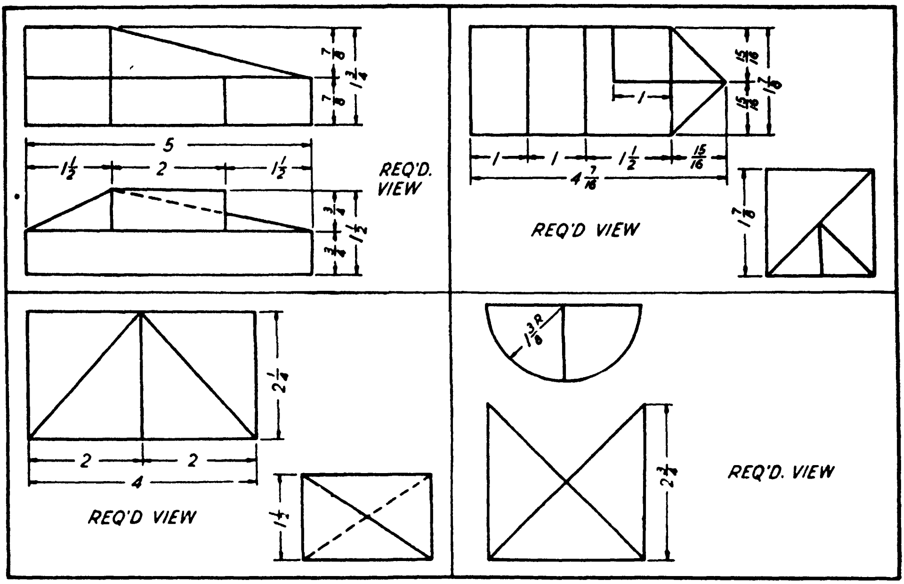


Fig. 139.

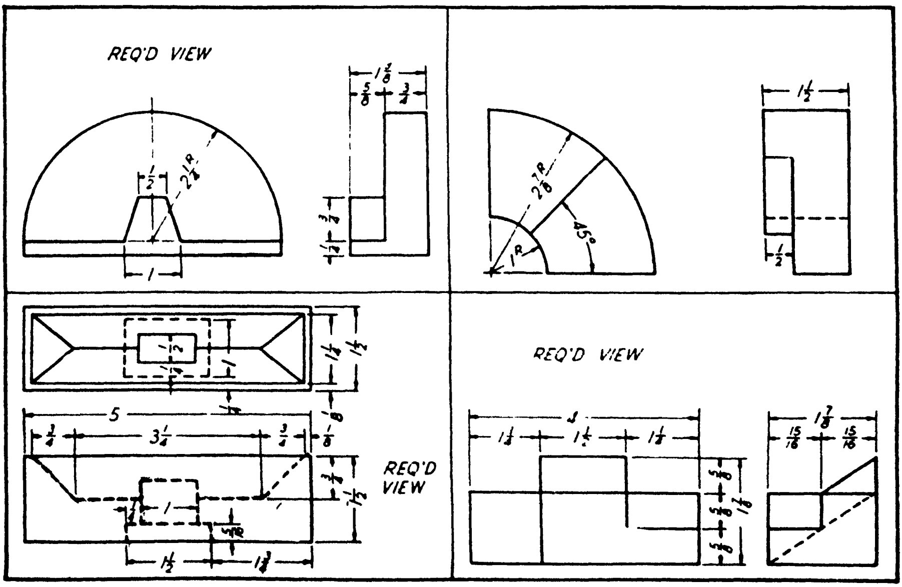


Fig. 140.

9–33. (Figs. 141–165.) These problems are designed to give the student further study in multiview drawing and, at the same time, offer him the opportunity to apply good line technique to the preparation of elementary working drawings. The views of the drawings of the given objects may or may not be dimensioned.

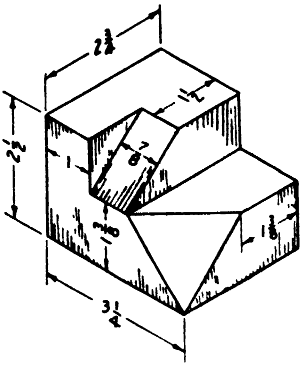


Fig. 141. Corner block.

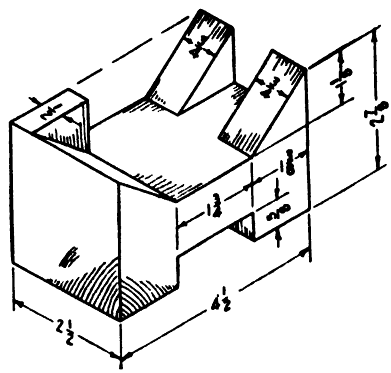


Fig. 142.

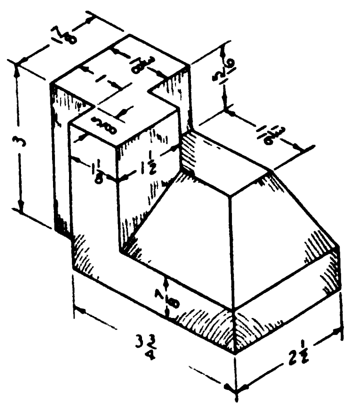


Fig. 143. Angle block.

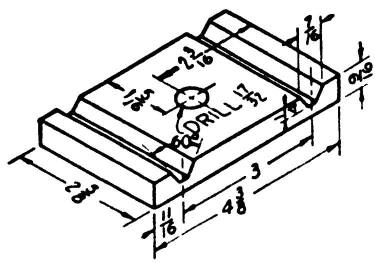


Fig. 144. Saddle block.

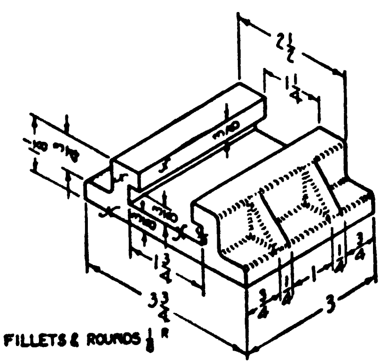


Fig. 145. Slotted base

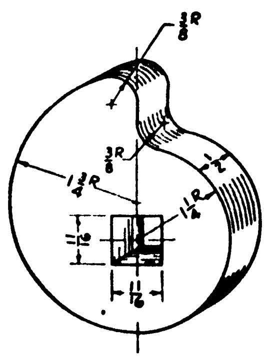


Fig. 146. Cam.

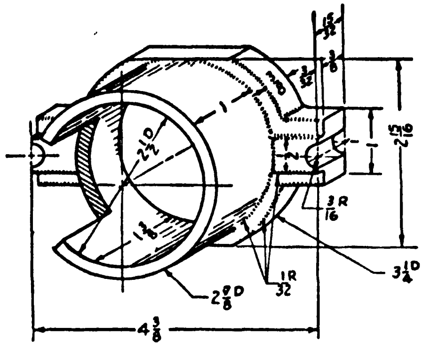


Fig. 147. Housing.

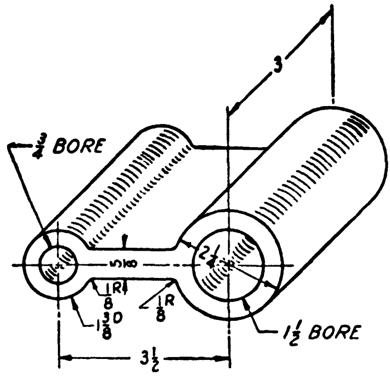


Fig. 148. Rod guide.

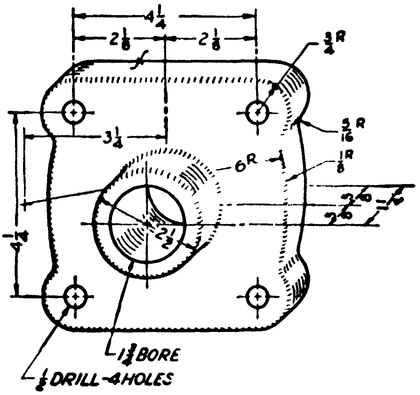


Fig. 149. Regulator body.

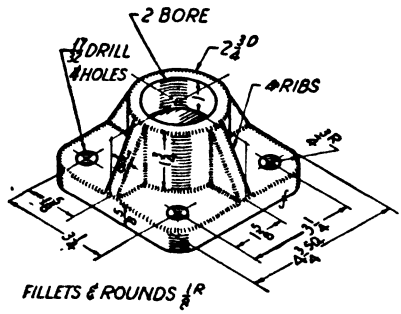
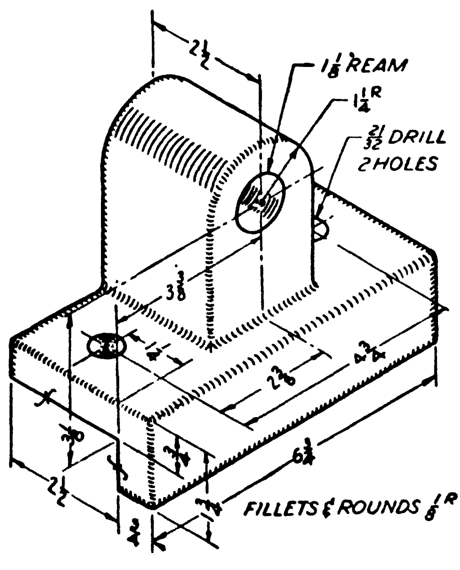


Fig. 150. Stanchion support.



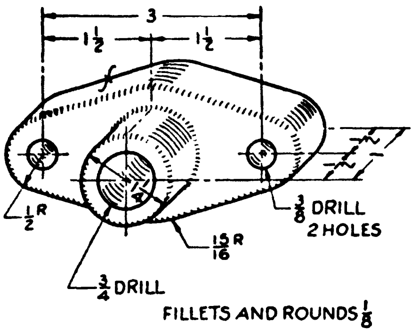


Fig. 152. Release bearing.

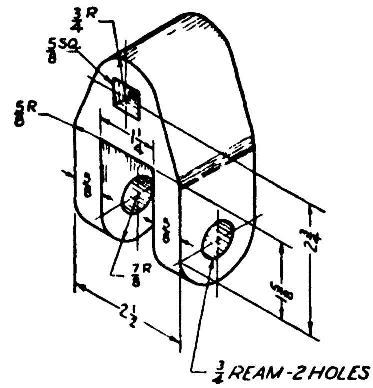


Fig. 153. Hinge link.

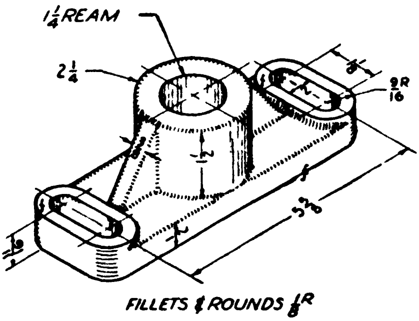


Fig. 154. Support base.

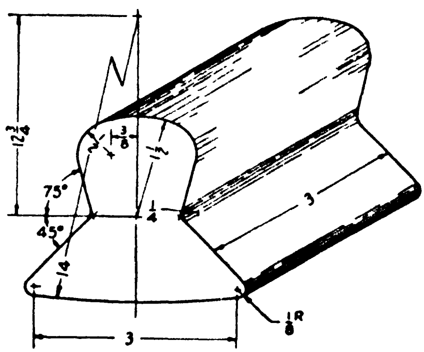


Fig. 155. Dolly block.

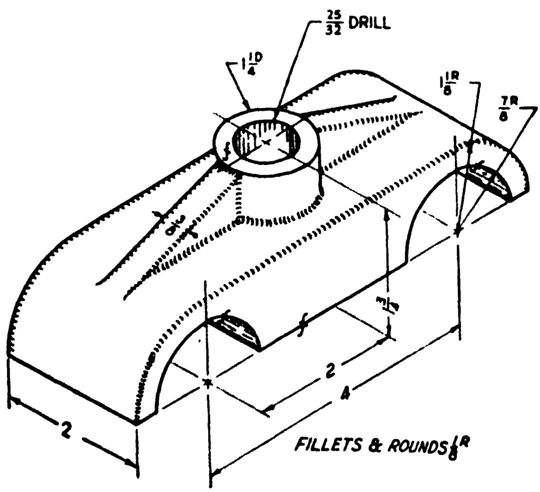


Fig. 156. Support stop.

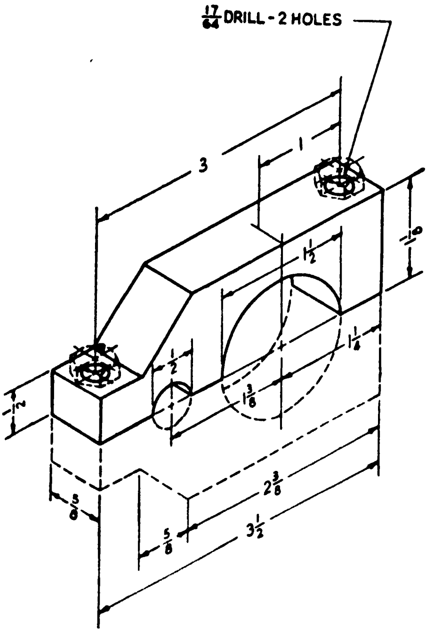


Fig. 157. Clamp spacer.

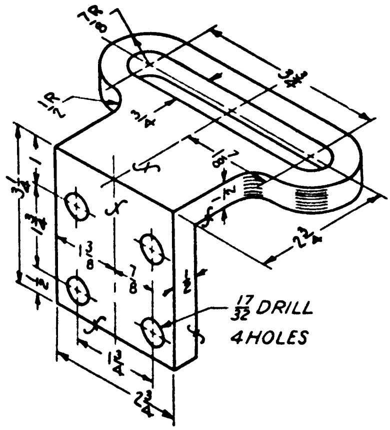


Fig. 158. Guide bracket.

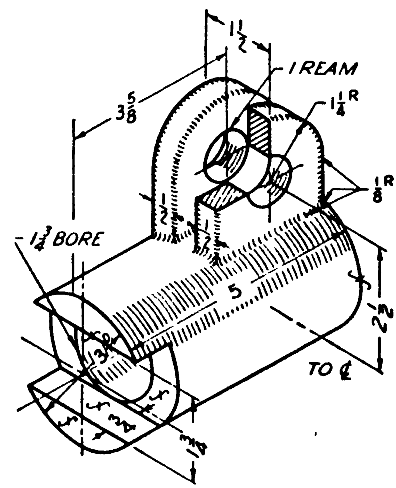


Fig. 159. Sliding link.

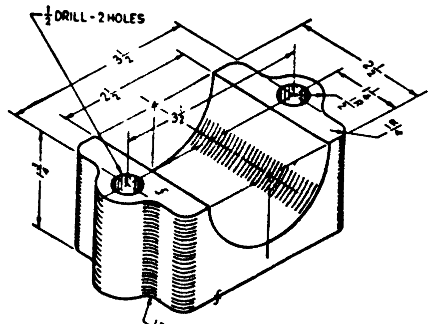


Fig. 160. Bearing block.

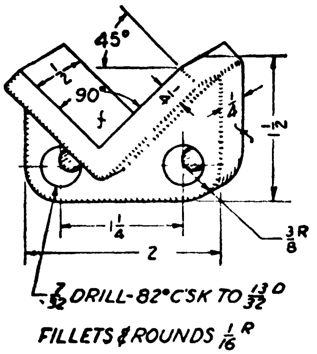


Fig. 161. Corner stop.

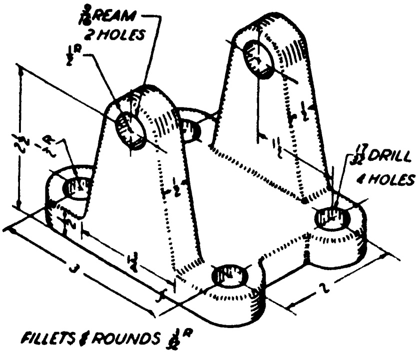


Fig. 162. Support bracket.

(Fig. 163.) Make an orthographic drawing or sketch of the bench stop. The views may be dimensioned. The shaft portion which fits into the hole in the bench top is $\frac{3}{4}''$ in diameter and 2″ long.

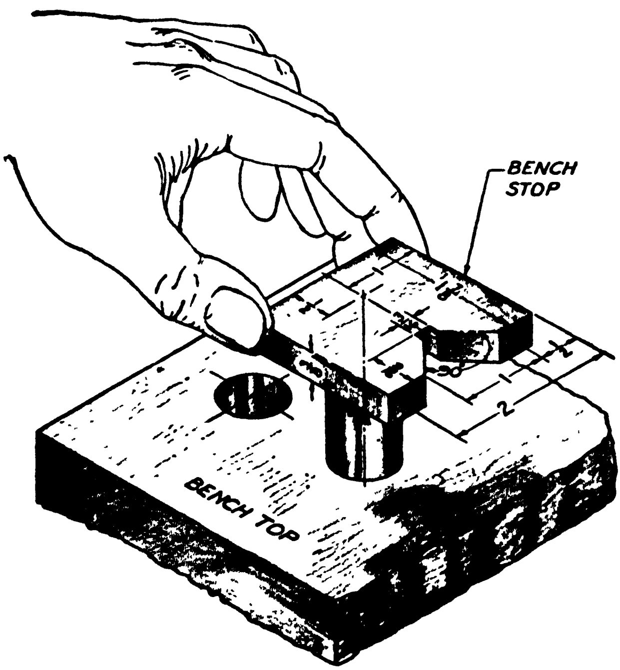


Fig. 163.

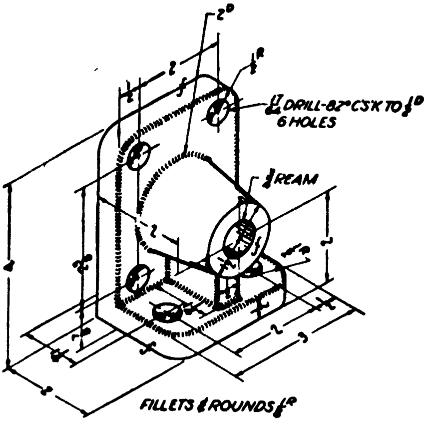


Fig. 164. Shaft bracket.

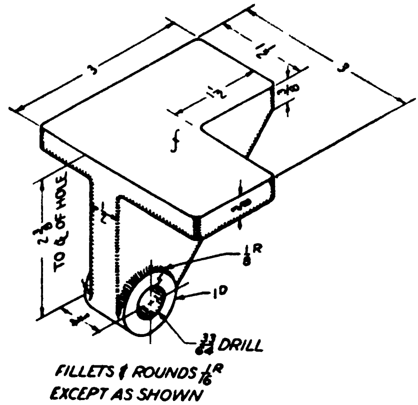


Fig. 165. Tool rest.

7

FREEHAND DRAFTING

129. Value of freehand drafting. Freehand technical drafting is primarily the language of those in responsible charge of the development of technical designs and plans. Chief engineers, chief draftsmen, designers, and squad bosses have found that the best way to present their ideas for either a simple or complex design is through the medium of sketches. Figure 166 is an example of a working sketch.

130. Sketching materials. For the type of sketching discussed here, the required materials are a pencil, a soft eraser, and some paper. In the industrial field, men who have been improperly trained in sketching often use straight-edges and cheap pocket compasses which they could well dispense with if they would adopt the correct technique. Preparing sketches with instruments consumes much unnecessary time.

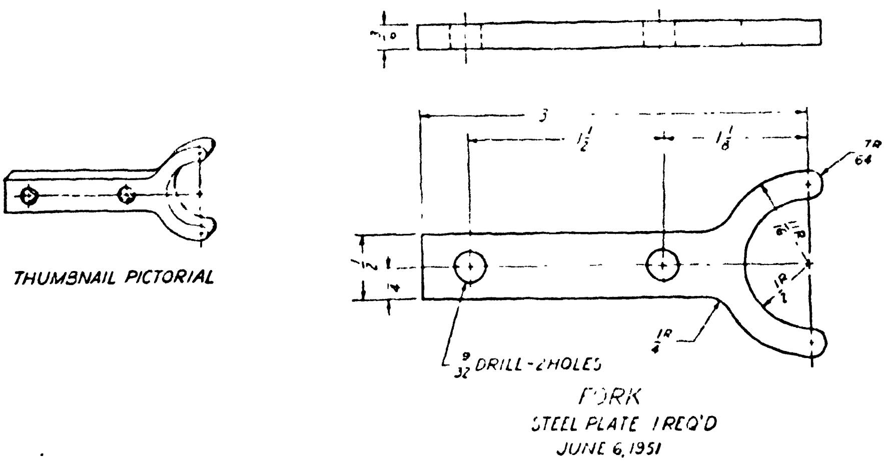


Fig. 166. Working sketch.

For the person who cannot produce a satisfactory sketch without guide lines, cross-section paper is helpful. Ordinarily, the ruling on it forms one-inch squares which are subdivided into one-eighth or one-tenth inch squares.

131. Technique of lines. Freehand lines quite naturally will differ in their appearance from mechanical ones. A well-executed freehand line will never be perfectly straight and absolutely uniform in weight, but an effort should be made to approach *exacting uniformity*. As in the case of mechanical lines, they should be black and clear and not broad and fuzzy.

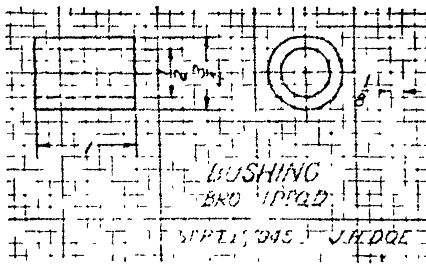


Fig. 167. Sketches on cross-section paper.

132. Sharpening the sketching pencil. A sketching pencil should be sharpened, on a file or piece of sandpaper, to a conical point. The point then should be rounded slightly, on the back of the sketch pad or on another sheet of paper, to the correct degree of dullness. When rounding the point, the pencil should be rotated to prevent the formation of sharp edges.

133. Straight lines. The pencil should rest on the second finger and be held loosely by the thumb and index finger about 1 to $1\frac{1}{2}$ inches above the point.

Horizontal lines are sketched from left to right with an easy arm motion which is pivoted about the muscle of the forearm.

When sketching a straight line, it is advisable to first mark the end points with light dots or small crosses. The complete procedure for sketching a straight line is as follows:

1. Mark the end points.
2. Make a few trial motions between the marked points, so as to adjust the eye and hand to the contemplated line.
3. Sketch a *very* light line between the points by moving the pencil in two or three sweeps. When sketching the trial line, the eye should be on the point toward which the movement is directed. With each stroke, an attempt should be made to correct the most obvious defects of the stroke preceding, so that the finished trial line will be relatively straight.
4. Darken the finished line, keeping the eye on the pencil point on the trial line.

The final line, replacing the trial line, should be distinct, black, uniform, and straight.

It is helpful to turn the paper through a *convenient angle* so that the horizontal and vertical lines assume a slight inclination (Fig. 168). A horizontal line, when the paper is in this position, is sketched to the right and upward, thus allowing the arm to be held slightly away from the body and making possible a free arm motion.

Short vertical lines may be sketched either downward or upward, without changing the position of the paper. When sketching downward, the arm is held slightly away from the body and the movement is toward the sketcher (see Fig. 169). To sketch vertical lines upward, the arm is held well away from the body.

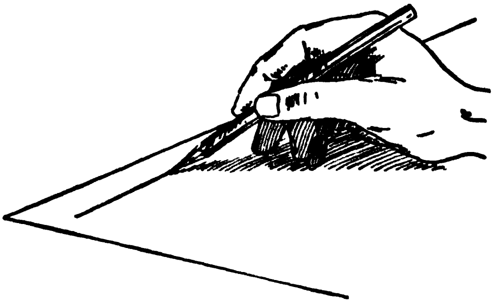


Fig. 168. Sketching horizontal lines.

By turning the paper, a long vertical line may be made to assume the position of a horizontal line and can be sketched with the same general movements used for the latter.

Inclined lines running upward from lower left to upper right may be sketched upward with the same movements used for horizontal lines, but those running downward from upper left to lower right are sketched with the general movements used for either horizontal or vertical ones, depending upon their inclination (Fig. 170). Inclined lines may be more easily sketched by turning the paper to make them conform to the direction of horizontal lines.

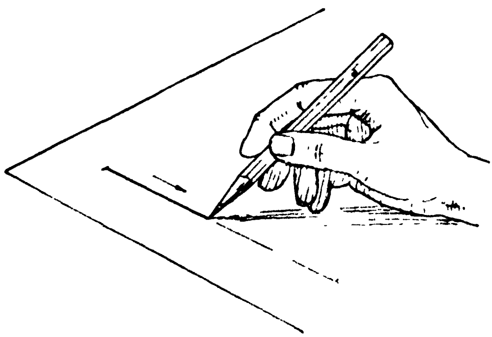


Fig. 169. Sketching vertical lines.

134. Circles. Small circles may be sketched by marking radial distances on perpendicular center lines (Fig. 171). These distances can be marked off either by eye or by measuring with a marked strip of paper (see Fig. 172). Larger circles may be constructed more accurately by sketching two or more diagonals, in addition to the center lines. A circle is completed with a light construction line, and all defects are corrected before darkening (Fig. 173).

135. Making a sketch. When making orthographic working sketches, a systematic order should be followed and all the rules and conventional practices used in making working drawings should be applied.

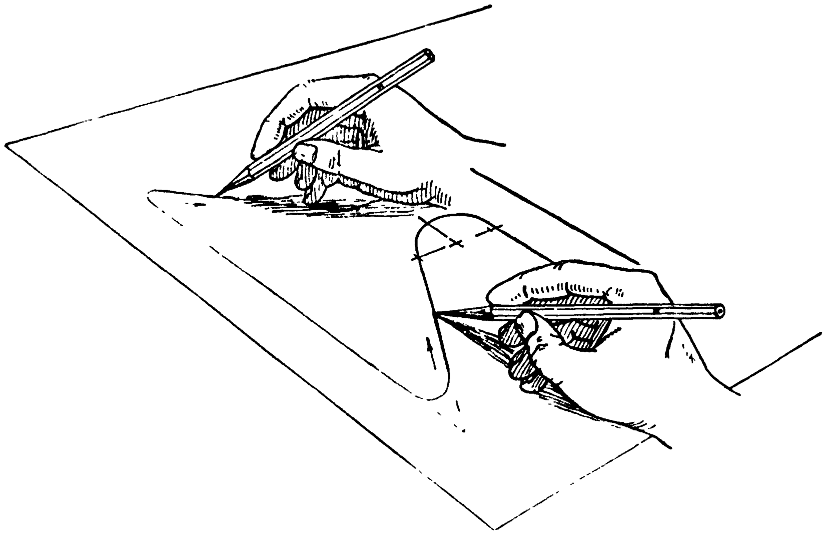


Fig. 170. Sketching inclined lines.

The following procedure is recommended:

1. Examine the object, giving particular attention to detail.
2. Determine which views are necessary.
3. Sketch in the views, using light construction lines.
4. Complete the detail and darken the object lines.
5. Sketch extension lines and dimension lines, including arrowheads.
6. Complete the sketch by adding dimensions, notes, title, date, sketcher's name, and so on.
7. Check the entire sketch carefully to see that no dimensions have been omitted.

136. Measurements and measuring instruments. If a sketch is to serve as a working drawing, it must contain all the necessary dimensions and instructional notes needed by the workmen. If a sketch is for the manufacture of a part which is to replace a worn or broken part in an existing machine, measurements must be taken from the original part with the same general types of measuring devices to be used in manufacturing the new part. The instrument selected for each particular detail should be of a type that will allow measurements to be made with the correct degree of accuracy. For most machine parts, a steel scale and a set of inside and outside calipers will prove sufficient. When more accurate measurements are necessary, a micrometer must be used. In any case, the selection of the instrument for a measurement should be

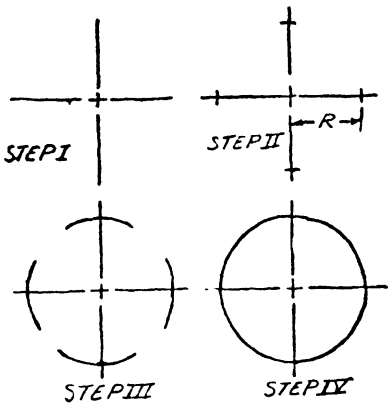


Fig. 171. Sketching small circles.

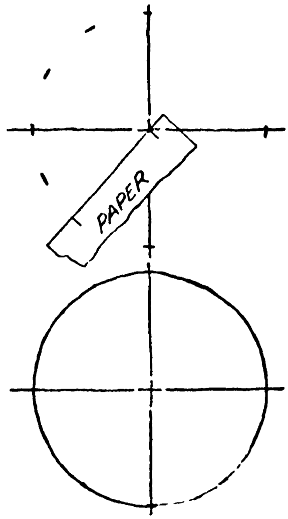


Fig. 172. Marking off radial distances.

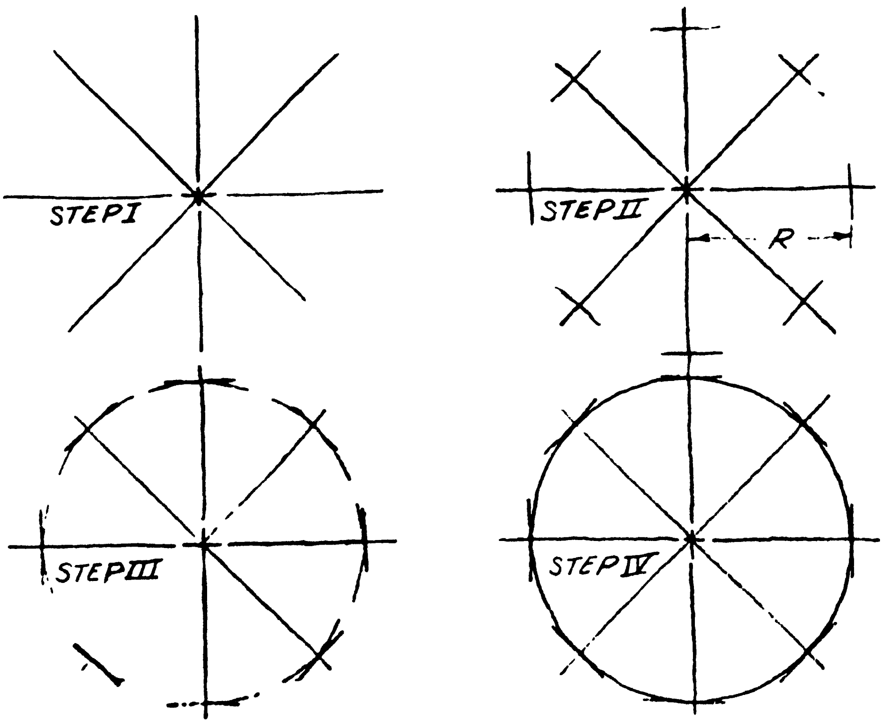


Fig. 173. Sketching large circles.

determined by exercising good judgment backed by practical shop experience. Fig. 174 shows how the outside calipers are used to take measurements from an object. Fig. 175 shows the use of the inside calipers for measuring the diameter of a hole.

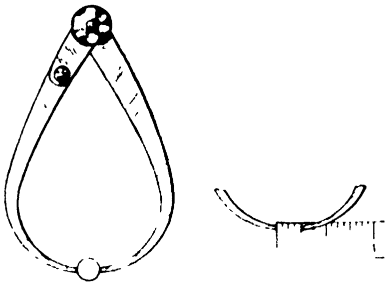


Fig. 174. Outside calipers.

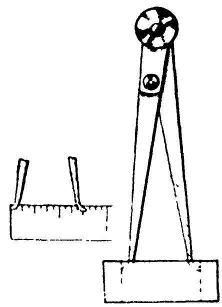


Fig. 175. Inside calipers.

When taking measurements, certain practices are recommended. For example, to obtain the distance between holes (shown on the sketch as between centers), measure the distance between corresponding edges. To locate other features and to take off size dimensions, measure from a finished surface whenever possible, for a finished surface is usually a mating surface. The man in the shop must work from such a surface if he is to produce a part accurate enough to function in the existing machine.

137. The title. A title is far more important on a sketch than many persons realize. It serves to identify it and usually contains additional valuable information such as (1) the type of material, (2) the number required, (3) the name of the sketcher, and (4) the date.

138. Pictorial sketching. Often an engineer or draftsman must sketch an object pictorially, freehand, in order to present an idea to another who has not been trained to read a multiview (orthographic) drawing.

139. Isometric sketching. Isometric sketching starts with three isometric lines, called axes, which represent three mutually perpendicular lines. One of these axes is sketched vertically, the other two at 30° with the horizontal. In Fig. 176 (step 1), the near front corner of the enclosing box lies along the vertical axis, while the two visible receding edges of the base lie along the axes receding to the left and to the right.

If the object is of simple rectangular form as in Fig. 176, it may be sketched by drawing an enclosing isometric box (step I) upon the surfaces of which the orthographic views may be sketched (step II). Care must be taken in assuming lengths and distances so that the finished view (step III) will have relatively correct proportions. In constructing the enclosing box (step I), the vertical edges are parallel to the vertical axis, and edges receding to the right and to the left are parallel to the right and left axes, respectively.

Objects of more complicated construction may be "blocked in" as shown in Fig. 177. Note that the projecting cylindrical features are

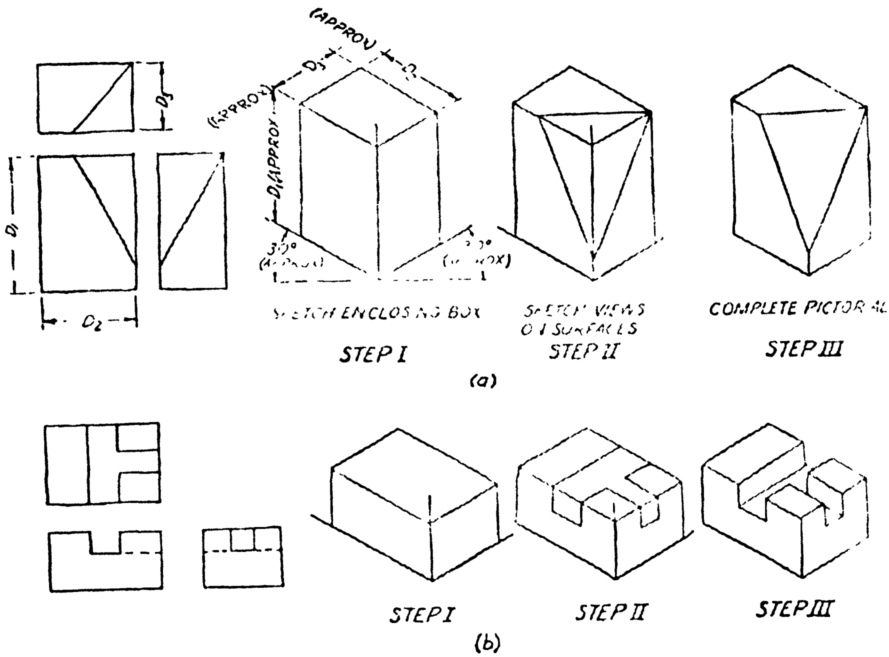


Fig. 176. Steps in isometric sketching.

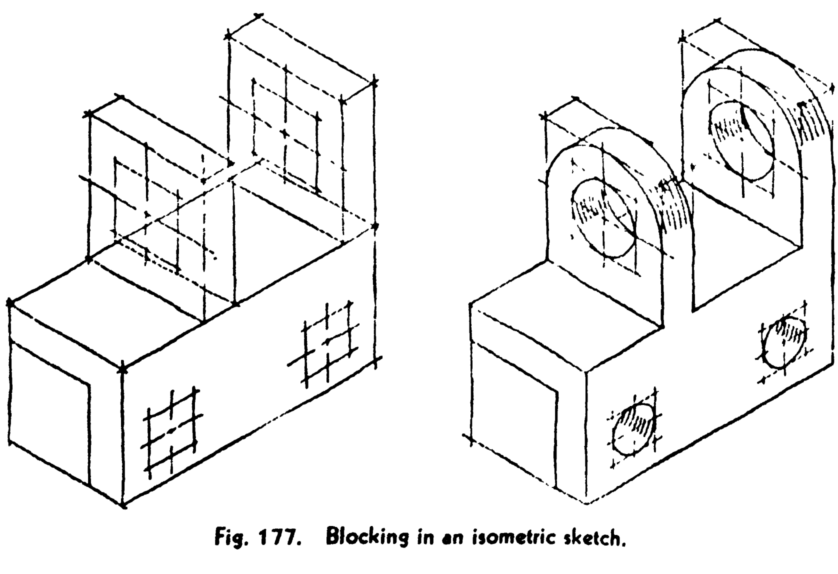


Fig. 177. Blocking in an isometric sketch.

enclosed in "isometric" prisms, and that the circles are sketched within isometric squares.

In sketching an ellipse to represent a circle pictorially, an enclosing "isometric square" (rhombus) is drawn having sides equal approximately to the diameter of the true circle (step I, Fig. 178). The ellipse is formed

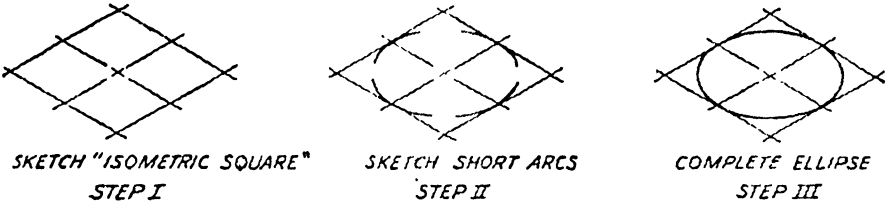


Fig. 178. Isometric circles.

by first drawing arcs tangent to the mid-points of the sides of the isometric square in light sketchy pencil lines (step II). In finishing the ellipse (step III) with a dark heavy line, care must be taken to obtain a nearly elliptical shape.

140. Oblique projection. A sketch in oblique projection shows the front face without distortion, in its true shape.

Fig. 179 shows the steps for making an oblique sketch. The receding lines of the enclosing box are parallel and may be drawn at any angle.

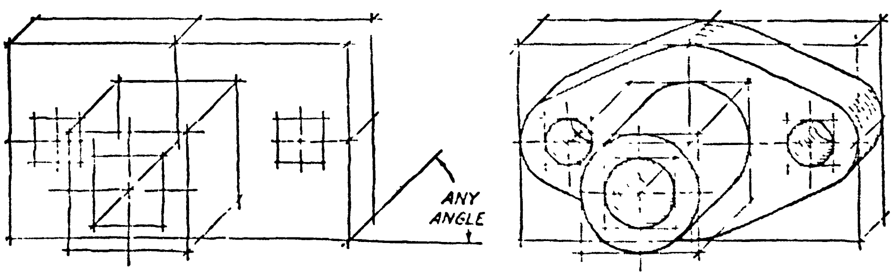


Fig. 179. Blocking in an oblique sketch.

141. Perspective sketching. A sketch that has been prepared in accordance with the concepts of perspective will present a somewhat more pleasing and realistic effect than one in oblique or isometric projection. A perspective sketch actually presents an object as it would appear when observed from a particular point. The recognition of this fact, along with an understanding of the concepts that an object will appear smaller at a distance than when it is close, and that horizontal lines converge as they recede until they meet at a vanishing point, should enable one to produce sketches having a perspective appearance.

At the start, the principal lines should be sketched in lightly, extending each line for some length toward its vanishing point. After this has been accomplished, the enclosing perspective squares for circles should be blocked in and the outline for minor details added. When the object lines have been darkened, the construction lines extending beyond the figure may be erased.

Fig. 180 shows a parallel or one-point perspective which bears some resemblance to an oblique sketch. All faces in planes parallel to the front

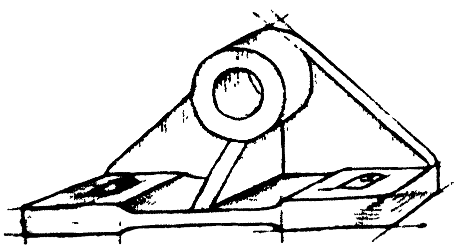


Fig. 180. A sketch in parallel perspective.

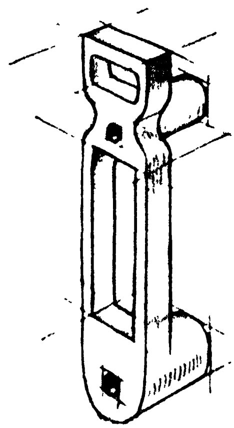


Fig. 181. A sketch in angular perspective.

show their true shape. All receding lines should meet at a single vanishing point. Fig. 181 is an angular perspective. All horizontal lines receding upward to the right extend toward a vanishing point at the right, and those receding to the left extend toward a vanishing point at the left.

142. Problems. The following pictorials of practical machine parts provide practice in sketching and lettering.

1–6. Figs. 182–187. Sketch, freehand, the necessary views of each of the objects shown. For convenience important distances have been marked off in units.

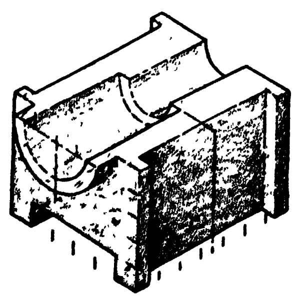


Fig. 182. Bearing block.

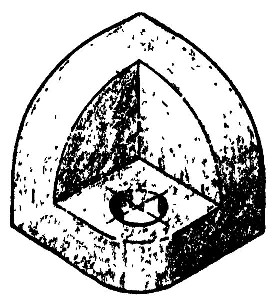


Fig. 183. Corner block.

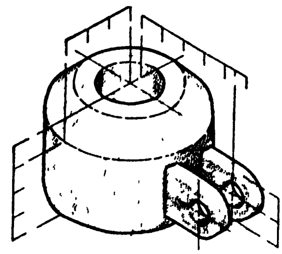


Fig. 184. Feeder cone.

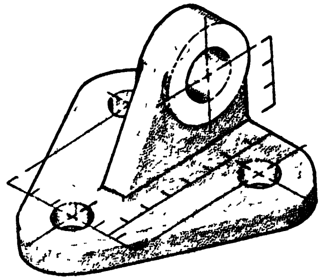


Fig. 185. Bracket.

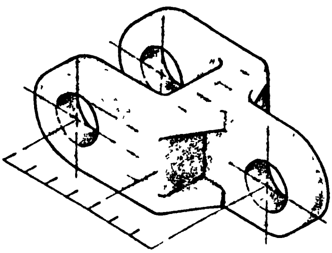


Fig. 186. Link.

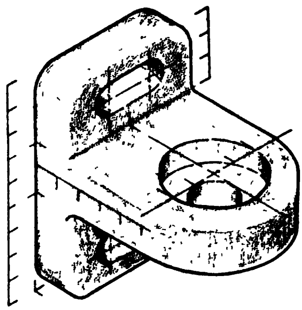


Fig. 187. Bearing bracket.

8

SECTIONAL VIEWS

143. Sectional views. Although the invisible features of a simple object usually may be described on an exterior view by the use of hidden lines, it is unwise to depend upon a perplexing mass of such lines to describe adequately the interior of a complicated object or an assembled mechanism. Whenever a representation becomes so confused that it is difficult to read, it is customary to make one or more of the views "in section" (Fig. 188). A view "in section" is one obtained by imagining the object to have been cut by a cutting plane, the front portion being removed so as to reveal the interior features clearly. Fig. 189(*e*) illustrates the use of an imaginary cutting plane. The resulting sectional (front) view, accompanied by a top view, is shown in Fig. 189(*f*). At this point it should be understood that a portion is shown removed only in a sectional view, not in any of the other views. (See Fig. 189*f*.)

When the cutting plane cuts an object lengthwise, the section obtained is commonly called a longitudinal section; when crosswise, it is called a cross section. It is designated as being either a full section, a half section, or a broken section. If the plane cuts entirely across the object, the section represented is known as a full section. If it cuts only halfway across a symmetrical object, the section is a half section. A broken section is a partial one which is used when less than a half section is needed.

On a completed sectional view, fine section lines are drawn across the surface cut by the imaginary plane, to emphasize the contour of the interior (see Sec. 150).

144. A full section. Since a cutting plane which cuts a full section passes entirely through an object, the resulting view will appear as illustrated in Fig. 189(*f*). Although the plane usually passes along the main axis, it may be offset (see Fig. 190) to reveal important features.

A full sectional view, showing an object's characteristic shape, usually replaces an exterior front view; however, one of the other principal views, side or top, may be converted into a sectional view if some interior feature thus can be shown to a better advantage or if such a view is needed in addition to a sectioned front view.

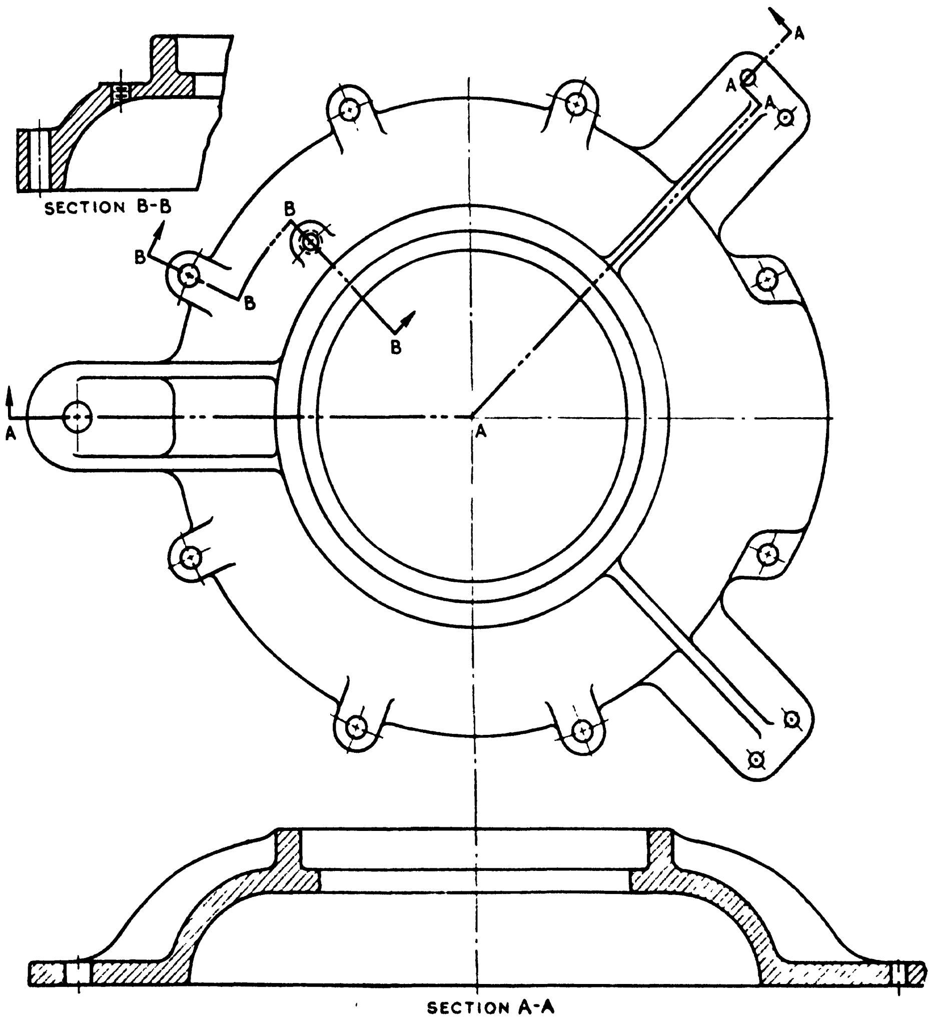


Fig. 188.*

The procedure in making a full sectional view is simple, in that the sectional view is a true orthographic one. The imaginary cut face of the object simply is shown as it would appear to an observer looking directly at it from a point an infinite distance away. In any sectional view, it is considered good practice to omit all invisible lines unless such lines are

* ASA Z14.1-1946.

necessary to clarify the representation. Even then they should be used sparingly.

145. A half section. The cutting plane for a half section removes one quarter of an object. The plane cuts halfway through to the axis or center line so that half the finished sectional view appears in section and

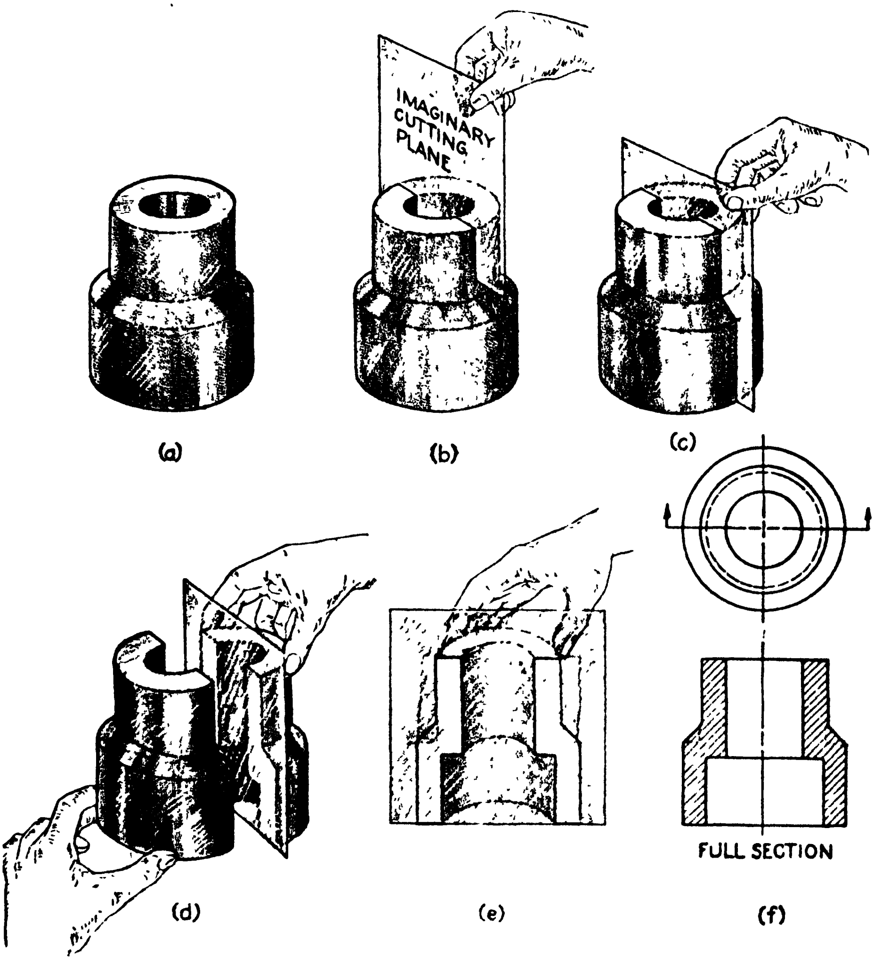


Fig. 189. The theory of the construction of a sectional view.

half appears as an external view. (See Fig. 191.) This type of sectional view is used when a view is needed showing both the exterior and interior construction of a symmetrical object. Good practice dictates that hidden lines be omitted from both halves of the view unless they are absolutely necessary for dimensioning purposes or for explaining the construction. The use of a center line at the center of the view is

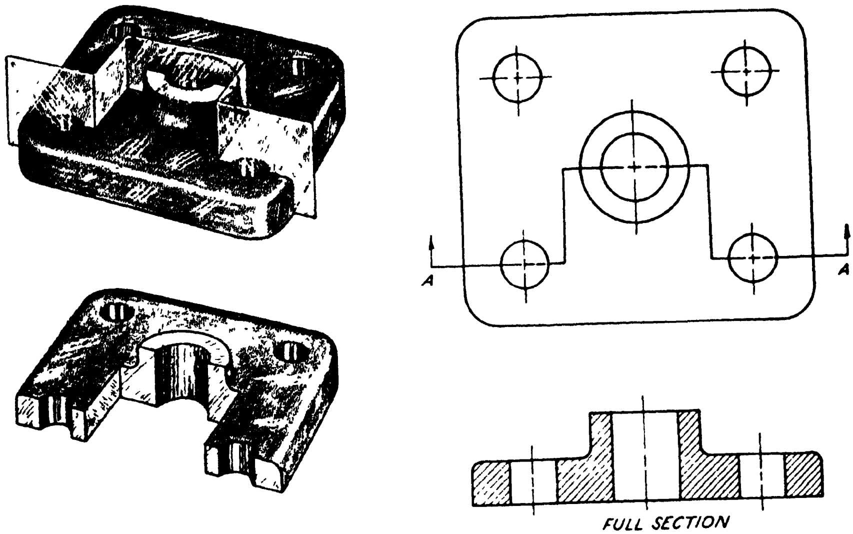


Fig. 190. An offset cutting plane.

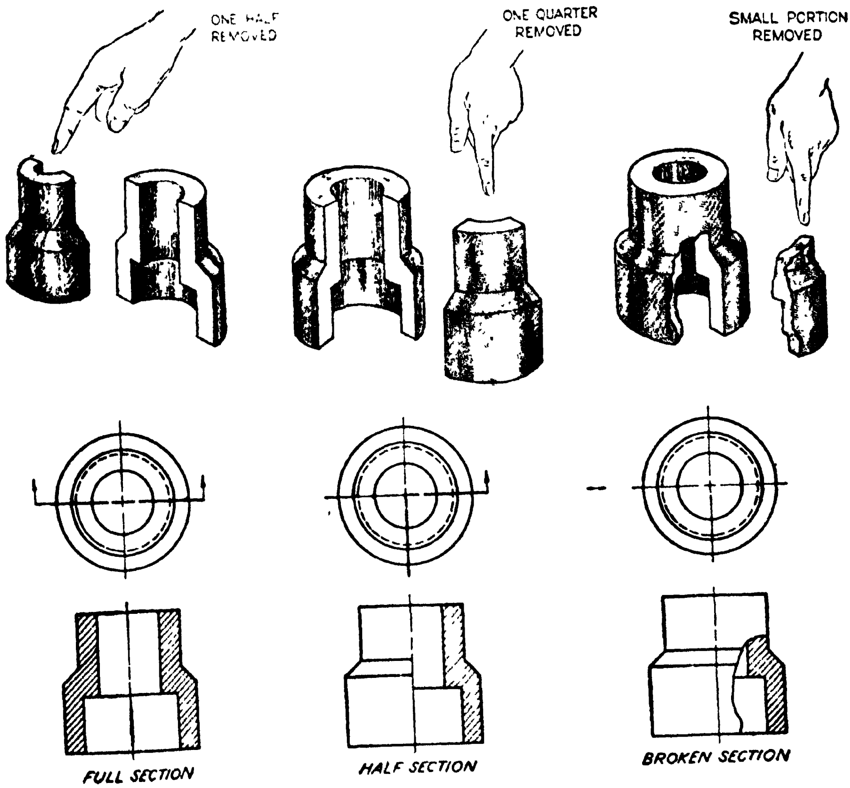


Fig. 191 Types of sectional views.

recommended in place of an object line even though a solid line is often used by industrial draftsmen.

146. A broken section. A broken or partial section is used mainly to expose the interior of objects so constructed that less than a half section is required for a satisfactory description (Fig. 191). The object theoretically is cut by a cutting plane and the front portion is removed by breaking it away. The "breaking away" gives an irregular boundary line to the section.

147. A revolved section. A revolved section is useful for showing the true shape of the cross section of some elongated object, such as a bar, or some feature of an object, such as an arm, spoke, or rib (Fig. 192).

To obtain such a cross section, an imaginary cutting plane is passed through the member perpendicular to its axis, and then is revolved through 90 degrees to bring the resulting view into the plane of the paper. When revolved, the section should show in its true shape and in its true revolved position, regardless of the location of the lines of the exterior view. If any lines of the view interfere with the revolved section, they should be omitted. It sometimes is advisable to provide an open space for the section by making a break in the object (see Fig. 192).

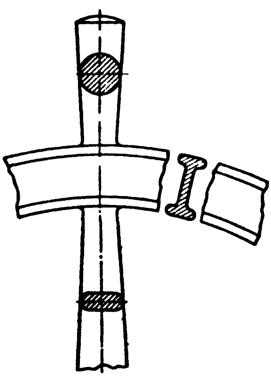


Fig. 192. A revolved section.*

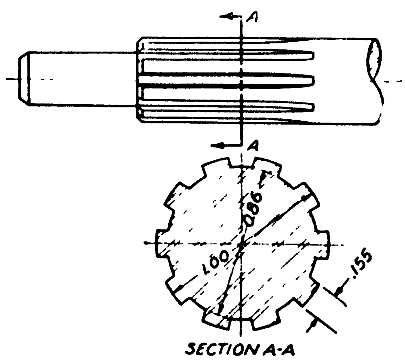


Fig. 193. A detail section.

148. Detail or removed sections. A detail section is similar to a revolved section, except that it does not appear on an external view but, instead, is drawn "out of place," and appears adjacent to it (Fig. 193). There are two good reasons why detail sections frequently are desirable. First, their use may prevent a principal view of an object, the cross section of which is not uniform, from being cluttered with numerous revolved sections. Second, they may be drawn to an enlarged scale in order to emphasize detail and allow for adequate dimensioning (Fig. 193).

Whenever a detail section is used, there must be some means of

* ASA Z14.1-1946.

identifying it. Usually this is accomplished by showing the cutting plane on the principal view and then labeling both the plane and the resulting view, as shown in Fig. 193.

149. Phantom sections. A phantom or hidden section is a regular exterior view upon which the interior construction is emphasized by crosshatching an imaginary cut surface with dotted section lines (see Fig. 194). This type of section is used only when a regular section or a broken section would remove some important exterior detail, or, in some instances, to show an accompanying part in its relative position with regard to a particular part.

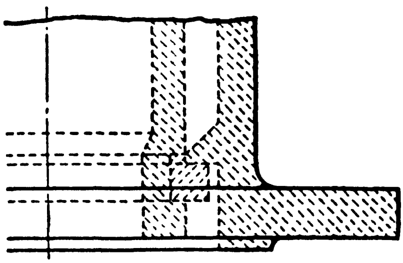


Fig. 194. A phantom section.*

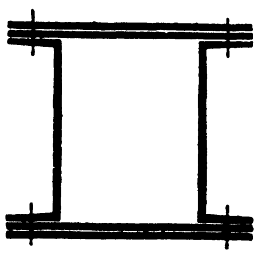


Fig. 195. Thin sections.*

150. Section lining. Section lines are light continuous lines drawn across the imaginary cut surface of an object for the purpose of emphasizing the contour of its interior. Usually they are drawn at an angle of 45 degrees, except in cases where a number of adjacent parts are shown assembled. (See Fig. 198.)

To be pleasing in appearance, these lines must be correctly executed. While on ordinary work they are spaced about $\frac{1}{16}''$ apart by eye, there is no set rule governing their spacing. They simply should be spaced to suit the drawing and the size of the areas to be crosshatched. In the case of very thin plates, the cross section is shown "solid black" (Fig. 195).

The usual mistake of the beginning student is to draw the lines too close together. This, plus the unavoidable slight variations, causes the section lining to appear streaked. An example of correct section lining is shown in Fig. 196(*a*), and, for comparison, examples of faulty practice may be seen in Fig. 196(*b*), (*c*), and (*d*).

As shown in Fig. 197, the section lines on two adjacent pieces should slope at 45 degrees in opposite directions. If a third piece adjoins the two other pieces, as in Fig. 198(*a*), it ordinarily is section-lined at 30 degrees. An alternate treatment, which might be used, would be to vary the spacing without changing the angle. On a sectional view show-

* ASA Z14.1-1946.

ing an assembly of related parts, *all portions of the cut surface of any part must be section-lined in the same direction, for a change would lead the reader to consider the portions as belonging to different parts. Furthermore,*

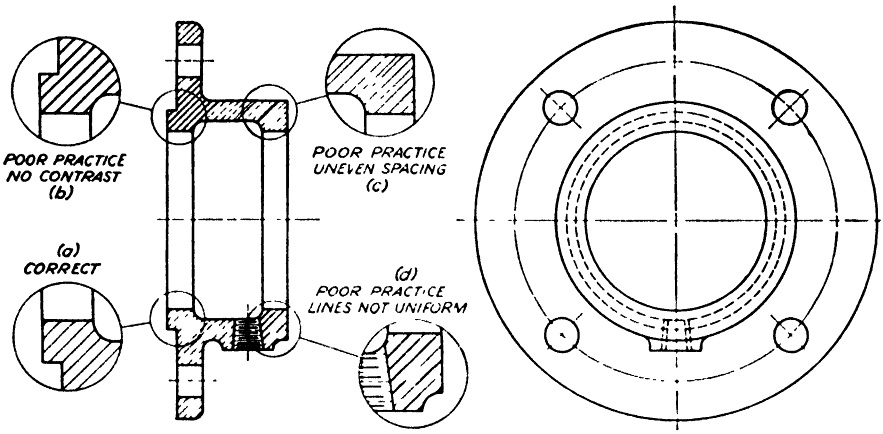
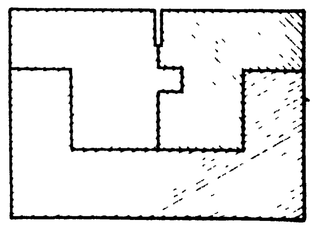


Fig. 196. Faults in sectional lining.

to allow quick identification, each piece (and all identical pieces) in every view of the assembly drawing should be section-lined in the same direction.

Shafts, bolts, pins, rivets, balls, and so on, whose axes lie in the plane of section are not treated the same as ordinary parts. Having no interior construction to be shown, they are drawn in full and thus tend to make the adjacent sectioned parts stand out to better advantage (Fig. 199).

Whenever section lines drawn at 45 degrees with the horizontal are parallel to part of the outline of the section, it is advisable to draw them at some other angle (say 30 degrees or 60 degrees).



(a)

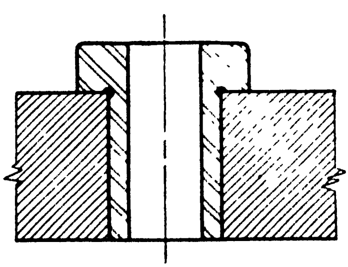
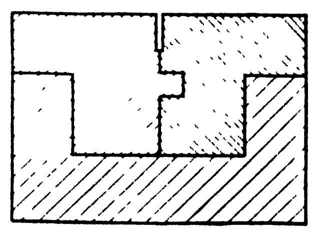


Fig. 197. Two adjacent pieces.



(b)

Fig. 198. Three adjacent pieces.

151. Outline sectioning. Very large surfaces may be section-lined around the bounding outline only, as illustrated in Fig. 200.

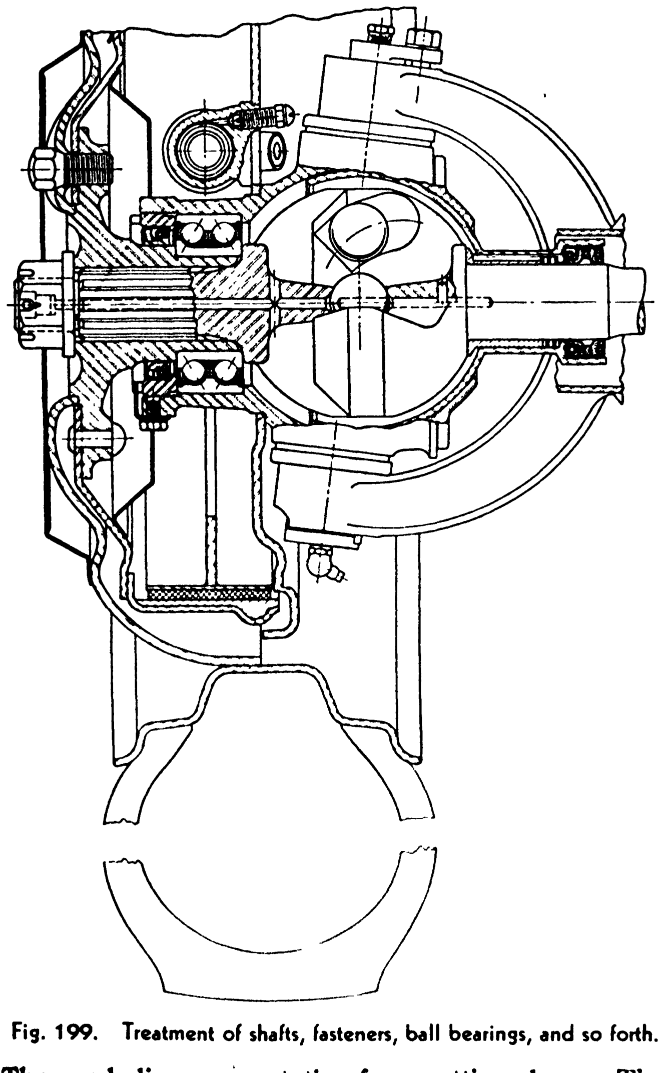


Fig. 199. Treatment of shafts, fasteners, ball bearings, and so forth.*

152. The symbolic representation for a cutting plane. The symbolic line that is used to represent the edge view of a cutting plane is shown in Fig. 201(*a*). It is as heavy as an object line and is composed of alternate long and short dashes. On drawings of ordinary size, the long dashes are $\frac{3}{4}''$ long, the short dashes $\frac{1}{8}''$ long, and the spaces $\frac{1}{16}''$ wide. When drawn in ink, the dashes are $\frac{1}{40}''$ to $\frac{1}{32}''$ wide, depending on the size of the drawing. When drawn in pencil on manila paper, they are made with a $2H$ pencil.

* Courtesy of New Departure, Division General Motors Sales Corporation.

Arrowheads are used to show the direction in which the imaginary cut surface is viewed, and reference letters are added to identify it (*b*).

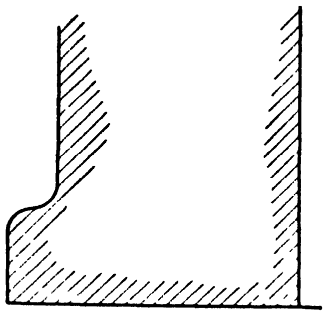


Fig. 200. Outline sectioning.

Whenever the location of the cutting plane is obvious, it is common practice to omit the edge-view representation, particularly in the case of symmetrical objects. If it is shown, however, and coincides with a center line, it takes precedence over the center line (Fig. 188).

153. Conventional sections. Sometimes a less confusing sectioned representation is obtained if certain of the strict rules of projection are violated. For example, an unbalanced and confused view results when the sectioned view of the pulley shown in Fig. 202 is drawn in true projection, as in (*a*). It is better practice to preserve symmetry by showing the spokes as if they were aligned into one plane, as in (*c*). Such treatment of unsymmetrical features is not misleading, since their actual arrangement is revealed in the circular view. The spokes are not sectioned in the preferred view. If they were, the first impression would be that the wheel had a solid web.

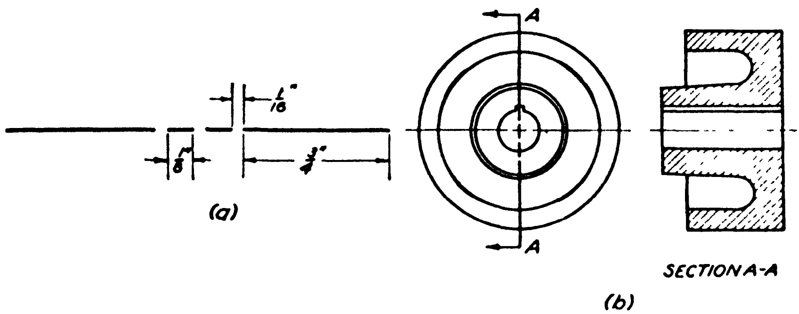


Fig. 201. Cutting plane line.

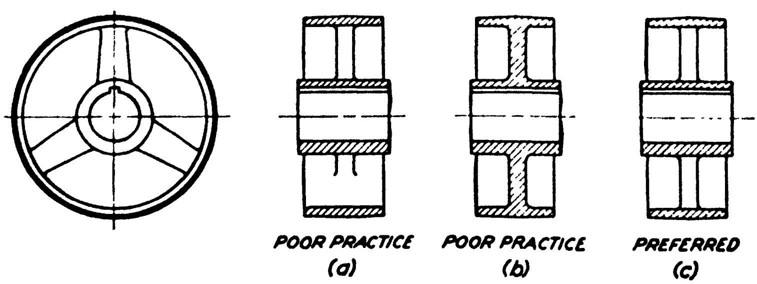


Fig. 202. Conventional treatment of spokes in section.

The holes in a flange should be shown in a sectioned view at their true distance apart, across the bolt circle, even though their axes do not fall in the plane of section. (See Fig. 204.) The unbalanced view in (*b*) conveys no impression of symmetry, nor does it reveal the true location of the holes with reference to rim. The view in (*a*), showing the upper hole as if it had been swung into the plane of section, is less misleading and is therefore to be preferred.

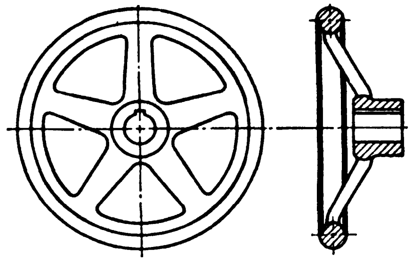


Fig. 203. Spokes in section.*

154. Ribs in section. When a machine part has a rib cut by a plane of section (Fig. 205), a "true" sectional view taken through the rib proves false and misleading, for the reason that the crosshatching on the rib causes the object to appear "solid." The preferred treatment is to omit arbitrarily the section lines from the rib, as illustrated by Fig. 205(*a*).

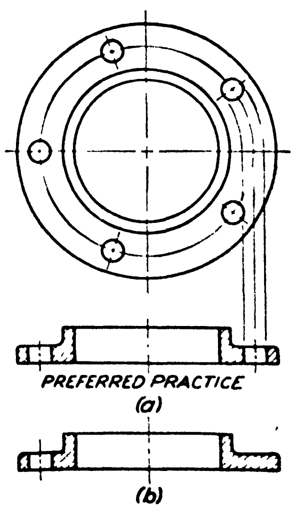


Fig. 204. Drilled flanges.

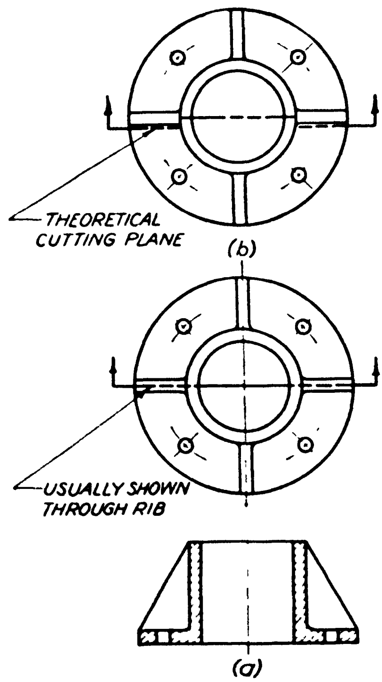


Fig. 205. Conventional treatment of ribs in section.

The resulting sectional view may be considered the view that would be obtained if the plane were offset to pass just in front of the rib (*b*). Study Fig. 188.

* ASA Z14.1-1946.

155. Material symbols. The section-line symbols recommended by the American Standards Association for indicating various materials are shown in Fig. 206. Code section lining ordinarily is not used on a work-

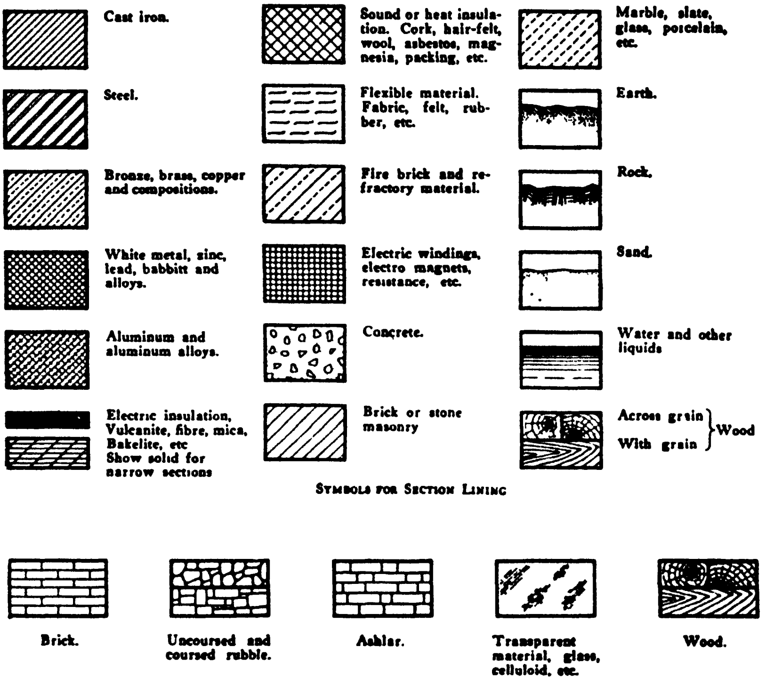


Fig. 206. Material symbols.

ing (detail) drawing of a separate part. It is considered unnecessary to indicate a material symbolically, when its exact specification must be given also as a note. For this reason, and in order to save time as well, the easily drawn symbol for cast iron is commonly used on detail drawings for all materials.

Code section lining usually is employed on an assembly section showing the various parts of a unit in position, because a distinction between the materials causes the parts to "stand out" to better advantage. Furthermore, a knowledge of the type of material of which an individual part is composed often helps the reader to identify it more quickly and understand its function.

156. Problems. The following problems were designed to emphasize the principles of sectioning.

1. (Fig. 207.) Reproduce the top and side views and change the front view into a sectional view which will be in accordance with the indicated cutting plane.

2. (Fig. 208.) Reproduce the top view and change the front view into a full section view in accordance with the indicated cutting plane.

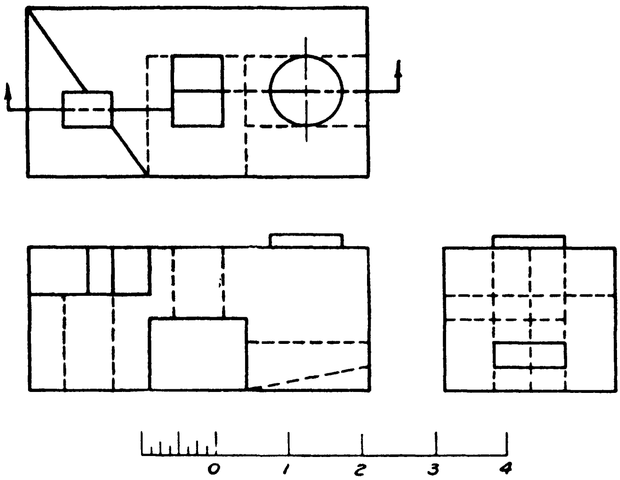


Fig. 207. Mutilated block.

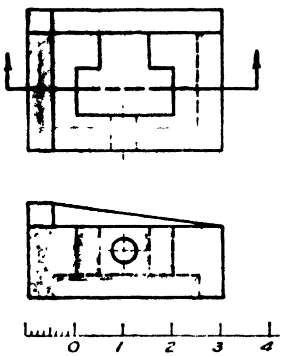


Fig. 208. Mutilated block.

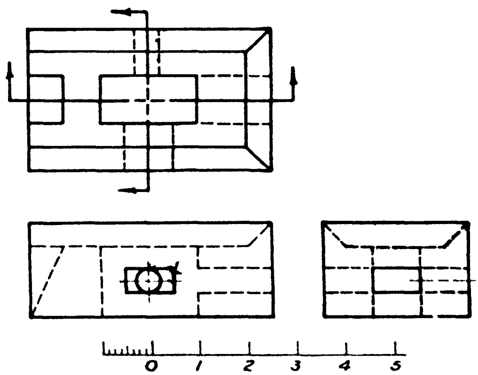


Fig. 209. Mutilated block.

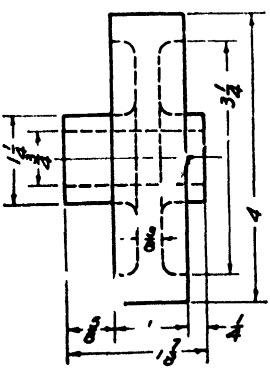


Fig. 210. Pulley.

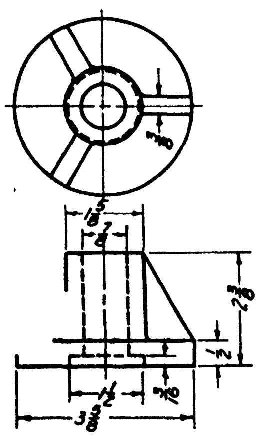


Fig. 211. Rod support.

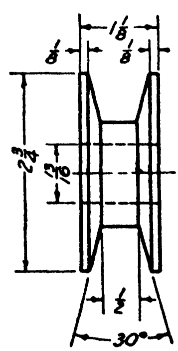


Fig. 212. "V" pulley.

3. (Fig. 209.) Reproduce the top view and change the front and side views into sectional views which will be in accordance with the indicated cutting planes.

4. (Fig. 210.) Draw a front view of the pulley (circular view) and a side view in full section.

5. (Fig. 211.) Reproduce the top view of the rod support and draw the front view in full section. Read Sec. 160 before starting to draw.

6. (Fig. 212.) Draw a front view of the "*V*" pulley (circular view) and a side view in full section.

7–12. (Figs. 213–218.) These problems may be dimensioned, as are working drawings. For each object, the student should draw all the views necessary for a working drawing of the part. Good judgment should be exercised in deciding whether the sectional view should be a full section or a half section.

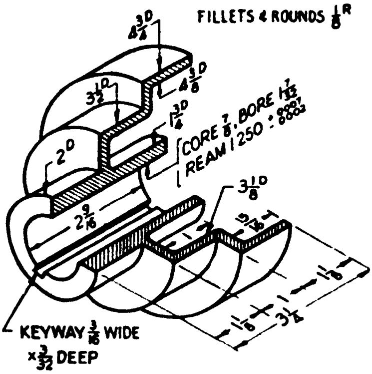


Fig. 213. Cone pulley.

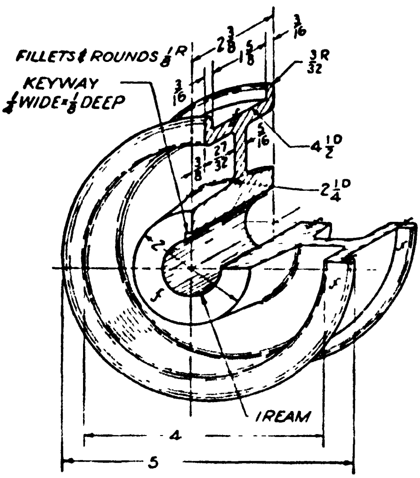


Fig. 214. Flanged pulley.

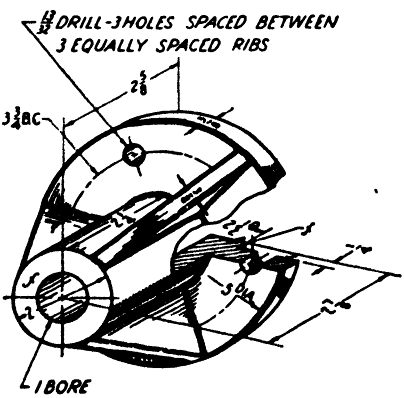


Fig. 215. Rod yoke.

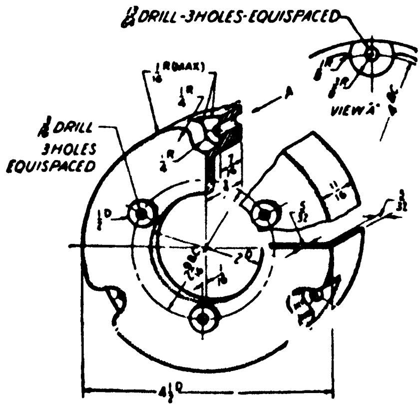


Fig. 216. Cover.

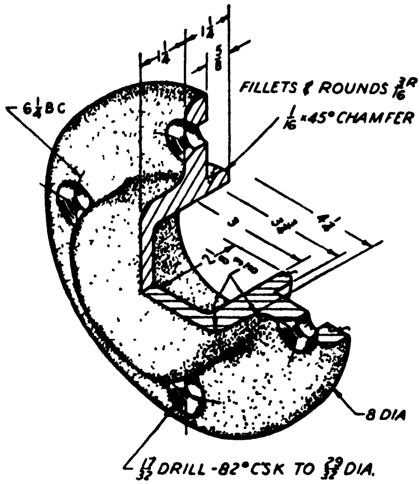


Fig. 217. Cover.

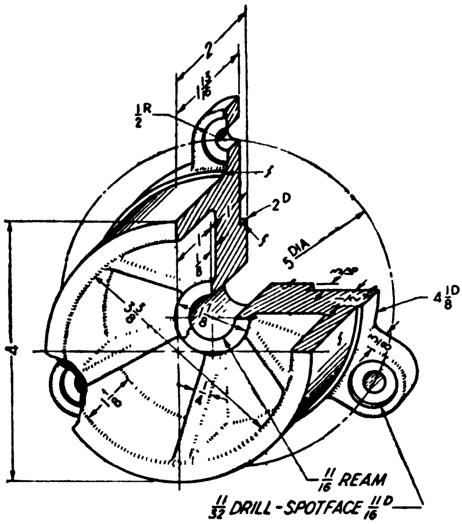


Fig. 218. End guide.

9

CONVENTIONAL PRACTICES IN ORTHOGRAPHIC DRAWING

157. In commercial drafting, certain conventional practices have been adopted in order to obtain added clearness. Many of them eliminate particularly awkward conditions which arise from strict adherence to the rules of projection. These idioms of drawing have slowly developed with the graphic language until at the present time they are universally recognized and observed.

158. The treatment of unimportant intersections. The conventional methods of treating various unimportant intersections are shown in Fig. 219(*a*, *b*, *c*, and *d*). To show the true line of intersection in each case would add little to the value of the drawing. Therefore, in the views

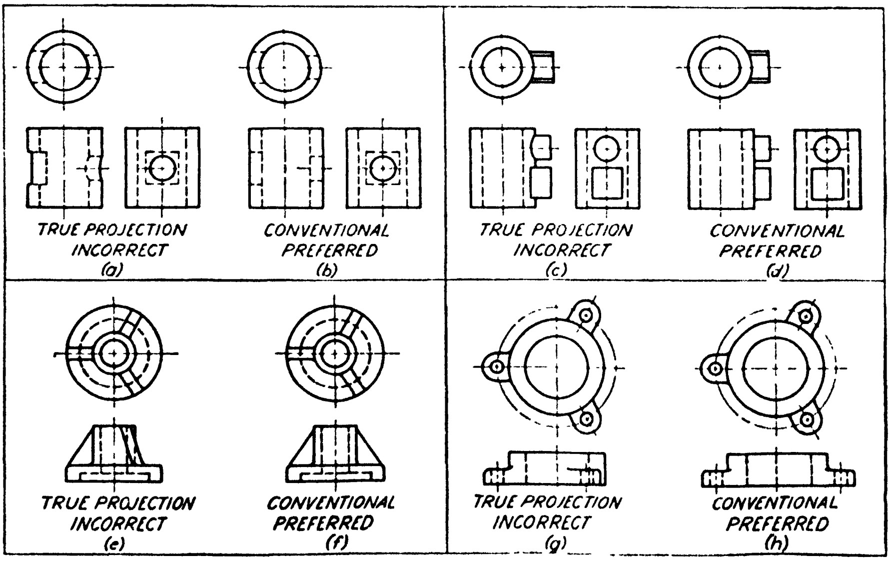


Fig. 219. Conventional practice of representing unimportant intersections, ribs, and lugs.

designated as preferred, true projection has been ignored in the interest of simplicity. On the front views, in (*a*) and (*b*) for example, there is so little difference between the descriptive values of the true and approximate representations of the holes that the extra labor necessary to draw the true representations is unwarranted.

