BASIC UNITS
IN
MECHANICAL DRAWING

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MECHANICAL DRAWING

BOOK II

BY

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PREFACE

This volume, like Book I which preceded it, is designed to be a real teaching aid. It is not organized as a series of conventional chapters but as a group of teaching or learning units. The material in each unit is so organized that a student can easily find the facts he needs in order to understand the unit and the directions telling him how to perform the operations involved.

The two volumes taken together are intended to cover the field of mechanical drawing, the graphical language, in the same sense that grammar and rhetoric cover the written language. The four forms of expression, namely, orthographic, isometric, oblique and perspective, have been dealt with thoroughly and fundamentally. The principles laid down in these four forms of expression may be applied in any of the specialized fields of drawing such as machine, map, architectural or structural drawing.

Mechanical drawing embraces a body of knowledge which may be applied to many practical uses, just as rhetoric may be employed in many forms of literary expression. Although this body of knowledge exists separate and apart from its practical applications, such applications have been indicated in many of the problems given in order to provide a motivation for the work.

In addition, several units of specialized applications, such as "Pipe Layouts," "Wiring Diagrams" and "Charts and Diagrams," have been included because of their immediate usefulness to students.

The text has been designed so that a unit may be covered in a forty-minute study period, thus laying the foundation for a recitation period in which the instructor may amplify the text discussion and clear up difficulties. It will also be found serviceable for individual instruction where classes are large since each unit is in reality an instruction sheet for the guidance of the pupil and not merely a theoretical discussion.

Questions have been given with each unit for the twofold purpose of guidance and quizzing. The student should be encouraged to use them as a guide and check upon the thoroughness of his study. They will also be found convenient as a basis for weekly written quizzes.

A graded series of problems accompanies each unit. The easier problems are given first and the more difficult ones last. One student is not expected to cover all the problems in any one unit. By a judicious assignment of problems the class may be kept moving forward as a homogeneous unit, each student finding work of a challenging character yet within the limits of his ability. The problems have also been selected to provide as wide a range of practical application as seemed necessary to give reality and motivation to the work.

Standard sheet layouts are presented at the close of the first unit. Two scales are used for most problems throughout the book. Scale A is for the larger-size sheet, and Scale B for any one of the four smaller sizes.

The book is arranged in two parts of seventeen units each. Each part is intended to supply an abundance of material for one semester's work. The order of units as arranged will be found satisfactory, but they may be assigned in a different order if so desired except that groups of units dealing with one major topic, as, for example, the units on "intersections" or those on "isometric drawing" should be assigned in the order given.

The text is designed primarily for students in high schools, technical institutes or teachers' colleges. Flexibility and practical utility have been the guiding principles of the authors. The book is planned to be used in both class and drafting room.

The authors wish to acknowledge their indebtedness to the Crane Company, Pratt & Whitney, the Simmons-Boardman Publishing Company and others whose courtesies are acknowledged at specific points in the book; also to their colleagues, Messrs. Albert Jorgensen and J. T. Lendrum, for their assistance in preparing some of the drawings.

R. P. Hoelscher
A. B. Mays

CONTENTS

Part I

Part II

BASIC UNITS IN MECHANICAL DRAWING

PART I

UNIT I

LETTERING

PURPOSE OF UNIT 1

It is the purpose of Unit 1 to teach the shapes of the lower-case letters and to show how to make them.

WHAT YOU SHOULD KNOW ABOUT LOWER-CASE OR SMALL LETTERS

Two kinds of letters. Two kinds of letters are commonly used in lettering notes and titles upon drawings intended for shop or construction purposes, namely, capital, or upper-case, letters; and small, or lower-case, letters. The names upper- and lower-case letters came from the fact that formerly the capitals were kept in the upper part of the case of type which the printer used, while the small letters were kept in the lower part.

Basic elements of letters. As is true of capital letters so with small letters, the oval and the straight stem form the basic elements from which most of the letters are made. The shape of the oval in lower-case letters is the same as for capital letters but it is smaller in size. For normal letters the oval should be about four-fifths as wide as it is high.

Guide lines. Guide lines should always be used in lettering. The middle guide line is drawn two-thirds of the total height from the bottom.

Slope lines. The proper slope for slant letters is about 1 to 2½. Slope lines may be used at first, but as soon as possible one should learn to letter without them.

Letter shapes. The letter shapes may best be learned by arranging them in groups of similar letters as shown below. This aids the beginner to build correct habits in making the strokes which form the letters.

Speed in lettering. It is important for the beginner to try to letter rapidly as well as accurately so that he will form the correct habits of speed and accuracy at the same time.

Position of the pen or pencil. Hold the pen or pencil lightly in the fingers in the usual writing position. The pen should be held straight forward and not twisted to right or left.

HOW TO MAKE LOWER-CASE LETTERS

First, always rule guide lines for any lettering whether for a practise exercise or for only a word upon a drawing.

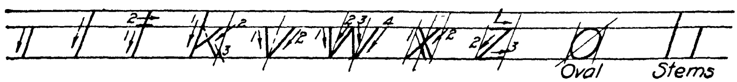


Fig. 1. Straight stroke letters.

For practise begin with guide lines about ⅜-inch high and practise the ovals and straight stems independently until both can be made smoothly and perfectly.

Then with the correct copies of the letters before you practise making the letters. Criticize each letter as you make it, by comparison with the text to see wherein it is wrong, and then attempt to improve it. Make few letters thoughtfully rather than many without critical examination.