159. Aligned views. Pieces which have arms, ribs, lugs, or other parts at an angle are often shown aligned or "straightened out" in one view, as illustrated in Fig. 220. By this method, it is possible to show the true shape as well as the true position of such features.

160. Conventional treatment of radially arranged features. Many objects that have radially arranged features may be shown more clearly if true projection is violated (Fig. 221). Violation of true projection in such cases consists of intentionally showing such features swung out of position in one view so as to present the idea of symmetry and show the true relationship of the features at the same time.

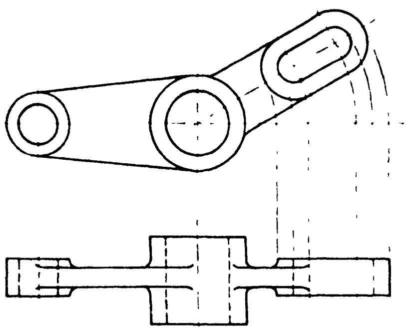


Fig. 220. Aligned views.

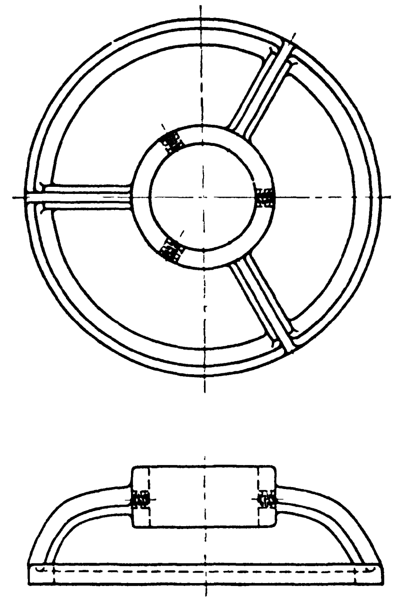


Fig. 221. Symmetry.

161. Representation of fillets and rounds. Interior corners, which are formed on a casting by unfinished surfaces, always are filled in (filleted) at the intersection, in order to avoid possible fracture at that point. Sharp corners are also difficult to obtain and are avoided for this reason as well. Exterior corners are rounded for appearance and for the comfort of persons who must handle the part when assembling or repairing the machine on which the part is used. A rounded internal corner is known as a "fillet"; a rounded external corner is known as a "round."

When two intersecting surfaces are machined, however, their intersection will become a sharp corner. For this reason, all corners formed by unfinished surfaces should be shown "broken" by small rounds, and all corners formed by two finished surfaces or one finished surface and one unfinished surface should be shown "sharp."

Since fillets and rounds eliminate the intersection lines of intersecting surfaces, they create a special problem in orthographic representation. To treat them in the same manner as they would be treated if they had

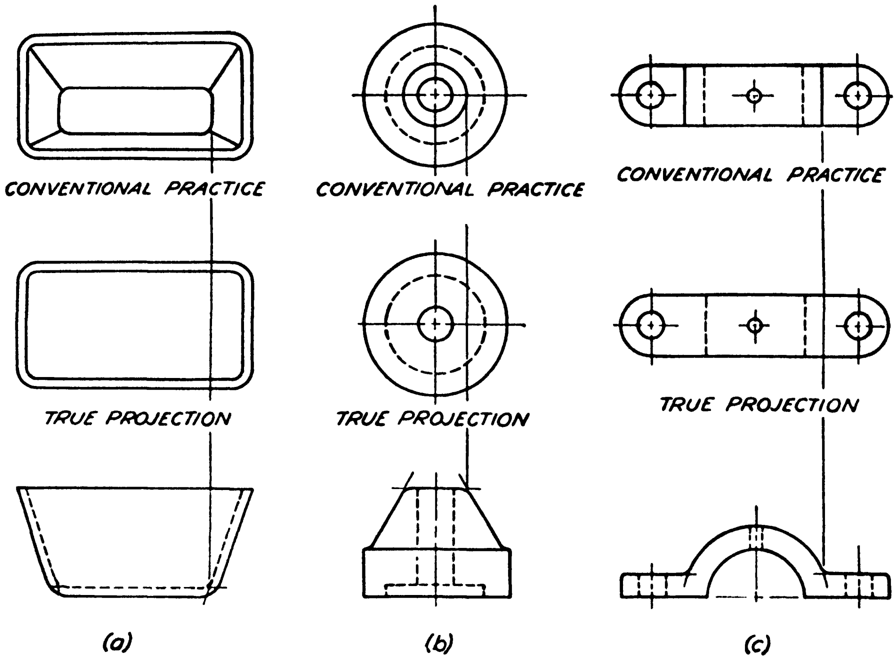


Fig. 222. Conventional practice of representing nonexisting lines of intersection

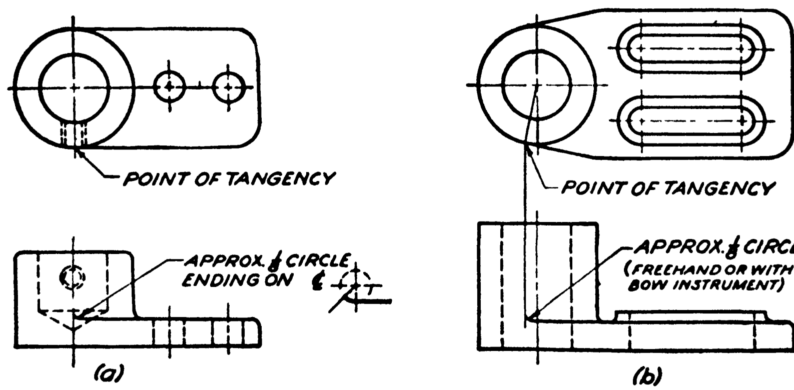
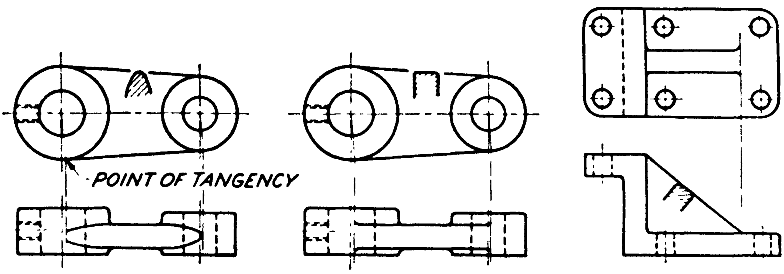


Fig. 223. The conventional treatment of fillets.

large radii results in views that are misleading. For example, the true projection view in Fig. 222(*a*) confuses the reader, because at a first glance it does not convey the idea that there are abrupt changes in direction. To prevent such a probable first impression and to improve the descriptive value of the view, it is necessary to represent these theoretically nonexisting lines. These characteristic lines are projected from the approximate intersections of the surfaces, with the fillets disregarded.

Fig. 223 illustrates the accepted conventional method of representing the "run-out" intersection of a fillet in cases where a plane surface is tangent to a cylindrical surface. Although run-out arcs such as these are usually drawn freehand, a French curve or a bow instrument may be used. If they are drawn with the latter type of instrument, a radius should be used that is equal to the radius of the fillet, and the completed arc should form approximately one-eighth of a circle.

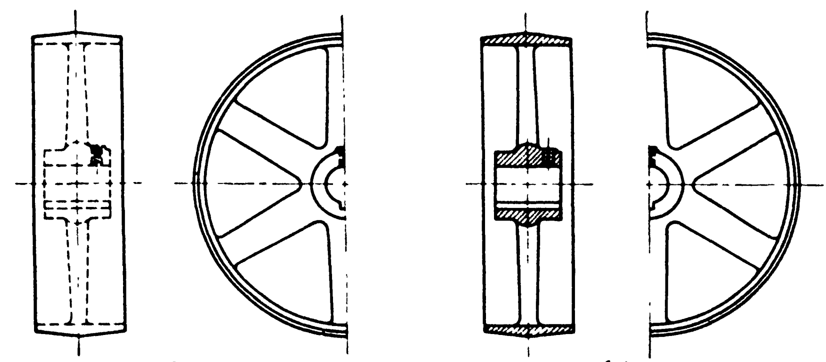
The generally accepted methods of representing intersecting fillets and rounds are illustrated in Fig. 224. The treatment, in each of the



(a) (b) (c)

Fig. 224. The approximate methods of representing intersecting fillets, rounds.

cases shown, is determined by the relationship existing between the sizes of the intersecting fillets and rounds.



(a) (b)

Fig. 225. A half view.

162. Half views. When the space available is insufficient to allow a satisfactory scale to be used for the representation of a symmetrical piece, it is considered good practice to make one view a half view, as shown in Fig. 225. The half view, however, must be the top or side view and not the front view, which shows the characteristic contour. When the front view is an exterior view, the half view should be the front half of the top or side view; when the front view is a sectional view, it should be the rear half.

163. Conventional breaks. A relatively long piece of uniform section may be shown to a larger scale, if a portion is broken out so that the ends can be drawn closer together. When such a scheme is employed, a conventional break is used to indicate that the length of the representation

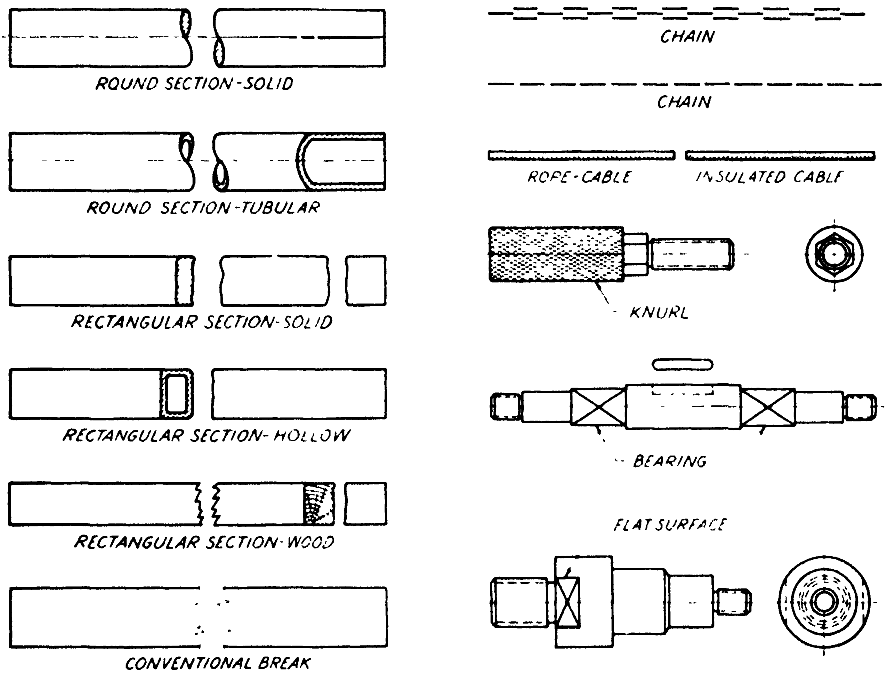


Fig. 226. Conventional breaks and symbols.

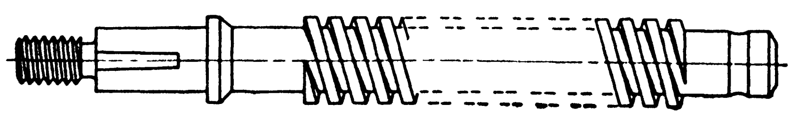


Fig. 227. Ditto lines.

is not to scale. The American Standard conventional breaks, shown in Fig. 226, are used on either detail or assembly drawings. The breaks representation for indicating the broken ends of rods, shafts, tubes, and so forth, are so designed as to reveal the characteristic shape of the cross section in each case. Although break lines for round sections may be drawn freehand, particularly on small views, it is better practice to draw them with either an irregular curve or a bow instrument. The breaks for wood sections, however, always should be drawn freehand.

Other recognized symbolic representations which are commonly used are shown in Fig. 226.

164. Ditto lines. When it is desirable to minimize labor in order to save time, ditto lines may be used to indicate a series of identical features. For example, the threads on the shaft shown in Fig. 227 are just as effectively indicated by ditto lines as by a completed profile representation. When ditto lines are used, a long shaft of this type may be shortened without actually showing a conventional break.

10

AUXILIARY VIEWS

165. When it is desirable to show the true size and shape of an irregular surface which is inclined to two or more of the co-ordinate planes of projection, a view of the surface must be projected on a plane parallel to it. This imaginary projection plane is called an auxiliary plane, and the view obtained is called an auxiliary view (Fig. 228).

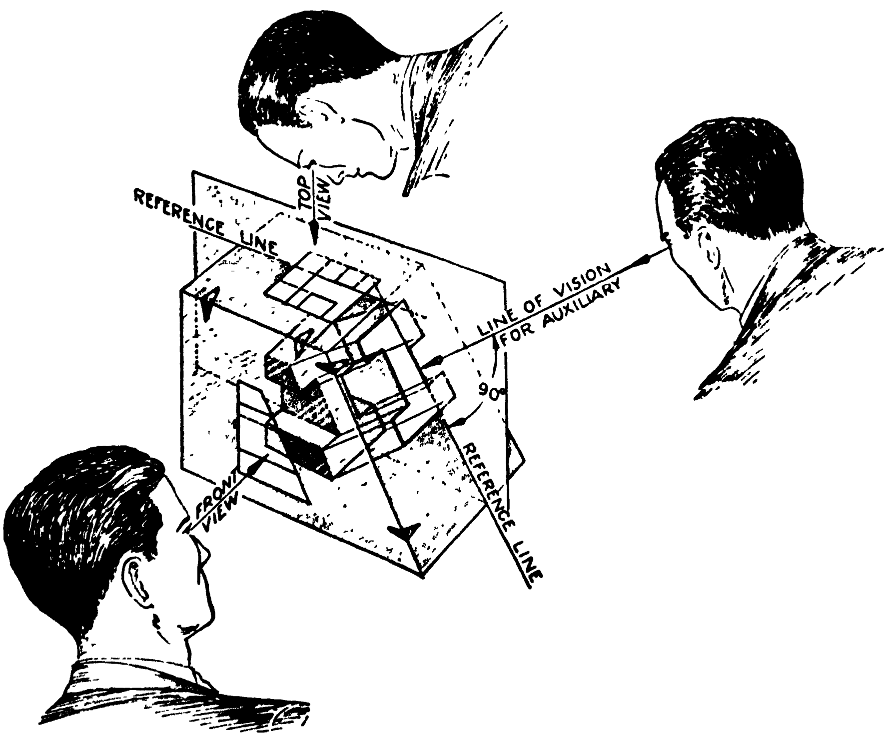


Fig. 228. Theory of projecting an auxiliary view.

The theory underlying the method of projecting principal views applies also to auxiliary views. In other words, an auxiliary view shows an inclined surface of an object as it would appear to an observer stationed an infinite distance away (Fig. 229).

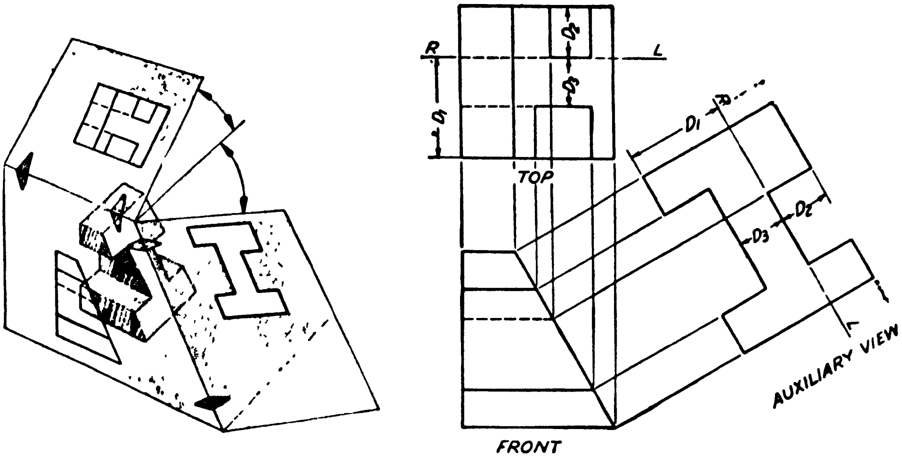


Fig. 229. An auxiliary view.

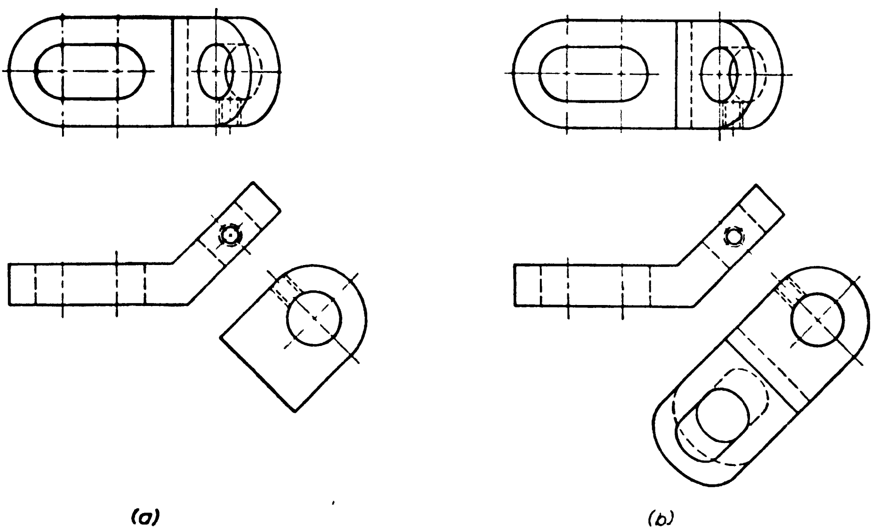


Fig. 230. Partial and complete auxiliary views.

166. The use of auxiliary views. In commercial drafting, an auxiliary view ordinarily is a partial view showing only an inclined surface. The reason for this is that a projection showing the entire object adds nothing to the shape description. The added lines are likely to defeat the intended purpose of an auxiliary view. For example, a complete drawing of the casting in Fig. 230 must include an auxiliary view of the inclined surface in order to show the true shape of the surface and the location of the holes. Compare the views in (*a*) and (*b*) and note the confused appearance of the view in (*b*).

167. Types of auxiliary views. Although auxiliary views may have an infinite number of positions in relation to the three principal planes of projection, primary auxiliary views may be classified into three general types in accordance with position relative to the principal planes. Fig. 231 shows the first type where the auxiliary plane is perpendicular to the

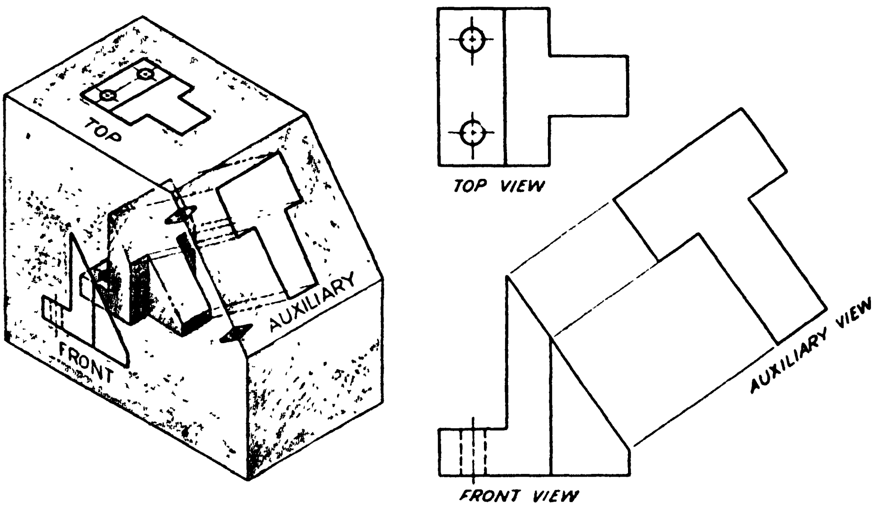


Fig. 231. Auxiliary view projected from front view.

front (vertical) plane and inclined to the top (horizontal) plane of projection. Here the auxiliary view and top view have one dimension which is common to both, the width. Note that the auxiliary plane is hinged to the front plane, and that the auxiliary view is projected from the front view.

In Fig. 232 the auxiliary plane is perpendicular to the horizontal plane and inclined to the front and side planes of projection. The auxiliary view is projected from the top view, and its height is the same as the height of the front view.

The third type of auxiliary view, as shown in Fig. 233, is projected from the side view and has a common dimension with both the front and top views. To construct it, distances may be taken from either the front or top view.

All three types of auxiliary views are constructed similarly. Each is projected from the view which shows the surface as an oblique line, and the distances for the view are taken from the other principal view which has a common dimension with the auxiliary. A careful study of the three illustrations will reveal the fact that the inclined auxiliary plane is always hinged to the principal plane to which it is perpendicular.

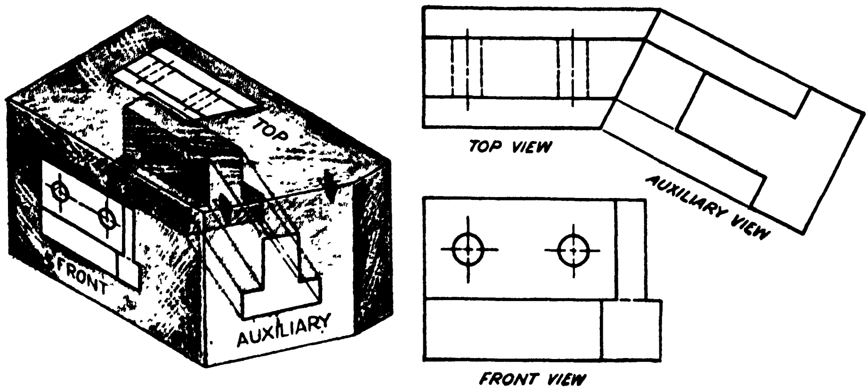


Fig. 232. Auxiliary view projected from top view.

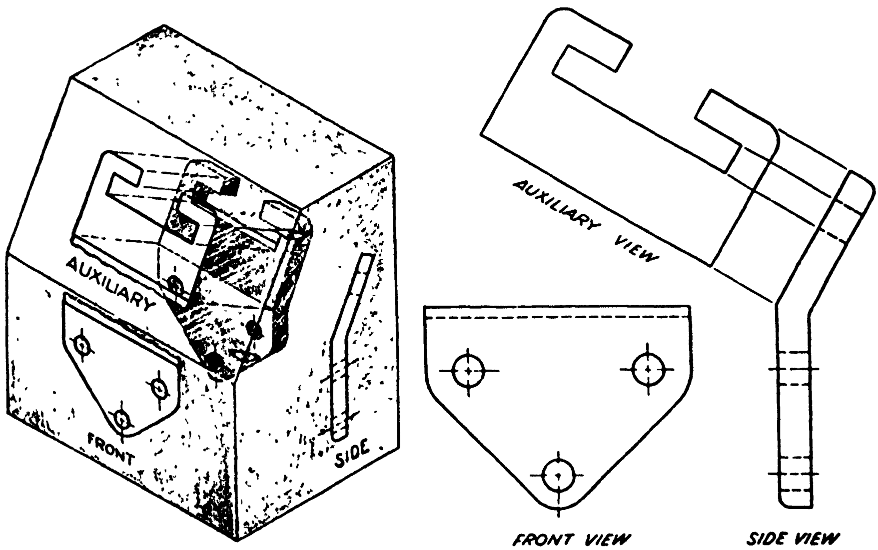


Fig. 233. Auxiliary view projected from side view.

168. To draw a symmetrical auxiliary view. When an inclined surface is symmetrical, the auxiliary view is "worked" from a center line (Fig. 234). The first step in drawing such a view is to draw a center line parallel to the oblique line which represents an edge view of the surface. If the object is assumed to be enclosed in a glass box, this center line may be considered the line of intersection of the auxiliary plane and an imaginary vertical center plane. There are professional draftsmen who, not acquainted with the "glass" box, proceed without theoretical explanation. Their method is simply to draw a working center line for the auxiliary view and a corresponding line in one of the principal views.

Although, theoretically, this working center line may be drawn at any distance from the principal view, actually it should be so located that it gives the whole drawing a balanced appearance. If not already shown, it also must be drawn in the principal view showing the true width of the inclined surface.

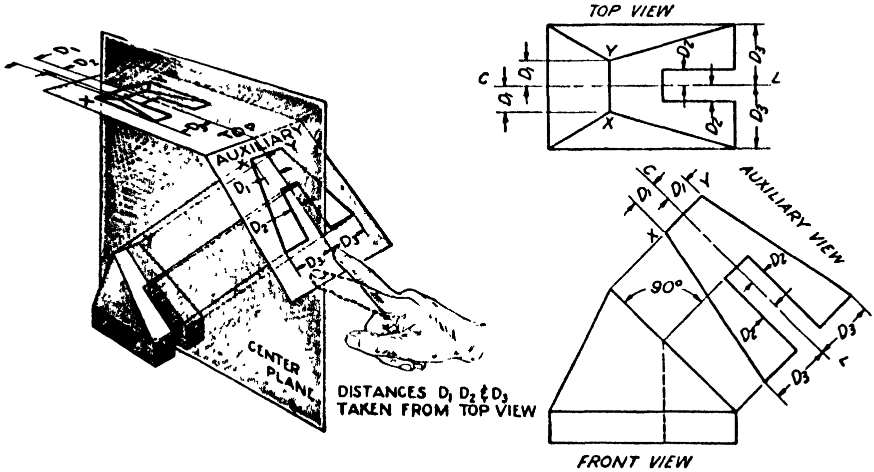


Fig. 234. A symmetrical auxiliary view of an inclined surface.

The next step is to draw projection lines from each point of the sloping face, remembering that the projectors make an angle of 90 degrees with the inclined line representing the surface. With the projectors drawn, the location of each point in the auxiliary can be established by setting the dividers to each point's distance from the center line in the principal view and transferring the distance to the auxiliary view. For example, point *X* is projected to the auxiliary by drawing a projector from point *X* in the front view perpendicular to the center line. Since its distance from the center line in the top view is the same as it is from the center line in the auxiliary view, the point's location along the projector may be established by using the distance taken from the top view. In the case of point *X*, the distance is set off from the center line toward the front view. Point *Y* is set off from the center line away from the front view.

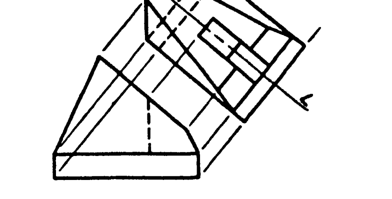


Fig. 235. An auxiliary view of an object.

Fig. 235 shows an auxiliary view of an entire object. In constructing such a view, the projectors from all points of the object must be perpendicular to the working center line, since the observer views the entire figure by looking directly at the inclined surface. The distances perpendicular to the auxiliary center line are taken from the top view.

169. Unsymmetrical auxiliary views (Fig. 236). When constructing an unsymmetrical auxiliary view, it is necessary to work from a reference line that is drawn in a manner similar to the working center line of a symmetrical view (Fig. 228).

170. Curved lines in auxiliary views. To draw a curve in an auxiliary view, the draftsman must plot a sufficient number of points to insure a smooth curve (see Fig. 237). The points are projected first to the

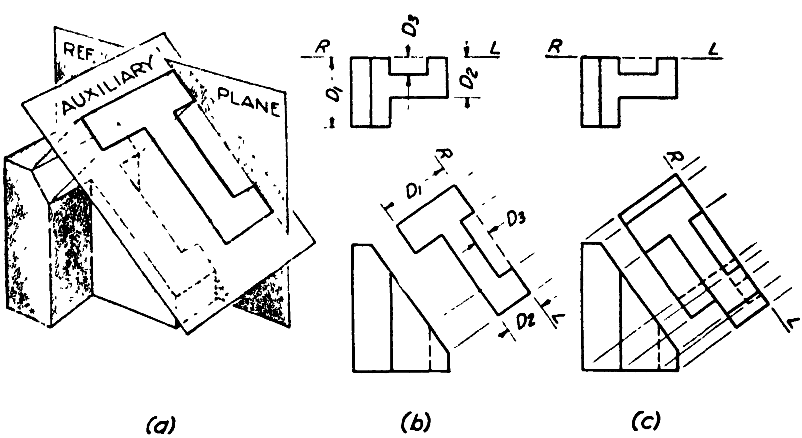


Fig. 236. An unsymmetrical auxiliary view.

oblique line representing the surface in the front view and then to the auxiliary view. The distance of any point from the center line in the auxiliary view is the same as its distance from the center line in the end view.

171. The use of an auxiliary view to complete a principal view. It is frequently necessary to project a foreshortened feature in one of the principal views from an auxiliary view. In the case of the object shown in Fig. 238, the foreshortened projection of the inclined face in the top view can be projected from the auxiliary view. The elliptical curves are plotted by projecting points from the auxiliary view to the front view and from there to the top view. The location of these points in the top view with respect to the center line is the same as their location in the auxiliary view with respect to the auxiliary center line. For example, the distance D_1 from the center line in the top view is the same as the distance D_1 from the auxiliary center line in the auxiliary view.

172. Problems. The problems shown in Fig. 239 are designed to give the student practice in constructing auxiliary views of the inclined

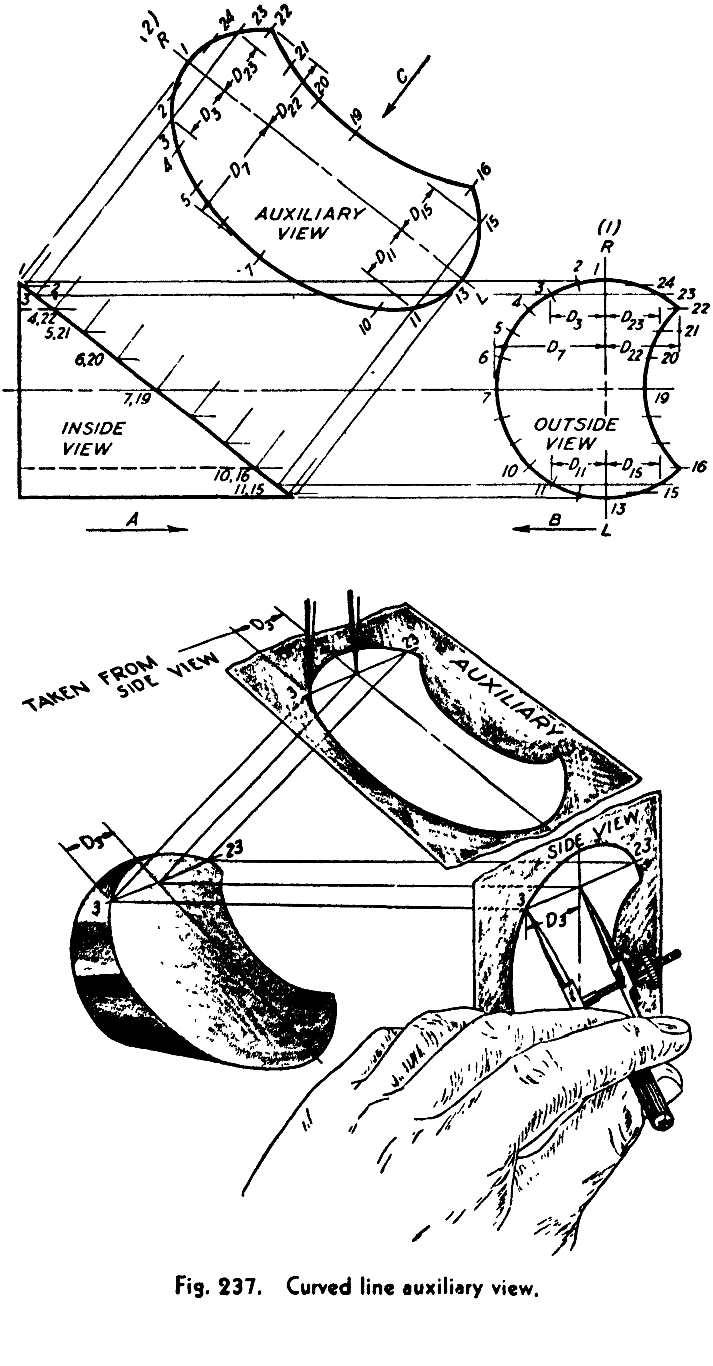


Fig. 237. Curved line auxiliary view.

surfaces of simple objects formed mainly by straight lines. They will provide needed drill in projection if, for each of the objects, an auxiliary is drawn showing the entire object. Complete drawings may be made of the objects shown in Figs. 240–249. If the views are to be dimen-

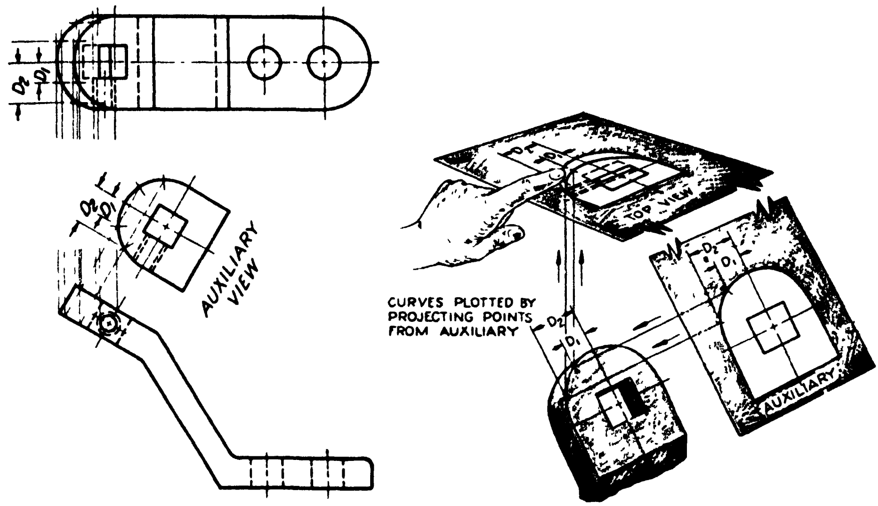


Fig. 238. Use of auxiliary to complete a principal view.

sioned, the student should adhere to the rules of dimensioning given in Chapter 13 and should not take too seriously the locations for the dimensions on the pictorial representations.

1. (Fig. 239.) Using instruments, reproduce the given views of an assigned object and draw an auxiliary view of its inclined surface.

2. (Fig. 240.) Draw the views that are necessary to describe fully the *sliding guide*. The auxiliary view should show only the inclined surface.

3. (Fig. 241.) Draw the views that would be necessary on a working drawing of the *angle bearing*.

4. (Fig. 242.) Draw the necessary views of the *offset bracket*. It is suggested that partial views be used, except in the view where the inclined surface appears as a line.

5. (Fig. 243.) Draw the necessary views of the *hinge bracket*.

6. (Fig. 244.) Draw the necessary views of the *anchor bracket*. Make partial views for the top and end views.

7. (Fig. 245.) Draw the views that would be necessary on a working drawing of the *angle bracket*. Note that two auxiliary views will be required.

8. (Fig. 246.) Draw the views that would be necessary on a working drawing of the *gear cover*. The opening on the inclined face is circular.

9. (Fig. 247.) Draw the views that would be necessary on a working drawing of the *45° elbow*.

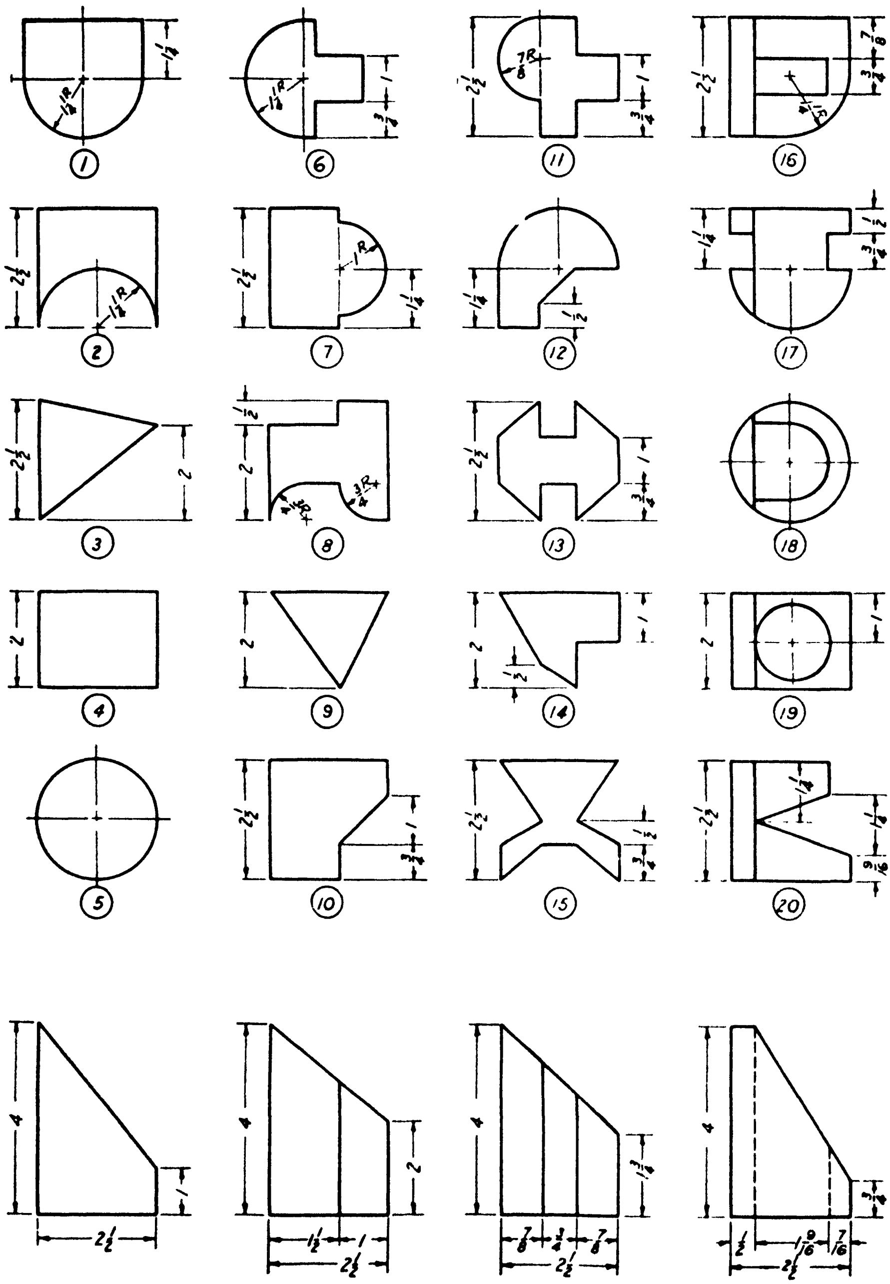


Fig. 239.

10. (Fig. 248.) Draw the views as given. Complete the auxiliary view and the front view.

11. (Fig. 249.) Draw the views as given. Complete the top view.

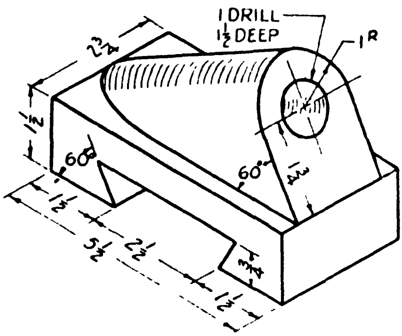


Fig. 240. Sliding guide.

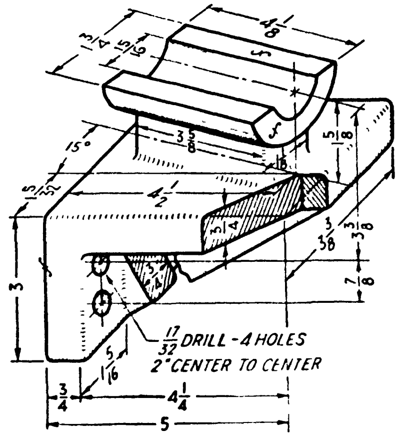


Fig. 241. Angle bearing.

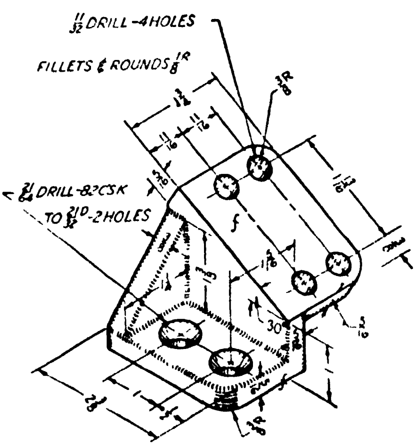


Fig. 242. Offset bracket.

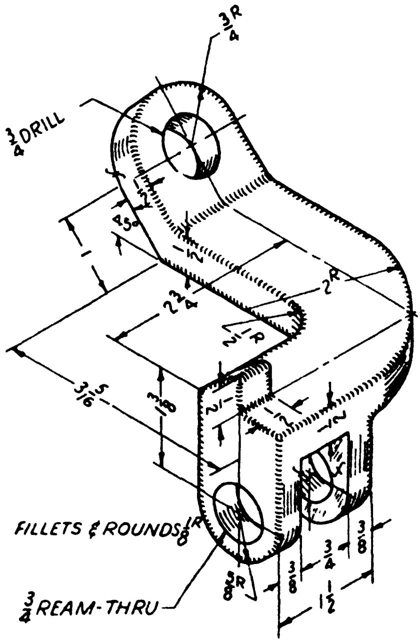


Fig. 243. Hinge bracket.

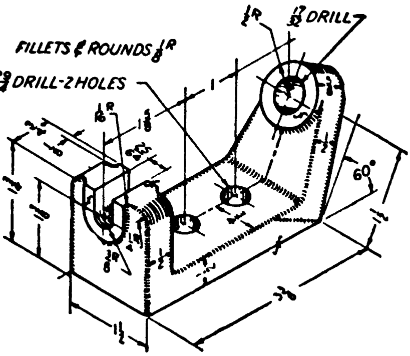


Fig. 244. Anchor bracket.

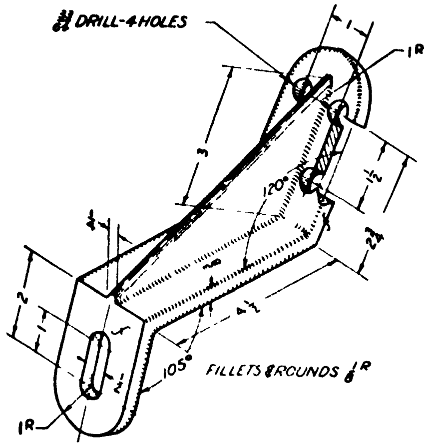


Fig. 245. Angle bracket.

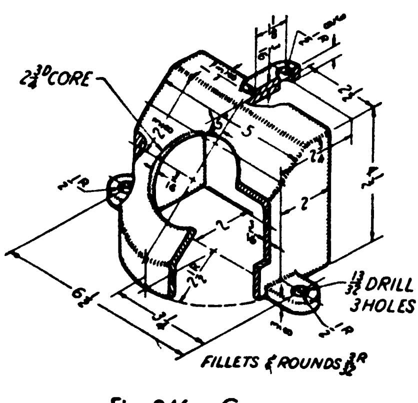


Fig. 246. Gear cover.

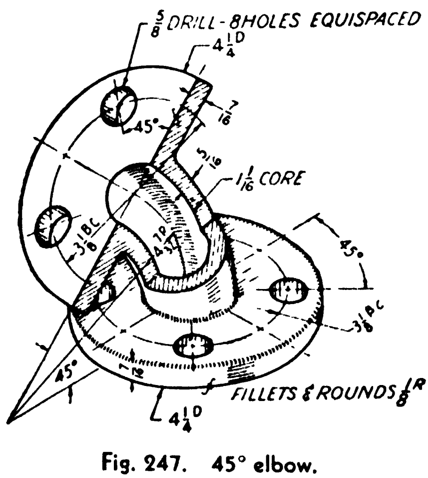


Fig. 247. 45° elbow.

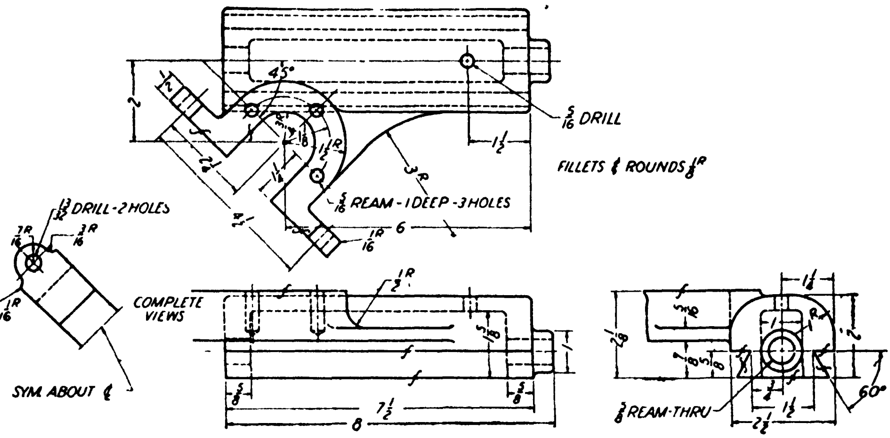


Fig. 248. Sliding tool base.

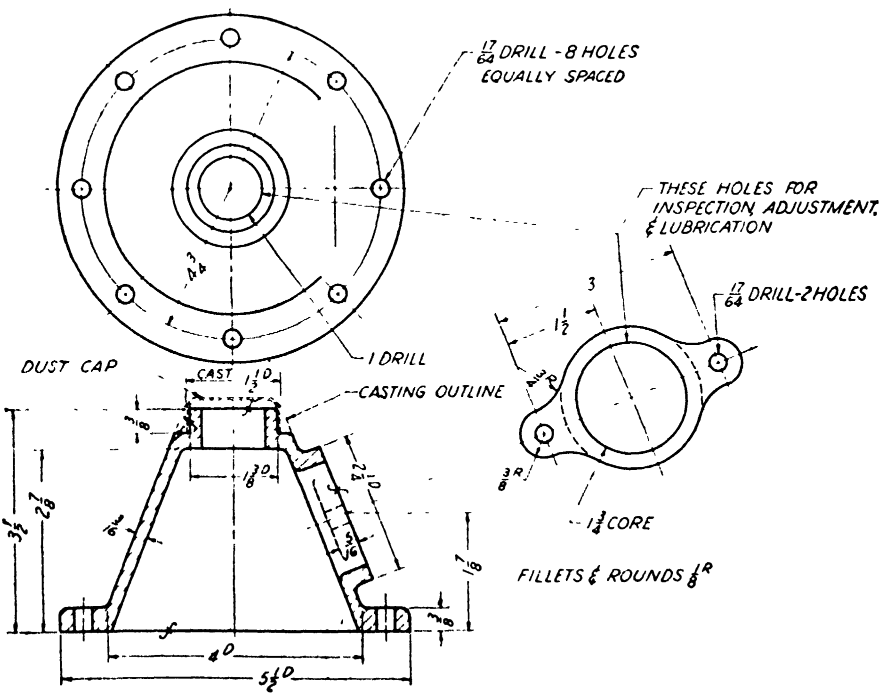


Fig. 249. Housing cover.

11

REVOLUTION

173. Revolution. Although in general the views on a working drawing represent satisfactorily an object in a fixed natural position, it sometimes is desirable to revolve an elemental part until it is parallel to a co-ordinate plane in order to improve the representation or to reveal the true size and shape of a principal surface.

The distinguishing difference between this method and the method of auxiliary projection is that, in the procedure of revolution, the observer turns the object with respect to himself instead of shifting his viewing position with respect to an oblique surface of the object.

174. Simple (single) revolution. When the regular views are given, an object may be drawn in any oblique position by imagining it to be

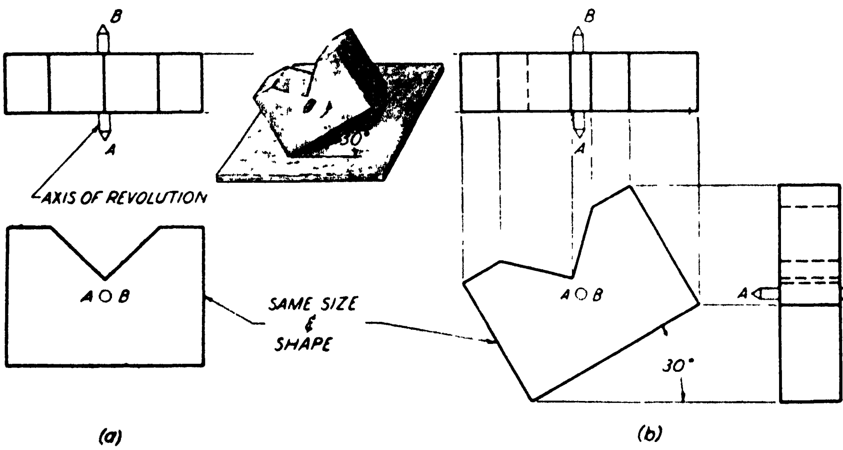


Fig. 250. A single revolution about an axis perpendicular to the front plane.

revolved about an axis perpendicular to one of the principal co-ordinate (top, front, or side) planes. A single revolution about such an axis is known as a "simple revolution." Figs. 250, 251, and 252 illustrate the three general cases.

175. Revolution about a horizontal axis perpendicular to the front plane. A simple revolution about an axis perpendicular to the front plane is illustrated in Fig. 250. The object is first revolved about an imaginary assumed axis, AB, until it is in the desired position. The views of it then are obtained by orthographic projection, as in the case of any ordinary multiview drawing. Because the front face revolves parallel to the front plane, the projection on that plane will change in position but will retain its true size and shape. For this reason, the most convenient drawing procedure is to first copy the front view, as it is shown in (*a*), in its new revolved position (say at 30 degrees). Then, since the depth of the top view is unchanged by the revolution of the object, the required top view can be drawn easily by projecting each point horizontally from the top view in (*a*) to a projection line drawn upward through the corresponding point on the revolved front view in (*b*). The side view may be constructed by regular projection.

The front view may be drawn directly in a revolved position, without first drawing the normal orthographic front view. If this procedure is followed, the depth of the top and side views may be set off to the known dimensions.

176. Revolution about a vertical axis perpendicular to the top plane. If an object is revolved about an imaginary axis perpendicular to the top plane, as shown in Fig. 251, the top view changes in position but not

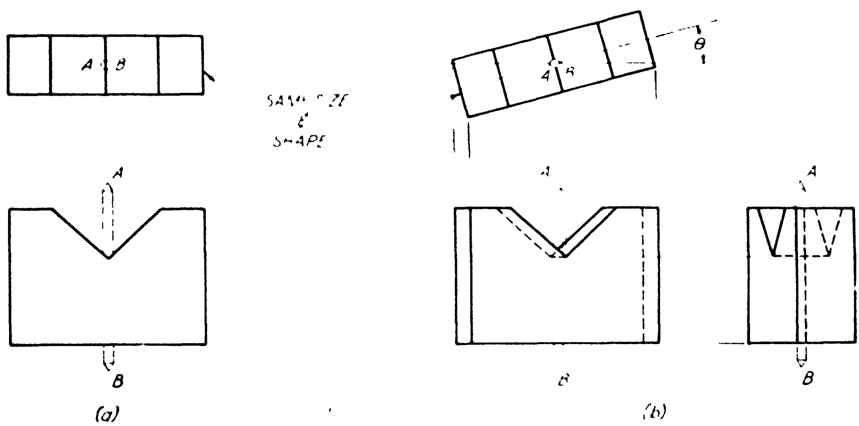


Fig. 251. A single revolution about an axis perpendicular to the top plane.

in size and shape. The top view therefore should be drawn first in its revolved position, and the front and side views should be projected from it. The height of the front view and the side view is the same as the height of the normal front and side views.

177. Revolution about a horizontal axis perpendicular to the side plane. A single revolution of an object about an axis perpendicular to the side or profile plane is illustrated in Fig. 252. In this case it is the side view that remains unchanged in size and shape. The length of the top and front views is not affected by the revolution. Therefore, horizontal dimensions for these views may be set off by measurement.

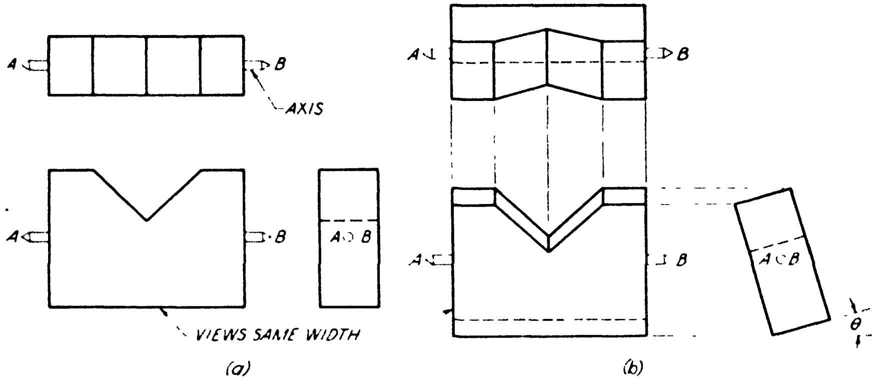


Fig. 252. A single revolution about an axis perpendicular to the side plane.

From these general cases of simple revolution, two principles have appeared which can be stated as follows:

1. The view that is perpendicular to the axis of revolution changes only in position.
2. The lengths of the lines parallel to the axis do not change during the revolution and, therefore, may be projected from the normal views of the object.

178. Clockwise and counterclockwise revolution. An object may be revolved either clockwise or counterclockwise about an axis of revolution. The direction is indicated by the view to which the axis is perpendicular.

179. Successive (multiple) revolution. Since it is possible to draw an object in any oblique position relative to the co-ordinate planes, it is possible to show it revolved through a series of successive simple revolutions. Usually such a series is limited to three or four stages. Fig. 253 shows an object revolved successively about three separate axes. The normal orthographic view is shown in space I. In space II, the object has been revolved clockwise through an angle of 30 degrees about an axis perpendicular to the front plane. Next, in space III, the object has been revolved counterclockwise from its position in space II through an angle of 15 degrees about an axis perpendicular to the top plane. From this position, represented in space III, the object is revolved clockwise through 15 degrees into the position shown in space IV.

180. To find the true length of a line by revolution. In engineering drafting, it frequently is necessary to determine the true length of an oblique line when constructing the development of a surface.

The practical as well as the theoretical procedure is to revolve any such oblique line into a position parallel to a co-ordinate plane so that its projection on that particular plane will be the same length as the line. In Fig. 254(*a*), this is illustrated by the edge *AB* on the pyramid. *AB* is oblique to the co-ordinate planes and its projections are foreshortened. If this edge line is imagined to be revolved until it becomes parallel to the front plane, then the projection ab_r in the front view will be the same length as the true length of *AB*.

A practical application of this method is shown in Fig. 254(*c*). The true length of the edge *AB*, in Fig. 254(*a*), would be found by revolving

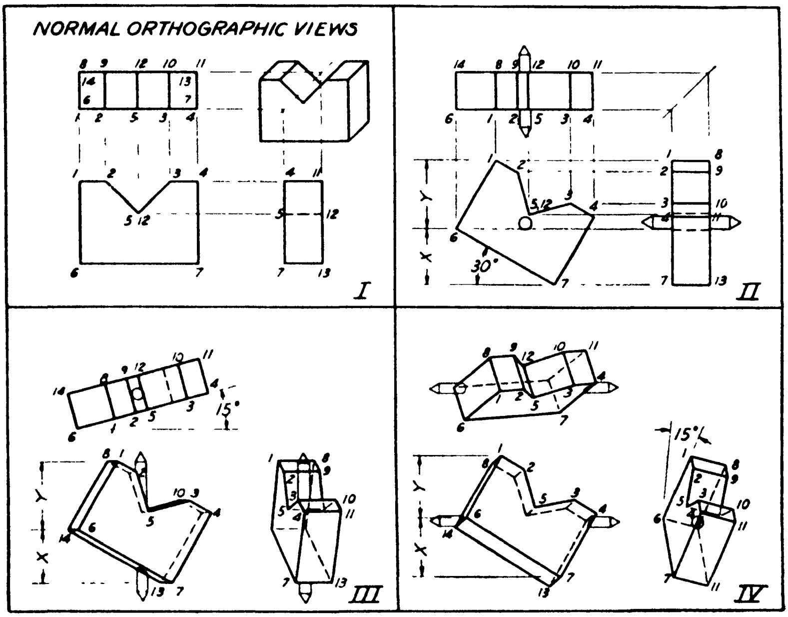


Fig. 253. Successive revolution.

its top projection into the position ab_r representing *AB* revolved parallel to the front plane, and then projecting the end point b_r down into its new position along a horizontal line through *b*. The horizontal line represents the horizontal plane of the base in which the point *B* travels as the line *AB* is revolved.

Commercial draftsmen who are unfamiliar with the theory of co-ordinate planes find the true length projection of a line by visualizing the line's revolution. They think of an edge as being revolved until it is in a plane perpendicular to the line of sight of an observer stationed an infinite distance away.

Note in Fig. 254(*a* and *b*) that the true length of a line is equal to the hypotenuse of a right triangle whose altitude is equal to the difference in the elevation of the end points and whose base is equal to the top

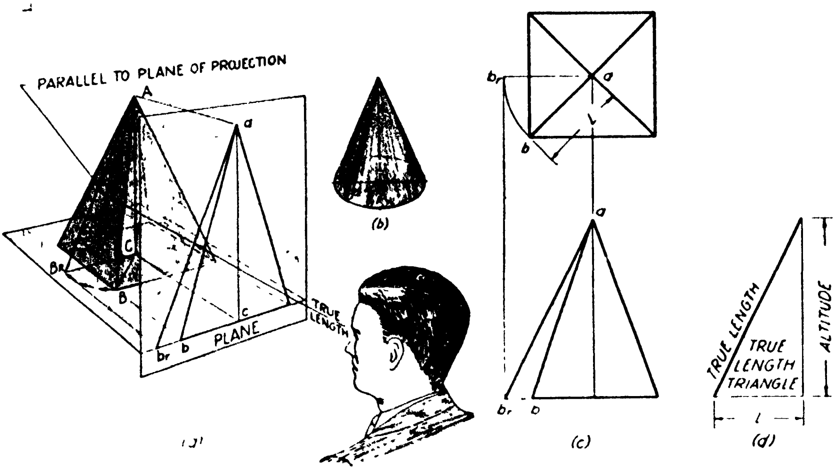


Fig. 254. True length of a line, revolution method.

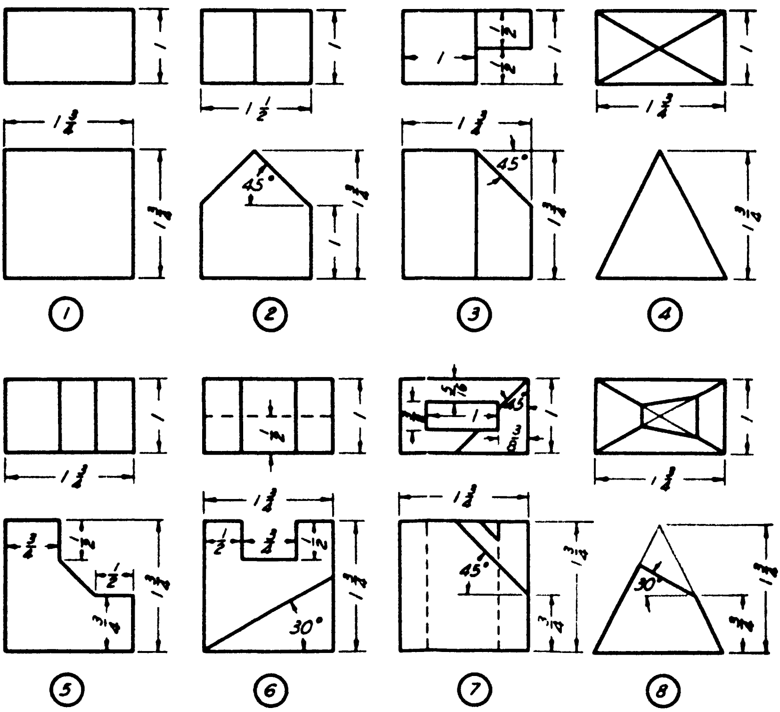


Fig. 255.

projection of the line. With this fact in mind, many draftsmen determine the true length of a line by constructing a true-length triangle similar to the one illustrated in Fig. 254(*d*).

181. Problems. The following problems in revolution furnish excellent drill in projection and offer the student a chance to develop further his imagination and ability to visualize in three dimensions. It will be found worth while to number all the corners of each object used, both on the normal views and on the views of the successive stages.

1–8. Divide, into four equal areas, the space inside the border line of a sheet of drawing paper. In the upper left-hand space, draw the normal orthographic views of an object assigned from Fig. 255. In the lower left-hand space, show the object revolved through an angle of 30° about an axis perpendicular to the front plane (see Fig. 250). In the upper right-hand space, show a simple revolution from the normal orthographic view about an axis perpendicular to the top plane (see Fig. 251). Revolve the object through an angle of 30°. Complete the drawing by making a simple revolution about an axis perpendicular to the side or profile plane (see Fig. 252). Revolve the object from the original normal position through an angle of 30°.

9–16. Divide a sheet of drawing paper into four equal areas and make a series of successive revolutions of an object assigned from Fig. 255. Revolve the object through the three stages shown in Fig. 253. Make the revolutions in the following order. (1) in the lower left-hand space, revolve the object through an angle of 30°, about an axis perpendicular to the front plane; (2) in the lower right-hand space, revolve the object from its previous position through an angle of 15° about an axis perpendicular to the top plane; (3) in the upper right-hand space, make a revolution through an angle of 15° about an axis perpendicular to the side or profile plane.

12

INK WORK AND TRACING

182. Inking a working drawing. An original working drawing is never sent to the shop. Instead, it is safely filed away in the engineering department. The shop gets a blueprint. Prints may be made from pencil drawings which have been executed on light bond tracing paper or pencil cloth, or from inked tracings done on cloth.

183. Use of the ruling pen. The ruling pen is used to ink mechanical lines. It is always guided by the working edge of a T-square, triangle, or French curve, and is never used freehand.

When ruling a line, the pen should be in a vertical plane and inclined slightly (approximately 60 degrees) in the direction of the movement. It is held by the thumb and forefinger, as illustrated in Fig. 256, with the blade against the second finger and the adjusting screw on the outside away from the ruling edge. The third and fourth fingers slide along the T-square blade and help control the pen. Short lines are drawn with a hand movement; long lines with a free arm movement which finishes with a finger movement. While drawing, the angle of inclination and speed must remain constant to obtain a line of uniform width and straightness. Particular attention should be given to the position of the pen, as practically all faulty lines are due to incorrect inclination or to leaning the pen so that the point is too close to the straightedge or too far away from it.

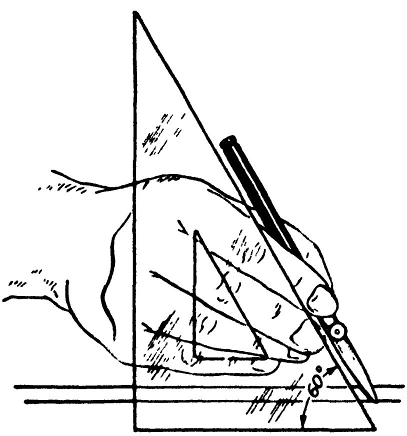


Fig. 256. Holding the pen.

If the pen is held so that it leans outward, as shown in Fig. 257(*a*), the point will be against the straightedge, and ink will run under and cause a blot; or, if it leans inward, as in Fig. 257(*b*), the outer nib will not touch the paper and the line will be ragged.

Unnecessary pressure against the straightedge changes the distance between the nibs, which in turn may either reduce the width of the line along its entire length or cause its width to vary as in Fig. 257(*d*).

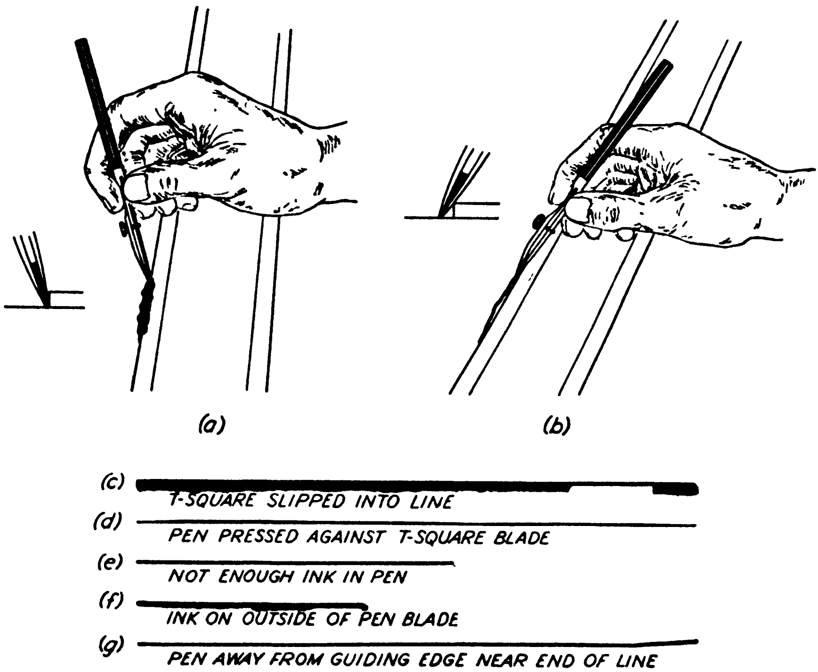


Fig. 257. Common faults in handling a ruling pen.

It will not take any beginner long to discover that care must be taken when removing a T-square or triangle away from a wet ink line.

The ruling pen is filled by inserting the quill or dropper device between the nibs. Care must be taken, while filling, to see that there is enough ink to finish the line and that none of the ink from the filler gets on the outside of the blades. No more than $\frac{1}{4}$ inch should ever be put in, as there is a danger of blotting if the pen is used with a greater amount.

The width of a line is determined by the distance between the nibs, which is regulated by the adjusting screw. When setting the pen, a series of test lines should be drawn with a straightedge on a small piece of the same kind of paper or cloth to establish the setting for the desired width of the line.

Ruling pens will not perform satisfactorily unless kept clean. For the best results, the ruling pen or any inking instrument *always* must be wiped before each refilling, and before laying it down, so that it will be ready for use again. A dirty pen in which the ink has been allowed to thicken will not draw any better than a dull one. To avoid changing the setting of the pen when cleaning it, fold the pen wiper twice at 90 degrees and draw the corner of the fold between the ends of the blades.

Either a speck of ink or a small piece of loose dirt or lint will cause the width of a line to change suddenly for no apparent reason, or will cause the second of two consecutively drawn lines to be broader than the first, even though the setting of the pen has not been changed.

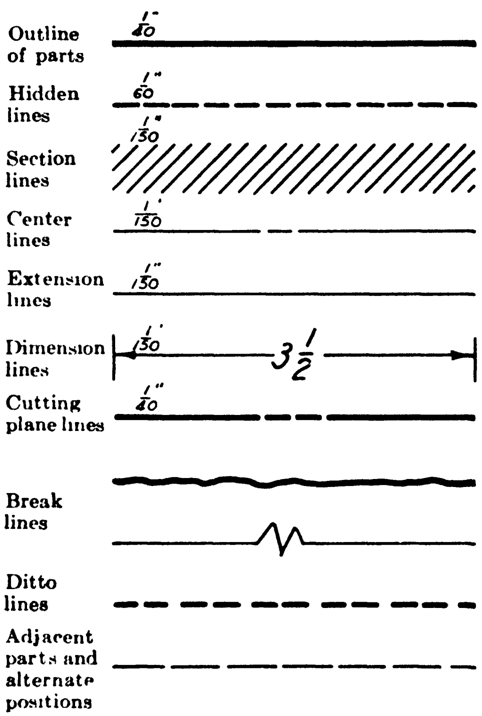


Fig. 258. Conventional ink lines.

If the ink refuses to flow when the pen is touched to the paper, either the ink has thickened or the opening between the nibs has become clogged. To start it flowing, draftsmen often touch the point to the back of a finger or pinch the blades together. Whenever this fails to produce an immediate flow, the pen should be cleaned and refilled.

184. Conventional ink lines. The American Standards Association conventional symbols for ink lines for different purposes are shown in Fig. 258. They have been reproduced full width so that they appear as required for a well-executed ink tracing. Recommended line widths have been given for the conventional lines most commonly used, such as the visible object line, invisible object line, center line, and dimension line.

185. Tracing. Original pencil drawings are traced in ink on a tracing medium, usually tracing cloth. Contrary to the practice of old-time draftsmen, the dull side is now almost universally used for the inking surface instead of the slick side because it produces less light glare, it will take both pencil and ink lines better, and it will withstand more erasing. The fact that the dull side will take pencil lines is important because, on some occasions, in order to save time, drawings are made directly on the cloth and then traced. Upon completion of the tracing, all pencil lines, including the guide lines and slope lines for the lettering, may be removed by wiping the surface of the cloth with a rag which has been moistened with a small amount of gasoline, benzine, or cleaning fluid.

When the tracing cloth has been fastened down over the drawing, a small quantity of tracing cloth powder may be sprinkled over the surface to make it take the ink evenly and smoothly. After it has been well rubbed in, the excess must be thoroughly removed by wiping with a clean cloth, for even a small amount of loose powder left on the surface can cause clogging of the pen. Powder is also used by some persons over a spot where an erasure has been made; but a better practice is to use a piece of soapstone, which will put a smooth, slick finish over the damaged

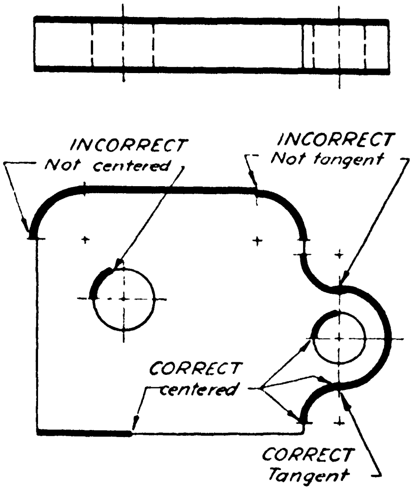


Fig. 259. Inking over pencil lines.

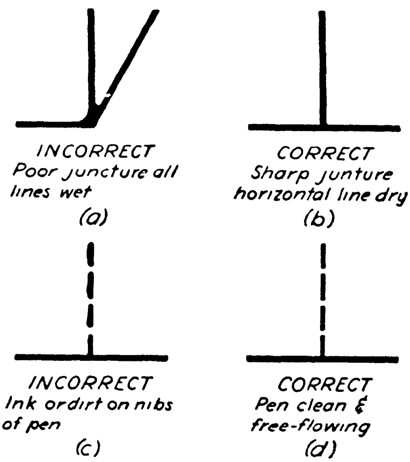


Fig. 260. Ink lines.

area. In applying the soapstone, rub the spot and then wipe a finger over it a few times.

Since ink lines are made much wider than pencil lines, in order to get a good contrast on a blueprint, they should be carefully centered over the pencil lines when tracing. The center of an ink line should fall directly on the pencil line as shown correctly in Fig. 259. For ink work it might be said that ink lines are tangent when their center lines touch. In this same illustration, note the poor junctures obtained when ink lines are not centered so that their center lines are tangent.

Fig. 260(*a*) shows the filled-in corner effect which frequently appears to the disgust of the draftsman, when an ink line is drawn from or to another previously drawn line that is still wet.

When a working drawing is traced in ink on either paper or cloth, the lines should be "inked" in a definite order. Otherwise, the necessity of waiting for the ink to dry after every few lines not only wastes time, but often results in a line here and there being left out. Furthermore, hit-and-miss inking may produce lines of unequal width. It is therefore recommended that the student make a conscientious attempt to follow the order of inking suggested in this chapter.

After the paper or cloth has been fastened down over the drawing, and before the inking is begun, each tangent point should be marked and all centers should be indented.

Order of Inking

I. Curved Lines:
   1. Circles and circle arcs (small circles first) in the order of (*a*), (*b*), and (*c*).
      (*a*) Visible.
      (*b*) Invisible.
      (*c*) Circular center lines and dimension lines.
   2. Irregular curves.
      (*a*) Visible.
      (*b*) Invisible.

II. Straight Lines:
   1. Visible.
      (*a*) Horizontal, from the top of the sheet down.
      (*b*) Vertical, from the left side of the sheet to the right.
      (*c*) Inclined, from the left to the right.
   2. Invisible.
      (*a*) Horizontal.
      (*b*) Vertical.
      (*c*) Inclined.
   3. Auxiliary (center, extension, and dimension lines, etc.).
      (*a*) Horizontal.
      (*b*) Vertical.
      (*c*) Inclined.
      (*d*) Section lines.

III. Arrowheads and Dimension Figures.

IV. Notes and Titles.

V. Border.

186. Use of the drawing ink. All pens are filled by means of a quill or dropper, and *never* by dipping them in the ink.

The bottle should be kept tightly corked at all times when not in use, as India ink evaporates and thickens when exposed to the air.

13

DIMENSIONING

187. A detail drawing, in addition to giving the shape of a part, must furnish the workman with information as to the distances between surfaces, locations of holes, kind of finish, type of material, number required, and so forth. The expression of this information on a drawing by the use of lines, symbols, figures, and notes is known as dimensioning.

Intelligent dimensioning requires engineering judgment and a thorough knowledge of the practices of pattern making, forging, and machining. It should be remembered that the shopman must be able to produce the part exactly as it is designed and shown on the blueprint. He should not be required to seek additional information, add or subtract dimensions, or use his judgment as to a class of fit.

188. Theory of dimensioning. Any part may be dimensioned easily and systematically by dividing it into simple geometrical solids. Even complicated parts, when analyzed, usually are found to be composed principally of cylinders and prisms and, frequently, frustums of pyramids and cones. The dimensioning of an object may be accomplished by dimensioning each elemental form to indicate its size and relative location from a center line, base line, or finished surface. A machine drawing requires two types of dimensions: *size dimensions* and *location dimensions.*

189. Size dimensions. Size dimensions give the size of a piece, component part, hole, or slot.

Fig. 261 should be carefully analyzed, as the placement of dimensions shown is applicable to the elemental parts of almost every piece.

The rule for placing the three principal dimensions (length, breadth, thickness) on the drawing of a prism or modification of a prism is: *Give two dimensions on the principal view and one dimension on one of the other views.*

The circular cylinder, which appears as a boss or shaft, requires only *the diameter and length, both of which are shown preferably on the rectangular view.* It is better practice to dimension a hole (negative cylinder) by giving the diameter and operation as a note on the contour view with a leader to the circle (Fig. 295).

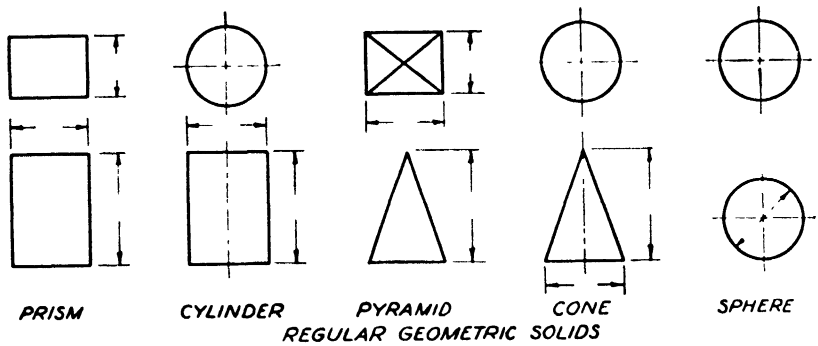


Fig. 261. Dimensioning geometrical shapes.

Cones are dimensioned by giving the diameter of the base and the altitude on the same view. A taper is one example of a conical shape found on machine parts (Fig. 292).

A sphere requires only the diameter.

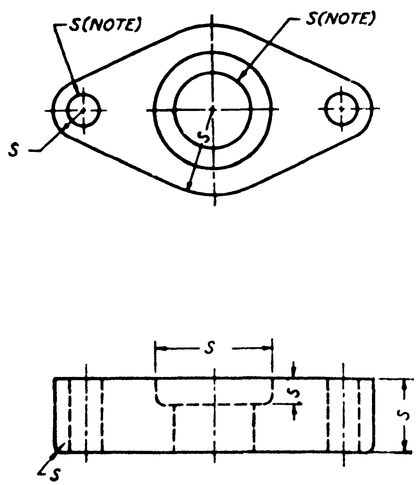


Fig. 262. Size dimensions.

190. Location dimensions. Location dimensions fix the relationship of the component parts (projections, holes, slots, and other significant forms) of a piece or structure. Particular care must be exercised in their selection and placing, because upon them depend the accuracy of the operations in making a piece and the proper mating of the piece with other parts. To select location dimensions intelligently, the draftsman should determine the contact surfaces, finished surfaces, and center lines of the elementary geometrical forms and, with the accuracy demanded and the method of production in mind, decide from what other surface or center line each should be located. Mating location dimensions must be given from the same center line or finished surface on both pieces.

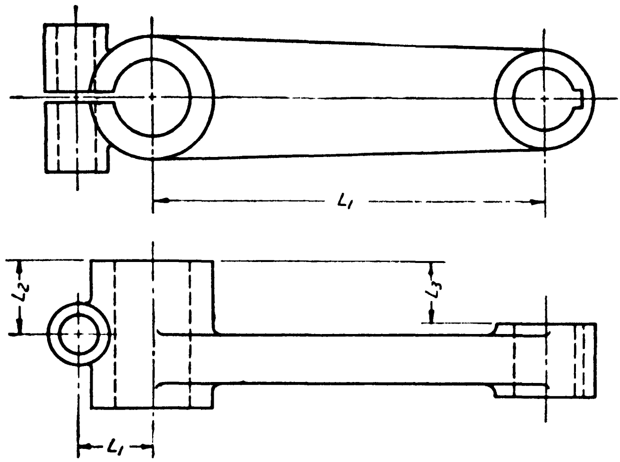


Fig. 263. Types of location dimensions.

Location dimensions are given center to center, surface to center, or surface to surface. Fig. 263 illustrates each of these cases.

191. Placing dimensions. Dimensions must be placed where they will be most easily understood—in the locations where the shopman will expect to find them. They generally are attached to the view that shows the contour of the features to which they apply, and a majority of them usually will appear on the principal view.

Spacing dimension lines ½″ from the view and ⅜″ from each other provides an ample distance to satisfy the one rule to which there is no exception: *Never crowd dimensions.*

Dimensioning Practices

192. A generally recognized system of lines, symbols, figures, and notes is used to indicate size and location. Fig. 265 illustrates dimensioning terms and notation.

A *dimension line* is lightweight and continuous, broken only near the center to receive the figure giving the distance that it indicates. It is terminated at each end by an arrowhead whose point touches the extension line (Fig. 265).

Fig. 264. A dimension line.

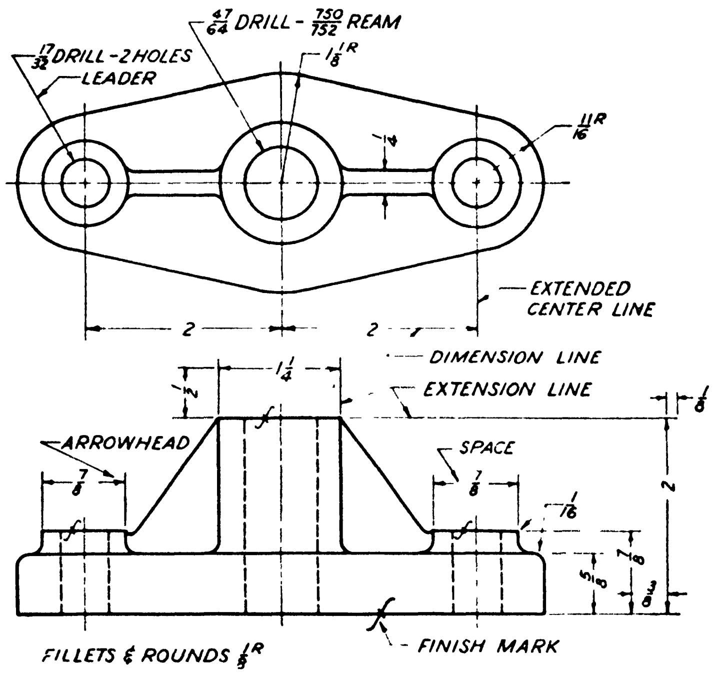


Fig. 265. Terms and dimensioning notation.

Extension lines are light continuous lines extending from a view to indicate the extent of a measurement given by a dimension line that is located outside of a view. They start $\frac{1}{16}''$ from the view and extend $\frac{1}{8}''$ beyond the dimension line (Fig. 265).

Arrowheads are drawn for each dimension line, before the figures are lettered. They are made with the same pen or pencil used for the lettering. To have the proper proportions, the length of an arrowhead must be approximately three times its spread (American Standard). This length for average work is usually $\frac{1}{8}''$. Fig. 266 shows enlarged drawings of both correct and incorrect heads. Although many draftsmen draw an arrowhead with one stroke, the beginner will get better results by using two slightly concaved strokes drawn toward the point (Fig. 267*a*) or, as shown in Fig. 267(*b*), one stroke drawn to the point and one away from it.

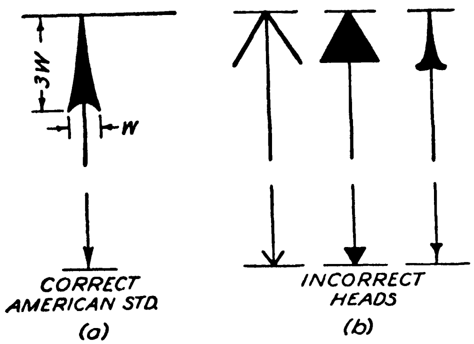


Fig. 266. Arrowheads.

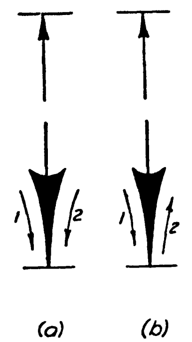


Fig. 267. Formation of arrowheads.

A *leader* or *pointer* is a light continuous line (terminated by an arrowhead) which extends from a note to the feature of a piece to which the note applies. It should be made with a straightedge.

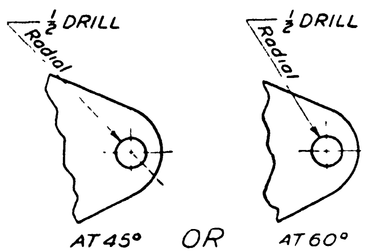


Fig. 268. A leader.

A leader pointing to a curve should be radial, and the first $\frac{1}{8}''$ of it should be in line with the note (Fig. 268).

Finish marks indicate the particular surfaces of a rough casting or forging which are to be machined or "finished." They are placed in all views, across the visible or invisible lines which are the edge views of surfaces to be machined.

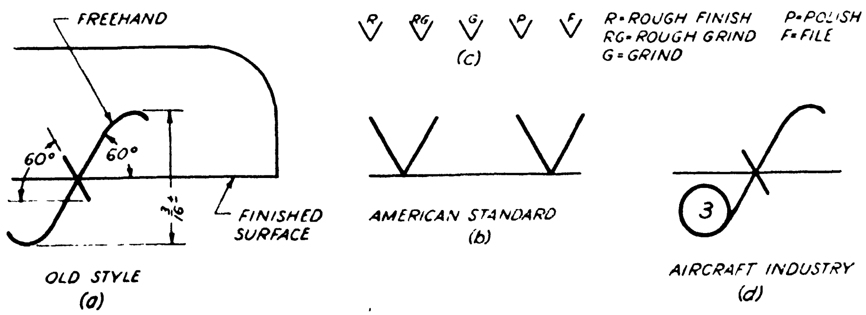


Fig. 269. Finish mark.

The modified italic *f*, shown in Fig. 269(*a*), is still widely used in spite of the fact that new forms have been recommended by the American Standards Association.

Fig. 269(*b*) shows the ASA recommended 60 degree *V* with its point touching the line view of the surface to be machined. In commercial practice a code letter oftentimes is used to indicate the type of machining required. The code letter or letters are placed in the *V* as shown in (c).

Fig. 269(*d*) shows the type of finish mark used by some aircraft companies. The numeral in the circle expresses the type of finish.

It is not necessary to show finish marks on drilled or reamed holes, when the finish is specified as an operation in a note, such as $\frac{3}{4}''$ Drill or 1″ Ream. They are also omitted, and a title note, "finish all over," is substituted, if the piece is to be completely machined. Finish marks are not required when limit dimensions are used.

Dimension figures should be lettered either horizontal or vertical with the whole numbers equal in height to the capital letters in the notes. Guide lines and slope lines must be used and should be drawn with the Braddock Triangle, as shown in Fig. 83.

193. General dimensioning practices.

The reasonable application of the selected dimensioning practices that follow should enable a student to dimension acceptably. The practices in boldfaced type should never be violated. In fact, these have been so definitely established by practice that they might be called rules.

1. Place dimensions so that they can be read from the bottom and right side of the drawing (Fig. 265). An exception to this rule should be made in the preparation of aircraft drawings (Fig. 270). This industry, along with a few manufacturing firms in other fields, uses the unidirectional system under which all dimensions are made to read from the bottom of the sheet.

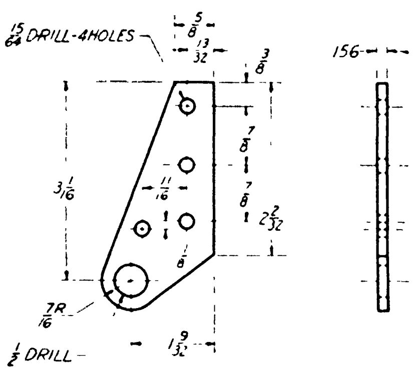


Fig. 270. Unidirectional system.

2. Place dimensions outside a view, unless they will be more easily and quickly understood if shown on it.

3. Place dimensions between views unless the rules such as the contour rule, the rule against crowding, and so forth, prevent their being so placed.

4. Do not use an object line or a center line as a dimension line.

5. Locate dimension lines so that they will not cross extension lines.

6. If possible, avoid crossing two dimension lines.

7. A center line may be extended to serve as an extension line (Fig. 271).

8. Keep parallel dimensions equally spaced (usually $\frac{3}{8}''$ apart) and the figures staggered.

9. Always give locating dimensions to the centers of circles which represent holes, cylindrical projections, or bosses (Fig. 273).

10. If possible, attach the location dimensions for holes to the view upon which they appear as circles (Fig. 272).

11. Group related dimensions on the view showing the contour of a feature.

12. Arrange a series of dimensions in a continuous line.

13. Dimension from a finished surface, center line, or base line that can be readily established (Fig. 273).

14. Stagger the figures in a series of parallel dimension lines to allow sufficient space for the figures and to prevent confusion (Fig. 274).

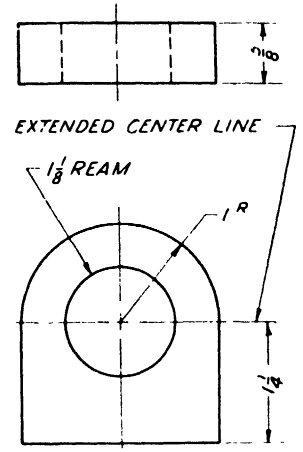


Fig. 271. Extended center line.

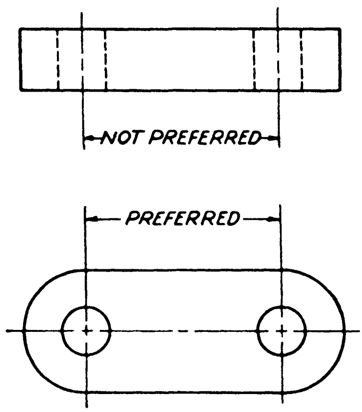


Fig. 272. Locating holes.

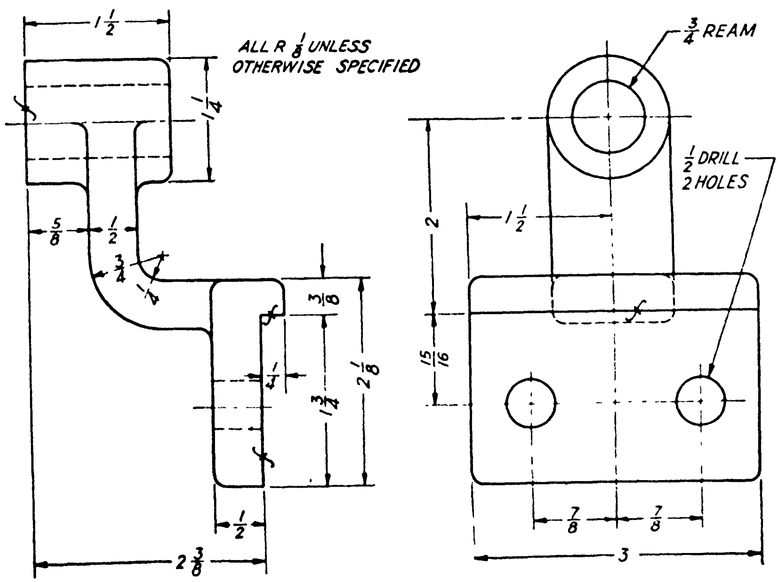


Fig. 273. Dimensioning a bracket.

15. Place longer dimensions outside shorter ones so that extension lines will not cross dimension lines.

16. Give three over-all dimensions located outside any other dimensions (unless the piece has cylindrical ends). When an over-all is given, one inter-

mediate distance should be omitted unless noted (REF) as being given for reference.

17. Do not repeat a dimension. One of the duplicated dimensions may be missed if a change is made. Give only those dimensions that are necessary to produce or inspect the part.

18. Make decimal points of a sufficient size that dimensions cannot be misread.

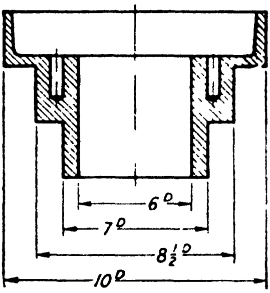


Fig. 274. Parallel dimensions.

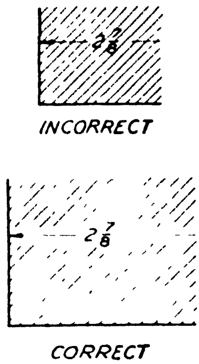


Fig. 275. Dimension figures on a section view.

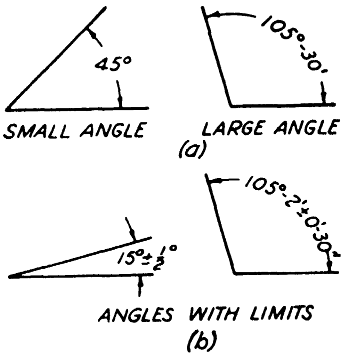


Fig. 276. Angular dimensions.

19. When dimension figures appear on a sectional view, show them in a small uncrosshatched portion so that they may be easily read. This may be accomplished by doing the section lining after the dimensioning has been completed (Fig. 275).

20. When an arc is used as a dimension line for an angular measurement, use the vertex of the angle as the center.

21. Place the figures of angular dimensions so they will read from the bottom of a drawing, except in the case of large angles (Fig. 276).

22. Always dimension an arc by giving its radius followed by the abbreviation *R*, and indicate the center with a small cross.

23. Show the diameter of a circle, never the radius. If it is not clear that the dimension is a diameter, the figures should be followed by the abbreviation *D* (Figs. 277 and 278). Often this will allow the elimination of one view.

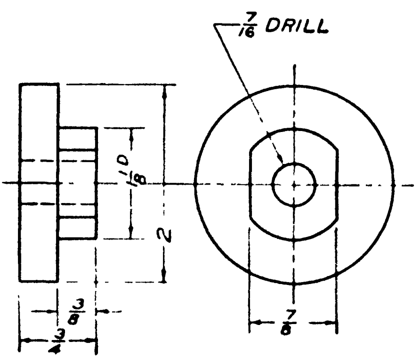


Fig. 277. Dimensioning a cylindrical part.*

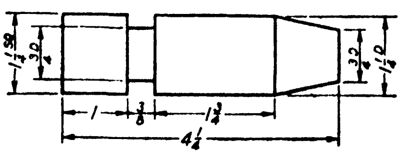


Fig. 278. Use of "D" in dimensioning cylindrical shapes.*

* ASA Z14.1-1935.

24. Letter all notes horizontally.

25. Make dimensioning complete, so that it will not be necessary for a workman to add or subtract to obtain a desired dimension or to scale the drawing.

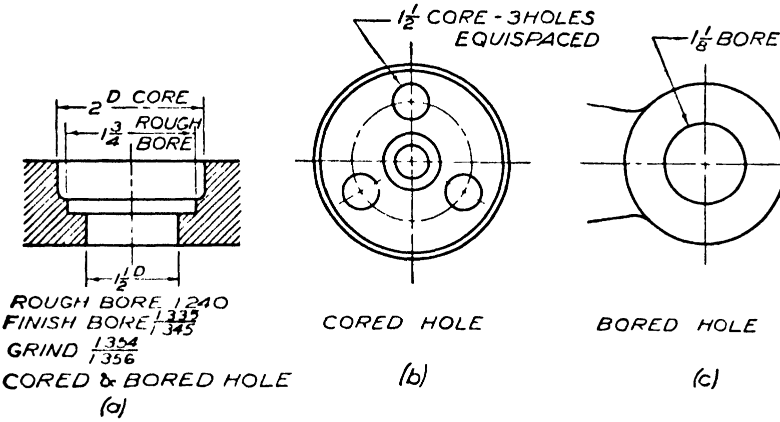


Fig. 279. Dimensioning cored and bored holes.

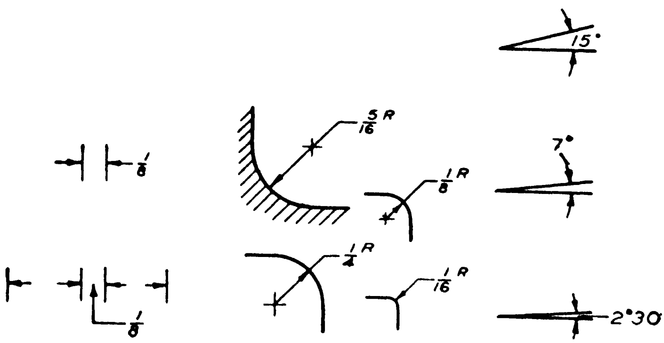


Fig. 280. Dimensioning in limited spaces.

26. Letter the word *bore* or *core* with the diameter of bored or cored holes (Fig. 279).

27. Give the diameter of a circular hole, never the radius, because all hole-forming tools are specified by diameter. If the hole does not go through the piece, the depth may be given as a note.

28. Never crowd dimensions into small spaces. Use the practical methods suggested in Fig. 280.

29. Avoid placing inclined dimensions in the shaded areas on Fig. 281. Place them so that they may be conveniently read from the bottom and right side of the drawing. If this is not possible, make the figures read from the left in the direction of the dimension line (Fig. 281).

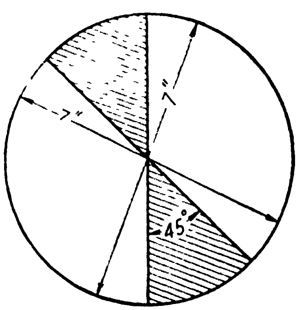


Fig. 281.

30. Omit superfluous dimensions. Do not supply dimensional information for the same feature in two different ways.

31. Give dimensions up to 72″ in inches, except on structural and architectural drawings (Fig. 282). Omit the inch marks when all dimensions are in inches.

Fig. 282. Dimension values.

32. Show dimensions in feet and inches as illustrated in Fig. 283. Note that the use of the hyphen in (*a*) and (*b*), and the cipher in (*b*), eliminates any chance of uncertainty and misinterpretation.

Fig. 283. Feet and inches.

33. Dimension a 45 degree chamfer by giving the width and angle as a note (Fig. 284) or as shown in (*b*).

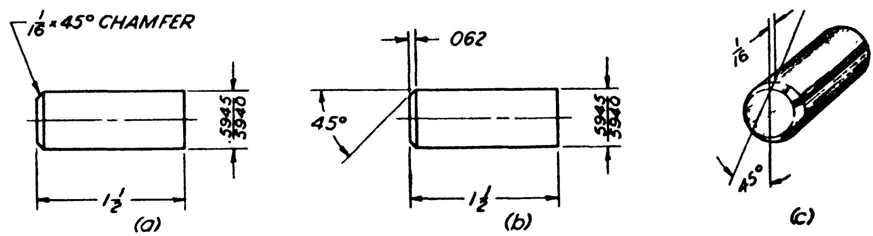


Fig. 284. Dimensioning a chamfer.

34. Dimension equally spaced holes in a circular flange by giving the diameter of the bolt circle, across the circular center line, and the size and number of holes in a note.

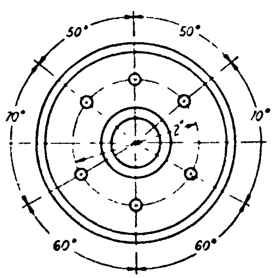


Fig. 285. Unequally spaced holes.

35. When holes are unequally spaced in a circular flange, give the angles as illustrated in Fig. 285.

36. Holes that must be very accurately located should be dimensioned using a co-ordinate method (Fig. 286 and 287), rather than through the use of angular measurements as illustrated in Fig. 285.

37. Dimension a curved line by giving offsets (Fig. 288) or radii (Fig. 289).

38. Show an offset dimension line for an arc having an inaccessible center. Locate with true dimensions the point placed in a convenient location which represents the true center (Fig. 289).

39. Dimension, as required by the method of production, a piece with rounded ends (see Figs. 290 and 291).

(*a*) Give the dimensions representing the diameter of the cutter and the travel of the table for a slot that is to be machined on a milling machine (see Fig. 290*a*).

(*b*) Give the width and over-all length for Pratt and Whitney keyways. This is the manner in which the keys are specified (see Fig. 290*b*).

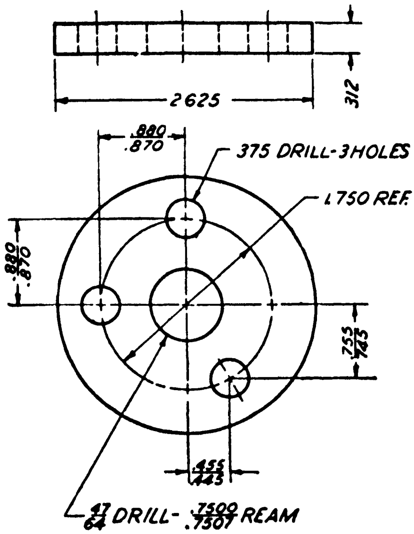


Fig. 286. Accurate location dimensioning of holes.

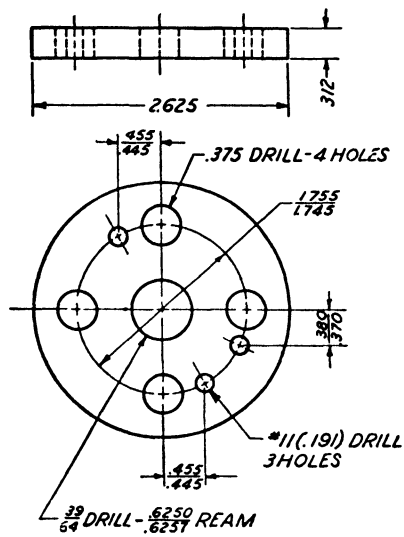


Fig. 287. Accurate location dimensioning of holes.

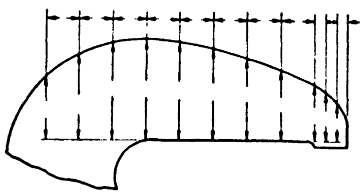


Fig. 288. Dimensioning curves by offsets.*

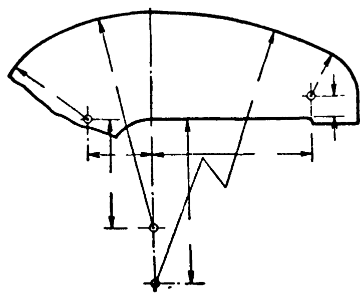


Fig. 289. Dimensioning curves with radii.*

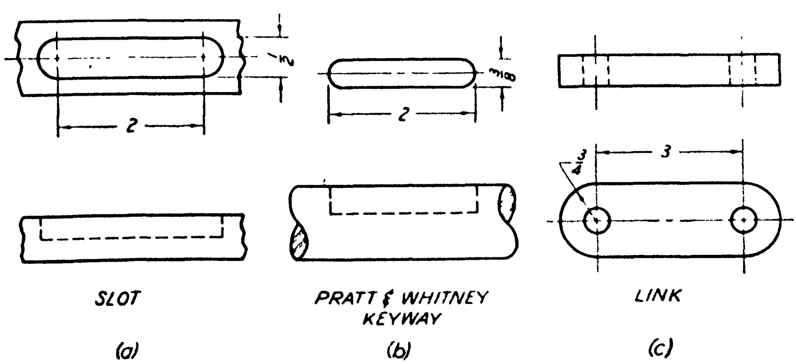
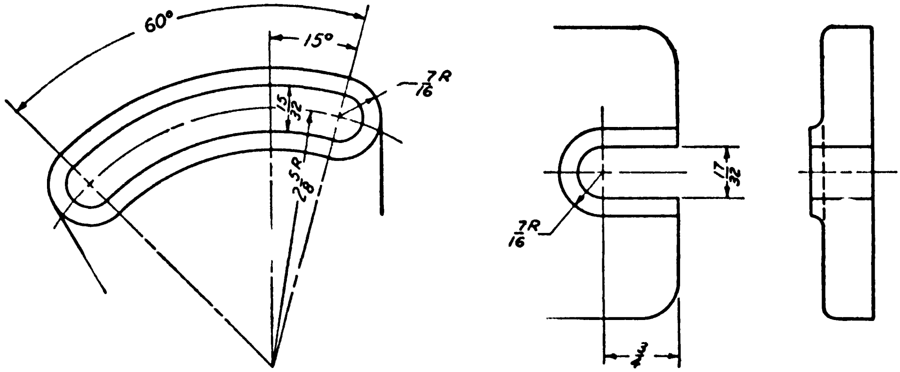


Fig. 290. Dimensioning pieces with rounded ends.

* ASA Z14.1-1946.



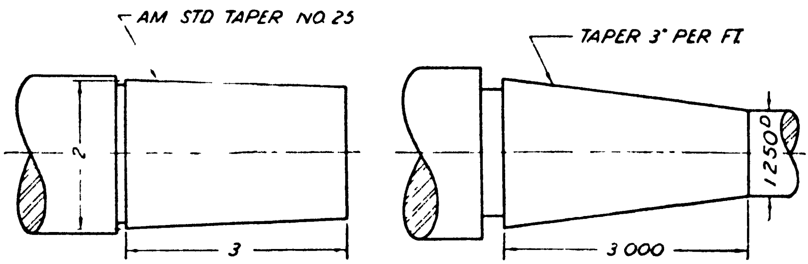
(a) (b)

Fig. 291. Semicircular features.

(c) Give the radii and center-to-center distance on parts that would be laid out by using centers and radii. *Do not show an over-all dimension.* It is not required. (See Fig. 290c.)

40. Dimension standard and special tapers as illustrated in Fig. 292.

(a) Standard tapers require one diameter, the length, and a note specifying the taper by number. (American Standard.) (See Fig. 292a.)



STANDARD TAPER (American Standard)

SPECIAL TAPER

(a) (b)

Fig. 292. Dimensioning a taper.

(b) Special tapers require one diameter, the length, and a note, "Taper per ft." Often two diameters are shown and the length is omitted. ("Taper per foot" is the difference in diameter in one foot.)

41. Indicate a changed dimension or a dimension not to scale, by one of the methods illustrated in Fig. 293.

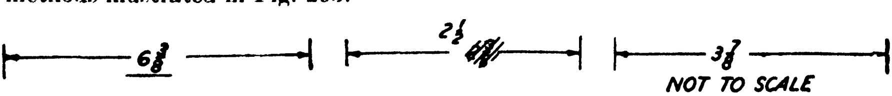


Fig. 293. Changed dimensions.

42. A half section may be dimensioned through the use of hidden lines on the external portion of the view.

194. Base-line dimensioning. In certain types of precision work, principally diemaking, all dimensions are given from base lines. These may be finished surfaces at right angles or important center lines. The use of this method prevents cumulative errors, as each dimension is independent of the others (Fig. 294).

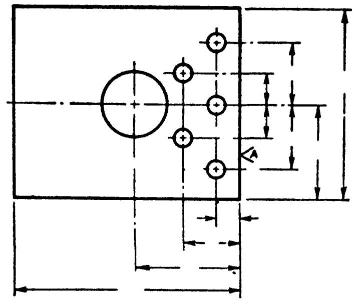


Fig. 294. Base-line dimensioning.

195. Notes. The use of properly composed notes often adds clarity to the presentation of dimensional information involving specific operations. Notes also are used to convey supplementary instructions as to the kind of material, kind of fit, degree of finish, and so forth (Fig. 295). It is good practice to specify a dimension representing a tool operation or a series of tool operations by a note rather than by figured dimensions. Brevity in form is desirable for notes of general information or specific instruction.

196. Fractional and decimal dimensioning. For ordinary work, where accuracy is relatively unimportant, shopmen work to nominal dimensions given as common fractions of an inch, as $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$, $\frac{1}{64}$. When dimensions are given in this way, many large corporations specify the required accuracy through a note on the drawing which reads as follows: *Permissible variations on common fraction dimensions to machined surfaces to be plus or minus .010 unless otherwise specified.* It should be understood that the allowable variations will differ among manufacturing concerns because of the varying degrees of accuracy required for different types of work.

When greater accuracy is required, the American Standards Association recommends a complete decimal system of dimensioning in American Standard for Drawings and Drafting Room Practice (Z14.1-1946).

Fig. 296 shows the application of the complete decimal system in dimensioning a plate. In Fig. 297 a drawing is shown which was obtained from the Ford Motor Co., where some years ago, the decimal system was adopted principally for precision work.

197. Limit dimensions. Present-day competitive manufacturing requires quantity production and interchangeability for many closely mating cylindrical parts made and assembled in different factories. The production of each of these mating parts to an exact decimal dimension, although theoretically possible, is economically unfeasible, since the cost of a part rapidly increases as an absolute correct size is approached. For this reason, the commercial draftsman specifies an allowable error (tolerance) between decimal limits (see Figs. 284, 287, and 297). The determination of these limits depends upon the accuracy and clearance required for the moving parts to function satisfactorily in the machine.

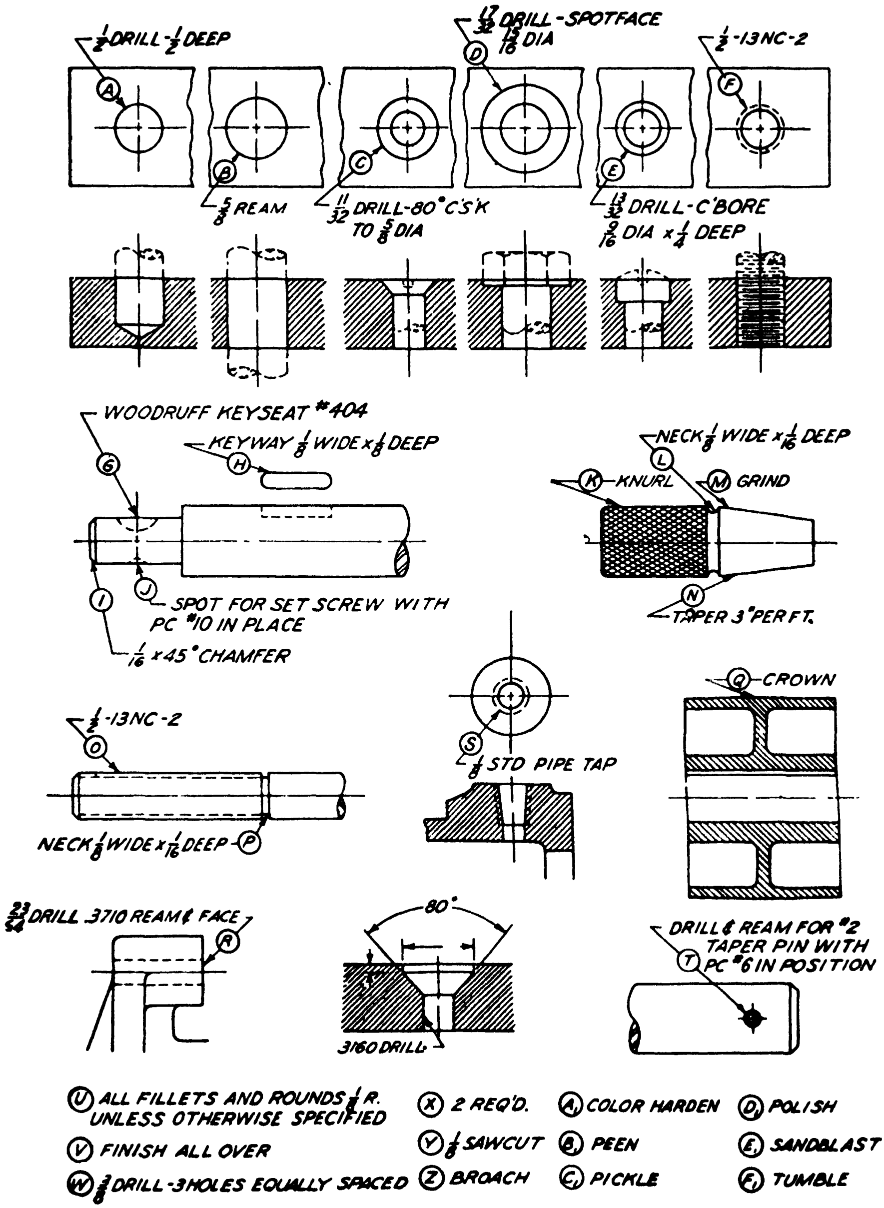


Fig. 295. Shop notes.

Although manufacturing experience is often used to determine the proper limits for the parts of a mechanism, it is better and safer practice to adhere to the eight classes of fits recommended by the American Standards Association in ASA-B4a-1925.

198. Problems. The following problems offer the student the opportunity to apply the rules of dimensioning given in this chapter.

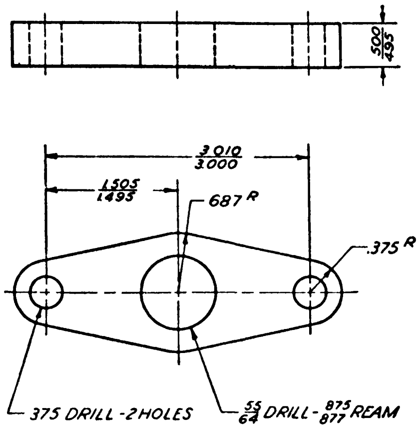


Fig. 296. Decimal dimensioning.

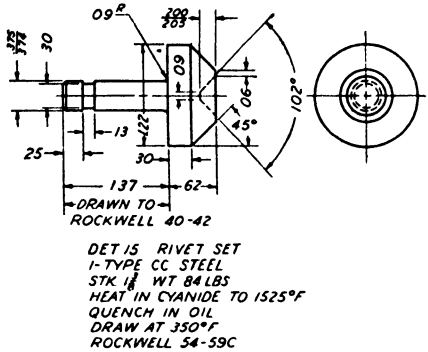


Fig. 297. Ford Motor Company decimal system.

1–6. (Fig. 298.) Reproduce the given views of an assigned part. Determine the dimensions by transferring them from the drawing to the open-divided scale, by means of the dividers.

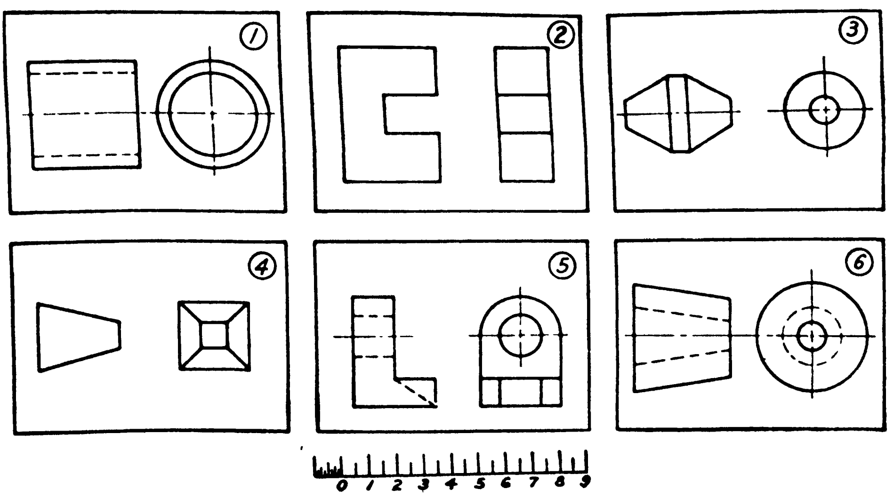


Fig. 298. Dimensioning problems.

14

SCREW THREADS, FASTENERS, AND WELDING

199. In the commercial field, where the practical application of engineering drawing takes the form of working drawings, screw threads and fasteners are important in design. There is always the necessity for assembling parts together either with permanent fastenings, such as rivets, or with bolts, screws, and so forth, which may be removed quite easily.

Detailers and draftsmen must be completely familiar with the common types of threads and fastenings, as well as their use and correct methods of representation, because of the frequency of their occurrence in structures and machines. Information concerning special types of fasteners may be obtained from manufacturers' catalogues.

200. Threads. The principal uses of threads are: (1) for fastening, (2) for adjusting, and (3) for transmitting power.

The American Standard (National Form *N*) thread with flattened crests and roots is the thread most widely used in the United States. The sharp *V* has been practically superseded by the American Standard but is still used to some extent where adjustment and holding power are essential.

For the transmission of power and motion, the square, Acme, and Brown and Sharpe worm threads have been adopted. The square thread with its vertical faces transmits power parallel to its axis. A modification of the square thread is the stronger Acme, which is easier to cut and more readily disengages split nuts (as lead screws on lathes). The Brown and Sharpe worm thread, with similar proportions but with longer teeth, is used for transmitting power to a worm wheel.

The knuckle thread, commonly found on incandescent lamps, plugs, and so on, can be cast or rolled.

A new Unified Thread Standards (ASA B1. 1-1949) came into existence after the representatives of the United States, Great Britain, and

Canada signed a unification agreement on Nov. 18, 1948 in Washington, D. C. This accord, which made possible the interchangeability of threads for these countries, created a new thread form (Fig. 300) which is a compromise between our own American Standard design and the British Whitworth. The external thread of the new form has a rounded root and may have either a flat or rounded crest.

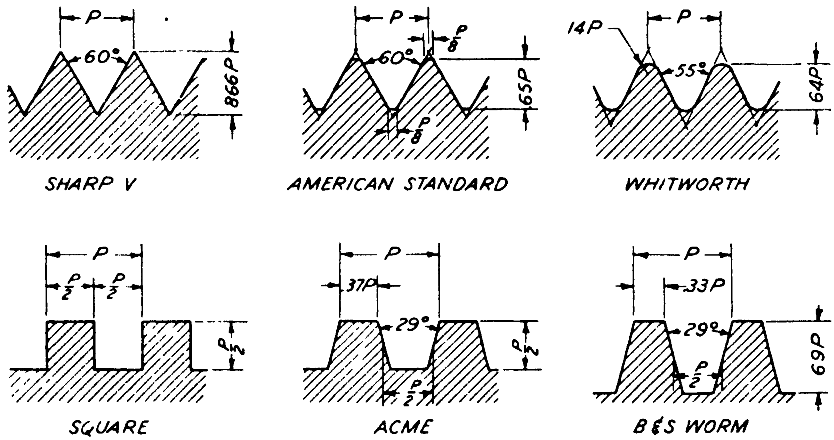


Fig. 299. Screw threads.

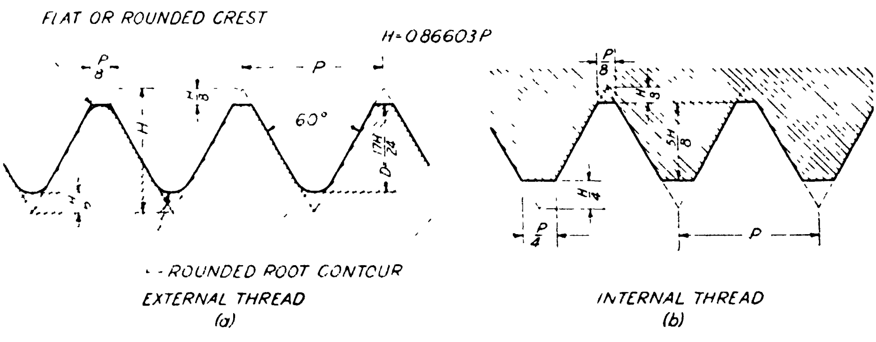


Fig. 300. American-British unified thread.

201. Right-hand and left-hand threads. A right-hand thread advances into a threaded hole when turned clockwise; a left-hand thread advances when turned counter-clockwise. They can be easily distinguished by the thread slant. A right-hand thread on a horizontal shank always slants upward to the left \ and a left-hand upward to the right / . A thread is always considered to be right-hand if it is not otherwise specified. A left-hand thread is always marked *L.H.* on a drawing.

202. Multiple threads. Whenever a quick advance is desired, as on fountain pens, valves, and so on, two or more threads are cut side by side. Two threads form a double thread, three a triple thread, and so on.

203. Pitch. The pitch of a thread is the distance from any point on a thread to the corresponding point on the adjacent thread, measured parallel to the axis as shown in Fig. 299.

204. Lead. The lead of a screw may be defined as the distance advanced parallel to the axis when the screw is turned one revolution. For a single thread, the lead is equal to the pitch; for a double thread, the lead is twice the pitch; for a triple thread, the lead is three times the pitch, and so on.

205. Semiconventional screw-thread representation. The true representation of screw threads by helical curves, requiring unnecessary time

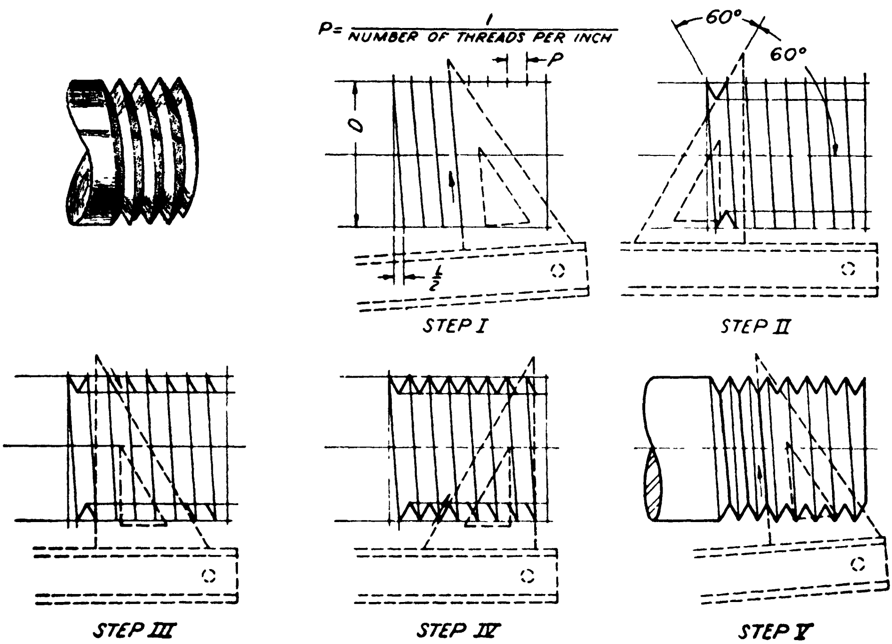


Fig. 301. Semiconventional American Standard and sharp V-threads (external).

and laborious drafting, is rarely used. The semiconventional method, which consists of drawing the true profile of the thread and the helical curves as straight lines, is preferred in commercial practice.

The steps in drawing a sharp V-thread are shown in Figs. 301 and 302. The flattened roots and crests are disregarded in the representation of American Standard threads and they are drawn as sharp V's. An effective relief and finish is given by drawing all lines fine except root lines.

In drawing a single, triple, or an odd-number multiple thread, a crest is always diametrically opposite a root; in a double or even-number multiple thread, a crest is opposite a crest and a root opposite a root.

The stages in drawing semiconventional square and Acme threads are shown in Figs. 303 and 304. All lines of the finished square thread

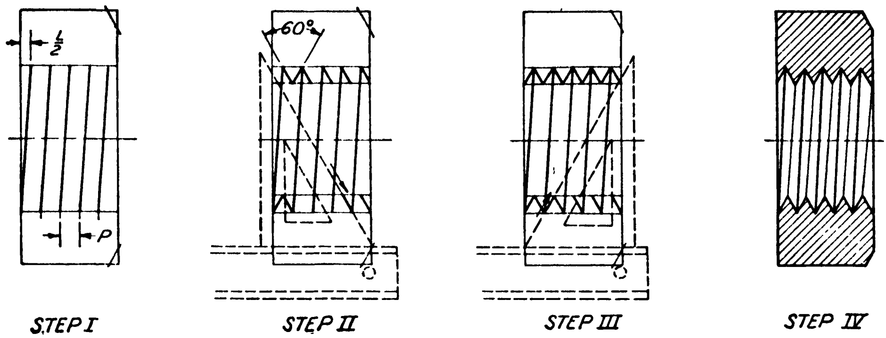


Fig. 302. Semiconventional American Standard and sharp V-threads (internal).

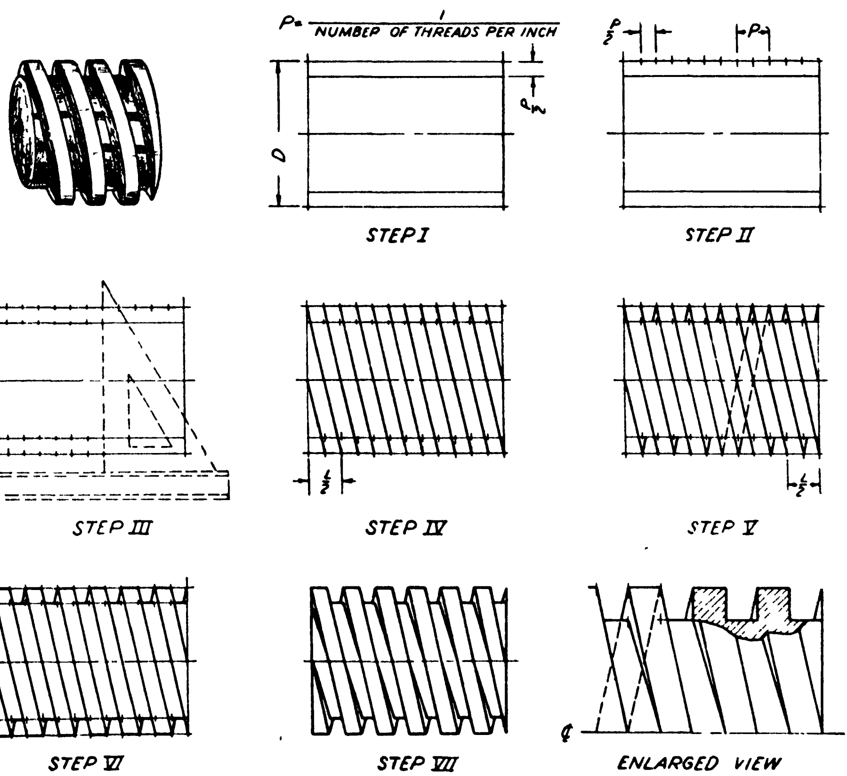


Fig. 303. Semiconventional square threads (external).

are made the same weight. The root lines of the Acme thread are made heavier than the other lines.

206. Conventional thread symbols. Recognizing the necessity for saving time and expense in the preparation of drawings, the American Standards Association has adopted the "regular" and "simplified" series of conventional thread symbols to be used to represent threads having a diameter of one inch or less. Regular and simplified symbols for threads of small diameter are shown in Figs. 305 and 306.

The simplified symbols were adopted to simplify drafting on both detail and assembly drawings. The root of the thread is represented by invisible lines drawn parallel to the axis.

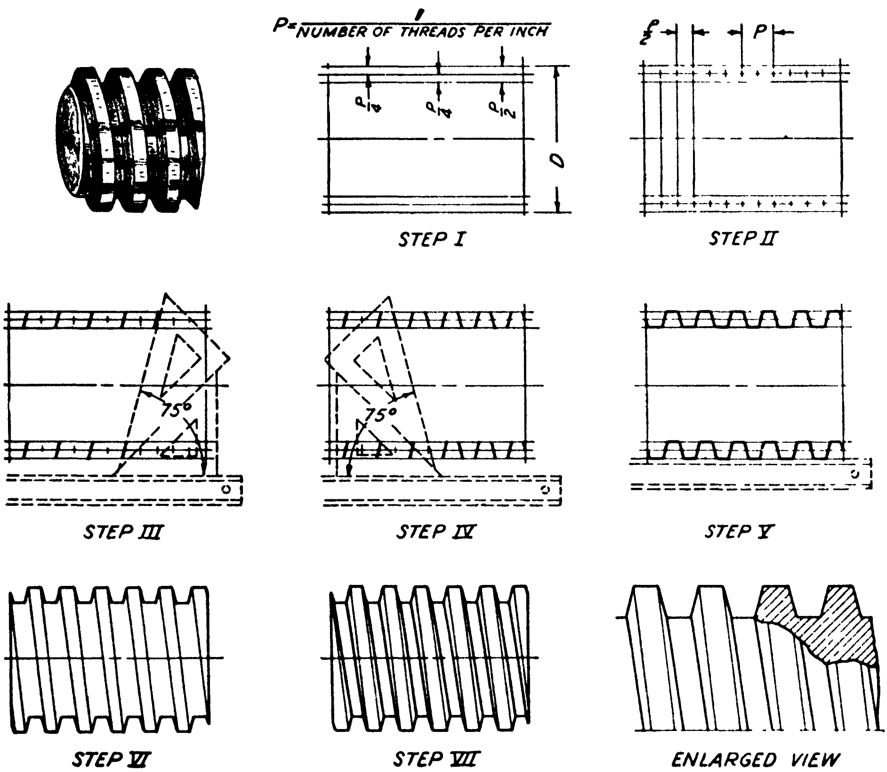


Fig. 304. Semiconventional Acme thread.

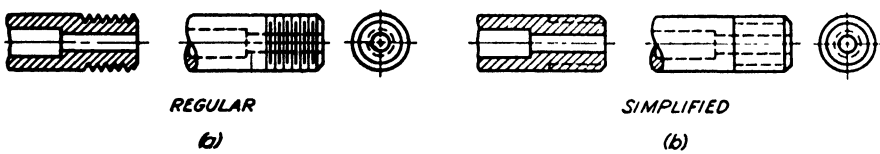


Fig. 305. External thread symbols.*

The regular symbol consists of alternate long and short lines perpendicular to the axis. Although these lines, representing the crests and roots of the thread, are not spaced to actual pitch, their spacing should indicate noticeable differences in the number of threads per inch of

* ASA Z14.1-1946.

different threads on the same working drawing or group of drawings. The root lines are made heavier than the crest lines.

Before a hole can be tapped (threaded), it must be drilled to a diameter a little more than the root diameter of the thread to permit the tap to enter. Since the last of the thread cut is not well formed or usable, the hole must be shown drilled and tapped deeper than the screw will enter. (See Fig. 306*D*, *E*, *F*.)

207. Threads in section. The semiconventional representation of threads in section which is used for large diameters only is shown in Fig. 302. Since the far side of an internal thread in section is visible, the crest and root lines incline in the opposite direction to those of an external thread having the same specifications.

A sectional assembly drawing is shown in Fig. 307. When assembled pieces are both sectioned, the semiconventional representation is used.

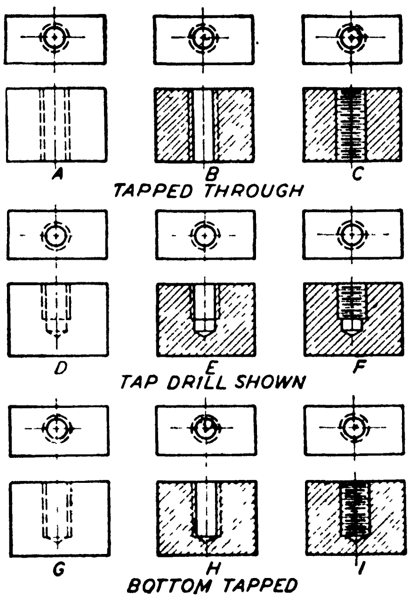


Fig. 306. Internal thread symbols. American Standards (ASA Z14.1-1946).

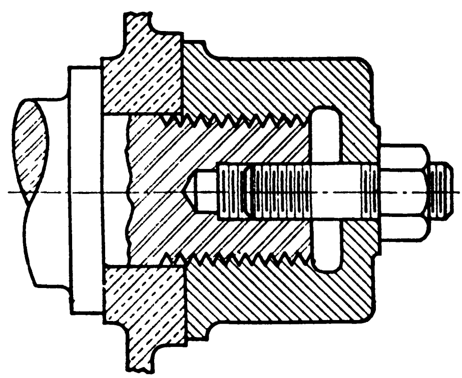


Fig 307. Screw threads in assembly.

208. American Standard thread series. The profile of the American Standard Thread (Fig. 299) is similar to a 60 degree V, except that the crest is flattened and the root is built up so that the depth of the American Standard thread is $\frac{3}{4}$ the depth of a V thread of the same pitch. This results in a much stronger screw for a given outside diameter and pitch.

The American Standard, consisting of five series of screw threads, uses the same form or profile in each series but not the same number of threads per inch for any given diameter.

1. *The coarse thread series* is recommended for general industrial use.
2. *The fine thread series* is used when greater strength is needed for a given diameter and when vibration is an important consideration.
3. *The 8-pitch thread series*, having 8 threads per inch for all diameters from

1 to 6 inches, is used on bolts for high-pressure flanges and for cylinder head studs which require a proper initial tension so that joints will not open up.

4. *The 12-pitch thread series*, having 12 threads per inch for diameters from $\frac{1}{2}$ inch to 6 inches, is used in boiler work, railroad work, and in machine construction for thin nuts on shafts and sleeves.

5. *The 16-pitch series*, having 16 threads per inch for all diameters from $\frac{3}{4}$ inch to 4 inches, is used mainly for threaded adjusting collars and bearing-retaining nuts.

209. Screw-thread fits. The American Standards Association in 1935 adopted four classes of fits* between mating threads (as between a bolt and nut). Each class of fit has a definite purpose and use in the field of commercial design. It is neither sound economics nor good practice to employ higher quality of fit than is required for satisfactory performance.

Class 1 fit. Recommended only for screw-thread work where clearance between mating parts is essential for rapid assembly and where shake or play is not objectionable.

Class 2 fit. Represents a high quality of commercial thread product and is recommended for the great bulk of interchangeable screw-thread work.

Class 3 fit. Represents an exceptionally high quality of commercially threaded product and is recommended only in cases where the high cost of precision tools and continual checking is warranted.

Class 4 fit. Intended to meet very unusual requirements more exacting than those for which class 3 is intended. It is a selective fit if initial assembly by hand is required. It is not, as yet, adaptable to quantity production.

210. Identification symbols for American Standard threads (Fig. 308). American Standard threads are specified on drawings, in specifications,

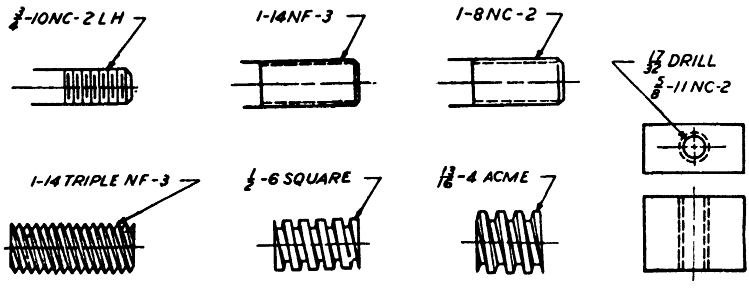


Fig. 308. Thread identification symbols.

and in stock lists by the thread information being given in the following order:

1. Diameter in inches (or screw number).
2. Number of threads per inch.
3. Initial letters of the series. (*NC* for National Coarse, *NF* for National Fine, and *N* for National Form with a special pitch.)
4. Class of fit.

---

* ASA B1.1-1935.

211. Unified and American screw thread series. The Unified and American screw thread series as given in ASA B1. 1-1949 consists of six series and a selection of special threads which cover special combinations of diameter and pitch. Each series differs from the other by the number of threads per inch for a specific diameter.

The coarse thread series (UNC and NC) is designated UNC for sizes above $\frac{1}{4}''$ in diameter. This series is recommended for general industrial use.

The fine thread series (UNF and NF) designated UNF for sizes above $\frac{1}{4}''$, was prepared for use when a fine thread is required and for general use in the automotive and aircraft fields.

The Extra-fine thread series, designated NEF is used for automotive and aircraft work when a maximum number of threads is required for a given length. A few specific sizes of this series are designated UN.

The 8, 12, and 16 thread series, designated 8N or 8UN, 12N or 12UN, and 16N or 16UN are used for the same purposes as the 8, 12, and 16 pitch thread series of the old American Standard series.

212. Unified and American screw thread fits. Classes of fits are determined by the amounts of tolerance and allowance specified. Under the new unified system classes 1A, 2A, and 3A apply only to external threads; classes 1B, 2B, and 3B apply to internal threads. Class 2 and class 3 from the former American Standard are part of the new standard for United States only and apply to both external and internal threads.

Class 1A and Class 1B replace class 1 of the old American Standard.

Class 2A and Class 2B were adopted as the recognized standards for screws, bolts, and nuts.

Class 3A and class 3B invoke new classes of tolerances. These classes along with class 2A and class 2B should eventually replace class 2 and class 3 now retained from the American Standard.

213. Identification symbols for Unified screw threads. Threads are specified under the new unified system by giving the diameter, number of threads per inch, initial letters (UNC, UNF, etc.), and class of fit (1A, 2A, and 3A; or 1B, 2B, and 3B). See Fig. 309.

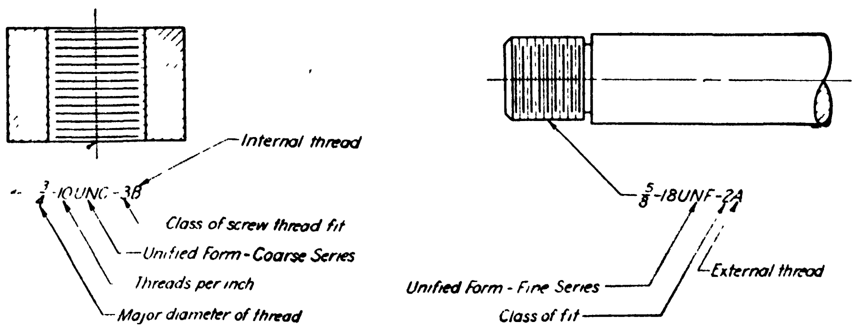


Fig. 309. Unified thread identification symbols.

214. American Standard bolts and nuts. Commercial producers of bolts and fasteners manufacture their products in accordance with the standard specifications given in the American Standard entitled "Wrench-Head Bolts and Nuts, and Wrench Openings (Revised 1941)."* See table in Appendix. The specifications cover three series, which are:

1. *Regular series.* The regular series was adopted for general use.
2. *Heavy series.* Heavy boltheads and nuts are designed to satisfy the special commercial need for greater bearing surface.
3. *Light-series nuts.* Light nuts are used under conditions requiring a substantial savings in weight and material. They are usually supplied with a fine thread.

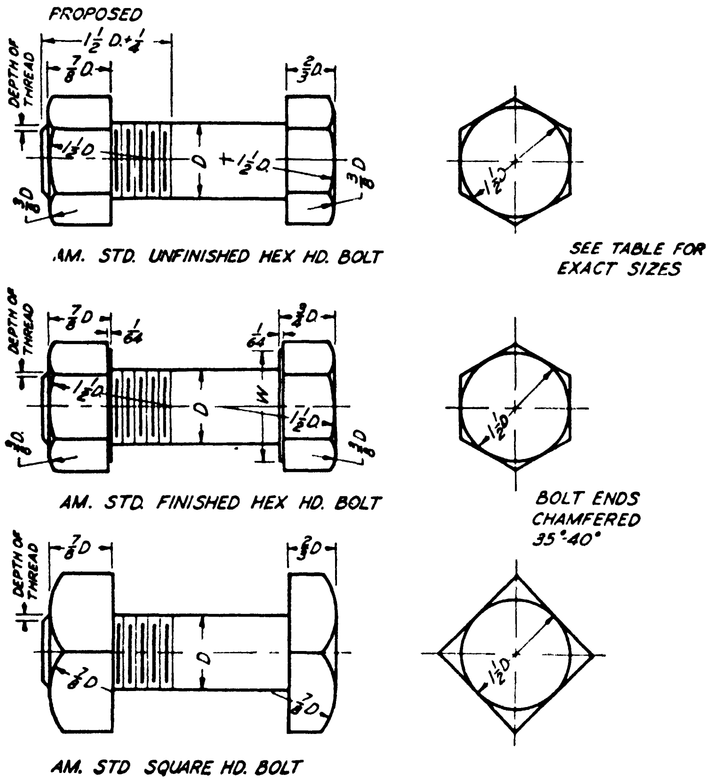


Fig. 310. Formula proportions for American Standard bolts.

The amount of machining is the basis for further classification of hexagonal bolts and nuts in both the regular and heavy series as unfinished, semifinished, and finished. Square-head bolts and nuts are supplied as unfinished and semifinished.

Unfinished heads and nuts are not washer-faced, nor are they machined on any surface.

* ASA B18.2-1941.

Semifinished bolt heads and nuts are machined or treated on the bearing surface so as to provide a washer face for bolt heads and either a washer face or a circular bearing surface for nuts. Nuts, not washer-faced, have the circular bearing surface formed by chamfering the edges.

Finished heads and nuts are washer-faced and are machined on all surfaces. The washer face is $\frac{1}{64}$ inch thick and has a diameter equal to the distance across flats.

Bolts and nuts are *always* drawn across corners in all views. This recognized commercial practice, which violates the principles of true projection, prevents confusion of square and hexagonal forms on drawings.

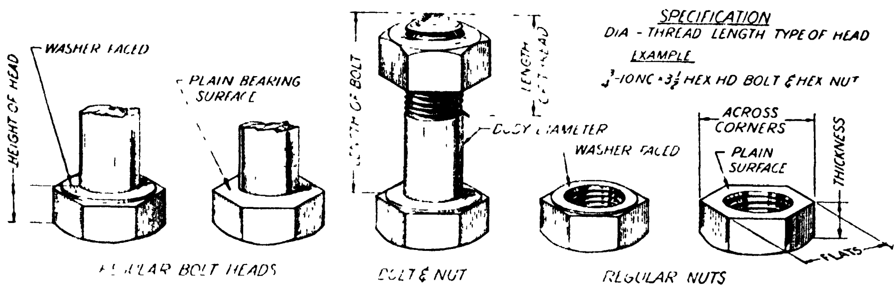


Fig. 311. American Standard bolts and nuts.

The chamfer angle on the tops of heads and nuts is 30 degrees on hexagons and 25 degrees on squares, but both are drawn at 30 degrees on bolts greater than 1″ in diameter.

Bolts are specified in parts lists and elsewhere by giving the diameter, length, number of threads per inch, series, class of fit, finish, and type of head (Fig. 311).

EXAMPLE: $\frac{1}{2}$ - 13NC-2 × $1\frac{3}{4}$ SEMI-FIN. HEX. HD. BOLT.

Frequently it is advantageous and practical to abbreviate the specification thus:

EXAMPLE: $\frac{1}{2}$ × $1\frac{3}{4}$NC SEMI-FIN. HEX. HD. BOLT.

215. To draw boltheads and nuts. Using the dimensions given in Fig. 310 or taken from the tables, draw the lines representing the top

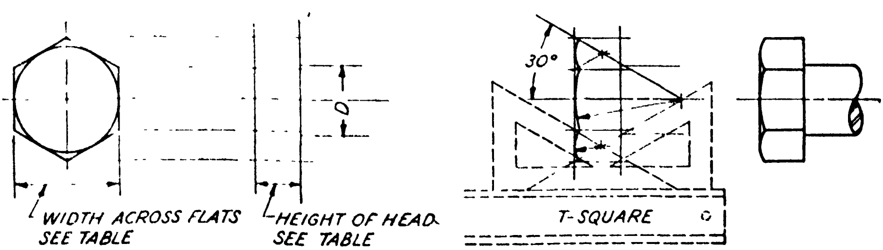


Fig. 312. Steps in drawing a hexagonal bolt head.

and contact surface of the head or nut and the diameter of the bolt. Lay out a hexagon about an inscribed chamfer circle equal to $1\frac{1}{2}$D (Fig. 312) and project the necessary lines to block in the view. Draw in the arcs after finding the centers as shown in Fig. 312.

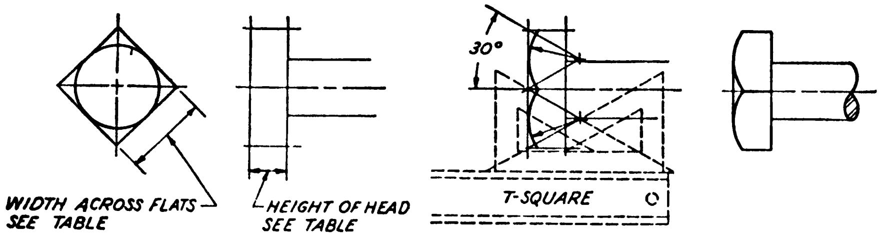


Fig. 313. Steps in drawing a square bolt head.

A square-head bolt or nut may be drawn by following the steps indicated in Fig. 313.

216. Studs. Studs, or stud bolts, which are threaded on both ends, as shown in Fig. 314, are used where bolts would be impractical and for parts which must be frequently removed (cylinder heads, steam chest covers, pumps, and so on). They are first screwed permanently into the tapped holes in one part before the removable member with its corresponding clearance holes is placed in position. Nuts are used on the projecting ends to hold the parts together.

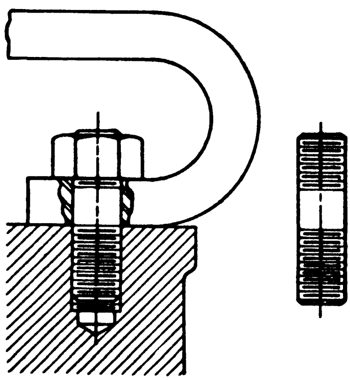


Fig. 314. Stud bolt.

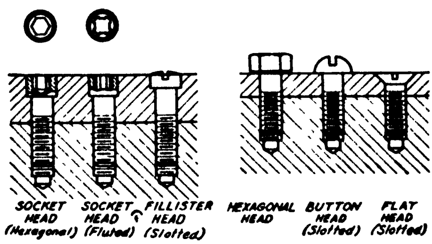


Fig. 315. Cap screws.

217. Cap screws. Cap screws are similar to machine screws. They are available in four standard heads, usually in finished form. When parts are assembled, the cap screws pass through clear holes in one member and screw into threaded holes in the other (Fig. 315). Hexagonal cap screws have a washer face $\frac{1}{64}$" thick with a diameter equal to the distance across flats.

Cap screws are specified by giving the diameter, number of threads per inch, series, class of fit, length, and type of head.

EXAMPLE: $\frac{5}{8}$"-11*NC*-2 × 2" FIL. HD. CAP SC.

It is good practice to abbreviate the specification thus:

EXAMPLE: $\frac{5}{8}'' \times 2''$ FIL. HD. CAP SC.

218. Machine screws. Machine screws, which fulfill the same purpose as cap screws, are used chiefly for small work having thin sections. The four forms of heads shown in Fig. 316 have been standardized.

To specify machine screws, give the diameter, threads per inch, thread series, fit, length, and type of head.

EXAMPLE: No. 12-24NC-3 $\times \frac{3}{4}''$ FIL. HD. MACH. SC.

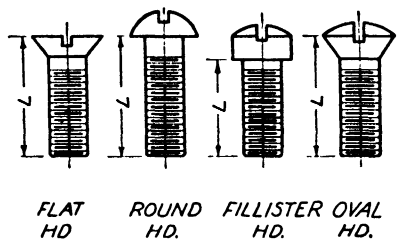


Fig. 316. Types of machine screws.

It is good practice to abbreviate by omitting the thread series and class of fit.

EXAMPLE: No. 12-24 $\times \frac{3}{4}''$ FIL. HD. MACH. SC.

219. Commercial lengths: studs, cap screws, machine screws. The length of the fastening should be determined to the nearest commercial length that will allow it to fulfill the conditions specified in

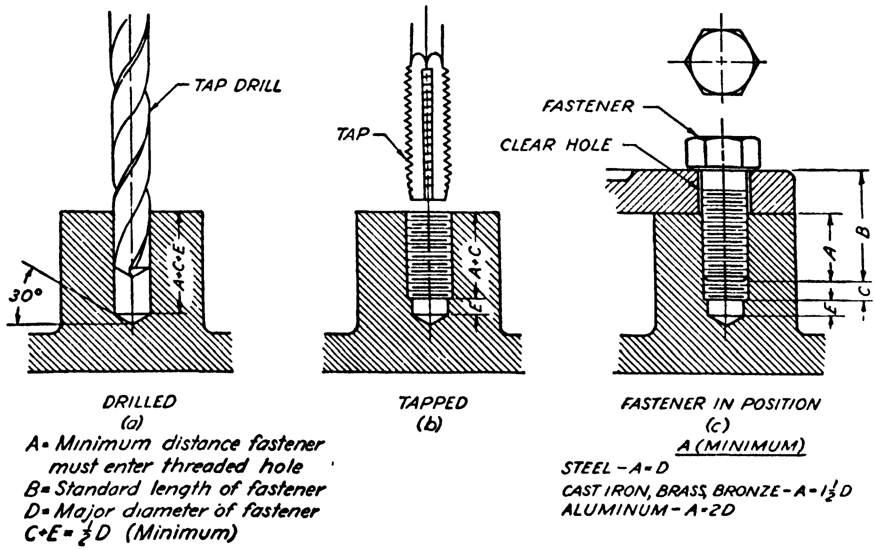


Fig. 317. Threaded hole and fastener.

Fig. 317. In the case of a stud, care should be taken that the length allows for a full engagement of the nut.

220. Set screws. Set screws are used principally to prevent rotary motion between two parts, such as that which tends to occur in the case of a rotating member mounted on a shaft. A set screw is screwed through one part until the point presses firmly against the other part (Fig. 318).

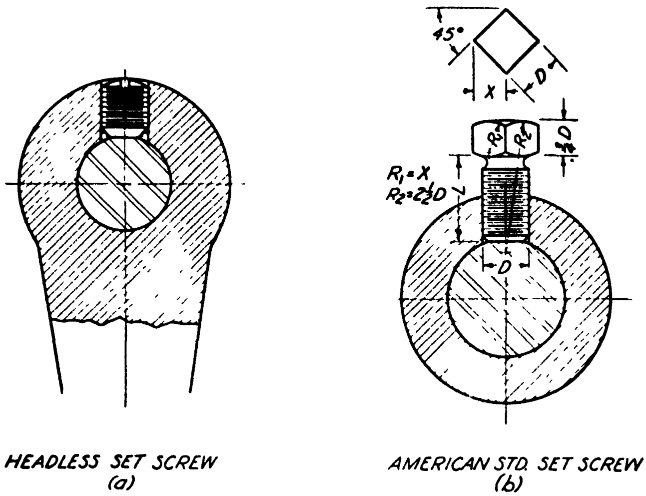


Fig. 318. Use of set screws.

The several forms of safety heads shown in Fig. 319 are available in combination with any of the points.

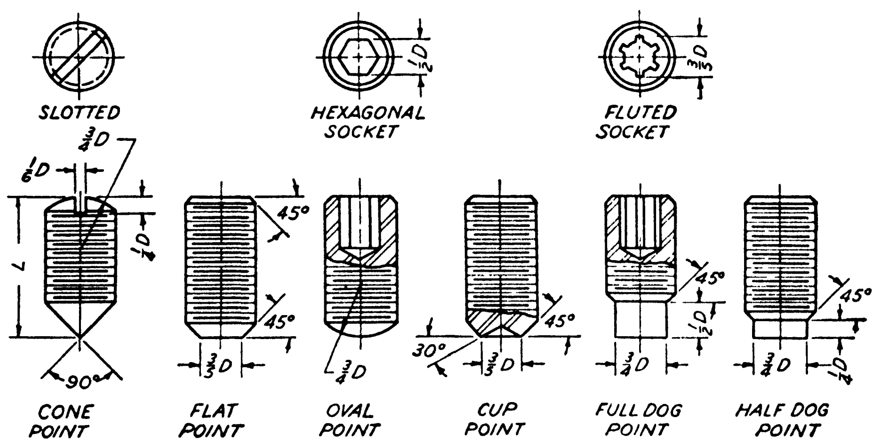


Fig. 319. Set screws.

Set screws are specified by giving the diameter, number of threads per inch, series, class of fit, length, type of head, and type of point.

The preferred abbreviated form gives the diameter, number of threads per inch, length, type of head, and type of point.

EXAMPLE: $\frac{1}{4}$-20NC-2 × $\frac{1}{2}$ H'DLESS CONE PT. SET. SC.
EXAMPLE: $\frac{1}{4}$-20 × $\frac{1}{2}$ H'DLESS CONE PT. SET. SC.

221. Application of set screws. Fig. 320 illustrates the method of milling a flat surface on a shaft to provide a seat for a set screw.

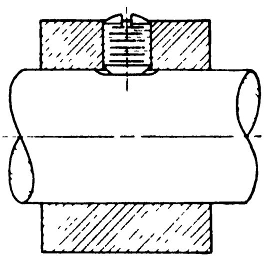


Fig. 320. Treatment of shaft for flat point set screw.

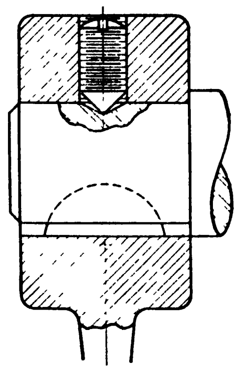


Fig. 321. Treatment of shaft for cone point set screw.

The cone point which fits into a conical spot in the shaft (Fig. 321) is sometimes used to prevent both rotary and longitudinal axial motion.

222. Keys. Keys are used in the assembling of machine parts to secure them against relative motion, generally rotary, as is the case

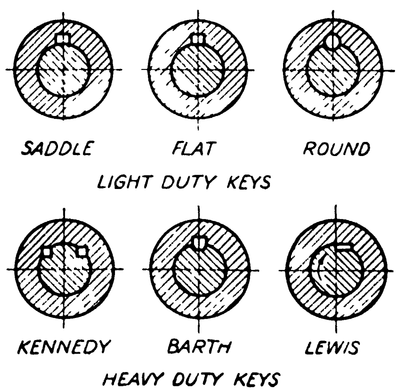


Fig. 322. Special light- and heavy-duty keys.

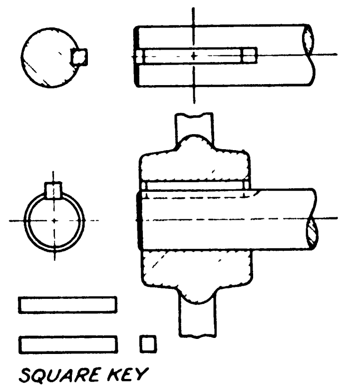


Fig. 323. A square key.

between shafts, cranks, wheels, and so on. When the relative forces are not great, a round key, saddle key, or flat key is used. For heavier duty, rectangular keys are more suitable. See Fig. 322.

The square key (Fig. 323) and the Pratt and Whitney key (Fig. 324) are the two keys most frequently used in machine design. A plain milling cutter is used to cut the keyway for the square key, while an end mill is used for the Pratt and Whitney keyway. Both keys fit tightly in the shaft and in the part mounted upon it.

The gib-head key (Fig. 325) is designed so that the head remains far enough from the hub to allow a drift pin to be driven to remove the key. The hub side of the key is tapered $\frac{1}{8}''$ per foot to insure a fit tight enough to prevent both axial and rotary motion. For this type of key, the keyway must be cut to one end of the shaft.

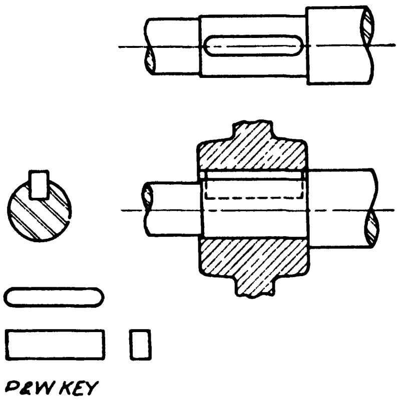


Fig. 324. A Pratt and Whitney key.

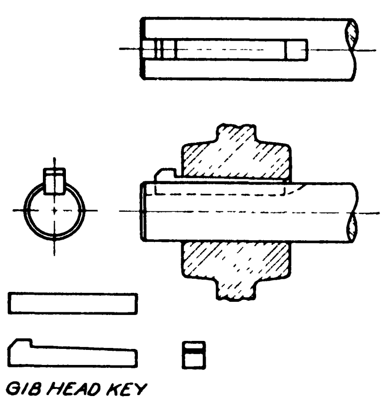


Fig. 325. A gib-head key.

223. Woodruff keys. A Woodruff key is a flat segmental disc which may have either a flat or a round bottom (Fig. 326). It is always specified by a number, the last two digits of which indicate the nominal diameter in eighths of an inch, while the digits preceding the last two give the nominal width in thirty-seconds of an inch.

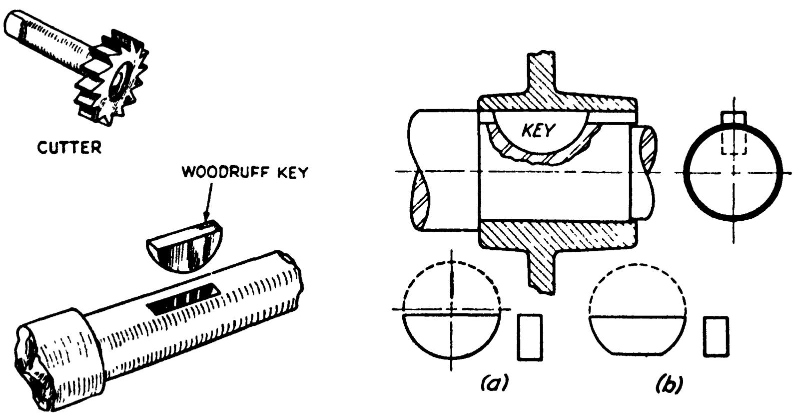


Fig. 326. A Woodruff key.

A practical rule for selecting a Woodruff key for a given shaft is: Choose a standard key which has a width approximately equal to one-fourth of the diameter of the shaft, and a radius nearly equal (plus or minus) to the radius of the shaft. Table VI in the Appendix gives the dimensions for American Standard Woodruff keys.

When Woodruff keys are drawn, it should be remembered that the center of the arc is placed above the top of the key at a distance shown in column E in the table.

224. Locking devices. A few of the many types of locking devices that prevent nuts from becoming loose under vibration are shown in Fig. 327.

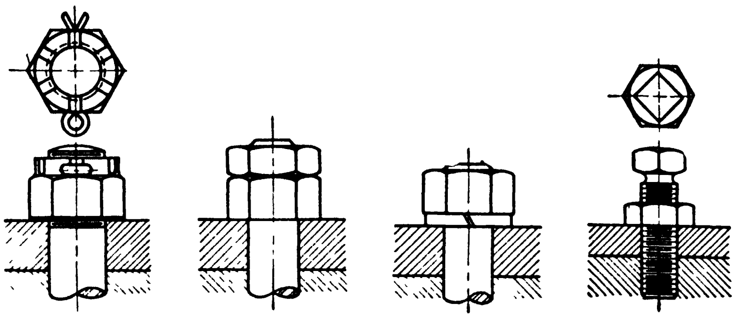


Fig. 327. Locking schemes.

In common use is the castellated nut (Fig. 327*a*) with a spring cotter pin which passes through the shaft and the slots in the top. This type is used extensively in automotive and aeronautical work.

Fig. 327(*b*) shows a regular nut which is prevented from loosening by an American Standard jam nut. A jam nut has the same across-flats dimension as a regular nut of the same diameter (Table III, Appendix).

A regular nut with a spring-lock washer is shown in Fig. 327(*c*). The reaction provided by the lock washer tends to prevent the nut from turning.

225. Miscellaneous bolts, screws, and nuts. Other types of bolts and screws which have been adopted for commercial use are illustrated in Fig. 328.

Wood screws have threads proportioned for the holding strength of wood. They are available with different forms of heads (flat, round, and oval).

226. Rivets. Rivets are permanent fasteners used chiefly for connecting members in such structures as buildings and bridges and for assembling steel sheets and plates for tanks, boilers, and ships. They are cylindrical rods of wrought iron or soft steel, with one head formed when manufactured. A head is formed on the other end after the rivet has been put in place through the drilled or punched holes of the mating parts. A hole for a rivet is generally drilled, punched, or punched and reamed $\frac{1}{16}''$ larger than the diameter of the shank of the rivet. For specialized types of engineering work, rivets are manufactured of chrome-

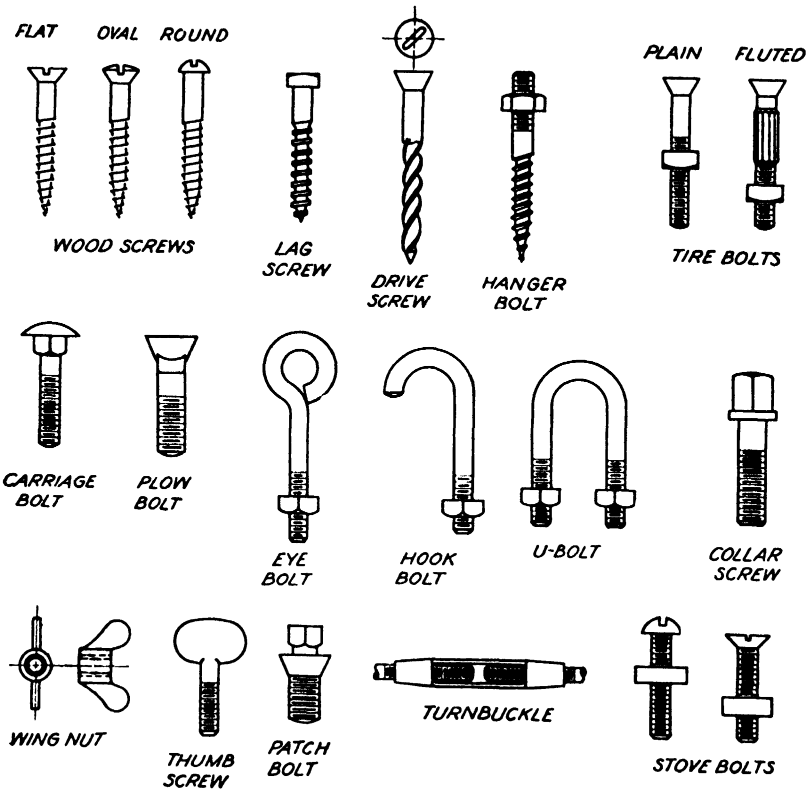


Fig. 328. Miscellaneous bolts, screws, and nuts.

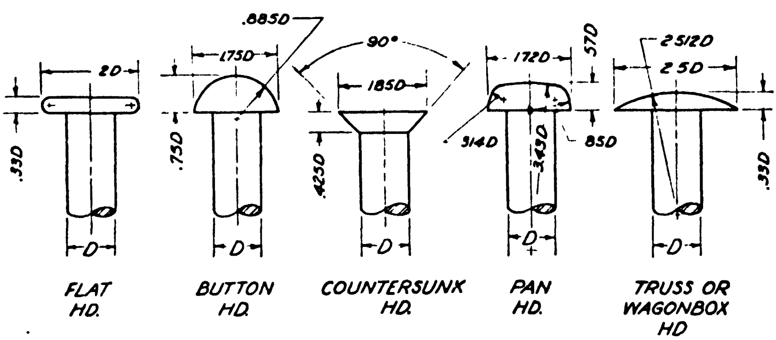


Fig. 329. Formula dimensions for American Standard rivets.

iron, nickel, brass, copper, and so on. Formula proportions for American Standard small-head rivets are shown in Fig. 329.

227. Welding processes. For convenience, the various welding processes used in commercial production may be classified into three types: pressure processes, nonpressure processes, and casting processes. The nonpressure processes are arc welding and gas welding. Metallic arc welding is the joining of two pieces of metal through the use of a sustained arc formed between the work and a metal rod held in a holder. The intense heat melts the metal of the work and at the same time heats the end of the electrode, causing small globules to form and cross the arc to the weld. In gas welding, the heat is produced by a burning mixture of two gases, which ordinarily are oxygen and acetylene. The weld is formed by melting a filler rod with the torch flame, along the line of contact, after the metal of the work has been preheated to a molten state. Resistance welding is a pressure process, the fusion being made through heat and mechanical pressure. The work is heated by a strong electrical current which passes through it until fusion temperature is reached; then pressure is applied to create the weld.

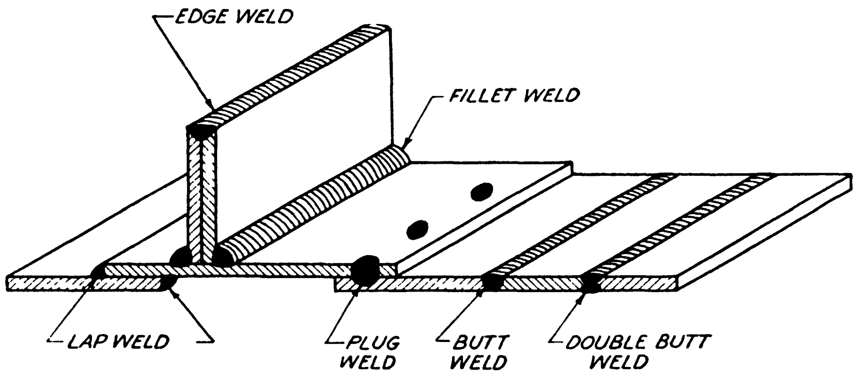


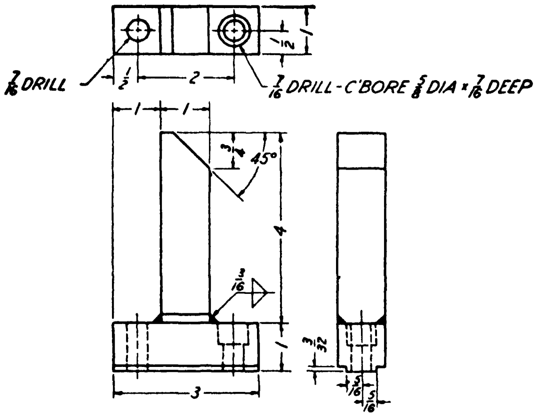
Fig. 330. Welding symbols.

The forms of resistance welding are: butt welding, seam welding, spot welding, and flash welding. In spot welding, the parts are overlapped and welds are made at successive single spots. In butt welding, the pieces are so placed that they are butted; then the weld is made by heating electrically and squeezing the parts together. A seam weld is similar to a spot weld, except that a continuous weld is produced. In projection welding, one part is embossed and welds are made at the successive projections.

228. Types of joints. Fig. 330 shows the ordinary types of welded joints.

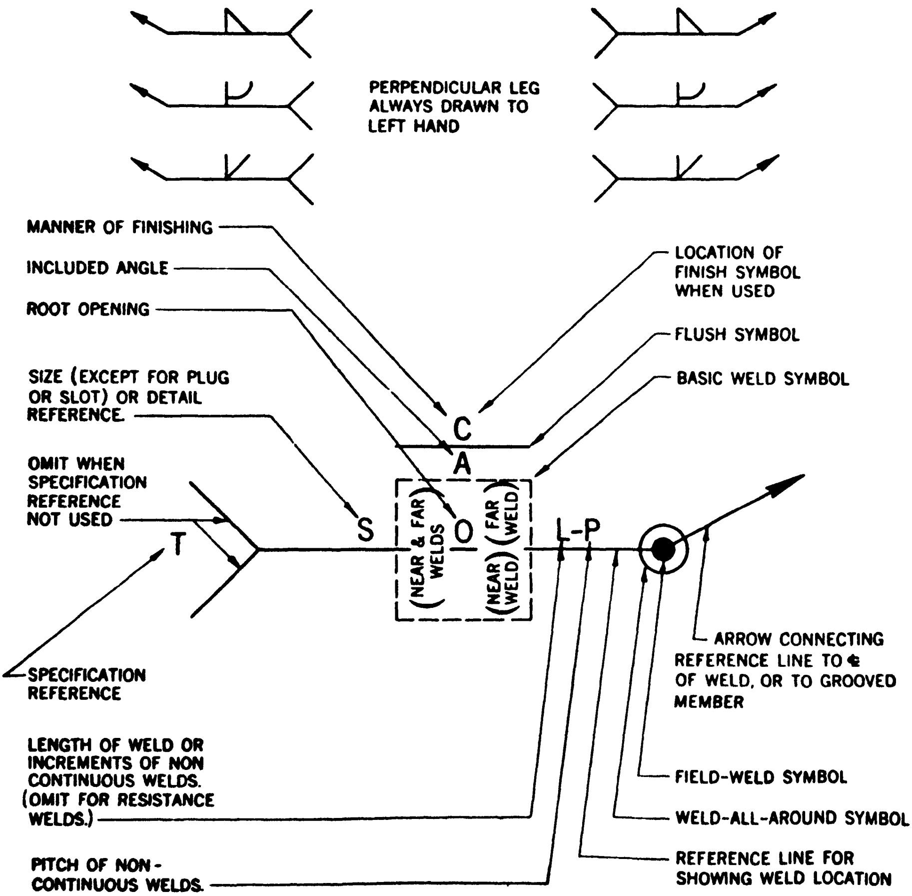
229. Working drawings of welded parts. Fig. 331 shows a part that is to be constructed by welding rolled shapes. It should be noted that each joint is completely specified through the use of a welding symbol. A careful study will show that the drawing, except for the absence of fillets and rounds and the fact that properly composed welding symbols are directed to the necessary joints, is very much like a casting drawing.

A satisfactory welding design may be produced by a competent designer who possesses a fair amount of ingenuity, and the necessary



Courtesy Lincoln Electric Company

Fig. 331. A welding drawing



From the pamphlet "Welding Symbols" by the American Welding Society.

Fig. 332. The basic welding symbol.

drawing can be made by any draftsman who has a thorough understanding of the construction of the symbols created by the American Welding Society.

230. Near welds and far welds. In order that they may be identified on a drawing and properly specified, welds are classified as *near welds* or *far welds*. A near weld is one that is parallel to the plane of the paper and toward the observer. It is on the same side as the symbol, and the arrow points to its face. The far weld is away from the observer, on the far side of the piece, and its face is away from the arrow.

231. Welding symbols. An enlarged drawing of the approved welding symbol is shown in Fig. 332, along with explanatory notes which indicate the proper locations of the marks and size dimensions necessary for a complete description of a weld.

The arrow is the basic portion of the symbol, as shown in Fig. 333(*a*). It points toward the joint where the required weld is to be made, as in Fig. 333(*b*).

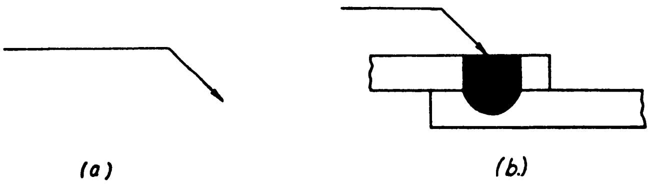


Fig. 333. Welding arrow.

If the weld is on the near side, toward the observer, the symbol indicating the type of weld is placed below or to the right of the base line, depending upon whether that line is horizontal or vertical (Fig. 334c).

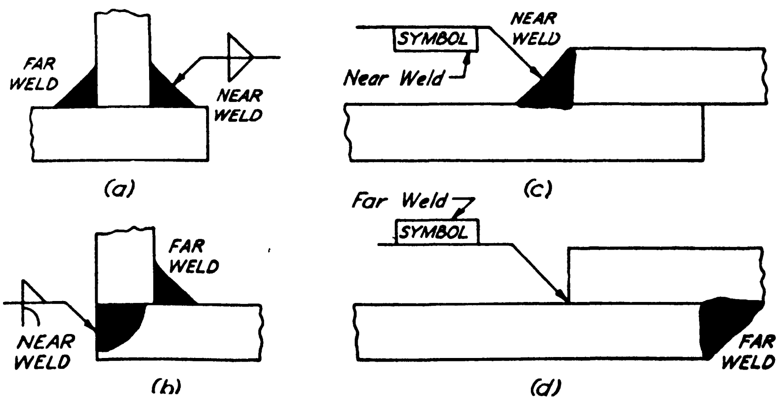


Fig. 334. Location of welding symbols.

If the weld is located on the far side, the symbol should be above or to the left, as shown in (*d*).

To indicate that a weld is to be made all around a connection, as is necessary when a piece of tubing must be welded to a plate, a weld-all-around symbol, a circle, is placed as shown in Fig. 335.

The size of a weld is given along the base of the arrow, at the side of the symbol, as shown in Fig. 336. If the welds on the near side and the far side of a lap joint are the same size, only one dimension should be given

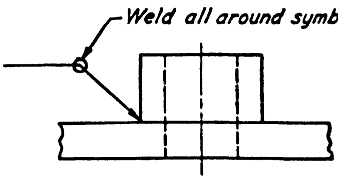


Fig. 335. Weld all-round symbol.

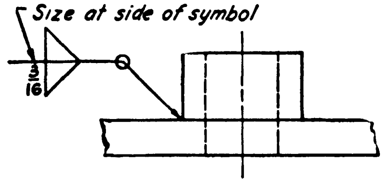


Fig. 336. Method of specifying the size of weld.

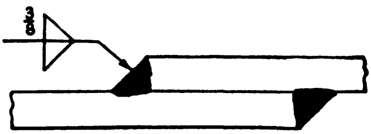


Fig. 337. Dimensioning a weld.

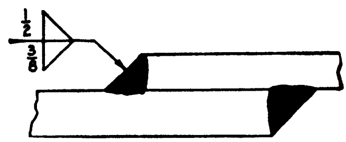
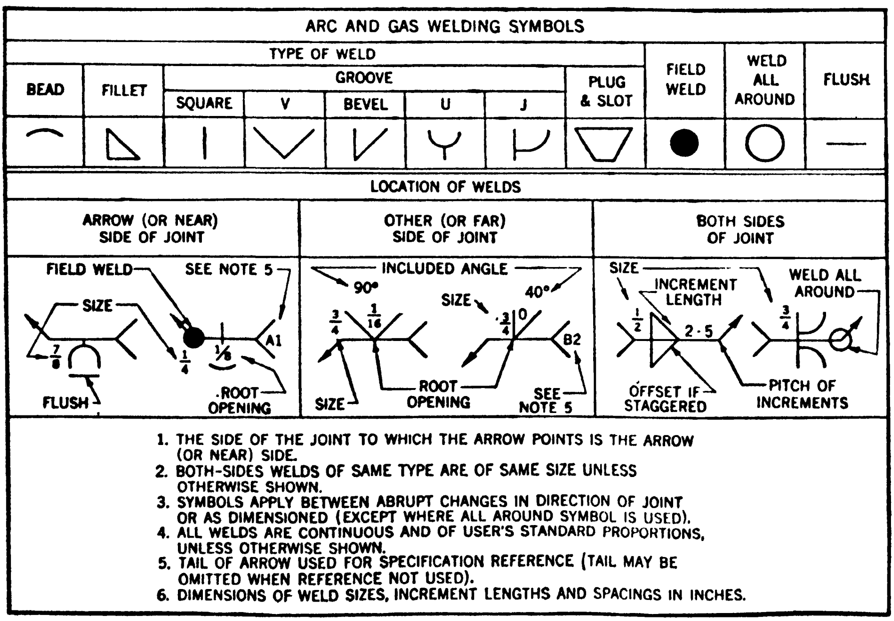


Fig. 338. Dimensioning a weld.

(Fig. 337). If they are not the same size, each dimension should be placed beside its associated symbol (Fig. 338).

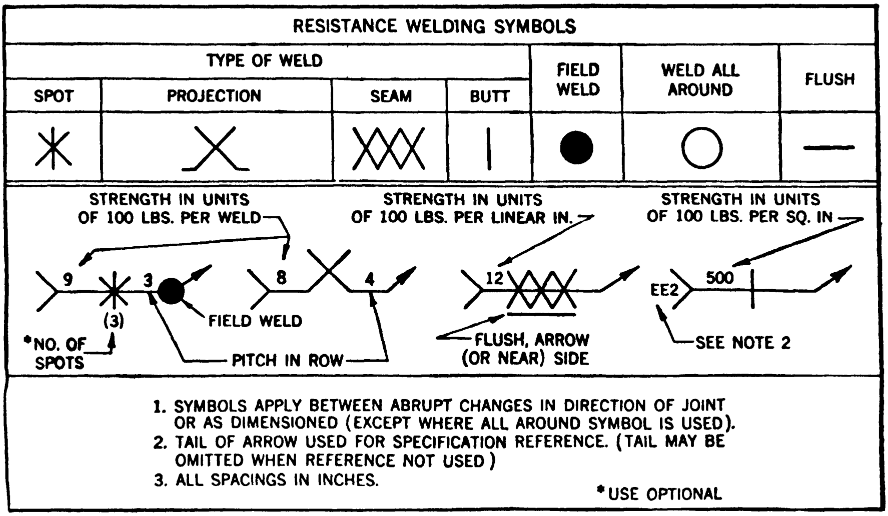
232. Gas and arc welding symbols. In order to satisfy the need for a standard group of symbols which could be understood in all manu-



From the pamphlet "Welding Symbols" by the American Welding Society.

Fig. 339. Arc and gas welding symbols.

facturing plants, the American Welding Society recommended in 1940 a set of conventional symbols so designed that each symbol resembled in a general way the type of weld it represented. Fig. 339 shows a condensed table of symbols. The few examples given here show the proper construction of welding specifications.



From the pamphlet "Welding Symbols" by the American Welding Society.

Fig. 340. Resistance welding symbols.

233. Resistance welding. Fig. 340 shows the symbols for the four principal types of resistance welding. The method of specifying resistance welds differs from the methods used for arc and gas welds. In the former, the strength of a weld is given in units instead of size, and the symbols do not show the form of the weld. In the table, the strength of spot and projection welds is given in units of 100 pounds per weld. The strength for seam welds is given in units of 100 pounds per linear inch, while for a butt weld the same units are applied to the square inch of weld.

234. Problems. Excellent practice in drawing threads, threaded fasteners, keys and rivets is provided through the making of some of the assembly drawings given in Chapter 15. However, a few of the typical situations are offered here, in order to familiarize the student with the approved methods of representation before he is required to use them on a working drawing.

1. Draw a semiconventional representation of a V-thread (Fig. 301). Make the diameter of the thread 2″, the pitch ¼″, and the length 3″.

2. Draw a semiconventional representation of a square thread. Make the diameter of the thread 2¼″, the pitch ½″, and the length 3″.

3. Draw a semiconventional representation of an Acme thread. Make the diameter 2¼″, the pitch ½″, and the length 3″.

4. Same as problem 3, but show a B & S worm thread.

5. Draw an American Standard hexagonal-head bolt and nut. The diameter of the bolt is to be 1″; the thread is to be NC. The bolt is to be semifinished and have a length of 5″. Use the semiconventional representation. The length of the thread should be 1½ *D* plus ¼″.

6. Using the regular symbol, as shown in Fig. 305, draw the following fasteners in the order given: (1) a ¾″ × 3″ hexagonal-head cap screw, (2) a ⅝″ × 3″ fillister-head cap screw, (3) a ¾″ × 3″ flat-head cap screw. Balance the three drawings on an 8½″ × 11″ or a 9″ × 12″ sheet of drawing paper.

7. Draw the threads shown in Fig. 341.

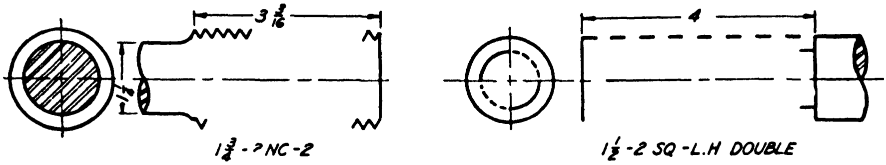


Fig. 341

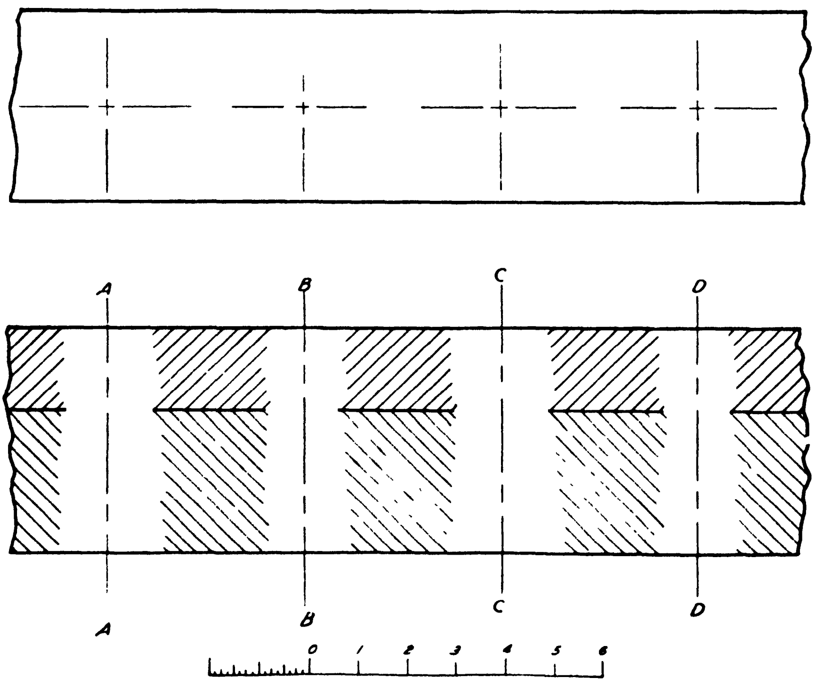


Fig. 342.

8. Draw the layout shown in Fig. 342, and on it show the following fasteners: (1) On center line *A-A* draw a ¾″ unfinished hexagonal-head bolt and nut. (2) On center line *B-B* draw a ⅞″ square-head bolt and nut. (3) On center line *C-C* draw a $\frac{3}{4}''$ fillister-head cap screw. (4) On center line *D-D* draw a $\frac{5}{8}''$ hexagonal head cap screw. Determine the measurements for the layout by using the given scale. Make each fastener a standard length. Use the regular symbol for the representation of the threads.

9. Reproduce the three layouts shown in Fig. 343 to full size, using the given scale to determine the measurements. On layout (1), complete the drawing to

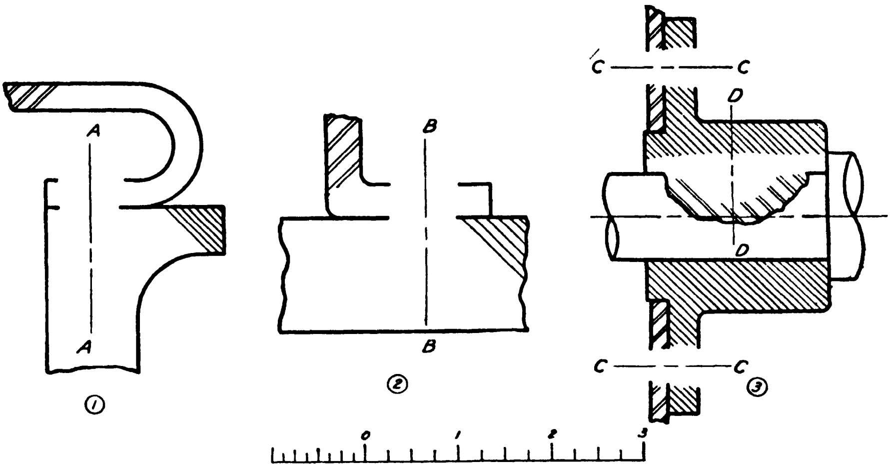


Fig. 343.

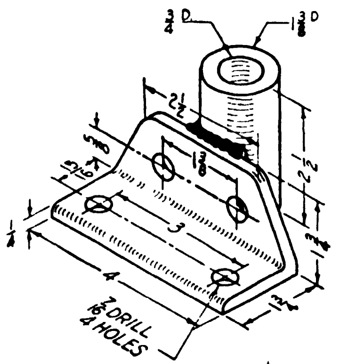


Fig. 344. Bracket.

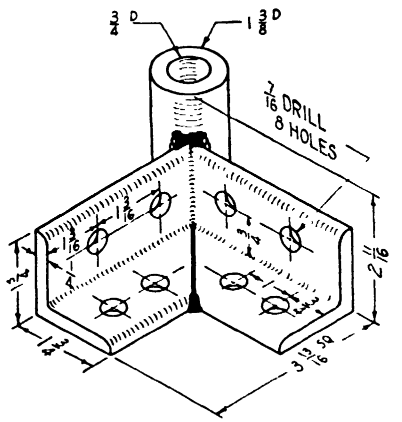


Fig. 345. Caster bracket.

show a suitable fastener on center line *A-A*. On layout (2), show a $\frac{1}{2}''$ hexagonal-head cap screw on center line *B-B*. On layout (3), show a $\frac{3}{8}''$ button-head rivet on center line *C-C* and a No. 608 Woodruff key on center line *D-D*. Use the regular symbol for the representation of threads.

Two problems offering experience in the preparation of welding drawings are given in Figs. 344 and 345. Others may be had by redesigning many of the cast parts, given at the end of the chapter on multiview drawing and in some of the other chapters, in such a way that they may be made of welded steel shapes. The student will find in these problems an opportunity to exercise some of his own ingenuity.

10. Prepare a welding drawing of the bracket shown in Fig. 344.

11. Prepare a welding drawing of the caster bracket shown in Fig. 345.

12. Make a two-view orthographic drawing of the object shown in Fig. 330. The dimensions are to be assumed. The plates are $\frac{3}{8}''$ thick. Show the correct specification for each type of weld.

15

WORKING DRAWINGS

235. A working drawing is prepared for the purpose of furnishing all necessary information to those persons who must manufacture and assemble the machine or structure represented. It is a technical record which must be so complete and accurate that no supplementary verbal or written explanations will be necessary. The information must be conveyed in the most understandable manner, in accordance with good drafting-room conventions and practices.

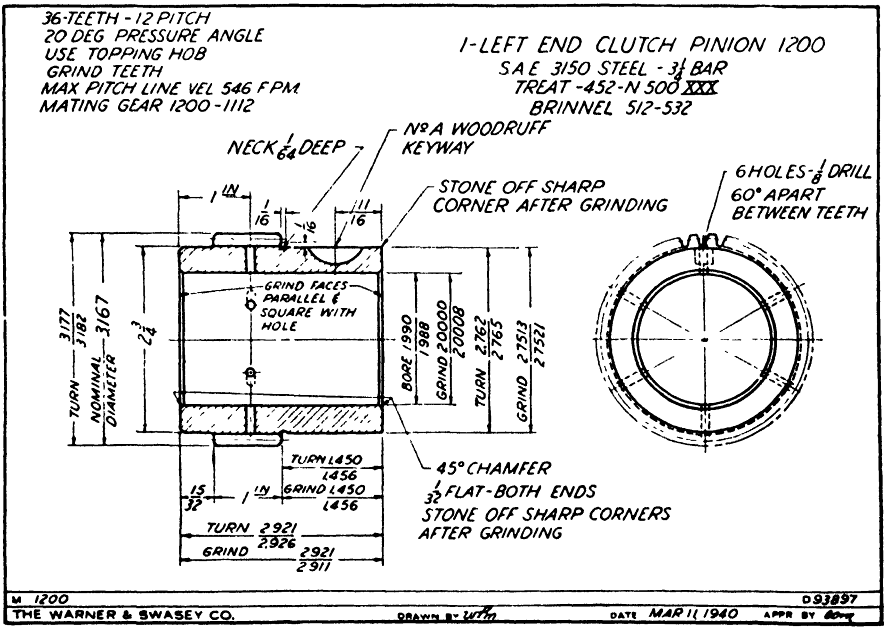
236. Sketches and design drawings. The first stage in the development of an idea for a structure or machine is the preparation of freehand sketches and the making of the necessary calculations required to determine the feasibility of the design. From these sketches the designer prepares a layout, on which an accurate analysis of the design is worked out. It is usually drawn full size and is executed with instruments in pencil. The layout should be sufficiently complete to allow a survey of the location of parts (to avoid interference), the accessibility for maintenance, the requirements for lubrication, and the method of assembly.

Usually, only center distances and certain fixed dimensions are given. The general dimensioning, as well as the determination of material and degree of finish of individual parts, is left for the draftsman who makes the detail drawings.

Design layouts require both empirical and scientific design. Empirical design involves the use of charts, formulas, tables, etc., which have been derived from experimental studies and scientific computations. Scientific design, which requires a broad knowledge of the allied fields such as mechanics, metallurgy, and mathematics is used when a new machine is designed to operate under special specified conditions for which data are not available in any handbook.

237. Classes of working drawings. There are two recognized classes of working drawings: detail drawings and assembly drawings.

238. Set of working drawings. A complete set of working drawings for a machine consists of detail sheets, giving all necessary shop information for the production of individual pieces, and an assembly drawing showing the location of each piece in the finished machine. In addition, the set may include drawings showing a foundation plan, piping diagram, oiling diagram, and so on.



Courtesy The Warner & Swasey Co.

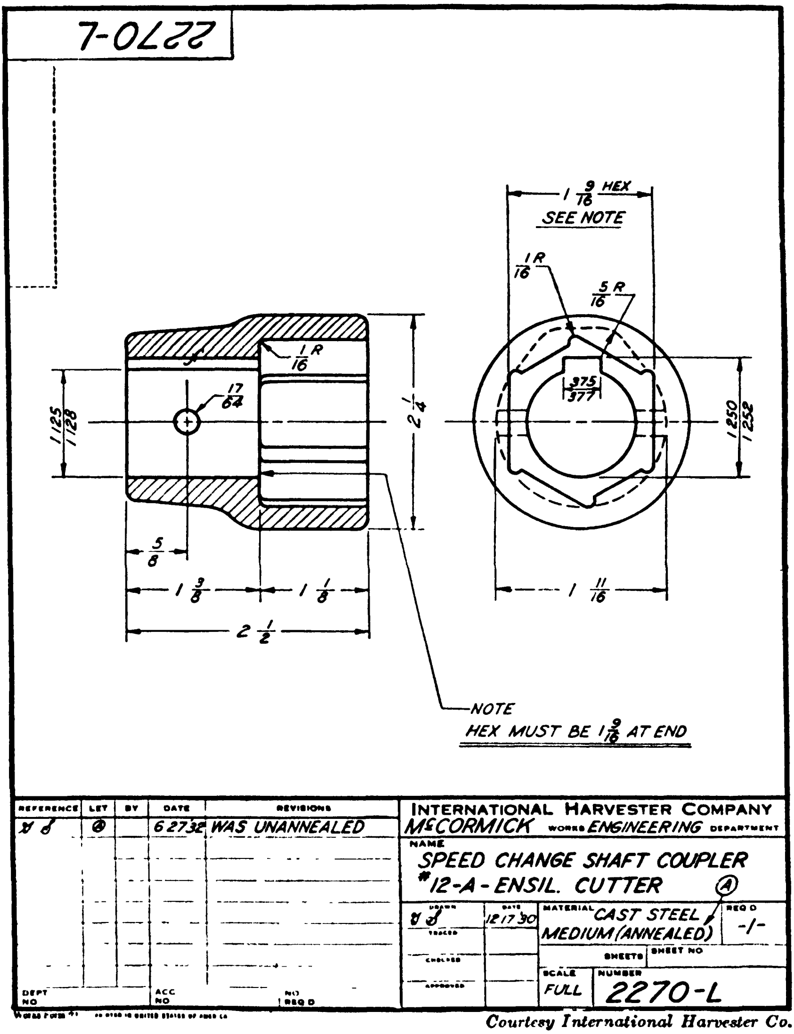
Fig. 346. A detail drawing.

239. Detail drawings. A detail drawing should give complete information for the manufacture of a part, describing with adequate dimensions the part's size. Finished surfaces should be indicated and all necessary shop operations shown. The title should give the material of which the part is to be made and should state the number of the parts that are required for the production of an assembled unit of which the part is a member. Commercial examples of detail working drawings are shown in Figs. 346 and 347.

240. Making a detail drawing. With a design layout or original sketches as a guide, the procedure for making a detail drawing is as follows:

1. Select the views, remembering that, aside from the view showing the characteristic shape of the object, there should be as many additional views as are necessary to complete the shape description. These may be sectional views which reveal a complicated interior construction, or auxiliary views of surfaces not fully described in any of the principal views.

2. Decide upon a scale that will allow, without crowding, a balanced arrangement of all necessary views and the location of dimensions and notes. Although very small parts should be drawn double size or larger, to show detail and to allow for dimensions, a full-size scale should be used when possible. In general, the same scale should be used for pieces of the same size.



Courtesy International Harvester Co.

Fig. 347. A detail drawing.

3. Draw the main center lines and block in the general outline of the views with light, sharp 6H pencil lines. Study Fig. 128.

4. Draw main circles and arcs in finished weight.

5. Starting with the characteristic view, work back and forth from view to view until the shape of the object is completed. Lines whose definite location and length are known may be drawn in their finished weight.

6. Put in fillets and rounds.
7. Complete the views by darkening the object lines.
8. Draw extension and dimension lines.
9. Add arrowheads, dimensions, and notes.
10. Complete the title.
11. Check the entire drawing carefully.

241. One-view drawings. Many parts, such as shafts, bolts, studs, and washers, may require only one properly dimensioned view. In the case of each of these parts, a note can imply the complete shape of the piece without sacrificing clearness.

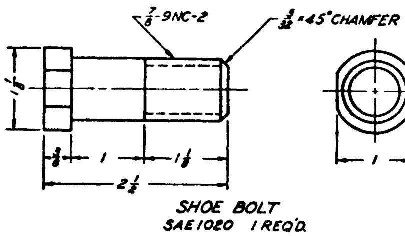


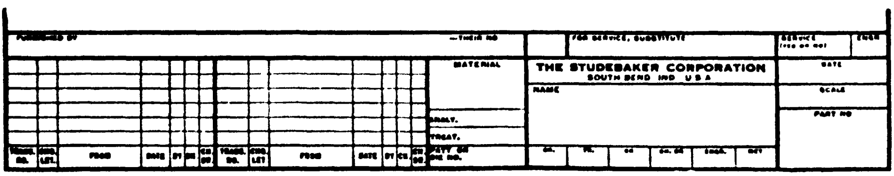
Fig. 348. A detail title.

242. Detail titles. Every detail drawing must give information which is not conveyed by the notes and dimensions, such as the name of the part, part number, material, number required, and so on. The method of recording and the location of this information on the drawing varies somewhat in different drafting rooms. It may be lettered either in the record strip or directly below the views. (See Figs. 347 and 348.)

If all surfaces on a part are machined, finish marks are omitted and a title note, "Finish all over," is added to the detail title.

243. Title blocks and record strips. The purpose of a title or record strip is to present in an orderly manner the name of the machine, name of the manufacturer, date, scale, drawing number, and other drafting-room information.

Every commercial drafting room has developed its own standard title forms, whose features depend upon the processes of manufacture, the



Courtesy Studebaker Corp.

Fig. 349. A record strip.

peculiarities of the plant organization, and the established customs of particular types of manufacturing. In large organizations, the blank form, along with the border line, is printed on standard sizes of drawing or tracing paper.

A record strip is a form of title which extends almost the entire distance across the bottom of the sheet. In addition to the usual title information, it may contain a section for recording revisions, changes, and so on, with the dates on which they were adopted (Fig. 349).

244. Contents of the title. The title on a machine drawing generally contains the following information:

1. Name of the part.
2. Name of the machine or structure. (This is given in the main title and is usually followed by one of two words: *details* or *assembly*.)
3. Name and location of the manufacturing firm.
4. Name and address of the purchasing firm, if the structure has been designed for a particular company.
5. Scale.
6. Date. (Often spaces are provided for the date of completion of each operation in the preparation of the drawing. If only one date is given, it is usually the date of completion of the tracing.)
7. Initials of the draftsman who made the pencil drawing.
8. Initials of the tracer.
9. Initials of the checker.
10. Initials or signature of the chief draftsman, chief engineer, or another in authority who approved the drawing.
11. Drawing number. This generally serves as a filing number and may furnish information in code form. Letters and numbers may be so combined as to indicate departments, plants, model, type, order number, filing number, and so on. The drawing number is sometimes repeated in the upper left-hand corner (in an upside-down position), so that the drawing may be quickly identified if it should become reversed in the file.

Some titles furnish information such as material, part number, pattern number, finish, treatment, estimated weight, superseded drawing number, and so on.

245. Corrections and alterations. Alterations on working drawings are made either by cancellation or by erasure. Cancellations are indicated by parallel inclined lines drawn through the views, lines, notes, or dimensions to be changed.

Superseding dimensions should be placed above or near the original ones. If alterations are made by erasure, the changed dimensions are often underlined.

All changes on a completed or approved drawing should be recorded by a note in a section of the record strip (Fig. 347). This note should contain the identification symbol, date, character of the revision, and the initials of the draftsman or checker who made the change. The identification symbol is a letter or numeral placed in small circle near the alteration on the body of the drawing.

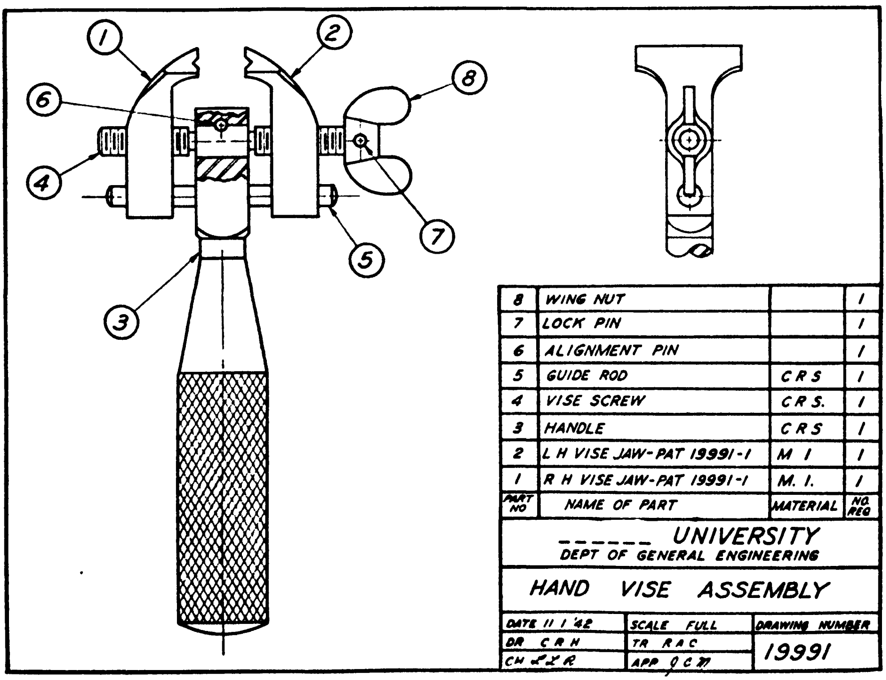
If changes are made by complete erasure, record prints should be made for the file before the original is altered. Many companies make record prints whenever changes are extensive.

246. Pattern-shop drawings. Sometimes special pattern-shop drawings, giving information needed for making a pattern, are required for large and complicated castings. If the pattern maker receives a drawing that shows finished dimensions, he provides for the draft necessary to draw the pattern and for the extra metal for machining. He allows for shrinkage by making the pattern oversize. When, however, the draft and allowances for finish are determined by the engineering department, no finish marks appear on the drawing. The allowances are included in the dimensions.

247. Forge-shop drawings. If a forging is to be machined, separate detail drawings usually are made for the forge and machine shops. A forging drawing gives all the nominal dimensions required by the forge shop for a completed rough forging.

248. Machine-shop drawings. Rough castings and forgings are sent to the machine shop to be finished. Since the machinist is not interested in the dimensions and information for the previous stages, a machine-shop drawing frequently gives only the information necessary for machining.

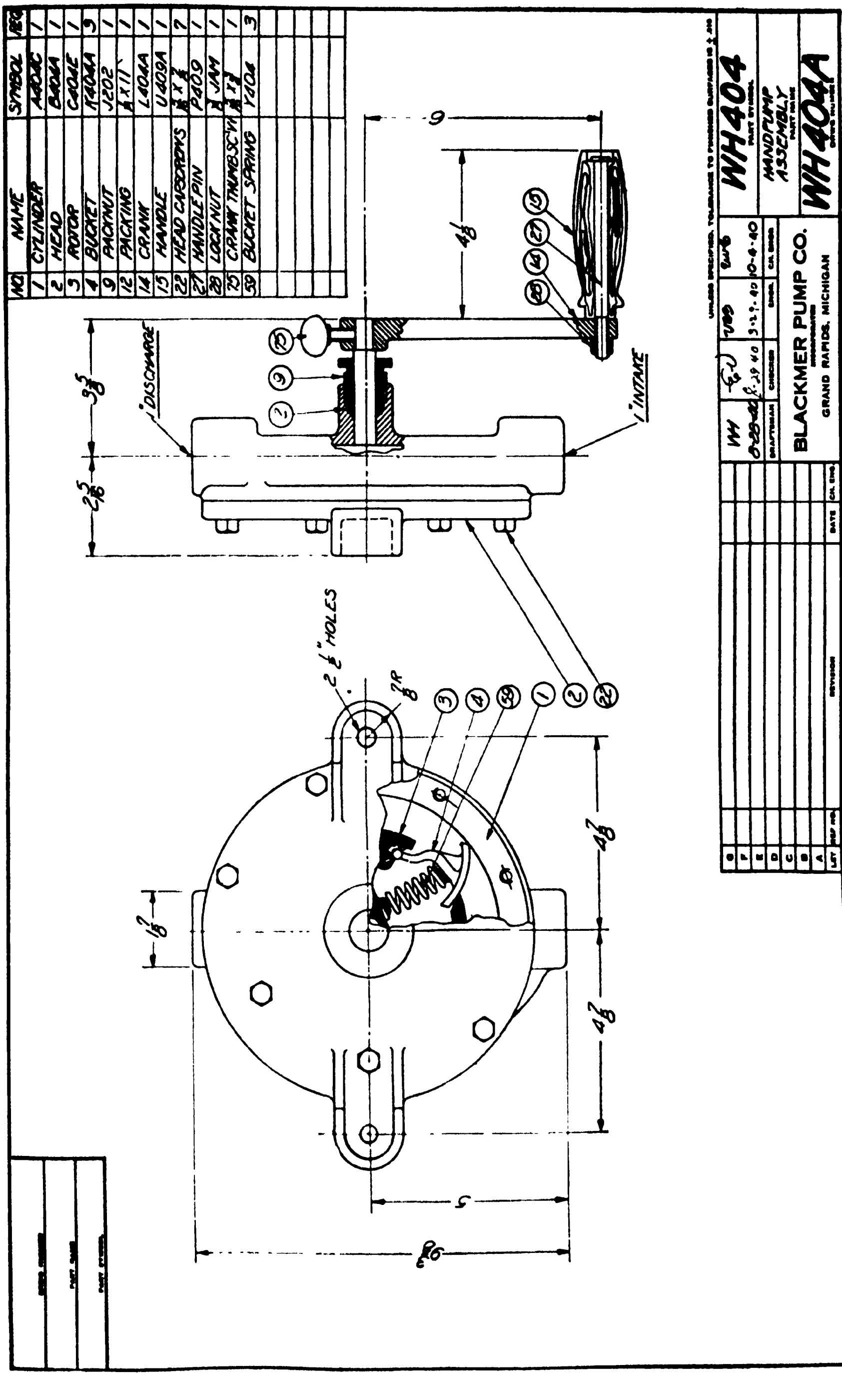
249. Assembly drawings. A drawing which shows the parts of a machine or machine unit assembled in their relative working positions is an assembly drawing (Figs. 350 and 351). There are several types of



PART NO	NAME OF PART	MATERIAL	NO REQ
8	WING NUT		1
7	LOCK PIN		1
6	ALIGNMENT PIN		1
5	GUIDE ROD	C R S	1
4	VISE SCREW	C R S.	1
3	HANDLE	C R S	1
2	L H VISE JAW-PAT 19991-1	M I	1
1	R H VISE JAW-PAT 19991-1	M. I.	1

Fig. 350. An assembly drawing.

such drawings: design assembly drawings, working assembly drawings, unit assembly drawings, installation diagrams, and so on, each of which will be described separately.



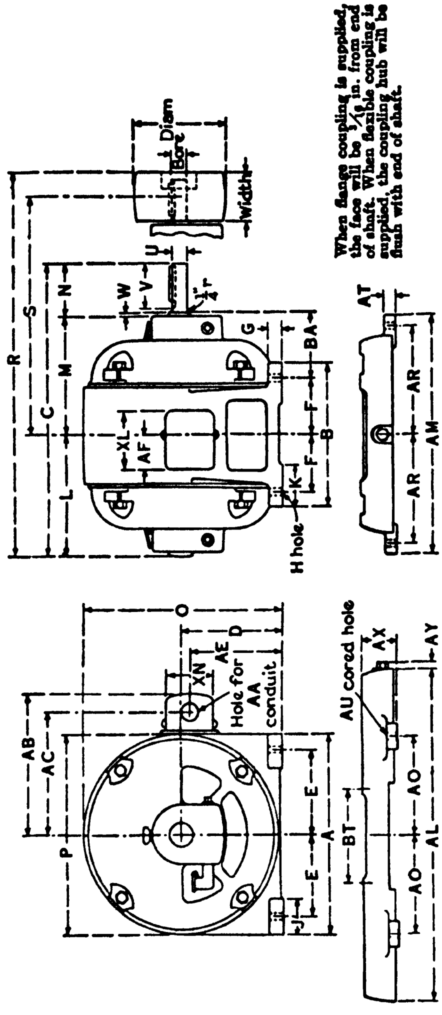
Courtesy Blackmer Pump Co.

Fig. 351. An assembly drawing.

TRI/CLAD INDUCTION MOTORS
Horizontal, Open, Squirrel-cage

Types K, KG and KR (2- and 3-phase)
Frames 203 to 326 Inclusive

Belt Drive, Two Sleeve or Ball Bearings
For Direct Drive Omit Base and Pulley



When flange coupling is supplied, the face will be 3/16 in. from end of shaft. When flexible coupling is supplied, the coupling hub will be flush with end of shaft.

Providing mounting restrictions permit, conduit boxes may be placed so that entrance can be made upward, downward, or from either side.

BASE AND PULLEY FURNISHED ONLY WHEN CALLED FOR ON REQUISITION

Frame, Base and Pulley No.	Approx Net Wt in Lb: Motor Only	Base	Pulley	Dimensions in Inches: Pulley: Dia	Width Over-all	Bore	Belt Width	Keyway: Width	Depth	Key Length	A	B	C	D	E	F	G	H	J	K	L	M
203	67	19	1¼	3	3		2½	3/16	3/32	1⅝	9⅝	6⅞	14	5	4	2¾	1 1/16	1 3/32	1⅜	1 15/16	5⅛	5⅜
204	74	20	1¼	3	3	...	2½	3/16	3/32	1⅝	9⅝	7⅛	15	5	4	3¼	1 1/16	1 3/32	1⅜	1 15/16	6⅛	6¼

Courtesy General Electric Co.

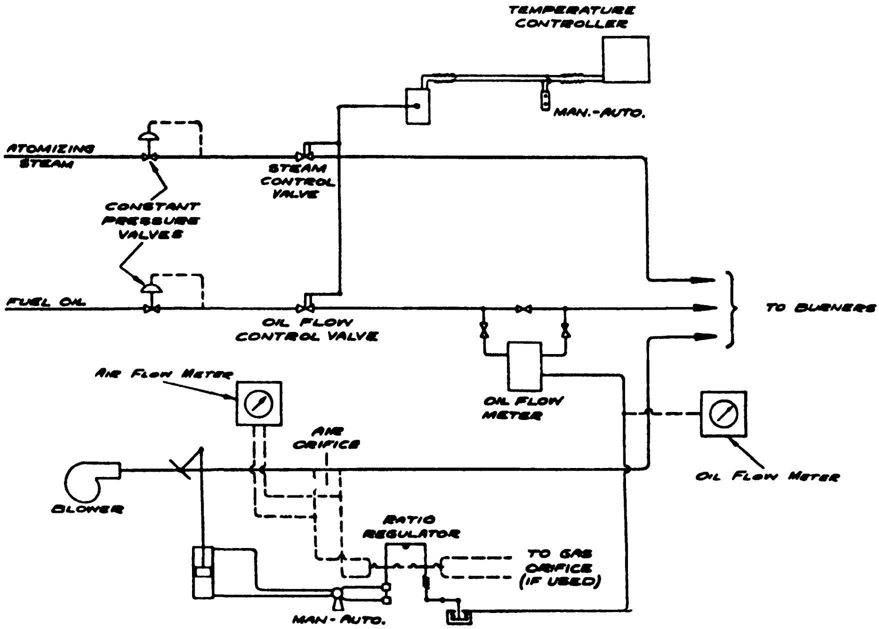
Fig. 352. An outline assembly drawing.

250. Working assembly drawings. A working assembly drawing, showing each piece completely dimensioned, is sometimes made for a simple mechanism or unit of related parts. No additional detail drawings of parts are required.

251. Sub-assembly (unit) drawings. A unit assembly is an assembly drawing of a group of related parts which form a unit in a more complicated machine. Such a drawing would be made for the tail stock of a lathe, the clutch of an automobile, or the carburetor of an airplane. A set of assembly drawings thus takes the place of a complete assembly of a complex machine.

252. Outline assembly drawings. Outline assembly drawings are most frequently made for illustrative purposes in catalogs. Usually they show merely over-all and principal dimensions. (See Fig. 352.) Their appearance may be improved by the use of line shading.

253. Diagram assembly drawings. Diagram drawings may be grouped into two general classes: (1) those composed of single lines and



Courtesy "Instruments Magazine."

Fig. 353. A diagram assembly drawing.

conventional symbols, such as piping diagrams, wiring diagrams, and so on (see Fig. 353), and (2) those drawn in regular projection, such as an erection drawing, which may be shown in either orthographic or pictorial projection.

254. Bill of material. A bill of material is a list of parts which is placed on an assembly drawing just above the title block, or, in the case of quantity production, on a separate sheet (Fig. 350). The bill contains the part number, descriptive name, material, quantity (number) required, and so on, of each piece. Additional information, such as stock size, pattern number (castings), and so forth, is sometimes listed.

For $\frac{1}{8}''$ letters, the lines should never be spaced closer than five-sixteenths of an inch. Fractions are made slightly less than full height and are centered between the lines.

When listing standard parts in a bill of material, the general practice is to omit the name of the materials and to use abbreviated descriptive titles. A pattern number may be composed of the commercial job number followed by the assigned number one, two, three, and so on. It is suggested that parts be listed in the following order: (*a*) castings, (*b*) forgings, (*c*) parts made from bar stock, (*d*) standard parts.

Sometimes bills of material are first typed on thin paper and then blueprinted. The form may be ruled or printed.

255. Title. The title strip on an assembly drawing usually is the same as that used on a detail drawing. It will be noted, when lettering in the block, that the title of the drawing is generally composed of the name of the machine followed by the word *assembly*. (See Figs. 350 and 351.)

256. Making the assembly drawing. The final assembly may be traced from the design assembly drawing, but more often it is redrawn to a smaller scale on a separate sheet. Since the redrawing, being done from both the design and detail drawings, furnishes a check which frequently reveals errors, the assembly always should be drawn before the details are accepted as finished and the blueprints are made. The assembly of a simple machine or unit is sometimes shown on the same sheet with the details.

Accepted practices to be observed on assemblies are:

1. *Sectioning.* Parts should be sectioned using the American Standard symbols shown in Fig. 206. The practices of sectioning apply to assemblies.

2. *Views.* The main view, which is usually in full section, should show to the best advantage nearly all the individual parts and their locations. Additional views are shown only when they add necessary information that should be conveyed by the drawing.

3. *Hidden lines.* Hidden lines should be omitted from an assembly drawing, for they tend merely to overload it and create confusion. Complete shape description is unnecessary, since parts are either standard or are shown on detail drawings.

4. *Dimensions.* Over-all dimensions and center-to-center distances indicating the relationship of parts in the machine as a whole are sometimes given. Detail dimensions are omitted, except on working assembly drawings.

5. *Identification of parts.* Parts in a machine or structure are identified on the assembly drawing by numbers which are used on the details and in the bill of material. These should be made at least $\frac{3}{16}''$ high and enclosed in a $\frac{3}{8}''$ circle. The centers of the circles are located not less than $\frac{3}{4}''$ from the nearest line of the drawing. Leaders, terminated by arrowheads touching the parts, are drawn radial with a straightedge. The numbers, in order to be centered in the circles, should be made first and the circles drawn around them. An alternate method used in commercial practice is to letter the name and descriptive information for each part and draw a leader pointing to it in the main view.

257. Checking drawings. Checking, the final assurance that the machine is correctly designed, should be done by a person (checker or squad foreman) who has not prepared the drawings but who is thoroughly familiar with the principles of the design. He must have a broad knowledge of shop practices and assembly methods. In commercial drafting rooms, the most experienced men are assigned to this type of work. The assembly drawing is checked against the detail drawings and corrections are indicated with either a soft or colored pencil. The checker should:

1. Survey the machine as a whole from the standpoint of operation, ease of assembly, and accessibility for repair work. He should consider the type, strength, and suitability of the materials.
2. Check each part with the parts adjacent to it, to make certain that proper clearances are maintained. (To determine whether or not all positions are free of interference, it may be necessary to lay out the extreme travel of moving parts to an enlarged scale.)
3. Study the drawing to see that each piece has been illustrated correctly and that all necessary views, types of views, treatments of views, and scales have been shown.
4. Check dimensions by scaling; calculate and check size and location dimensions which affect mating parts; determine the suitability of dimensions from the standpoint of the various departments' needs, such as pattern, forge, machine, assembly shop, and so on; examine views for proper dimensioning, and mark unnecessary, repeated, or omitted dimensions.
5. Check tolerances, making sure the computations are correct and that proper fits have been used, so that there will be no unnecessary production costs.
6. See that finishes and such operations as drilling, reaming, boring, tapping, and grinding are properly specified.
7. Check specifications for material.
8. Examine notes for correctness and location.
9. See that stock sizes have been used for standard parts such as bolts, screws, keys, and so on. (Stock sizes may be determined from catalogs.)
10. Add any additional explanatory notes that should supply necessary information.
11. Check the bill of material to see that each part is completely and correctly specified.
12. Check items in the title block.
13. Make a final survey of the drawing in its entirety, making certain there is either a check or correction for each dimension, note, and specification.

258. Problems. The four general types of problems presented in this chapter have been designed to furnish practice in the preparation of working drawings. The first type is composed of dimensioned pictorial drawings of individual pieces taken from a wide variety of mechanisms. The student should prepare complete working detail drawings of these pieces as they are assigned by his instructor. It should be recognized that dimensions are not necessarily placed the same on orthographic views as they are on pictorial drawings. In order to make it possible for the student to apply the principles presented in the previous chapters, no special effort has been made to place dimensions in accordance with the rules of good practice. Furthermore there are many cases where dimensions cannot be placed on pictorial drawings in the same locations as on the orthographic views.

The second type of problem is that which shows in pictorial all the parts of a unit mechanism. This gives the student an opportunity to prepare a complete set of working drawings of a simple unit. It is suggested that the detail drawings be prepared before the assembly is drawn.

The third and fourth types provide practice in both reading and preparing drawings, the third requiring the preparation of detail drawings from given assembly drawings, the fourth requiring the making of assembly drawings from the details.

1–13. (Figs. 354–366.) Make a detail drawing of an assigned machine part. Draw all necessary views. Give a detail title with suitable notes concerning material, number required, etc.

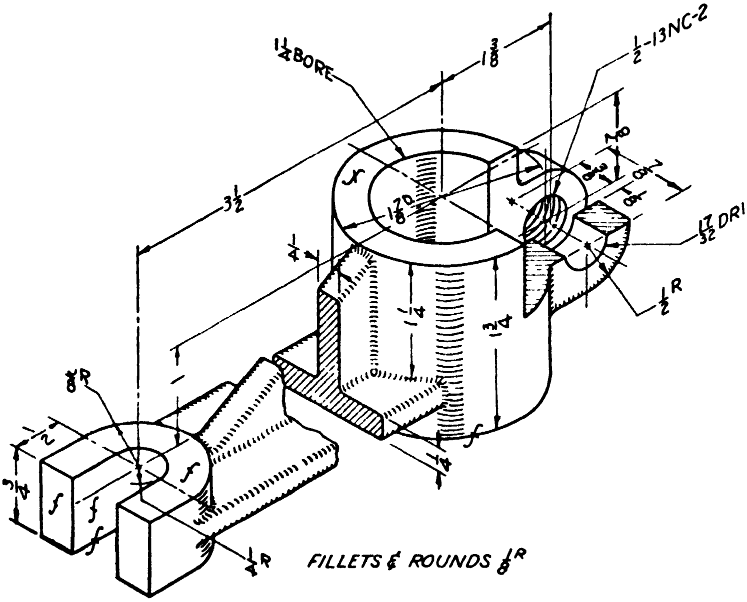


Fig. 354. Shifter.

14. (Fig. 367.) Make a detail drawing of the motor bracket. Draw all necessary views. Give a detail title with suitable notes concerning material, number required, etc.

15. (Fig. 368.) Make a complete detail working drawing (views, dimensions, notes, and title) of the motor base. The ribs are $\frac{3}{8}''$ thick. At points A, four holes are to be drilled for $\frac{1}{2}''$ bolts which are to be $2\frac{1}{2}''$ center to center in one direction and $3\frac{1}{8}''$ in the other. At points B, four holes are to be drilled for $\frac{1}{2}''$ bolts which fasten the motor base to a steel column. Fillets and rounds are $\frac{1}{8}$ R.

16–17. (Fig. 369.) Make a complete detail working drawing of the tool rest and/or the tool rest bracket. The rectangular top surface of the tool rest is to be $1\frac{1}{8}''$ above the center line of the hole for the $\frac{7}{16}''$ bolt. The over-all dimensions of the top are $1\frac{1}{4}'' \times 2\frac{1}{2}''$. It is to be $\frac{1}{4}''$ thick. The over-all dimensions of the rectangular pad of the bracket are $1\frac{1}{4}'' \times 1\frac{7}{8}''$. The center line of the adjustment slot is $\frac{9}{16}''$ above the center line of the top holes in the rectangular pad and the distance from center line to center line of the slot is $1\frac{3}{8}''$. The bracket is to be fastened to a housing with $\frac{1}{4}''$ round head machine screws.

18. (Fig. 370.) Make a detail drawing of an assigned part of the pipe stand. Draw all necessary views and give all dimensions that will be required by the shop. Compose a suitable title, giving the name of the part, the material, and the number required.

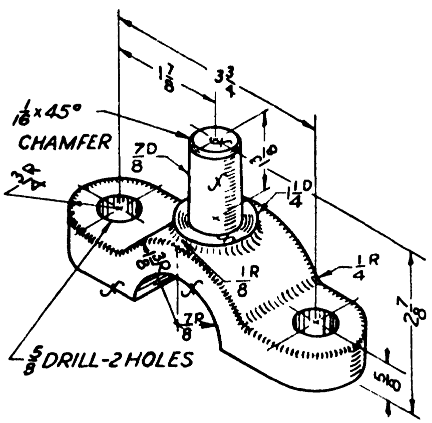


Fig. 355. Stud bracket.

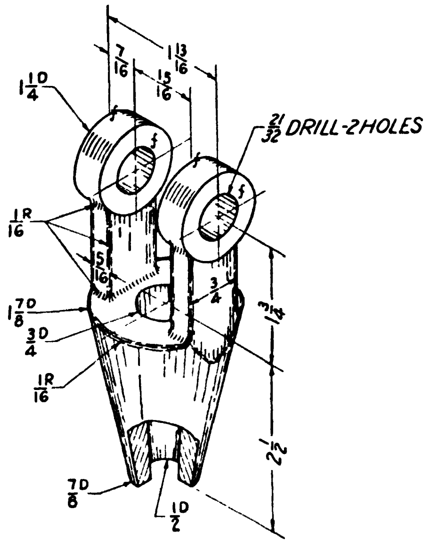


Fig. 356. Socket.

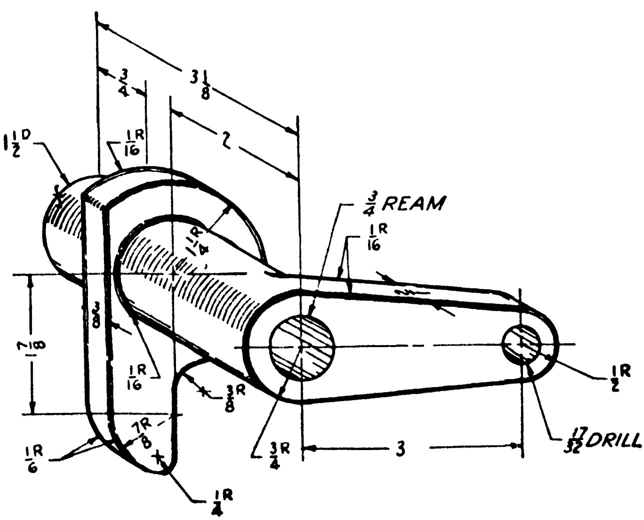


Fig. 357. Offset trip lever.

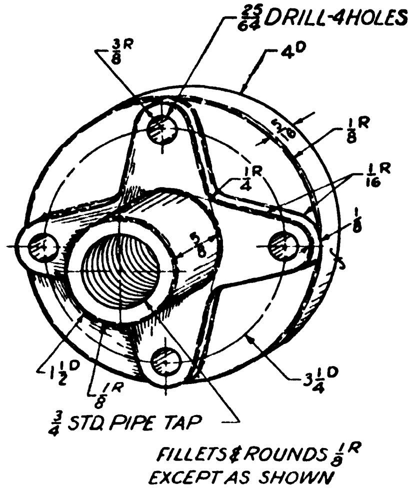


Fig. 358. Flange.

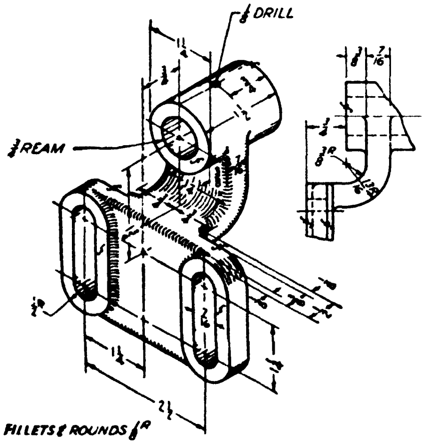


Fig. 359. Bearing bracket.

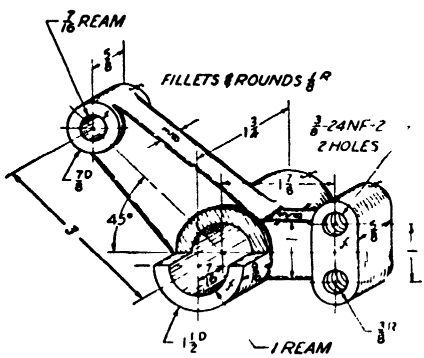


Fig. 360. Guide.

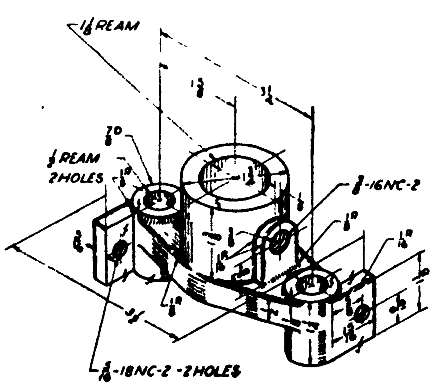


Fig. 361. Guide bracket.

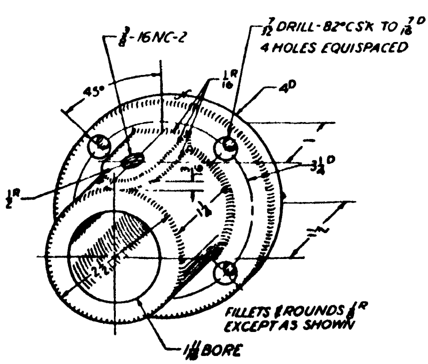


Fig. 362. Pipe support.

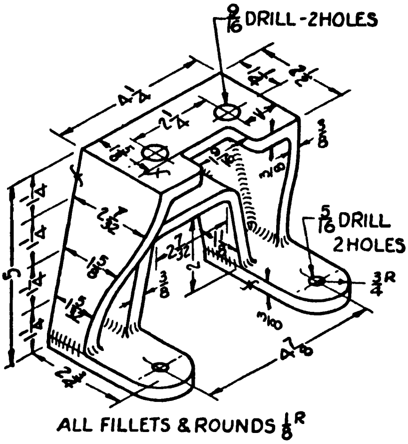


Fig. 363. Lathe leg.

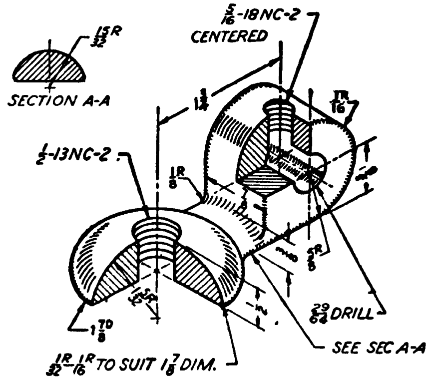


Fig. 364. Handle block.

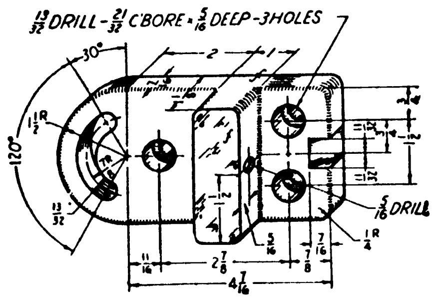


Fig. 365. Slotted base.

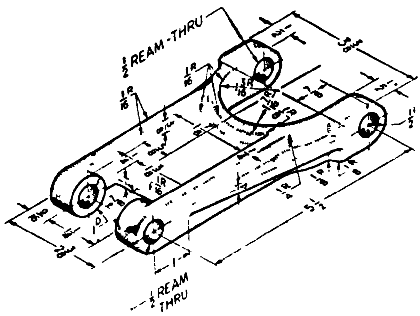


Fig. 366. Link.

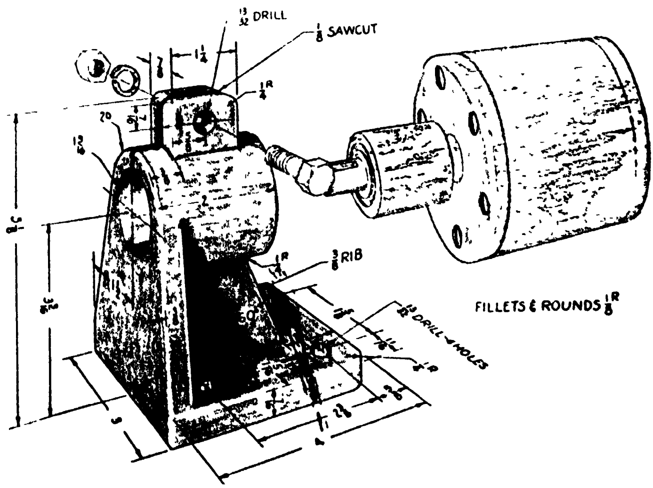


Fig. 367. Motor bracket.

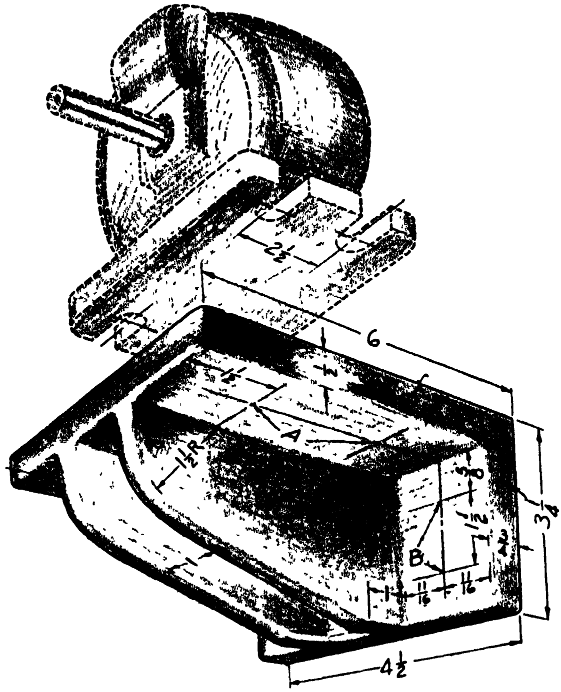


Fig. 368. Motor base.

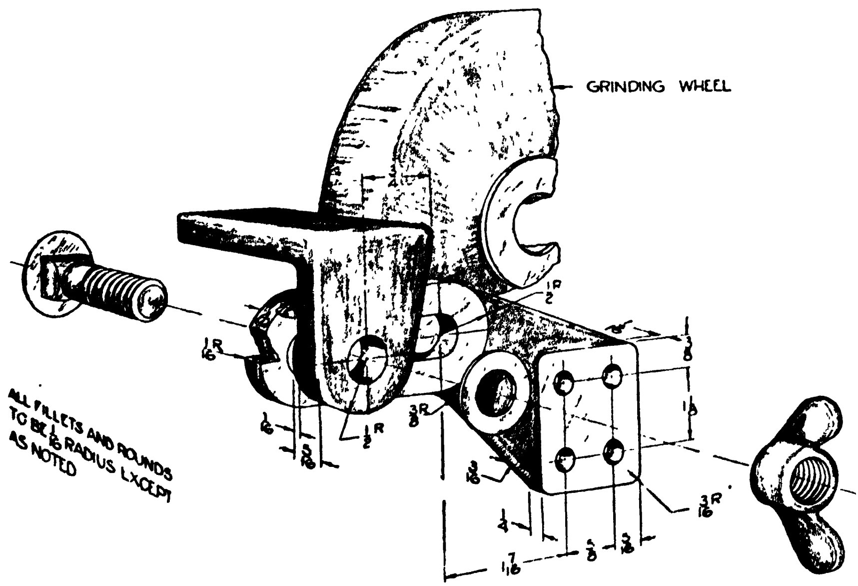
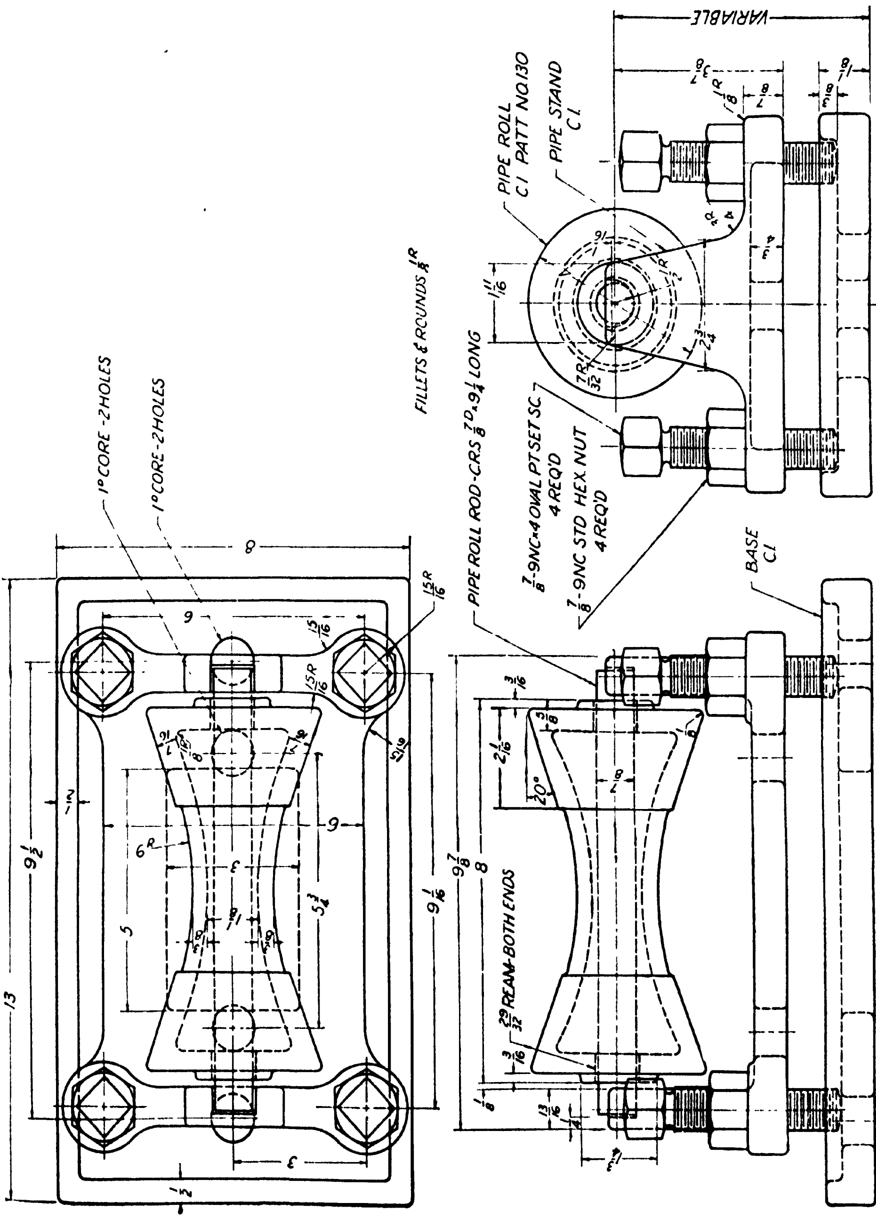


Fig. 369. Tool rest and tool rest bracket.



Courtesy Grinnell Co.

Fig. 370. Pipe stand.

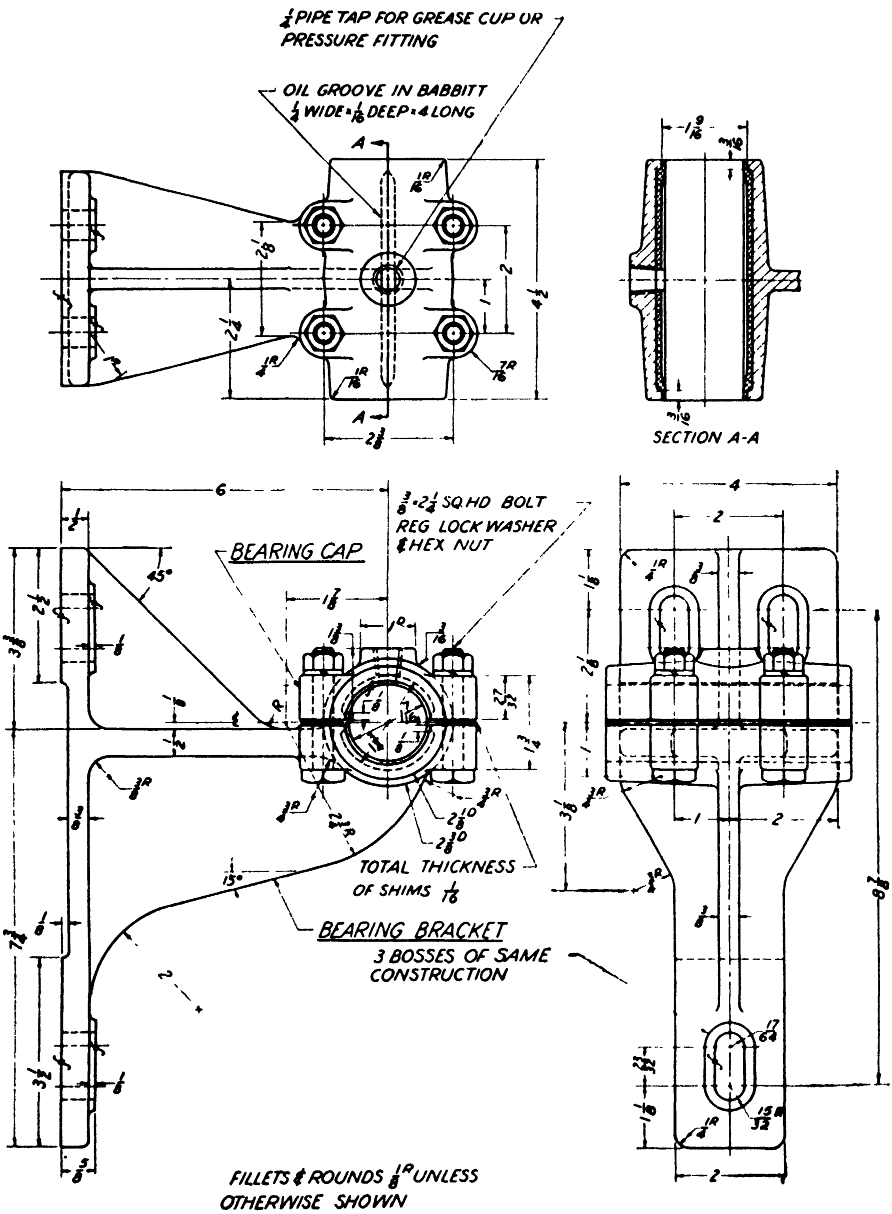


Fig. 371. Bearing bracket.

19. (Fig. 371.) Make a detail drawing of an assigned part of the bearing bracket. Compose a suitable detail title, giving the name of the part, the material, etc.

20. (Fig. 372.) Make a detail working drawing of an assigned part of the flexible joint. Compose a suitable title giving the name of the part, the material, etc.

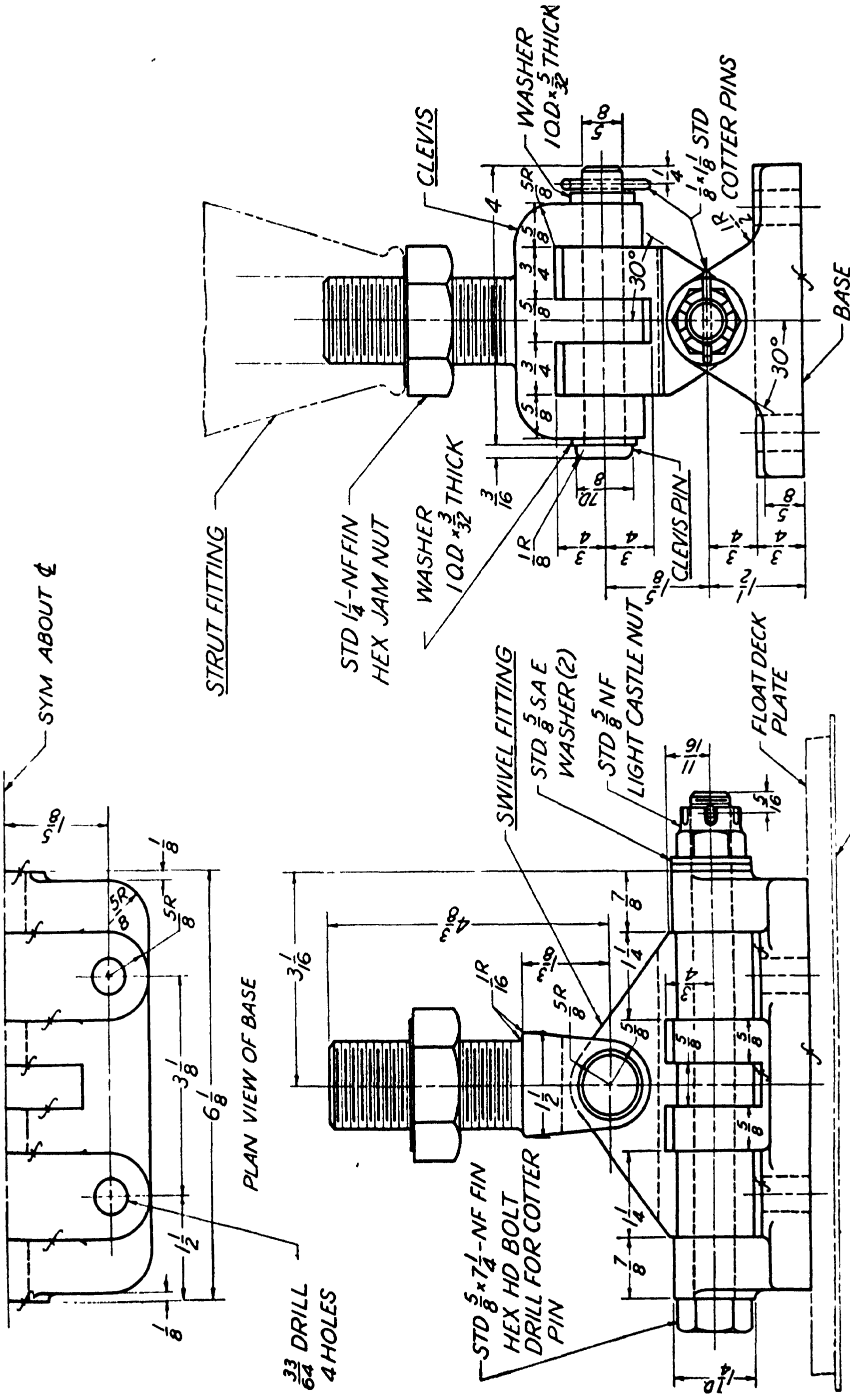


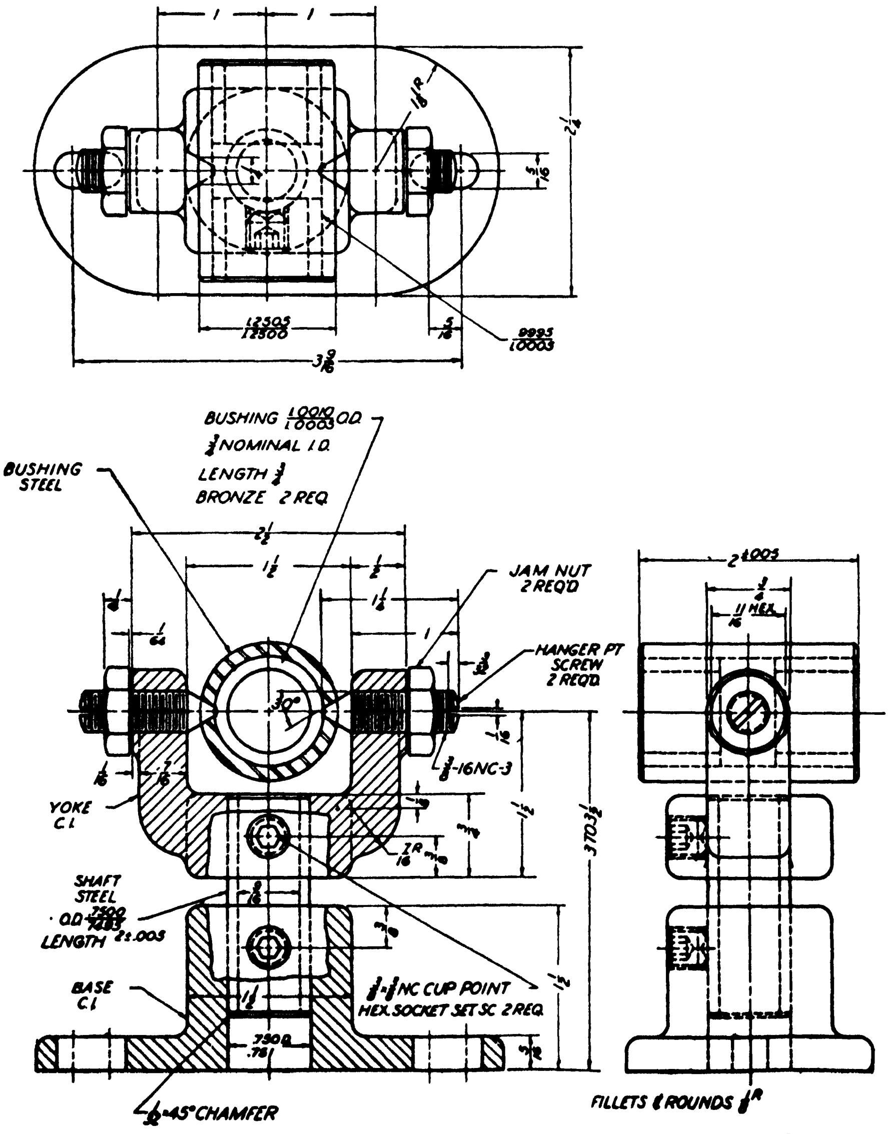
Fig. 372. Flexible joint.

21. (Fig. 373.) Make a detail working drawing of an assigned part of the self-aligning shaft support. Compose a suitable title, giving the name of the part, the material, etc.

22. (Fig. 374.) Make a detail drawing of an assigned part of the air cylinder.

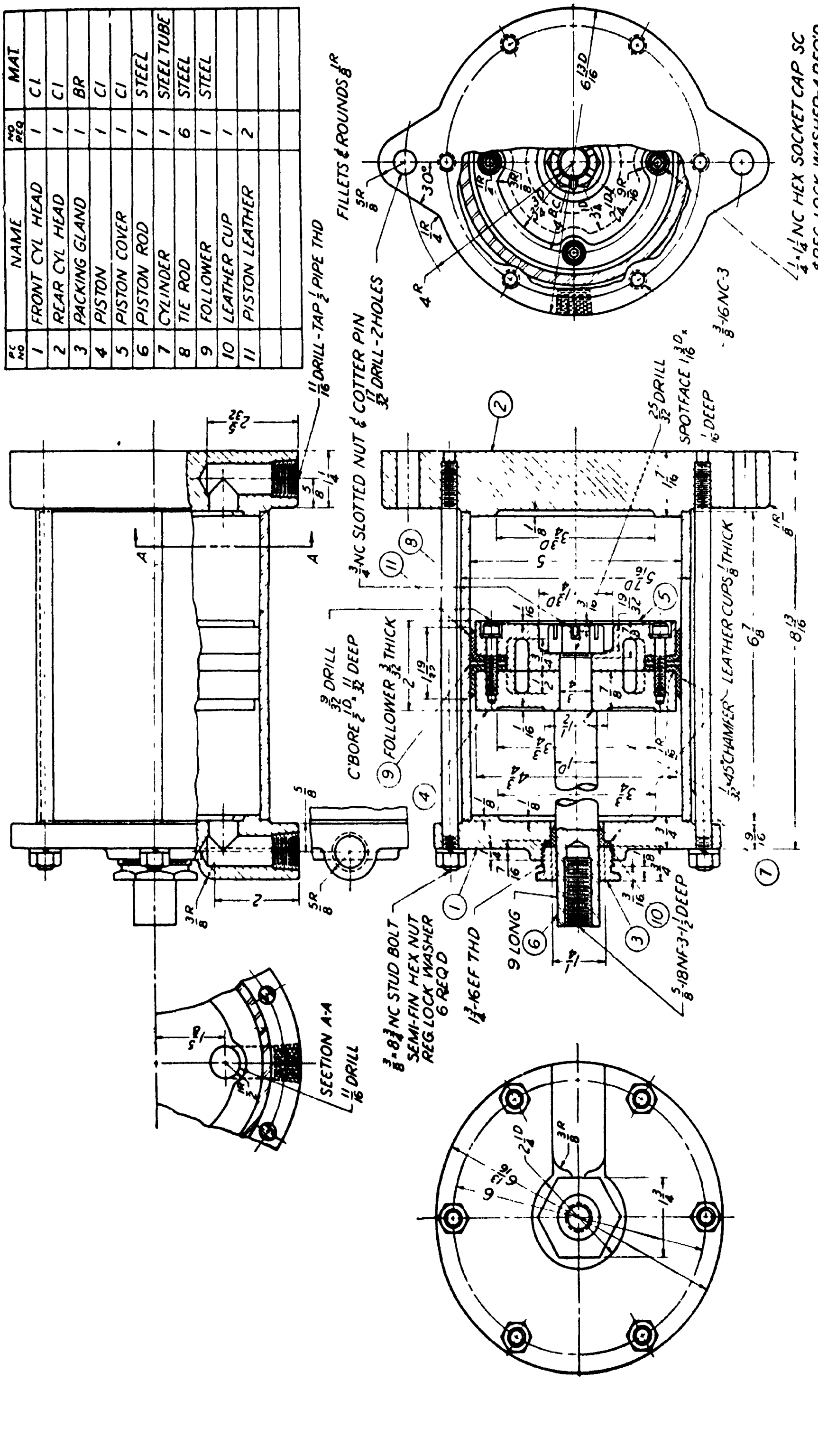
23. (Fig. 375.) Make a detail drawing of an assigned part of the screw jack.

24. (Fig. 376.) Make a detail drawing of an assigned part of the thermostatic radiator trap.



Courtesy Boston Gear Works, Inc.

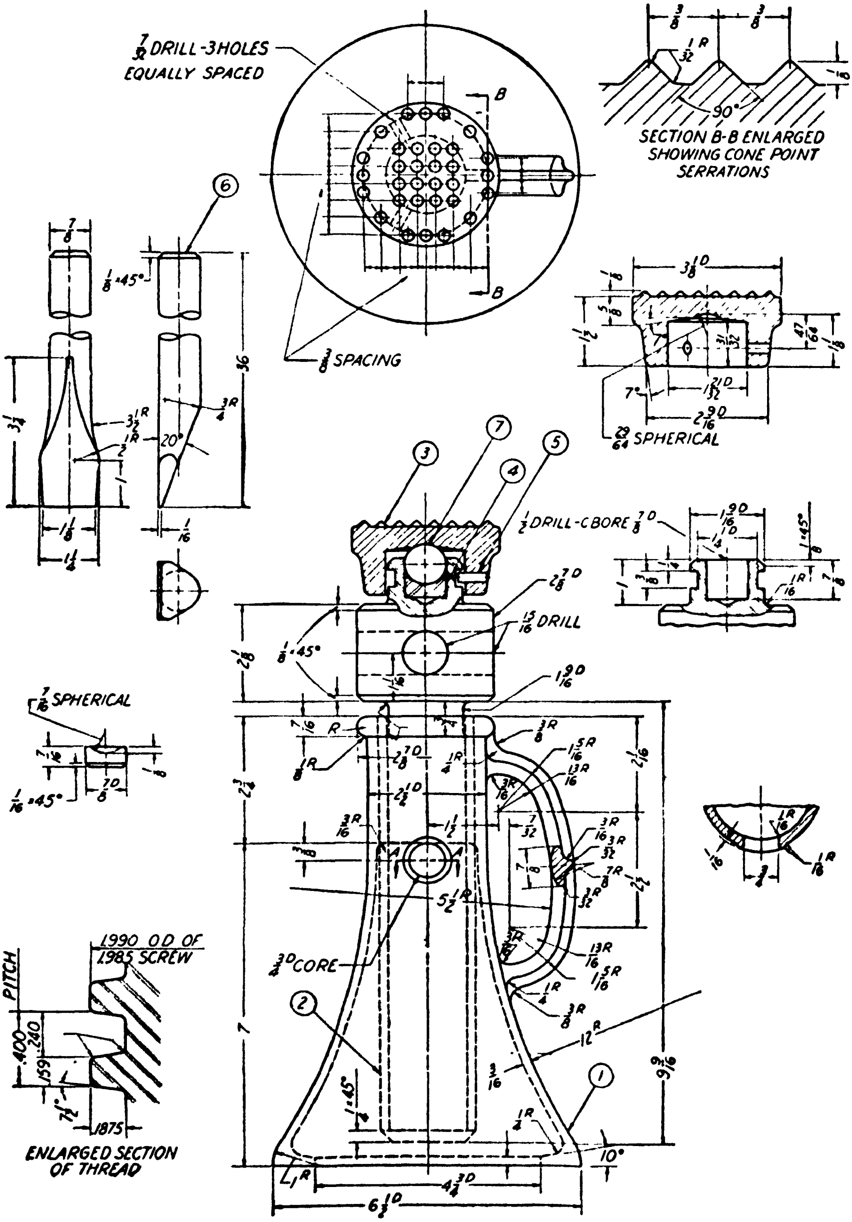
Fig. 373. Self-aligning shaft support.



PC NO	NAME	NO REQ	MAT
1	FRONT CYL HEAD	1	CI
2	REAR CYL HEAD	1	CI
3	PACKING GLAND	1	BR
4	PISTON	1	CI
5	PISTON COVER	1	CI
6	PISTON ROD	1	STEEL
7	CYLINDER	1	STEEL TUBE
8	TIE ROD	6	STEEL
9	FOLLOWER	1	STEEL
10	LEATHER CUP	1	
11	PISTON LEATHER	2	

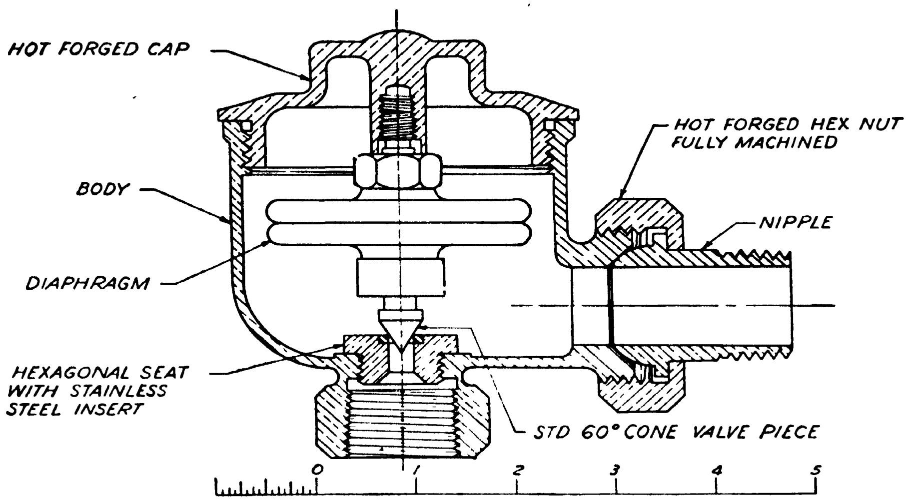
Fig. 374. Air cylinder

PC NO	NAME	QUAN	MATERIAL	PC NO	NAME	QUAN	MATERIAL
1	STANDARD	1	MALL IRON	5	GROOVE PIN	3	$\frac{7}{32}$D x $\frac{3}{8}$ STEEL ROD
2	SCREW	1	S.A.E. 1120 FORGING	6	LEVER BAR	1	REROLLED RAIL STK
3	CAP	1	S.A.E. 1045 FORGING	7	$\frac{7}{8}$ DIA BALL BEARING	1	STD
4	THRUST WASHER	1	S.A.E. 2315				



Courtesy of Templeton, Kenly & Co.

Fig. 375. Simplex ball bearing screw jack.



Courtesy Warren Webster & Company.

Fig. 376. Thermostatic radiator trap.

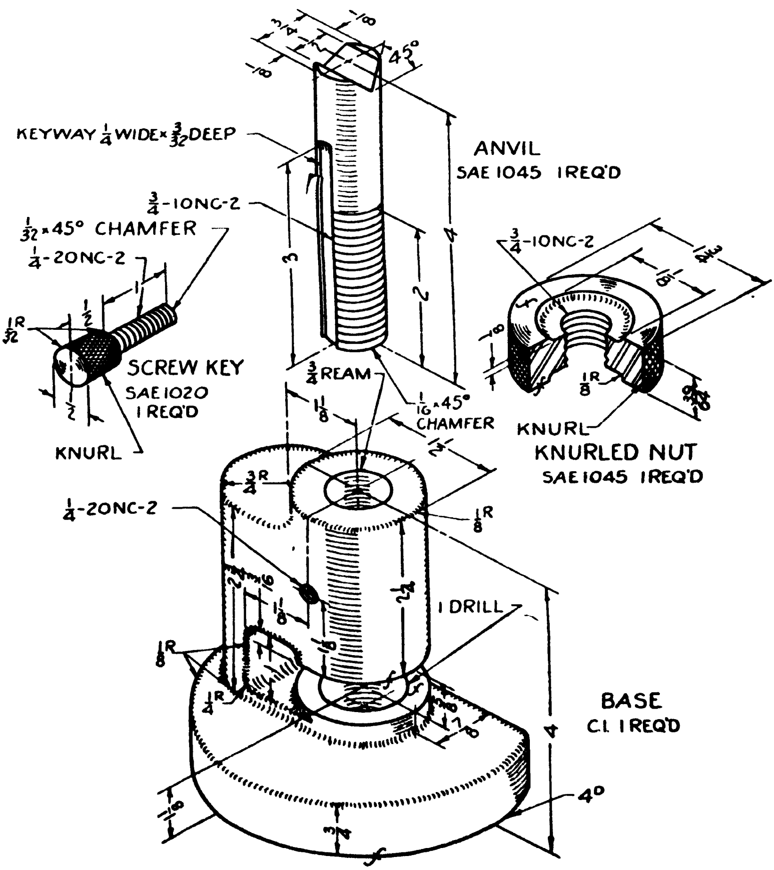
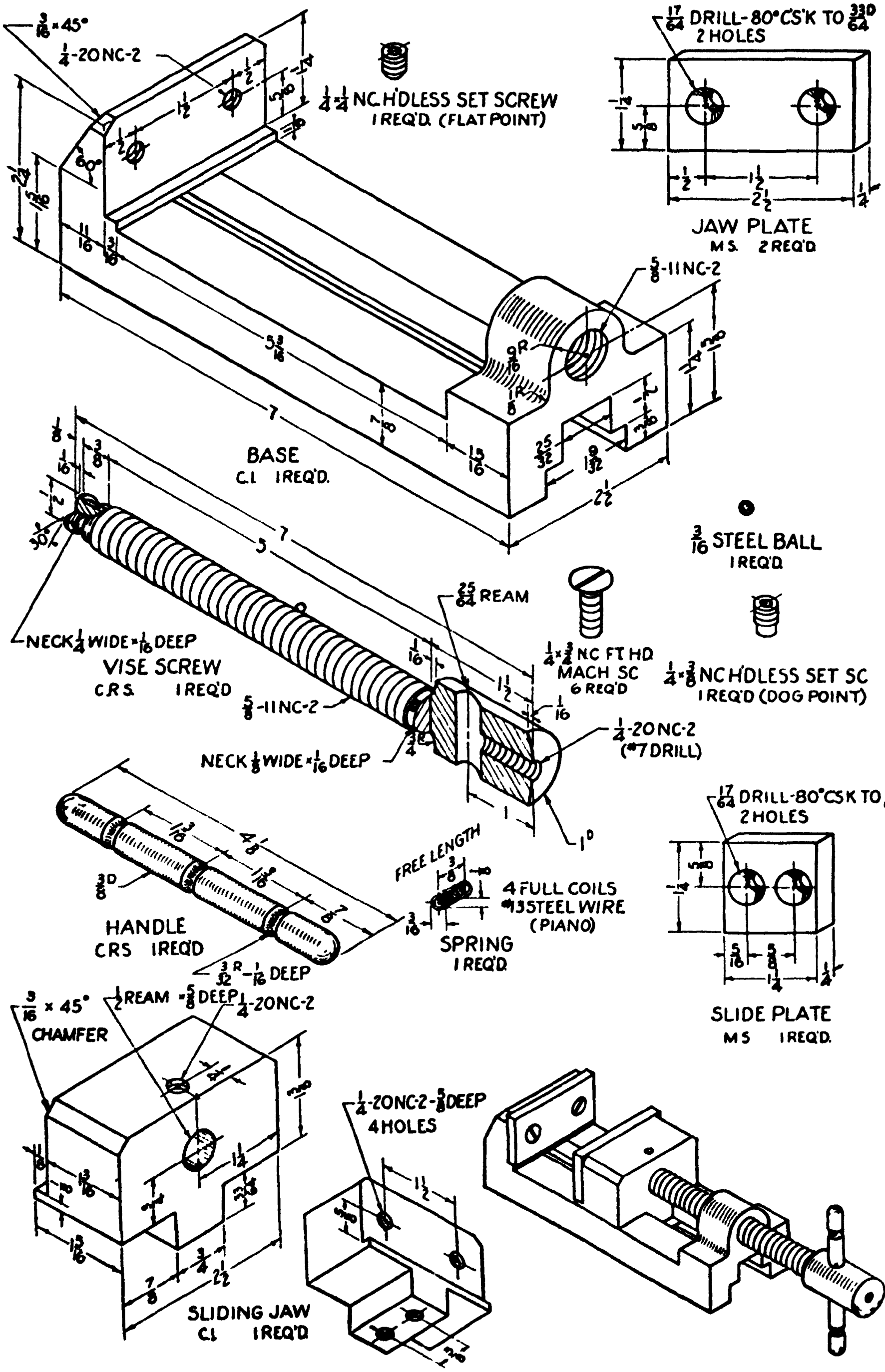


Fig. 377. Milling jack.



¼-20NC-2
¼×¼ NC H'DLESS SET SCREW
1 REQ'D. (FLAT POINT)
17/64 DRILL-80° CS'K TO 33/64 D
2 HOLES
JAW PLATE
M.S. 2 REQ'D
5/8-11NC-2
BASE
C.I. 1 REQ'D.
3/16 STEEL BALL
1 REQ'D.
25/64 REAM
NECK ¼ WIDE × 1/16 DEEP
VISE SCREW
C.R.S. 1 REQ'D
5/8-11NC-2
¼×3/4 NC FT HD MACH SC
6 REQ'D
¼×3/8 NC H'DLESS SET SC
1 REQ'D (DOG POINT)
NECK 1/8 WIDE × 1/16 DEEP
¼-20NC-2
(#7 DRILL)
17/64 DRILL-80° CSK TO 33/64 D
2 HOLES
FREE LENGTH
4 FULL COILS
#15 STEEL WIRE
(PIANO)
HANDLE
CRS 1 REQ'D
SPRING
1 REQ'D
3/32 R - 1/16 DEEP
SLIDE PLATE
M.S. 1 REQ'D.
3/16 × 45° CHAMFER
½ REAM × 5/8 DEEP
¼-20NC-2
¼-20NC-2-3/8 DEEP
4 HOLES
SLIDING JAW
C.I. 1 REQ'D

Fig. 378. Vise.

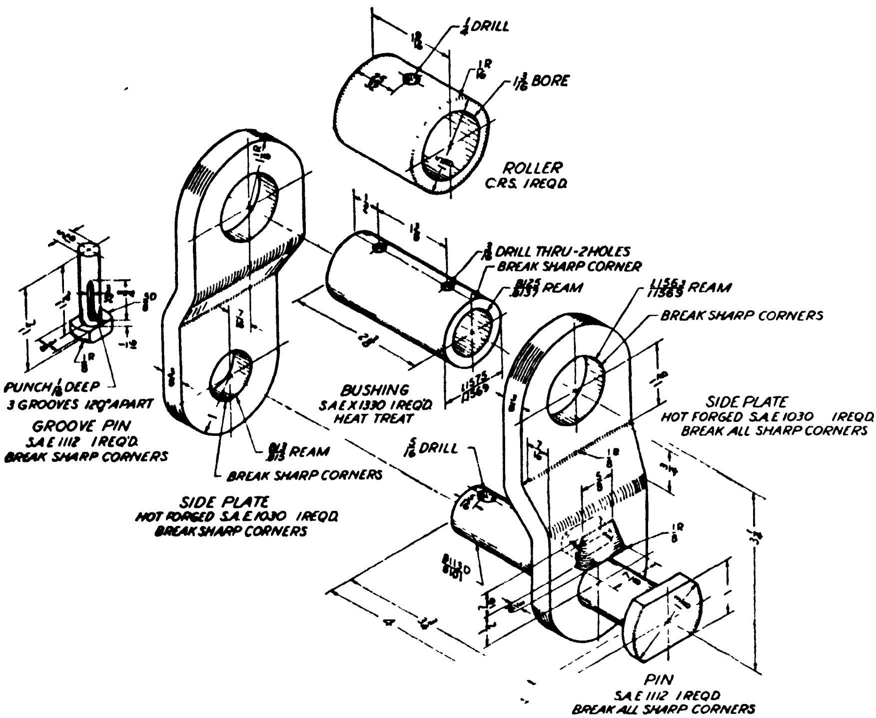


Fig. 379. Link.

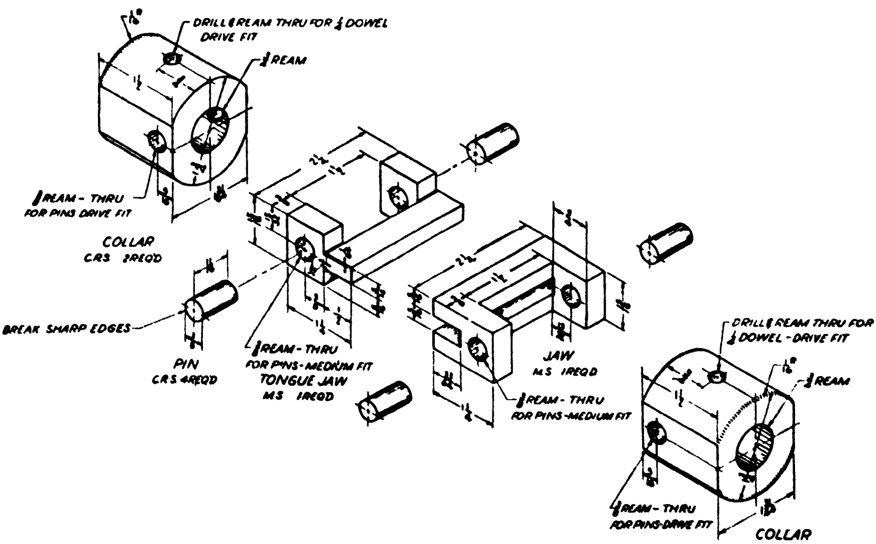


Fig. 380. Coupling.

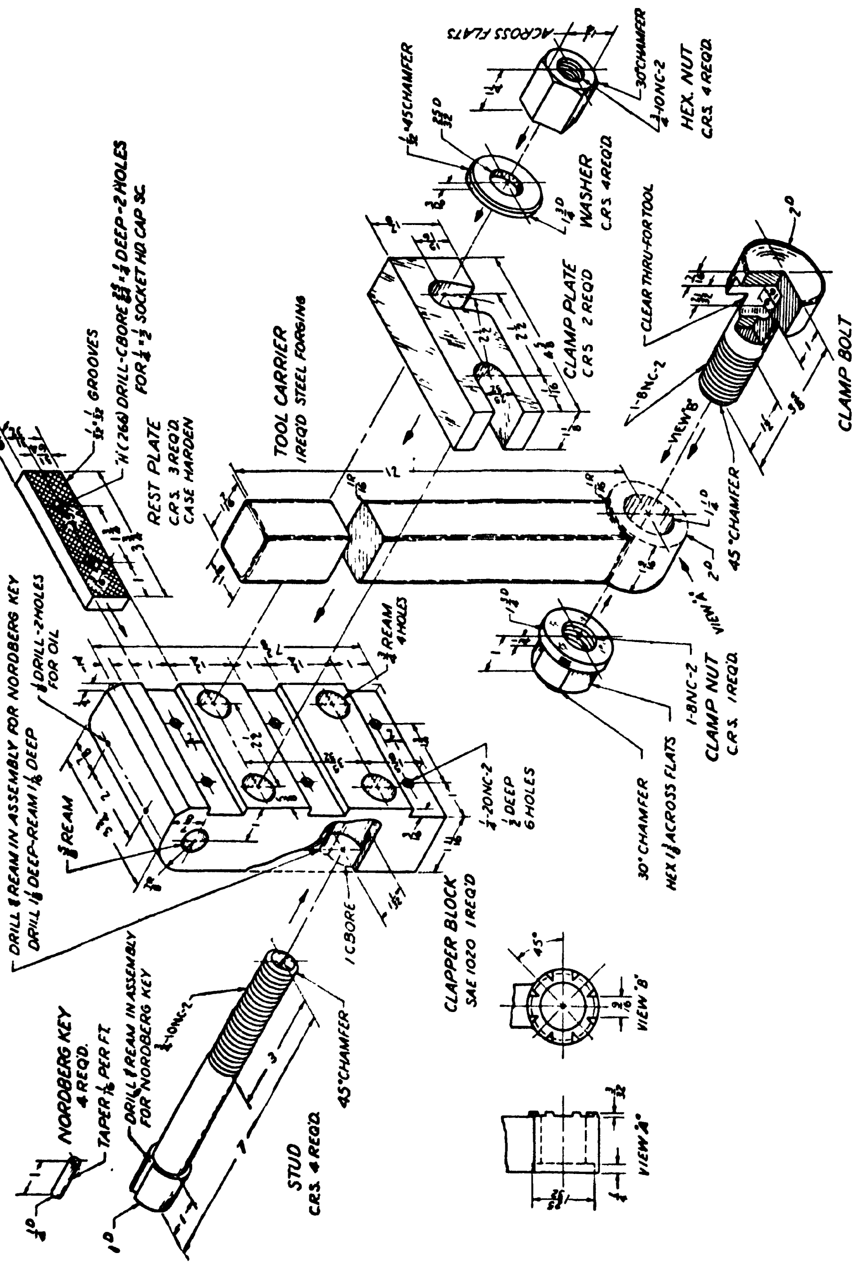


Fig. 381. Tool holder.

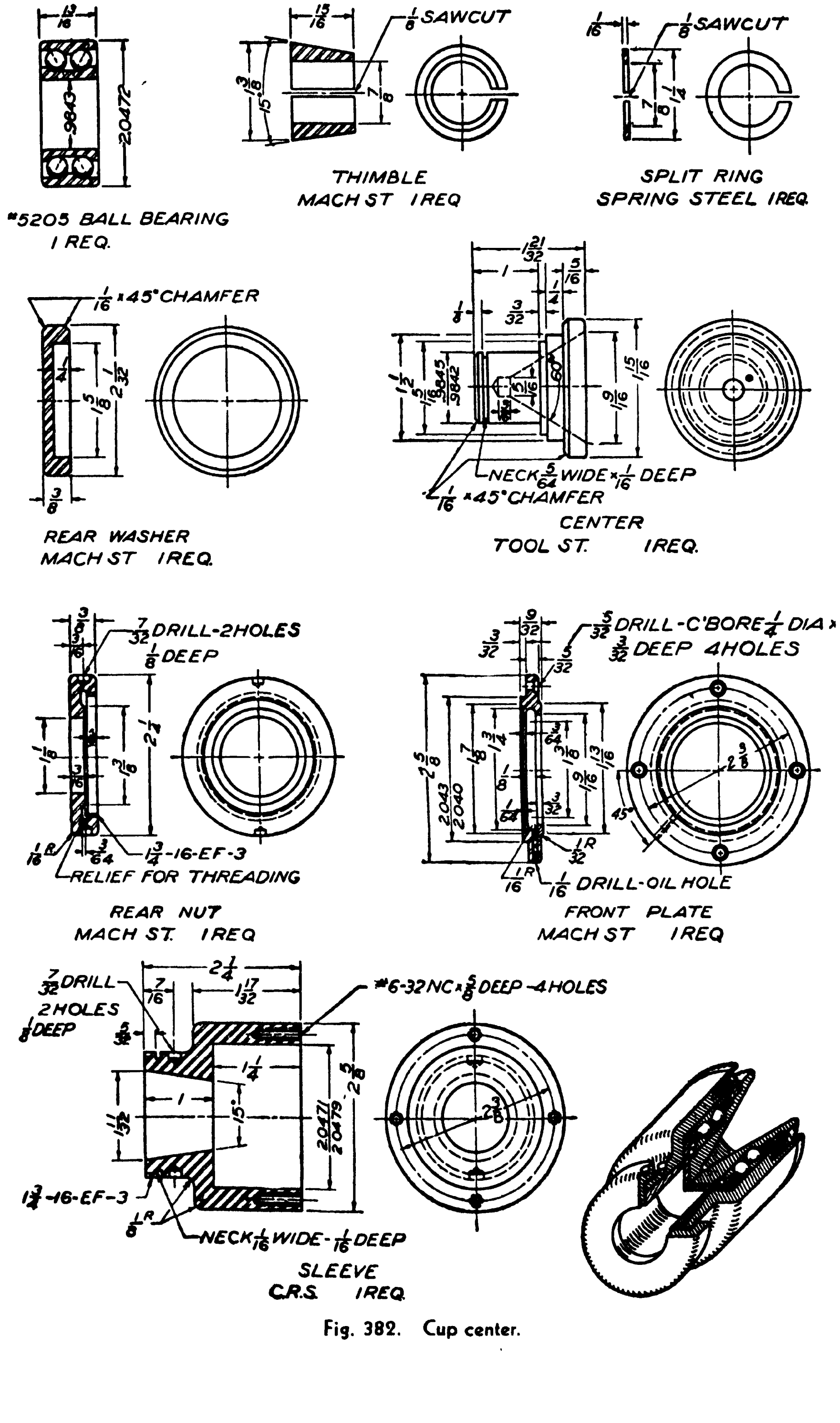


Fig. 382. Cup center.

25. (Fig. 377.) Make a complete set of working drawings of the milling jack. The complete set should be composed of detail drawings of the parts and an assembly drawing showing the parts in their relative positions.

26. (Fig. 378.) Make a complete set of working drawings of the vise. The complete set of drawings should be composed of detail drawings of the parts (except standard parts) and an assembly drawing.

27. (Fig. 379.) Make a complete set of working drawings of the link. The complete set should consist of detail drawings of the parts and an assembly drawing.

28. (Fig. 380.) Make a complete set of working drawings of the coupling. The complete set should consist of detail drawings of the parts and an assembly drawing.

29. (Fig. 381.) Make a complete set of working drawings of the tool holder. The complete set should consist of detail drawings of the parts and an assembly drawing.

30. (Fig. 382.) Make a two-view assembly drawing of the cup center, using the given details. Use the regular symbol for screw threads. Study the pictorial drawing carefully before starting the views.

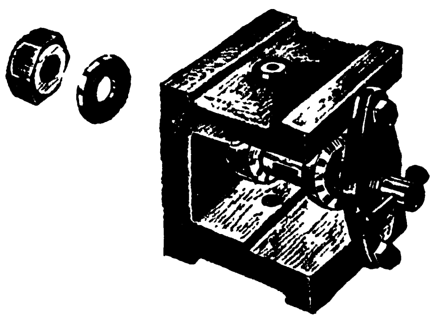
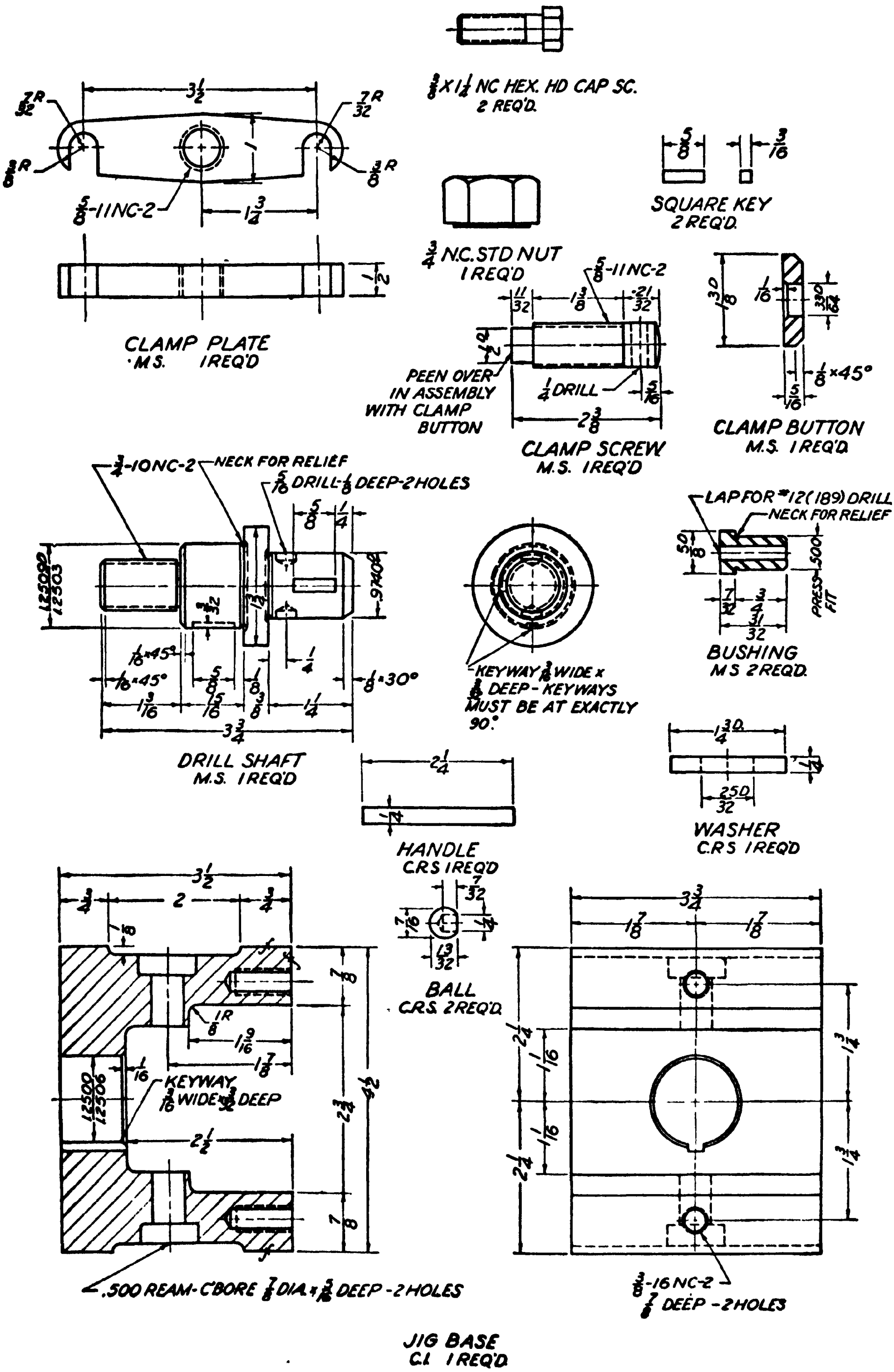


Fig. 383. Tumble jig.

31. (Figs. 383–384.) Make an assembly drawing of the tumble jig, using the given details. Use the regular symbol for screw threads. The pictorial drawing should prove helpful in deciding upon the relative locations of the assembled parts.

32. (Fig. 385.) Make an assembly drawing of the radial engine unit, using the given details. It is suggested that one piston be shown in full section so that the relative positions of the parts will be revealed.

33. (Figs. 386, 387, and 388.) Make an assembly drawing of the hand clamp vise, using the given details. Use the regular symbol for screw threads.



Courtesy Fairfield Mfg. Co.

Fig. 384. Tumble jig.

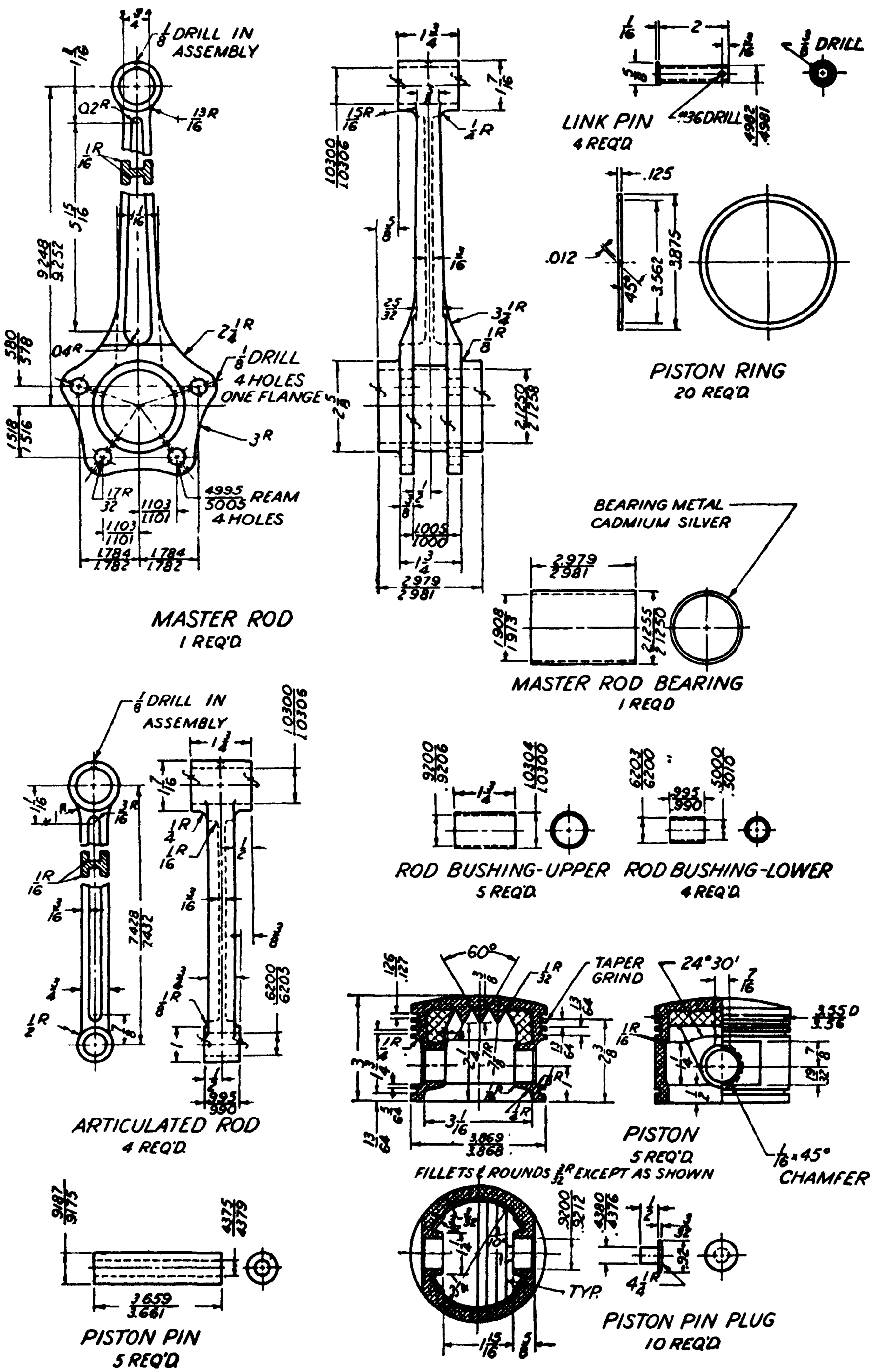
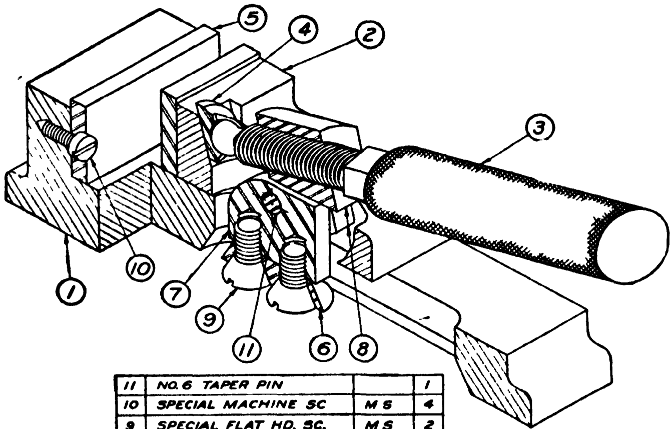
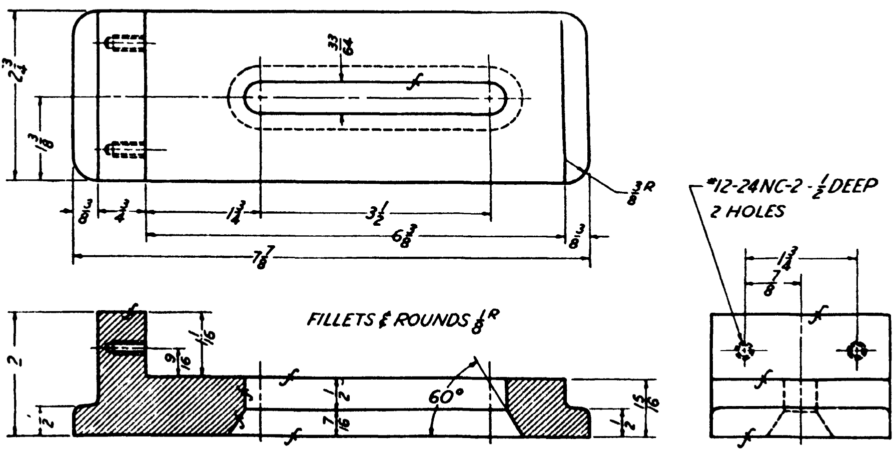


Fig. 385. Radial engine details.



PART NO.	NAME OF PART	MATERIAL	NO. REQ.
11	NO. 6 TAPER PIN		1
10	SPECIAL MACHINE SC	M S	4
9	SPECIAL FLAT HD. SC.	M S	2
8	LINK	C.R.S.	1
7	COUPLING	C.R.S.	1
6	WEDGE	C.R.S	1
5	JAW PLATE	C R S.	2
4	SHOE	C R S	1
3	HAND SCREW	C.R.S.	1
2	JAW	C.I	1
1	BASE	C I	1

Fig. 386. Hand clamp vise details.



PC #1 BASE
C.I. 1 REQ'D

Fig. 387. Hand clamp vise details.

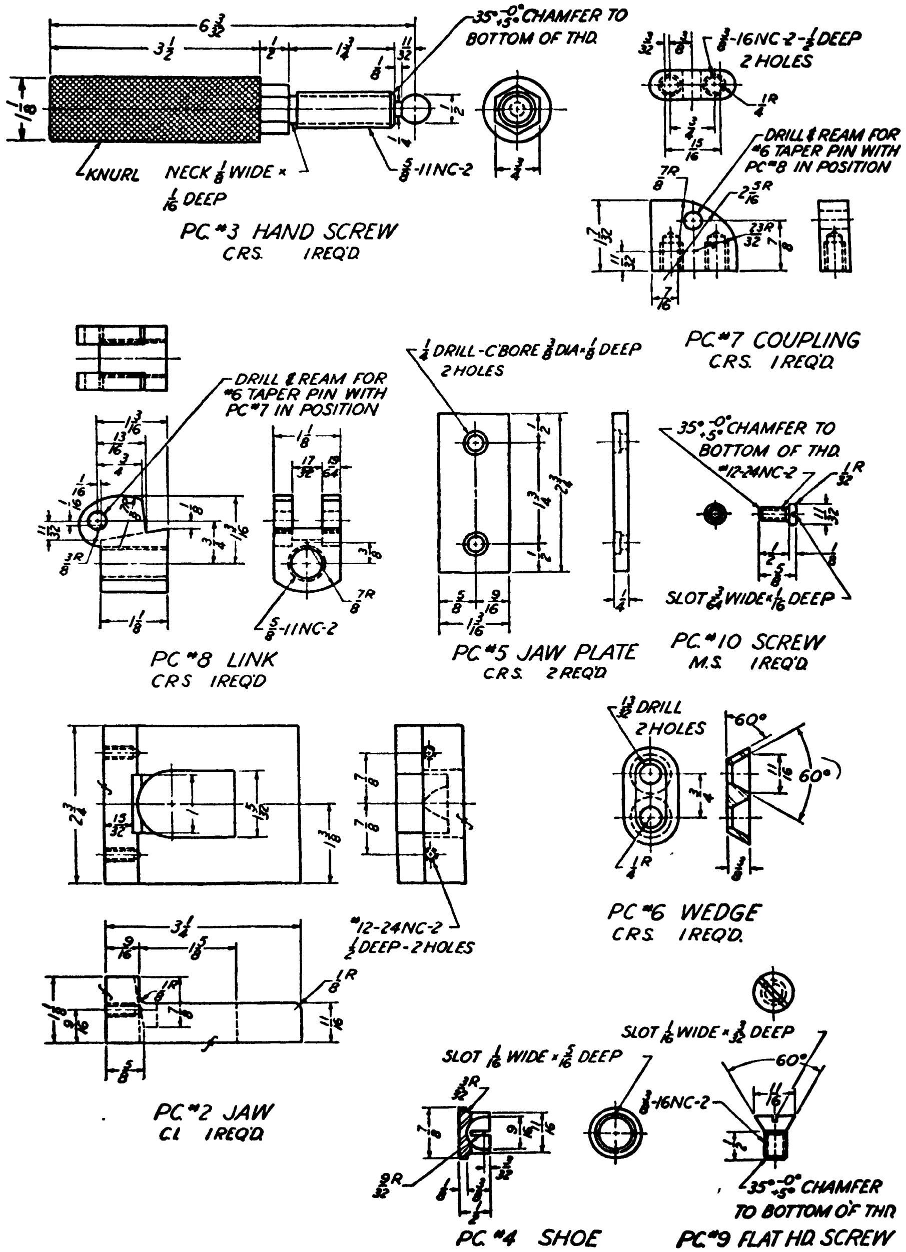


Fig. 388. Hand clamp vise details.

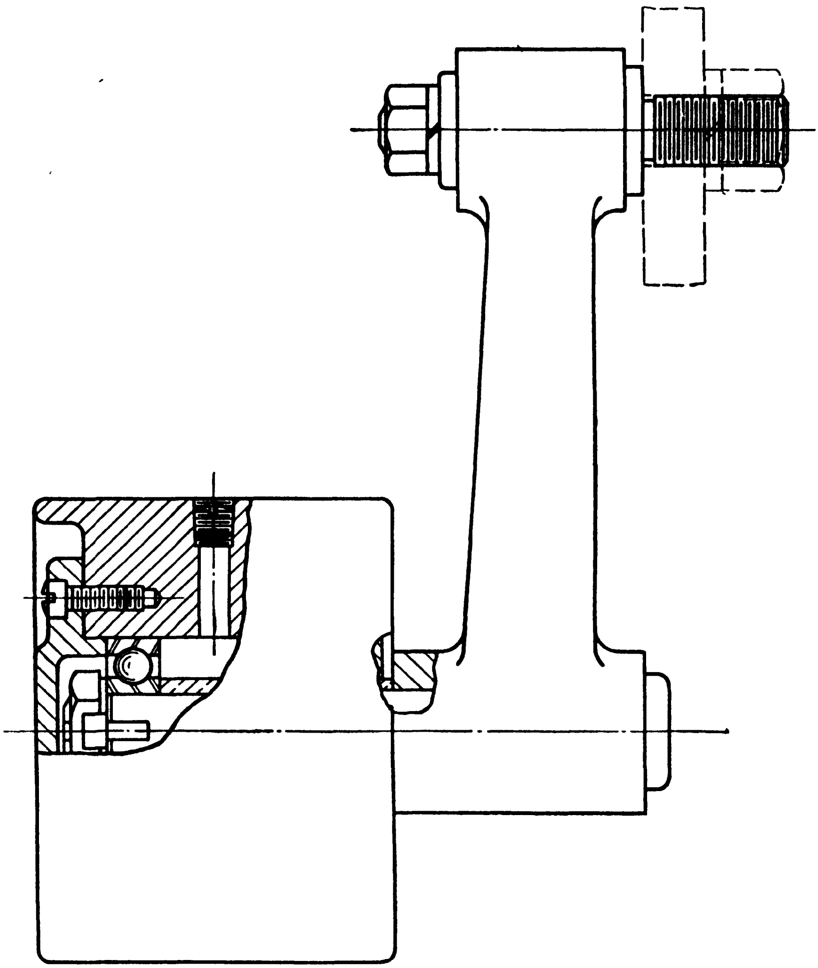


Fig. 389. Idler pulley.

34. (Figs. 389 and 390.) Make an assembly drawing of the idler pulley, using the given details. Use the regular symbol for screw threads.

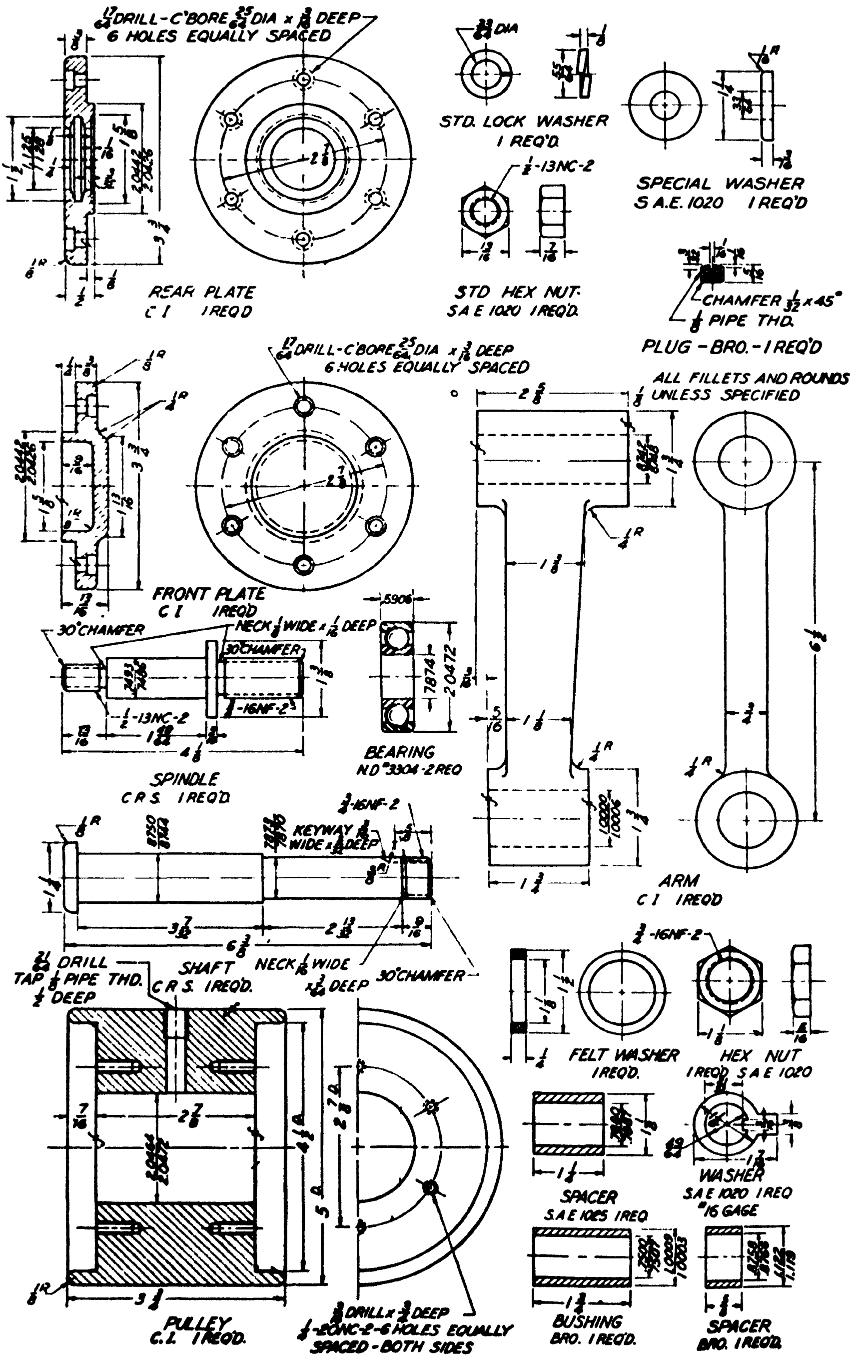


Fig. 390. Idler pully details.

16

PIPING DRAWINGS

259. Since piping is used in all types of construction for conveying fluids and gases such as oil, water, steam, and chemicals, some knowledge of it is essential for both the draftsman making drawings and the engineer who must select and use pipe in the design of machines, power plants, water systems, and so on. There are so many types of fittings and materials used for various purposes that only the most common can be discussed briefly in this chapter. Additional information may be obtained from publications of research associations and from the catalogs of manufacturers.

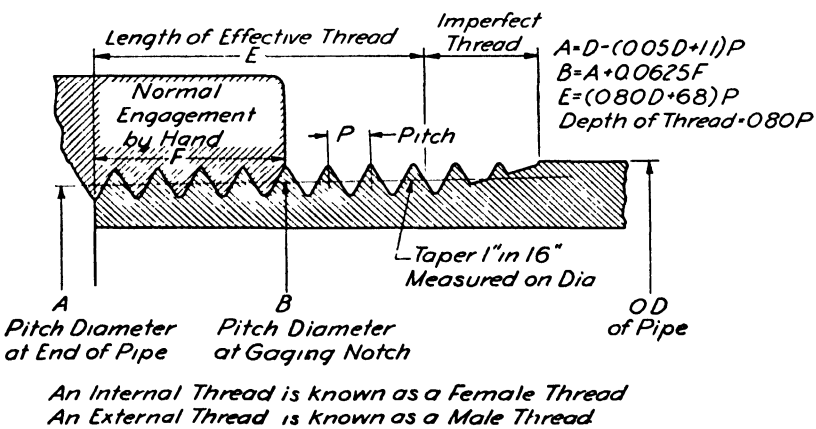


Fig. 391. American Standard pipe thread.

260. American Standard pipe thread. The American Standard pipe taper thread, illustrated in Fig. 391, is similar to the ordinary American Standard thread and has the same thread angle; but it is tapered $\frac{1}{16}''$ per inch, to insure a tight joint at a fitting. The crest is flattened and the root is filled in so that the depth of the thread is 0.80P. The number of threads per inch for any given nominal diameter and other related information can be obtained from Table VII in the Appendix.

An American National straight pipe thread, having the same number of threads per inch as the taper thread, is in use for pressure-tight joints for couplings, for pressure-tight joints for grease and oil fittings, and for hose couplings and nipples. This thread may also be used for free-fitting mechanical joints. Usually a taper external thread is used with a straight internal thread, as pipe material is sufficiently ductile for an adjustment of the threads.

In specifying pipe threads, the ASA recommends that the note be formulated using symbolic letters as illustrated in Fig. 392. For example,

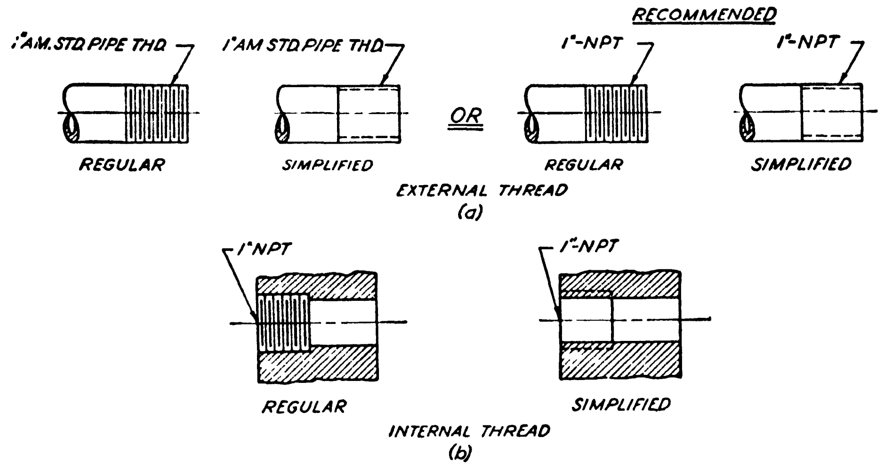


Fig. 392. American Standard representation of pipe threads.

the specification for a 1″ standard pipe thread should read, 1″-*NPT*. The letters *NPT*, following the nominal diameter, indicate that the thread is American National (N), pipe (P), taper (T) thread. Continuing with the same scheme of using letters, the specification for a 1″ straight pipe thread would read, 1″-*NPS* [National (N)—pipe (P)—straight (S)]. The form of note given in (a), reading 1″ *AM. STD. PIPE THD*, is quite commonly used in practice. Identification symbols and dimensions of American National pipe threads are given in the American Standard for Pipe Threads (ASA B2.1-1945).

261. Drawing pipe threads. The taper on a pipe thread is so slight that it will not attract attention on a drawing unless it is exaggerated. If it is shown at all, it is usually magnified to $\frac{1}{8}''$ per inch.

Pipe threads are generally represented by the same conventional symbols used for ordinary American Standard thread. (See Fig. 392.)

262. Specification of wrought-iron and steel pipe. The standardized weights commonly used are the standard, extra strong, and double extra strong. All are specified by the nominal inside diameter.

The three weights of pipe for any given nominal diameter have the same outside diameter and can be used with the same fittings.

Wrought-iron or steel pipe greater than 12″ in diameter is specified by giving the outside diameter and the thickness of the wall.

263. Sizes of wrought-iron, steel, and cast-iron pipe. The standard-weight pipe is used for normal pressures. It may be purchased in sizes ranging from $\frac{1}{8}$″ to 12″ (nominal diameter). Pipe is received threaded on both ends with a plain coupling attached.

Extra strong pipe, designed for steam and hydraulic pressures over 125 pounds per square inch, also is manufactured in sizes $\frac{1}{8}$″ to 12″.

Double extra strong pipe, designed for extremely high pressures, is furnished in nominal diameters from $\frac{1}{2}$″ to 8″ in the same lengths as the extra strong.

Cast-iron pipe, in sizes ranging up to 48″, can be used for pressures up to 350 pounds per square inch.

264. Pipe fittings. Fittings are parts, such as elbows, tees, crosses, couplings, nipples, flanges, and so on, which are used to make turns and connections. They fall into three general classes: screwed, welded, and flanged.

In small piping systems and for house plumbing, screwed fittings are generally used (Fig. 393).

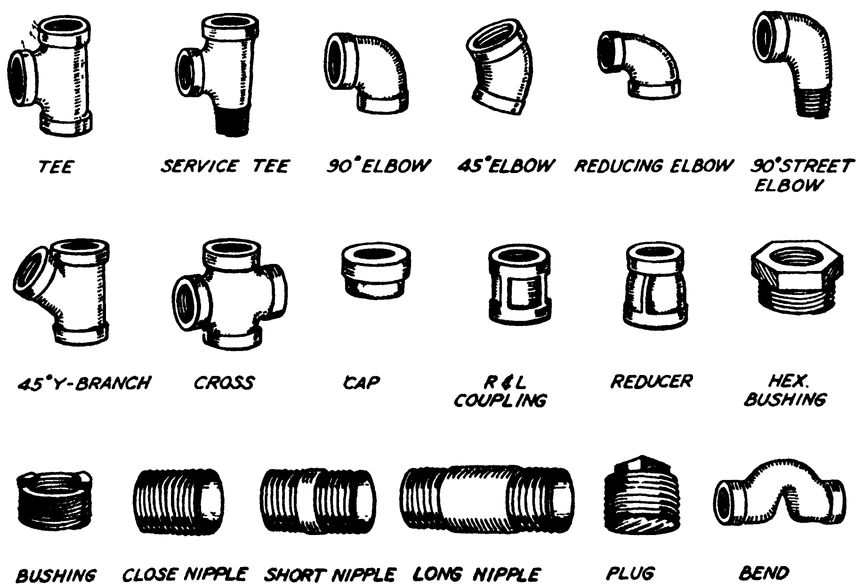


Fig. 393. Screwed fittings.

Welded fittings are used where connections are to be permanent. They are manufactured of forged seamless steel, having the same thickness as the pipe. In this type of construction, the weld is depended upon to seal the joint and to carry the pipe-line stresses. Many miles of line having welded fittings are giving satisfactory service to pipe-line corporations. See Fig. 394.

Flanged fittings are used in large piping systems where pressures are high and the connection must be strong enough to carry the weight of large pipes (Fig. 395).

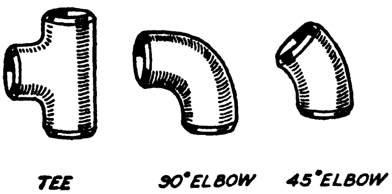


Fig. 394. Welded fittings.

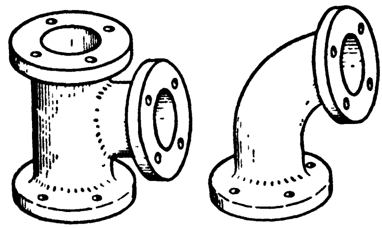


Fig. 395. Flanged fittings.

265. Screwed fittings (Fig. 393). Straight sections of pipe are connected by a short cylindrical fitting (threaded on the inside), which is known as a *coupling*. A *right and left coupling*, which can be recognized by the ribs on the outside, is often used to close a system. However, a *union* is preferable where pipe must be frequently disconnected.

A *cap* is screwed on the end of a pipe to close it.

A *plug* is used to close an opening in a fitting.

A *nipple* is a short piece of pipe which has been threaded on both ends. If it is threaded the entire length, it is called a *close nipple;* if not, it is called a *short* or *long nipple*. Extra long nipples may be purchased.

A *bushing* is used to reduce the size of an opening in a fitting when it would be inconvenient to use a reducing fitting.

Tees, crosses, and *laterals* form the connections for lines and branches in a piping system.

266. Specification of fittings. A fitting is specified by giving the nominal inside diameter of the pipe for which the openings are threaded, the type of fitting, and the material. If it connects more than one size of pipe, it is called a reducing fitting, and the largest opening of the through run is given first, followed in order by the opposite end and the outlet. Fig. 396 illustrates the order of specifying reducing fittings. If all of the openings are for the same size of pipe, the fitting is known as a straight tee, cross, and so on. A straight fitting is specified by the size of the openings followed by the name of the fitting (2″ tee, 4″ cross, etc.)

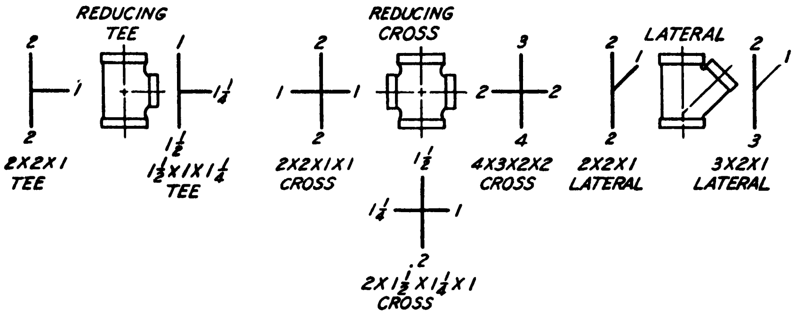


Fig. 396. Specification of fittings.

267. Unions. Screwed or flanged unions connect pipes that must be frequently disconnected for the purpose of making repairs. In many cases, screwed unions are used for making the final closing connection in a line. The union illustrated in Fig. 397(*a*) is made up of three separate pieces. The mating parts, *A* and *B*, are screwed on the ends

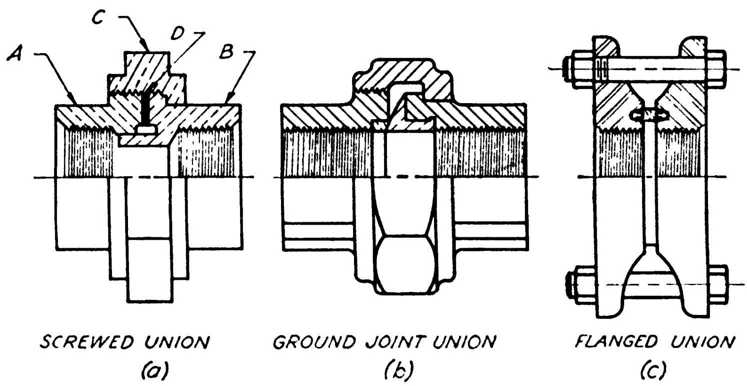


Fig. 397. Unions.

of the two pipes. The third part, the nut, draws them together so that *A* and *B* will be against the gasket, *D*, to insure a tight joint. In systems having pipes over 2″ in diameter, screwed unions are not generally used, because the stronger and more substantial flange unions, such as the one shown at (*c*), become desirable. A screwed union with a ground metal seat is shown at (*b*).

268. Valves. Valves are used in piping systems to stop or control the movement of fluids and gases.

Globe valves are used for throttling steam, in both high- and low-pressure steam lines, and to regulate the passage of other fluids.

A gate valve allows a straight-line movement of a fluid and offers only slight resistance to the flow. Since the disc moves completely out of the passage and leaves a full opening, this type of valve is particularly suitable for water lines, oil lines, and the like.

A swing-type check valve permits movement in one direction only and prevents any back flow. It will be noted from a study of this valve that the design makes the action automatic. Such valves are used in feed-water lines to boilers.

The dimensions of the valves given in Fig. 398, as well as those for many special types, may be found in the catalogs of manufacturers.

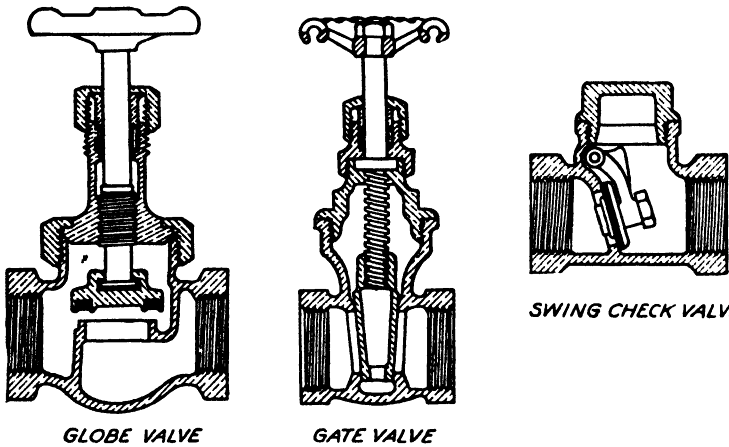


Fig. 398. Valves.

269. Piping drawings. Since standard pipe and fittings can be purchased for almost any purpose, a piping drawing usually shows only the arrangement of a system in some conventional form, and gives the size and location of fittings. The drawing may be a freehand sketch, single-line diagram (Fig. 399), double-line diagram (Fig. 400), or pictorial diagram (Fig. 402). Occasionally, when conditions necessitate the design of special valves or the redesign of an existing type, complete working drawings are made.

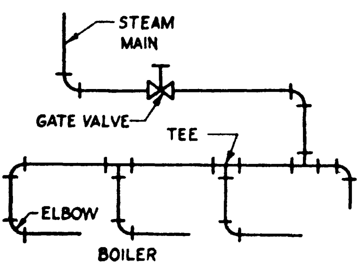


Fig. 399. Single-line drawing.

Single-line drawings or sketches are made in orthographic projection or are drawn as if the entire system were swung into one plane (Fig. 399). On these drawings, single lines represent the runs of pipe, regardless of variations in diameters; conventional symbols are used for the fittings (Fig. 401). A developed single-line sketch is frequently used for repair work, small jobs, and for making studies and calculations. For more complicated small-scale layouts, a single-line diagram drawn in orthographic projection is more suitable.

Double-line diagrams are drawn when many similar installations are to be made at the plants of various purchasers of pumps, manufacturing equipment, heating equipment, and so on (Fig. 400).

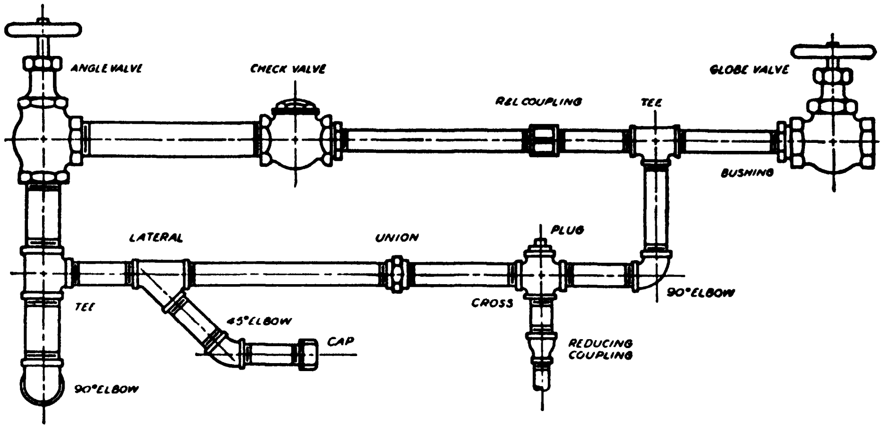


Fig. 400. Double-line drawing.

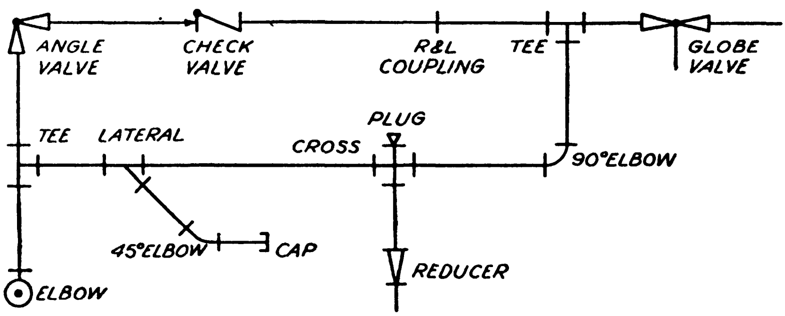


Fig. 401. Conventional symbols for fittings.

270. Dimensions on piping drawings. The rules for dimensioning working drawings apply to piping drawings. Fittings and pipes are always located by giving center-to-center distances, because the determination of pipe lengths is generally left to the pipe fitter. Notes should be used to specify the nominal size and type of each fitting and the nominal size of the pipe in each run.

271. Problems.

1. Make a freehand sketch (on $\frac{1}{8}''$ grid paper, if it is available) of a 1″ nipple connecting a 1″ cast-iron elbow and a 2″ × 2″ × 1″ malleable-iron tee. The distance between centers of fitting is to be 6″. Enter neatly, in draftsman's style, the length of the nipple to the nearest $\frac{1}{8}''$. Obtain dimensions from a handbook or pipe catalog.

2. Make a freehand sketch (on $\frac{1}{8}''$ grid paper) of a 1″ × 1″ × 1″ malleable-iron tee and a 1″ cast-iron elbow joined by a length of pipe. The distance between centers of fittings is 4″. Enter the length of the connecting pipe to the nearest $\frac{1}{8}$″ inch. Obtain dimensions from a handbook or pipe catalog

3. Make a single-line multiview sketch of the portion of a piping system shown in Fig. 402.

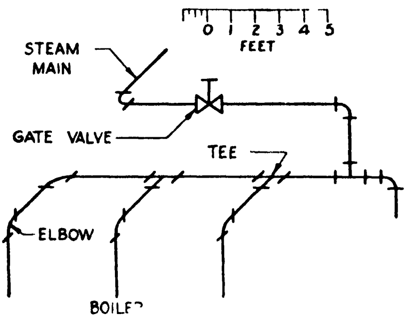


Fig. 402. Pictorial line diagram.

4. Make a double-line developed drawing of the portion of a piping system shown in Fig. 402. Use 2″ pipe and screwed fittings. Select a suitable scale. Determine the measurements by transferring distances from the drawing to the open-divided scale in the figure.

5. Dimension the drawing of problem 4.

17

GEARS AND CAMS*

272. Gears. The draftsman frequently is called upon to make representations of gears and gear teeth. It is therefore important for him to know the general proportions and nomenclature belonging to gearing. In Fig. 403 the nomenclature for bevel gears is shown. It will

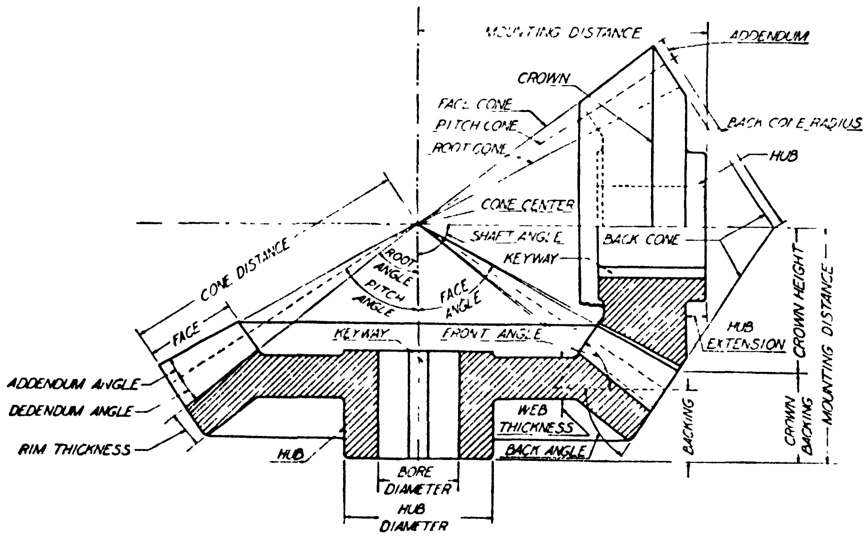


Fig. 403. Bevel-gear nomenclature.

be noted that, in general, the definitions pertaining to gear-tooth parts can be represented in a right section of the gear.

The theory of gears is a part of the study of mechanism. In working drawings of gears and toothed wheels it is necessary to draw at least one tooth of each gear. Some of the terms used in defining gear teeth are shown in Fig. 404.

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* Prepared by Professor E. W. Azpell, Purdue University.

Two systems of generating tooth curves are in general use, the involute system and the cycloidal system. The curve most commonly used for gear-tooth profiles is the involute of a circle.

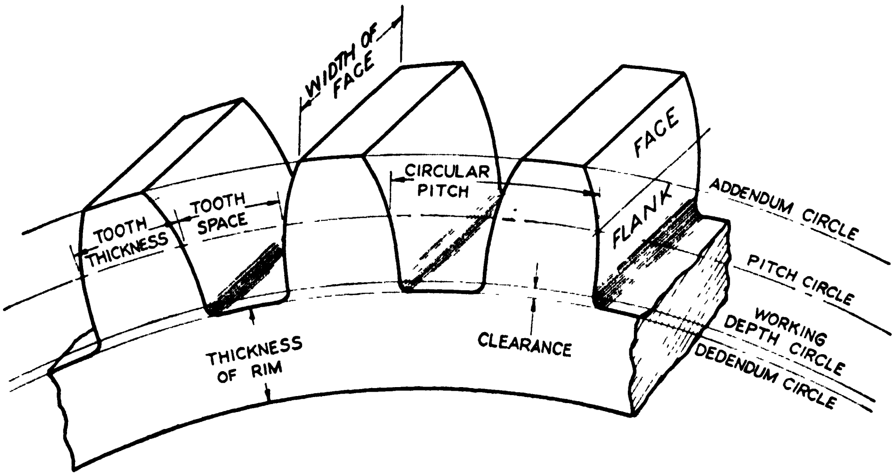


Fig. 404. Spur-gear nomenclature.

An involute is the curve generated by a point on a straight-edge as the straight-edge is rolled on a cylinder. It also may be defined as the curve generated by a point in a taut string as the string is unwrapped from a cylinder. The circle from which the involute is developed is called the *base circle.*

A method of constructing an involute curve is shown in Fig. 405. Starting with point 0, on the base circle, divide the base circle into a convenient number of equal arcs of length 0-1, 1-2, 2-3, etc. (Where the lengths of the divisions on the base circle are not too great, the chord can be taken as the length of the arc.) Draw a tangent to the base circle, at point 0, and divide this line to the left of 0 into equal parts of the same lengths as the arcs. Next, draw tangents to the circle from points 1, 2, 3, and so on.

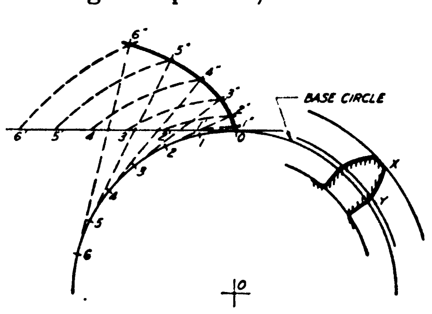


Fig. 405. Involute tooth.

With the center of the base circle "0" as a pivot, draw concentric arcs from 1′, 2′, 3′, etc., until they intersect the tangent lines drawn from 1, 2, 3, etc. The intersection of the arcs and the tangents are points on the required involute curve, such as 1″, 2″, 3″, etc. The illustration at the right in Fig. 405 shows the portion XY of the tooth outline as part of the involute curve.

Gear Terms

1. The addendum circle is drawn with its center at the center of the gear and bounds the ends of the teeth. (See Fig. 404.)

2. The dedendum circle, or root circle, is drawn with its center at the center of the gear and bounds the bottoms of the teeth. (See Fig. 404.)

3. The pitch circle is a right section of the equivalent cylinder the toothed gear may be considered to replace.

4. Pitch diameter is the diameter of the pitch circle.

5. The addendum is the radial distance from the pitch circle to the outer end of the tooth.

6. The dedendum is the radial distance from the pitch circle to the bottom of the tooth.

7. The clearance is the difference between the dedendum of one gear and the addendum of the mating gear.

8. The face of a tooth is that portion of the tooth surface lying outside the pitch circle.

9. The flank of a tooth is that portion of the tooth surface lying inside the pitch circle.

10. The thickness of a tooth is measured on the arc of the pitch circle. It is the length of an arc and not the length of a straight line.

11. The tooth space is the space between the teeth measured on the pitch circle.

12. Backlash is the difference between the tooth thickness of one gear and the tooth space on the mating gear, measured on the pitch circles.

13. The circular pitch of a gear is the distance between a point on one tooth and the corresponding point on the adjacent tooth, measured along the arc of the pitch circle. The circular pitches of two gears in mesh are equal.

14. The diametral pitch is the number of teeth per inch of pitch diameter. It is obtained by dividing the number of teeth by the pitch diameter.

15. A gear's width of face is measured parallel to the axis. It should not be confused with the face of a tooth, for the two are entirely different.

16. The pitch point is on the line joining the centers of the two gears where the pitch circles touch.

17. The common tangent is the line tangent to the pitch circles at the pitch point.

18. The pressure angle is the angle between the line of action and the common tangent.

19. The line of action is a line drawn through the pitch point at an angle (equal to the pressure angle) to the common tangent.

20. The base circle is used in involute gearing to generate the involutes that form the tooth outlines. It is drawn from the center of each pair of mating gears tangent to the line of action.

21. When two gears mesh with each other, the larger is called the *gear* and the smaller the *pinion*.

It should be noted that *circular pitch* is a linear dimension expressed in inches, whereas *diametral pitch* is a ratio. There must be a whole number of teeth on the circumference of a gear. Thus it is necessary that the circumference of the pitch circle, divided by the circular pitch, be a whole number.

For circular pitch, let P' = circular pitch in inches, D = pitch diameter, and T = number of teeth. Then

$$TP' = \pi D, \qquad T = \frac{\pi D}{P'}, \qquad P' = \frac{\pi D}{T}, \qquad \text{and} \qquad D = \frac{TP'}{\pi}.$$

For diametral pitch, let P = diametral pitch, D = pitch diameter, and T = number of teeth. Then

$$T = PD, \qquad D = \frac{T}{P}, \qquad \text{and} \qquad P = \frac{T}{D}.$$

The Brown and Sharpe 14½-degree involute system has been adopted as one of the American standards and is commonly known as the 14½-Degree Composite System. The tooth proportions of this system are given in terms of the diametral pitch P and circular pitch P'.

Pressure angle = 14½ degrees.

Addendum (inches) $= \dfrac{1}{\text{diametral pitch}} = \dfrac{1}{P}.$

Dedendum (inches) = addendum plus clearance $= \dfrac{1}{P} + 0.05P'.$

Clearance = 0.05 × circular pitch $= 0.05P'.$

Whole depth of tooth = 2 × addendum + clearance $= 2 \times \dfrac{1}{P} + 0.05P'.$

Working depth of tooth = 2 × addendum $= 2 \times \dfrac{1}{P}.$

Thickness of tooth $= \dfrac{\text{circular pitch}}{2} = \dfrac{P'}{2}.$

Width of tooth space $= \dfrac{\text{circular pitch}}{2} = \dfrac{P'}{2}.$

Minimum radius of fillet = clearance $= 0.05P'.$

In the above calculations the backlash is zero. Actually, however, it is common practice to provide backlash, and this is accomplished by using standard cutters and cutting the teeth slightly deeper than for standard teeth.

273. To lay out a pair of standard involute spur gears. The following facts are known regarding the laying out of a pair of standard spur gears: (1) number of teeth on each gear—large gear 24, small gear 16, (2) diametral pitch = 2, (3) pressure angle = 14½°.

To draw a pair of spur gears, determine the pitch diameters, thus:

$$D = \frac{T}{P} = \frac{24}{2} = 12'' \text{ for large gear.}$$

$$D = \frac{T}{P} = \frac{16}{2} = 8'' \text{ for small gear.}$$

In Fig. 406, with radii O_1P and O_2P equal to 6″ and 4″ respectively; draw the pitch circles and, through P, draw the common tangent. Draw the line of action XY at an angle of $14\frac{1}{2}°$ to the common tangent. Drop perpendiculars from the centers O_1 and O_2, cutting the line of action at A and B, respectively. O_1A and O_2B are the radii of the base circles which can now be drawn.

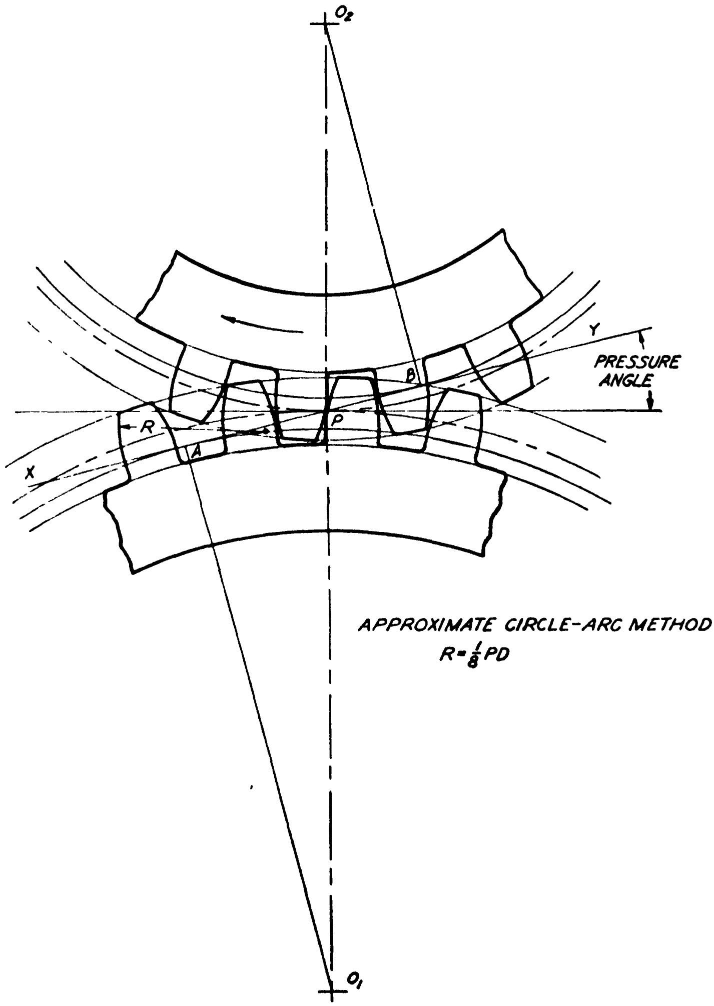


Fig. 406. To draw a pair of spur gears.

From Sec. 272, determine the addendum and dedendum of the teeth, and draw in the respective addendum and dedendum circles.

Divide the pitch circle of the smaller gear into 16 equal parts and the pitch circle of the larger gear into 24 equal parts, which will give the circular pitch. Assuming that no allowance is made for backlash, bisect the circular pitch on each of the gears, which will give 32 equal divisions on the small gear and 48 equal divisions on the large gear.

At any point on the base circle of each gear, develop an involute (see Fig. 405) and draw in the curves between the base and addendum circles through alternate points on the pitch circles. This produces one side of all the teeth in each gear. The curve for the other side of the tooth is the reverse of the side just drawn. The part of the tooth between the base and dedendum circles is part of a radial line drawn from the base circles to the centers of the gears. The tooth is finished by putting in a small fillet between the working depth and dedendum circles.

Whenever it is unnecessary to reproduce the exact involute shape of spur gear teeth, a more rapid construction method is to use an approximate circle-arc. The radius of the arc is made equal to one-eighth of the pitch diameter (Fig. 406). The arcs are centered on the base circle.

274. Dimensioning gears. On a detail drawing, a gear may be represented by a one-view section, except for the larger sizes where it

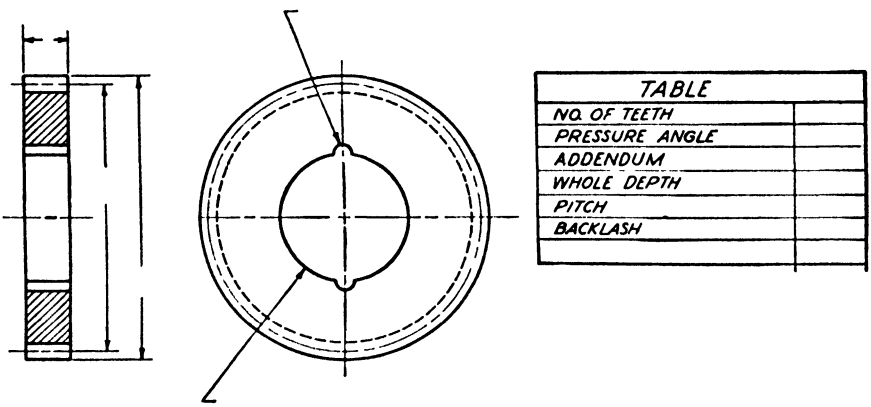


Fig. 407. Dimensioning a spur gear.

is necessary to show spokes and for the small sizes, when a full description of some feature would not be given. A second view was drawn in Fig. 407 to reveal the shape of the keyway. In dimensioning, it is recommended that the dimensions be given on the view or views as shown in Figs. 407 and 408 and that the cutting data be incorporated in an accompanying table.

275. Cams. A cam is a plate, cylinder, or any solid having a curved outline or curved groove which, by its oscillating or rotating motion, gives a predetermined motion to another piece, called the follower, in contact with it. The cam plays a very important part in the operation of

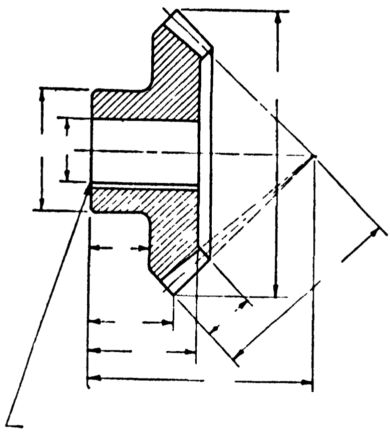


TABLE	
NO OF TEETH	
PITCH	
PRESSURE ANGLE	
SPIRAL ANGLE	
HAND OF SPIRAL	
FACE ANGLE	
PITCH DIA	
PITCH ANGLE	
ADDENDUM	
WHOLE DEPTH	

Fig. 408. Dimensioning a bevel gear.

many classes of machines. Cam mechanisms are commonly used to operate valves in automobiles and stationary and marine internal combustion engines. They also are used in automatic screw machines, clocks, locks, printing machinery, and in nearly all kinds of machinery which we generally regard as "automatic machines." The applications of cams are practically unlimited, and their shapes or outlines are found in wide variety.

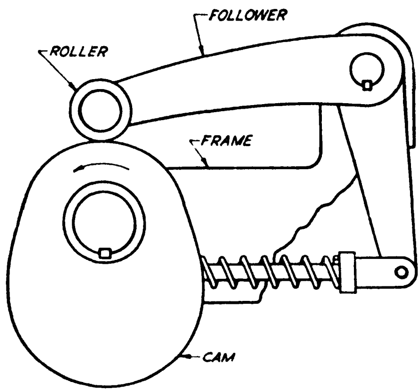


Fig. 409.

All cam mechanisms consist of at least three parts: (1) the cam, which has a contact surface either curved or straight; (2) the follower, whose motion is produced by contact with the cam surface; and (3) the frame, which supports the cam and guides the follower.

The most common type of cam is the disc or plate cam. Here the cam takes the form of a revolving disc or plate, the circumference of the disc or plate forming the profile with which the follower makes contact. In Figs. 409 and 410, two simple examples of a disc cam and follower are shown. In Fig. 409, the cam is given a motion of rotation, thus causing the follower to rise and then return again to its initial position. In cams of this type it is necessary to use some external force, such as the spring, to keep the follower in contact with the cam at all times. Contact between the follower and the cam is made through a roller, which serves to reduce friction. It is sometimes necessary to use a flat-faced follower, instead of the roller type, an example of which is shown in Fig. 410. The follower face that comes in contact with the cam is usually provided with a hardened surface, to prevent excessive wear.

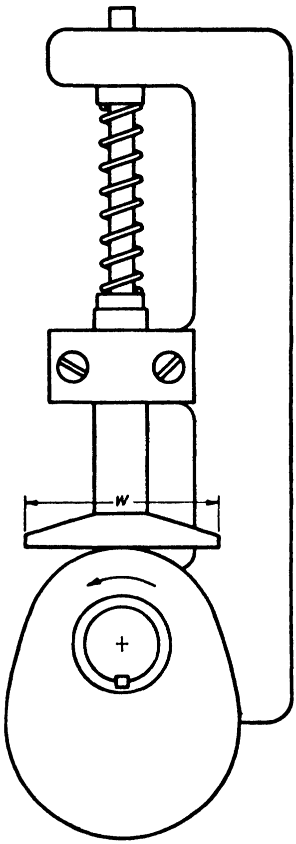


Fig. 410.

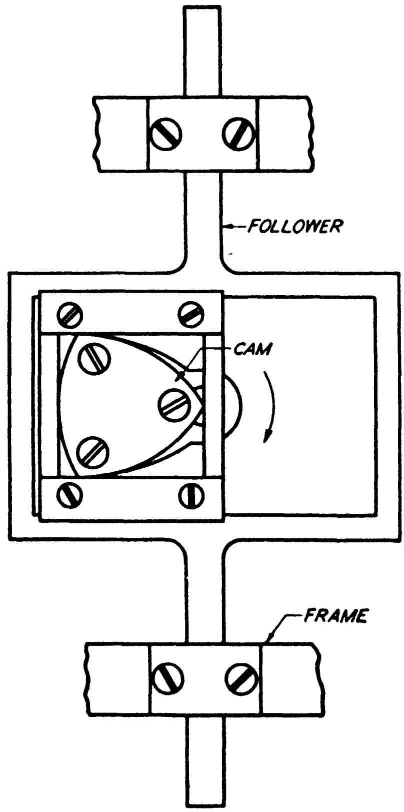


Fig. 411.

Another type of cam is one in which the follower is constrained to move in a definite path without the application of external forces. (See Fig. 411.) In this type, two contact surfaces of the follower bear on the cam at the same time, thus controlling the motion of the follower in two directions.

276. Design of a cam. The design of a cam outline is governed by the requirements with respect to the motion of the follower. In the layout of a cam, the initial position, displacement, and character of the motion of the follower are generally known. It is convenient to make first a graphical representation of the follower movement, a procedure which is called *making a displacement diagram.* This is a linear curve in which the length of the diagram represents the time for one revolution of the cam. The height of the diagram represents the total displacement of the follower; the length is made to any convenient length and is divided into equal time intervals, the total representing one rotation of the cam.

In Fig. 412 is shown a displacement diagram in which the follower rises 2″ during 180 degrees of rotation of the cam, then rests for 30 degrees and returns to its initial position for the remainder of the cam revolution. Cam outlines should be designed to avoid sudden changes of motion at the beginning and end of the follower stroke. This can be accomplished by having a uniformly accelerated and decelerated motion at the beginning and end of the constant-velocity curve. The construction for uniformly

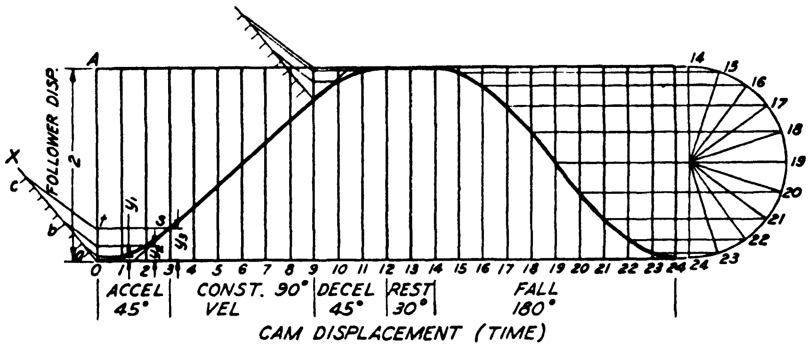


Fig. 412. A displacement diagram.

accelerated motion is shown in Fig. 412. On a line, *OX*, making any convenient angle with *OA*, mark off any unit of length in this figure equal to *Oa*. The next point, *b*, is found by marking off, from *O*, 4 units of length. Point *c* is found by marking off 9 units of length. Next, project the intersection (point *s*) of time unit 3 and the constant-velocity line over to the line *OA*, thus locating point *t*. Connect points *c* and *t* with a straight line and draw parallel lines from *a* and *b* intersecting the line *OA*. From these intersections draw lines parallel to *ts*, intersecting the time-unit lines 1 and 2, respectively. These intersections are points on the displacement curve. With uniformly decelerated motion, the series of points are laid off in the reverse order, such as 9-4-1. It will be noted that the units are laid off according to the square of the time unit. Thus, if there were four time units, the acceleration curve would be laid off according to the ratio of 1, 4, 9, 16, and the deceleration, 16, 9, 4, 1.

The construction for the displacement diagram for simple harmonic motion is shown in the same figure. A semicircle is drawn as shown, the follower displacement being used as a diameter, and is then divided into a convenient number of parts equal to the number of cam displacement units. Horizontal projection lines are drawn from the semicircle, and the intersections of these lines with the cam displacement lines are points on the displacement curve. Thus, the projection of point 15 on the semicircle to time unit line 15 locates one point on the displacement curve for simple harmonic motion.

The next step is that of finding the cam profile necessary to produce these movements. The construction is shown in Fig. 413. Select a

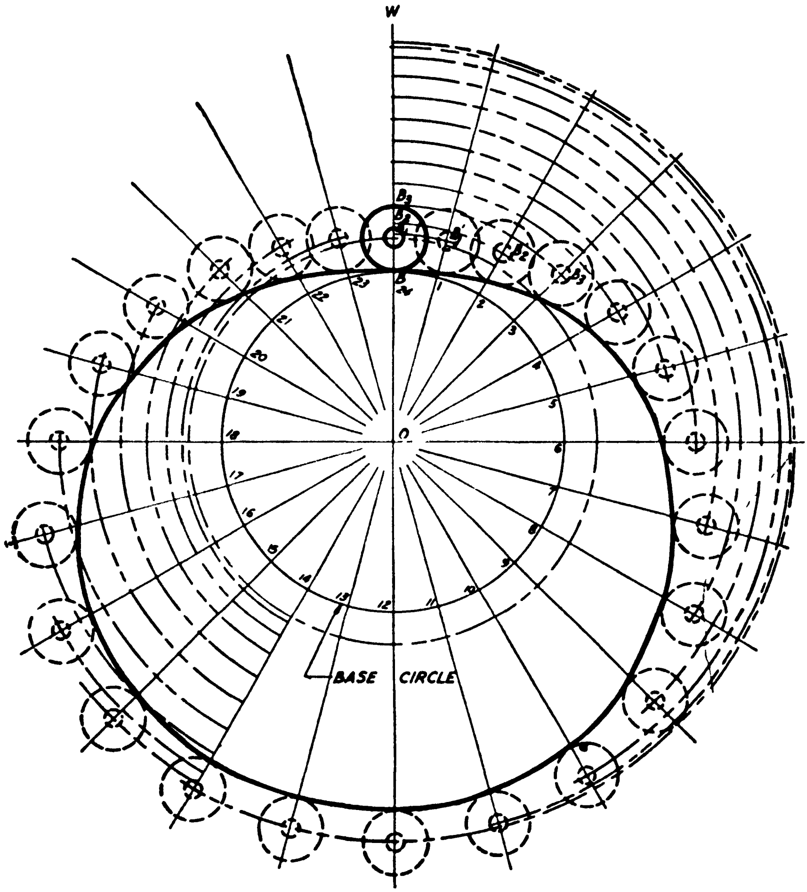


Fig. 413. Construction for cam profile.

base circle of convenient size, and on it lay off radial lines according to the number of time units of cam displacement. Draw line OB extended to W, and on it lay off the distances Y_1, Y_2, Y_3, etc., obtained from the displacement diagram, from the center of the roller shown in the starting position, thus locating points B_1, B_2, B_3, etc. With O as a center, draw arcs B_1-B_1', B_2-B_2', B_3-B_3', etc., and at B_1', B_2', B_3', etc. draw in the circles representing the diameter of the roller. To complete the cam outline, draw a smooth curve tangent to the positions of the roller.

277. Problems. Gears and cams.

GEAR PROBLEMS

1–6. Following the method shown in Sec. 273, lay out a pair of standard involute spur gears as assigned from the table below. The pinion is the driver.

	GEAR				PINION				
Prob. No.	*Circular Pitch*	*Diametral Pitch*	*Pitch Dia.*	*No. of Teeth*	*Circular Pitch*	*Diametral Pitch*	*Pitch Dia.*	*No. of Teeth*	*Pressure Angle*
1	1.31″			24	1.31″			16	$14\frac{1}{2}°$
2		2		20		2		14	$14\frac{1}{2}°$
3		2.5	10			2.5	8		$14\frac{1}{2}°$
4	1.0			30	1.0			20	$14\frac{1}{2}°$
5	2 0			18	2.0			12	$14\frac{1}{2}°$
6		3	8			3	6		$14\frac{1}{2}°$

CAM PROBLEMS

Cam Data:

Diameter of Cam Shaft.......................... $1\frac{1}{4}''$
Diameter of Cam Hub.............................. $2\frac{1}{4}''$
Diameter of Roller................................ 1″
Keyway... $\frac{1}{4}'' \times \frac{1}{8}''$
Diameter of Base Circle.......................... $2\frac{3}{4}''$
Follower Displacement............................ 2″
Scale: Full size
Cam rotation: As noted

Determine points on the cam profiles at intervals of 15°.

7. Using the above data, design a plate cam to satisfy the following conditions: (*a*) a rise of 2″ in 180°, with constant velocity, except for uniform acceleration for the first 30° and uniform deceleration for the last 45°; (*b*) rest 30°; (*c*) return with simple harmonic motion. Use clockwise cam rotation.

8. Same as problem 7, except that the follower is of the flat-face type and is $2\frac{1}{2}''$ wide.

9. Using the data for problem 7, design a plate cam to satisfy the following conditions: (*a*) rise of 2″ during 180°, the first 45° of which is uniformly accelerated motion, the next 60° being constant velocity, and the last 75° of rise being uniformly decelerated motion; (*b*) rest 15°; (*c*) return to starting position with simple harmonic motion. Use counterclockwise cam rotation.

10. Same as problem 9, except that the follower is of the flat-face type and is $2\frac{1}{2}''$ wide.

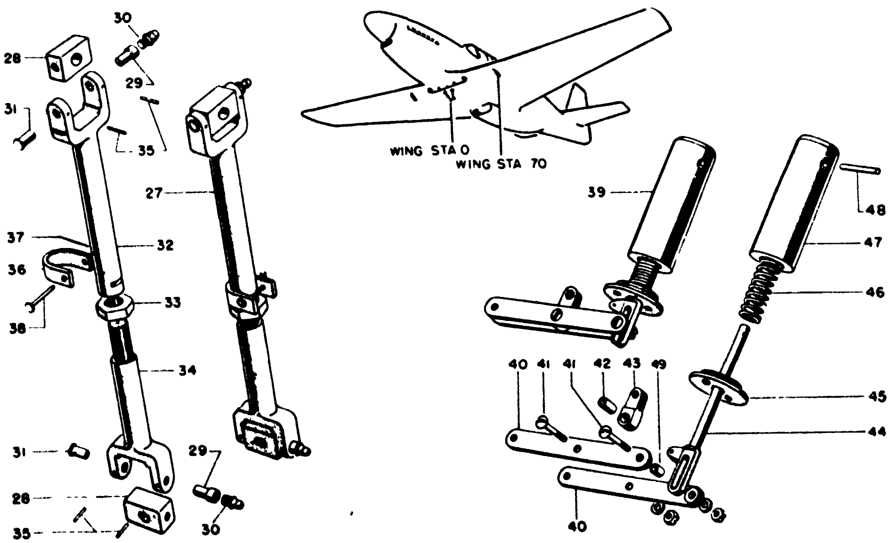
11. Using the data for problem 7, design a plate cam to satisfy the following conditions: (*a*) rise of 2″ during 150°, by simple harmonic motion; (*b*) rest 30°; (*c*) return to starting position during remainder of the revolution, with uniformly accelerated and decelerated motion, the value of the deceleration being two times that of the acceleration. Use clockwise cam rotation.

12. Using the data for problem 7, except that the follower is to be of the flat-face type, $2\frac{1}{2}$″ wide, design a plate cam to satisfy the following conditions: (*a*) rise of 2″, with simple harmonic motion, in 120°; (*b*) rest 30°; (*c*) return in 150°, with constant velocity, except for uniform acceleration for the first 45° and uniform deceleration for the last 30° of fall; (*d*) rest the balance of the revolution. Use counterclockwise cam rotation.

18

PICTORIAL DRAWING

278. An orthographic drawing of two or more views describes an object accurately in form and size but, since each of the views shows only two dimensions without any suggestion of depth, such a drawing can convey information only to those who are familiar with graphic representation. For this reason, multiview drawings are used mainly by engineers, draftsmen, contractors, and shopmen.



Courtesy North American Aviation Corp.

Fig. 414. A pictorial illustration.

Frequently, however, engineers and draftsmen find they must use conventional picture drawings to convey specific information to persons who do not possess the trained imagination necessary to construct mentally an object from views (Fig. 414). To make such drawings, several special schemes of one-plane pictorial drawing have been devised which combine the pictorial effect of perspective with the advantage of having the principal dimensions to scale.

Pictorial drawings are used extensively for catalogs, Patent Office records, piping diagrams, and furniture designs. Occasionally they are used, in one form or another, to supplement and clarify machine and structural details which would be difficult to visualize.

279. Divisions of pictorial drawing. Single-plane pictorial drawings are classified in three general divisions: (1) axonometric projection, (2) oblique projection, and (3) perspective projection. (See Fig. 415.)

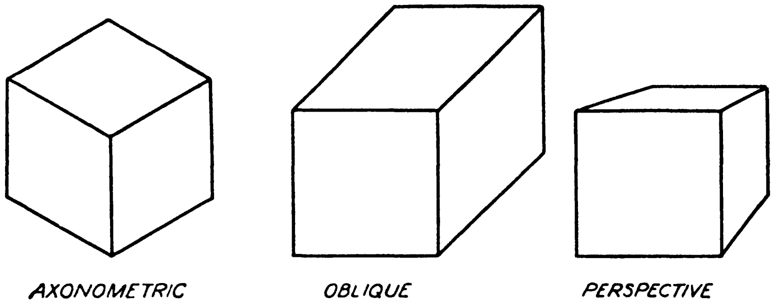


Fig. 415. Axonometric, oblique, and perspective projection.

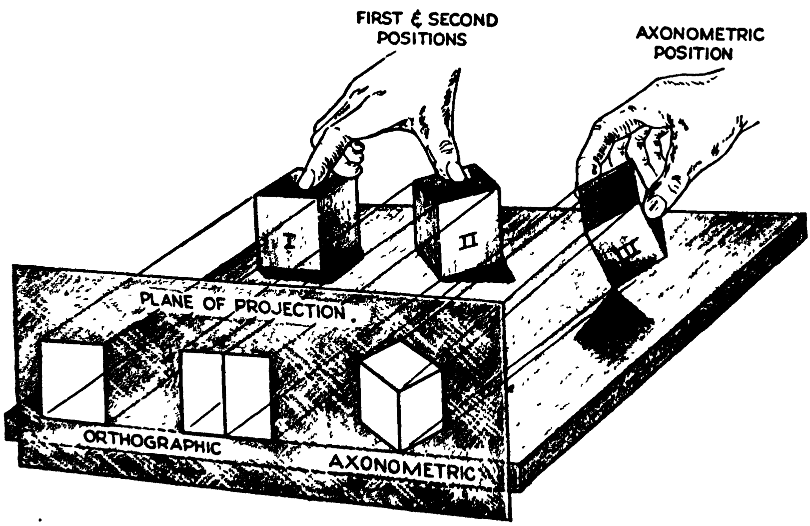


Fig. 416. Theory of axonometric projection.

280. Isometric projection. If the cube in Fig. 416 is revolved through an angle of 45 degrees about an imaginary vertical axis, as shown in II, and is then tilted forward until its body diagonal is perpendicular to the vertical plane, the edges will be foreshortened equally and the cube will be in the correct position to produce an isometric projection, a particular and recognized division of axonometric projection.

The three edges, called isometric axes, will make angles of approximately 35° 16′ with the vertical plane of projection or picture plane. In this form of pictorial, the angles between the projections of these axes are 120 degrees, and the projected lengths of the edges of an object, along and parallel to these axes, are approximately 81 per cent of their true lengths. Now, if instead of turning and tilting the object in relation to a principal plane of projection, an auxiliary plane is used which will be perpendicular to the body diagonal, the view projected on the plane will be an isometric projection. Since the auxiliary plane will be inclined to the principal planes upon which the front, top, and side views would be projected, the auxiliary view, taken in a position perpendicular to the body diagonal, will be a secondary auxiliary view, as shown in Fig. 417.

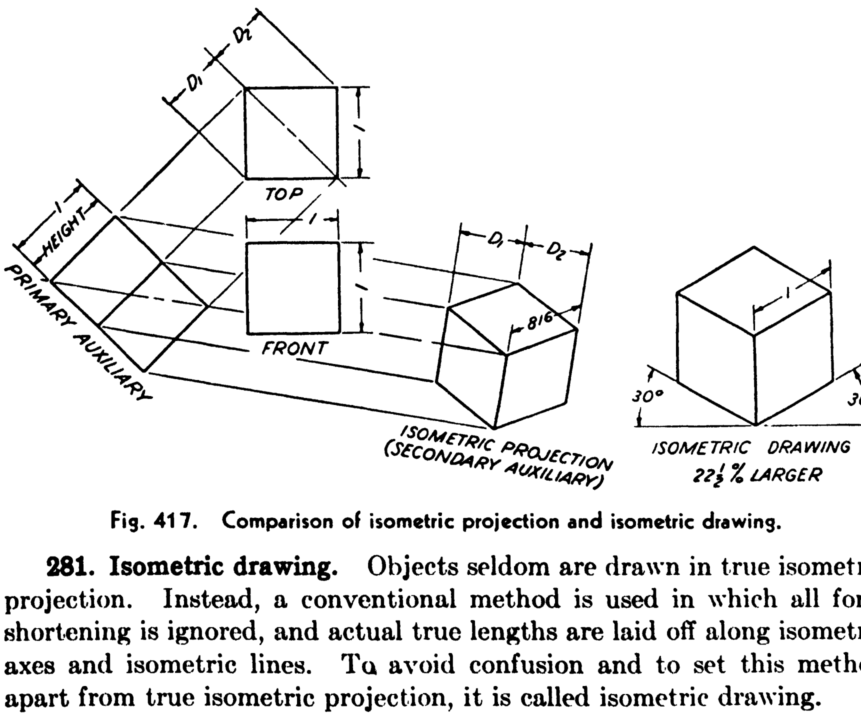


Fig. 417. Comparison of isometric projection and isometric drawing.

281. Isometric drawing. Objects seldom are drawn in true isometric projection. Instead, a conventional method is used in which all foreshortening is ignored, and actual true lengths are laid off along isometric axes and isometric lines. To avoid confusion and to set this method apart from true isometric projection, it is called isometric drawing.

The isometric drawing of a figure is slightly larger (approximately 22½ per cent) than the isometric projection, but, since the proportions are the same, the increased size does not affect the pictorial value of the representation. (See Fig. 417.) The use of a regular scale makes it possible for a draftsman to produce a satisfactory drawing with a minimum expenditure of time and effort.

In isometric drawing, lines which are parallel to the isometric axes are called *isometric lines*.

282. To make an isometric drawing of a rectangular object. The procedure followed in making an isometric drawing of a rectangular block is illustrated in Fig. 418. The three axes which establish the front edges, as shown in (*b*), should be drawn through point *A* so that one extends vertically downward and the other two upward to the right and left at an angle of 30 degrees from the horizontal. Then the actual lengths of the edges may be set off, as shown in (*c*) and (*d*), and the remainder of the view completed by drawing lines parallel to the axes through the corners thus located, as in (*e*) and (*f*).

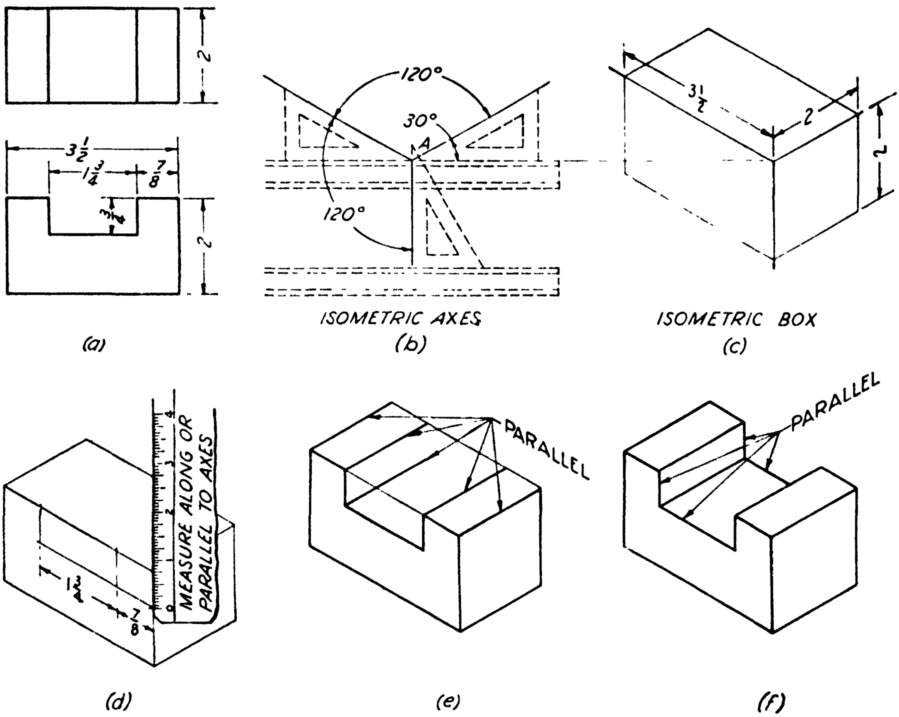


Fig. 418. Procedure for constructing an isometric drawing.

Hidden lines, unless absolutely necessary for clearness, always should be omitted on a pictorial representation.

The same object may be drawn by starting with point *B*. (See Fig. 419.) Often it is more convenient to start at a lower corner.

283. Nonisometric lines. In a pictorial view, the lines that are oblique to the isometric axes are called nonisometric lines. Since a line of this type does not appear in its true length and cannot be measured directly, its position and projected length must be established by locating its extremities. In Fig. 420, *AB* and *CD*, which represent the edges of the block, are nonisometric lines. The location of *AB* is established in the pictorial view by locating points *A* and *B*. Point *A* is on the top edge, *X* distance from the left side surface. Point *B* is on the upper edge of the base, Y distance from the right side surface. All other lines coincide with or are parallel to the axes, and therefore may be measured off with the scale.

The pictorial representation of an irregular solid containing a number of nonisometric lines may be conveniently constructed by the prism method; that is, the object may be enclosed in a rectangular prism so that both isometric and nonisometric lines may be located by points of contact with its surfaces and edges. (See Fig. 421.)

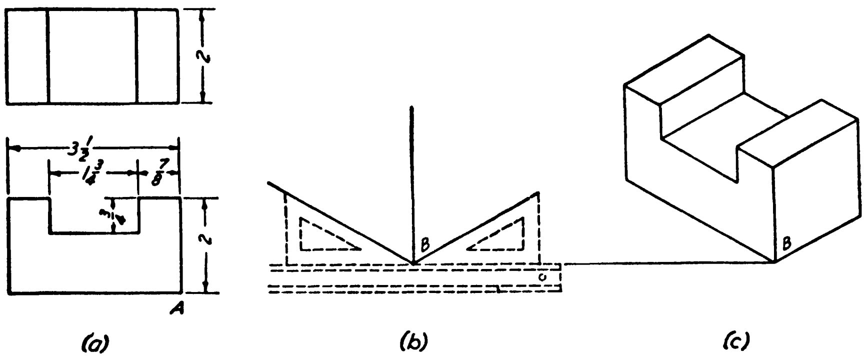


Fig. 419. Alternate procedure of construction.

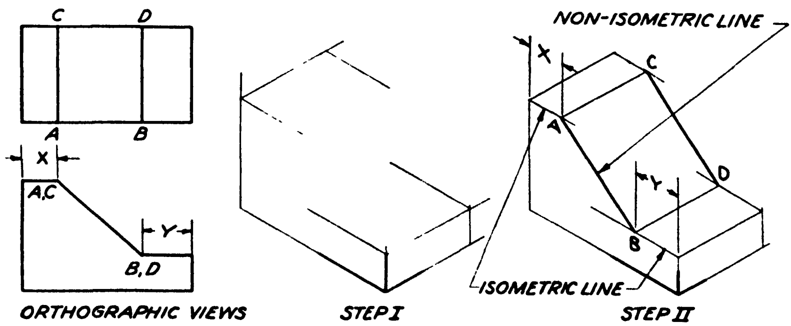


Fig. 420. Nonisometric lines.

A study of Figs. 420 and 421 reveals the important fact that lines which are parallel on an object are parallel in the pictorial view, and, conversely, lines which are not parallel on the object are not parallel on the view. It is often possible to eliminate much tedious construction work by the practical application of this principle of parallel lines.

284. Co-ordinate construction method. When an object contains a number of inclined surfaces, such as the one shown in Fig. 422, the use of the co-ordinate construction method is desirable. In this method, the end points of the edges are located in relation to an assumed isometric base line located upon an isometric reference plane. For example, the line RL is used as a base line from which measurements are made along iso-

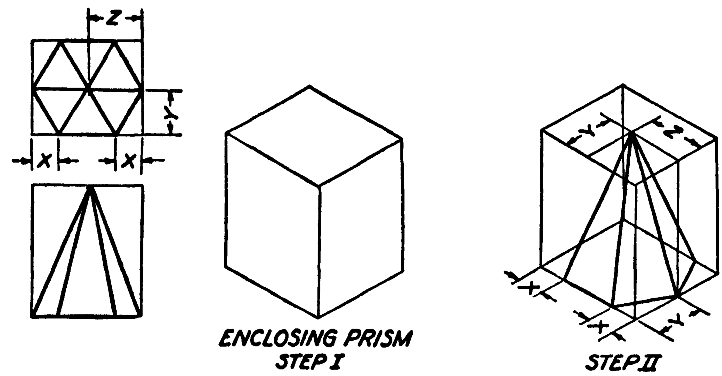


Fig. 421. Prism construction.

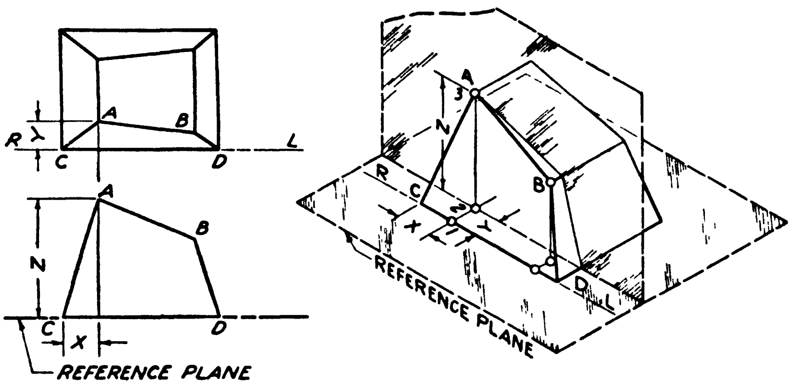


Fig. 422. Co-ordinate construction.

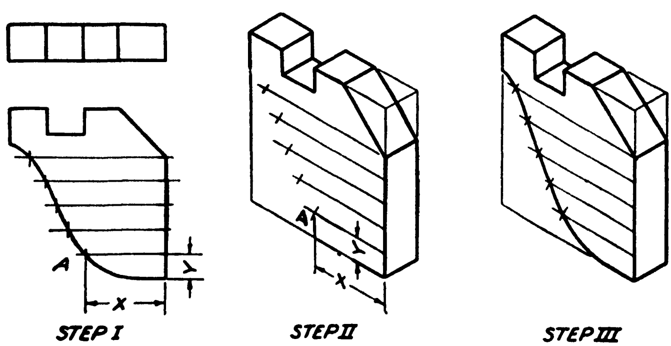


Fig. 423. Offset construction.

metric lines, as shown. The distances required to locate point *A* are taken directly from the orthographic views.

Irregular curved edges are most easily drawn in isometric by the offset method, which is a modification of the co-ordinate construction method (Fig. 423). The position of the curve readily can be established by plotted points which may be located by measuring along isometric lines.

285. Angles in isometric drawing. When nonisometric lines are located by angular measurements (Fig. 424), it is necessary to draw at least a partial orthographic view of the object and take off the dimensions.

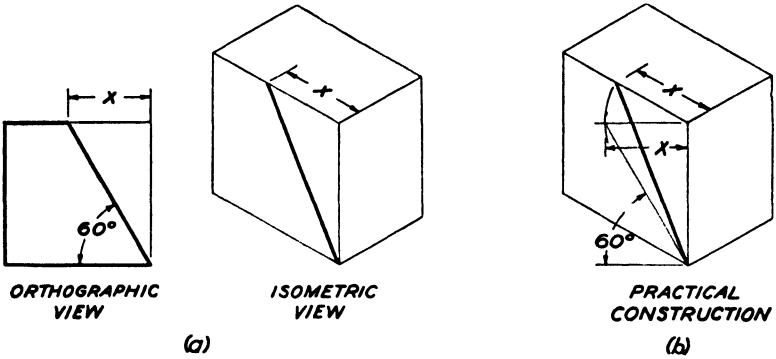


Fig. 424. Angles in isometric.

The scale should be the same as that of the pictorial view (*a*). A practical application of this principle, to the construction of an isometric drawing of a 60 degree angle, is shown in (*b*). By making this construction at the place where the angle is to appear on the isometric drawing, the position of the required line is obtained graphically.

286. Circles, circle arcs, and spheres in isometric drawing. In isometric drawing, a circle appears as an ellipse. The tedious construction required for plotting an ellipse accurately (Fig. 425) often is avoided by using some approximate method of drawing. For an approximate construction, a four-center method is generally used.

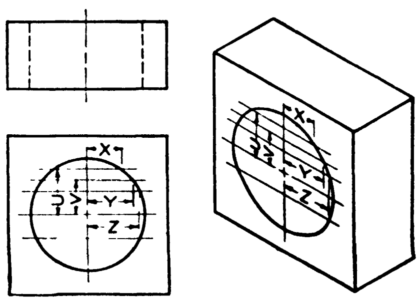


Fig. 425. To plot an isometric circle.

To draw an ellipse representing a pictorial circle, a square is conceived to be circumscribed about the circle in the orthographic projection. When transferred to the isometric plane in the pictorial view, the square becomes a rhombus (isometric square) and the circle an ellipse tangent to the rhombus at the mid-points of its sides. If the ellipse is to be drawn by the four-center method (Fig. 426), the points of intersection of the perpendicular bisectors of the sides of the rhombus will be centers for the four arcs forming the approximate ellipse. The two intersections which lie on the the corners of the rhombus are centers for the two large arcs, while the remaining intersections are centers for the two small arcs. Furthermore, the length along the perpendicular from the center of each arc to the point at which the arc is tangent to the rhombus (mid-point) will be the radius. All construction lines required by this method may be made with a T-square and a 30° × 60° triangle.

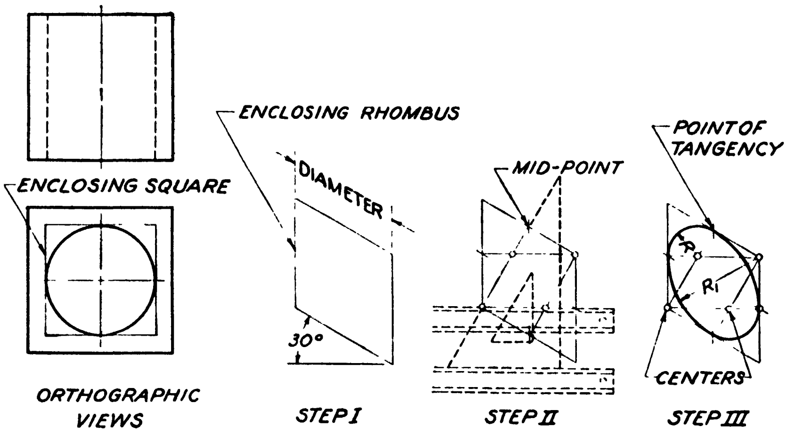


Fig. 426. Four-center approximation.

A circle arc will appear in pictorial representation as a segment of an ellipse. Therefore, it may be drawn by using as much of the four-center method as is required to locate the needed centers. (See Fig. 427.) For example, to draw a quarter circle, it is only necessary to lay off the true radius of the arc along isometric lines drawn through the center and to draw intersecting perpendiculars through these points.

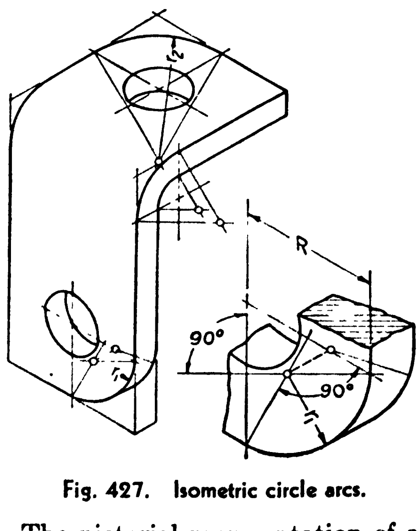


Fig. 427. Isometric circle arcs.

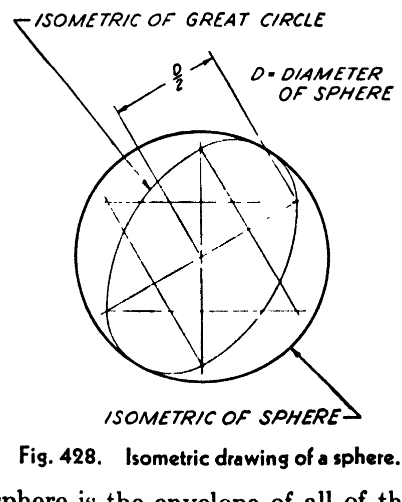


Fig. 428. Isometric drawing of a sphere.

The pictorial representation of a sphere is the envelope of all of the great circles which could be drawn on the surface. In isometric drawing, the great circles appear as ellipses and a circle is their envelope. In practice it is necessary to draw only one ellipse, using the true radius of the sphere and the four-center method of construction. The diameter of the circle is the long diameter of the ellipse (Fig. 428).

287. Positions of isometric axes. It sometimes is desirable to place the principal isometric axes so that an object will be in position to reveal certain faces to a better advantage (Fig. 429).

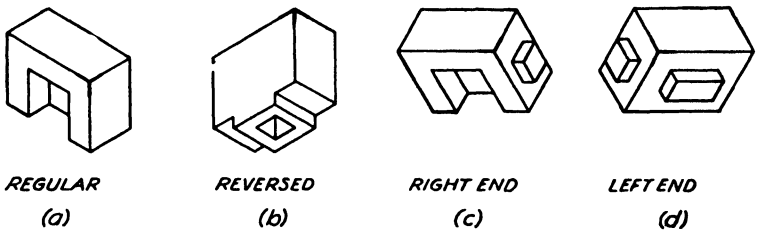


Fig. 429. Convenient position of axes.

The difference in direction should cause no confusion, since the angle between the axes and the procedure followed in constructing the view are the same for any position.

Reversed axes are used in architectural work to show a feature as it would be seen from a natural position below.

288. Isometric sectional views. Generally, an isometric sectional view is used for showing the inner construction of an object, when there is a complicated interior to be explained or when it is desirable to emphasize

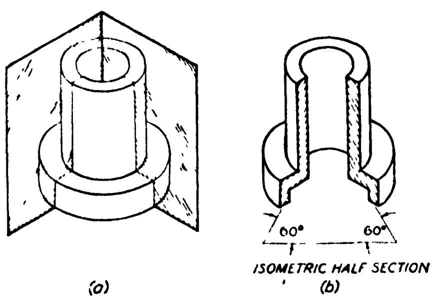


Fig. 430. Isometric section.

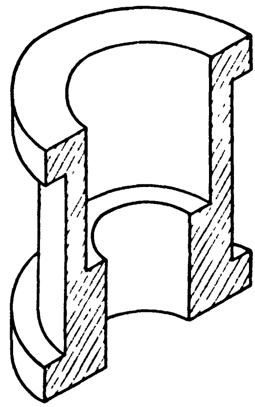


Fig. 431. Isometric full section.

features which would not appear in a usual outside view. Sectioning in isometric drawing is based upon the same principles as sectioning in orthographic drawing. Isometric planes are used for cutting an object, and the general procedure followed in constructing the representation is the same as for an exterior view.

Fig. 431 illustrates a full section in isometric. The accepted procedure for constructing this form of sectional view is to draw the cut face and then add the portion that lies behind.

Fig. 430 shows an isometric half section. It is easier, in this case, to outline the outside view of the object in full and then remove a front quarter with isometric planes.

Section lines should be sloped at an angle which produces the best effect, but they should never be drawn parallel to object lines.

289. Principle of oblique projection. The theory of oblique projection can be explained by imagining a vertical plane of projection in

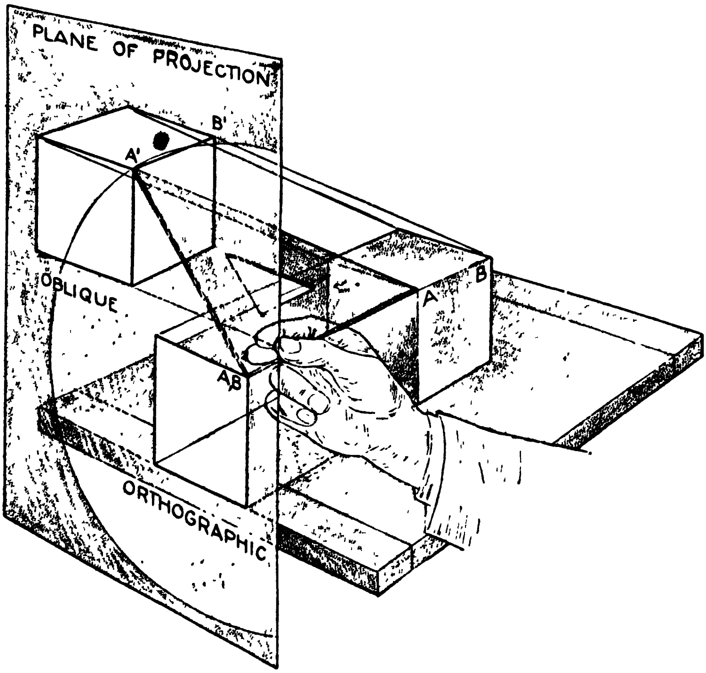


Fig. 432. Theory of oblique projection.

front of a cube parallel to one of its faces (Fig. 432). When the projectors make an angle of 45 degrees in any direction with the picture plane the length of any oblique projection $A'B'$ of the edge AB is equal to the true length of AB. Note that the projectors could be parallel to any element of a 45-degree cone having its base in the plane of projection. With projectors at this particular angle (45 degrees), the face parallel to the plane is projected in its true size and shape and the edges perpendicular to the picture plane are projected in their true length.

290. Oblique drawing. This form of drawing is based upon three mutually perpendicular axes along which, or parallel to which, the necessary measurements are made for constructing the representation. Oblique drawing differs from isometric drawing principally in that two axes are always perpendicular to each other while the third (receding axis) is at some convenient angle, such as 30 degrees, 45 degrees, or 60 degrees, with the horizontal. (See Fig. 433.)

291. To make an oblique drawing. The procedure followed in constructing an oblique drawing of an object is illustrated in Fig. 433. The three axes that establish the perpendicular edges in (*b*) are drawn through point *O* representing the front corner. *OA* and *OB* are perpendicular

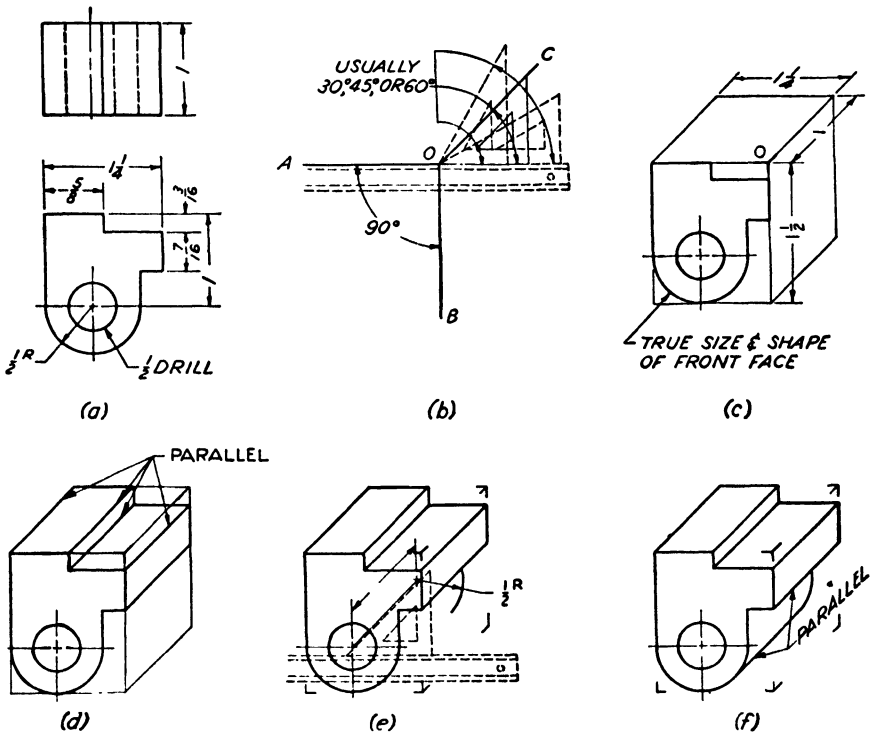


Fig. 433. Procedure for constructing an oblique drawing.

to each other and *OC* is at any desired angle (say 45 degrees) with the horizontal. After the length, height, and depth have been set off, as in (*c*), the front face may be laid out in its true size and shape and the view can be completed by drawing lines parallel to the receding axes through the established corners. The circle and semicircle are shown parallel to the picture plane in order to avoid distortion and because, from the draftsman's standpoint, it is easier to draw a circle than to construct an ellipse.

In general, the procedure for constructing an oblique drawing is the same as for an isometric drawing.

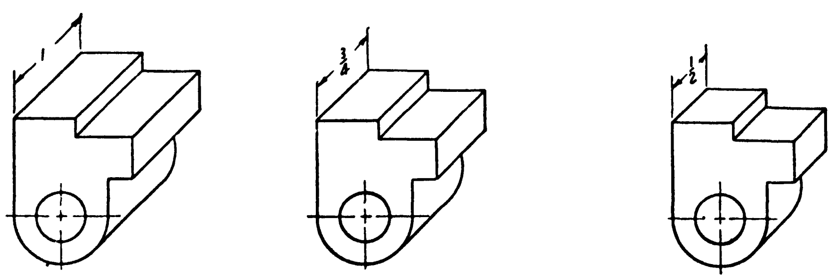
292. Rules for placing an object. Generally, the most irregular face, or the one containing the most circular outlines, should be placed parallel to the picture plane, in order to minimize distortion and simplify construction. By following this practice, all or most of the circles and circle arcs can be drawn with a compass. In selecting the position of an object, two rules should be followed. The first is to place the face having the most irregular contour, or the most circular outlines, parallel to the picture plane.

When the longest face of an object is used as the front face, the pictorial view will be distorted to a lesser degree and, therefore, will have a more realistic and pleasing appearance. Hence, the second rule is to place the longest face parallel to the picture plane.

293. Angles, circles, and circle arcs in oblique. As previously stated, angles, circles, and irregular outlines on surfaces parallel to the plane of projection show in true size and shape. In constructing the elliptical representation of a circle or circle arc located on a receding face, the construction methods used in isometric drawing usually may be applied. If a 30° angle is used for the receding axis the perpendicular bisectors of the sides will intersect at opposite corners of the rhombus as in isometric drawing. If taken as 45° they will intersect outside of the enclosing rhombus.

294. Reduction of measurements in the direction of the receding axis. An oblique drawing often presents a distorted appearance which is unnatural and disagreeable to the eye. In some cases the view constructed by this scheme is so misleading in appearance that it is unsatisfactory for any practical purpose. As a matter of interest, the effect of distortion is due to the fact that the receding lines are parallel and do not appear to converge as the eye is accustomed to anticipating.

The appearance of excessive thickness can be overcome somewhat by reducing the length of the receding lines. For practical purposes,



OBLIQUE (a) (b) CABINET (c)

Fig. 434. Foreshortening in the direction of the receding axis.

measurements usually are reduced one-half, but any scale of reduction may be arbitrarily adopted if the view obtained will be more realistic in appearance. When the receding lines are drawn one-half their actual length, the resulting pictorial view is called a cabinet drawing. Fig. 434 shows an oblique drawing (*a*) and a cabinet drawing (*c*) of the same object, for the purpose of comparison.

295. Oblique sectional views. Oblique sectional views are drawn to show the interior construction of objects. The construction procedure is the same as for an isometric sectional view, except that oblique planes are used for cutting the object.

296. Pictorial dimensioning. The dimensioning of isometric and other forms of pictorial working drawings is done in accordance with the following rules:

1. Draw extension and dimension lines (except those dimension lines applying to cylindrical features) parallel to the pictorial axes in the plane of the surface to which they apply (Fig. 435).

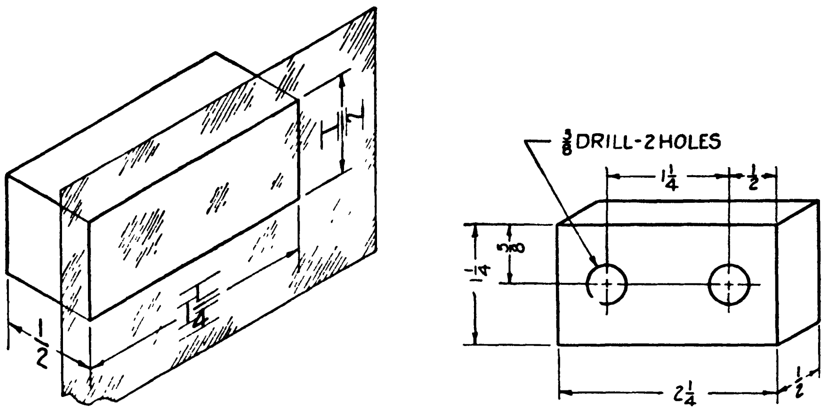


Fig. 435. Extension and dimension lines in isometric (left); numerals, fractions, and notes in oblique (right).

2. If possible, apply dimensions to visible surfaces.
3. Place dimensions on the object, if, by so doing, better appearance, added clearness, and easy readings result.
4. Letter the notes as on ordinary drawings, avoiding the difficulties encountered in forming pictorial letters.
5. Make the figures of a dimension appear to be lying in the plane of the surface whose dimension it indicates, by using vertical figures drawn in pictorial (Fig. 435). (Note: Guide lines and slope lines are drawn parallel to the pictorial axes.)

297. Perspective. In perspective projection (Fig. 436) an object is shown much as the human eye or camera would see it at a particular point. Actually, it is a geometrical method by which a picture can be projected upon a picture plane in much the same way as in photography. Perspective drawing differs from the methods previously discussed in that, although the projectors or visual rays are oblique to the picture plane, they intersect at a common point which is known as the station point.

Fig. 436 illustrates pictorially the accepted nomenclature of perspective drawing. The horizon line is the line of intersection of the horizontal plane through the observation point (eye of the observer) and the picture plane. The horizontal plane is known as the *plane of the horizon.* The ground line is the line of intersection of the ground plane and the picture plane. The *CV* point is the center of vision of the observer. It is located directly in front of the eye in the plane of the horizon on the horizon line.

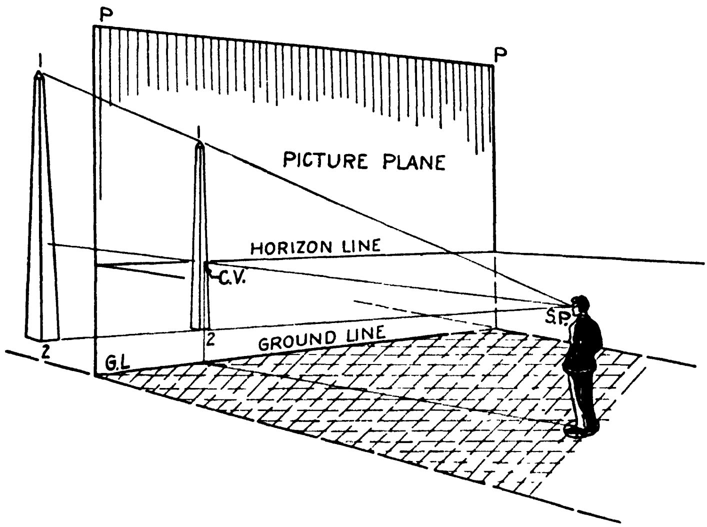


Fig. 436. Nomenclature.

298. Location of picture plane. The picture plane is usually placed between the object and the *SP* (station point). In parallel perspective (Sec. 303) it may be passed through a face of the object in order to show the true size and shape of the face.

299. Location of the station point. The station point should be located in front of the object, where the object can be viewed to the best advantage. It is desirable that it should be at a distance from the picture plane equal to at least twice the height or width of the object, in order to avoid distortion, for at such distance, or greater, the entire object can be viewed without moving the head.

300. Position of the object in relation to the horizon. When making a perspective of a tall object, such as a building, the horizon usually is assumed to be at a height above the ground plane equal to the height of a man's eye ($5\frac{1}{2}$ feet). A small object may be placed above or below the horizon, depending upon the view desired.

301. Lines. The following facts should be recognized concerning the perspective of lines:

1. Parallel horizontal lines vanish at a single *VP* (vanishing point).

Usually the *VP* is at the point where a line parallel to the system through the *SP* pierces the *PP* (picture plane).

2. A system of horizontal lines has its *VP* on the horizon.

3. Vertical lines, since they pierce the picture plane at infinity, will appear vertical in perspective.

4. When a line lies in the picture plane, it will show its true length because it will be its own perspective.

5. When a line lies behind the picture plane, its perspective will be shorter than the line.

302. Types of perspective. In general, there are two types of perspective: *parallel perspective* and *angular perspective.* In parallel per-

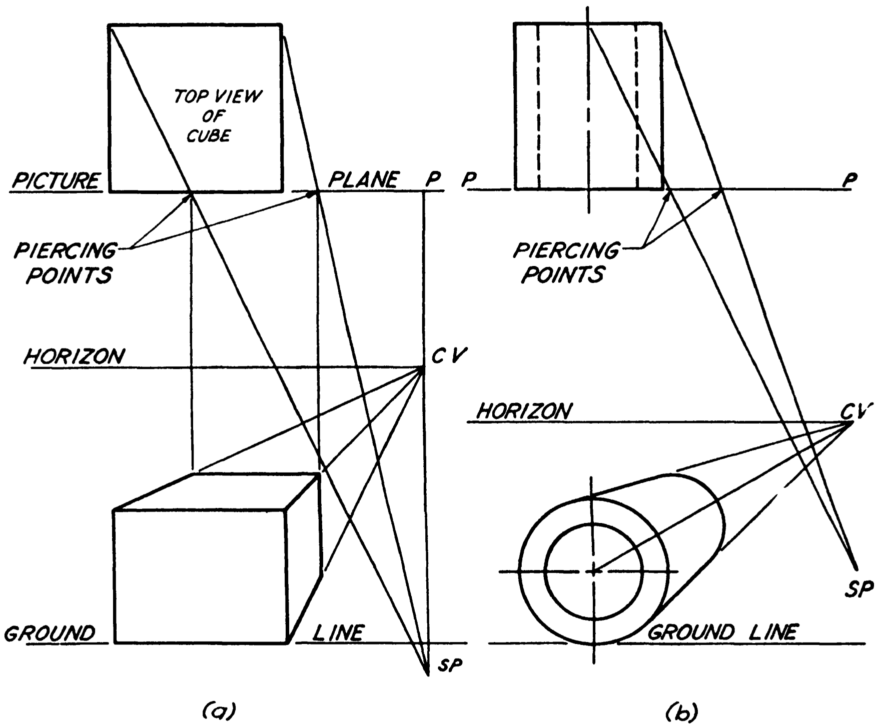


Fig. 437. Parallel perspective.

spective, one of the principal faces is parallel to the picture plane and is its own perspective. All vertical lines are vertical, and the receding horizontal lines converge to a single vanishing point. In angular perspective, the object is placed so that the principal faces are at an angle with the picture plane. The horizontal lines converge at two vanishing points.

303. Parallel perspective. Fig. 437(*a*) shows the parallel perspective of a cube. The *PP* line is the top view of the picture plane, *SP* is the top view of the station point, and *CV* is the center of vision. The receding horizontal lines vanish at CV. The front face, since it lies in the picture plane, is its own perspective and shows in its true size. The lines representing the edges back of the picture plane are found by projecting downward from the points at which the visual rays pierce the picture plane, as shown by the top views of the rays. Fig. 437(*b*) shows a parallel perspective of a hollow cylinder.

304. Angular perspective. Fig. 438 shows pictorially the graphical method for the preparation of a two-point perspective drawing of a cube.

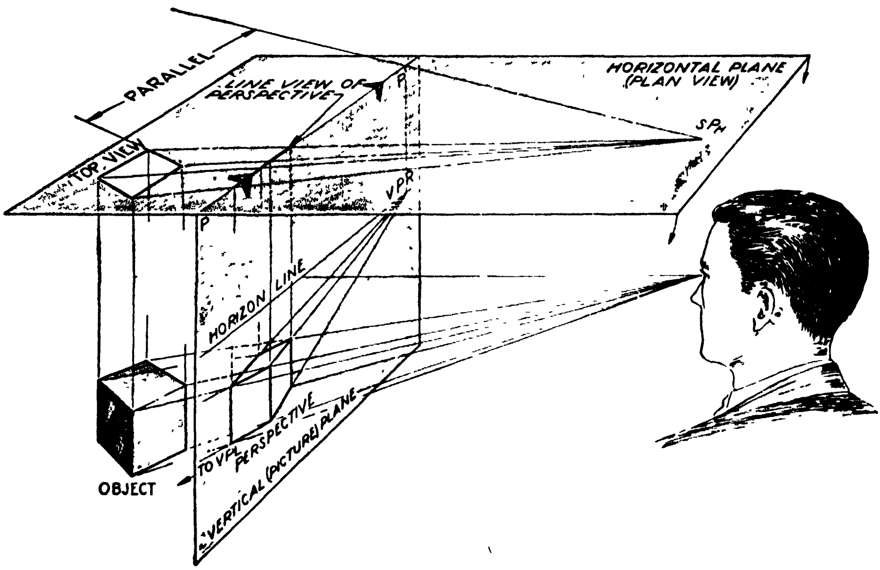


Fig. 438. Angular perspective.

To visualize the true layout on the surface of a sheet of drawing paper, it is necessary to revolve mentally the horizontal plane downward into the vertical or picture plane. Upon completion of Sec. 304, it is suggested that the reader turn back and endeavor to associate the development of the perspective in Fig. 439 with the pictorial presentation in Fig. 438. For a full understanding of the construction in Fig. 439, it is necessary to differentiate between the lines that belong to the horizontal plane and those that are on the vertical or picture plane. In addition, it must be fully realized that there is a top view for the perspective which is a line, and that in this line view lie the points which must be projected downward to the perspective representation (front view).

Fig. 439 shows an angular perspective of a mutilated block. The block has been placed so that one vertical edge lies in the picture plane. The other vertical edges are parallel to the plane, while all of the horizontal lines are inclined to it so that they vanish at the two vanishing points, *VPL* and *VPR*, respectively.

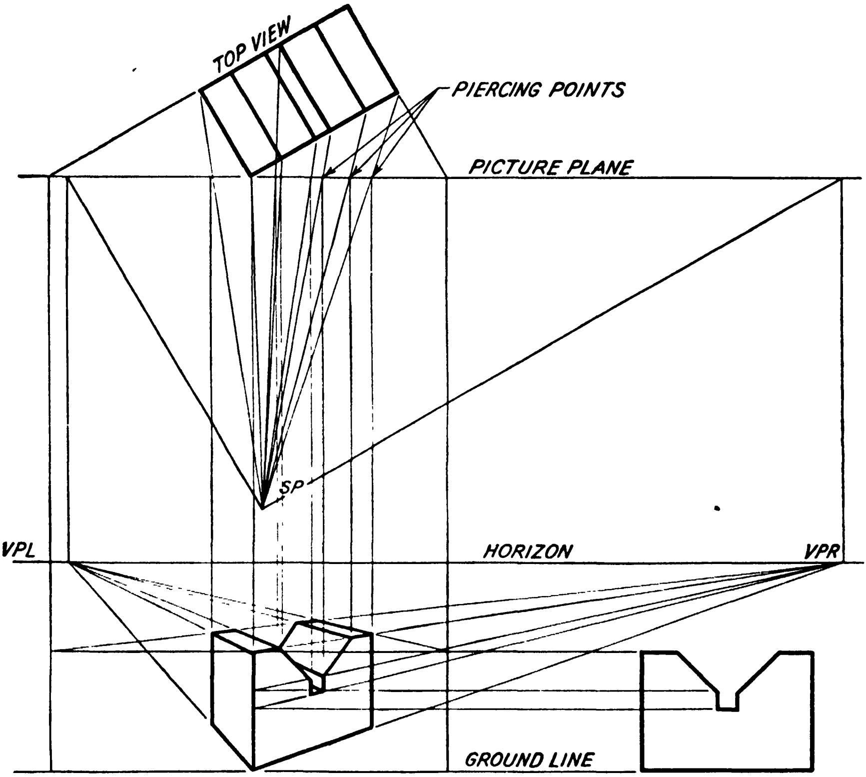


Fig 439. Angular perspective.

In constructing the perspective shown in this illustration, an orthographic top view was drawn in such a position that the visible vertical faces made angles of 30 degrees and 60 degrees with the picture plane. Next, the location of the observer was assumed and the horizon line was established. The vanishing points *VPL* and *VPR* were found by drawing a 30 degree line and a 60 degree line through the *SP*. Since these lines are parallel to the two systems of receding horizontal lines, each will establish a required vanishing point at its intersection with the picture plane. The vertical line located in the picture plane, which is its own perspective, was selected as a measuring line on which to project vertical measurements from the orthographic front view. The lines shown from these division points along this line to the vanishing points (*VPL-VPR*) established the direction of the receding horizontal edge lines in the perspective. The position of the back edges was determined by projecting downward from the points at which the projectors from the station point (*SP*) to the corners of the object pierced the picture plane, as shown by the top view of the object and projectors.

If a circle is on a surface which is inclined to the picture plane (*PP*), its perspective will be an ellipse. It is the usual practice to construct the representation within an enclosing square by finding selected points along the curve in the perspective as shown in Fig. 440.

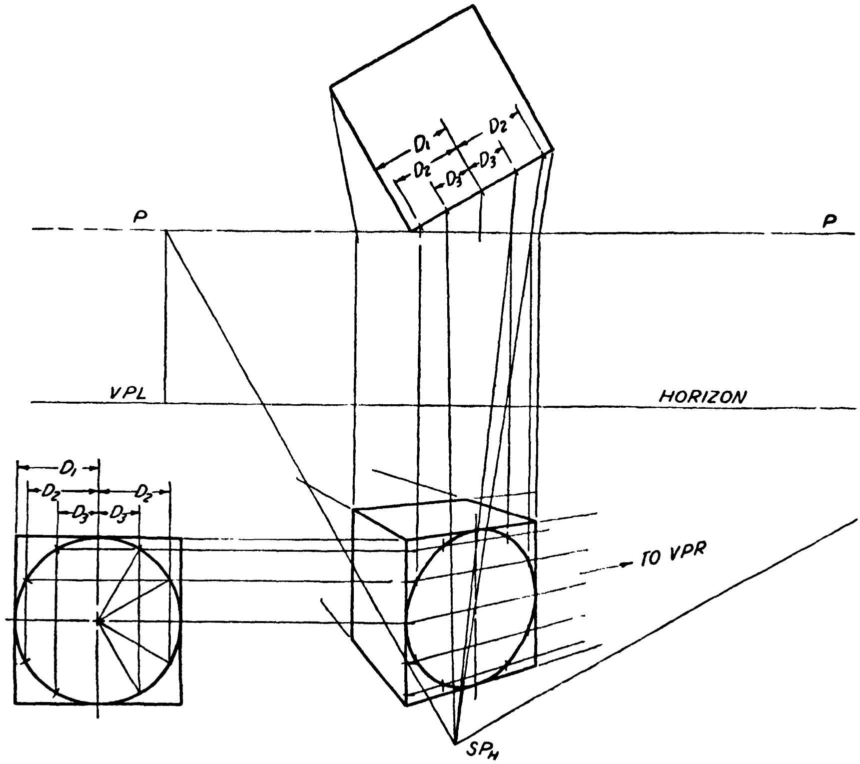


Fig. 440. Circles in perspective.

305. Problems.

1. (Fig. 441.) Prepare instrumental isometric drawings or freehand sketches of the objects as assigned.

2. (Fig. 442.) Prepare instrumental oblique drawings or freehand sketches of the objects as assigned.

3. (Fig. 443.) Make an isometric drawing of the sawhorse. Select a suitable scale.

4. (Fig. 444.) Make an oblique drawing of the locomotive drive nut.

5. (Fig. 445.) Make an isometric drawing of the stepladder. Select a suitable scale.

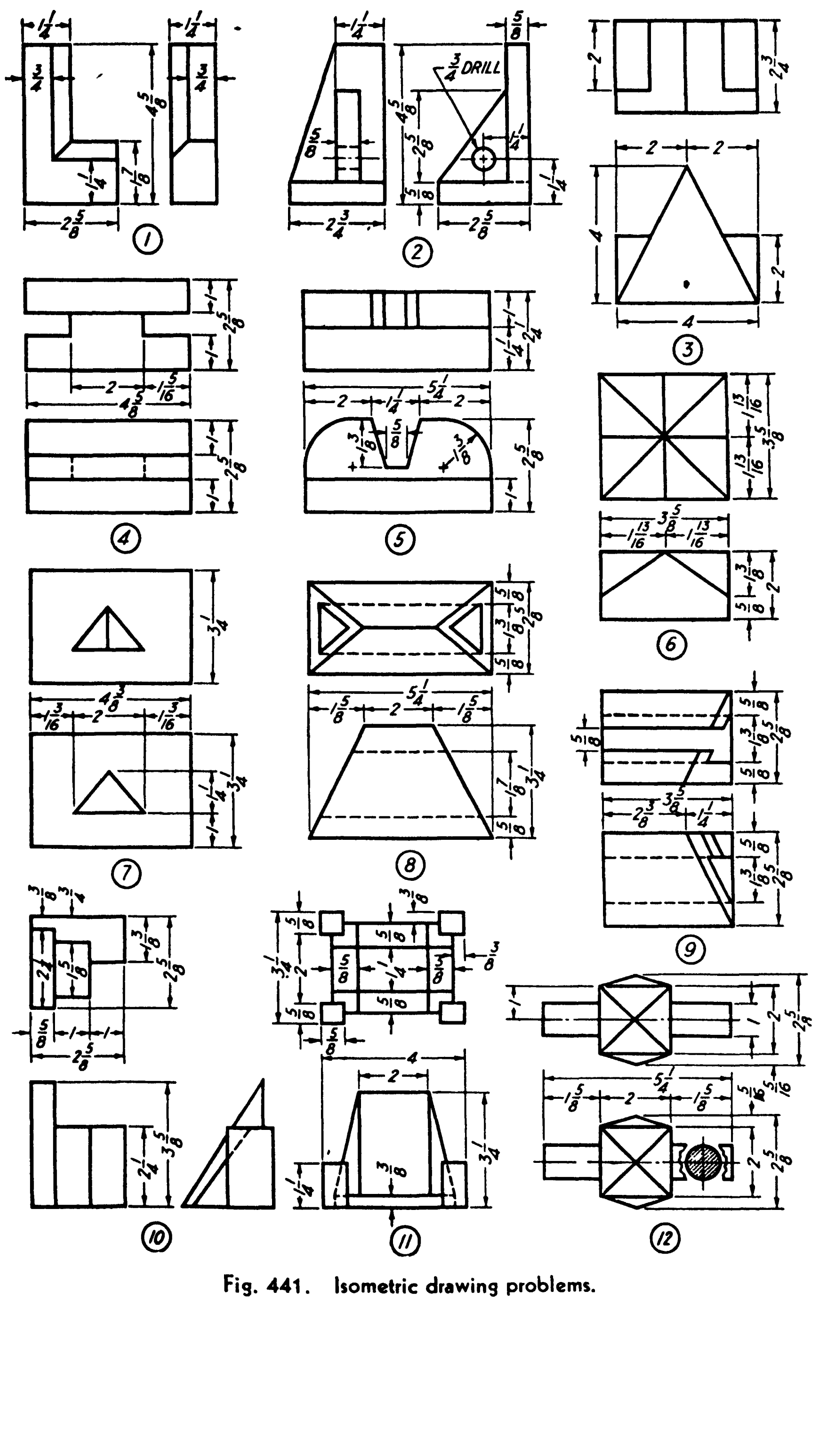


Fig. 441. Isometric drawing problems.

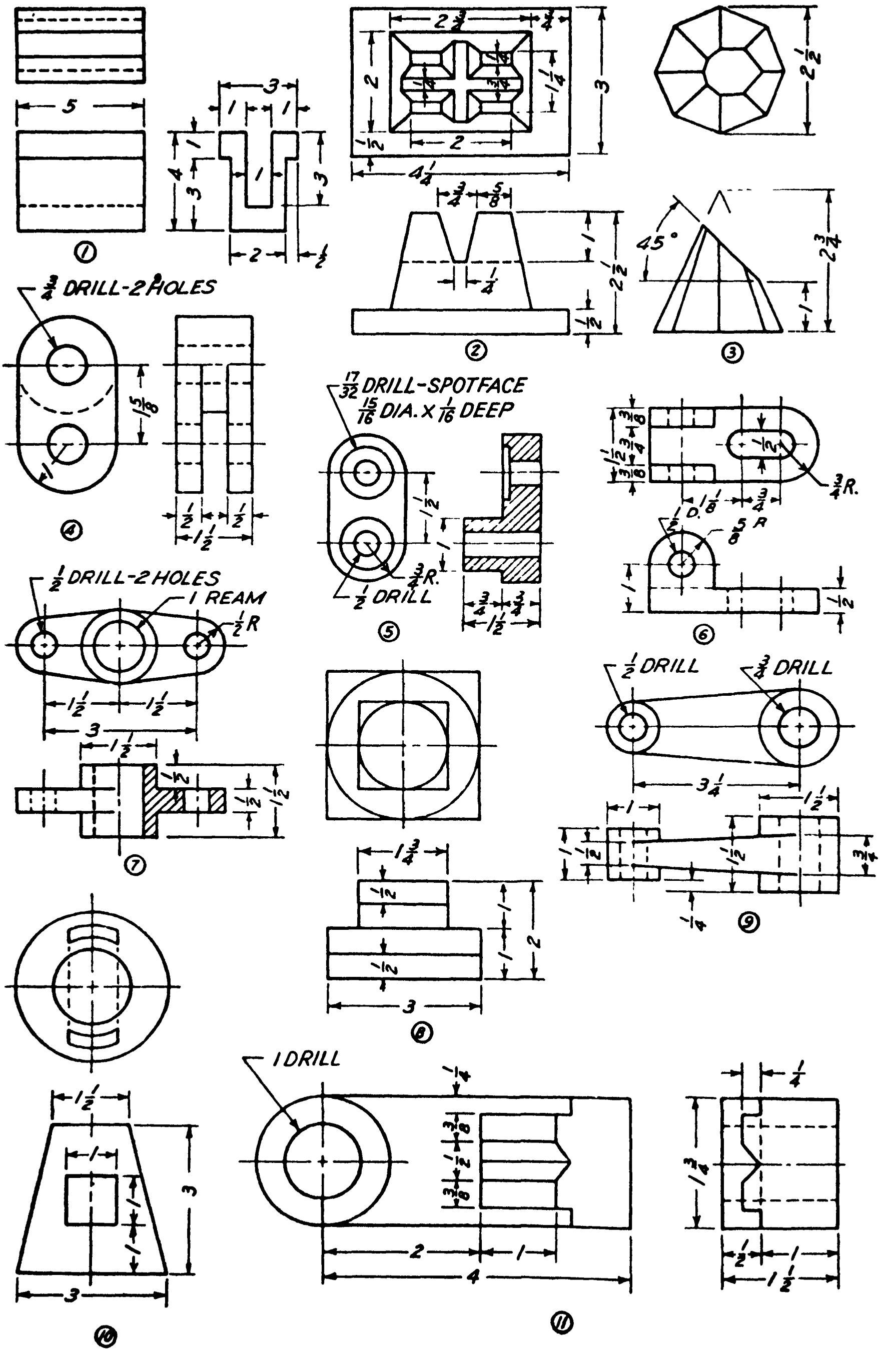


Fig. 442. Oblique drawing problems.

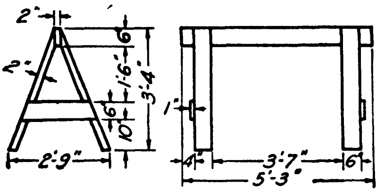


Fig. 443. Sawhorse.

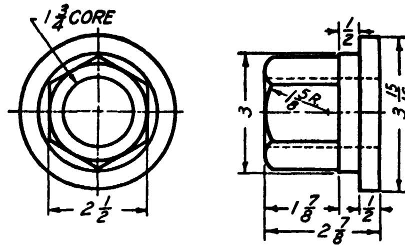


Fig. 444. Locomotive driver nut.

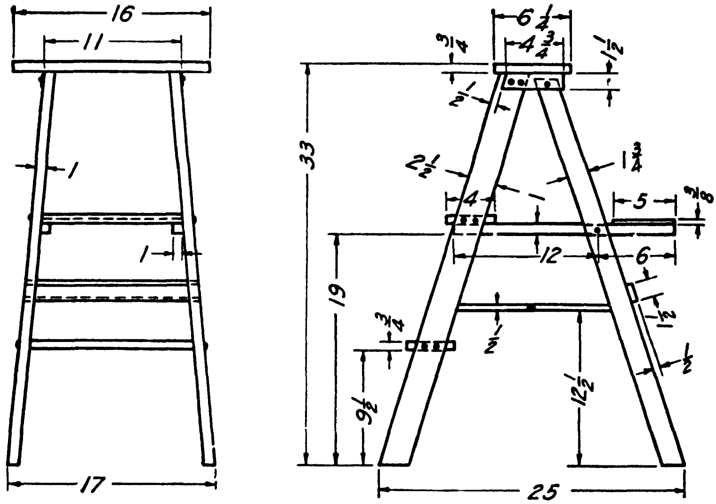


Fig. 445. Stepladder.

19

SHEET METAL DRAFTING

Developments and Intersections

306. A comprehensive study of intersections and developments is logically a part of the subject of Descriptive Geometry. However, the many practical applications that can be handled just as well by the method of orthographic projection should be discussed in a drawing text in connection with that subject. Desired lines of intersection between geometrical surfaces may be obtained by applying the principles of orthographic projection with which the student is already familiar. Although developments are laid out and are not drawn by actual projection in the manner of exterior views, their construction nevertheless requires the application of orthographic projection in finding the true lengths of elements and edges.

Developments

307. Developments. A layout of the complete surface of an object is called a development or pattern. The development of an object bounded by plane surfaces may be thought of as being obtained by turning the object, as illustrated in Figs. 446 and 447, so as to unroll the imaginary

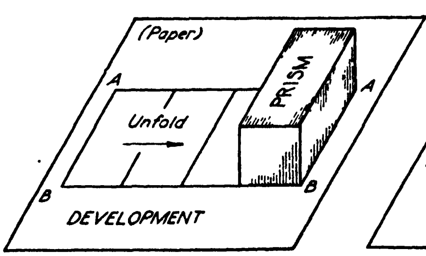


Fig. 446. The development of a prism.

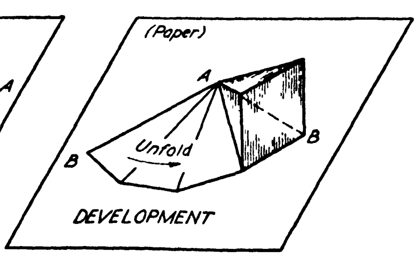


Fig. 447. The development of a pyramid.

enclosing surface upon a plane. Practically, the drawing operation consists of drawing the successive surfaces in their true size with their common edges joined.

The surfaces of cones and cylinders also may be unrolled upon a plane. The development of a right cylinder (Fig. 448) is a rectangle having a width equal to the altitude of the cylinder and a length equal to the cylinder's computed circumference (πd). The development of a right circular cone (Fig. 449) is a sector of a circle having a radius equal to the slant height of the cone and an arc length equal to the circumference of its base.

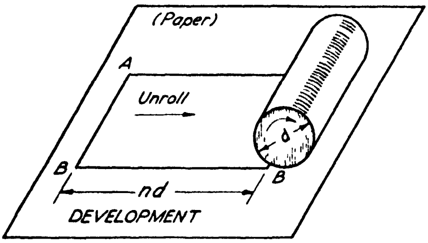


Fig. 448. The development of a cylinder.

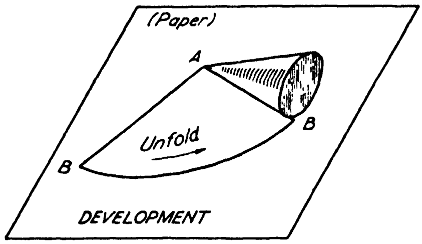


Fig. 449. The development of a cone.

Warped and double curved surfaces cannot be developed accurately, but they may be developed by some approximate method. Ordinarily, an approximate pattern will prove to be sufficiently accurate for practical purposes if the material of which the piece is to be made is somewhat flexible.

Plane and single curved surfaces (prisms, pyramids, cylinders, and cones), which can be accurately developed, are said to be developable. Warped and double curved surfaces, which can be only approximately developed, are said to be nondevelopable.

308. Practical developments. On many industrial drawings, a development must be shown to furnish the necessary information for making a pattern to facilitate the cutting of a desired shape from sheet metal. Present-day draftsmen must have a broad knowledge of the methods of constructing varied types of developments, because of the rapid advance of the art of manufacturing an ever-increasing number of pieces by folding, rolling, or pressing cut sheet-metal shapes. Patterns also are used in stone cutting as guides for shaping irregular faces.

A development of a surface should be drawn with the inside face up, as it theoretically would be if the surface were unrolled or unfolded as illustrated in Figs. 446–449. In commercial drafting, this practice is further justified by the fact that sheet-metal workers must make the necessary punch marks for folding on the inside surface.

Although in actual sheet-metal work extra metal must be allowed for lap at seams, no allowance will be shown on the developments in this chapter. Many other practical considerations have been purposely ignored, as well, in order to avoid confusing the beginner.

309. To develop a right truncated prism. Before the development of the lateral surface of a prism can be drawn, the true lengths of the edges and the true size of a right section must be determined. In the right truncated prism, shown in Fig. 450, the true lengths of the prism edges are shown in the front view and the true size of the right section is shown in the top view.

The lateral surface is "unfolded" by first drawing a "stretch-out line" and marking off the widths of the faces (distances 1-2, 2-3, 3-4, and so on, from the top view) along it in succession. Through these points light construction lines are then drawn perpendicular to the line 1_D-1_D,

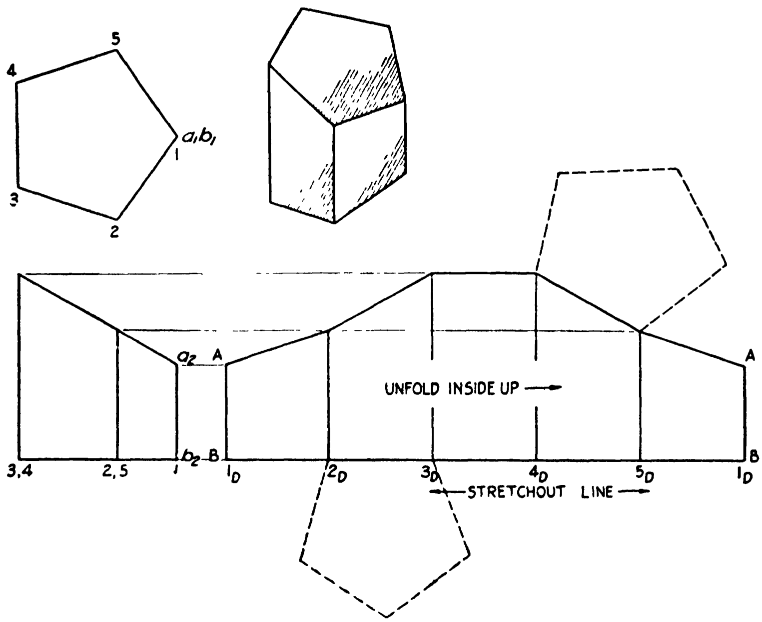


Fig. 450. The standard method of developing the lateral surface of a right prism.

and the length of the respective edge is set off on each by projecting from the front view. When projecting edge lengths to the development, the points should be taken in a clockwise order around the perimeter as indicated by the order of the figures in the top view. The outline of the development is completed by joining these points. Thus far, nothing has been said about the lower base or the inclined upper face. These may be joined to the development of the lateral surface, if so desired.

In sheet-metal work, it is the usual practice to make the seam on the shortest element in order to save time and conserve solder or rivets.

310. To develop an oblique prism. The lateral surface of an oblique prism, such as the one shown in Fig. 451, is developed by the same general method used for a right prism. Similarly, the true lengths of the edges are shown in the front view, but it is necessary to find the true size of the right section by auxiliary plane construction. The width of the faces, as taken from the auxiliary right section, are set off along the stretch-out line, and perpendicular construction lines representing the edges are drawn through the division points. The lengths of the portions of each respective edge, above and below plane X-X, are transferred to the corresponding line in development.

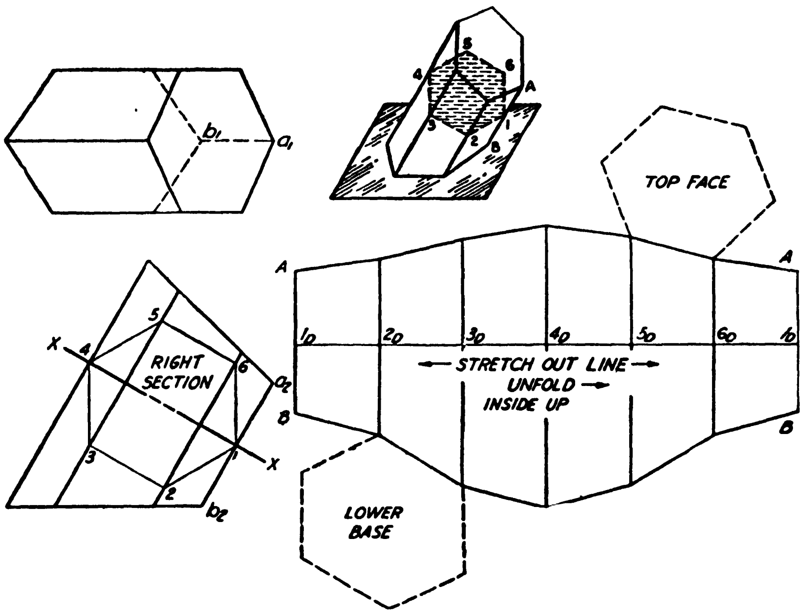


Fig. 451. The development of an oblique prism.

311. To develop a right cylinder. When the lateral surface of a right cylinder is rolled out upon a plane, the base develops into a straight line (Fig. 452). The length of this line, which is equal to the circumference of a right section ($\pi \times$ dia.), may be calculated and laid off as the stretch-out line 1_D-1_D.

Since the cylinder can be thought of as being a many-sided prism, the development may be constructed in a manner similar to the method illustrated in Fig. 450. The elements drawn on the surface of the cylinder serve as edges of the many-sided prism. Twelve or twenty-four of these elements ordinarily are used, the number depending upon the size of the cylinder. Usually they are spaced by dividing the circumference of the base, as shown by the circle in the top view, into an equal number of parts. The stretch-out line is divided into the same number of equal parts, and perpendicular elements are drawn through each division point. Then the true length of each element is projected to its respective representation on the development, and the development is completed by joining the points with a smooth curve. In joining the points, it is advisable to sketch the curve in lightly, freehand, before using the French curve. Since the surface of the finished cylindrical piece forms a continuous curve, the elements on the development are not heavied. When the development is symmetrical, as in this case, only one-half need be drawn.

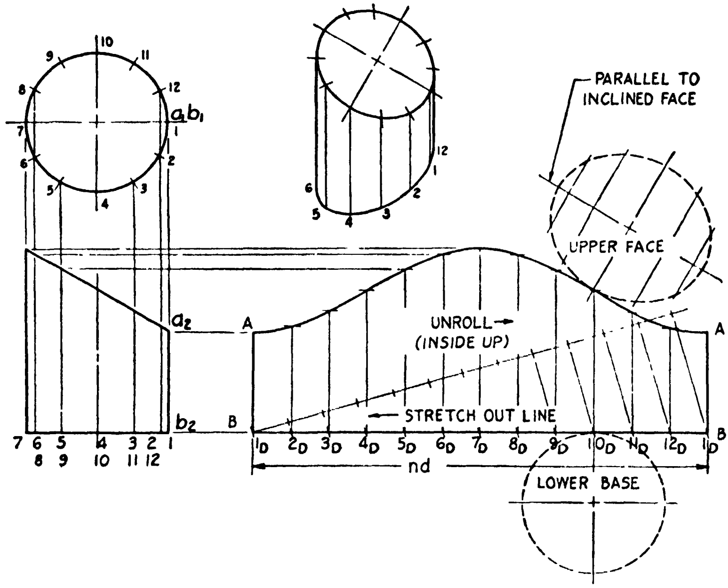


Fig. 452. Development of a right circular cylinder.

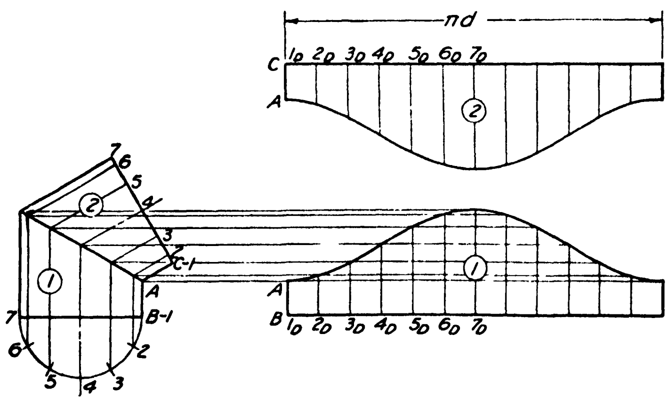


Fig. 453. Two-piece elbow.

A piece of this type might form a part of a two-piece, three-piece, or four-piece elbow. The pieces are usually developed as illustrated in Fig. 453. The stretch-out line of each section is equal in length to the computed perimeter of a right section.

312. To develop an oblique cylinder. Since an oblique cylinder theoretically may be thought of as enclosing a regular oblique prism having an infinite number of sides, the development of the lateral surface of the cylinder may be constructed by using a method similar to the method illustrated in Fig. 451. The circumference of the right section becomes stretch-out line 1_D-1_D for the development.

313. True length of a line. In order to construct the development of the lateral surface of some objects, it frequently is necessary to determine the true lengths of oblique lines that represent the edges. The general method for determining the true lengths of lines inclined to all of the co-ordinate planes of projection has been explained in Sec. 180.

314. True-length diagrams. When it is necessary, in developing a surface, to find the true lengths of a number of edges or elements, some

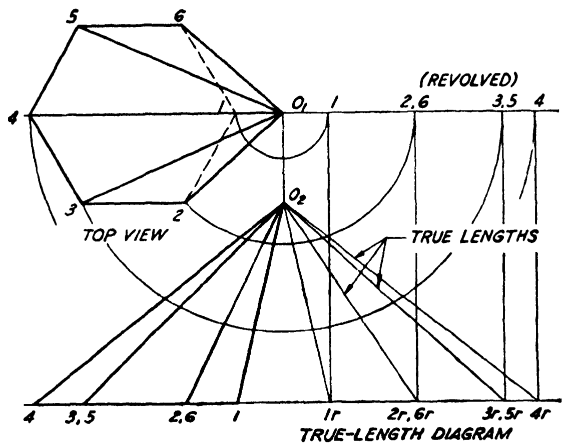


Fig. 454. A true-length diagram (the revolution method).

confusion may be avoided by constructing a true-length diagram adjacent to the orthographic view as shown in Fig. 454. The elements were revolved into a position parallel to the V (front) plane so that their true lengths show in the diagram. This practice prevents the front view in the illustration from being cluttered with lines, some of which would represent elements and others their true lengths.

Fig. 456 shows a diagram which gives the true lengths of the edges of the pyramid. Each line representing the true length of an edge is the hypotenuse of a right triangle whose altitude is the altitude of the edge in the front view and whose base is equal to the length of the projection of the edge in the top view.

315. To develop a right pyramid. To develop (unfold) the lateral surface of a right pyramid, it is first necessary to determine the true lengths of the edges and the true size of the base. With this information, the development can be constructed by laying out the faces in successive order with their common edges joined. If the surface is imagined to be unfolded by turning the pyramid, as shown in Fig. 447, each triangular face is revolved into the plane of the paper about the edge that is common to it and the preceding face.

Since the edges of the pyramid shown in Fig. 455 are all equal in length, it is necessary only to find the length of the one edge $A1$ by revolv-

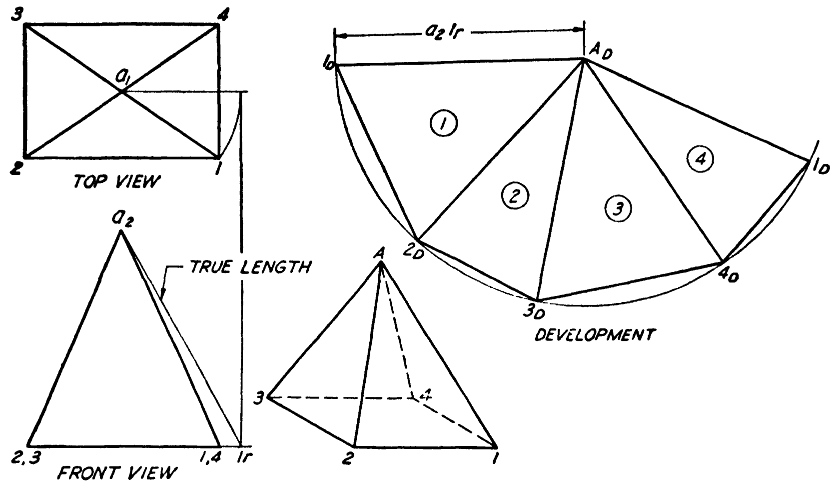


Fig. 455. The development of a rectangular right pyramid.

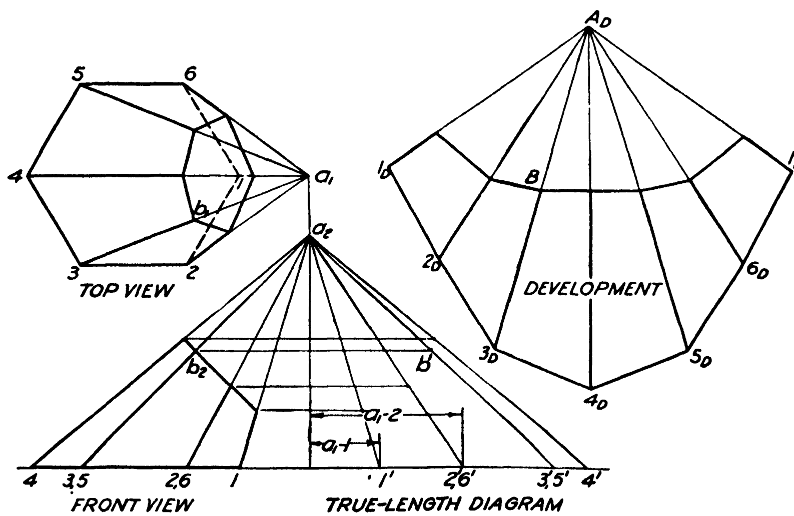


Fig. 456. Development of the frustum of a pyramid.

ing it into the position $a_2 1_r$. The edges of the base, 1-2, 2-3, and so on, are parallel to the horizontal plane of projection and consequently show in their true length in the top view.

316. To develop the surface of a frustum of a pyramid. To develop the lateral surface of the frustum of a pyramid (Fig. 456), it is necessary to determine the true lengths of edges of the complete pyramid as well as the true lengths of edges of the frustrum. The desired development is obtained by first constructing the development of the complete pyramid and then laying off the true lengths of the edges of the frustrum on the corresponding lines of the development. It may be noted with interest that the true length of the edge $B3$ is equal to the length $b'3'$ on the true-length line a_23', and that the location of point b' can be established by the short-cut method of projecting horizontally from point b_2. Point b' on a_23' is the true revolved position of point B, because the path of point B is in a horizontal plane which projects as a line in the front view.

317. To develop a right cone. As previously explained in Sec. 307, the development of a regular right circular cone is a sector of a circle.

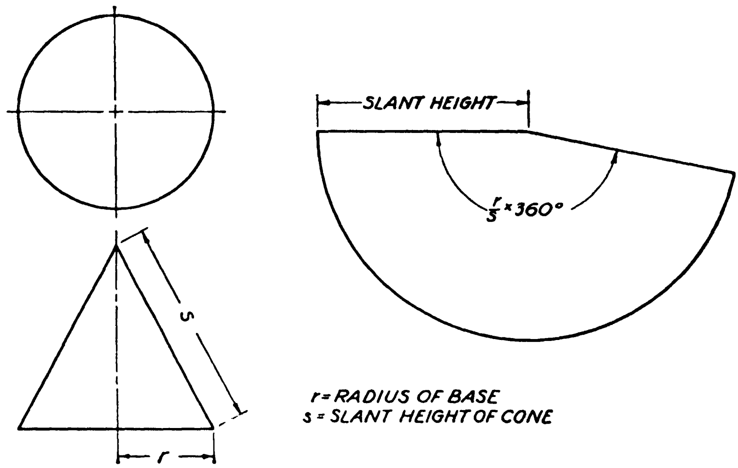


Fig. 457. Development of a right cone.

The development will have a radius equal to the slant height of the cone and an included angle at the center equal to $\frac{r}{s} \times 360°$ (Fig. 457). In this equation, r is the radius of the base and s is the slant height.

318. To develop a right truncated cone. The development of a right truncated cone must be constructed by a modified method of triangulation, in order to develop the outline of the elliptical inclined surface. This commonly used method is based upon the theoretical assumption that a cone is a pyramid having an infinite number of sides. The development of the incomplete right cone shown in Fig. 458 is constructed upon a layout of the whole cone by a method s milar to the standard method illustrated for the frustrum of a pyramid in Fig. 456.

Elements are drawn on the surface of the cone to serve as edges of the many-sided pyramid. Either twelve or twenty-four are used, depending upon the size of the cone. Their location is established upon the developed sector by dividing the arc representing the unrolled base into the same number of equal divisions, into which the top view of the base has been divided. At this point in the procedure, it is necessary to determine the true lengths of the elements of the frustrum in the same manner that the true lengths of the edges of the frustum of a pyramid were obtained in Fig. 456. With this information, the desired development can be completed by setting off the true lengths on the corresponding lines of the development and joining the points thus obtained with a smooth curve.

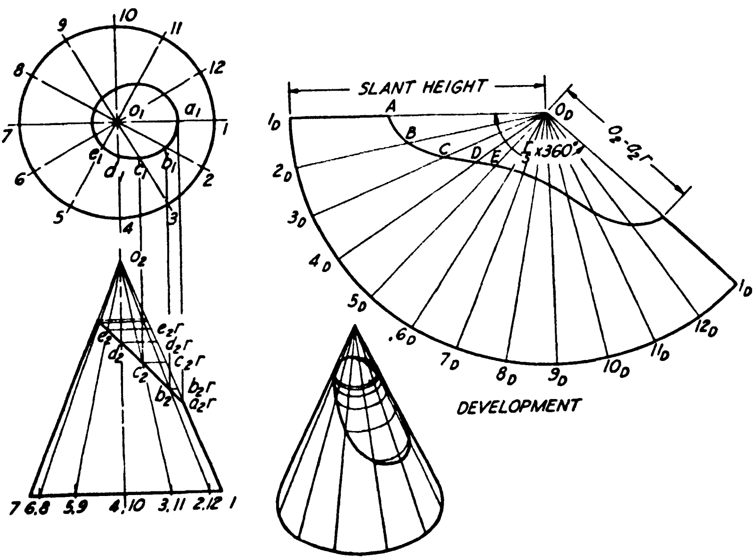


Fig. 458. Development of a truncated cone.

319. The triangulation method of developing approximately developable surfaces. A nondevelopable surface may be developed approximately if the surface is assumed to be composed of a number of small developable surfaces. The particular method ordinarily used for warped surfaces and the surfaces of oblique cones is known as the triangulation method. The procedure consists of completely covering the lateral surface with numerous small triangles which will lie approximately on the surface. These triangles, when laid out in their true size with their common edges joined, produce an approximate development which is nearly enough accurate for most practical purposes.

320. To develop an oblique cone using the triangulation method. A development of the lateral surface of an oblique cone is constructed by a method similar to that used for an oblique pyramid. The surface is divided into a number of unequal triangles having sides which are elements on the cone and bases which are the chords of short arcs of the base.

The first step in developing an oblique cone (Fig. 459) is to divide the circle representing the base into a convenient number of equal parts and draw elements on the surface of the cone through the division points (1, 2, 3, 4, 5, and so on). To construct the triangles forming the development, it is necessary to know the true lengths of the elements (sides of the triangles) and chords. In the illustration, all the chords are equal. Their true lengths are shown in the top view.

Since the seam should be made along the shortest element, *A*1 will lie on the selected starting line for the development and *A*7 will be on the center line. To obtain the development, the triangles are constructed in order, starting with the triangle *A*-1-2 and proceeding around the cone in a clockwise direction (as shown by the arrow in the top view).

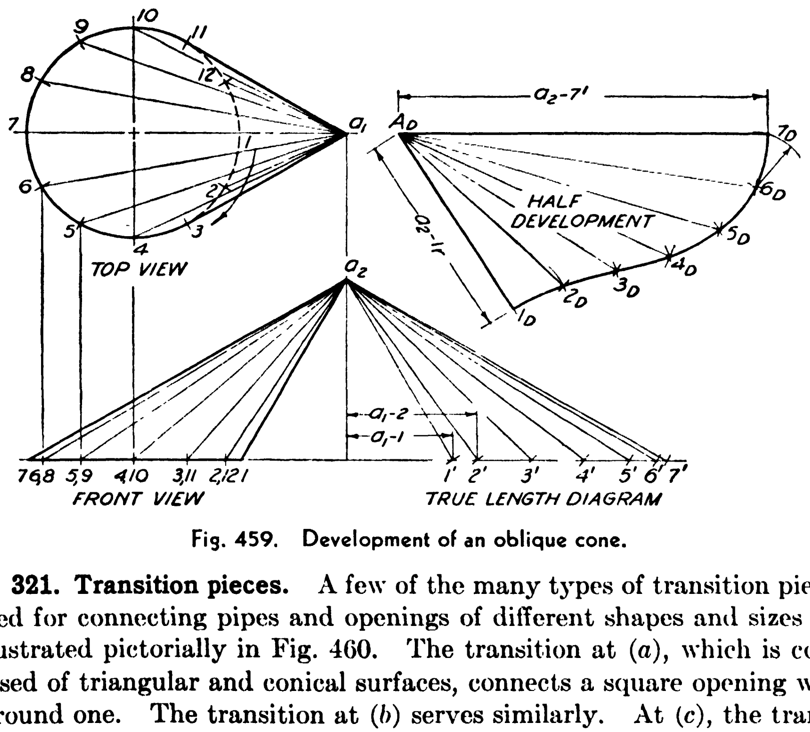


Fig. 459. Development of an oblique cone.

321. Transition pieces. A few of the many types of transition pieces used for connecting pipes and openings of different shapes and sizes are illustrated pictorially in Fig. 460. The transition at (*a*), which is composed of triangular and conical surfaces, connects a square opening with a round one. The transition at (*b*) serves similarly. At (*c*), the transition piece is the frustum of a pyramid. The transition shown at (*d*) is formed of cylinders. The ones at (*e*) and (*f*) are special types which are not frequently encountered.

322. To develop a transition piece connecting a circular and a square pipe. A detailed analysis of the transition piece shown in Fig. 461 reveals the fact that it is composed of four isosceles triangles whose bases form the square base of the piece and four conical surfaces which are parts of oblique cones. It is not difficult to develop this type of transition piece, because, since the whole surface may be "broken up" into component surfaces, the development may be constructed by developing

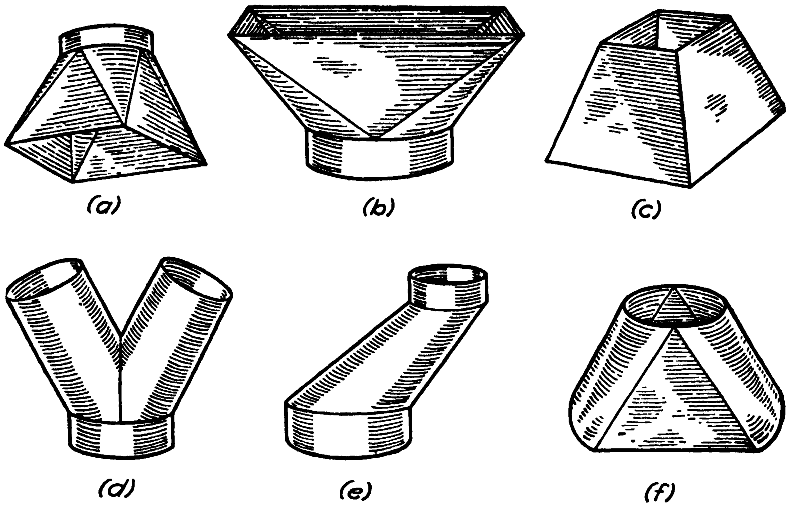


Fig. 460. Transition pieces.

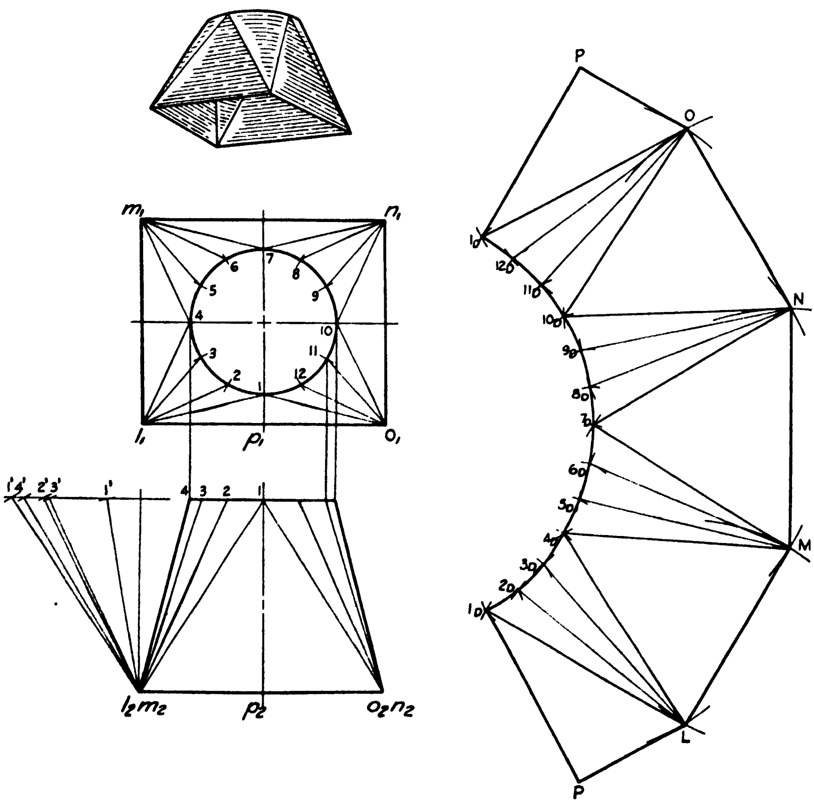


Fig. 461. Transition piece connecting a circular and square pipe.

the first and then each succeeding component surface separately. The surfaces are developed around the piece, in a clockwise direction, in such a manner that each successive surface is joined to the preceding surface at their common element. In the illustration, the triangles 1*LO*, 4*LM*, 7*MN*, and 10*NO* are clearly shown in top view. Two of these, 1*LO* and 10*NO*, are visible on the pictorial drawing. The apexes of the conical surfaces are located at the corners of the base.

Before starting the development, it is necessary to determine the true lengths of the elements by constructing a true-length diagram as explained in Sec. 314. The true lengths of the edges of the lower base (*LM*, *MN*, *NO*, and *OL*) and the true lengths of the chords (1-2, 2-3, 3-4, and so on) of the short arcs of the upper base are shown in the top view. The development is constructed in the following manner: First, the triangle 1_DPL is constructed, using the length p_1l_1, taken from the top view, and true lengths from the diagram. Next, using the method explained in Sec. 320, the conical surface whose apex is at *L* is developed in an attached position. Triangle 4_DLM is then added, and so on, until all component surfaces have been drawn.

Intersections

323. Lines of intersection of geometric surfaces. The line of intersection of two surfaces is a line that is common to both. It may be considered the line that would contain the points in which the elements of one surface would pierce the other. Almost every line on a practical orthographic representation is a line of intersection; therefore, the following discussion may be deemed an extended study of the same subject. The methods presented in this chapter are the recognized easy procedures for finding the more complicated lines of intersection created by intersecting geometric surfaces.

Commercial draftsmen, in order to complete a view of a working drawing or a view necessary for developing the surfaces of intersecting geometric shapes, frequently must find the line of intersection between surfaces. On an ordinary working drawing, the line of intersection may be "faked in" through a few critical points. On a sheet-metal drawing, however, a sufficient number of points must be located to obtain an accurate line of intersection and an ultimately accurate development.

The line of intersection of two surfaces is found by determining a number of points common to both surfaces and drawing a line or lines through these points in correct order. The resulting line of intersection may be straight, curved, or straight and curved. The problem of finding such a line may be solved by one of two general methods, depending upon the type of surfaces involved.

324. To find the intersection of two prisms. In Fig. 462 (see pictorial), points *A*, *B*, *C*, and *D*, through which the edges of the horizontal prism pierce the faces of the triangular prism, are the critical points or vertices of the closed intersection. The location of these piercing points may be found in the top view by inspection. Then they may be projected to the front view, to establish their location there. For example, the top view shows that the front edge of the horizontal prism pierces the near face of the vertical triangular prism at point a_1. Point a_1, projected downward to the line representing that edge in the front view, locates point a_2 in the front view. After the piercing points B, C, and D have been found and projected to the front view in a similar manner, the inter-

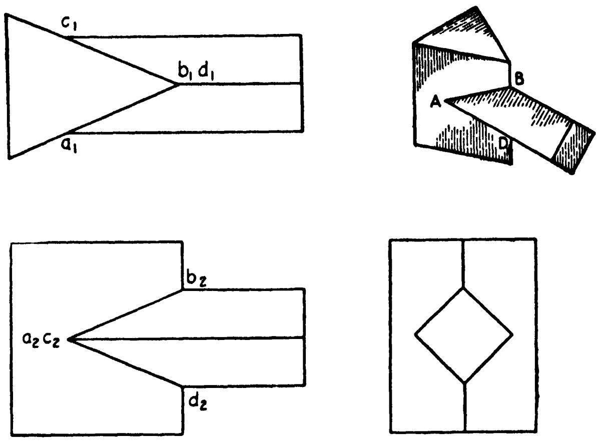


Fig. 462. Intersecting prisms.

section is completed by joining, in order, the projected points a_2, b_2, c_2, and d_2 with straight lines.

325. To establish the location of the piercing point of an edge intersecting an inclined surface. In Fig. 463, points A, C, and D, through which the edges of the horizontal prism pierce the vertical prism, are first found in the top view and are then projected downward to the corresponding edges in the front view. The reason that point B, through which the edge of the vertical prism pierces the near face of the triangular prism, cannot be found in this manner is that the side view from which it could be projected to the front view is not shown. Its location, however, can be established in the front view without even drawing a partial side view, if some scheme like the one illustrated in the pictorial drawing is used. In this scheme, the intersection line AB, whose direction is shown in the top view as line a_1b_1, is extended on the triangular face to point X on the top edge. Point X is then projected to the corresponding edge in the front view and a light construction line is drawn between the points a_2 and X. Since point B is located on line AX (see pictorial) at the point where the edge of the prism pierces the line, its location in the front view is at point b_2 where the edge cuts the line a_2X.

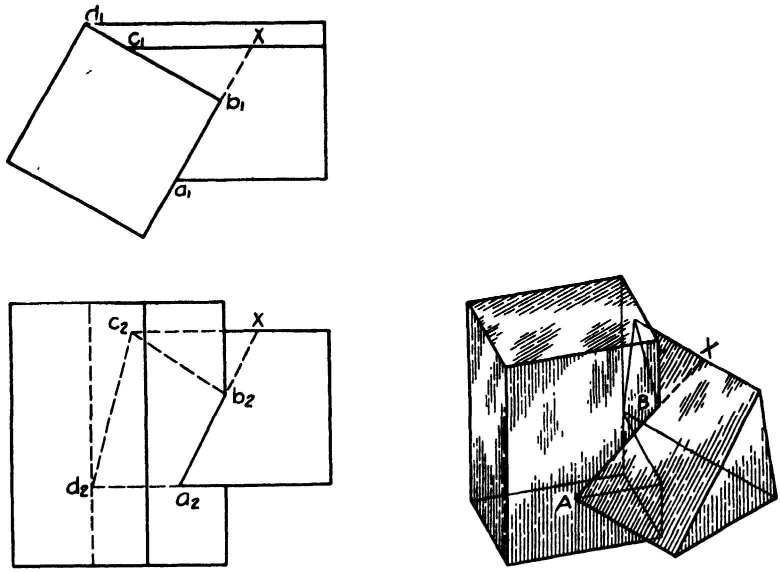


Fig. 463. Intersecting prisms.

326. To find the intersection of a pyramid and a prism. The intersection of a right pyramid and a prism (see Fig. 464) may be found by the same general method used for finding the intersection of two prisms (see Sec. 324).

327. To find the intersection of two cylinders. If a series of elements are drawn on the surface of the small horizontal cylinder, as in

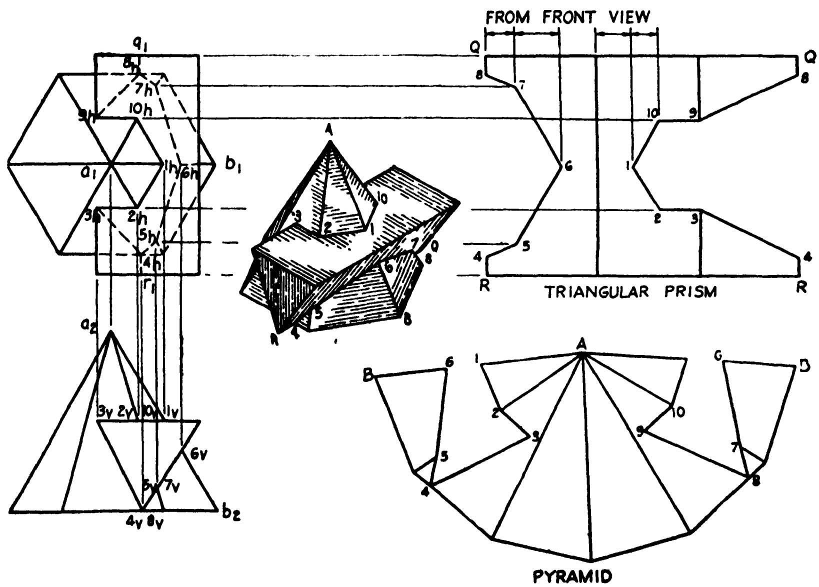


Fig. 464. Intersecting pyramid and prism.

Fig. 465, the points *A*, *B*, *C*, and *D* in which they intersect the vertical cylinder will be points on the line of intersection (see pictorial). These points, which are shown as a_1, b_1, c_1, and d_1 in the top view, may be located in the front view by projecting them downward to the corresponding elements in the front view where they are shown as points a_2, b_2, c_2, and

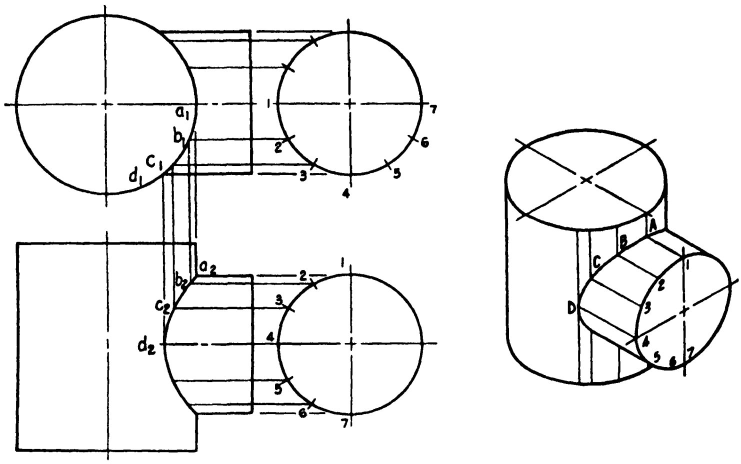


Fig. 465. Intersecting cylinders.

d_2. The desired intersection is represented by a smooth curve drawn through these points.

328. To find the intersection of two cylinders oblique to each other. The first step in finding the line of intersection of two cylinders which are oblique to each other (see Fig. 466) is to draw a revolved right section of the oblique cylinder directly on the front view of that cylinder. If the circumference of the right section then is divided into a number of equal divisions (say six) and elements are drawn through the division points, the points *A*, *B*, *C*, and *D* in which the elements intersect the surface of the vertical cylinder will be points on the line of intersection (see pictorial). In the case of the above illustration, these points are found first in the top view and then are projected downward to the corresponding elements in the front view. The line of intersection in the front view is represented by a smooth curve drawn through these points.

329. To find the intersection of a cylinder and a cone. The intersection of a cylinder and a cone may be found by assuming a number of elements upon the surface of the cone. The points at which these elements cut the cylinder are on the line of intersection (see pictorial drawings in Figs. 467 and 468). In selecting the elements, it is the usual practice to divide the circumference of the base into a number of equal parts and draw elements through the division points. However, to

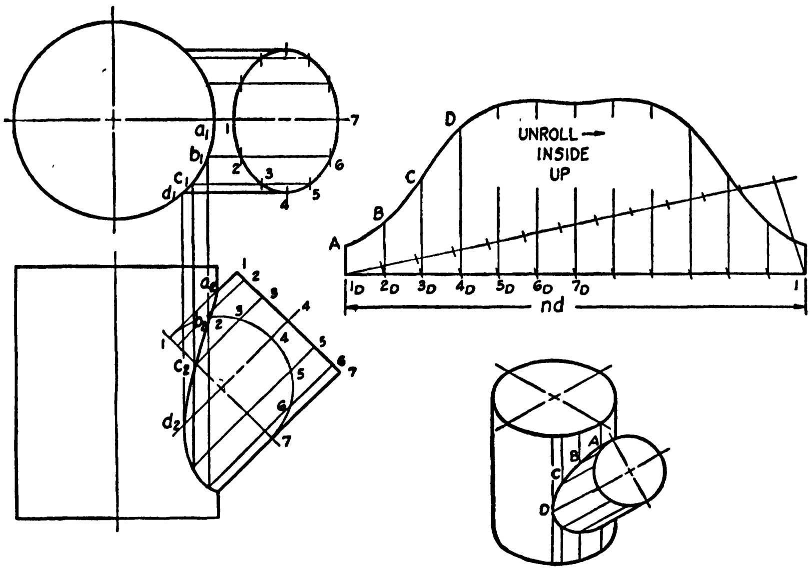


Fig. 466. Intersecting cylinders.

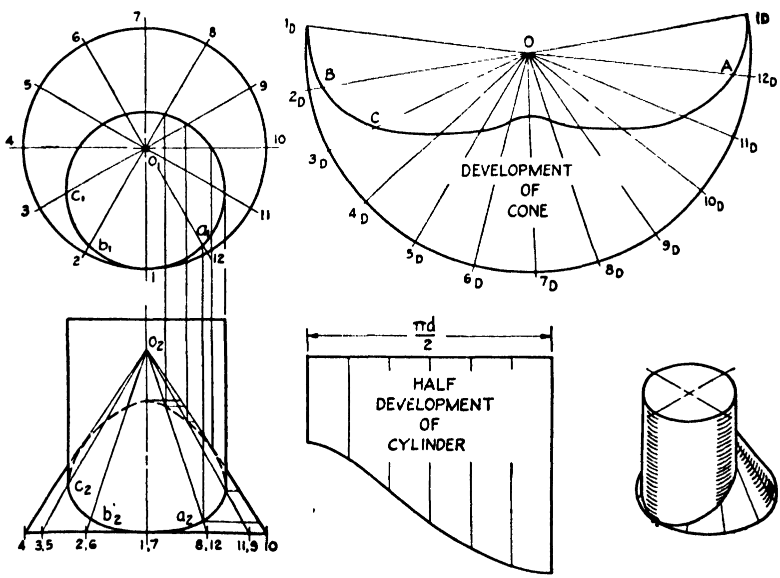


Fig. 467. Intersecting cylinder and cone.

obtain needed points at locations where the intersection line will change suddenly in curvature, there should be additional elements.

In Fig. 467, the points at which the elements pierce the cylinder are first found in the top view and are then projected to the corresponding elements in the front view. A smooth curve through these points forms the figure of the intersection.

In Fig. 468, the intersection points are first found in the side view.

An alternate method for finding the line of intersection of a cylinder and a right cone is illustrated in Fig. 469. Here horizontal cutting planes are passed through both geometrical shapes in the region of their line of intersection. In each cutting plane, the circle cut on the surface of the

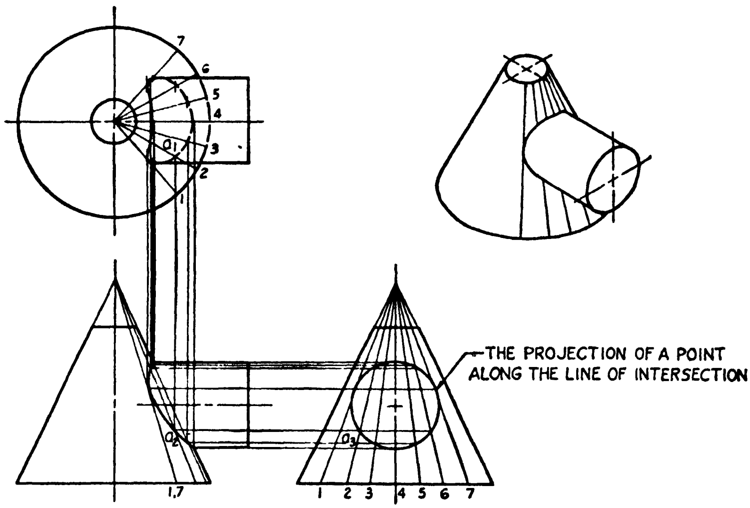


Fig. 468. Intersecting cylinder and cone.

cone will intersect elements cut on the cylinder at two points common to both surfaces (see pictorial). A curved line traced through a number of such points in different planes is a line common to both surfaces and is therefore the line of intersection.

330. To find the intersection of a prism and a cone. The complete line of intersection may be found by drawing elements on the surface of the cone (see Fig. 470) to locate points on the intersection as explained in Sec. 329. To obtain an accurate curve, however, some thought must be given to the placing of these elements. For instance, although most of the elements may be equally spaced on the cone to facilitate the construction of its development, additional ones should be drawn through the critical points and in regions where the line of intersection changes sharply in curvature. The elements are drawn on the view that will reveal points on the intersection; then, the determined points are projected to the corresponding elements in the other view or views. In this particular illustration a part of the line of intersection in the top view is a portion of the arc of a circle that would be cut by a horizontal plane containing the bottom surface of the prism.

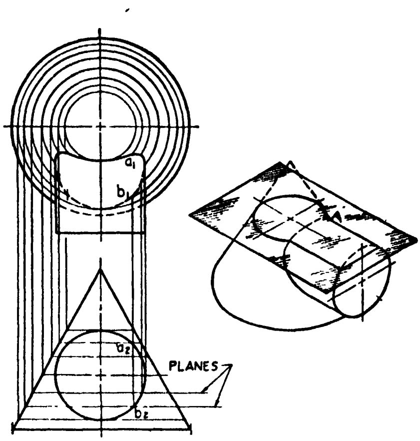


Fig. 469. Intersecting cylinder and cone.

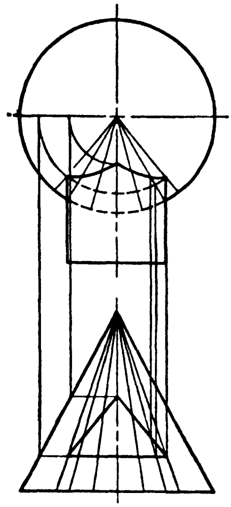


Fig. 470. Intersecting cone and prism.

331. Problems. The problems of this chapter have been designed to offer an opportunity to apply the principles of intersections and developments and to provide further drill in projection.

1. (Fig. 471.) Develop the lateral surface of one or more of the prisms as assigned.

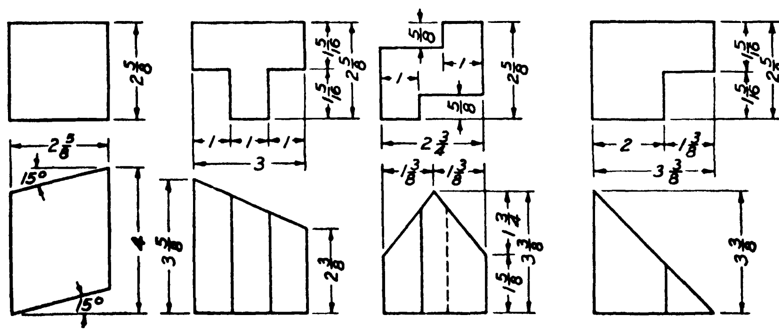


Fig. 471. Prisms.

2. (Fig. 472.) Develop the lateral surface of one or more of the pyramids as assigned. Make construction lines light. Show construction for finding the true lengths of the lines.

3. (Fig. 473.) Develop the lateral surface of one or more of the pyramids as assigned. With 6*H* pencil, show the construction for finding the true lengths of the lines.

4. (Fig. 474.) Develop the lateral surface of one or more of the cylinders as assigned. Use a 6*H* pencil for construction lines and make them light.

5. (Fig. 475.) Develop the lateral surface of one or more of the cones as assigned. Show all construction. Use a 6*H* pencil for construction lines and

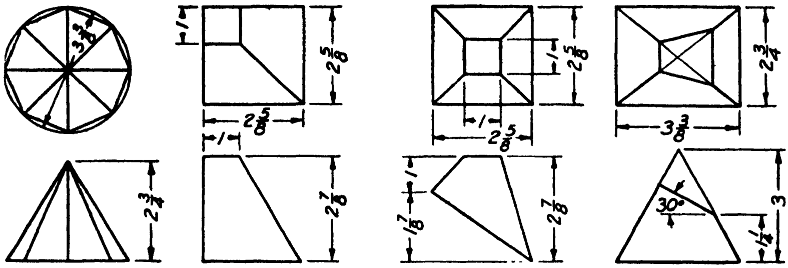


Fig. 472. Pyramids.

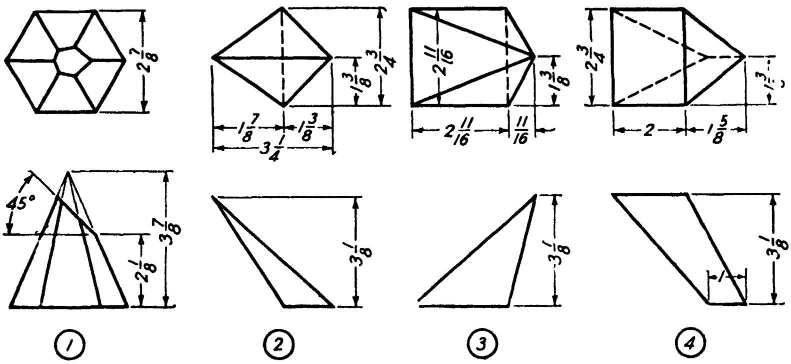


Fig. 473. Pyramids.

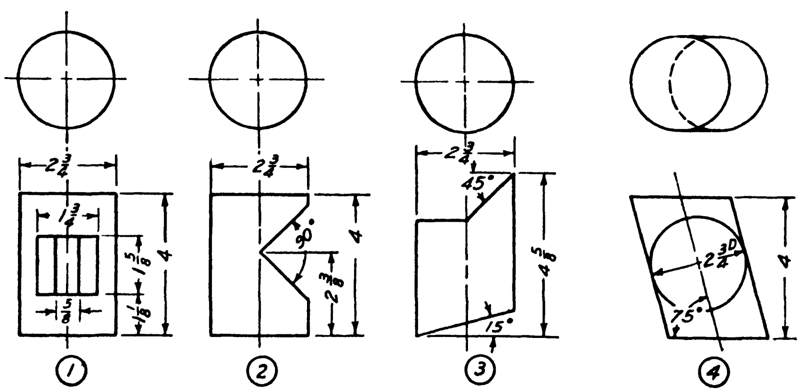


Fig. 474. Cylinders.

make them light. In each case start with the shortest element and unroll, inside up. It is suggested that 12 elements be used, in order to secure a reasonably accurate development.

6. (Fig. 476.) Develop the lateral surface of one or more of the transition pieces as assigned. Show all construction lines in light sharp 6*H* pencil lines. Use a sufficient number of elements on the curved surfaces to assure an accurate development.

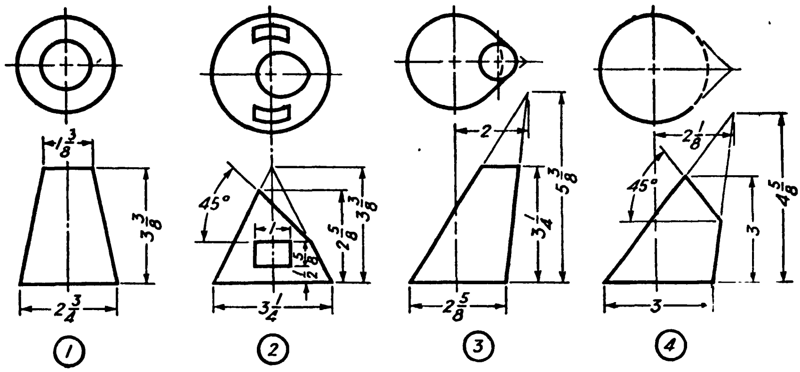


Fig. 475. Cones.

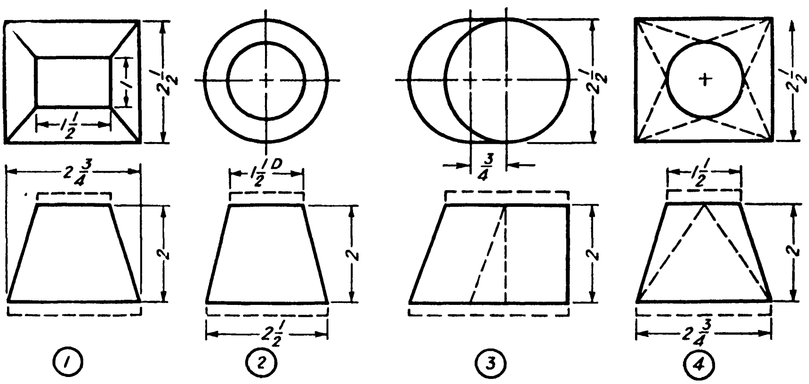


Fig. 476. Transition pieces.

7. (Fig. 477.) Develop the sheet-metal connections. On pieces 3 and 4, use a sufficient number of elements to obtain a smooth curve and an accurate development.

8. (Fig. 478.) Draw the line of intersection of the intersecting geometrical shapes as assigned. Show the invisible portions of the lines of intersection as well as the visible. Consider that the interior is open.

9 and **10.** (Figs. 479 and 480.) Draw the line of intersection of the intersecting geometrical shapes as assigned. It is suggested that the elements that are used to find points along the intersection be spaced 15 degrees apart. Do not erase the construction lines. One shape does not pass through the other.

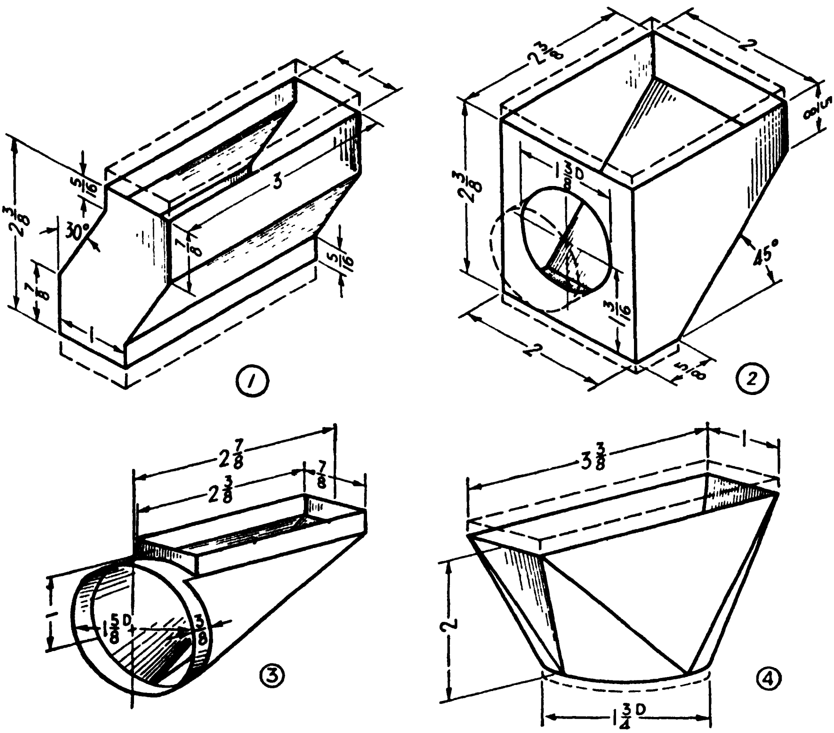


Fig. 477. Sheet-metal connections (transitions).

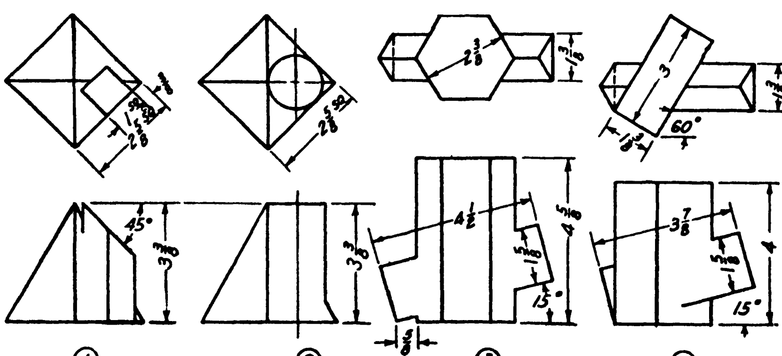


Fig. 478. Intersecting prisms.

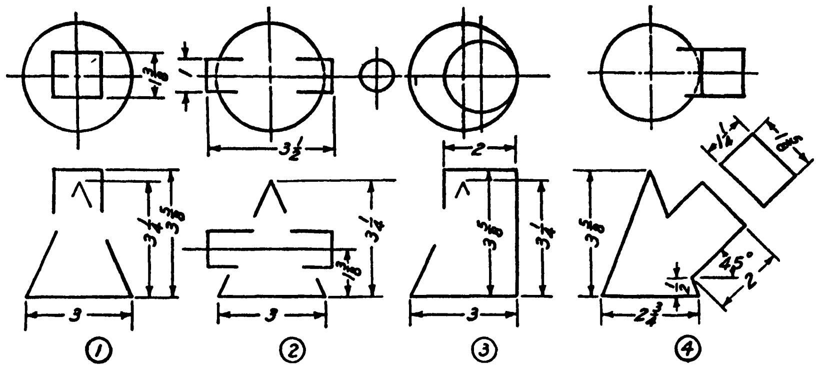


Fig. 479. Intersecting surfaces.

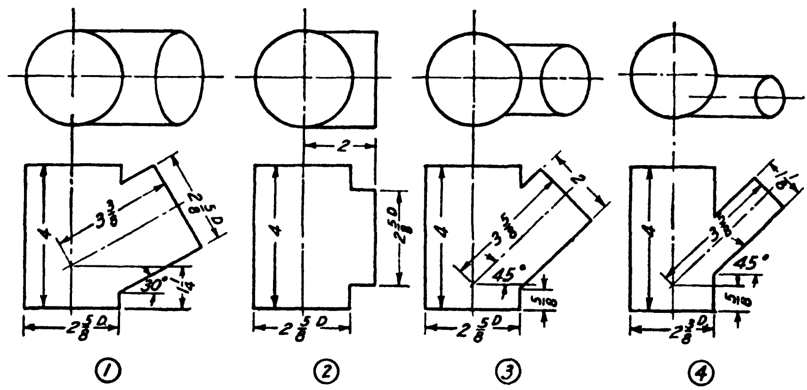


Fig. 480. Intersecting cylinders.

20

MAP DRAFTING

332. Map drawing. A map is a drawing which represents a portion of the earth's surface area. Since it usually represents a relatively small part, and the third dimension (the height) is not shown except in some cases by contour lines, a map may be thought of as a one-view orthographic projection (Figs 481 and 483). Various forms of

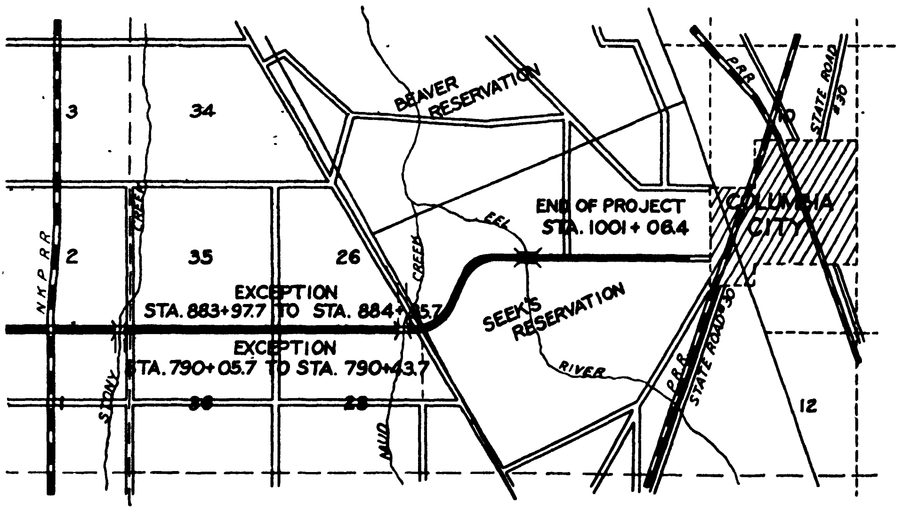


Fig. 481. A section from an engineering map.

maps have been devised to satisfy different requirements. Land maps, plats, and so on, which fulfill their purpose by revealing only the natural and man-made features along with imaginary division lines and geometrical measurements, show only two dimensions. Others, such as topographical maps, show three dimensions, by representing height by means of contours.

333. Topographic maps. Topographic maps, although they are drawn to a relatively small scale, contain much detail. All natural features, such as lakes, streams, forests, fields, mines, and so on, and important permanent man-made creations, such as buildings, bridges, and houses, may be represented if necessary to fulfill the purpose of a map. Topographic maps, prepared by the United States Geological survey to a

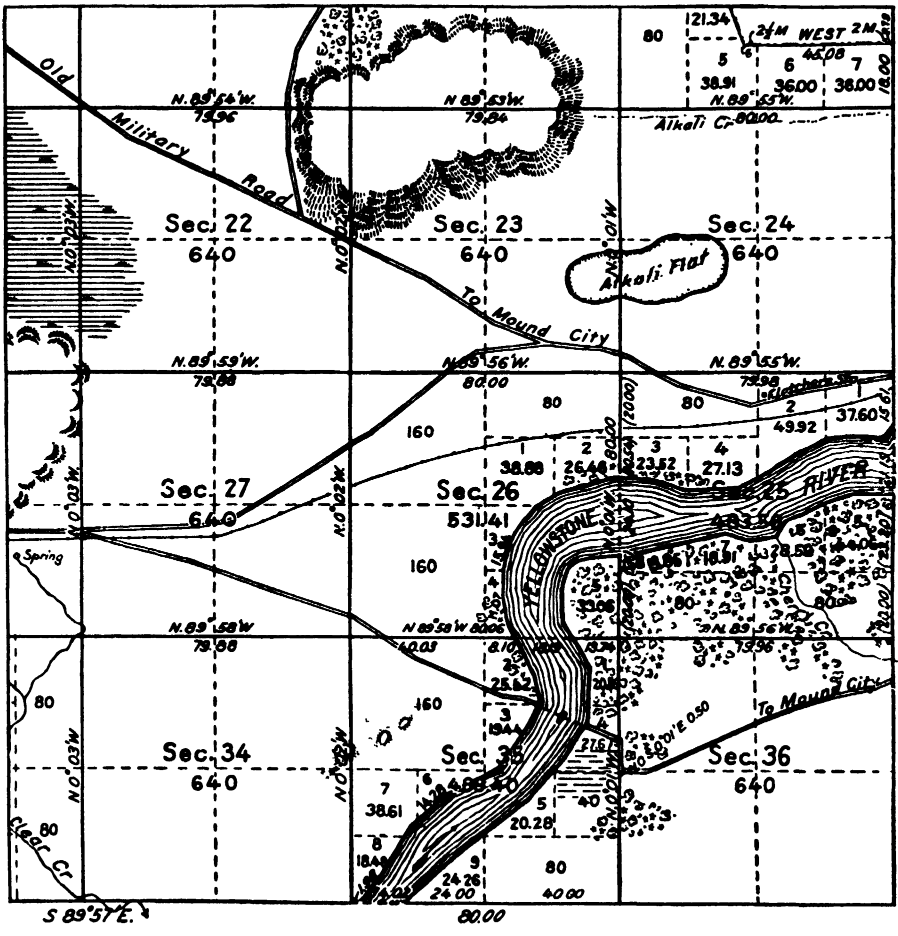


Fig. 482. A topographic map.*

scale of approximately one inch to a mile $\left(\frac{1}{62,500}\right)$, naturally do not contain very much detail. The form of the surface of the ground is represented by contour lines. Any one contour line passes through points of the same elevation and closes either on the map or beyond its limits. Closed contour lines represent either a hill or a depression. Fig. 482 shows a topographic map.

* A portion of a topographic map taken from a manual prepared by the U.S. Department of the Interior—1930.

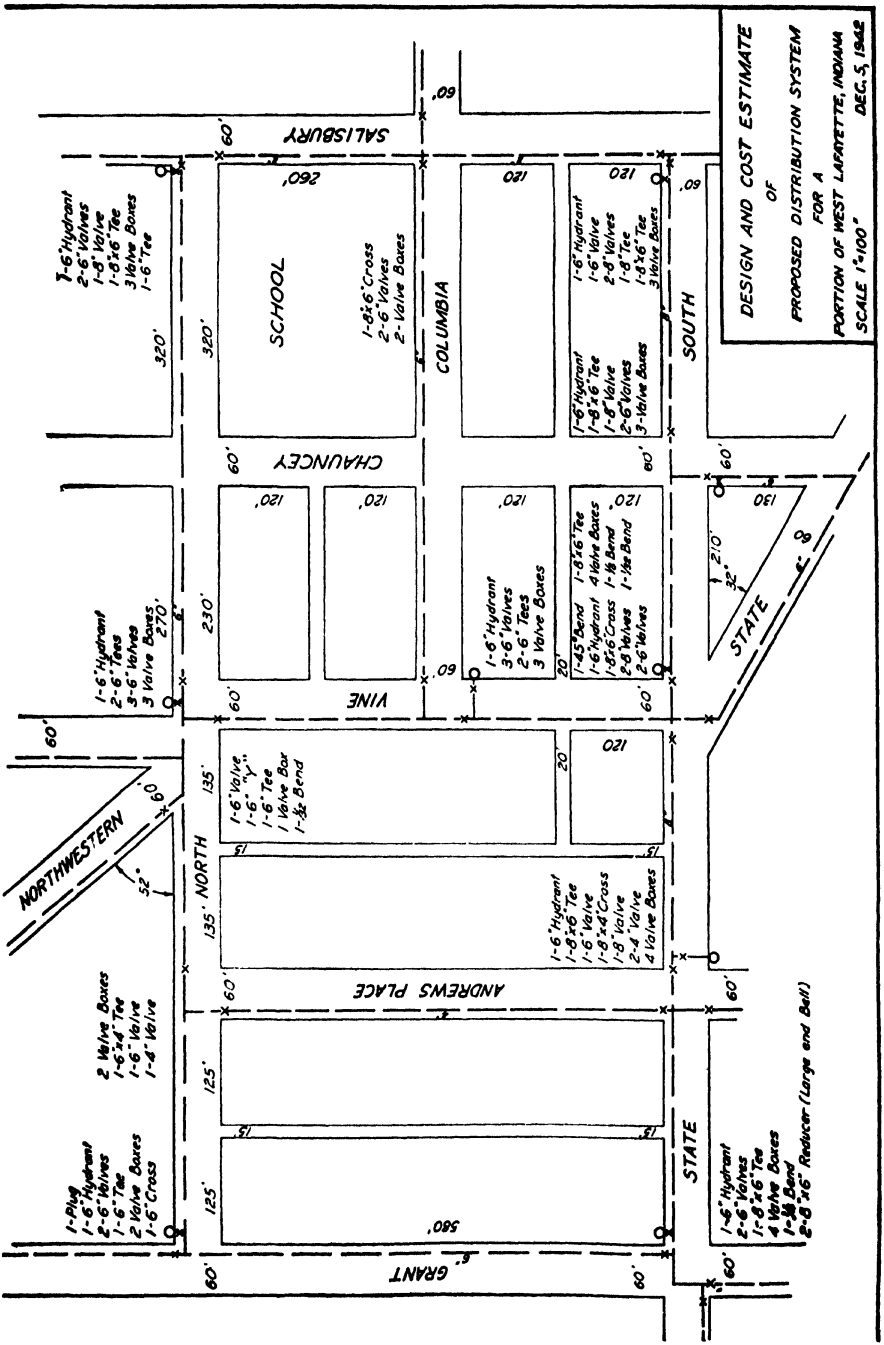


Fig. 483. A plat or partial city map showing the proposed location of water mains and fire hydrants.

334. Engineering maps. Working maps prepared for engineering projects are known as engineering maps. They may be drawn for either reconnaissance or construction purposes. They usually are made to a large scale, and accurately show the location of all property lines and important features. On maps of a topographic nature, practically all natural and man-made features along a right-of-way or on a site are shown, and the form of the surface of the ground is indicated by means of contours.

335. Plats of land surveys. A plat of a tract of land should contain a complete description of the land surveyed. It should show the lengths and bearings of the bounding sides and division lines, the included acreages, the locations of the monuments, and the names of the owners of the adjoining properties.

336. Subdivision plats. A plat of a real-estate development should show the measurements and angles of the survey of the whole tract of land, the size of the included lots, the widths of the streets and drives, and the location of all monuments. Plats of subdivisions must be complete and accurate, since they are filed as a public record in the county recorder's office.

337. Topographic drawing. As previously stated, a topographic map is a reproduction, to scale, of a small area. On a complete topographic map, the natural and artificial features are represented by recognized conventional symbols and the form of the ground is shown by contours.

338. Standard topographic symbols (U.S.G.S.). Conventional symbols used by the United States Geological Survey for representing the works and structures of man are shown in Fig. 484. Symbols for natural land formations, water features, and vegetation growths, both natural and cultivated, are shown in Figs. 485 to 487.

339. The drawing of symbols. Topographic symbols are drawn either freehand or mechanically, depending upon the character of the features to be represented. For example, the symbols representing natural features are drawn freehand, while those representing artificial works are drawn mechanically. (See Figs. 484 to 487.)

The beginner should study carefully the symbols as given in the various illustrations, so as not to miss some of the essential points in their construction.

340. The drawing of water lines. Water lining, used to indicate water surfaces, is done entirely freehand with an ordinary lettering pen. The starting line (shore line) should be fairly heavy, and each successive line should decrease in width until the center of the body of water is reached. (Fig. 486.) The line next to the shore line should be drawn parallel to it throughout its entire length, and the space between should be equal to the width of the shore line. The spacing between succeeding lines should increase gradually to the center, but the change should be

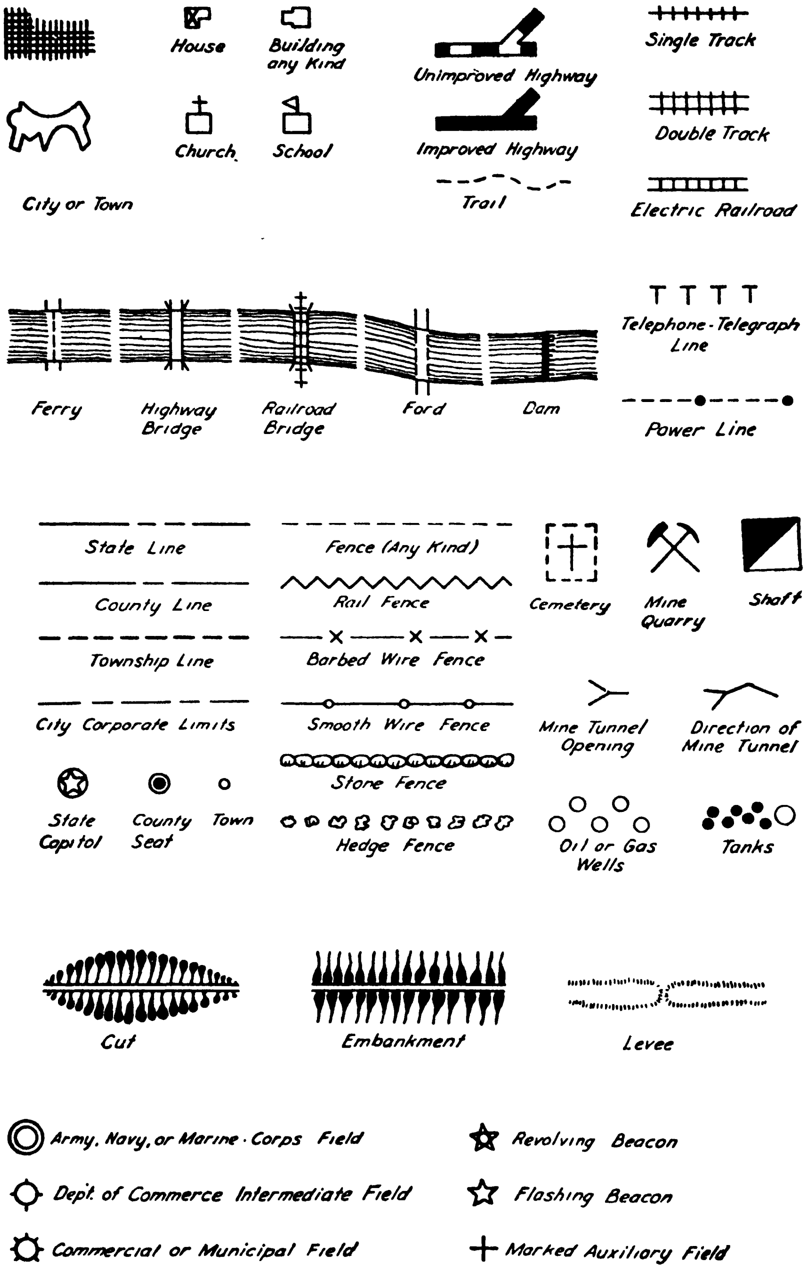


Fig. 484. Standard symbols for works and structures.

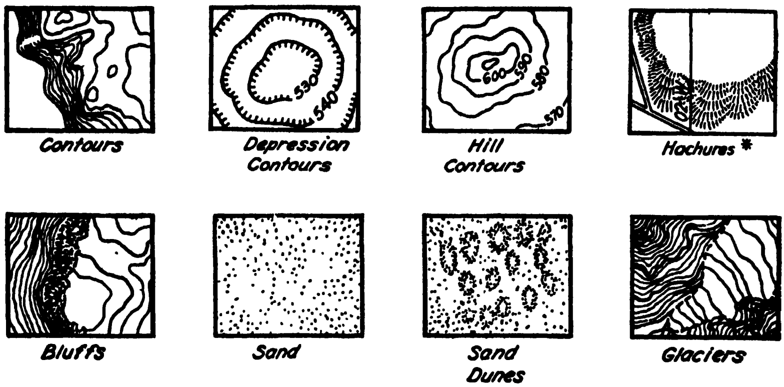


Fig. 485. Relief (natural land formations).

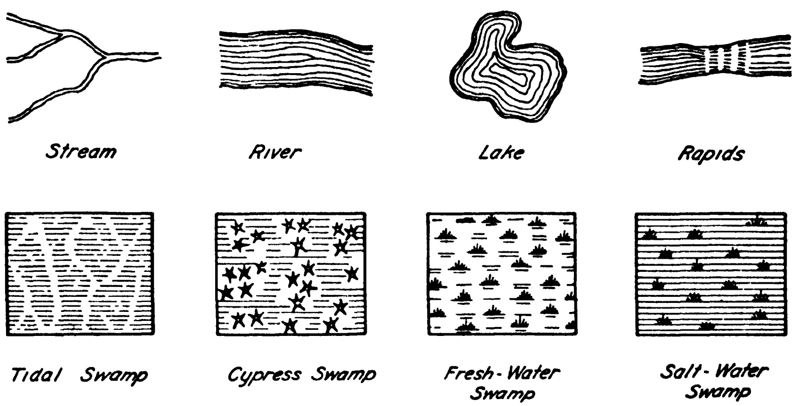


Fig. 486. Hydrographic symbols.

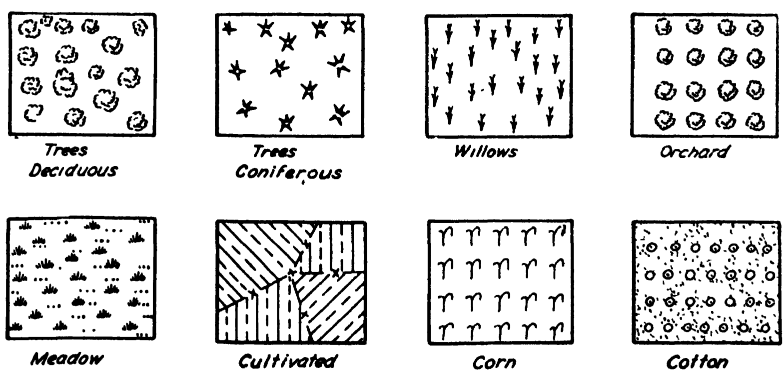


Fig. 487. Vegetation symbols.

* From topographic map shown in Fig. 482.

so slight that no marked increase will be noticeable. Each added line should show fewer of the small irregularities of the shore line, the last few following only the prominent ones.

341. Contour lines. A contour line is a line through points of the same elevation on the surface of the ground. Theoretically, the contour lines on a map may be thought of as the lines of intersection of a series of

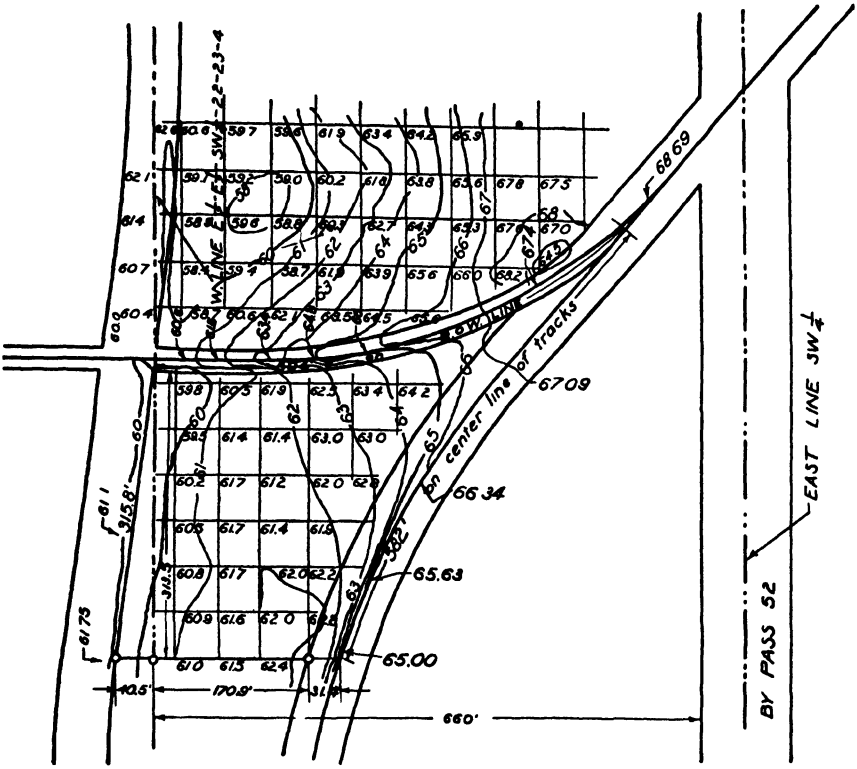


Fig. 488. A contour map of a small area.

horizontal planes and the ground surface. In practice, the imaginary planes are equally spaced vertically so that the contour intervals will be equal and the horizontal distances between contours on a map will indicate the steepness of the rise or descent of the surface. The closer they are together, the greater the slope, and conversely, the farther they are apart, the less the slope. An arrangement of contour lines that close indicates either a hill or a depression. The case, whatever it is, usually can be determined by reading the values of the elevations of the contours. Usually, each fifth contour is drawn heavier than the others and has a break in it where its elevation above a datum plane is recorded. If a U.S.G.S. bench mark is used, the datum plane will be at mean sea level.

Fig. 488 illustrates the use of contour lines on a map of a small area.

21

STRUCTURAL DRAFTING

342. Although structural drawings are prepared in accordance with the general principles of projection, they differ somewhat from machine drawings in certain practices. These differences have developed from methods of fabrication.

Steel structures are built of rolled shapes and plates permanently riveted or welded together. Small trusses may be riveted in the shops, but members of large trusses are shipped separately for field erection.

Sections of the principal shapes (angles, I-beam, channels, wide flange sections, and plates) are shown in Fig. 489.

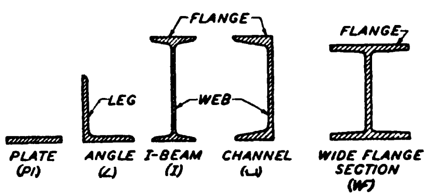


Fig. 489. Structural shapes.

The dimensions of the various standard shapes and other available information required by a structural detailer are given in structural steel handbooks published by different manufacturers and by the American Institute of Steel Construction.

343. Layouts. The first step in the development of structural steel detail drawings is the drawing of the layout sheets. These are intermediate drawings which are used only in the drafting room of the fabricating shop. Layouts are used for ordering material, obtaining early approval of details, and co-ordinating the work of the several draftsmen who may be employed on the project. Layouts of each joint of the structure are made to a scale larger than the detail drawing, to give the detailer further information concerning the design of the connection. They usually are made on bond paper that is thin enough to permit blueprinting. Layouts are not completely dimensioned, but the layout man may indicate any dimensions he wishes to be used.

344. Detail drawings. The making of the detail drawings is the final step in the process of creating structural steel working drawings. These drawings must be clear and concise, to enable men in the shops and field to do their portion of the work efficiently. To insure accuracy, a thorough check of all arrangements and dimensions is made in the drafting room by a checker.

Parts to be riveted together in the shop are detailed in their assembled positions in the structure, instead of being detailed individually, as is the practice for machine work. Fig. 490 is a detail drawing of a cross frame. It describes each plate and main member and shows the relations of the various elements of the structure to one another. When the structure is too large to be completely assembled in the shop and shipped in one piece, an assembly diagram becomes necessary. This is merely a line diagram of the structure, with each piece mark shown so that the pieces may be put together in their proper positions.

The scales in general use are not large enough to permit direct scaling of dimensions. One of the scales most commonly used in structural work is: $\frac{3}{4}'' = 1'$. Often structural members are too long to be drawn to scale. In this event, the transverse dimensions and the details are drawn to one scale and the longitudinal dimensions are shortened or drawn to a smaller scale.

In all structural work the view of the structure which corresponds to the front view in a machine drawing is termed the *elevation* of the structure. That view which corresponds to the top view in a machine drawing is called the *plan view* of the structure.

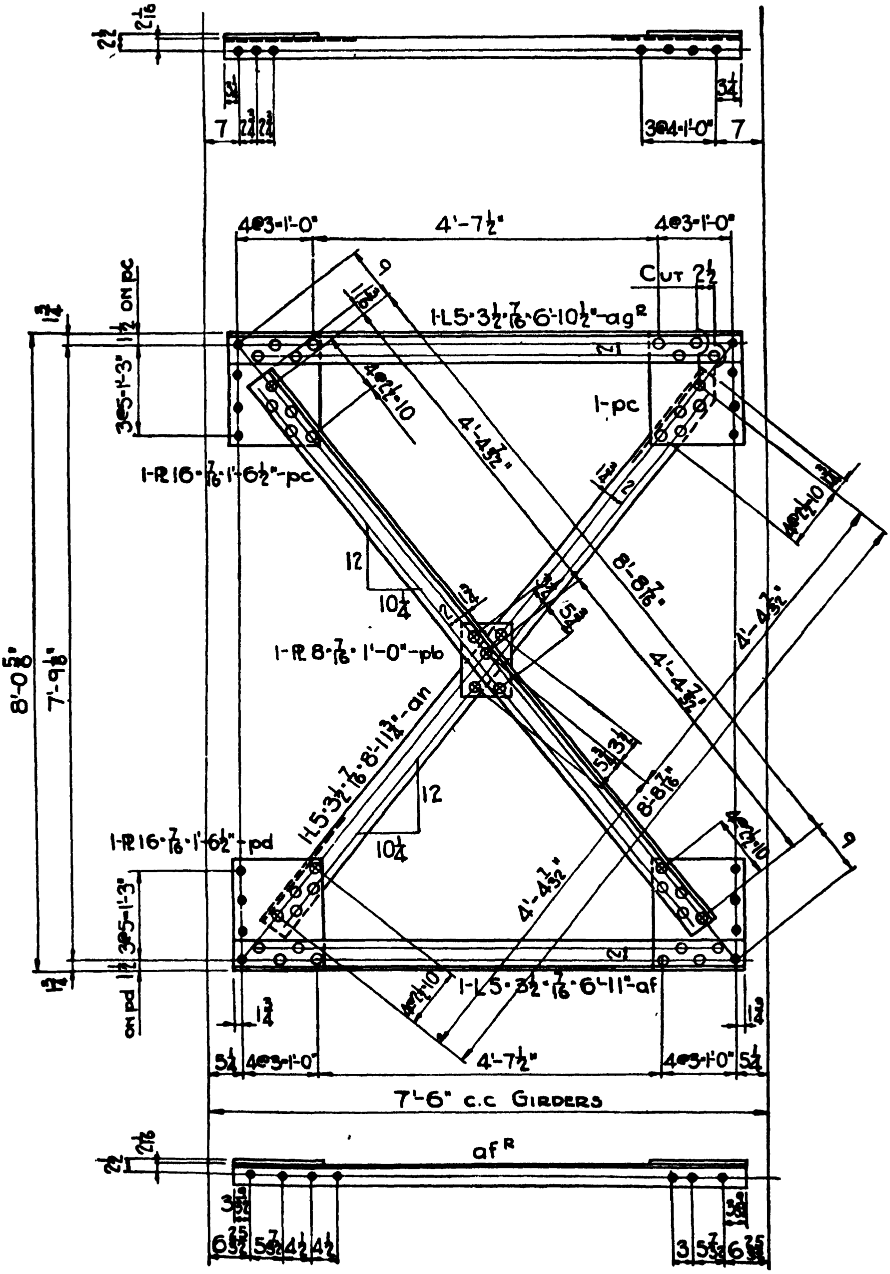
Angular dimensions on structural drawings are shown as slopes which are expressed in inches per foot. A slope triangle is a right triangle constructed with its hypotenuse on the gage or working line whose slope is to be shown. The longer of the two legs is always given as twelve inches, and the length of the shorter leg determines the slope. These slope triangles are not drawn to scale but are constructed any convenient size (Fig. 490).

345. Structural notations.

′ = foot or feet	∠ = angle
″ = inch or inches	I = I-beam
ϕ = diameter	⊔ = channel
# = pound or pounds	WF = wide flange section

346. Sizes of standard members. The following structural specifications and abbreviations are those adopted by the American Institute of Steel Construction.

Plates. Width (in inches) × thickness × length. (*Pl* 15 × $\frac{3}{8}$ × 1′-10″.) If it is a connection plate on a truss, cross frame, and so on, which is fabricated in the shop, the specification will be followed by the letters *pa*, *pb*, *pc*, or *pd*, and so on, which indicate the location of the plate. (*Pl* 15″ × $\frac{3}{8}$ × 1′-10″ *pa*.)



INTERNAL CROSS FRAME FOR
96'-0" DECK PLATE GIRDER
CHESAPEAKE & OHIO RAILWAY CO

Fig. 490. A detail drawing.

Angles—Equal legs. Size of leg × size of leg × thickness × length. (∠$3\frac{1}{2}$ × $3\frac{1}{2}$ × $\frac{3}{8}$ × 7′-6″.)

Angles—Unequal legs. Size of leg shown × size of outstanding leg

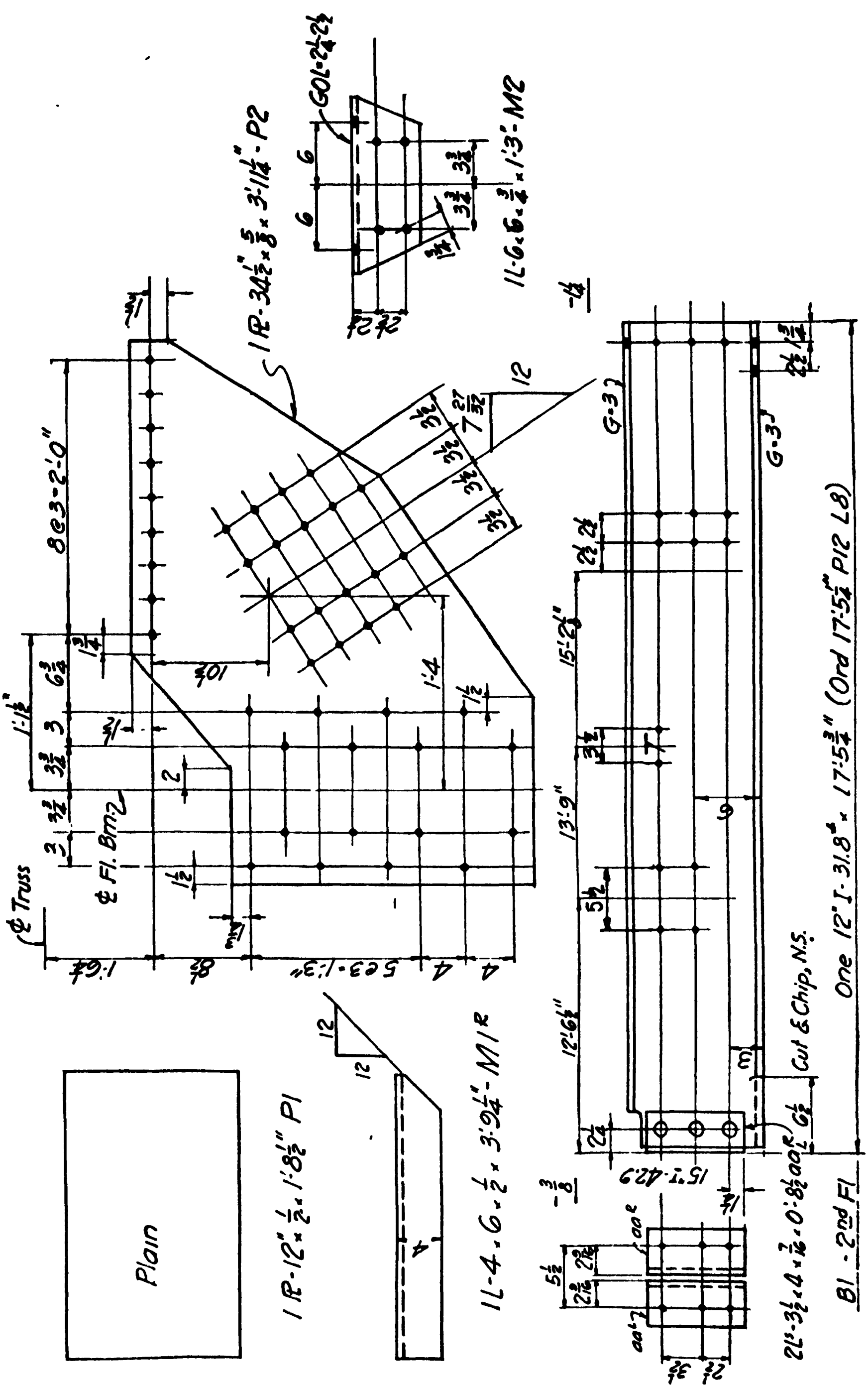


Fig. 492. Structural dimensioning.

over-all lengths are placed farther away so that extension lines will not cross dimension lines (Fig. 492).

Dimension figures are generally placed above continuous (unbroken) dimension lines, which are made narrow and black. These lines usually should be placed off the view, but oftentimes added clearness may be obtained by putting a few dimensions in an open area on the view itself. Dimension lines ordinarily should not be placed less than $\frac{3}{8}$ inch apart or closer to the view than $\frac{1}{2}$ inch. All of the above rules for the location of dimension lines may be modified to suit the available space (Fig. 492).

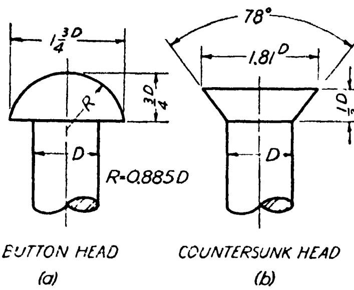


Fig. 493. Structural rivets.

349. Dimensions and notes in structural detailing.

1. Figures may be compressed without reducing their height in order to place them in a limited space between arrowheads.
2. Figures can be placed to one side, with a leader to the dimension line, if the available space is very small.
3. Figures and notes must read from the bottom and the right side of the sheet because shopmen are familiar with reading from these positions (Fig. 492).
4. For dimensions less than one foot, the inch marks (″) may be omitted (Fig. 492.)
5. With the exception of widths of plates and depths of sections, all dimensions of one foot or more are expressed in feet and inches (Fig. 492.)

Correct	*Incorrect*
$\frac{1}{4}$	$0\frac{1}{4}$
9	0′–9″
10	10″
1′–0″	12″
$2'\text{–}3\frac{1}{4}''$	$2'\text{–}03\frac{1}{4}''$
$4'\text{–}0\frac{1}{4}''$	$4'\frac{1}{4}''$

6. Usually, dimensions are given in multiples of $\frac{1}{8}$ inch or, preferably, $\frac{1}{4}$ inch. It is not desirable to use multiples of $\frac{1}{16}''$ or $\frac{1}{32}''$, except in rare cases.
7. Decimals found in tables should be converted into fractions to the nearest $\frac{1}{16}$ inch.
8. To avoid complications which arise when corrections are made, dimensions shown on one view should not be repeated on another.
9. Rivets and holes are located by dimensions from center to center (Fig. 492).
10. Edge distances are frequently omitted, unless they are necessary to insure clearances with connecting parts. (The shopmen understand that the distances on opposite edges are to be made equal.)
11. Dimensions *always* should be given to the center lines of I-beams and to the backs of angles and channels.
12. When three or more rivet spaces for a line of rivets are equal, they should be dimensioned as a group (4 @ 3″ = 1′–0″). Staggered rivets are dimensioned as if they were on one gage line (Fig. 492).

13. Since a workman must use a rule or tape to lay off angles, a slope triangle should be shown to give the inclination of a working line (Fig. 492).

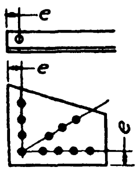
14. A man in the shop never should be compelled to add or subtract to obtain a necessary dimension.

15. A general note is usually placed on a detail drawing giving the edge distances, painting instructions, size of rivets, size of open holes, and so on.

16. Members that are shipped separately for field erection are given a shipping mark of a letter and number which appears on the drawing (Fig. 492).

17. The size of a member is indicated by a specification (in the form of a note) parallel to it (Fig. 492).

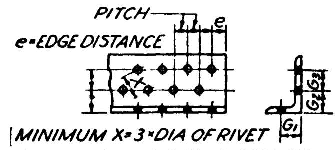
18. The width of a plate is always given in inches (Fig. 492).



DIA OF RIVET	EXTREME MINIMUM e	USUAL MINIMUM e	PREFERRED
3/8	9/16	3/4	3/4
1/2	3/4	1	1
5/8	15/16	1 1/8	1 1/4
3/4	1 1/8	1 1/4	1 1/2
7/8	1 5/16	1 1/2	1 3/4
1	1 1/2	1 3/4	2

EDGE DISTANCE "e"

Fig. 494. Edge distance "e."



LEG		8	7	6	5	4	3 1/2	3	2 1/2	2	1 3/4	1 1/2	1 3/8	1 1/4	1	3/4
GAGE	G1	4 1/2	4	3 1/2	3	2 1/2	2	1 3/4	1 3/8	1 1/8	1	7/8	7/8	3/4	5/8	1/2
	G2	3	2 1/2	2 1/2	2	—	—	—	-	—	—	—	—	—	—	—
	G3	3	3	2 1/4	1 3/4	—	—	—	—	—	—	—	—	—	—	—
MAX RIVET		1 1/8	1	1	1	1	7/8	7/8	3/4	5/8	1/2	3/8	3/8	3/8	1/4	1/4

Fig. 495. Gage distances.

350. Problem.

1. Using the dimensions given in a structural steel handbook make a drawing showing the shape of the 12″ I shown in Fig. 492. Use a scale of 3″ = 1.

2. Make a pencil layout of the lower left-hand joint of the cross-frame shown in Fig. 496. Make the width of the plate equal to a standard plate. The variation of plate widths is by inches. Read the instructions for Problem 4 and Art. 343.

3. Make a pencil layout of the upper right-hand joint of the cross-frame. Follow the instructions given for Problem 2.

4. Make a pencil drawing of the cross frame shown in Fig. 496. The following requirements must be observed:

Use 7/8″ rivets.
Use a minimum rivet pitch of 2 1/2″.
The elevation of the cross frame is the only view that is required.
Use standard gage and preferred edge distances as shown in Figs. 494 and 495.
Use Fig. 490 as a model for the placing of complete dimensions.
The open holes are spaced at 3 1/2″ pitch.

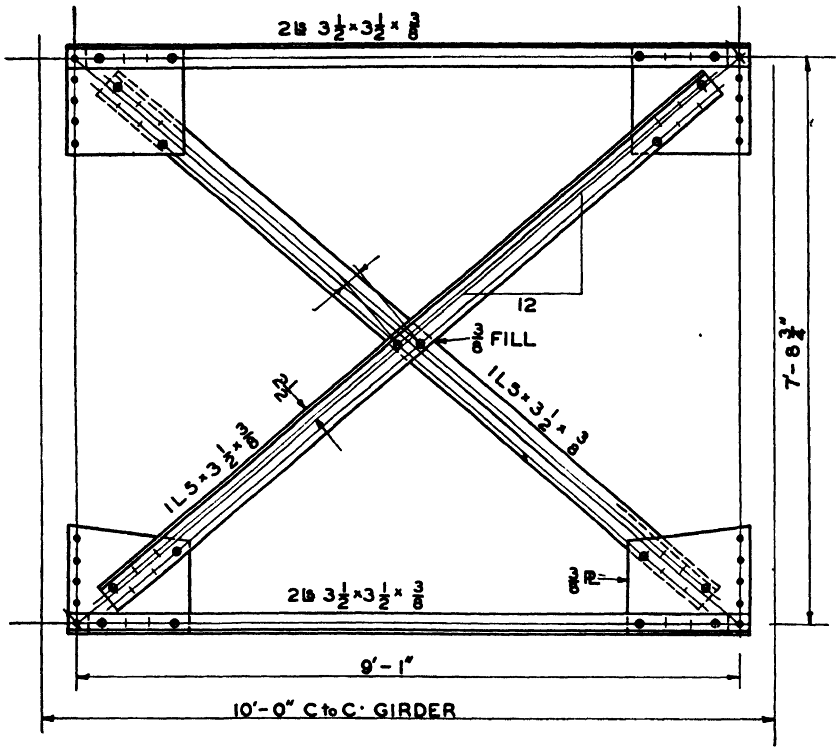


Fig. 496. Layout of interior cross-frame for 100-ft. railroad deck girder span.

22

ARCHITECTURAL DRAFTING

351. Introduction. The principles of architectural drafting are the same as those for other technical drawing work, except that the application of these principles requires special methods, symbols, and conventions. Architectural drawings of a building include floor plans, elevations, sections, and details sufficiently descriptive to permit the construction of the building according to the architect's ideas.

Although the architect and the architectural draftsman work hand-in-hand in the preparation of a set of plans for a structure, there is a wide gap between the experience and knowledge that each possesses. The architect may be his own draftsman, but the draftsman cannot be his own architect. The draftsman's function, therefore, is to assist in the execution of the architect's ideas. The architect must know not only how to prepare accurate working drawings, but also, he must understand the best uses of buildings from the economic and social points of view; he must know business administration so that he may understand the financial and legal transactions incident to modern building construction; he must develop a sense of proportion and a knowledge of pleasing form and color through the study of the history of Architecture; he must be familiar with the mechanical trades such as plumbing, heating, electricity, and other engineering features which have such an important bearing on the safety and durability of a structure.

352. Preliminary studies. Before the architect or draftsman is required to draw the plans and elevations or the working drawings of the house, the owner and architect should have reached certain conclusions as to the general design or style of the house, the kind of material to be used, the size, and the approximate cost of the proposed structure. While it is impossible to give an accurate schedule of costs at this point, the following is an indication of the relative percentage of the cost of materials, labor, and land involved in building the average home.

Cost of Materials	45.40%
Construction Labor	29.80%
Overhead and Profit	12.20%
Cost of Land	12.60%
	100.00%

Following is an outline that the architect may prepare for further development by himself or his draftsman after consulting with the owner.

DESIGN FOR TWO LEVEL STONE MASONRY AND FRAME HOUSE

ROOMS—MAIN FLOOR
1. Living room with fireplace
2. Dining room
3. Kitchen
4. Storage and heater room

SECOND FLOOR
5. Two bedrooms with closets
6. Bathroom
7. Terrace or sun deck

TYPE OF CONSTRUCTION
8. Concrete footings; masonry wall construction for first floor; frame walls for second floor; red wood siding.
9. Double hung frame windows; 6 lights for each frame
10. Flat canvas deck roofs, insulated
11. Heating: one-pipe hot water; recessed convectors
12. Sewage disposal: septic tank and leaching pool.
13. Provide for future breeze-way and one-car garage

353. Preliminary sketches. In many instances the architect will prepare for himself or submit to the draftsman a freehand sketch of the plan

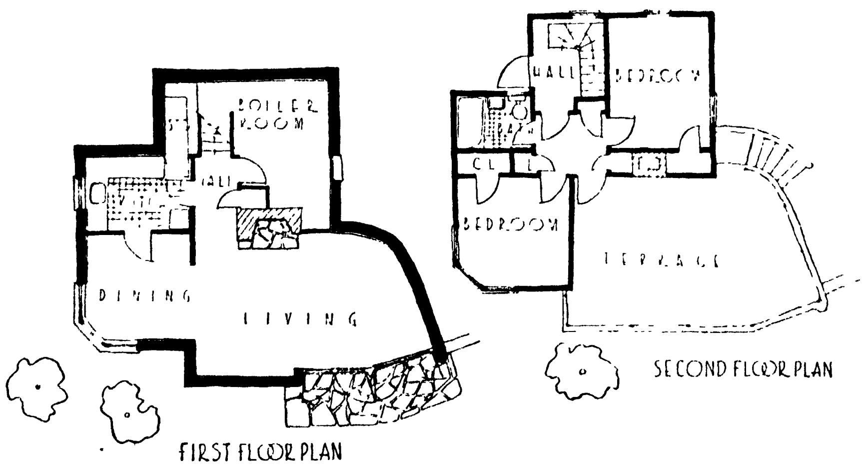


Fig. 497. Preliminary sketches.

showing the arrangement of rooms and indicating the approximate size of each room, Fig. 497. From this sketch the draftsman will prepare a preliminary drawing to a scale of $\frac{1}{8}'' = 1'\text{-}0''$. Of course, certain considerations and adjustments must be made as far as the arrangement and general dimensions of rooms are concerned, because the scale drawing will never quite work out in exact accordance with the preliminary rough sketch. When good circulation and a suitable arrangement of rooms are obtained, the draftsman will then layout the $\frac{1}{4}$-in. scale drawing of the main floor plan.

354. Presentation drawings. The primary purpose of presentation drawings is to give the owner a general, realistic picture of the proposed structure. Presentation drawings may be made in several ways. One method is to prepare a perspective view of the exterior of the building, rendered in pencil, ink, or color. Walks, shrubbery, or trees that may surround the building are included. With the rendered perspective it is customary to show the main-floor plan giving the names and sizes of rooms in order that the client may study the room arrangement. A rendered perspective drawing is shown in Fig. 498(*a* and *b*).

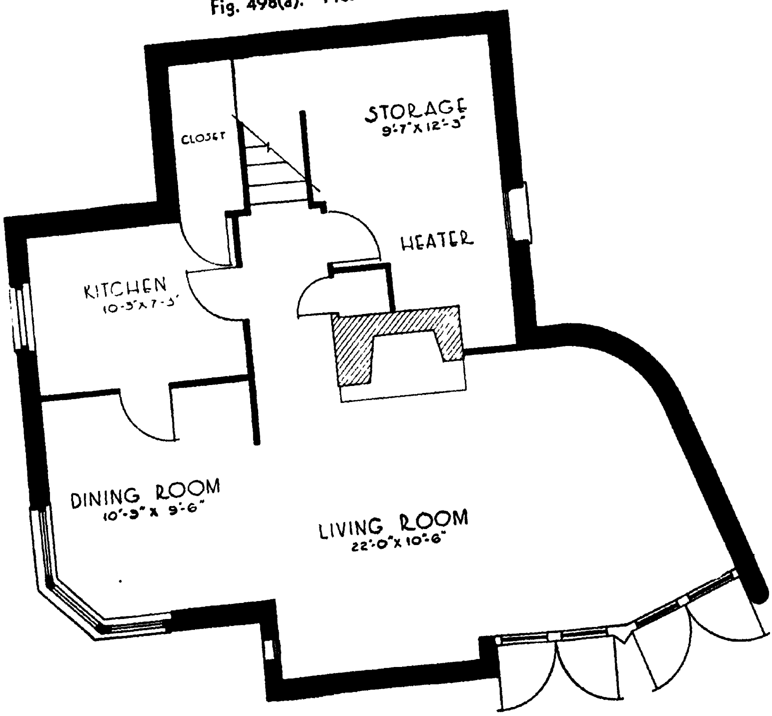
In place of the rendered perspective, actual scale models of the proposed building are finding favor with many architects. Models are made in the drafting room, using drawing paper and cardboard, cut to size and glued together forming an exact replica of the proposed building. The effect of shrubbery, trees, hedges, and grass can be attained by colored sponges, sawdust, and sand. Such models are of great value to both architect and client because they can be viewed from all angles and their proportions can be studied more accurately.

355. Working drawings. A set of working drawings consists of all of the drawings that are necessary for the contractor to erect the building. The set is composed of the plans, elevations, sections, details, and the lettered notes that assist in the interpretation of the drawings. In addition to the working drawings, the contractor also receives written instructions called *the specifications.* These specifications cover all the features that are not shown on the blueprints, such as the quality and quantity of the materials, and the methods to be used in the construction, or the manner in which the work is to be conducted. Like the plans, the specifications are indispensable to the builder. They are typed and accompany a set of working drawings.

356. The plans. When a set of working drawings is prepared, the main-floor plan is generally drawn first, as in Fig. 499. This plan is a horizontal cut taken through the building at a level half-way up the windows. Its purpose is to show the builder the location of both outside and inside walls, their thicknesses, lengths, and the materials of which they are constructed. The location of windows and doors, stairs and fireplace, and other data pertaining to electrical outlets, fixtures, floor finishes, and the direction and sizes of overhead floor joists are indicated.

From the main- or first-floor plan the outlines of other floor plans are traced, such as the basement or foundation plan, the second-floor plan (Fig. 500), or the roof plan. Since many drawings are needed in the

Fig. 498(a). Presentation drawing.



FIRST FLOOR PLAN
SCALE 1/4" = 1'-0"

Fig. 498(b).

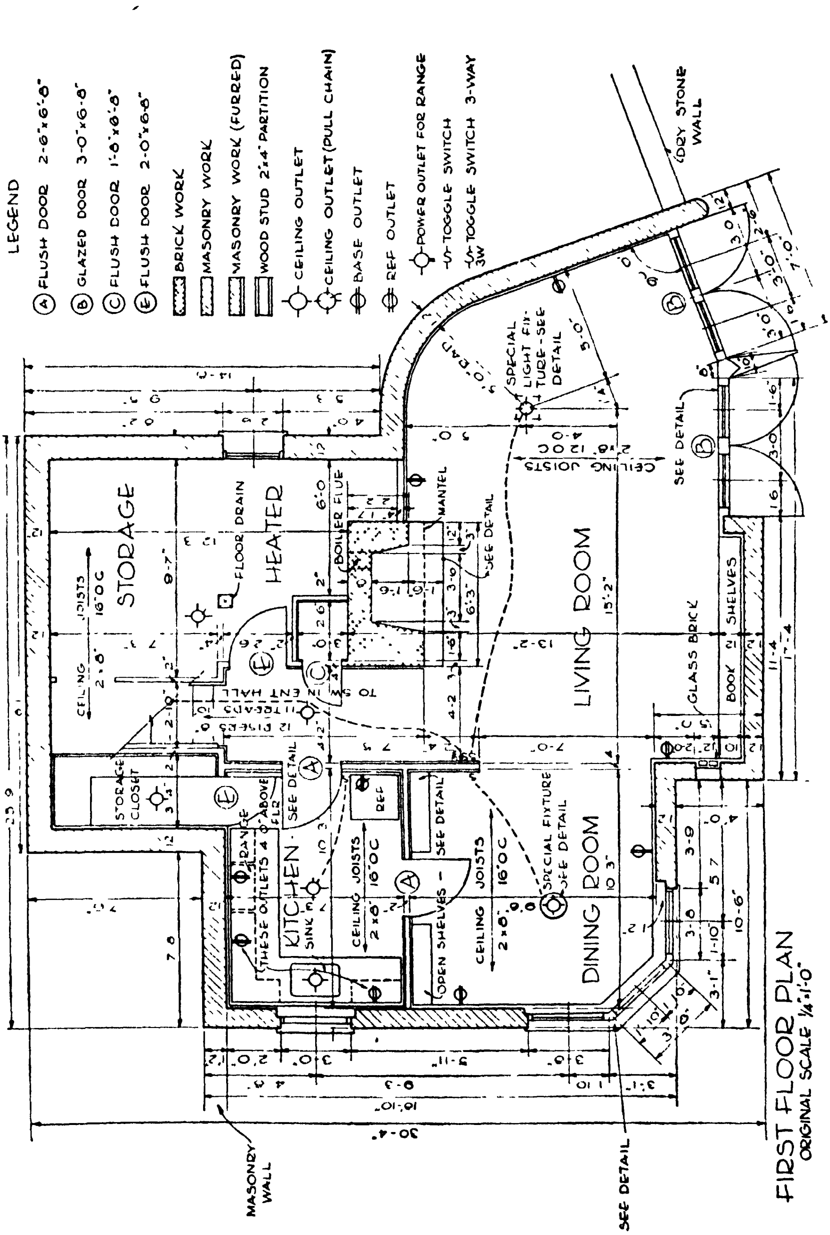


Fig. 499. First floor plan.

erection of a building, it is quite common to use a separate sheet for each plan. Special details which apply to the particular drawing are included.

357. The elevations. The primary purpose of the elevation drawings, Fig. 501 and 502, is to give the builder the height dimensions of doors, windows, floor-to-floor heights, ridge heights, chimney height, and the finished grade level in relation to the finished floor level. On the elevations are also indicated the type of outside wall finishes, roof finishes,

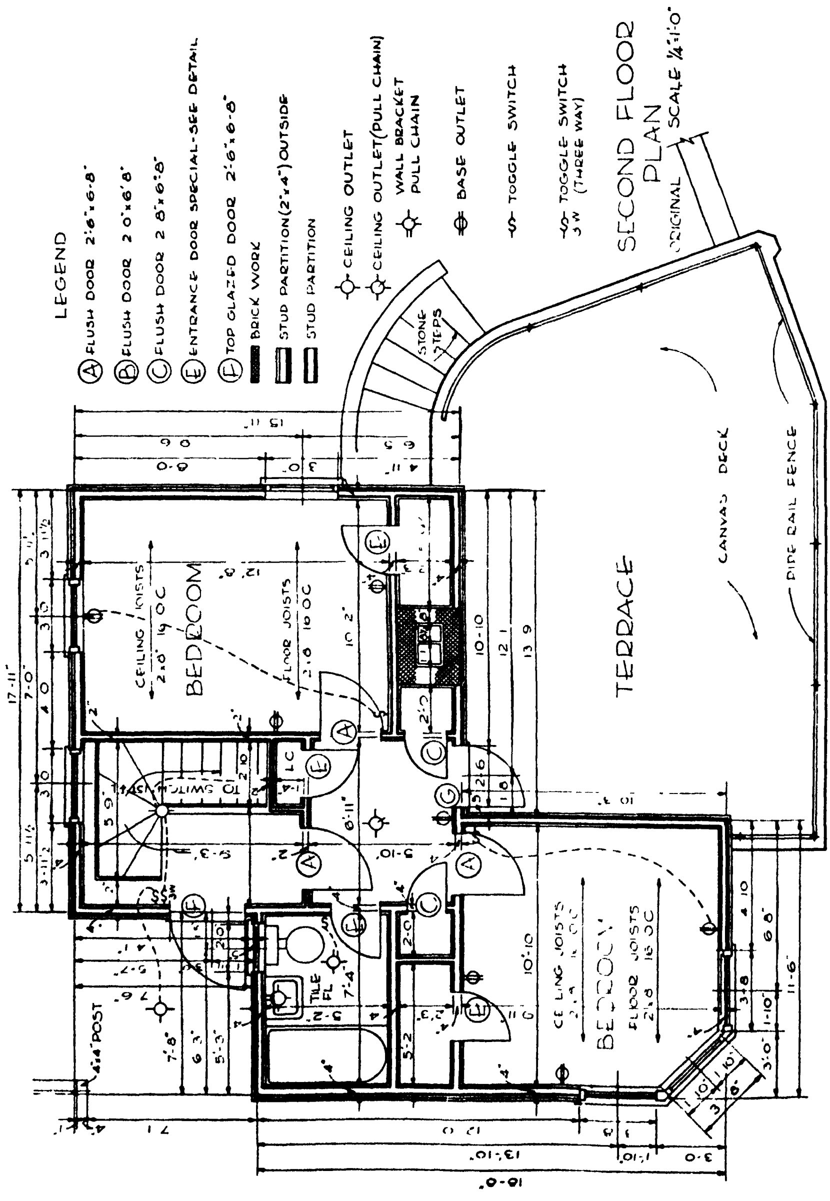


Fig. 500. Second floor plan.

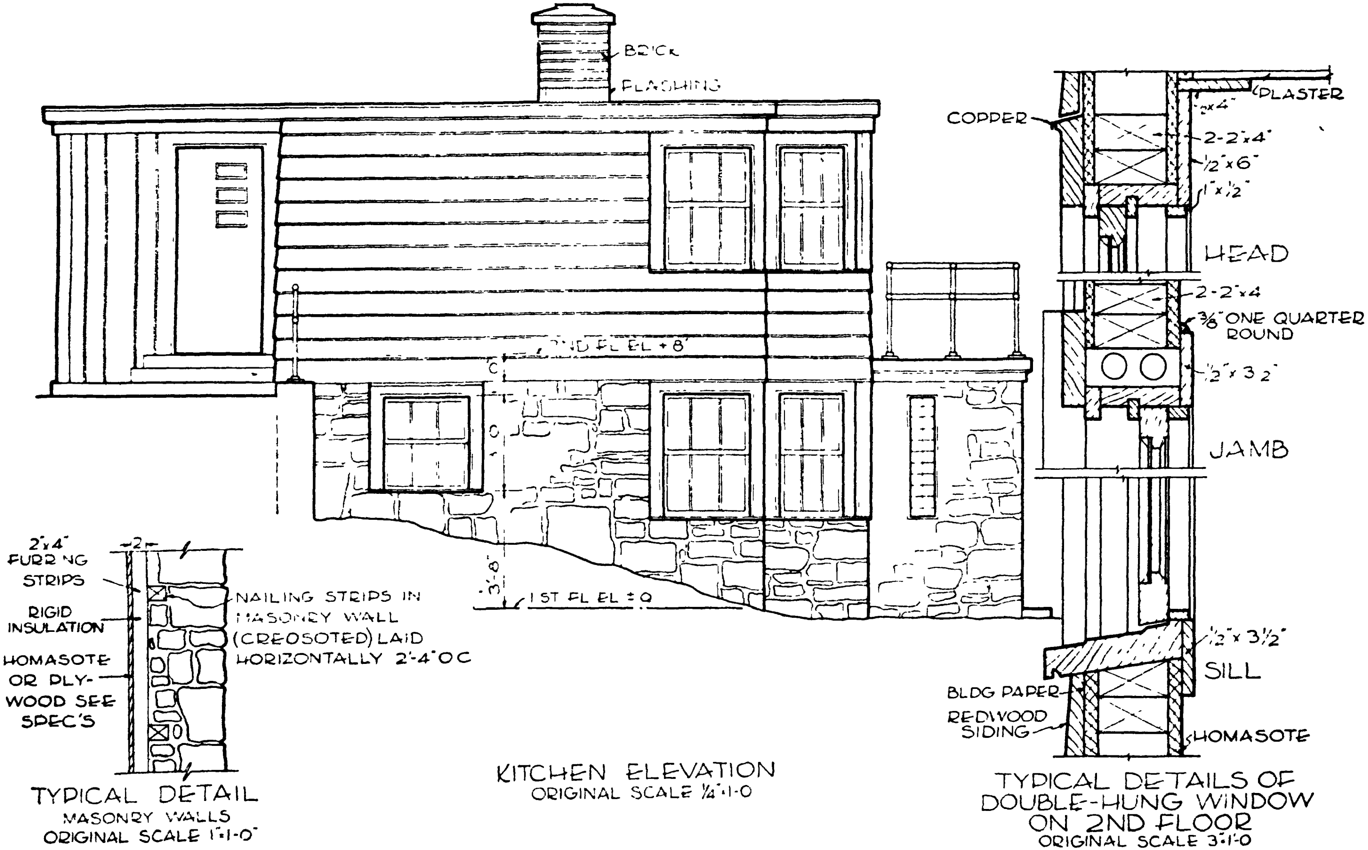


Fig. 501. Elevation.

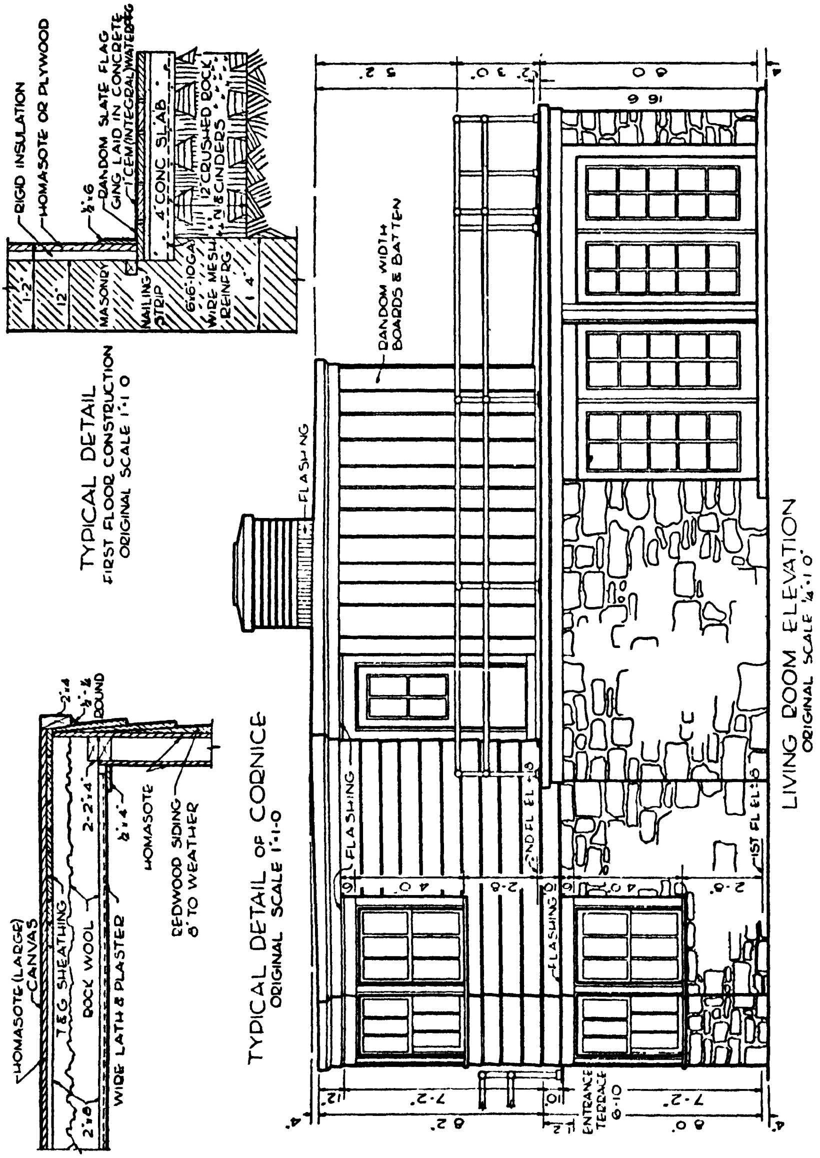


Fig. 502. Elevation.

and the style of doors and windows. In many cases two elevation drawings, front and side are sufficient to give the necessary information, but it is advisable to draw the four elevations of the building when each elevation has a distinct feature that could not be clearly shown on other drawings.

358. The plot plan. One of the functions of a plot plan is to locate the house on the lot so that the builder knows where to begin. When a tract of land is intended for a home development site it is generally the practice to lay in public utilities, such as sewerage disposal systems, water, gas, and electricity. This necessitates a pattern of streets and avenues with sidewalks forming blocks. A block is generally understood to mean an area of land rectangular in form bounded by streets and avenues. Each block, in turn, is subdivided into lots of the same or varying sizes, Fig. 503. Local building regulations frequently call for certain restrictions on the "frontage" or the distance that must be maintained between the street and the location of the house on the lot. In such cases the plot plan must show the exact location of the house on the lot. In unrestricted areas a land owner may build his house without

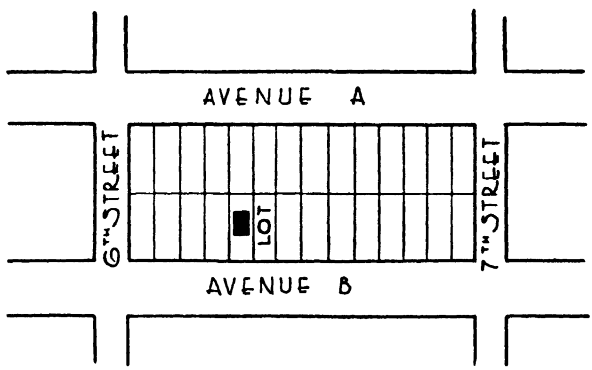


Fig. 503. Rectangular block bounded by streets and avenues subdivided into lots.

defining the location of the house on the land, as shown in Fig. 504. Plot plans also show where sewer lines, water, gas, and drainage lines are located. If driveways and walks are to be built, they must also be shown. Shrubbery, existing trees, and the points of the compass are included on a finished-plot plan.

359. Sections. In addition to the plans and elevations, "part sections" are often used to clarify the drawings further. These "part sections," Fig. 505, are often shown on the same drawing with the elevations, but generally are of larger scale. The longitudinal or cross section is intended to show the interior construction and architectural treatment. It is a cut taken on a vertical plane through the center of the building. This cutting plane need not be continuous, but may be staggered so as to include as much information as possible. Longitudinal or cross sections, as shown in Fig. 506, are of definite value to the builder. They show him the construction of the building from the footings to the roof rafters. This type of outside-wall construction is represented by its symbols; floor and ceiling joists are clearly shown and their sizes given; partition walls, stairs, fireplace, and interior wall finishes can be indicated. Important height dimensions given from finished floor to finished ceiling

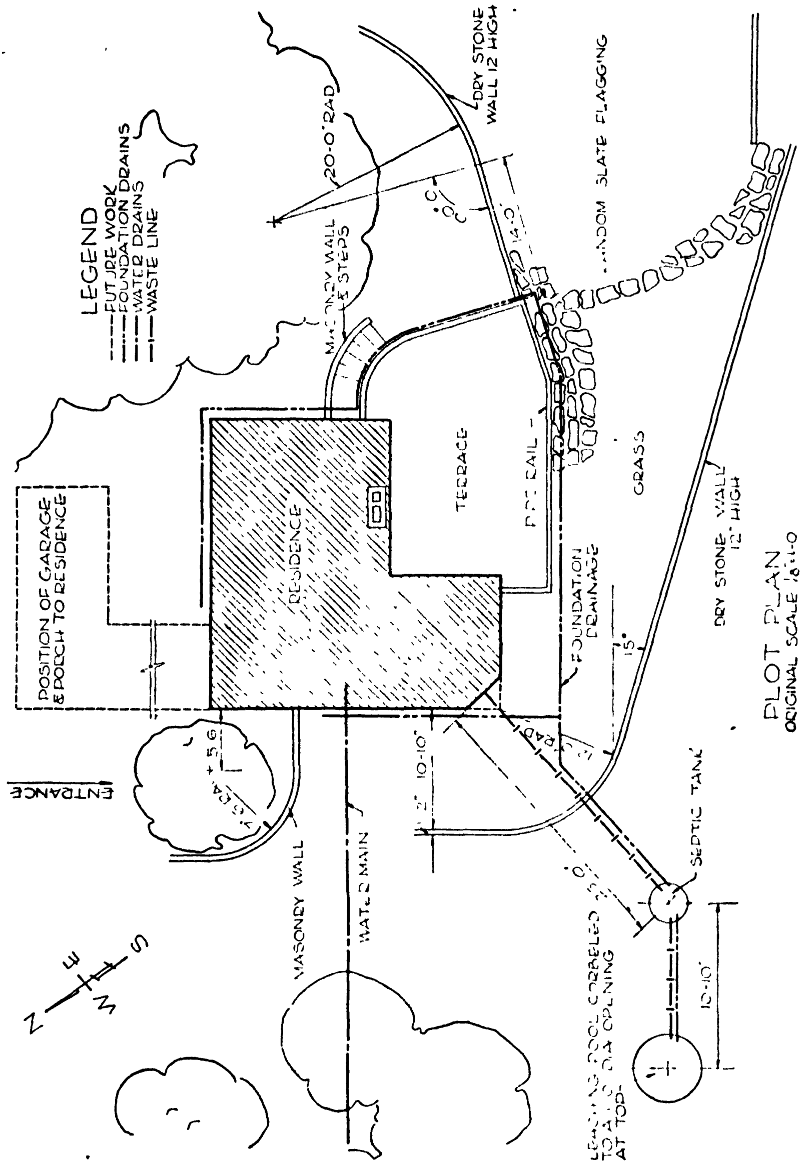


Fig. 504. Plot plan.

are a definite aid in understanding the construction. On longitudinal sections cellar floor constructions can also be indicated with dimensions and specifications so that in many instances larger details are not required.

360. Wall sections. On smaller construction it is often desirable to draw a "wall section" in place of the longitudinal or cross section so that all the necessary height dimensions and the construction can be shown. Wall sections are drawn to scales of $\frac{1}{2}''$, $\frac{3}{4}''$, or $1'' = 1'\text{-}0''$. A wall section such as that shown in Fig. 507 gives the depth of the footing below grade and the dimensions of the footing and the foundation wall. The 4-in. concrete floor on 6-in. cinder fill, on earth, is understood to be typical throughout. The section includes a window located by dimension above the finished floor level, and the height and type is shown. The method of spanning the window opening by a precast reinforced concrete lintel is indicated. The section further shows a built-up roof properly flashed to the wall. The exterior and interior wall finish can be represented by symbols and notes.

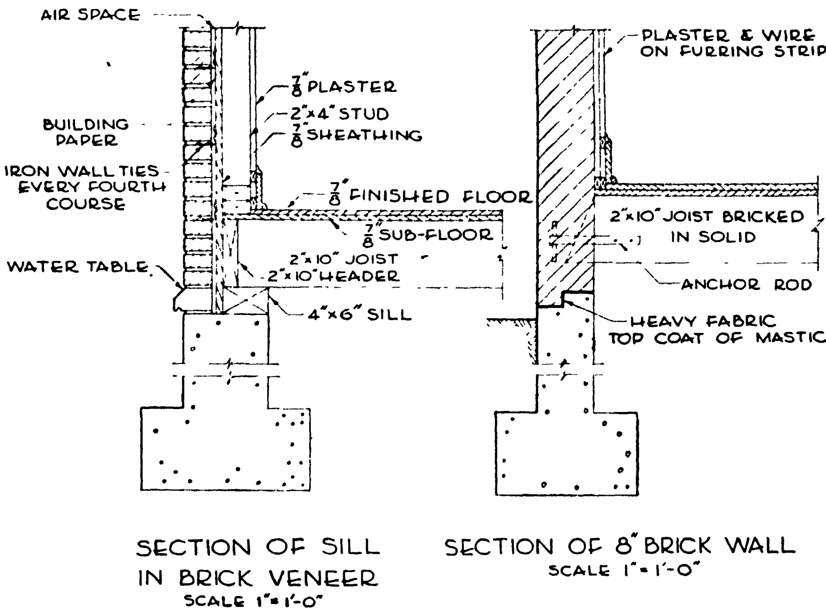


Fig. 505. Part sections.

361. Details. A set of working drawings is never quite complete without the large-scale detail drawings. Large-scale details are made when other drawings cannot describe the construction clearly. They are drawn to a scale of full size, half size, 3″ = 1′-0″, 1½″ = 1′-0″, 1″ = 1′-0″, ½″ = 1′-0″, ¾″ = 1′-0″. Typical details, such as that shown for the small house, Fig. 508, include the elevation of the fireplace wall in the living room, special lighting fixtures, entrance door details, and other details that can be clearly described but which could not be shown on other drawings at smaller scales. For larger buildings many additional detail drawings must be prepared, as illustrated in the window detail in Fig. 509. To be able to prepare good detail drawings the draftsman needs much experience in the use of trade literature, catalogs, and books dealing with the principles of construction. It might be well to mention

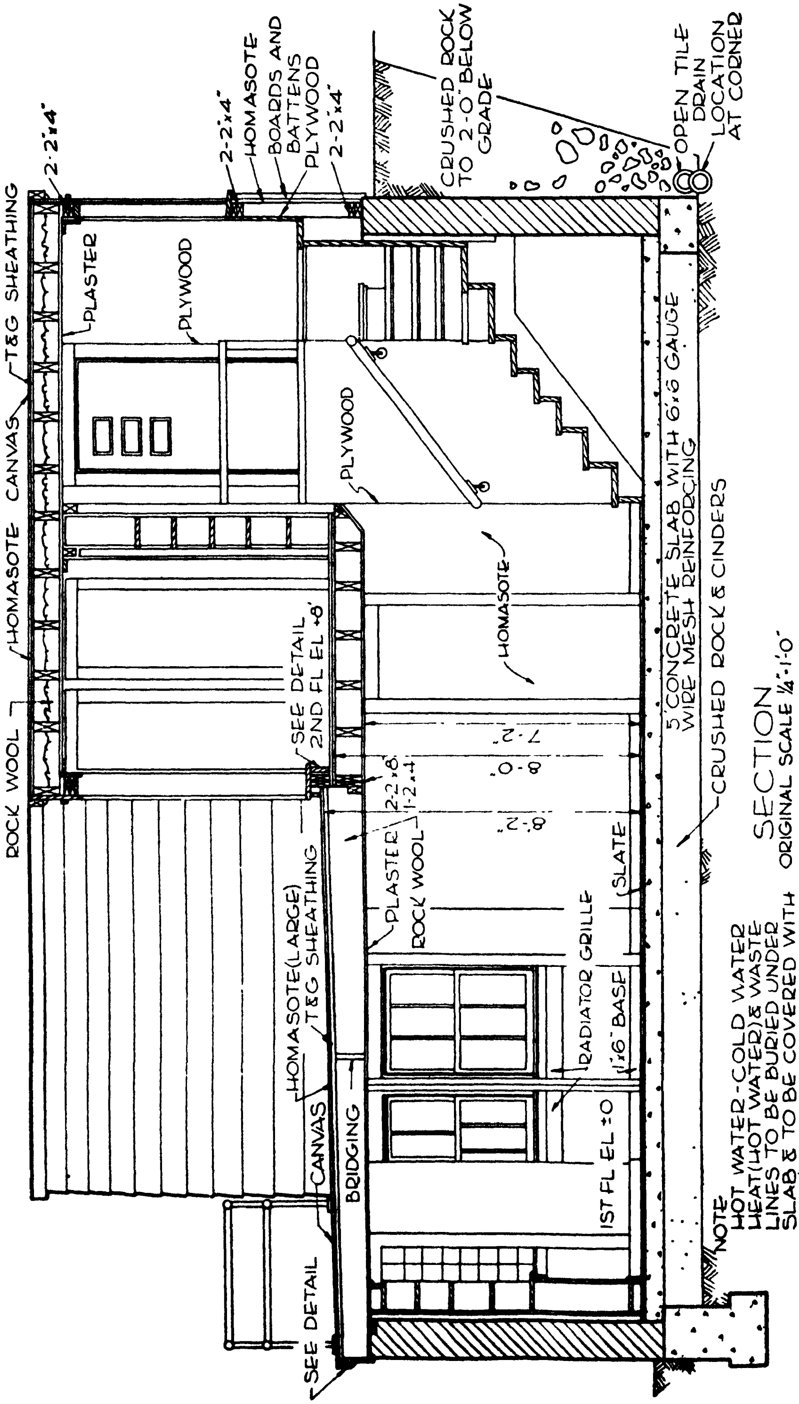


Fig. 506. Longitudinal sections.

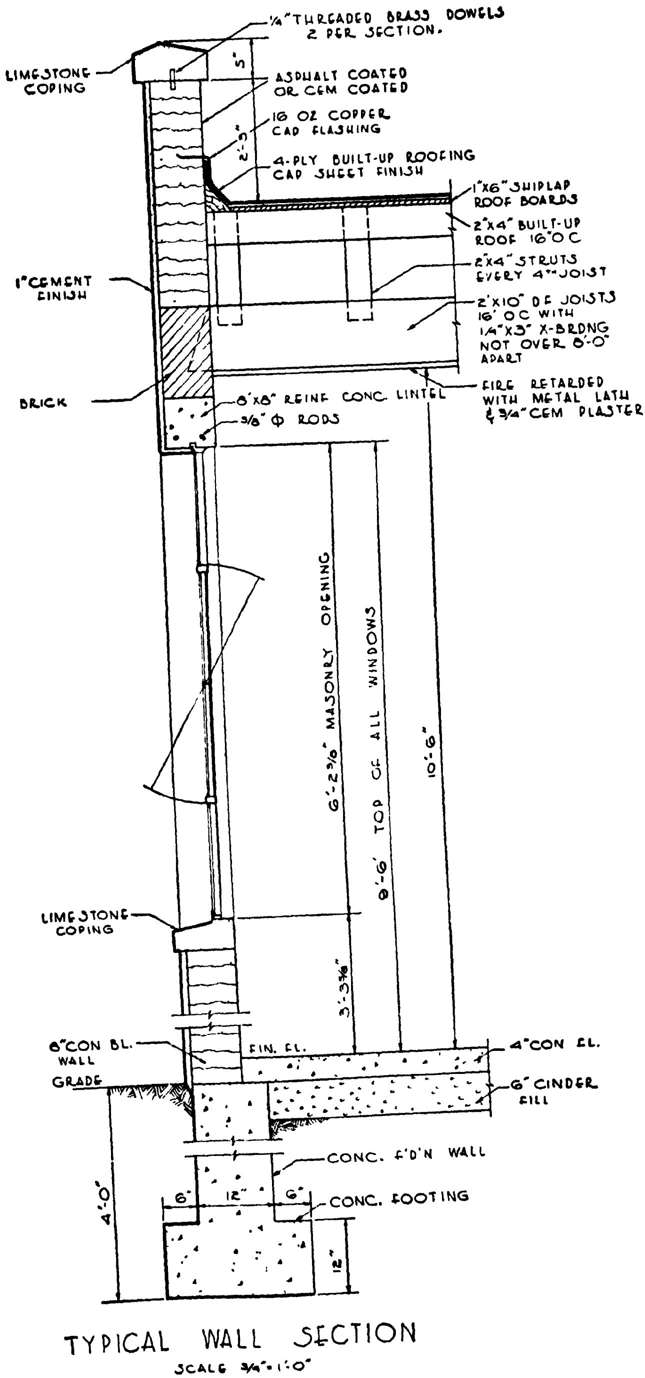


Fig. 507. **Wall sections.**

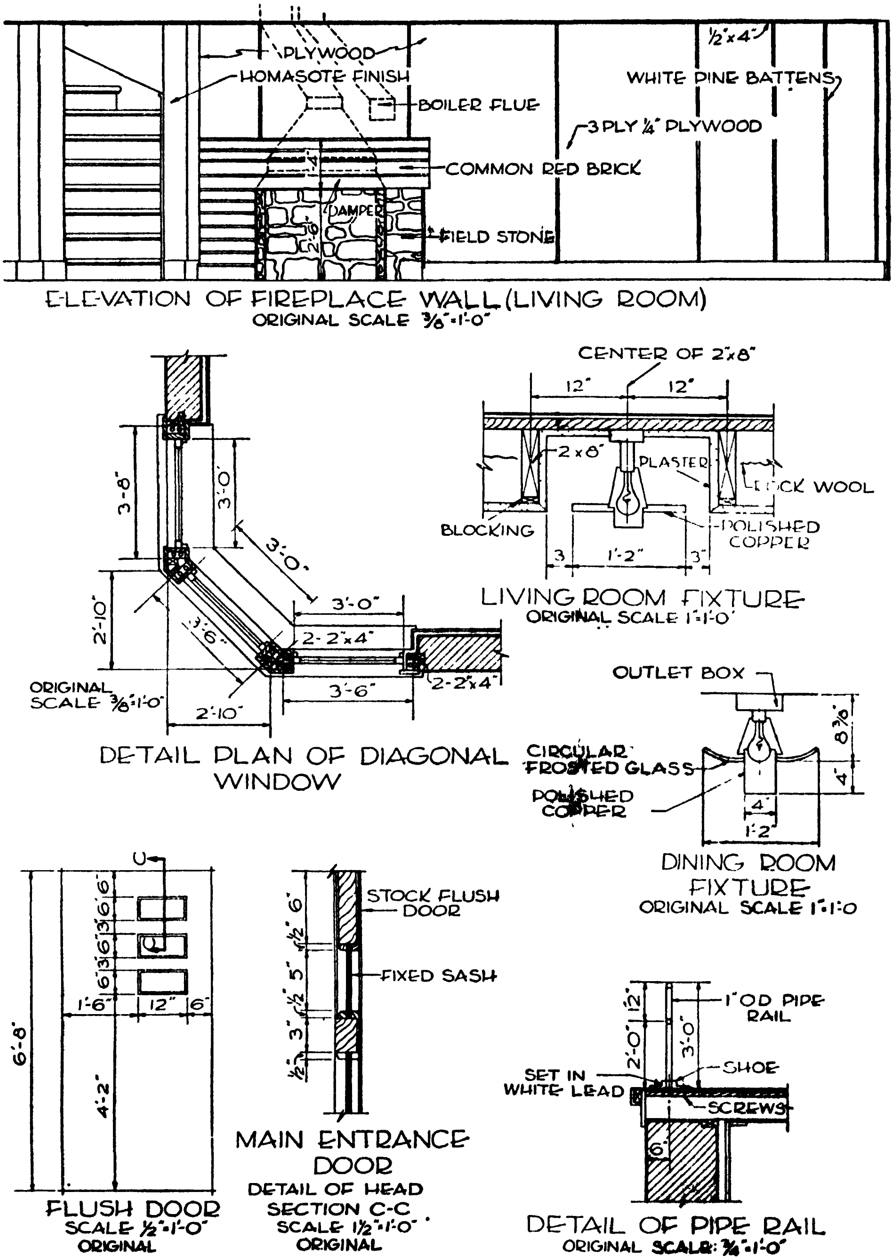


Fig. 508. Typical details.

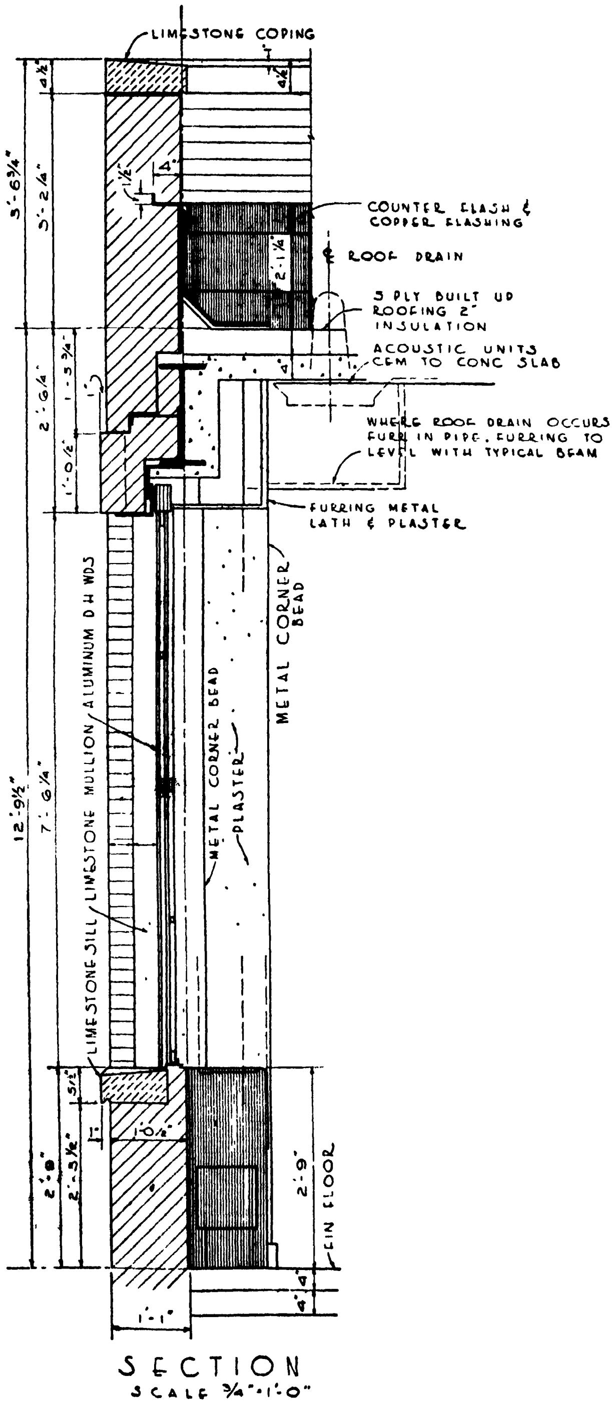


Fig. 509. Window detail.

here that in order to draw complex details the draftsman is largely dependent on manufacturer's information and previous similar drawings.

362. Special features. In present-day building construction, many parts that are used are manufactured by firms specializing in one particular item. As an example, wood sash details vary with different manufacturers. The architect gets scale details from the makers and draws his building to conform. Fig. 510 shows a detail of a double-hung window and a table of cellar window and picture window sizes as supplied by the manufacturer. Other items such as stair parts, doors, railings, fans, radiators, heating equipment, and many other special features are always planned from drawings supplied by the manufacturers.

363. Symbols. The working drawings for a structure are composed largely of symbols and conventions representing manufactured items and materials. For example, in a plan a foundation wall made up of concrete block has a symbol of cross lines and dots. This symbol is universally understood to mean concrete blocks. The symbol for concrete is represented by small triangles, circles, and dots representing crushed stone or gravel, sand, and cement. All architects, draftsmen, and builders understand these symbols which form a language of lines and correlate thought in the trade. Many symbols for materials have been standardized by the American Standards Association to facilitate understanding. Some of the new materials that have been added to the building industry in recent years have not as yet been standardized. When such materials are used on drawings a key to the materials must be included with the work. Fig. 511 shows materials and conventions which have been standardized.

364. Dimensioning. Dimensioning of the working plans and elevations is governed primarily by knowledge of building construction. Dimensions must be so placed that they are most convenient for the workman. On plans it is desirable to show dimensions around the outside of the plan whenever possible. Inside dimensions are generally those locating partitions, columns, beams, doors, or other openings. Dimensions on frame plans are given from the outside faces of studs on exterior walls to the center line of the window or door opening. Stud partitions may be located to the center of the partition or to the stud face. On masonry, outside walls dimensions are given from the outer face of the wall to the opening of the window or door, then across the opening. Masonry wall openings, such as doors and windows, may also be dimensioned to the center line of the opening. The elevations or cross sections must give the height or vertical dimensions of floors, windows, beams, roofs, and chimney. The plans in Figs. 499 and 500 and the elevations and cross section in Figs. 501, 502, and 506 should be carefully studied by the student before he attempts to place dimensions on a drawing.

365. Special notes. In addition to the written specifications furnished the contractor, special notes are lettered on the drawings to clarify

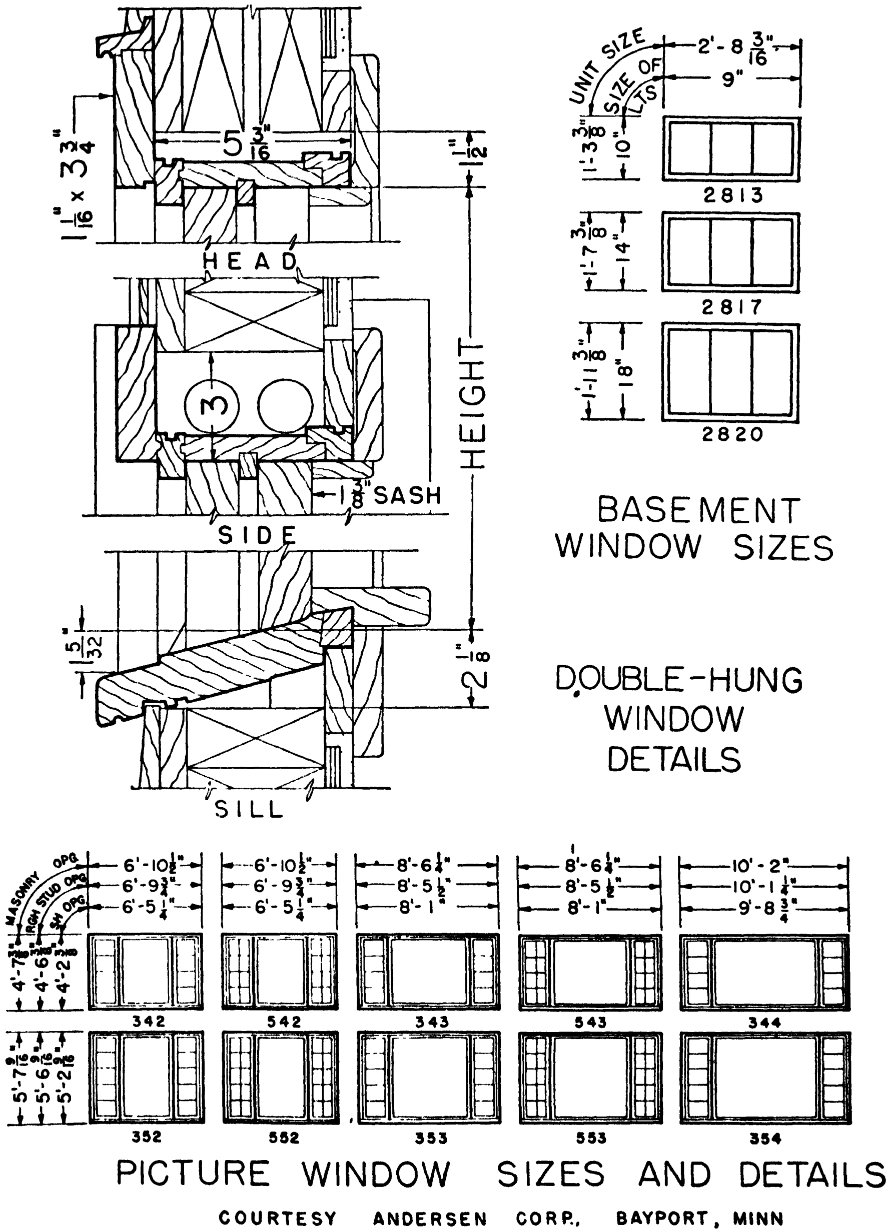


Fig. 510. Drawings supplied by the manufacturer.

the work. Builders are apt to overlook a point mentioned only in the specifications, but because they are using the drawings constantly they will be sure to see a reference or note on the drawing of the part in question. It is also common practice to use "schedules"—notes laid out in tabular form. The finish schedule shown in Fig. 512 gives finish treat-

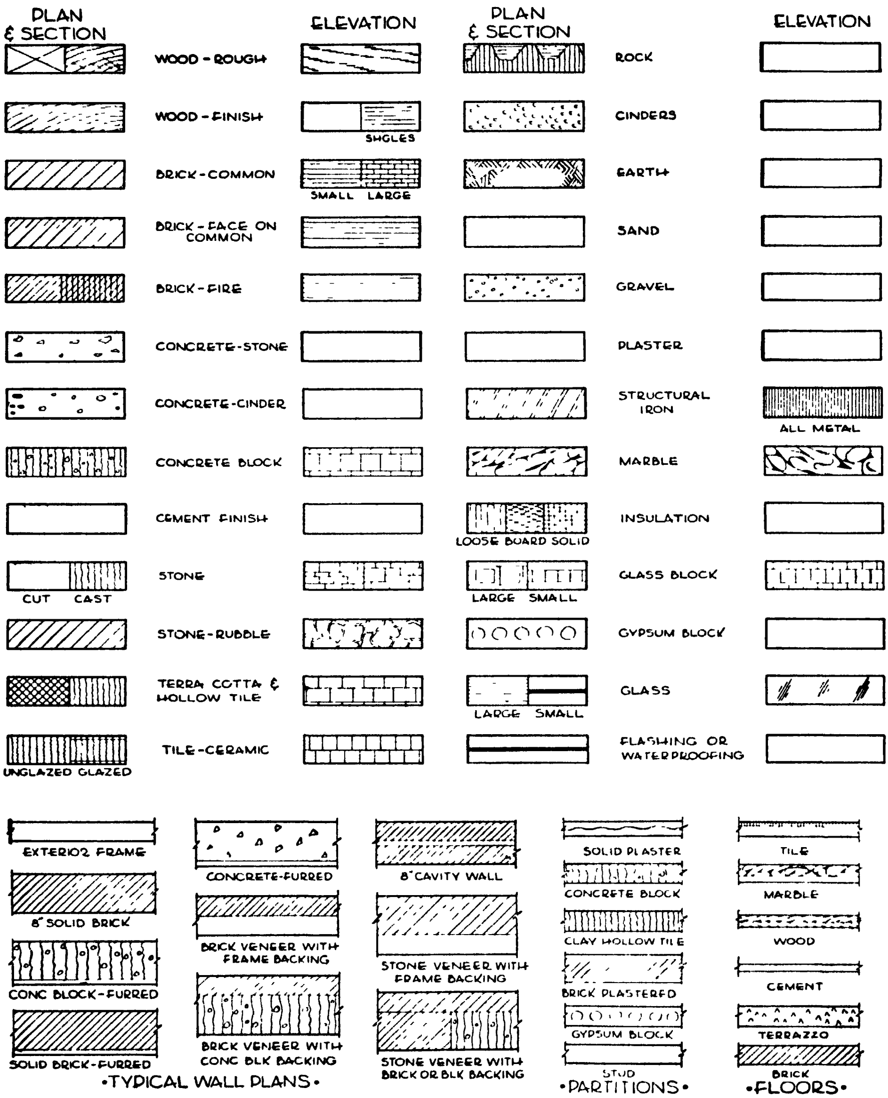


Fig. 511. Symbols and conventions.

ments of rooms, floors, and ceilings. Door schedules and window schedules are also commonly used on drawings so that the work will be better understood by the tradesmen.

366. Lettering. The lettering on drawings is as important as the plans of the building, because without lettered explanatory notes, titles, and dimensions, the plans could hardly be understood. The single stroke architectural letter shown in Fig. 513 is typical of that used by the architect. The style is closely related to the old Roman form. It is becoming increasingly evident that single stroke upper-case architectural letters are gaining favor over the lower-case form and the trend is towards letters which resemble more closely the mechanical style of letter used in previous chapters of this text. In large architectural firms where many

FINISH SCHEDULE						
ROOM	FLOOR	BASE	WAINSCOT	WALLS	CEILING	TRIM
SALES	CONCRETE	WOOD PAINTED	PLASTER PAINTED		PLASTER PAINTED	WOOD PAINTED
TOILETS	CERAMIC TILE	CERAMIC TILE	CERAMIC TILE	PLASTER PAINTED	PLASTER PAINTED	WOOD PAINTED
STORAGE	CONCRETE	NONE	MASONRY CLEANED UNPAINTED		CEMENT PLASTER UNPAINTED	WOOD PAINTED
SERVICE ROOMS	CONCRETE	NONE	MASONRY PAINTED		CEMENT PLASTER PAINTED	WOOD PAINTED
NOTE:	FOR COLOR OF PAINT AND NUMBER OF COATS SEE SPECIFICATIONS					

Fig. 512. Finish schedule.

Fig. 513. Architectural lettering.

draftsmen are employed, mechanical guides are used for lettering in order to minimize individuality of style of the draftsman and to make the drawings more consistent in character. Another type of lettering the architect is called upon to execute is the *incised* or the old Roman style used when letters are cut into stone or bronze or other material used in connection with design.

367. Problems. The following problems permit the student to prepare the necessary working drawings for building construction and introduce him to the study of Architectural Design. The problems may be modified or amplified by the teacher to the particular student needs.

1. Draw the first-floor plan of a small house similar to the one represented in Fig. 499. The student may modify the plan or create one of his own design. It is advisable first to prepare rough, freehand thumbnail sketches of the plan to study room arrangements, window locations, and space for furniture. Have instructor check preliminary sketches and then proceed to draw a $\frac{1}{8}''$ scale plan. After studying the plan again, proceed with the final $\frac{1}{4}'' = 1'\text{-}0''$ scale plan and dimension it completely. Check Fig. 508 for conventional representations of windows, doors, fireplace, stairs, fixtures, and material symbols.

2. Draw the foundation plan of the house to a scale of $\frac{1}{4}'' = 1'\text{-}0''$. Indicate concrete footings, foundation walls, footing for chimney, lally columns, if any, and windows. Completely letter and dimension the plan.

3. Draw the remaining two elevations of the house shown in Figs. 501 and 502. Refer to the plans in Figs. 499 and 500. Use scale of $\frac{1}{4}'' = 1'\text{-}0''$. Particular attention should be given to the conventional representations of windows on the elevation, and the important height dimensions.

4. Draw the detail of a window used in the plan of your own design showing the head section, jamb, and sill, to a scale of either $1\frac{1}{2}'' = 1'\text{-}0''$, or $3'' = 1'\text{-}0''$. Refer to window detail Fig. 509 or 510. Indicate the rough openings and sash openings. These dimensions can be secured from manufacturers catalogs.

5. Draw the front elevation to the plan drawn in Problem 1, to a scale of $\frac{1}{4}'' = 1'\text{-}0''$. Make preliminary sketches of the elevation and have them checked by the instructor before proceeding with the scale drawing. Check Figs. 501 and 502 for correct window conventions in elevation and symbols for exterior treatment. Place the necessary height dimensions on your drawing.

6. Draw a side elevation for the plan drawn in Problem 1 to a scale of $\frac{1}{4}'' = 1'\text{-}0''$. Heights, such as floor, grade, ceiling, and roof may be projected from the front elevation. Make use of the plans for location of windows and doors.

7. Make the framing plans of the house of your design. Trace the outline of the foundation plan in Problem 2, and select joist sizes from standard tables on "Joist Spans and Sizes." Double the floor joists where partitions run parallel to the joists. Study the framing around stairwell and chimney openings.

8. Draw a longitudinal cross section through the house of your design. Use scale of $\frac{1}{4}'' = 1'\text{-}0''$. Refer to plans and elevations for lengths and heights. Take section through stair and fireplace if possible. Use Fig. 506 for reference. Indicate all material by proper symbol and dimension section completely.

9. To a scale of $1\frac{1}{2}'' = 1'\text{-}0''$, draw a wall section showing the footing, foundation wall, sill construction, window-in-wall section, and cornice construction. Show all necessary dimensions. Refer to Fig. 507 for methods of dimensioning.

10. Draw any details necessary to clarify fully the working drawings completed. For suggestions as to the type of details, refer to Fig. 508.

23

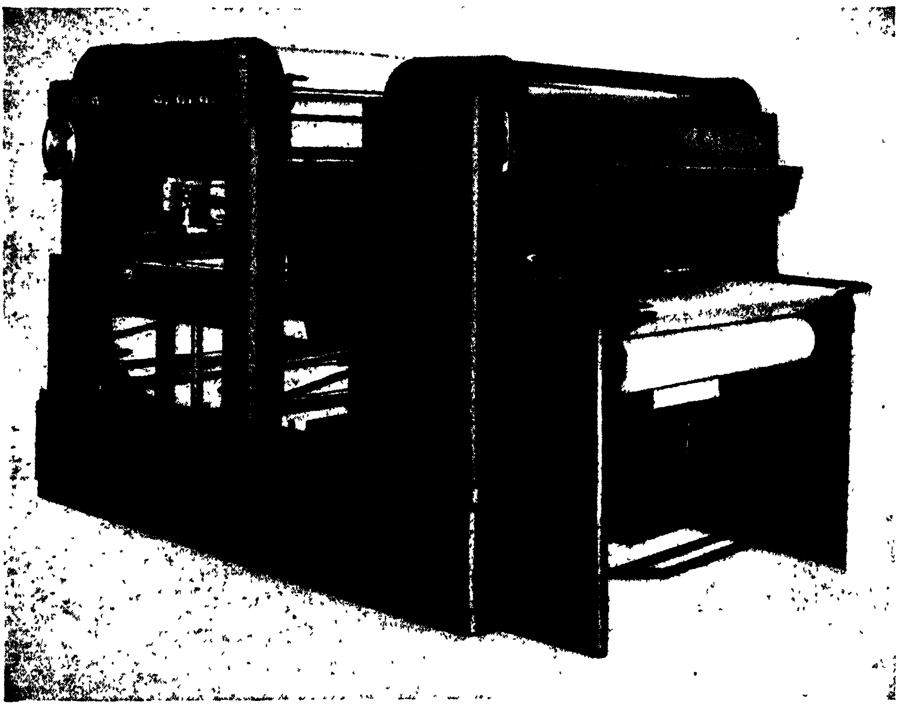
DUPLICATION OF ENGINEERING DRAWINGS

368. Usually it is necessary to duplicate a set of drawings of a machine or structure, one or more copies being made for the office and extra copies for interested persons connected with the home organization or an outside co-operating firm. Sometimes many sets are required. Under modern production methods, the various parts of a machine or structure may be produced in numerous departments and plants that are located miles apart. Each of these departments must have exact copies of the original drawings. To satisfy this demand, several economical processes have been devised.

369. Blueprints. At present the blueprint process is more widely used than any other method of reproduction, despite the fact that some of the others offer more advantages.

A blueprint may be considered a photographic copy of an original drawing in that the process is similar to that of photography. A piece of sensitized paper is exposed to light transmitted through a negative (tracing) and then is developed in water to bring out the image. The negative is a transparent sheet of paper or transparentized cloth upon which the image of the original drawing has been traced with opaque lines. The printing paper is a white paper that has been coated with a solution of ammonia citrate of iron and ferrocyanide of potassium. When the paper is exposed through the tracing, a chemical action takes place wherever the light is able to reach the sensitized surface. In the first bath of clear water, the coating is washed away from the parts of the surface protected by these lines, exposing the original surface of the paper against a developed blue background. The contrast between the blue background and white lines may be intensified by dipping the print in an oxidizing solution of potassium bichromate in water, after which the print must be rinsed thoroughly in clean water to avoid stain marks.

Since a good print with clear white lines against a uniform brilliant blue background can be obtained only by proper timing of the exposure, it is well to make one or two trial (part) prints on small scraps of blueprint paper before making the final print. If the background is a pale blue, the trial print was underexposed and the time of exposure should be increased; if the trial print has a scorched appearance with indistinct lines against a very dark blue background, the print was overexposed and the time of exposure should be decreased.

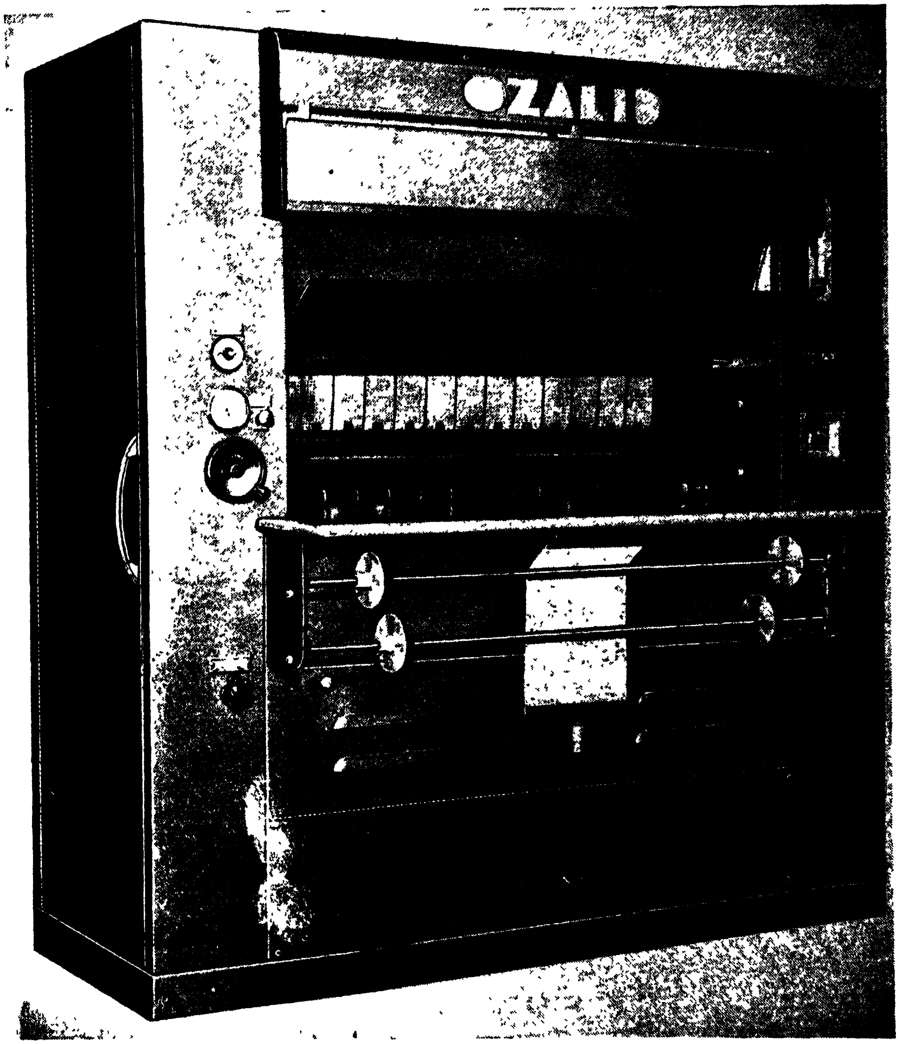


Courtesy C. F. Pease Company.

Fig. 514. Continuous printing machine with washer and drier.

When a large quantity of prints must be made daily, some form of continuous blueprint machine is desirable. On such a machine the paper unwinds continuously from a roll as the tracings are "fed in" with the inked sides up. The exposure is made as the tracing passes upward in contact with a glass cylinder containing a bank of arc lights. Some machines are equipped with a washer and drier, thus allowing the prints to be made in one operation (Fig. 514), but these are so expensive that only firms making a great number of prints daily find them a worth-while investment.

370. Ozalid prints. Ozalid prints, depending upon the type of Ozalid paper used, show black, blue, or maroon lines on a white background. The prints are exposed in the same manner as for other contact processes.



Courtesy General Analine and Film Corp.

Fig. 515. Ozalid printing machine.

They are developed in controlled dry ammonia vapor and, since no liquid solution is used with this process, a finished print will be an undistorted exact-scale reproduction of the original tracing.

371. Black and white prints (*BW*). Positive black-line prints may be made direct from an original tracing by using a specially prepared black-print paper. When developed, the sensitized surface turns black where it has been protected and remains white where exposed. Only two steps are required to obtain a fully developed print: exposure and development. This method of printing is similar to that used for making blueprints, except that the print is developed by a solution in a special developing unit on top of the printer.

APPENDIX

APPENDIX

TABLE I

Decimal Equivalents

	1/64	.015625		33/64	.515625
	1/32	.03125		17/32	.53125
	3/64	.046875		35/64	.546875
1/16		.0625	9/16		.5625
	5/64	.078125		37/64	.578125
	3/32	.09375		19/32	.59375
	7/64	.109375		39/64	.609375
1/8		.1250	5/8		.6250
	9/64	.140625		41/64	.640625
	5/32	.15625		21/32	.65625
	11/64	.171875		43/64	.671875
3/16		.1875	11/16		.6875
	13/64	.203125		45/64	.703125
	7/32	21875		23/32	.71875
	15/64	.234375		47/64	.734375
1/4		.2500	3/4		.7500
	17/64	.265625		49/64	.765625
	9/32	.28125		25/32	.78125
	19/64	.296875		51/64	.796875
5/16		.3125	13/16		.8125
	21/64	.328125		53/64	.828125
	11/32	.34375		27/32	.84375
	23/64	.359375		55/64	.859375
3/8		.3750	7/8		.8750
	25/64	390625		57/64	.890625
	13/32	.40625		29/32	.90625
	27/64	.421875		59/64	.921875
7/16		.4375	15/16		.9375
	29/64	.453125		61/64	.953125
	15/32	.46875		31/32	.96875
	31/64	.484375		63/64	.984375
1/2		.5000	1		1.0000

TABLE II

Screw Threads

Nominal Diameter	Unified and American Screw Threads*					
	Coarse (NC) (UNC)		*Fine (NF) (UNF)*		*Extra Fine (NEF)*	
	Threads per Inch	*Tap Drill*†	*Threads per Inch*	*Tap Drill*†	*Threads per Inch*	*Tap Drill*†
0	—	—	80	$\frac{3}{64}$	—	—
1	64	No. 53	72	No. 53	—	—
2	56	No. 50	64	No. 50	—	—
3	48	No. 47	56	No. 45	—	—
4	40	No. 43	48	No. 42	—	—
5	40	No. 38	44	No. 37	—	—
6	32	No. 36	40	No. 33	—	—
8	32	No. 29	36	No. 29	—	—
10	24	No. 25	32	No. 21	—	—
12	24	No. 16	28	No. 14	32	—
1/4	**20**	No. 7	**28**	No. 3	32	No. 2
5/16	**18**	*F*	**24**	*I*	32	*K*
3/8	**16**	$\frac{5}{16}$	**24**	*Q*	32	*S*
7/16	**14**	*U*	**20**	$\frac{25}{64}$	**28**	*Y*
½	**13**	$\frac{27}{64}$	—	—	—	—
1/2	**12**	*Z*	**20**	$\frac{29}{64}$	**28**	$\frac{15}{32}$
9/16	**12**	$\frac{31}{64}$	**18**	$\frac{33}{64}$	24	$\frac{17}{32}$
5/8	**11**	$\frac{17}{32}$	**18**	$\frac{37}{64}$	24	$\frac{19}{32}$
3/4	**10**	$\frac{21}{32}$	**16**	$\frac{11}{16}$	**20**	$\frac{45}{64}$
7/8	**9**	$\frac{49}{64}$	**14**	$\frac{13}{16}$	**20**	$\frac{53}{64}$
1	**8**	$\frac{7}{8}$	**12**	$\frac{59}{64}$	**20**	$\frac{61}{64}$
1 1/8	**7**	$\frac{63}{64}$	**12**	$1\frac{3}{64}$	18	$1\frac{5}{64}$
1 1/4	**7**	$1\frac{7}{64}$	**12**	$1\frac{11}{64}$	18	$1\frac{13}{64}$
1 3/8	**6**	$1\frac{13}{64}$	**12**	$1\frac{19}{64}$	18	—
1 1/2	**6**	$1\frac{21}{64}$	**12**	$1\frac{27}{64}$	18	$1\frac{29}{64}$
1 3/4	**5**	$1\frac{35}{64}$	—	—	**16**	$1\frac{11}{16}$
2	**4 1/2**	$1\frac{25}{32}$	—	—	**16**	$1\frac{15}{16}$
2 1/4	**4 1/2**	$2\frac{1}{32}$	—	—	—	—
2 1/2	**4**	$2\frac{1}{4}$	—	—	—	—
2 3/4	**4**	$2\frac{1}{2}$	—	—	—	—
3	**4**	$2\frac{3}{4}$	—	—	—	—
3 1/4	**4**	3	—	—	—	—
3 1/2	**4**	$3\frac{1}{4}$	—	—	—	—
3 3/4	**4**	$3\frac{1}{2}$	—	—	—	—
4	**4**	$3\frac{3}{4}$	—	—	—	—

* ASA B1.1-1949.

† Tap drill for a 75 per cent thread (not American Standard).

For recommended hole size limits before threading see Table 41, ASA B1.1-1949.

Bold type indicates Unified threads (UNC-UNF).

TABLE III

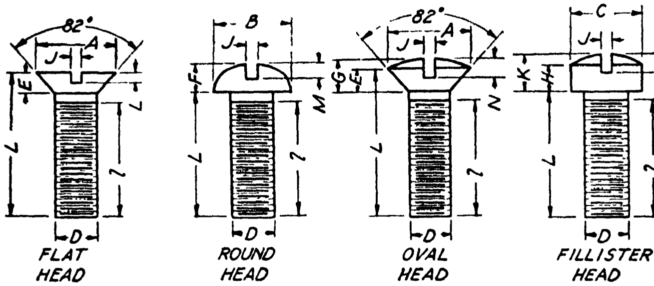
Standard Wrench-head Bolts and Nuts—Regular Series*

Bolt Dia.	Bolt Heads — Width across Flats — Unfinished and Semi-finished Square and Hexagonal	Bolt Heads — Height of Head — Unfinished Square and Hexagonal	Bolt Heads — Height of Head — Semi-finished Hexagonal Only	Nuts — Width across Flats — Regular and Jam	Nuts — Thickness — Regular — Unfinished Square and Hexagonal	Nuts — Thickness — Regular — Semi-finished Hexagonal Only	Nuts — Thickness — Jam — Unfinished Square and Hexagonal	Nuts — Thickness — Jam — Semi-finished Hexagonal Only
1/4	3/8	11/64	5/32	7/16	7/32	13/64	5/32	9/64
5/16	1/2	13/64	3/16	9/16	17/64	1/4	3/16	11/64
3/8	9/16	1/4	15/64	5/8	21/64	5/16	7/32	13/64
7/16	5/8	19/64	9/32	3/4	3/8	23/64	1/4	15/64
1/2	3/4	21/64	19/64	13/16	7/16	27/64	5/16	19/64
9/16	7/8	3/8	11/32	7/8	1/2	31/64	11/32	21/64
5/8	15/16	27/64	25/64	1	35/64	17/32	3/8	23/64
3/4	1 1/8	1/2	15/32	1 1/8	21/32	41/64	7/16	27/64
7/8	1 5/16	19/32	9/16	1 5/16	49/64	3/4	1/2	31/64
1	1 1/2	21/32	19/32	1 1/2	7/8	55/64	9/16	35/64
1 1/8	1 11/16	3/4	11/16	1 11/16	1	31/32	5/8	39/64
1 1/4	1 7/8	27/32	25/32	1 7/8	1 3/32	1 1/16	3/4	23/32
1 3/8	2 1/16	29/32	27/32	2 1/16	1 13/64	1 11/64	13/16	25/32
1 1/2	2 1/4	1	15/16	2 1/4	1 5/16	1 9/32	7/8	27/32
1 5/8	2 7/16	1 3/32	1 1/32	2 7/16	1 27/64	1 25/64	15/16	29/32
1 3/4	2 5/8	1 5/32	1 3/32	2 5/8	1 17/32	1 1/2	1	31/32
1 7/8	2 13/16	1 1/4	1 3/16	2 13/16	1 41/64	1 39/64	1 1/16	1 1/32
2	3	1 11/32	1 7/32	3	1 3/4	1 23/32	1 1/8	1 3/32
2 1/4	3 3/8	1 1/2	1 3/8	3 3/8	1 31/32	1 59/64	1 1/4	1 13/64
2 1/2	3 3/4	1 21/32	1 17/32	3 3/4	2 3/16	2 9/64	1 1/2	1 29/64
2 3/4	4 1/8	1 13/16	1 11/16	4 1/8	2 13/32	2 23/64	1 5/8	1 37/64
3	4 1/2	2	1 7/8	4 1/2	2 5/8	2 37/64	1 3/4	1 45/64

* ASA B18.2-1941.
All dimensions in inches.

TABLE IV

Slotted Head Machine Screws

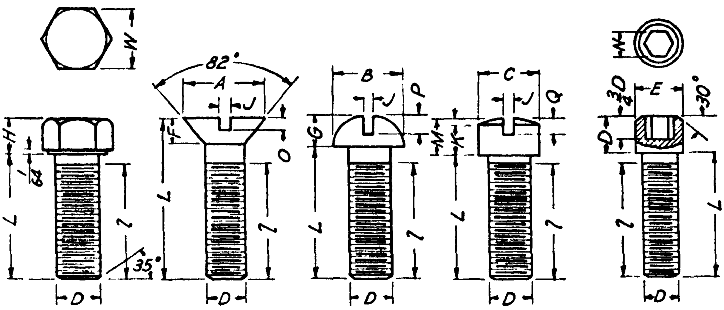


Size (Number) and Threads per Inch				American Standard Dimensions (Max.)														
Nominal Size	Diameter D	Thread		Head Diameter			Height Dimensions					Slot Width	Slot Depth			
		Coarse	Fine	A	B	C	E	F	G	H	K	J	L	M	N	O
0	.060	—	80	.119	.113	.096	.035	.053	.056	.045	.059	.023	.015	.039	.030	.025
1	.073	64	72	.146	.138	.118	.043	.061	.068	.053	.071	.026	.019	044	.038	.031
2	.086	56	64	.172	.162	.140	.051	.069	.080	.062	.083	.031	.023	.048	.045	.037
3	.099	48	56	.199	.187	.161	.059	.078	.092	.070	.095	.035	.027	.053	.052	.043
4	.112	40	48	.225	.211	.183	.067	.086	.104	.079	.107	.039	.030	.058	.059	.048
5	.125	40	44	.252	.236	.205	.075	.095	.116	.088	.120	.043	.034	.063	.067	.054
6	.138	32	40	.279	.260	.226	.083	.103	.128	.096	.132	.048	.038	.068	.074	.060
8	.164	32	36	.332	.309	.270	.100	.120	.152	.113	.156	.054	.045	.077	.088	.071
10	.190	24	32	.385	.359	.313	.116	.137	.176	.130	.180	.060	.053	.087	.103	.083
12	.216	24	28	.438	.408	.357	.132	.153	.200	.148	.205	.067	.060	.096	.117	.094
$\frac{1}{4}$	.250	20	28	.507	.472	.414	.153	.175	.232	.170	.237	.075	.070	.109	.136	.109
$\frac{5}{16}$	.3125	18	24	.635	.590	.518	.191	.216	.290	.211	.295	.084	.088	.132	.171	.137
$\frac{3}{8}$	.375	16	24	.762	.708	.622	.230	.256	.347	.253	.355	.094	.106	.155	.206	.164
$\frac{7}{16}$	.4375	14	20	.812	.750	.625	.223	.328	.345	.265	.368	.094	.103	.196	.210	.170
$\frac{1}{2}$	.500	13	20	.875	.813	.750	.223	.355	.354	.297	.412	.106	.103	.211	.216	.190
$\frac{9}{16}$	.5625	12	18	1.000	.938	.812	.260	.410	.410	.336	.466	.118	.120	.242	.250	.214
$\frac{5}{8}$	.625	11	18	1.125	1.000	.875	.298	.438	.467	.375	.521	.133	.137	.258	.285	.240
$\frac{3}{4}$	.750	10	16	1.375	1.250	1.000	.372	.547	.578	.441	.612	.149	.171	.320	.353	.281

ASA B18.6-1947.

TABLE V

Cap Screws

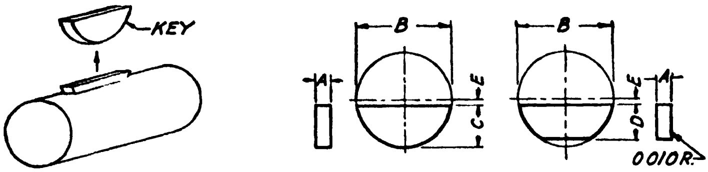


Nominal Size	American Standard Dimensions (Max.)														
	Head Diameter					*Height Dimensions*					*Slot Width*	*Slot Depth*			*Socket Width*
Dia	*A*	*B*	*C*	*E*	*W*	*F Ave.*	*G*	*H*	*K*	*M*	*J*	*O*	*P*	*Q*	*N*
1/4	500	.437	.375	3/8	7/16	.140	191	3/16	.172	.216	075	069	.117	097	3/16
5/16	625	.562	437	7/16	1/2	176	246	15/64	203	253	.084	086	.151	115	7/32
3/8	750	.625	562	9/16	9/16	210	273	9/32	250	314	.094	.103	168	.143	5/16
7/16	8125	750	625	5/8	5/8	210	.328	21/64	.297	.368	.094	.103	202	.168	5/16
1/2	875	.812	.750	3/4	3/4	210	.355	3/8	.328	412	106	.103	219	.188	3/8
9/16	1 000	.937	.812	13/16	13/16	245	410	27/64	375	466	118	.120	253	214	3/8
5/8	1 125	1 000	875	7/8	7/8	281	438	15/32	422	521	133	.137	270	240	1/2
3/4	1 375	1 250	1.000	1	1	.352	547	9/16	500	.612	149	.171	337	.283	9/16
7/8	1 625	—	1 125	1 1/8	1 1/8	.423	—	21/32	594	720	167	.206	—	.334	9/16
1	1 875	—	1 321	1 5/16	1 5/16	.491	—	3/4	656	802	188	240	—	.372	5/8
1 1/8	—	—	—	1 1/2	1 1/2	—	—	27/32	—	—	—	—	—	—	3/4
1 1/4	—	—	—	1 3/4	1 11/16	—	—	15/16	—	—	—	—	—	—	3/4

ASA B18.3-1947.
ASA B18.6-1947.

TABLE VI

Woodruff Key Dimensions*



Key Number	*Nominal Size*	HEIGHT OF KEY		*Distance above Center E*	*Depth of Key Slot in Shaft*
		$C_{max.}$	$D_{max.}$		
204	$\frac{1}{16} \times \frac{1}{2}$	0.203	.194	$\frac{3}{64}$	.1718
304	$\frac{3}{32} \times \frac{1}{2}$	.203	.194	$\frac{3}{64}$	.1561
305	$\frac{3}{32} \times \frac{5}{8}$	.250	.240	$\frac{1}{16}$	.2031
404	$\frac{1}{8} \times \frac{1}{2}$	.203	.194	$\frac{3}{64}$	.1405
405	$\frac{1}{8} \times \frac{5}{8}$	.250	.240	$\frac{1}{16}$	.1875
406	$\frac{1}{8} \times \frac{3}{4}$	.313	.303	$\frac{1}{16}$	.2505
505	$\frac{5}{32} \times \frac{5}{8}$	.250	.240	$\frac{1}{16}$	.1719
506	$\frac{5}{32} \times \frac{3}{4}$	.313	.303	$\frac{1}{16}$	.2349
507	$\frac{5}{32} \times \frac{7}{8}$	.375	.365	$\frac{1}{16}$	.2969
606	$\frac{3}{16} \times \frac{3}{4}$	.313	.303	$\frac{1}{16}$	.2193
607	$\frac{3}{16} \times \frac{7}{8}$	.375	.365	$\frac{1}{16}$	.2813
608	$\frac{3}{16} \times 1$	.438	.428	$\frac{1}{16}$	.3443
609	$\frac{3}{16} \times 1\frac{1}{8}$	.484	.475	$\frac{5}{64}$	.3903
807	$\frac{1}{4} \times \frac{7}{8}$	.375	.365	$\frac{1}{16}$	.2500
808	$\frac{1}{4} \times 1$	.438	.428	$\frac{1}{16}$	.3130
809	$\frac{1}{4} \times 1\frac{1}{8}$	.484	.475	$\frac{5}{64}$	.3590
810	$\frac{1}{4} \times 1\frac{1}{4}$	.547	.537	$\frac{5}{64}$	.4220
811	$\frac{1}{4} \times 1\frac{3}{8}$	.594	.584	$\frac{3}{32}$	.4690
812	$\frac{1}{4} \times 1\frac{1}{2}$	.641	.631	$\frac{7}{64}$	.5160
1008	$\frac{5}{16} \times 1$	.438	.428	$\frac{1}{16}$	.2818
1009	$\frac{5}{16} \times 1\frac{1}{8}$	.484	.475	$\frac{5}{64}$	.3278
1010	$\frac{5}{16} \times 1\frac{1}{4}$	.547	.537	$\frac{5}{64}$	.3908
1011	$\frac{5}{16} \times 1\frac{3}{8}$	.594	.584	$\frac{3}{32}$	.4378
1012	$\frac{5}{16} \times 1\frac{1}{2}$	.641	.631	$\frac{7}{64}$	.4848
1210	$\frac{3}{8} \times 1\frac{1}{4}$	.547	.537	$\frac{5}{64}$	.3595
1211	$\frac{3}{8} \times 1\frac{3}{8}$	.594	.584	$\frac{3}{32}$	.4065
1212	$\frac{3}{8} \times 1\frac{1}{2}$	.641	.631	$\frac{7}{64}$	.4535

* ASA B17f-1930.

All dimensions in inches. Key numbers indicate the nominal key dimensions. The last two digits give the nominal diameter in eighths of an inch and the digits preceding the last two give the nominal width in thirty-seconds of an inch.

TABLE VII

Wrought Iron and Steel Pipe

STANDARD WEIGHT							HEAVY			
					Nominal Wall Thickness		*Nominal Wall Thickness*			
							Extra Heavy		*Double Extra Heavy*[2]	
Nominal Size	*Outside Diameter (All Weights)*	*Threads per Inch*	*Tap Drill Sizes*[1]	*Distance Pipe Enters Fitting*	*Wrought Iron*	*Steel*	*Wrought Iron*	*Steel*	*Wrought Iron*	*Steel*
$\frac{1}{8}$	.405	27	$\frac{11}{32}$	$\frac{5}{16}$	.070	068	.098	.095	—	—
$\frac{1}{4}$	.540	18	$\frac{7}{16}$	$\frac{7}{16}$	.090	.088	.122	.119	—	—
$\frac{3}{8}$	.675	18	$\frac{19}{32}$	$\frac{7}{16}$	.093	.091	.129	.126	—	—
$\frac{1}{2}$	.840	14	$\frac{23}{32}$	$\frac{9}{16}$	111	.109	.151	.147	.307	294
$\frac{3}{4}$	1 050	14	$\frac{15}{16}$	$\frac{9}{16}$	115	113	.157	.154	.318	308
1	1 315	$11\frac{1}{2}$	$1\frac{5}{32}$	$\frac{11}{16}$	.136	.133	.183	.179	.369	358
$1\frac{1}{4}$	1 660	$11\frac{1}{2}$	$1\frac{1}{2}$	$\frac{11}{16}$	.143	140	.195	.191	.393	382
$1\frac{1}{2}$	1 900	$11\frac{1}{2}$	$1\frac{23}{32}$	$\frac{11}{16}$	.148	145	.204	.200	.411	400
2	2 375	$11\frac{1}{2}$	$2\frac{3}{16}$	$\frac{3}{4}$	158	154	.223	.218	.447	436
$2\frac{1}{2}$	2 875	8	$2\frac{5}{8}$	$1\frac{1}{16}$	208	.203	.282	276	.565	.552
3	3 500	8	$3\frac{1}{4}$	$1\frac{1}{8}$	221	216	.306	300	.615	600
$3\frac{1}{2}$	4 000	8	$3\frac{3}{4}$	$1\frac{3}{16}$	231	226	.325	318	—	—
4	4 500	8	$4\frac{1}{4}$	$1\frac{3}{16}$	242	.237	.344	.337	690	674
5	5 563	8	$5\frac{5}{16}$	$1\frac{5}{16}$	263	.258	.383	.375	.768	750
6	6 625	8	$6\frac{3}{8}$	$1\frac{3}{8}$	286	.280	441	.432	884	864
8	8.625	8	—	—	329	.322	510	.500	895	875

ASA B36.10-1939.
ASA B2.1-1945.
All dimensions in inches.

1. Not American Standard.
2. Not American Standard but is commercially available. See ASA B36.10-1939 for sizes larger than 8″.

INDEX

J

K

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M