To make *i, l, t, k, v, w, x* and *z*. Study carefully the direction and order of the strokes as shown in Fig. 1. Make all stems with an even pressure throughout the stroke. Cross the *t* slightly above the middle guide line. Make the stem of *k* the full height of the guide lines. Make the third stroke of *k* end slightly to the right of the beginning point of the second stroke, as shown in Fig. 1. Make the first and second strokes of *v* so that the slant lines will bisect the angle between them. Notice that *w* is merely two *v*'s. Make the top of *z* slightly narrower than the bottom.

To make *o, c, e* and *s*. Notice carefully the order and direction of the strokes as shown in Fig. 2. Start the strokes always at the top and use two strokes. Practise doing this until it is a habit. Slant the oval so that the slant line runs through the exact center from top to bottom. Start the second stroke of *e* as though you were to make an *o*, then curve it into a straight bar slightly above the center. Make the top part of *s* narrower than the bottom.

To make *a, b, d, g, p* and *q*. Again, study carefully the examples as given in Fig. 3. Notice that all these letters are

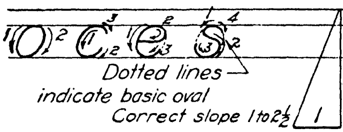


FIG. 2. Oval letters.

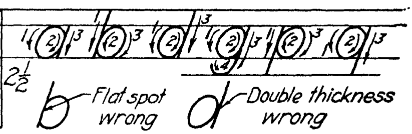


FIG. 3. Combination stem and oval letters.

combinations of straight stems and ovals. Be sure that there are no flat places where the stems join the ovals, and that there is only one thickness of line at the point where the ovals and stems join. Practise carefully the order of making the strokes as indicated by the numbers in Fig. 3. Make the lower part of the stems of *g*, *p* and *q* extend below the bottom guide line the same distance that the stems of *b* and *d* extend above the middle guide line. Avoid the wrong way of making *b* and *d* shown in Fig. 3.

To make *f, h, j, m, n, r, u* and *y*. Study the letters and the strokes used in Fig. 4. Notice that all these letters are combinations of parts of ovals and straight lines. Make the straight stem of *f* extend from the middle guide line to the bottom. Cross the *f* as you do *t*. Make *j* straight above the bottom guide line and curved below. Likewise begin the curve of the stem of *y* below the bottom guide line, and make it straight above this line. Make the straight part of the second stroke of *h*, *m* and *n* extend a little more than half the height of the letter, and the straight part of the strokes in *u* a little less than half the height as shown in Fig. 4.

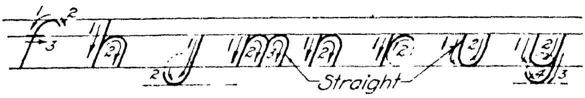


FIG. 4. Combination stem and partial oval letters.

To make numerals. Make numerals the full height of the guide lines, as shown in Fig. 5. Notice that the top parts of *2*, *3*, *5*, *6* and *8* are slightly narrower than the bottom parts. Practise carefully the order of strokes as shown in Fig. 5 and give special attention to the slant of the ovals, stems

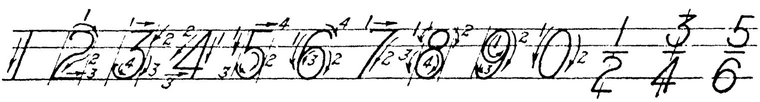


FIG. 5. Direction of strokes of numerals.

and part-ovals. Make fractions extend above and below the guide lines as shown in Fig. 5, and make the line between numerator and denominator horizontal. Each numeral in a fraction is two-thirds the size of the corresponding whole number.

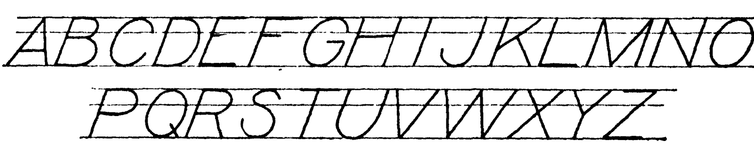


FIG. 6. Capital letters.

The capitals in Fig. 6 are reproduced from Book I only for convenient reference.

QUESTIONS

1. Show by a large free-hand sketch the proper relation of width and height of the normal letter *O*.

2. Show by a large sketch how the letter *C* is developed from the oval.

3. Show by a large sketch how the letter *e* is developed from the oval. Indicate on the sketch the direction of strokes.

4. Show by a large sketch how the letter *S* is developed from the oval.

5. Show by a large sketch just how the oval and straight stem should be made to form such letters as *a*, *b*, *d*, *p* and *g*.

6. Show by a large sketch how the bottom of the letters *g*, *j* and *y* should be made.

7. Make a large sketch showing the proper construction of the letter *k*.

8. Show by a large sketch how the slope of such letters as *v*, *w* and *x* is determined.

9. What should be the relative height of the letters *o*, *a*, *e* and *c*, to *b*, *d* and *h*?

10. What is the relative height of the numbers in fractions to the whole numbers?

11. In what direction should the bar separating the numerator and denominator of a fraction be drawn?

12. How may the greatest benefit be attained in lettering practise?

13. What is the proper slope for slant letters? Illustrate by a dimensioned sketch.

PROBLEMS

Draw the standard border line and title space for the small drawing sheet. (See general instructions following the problems.) Then divide the sheet into four equal rectangles by means of horizontal and vertical center lines.

Beginning $\frac{3}{8}$ inch from the top of each space, rule sets of $\frac{1}{4}$-inch guide lines with $\frac{3}{16}$-inch space between the sets until you come close to the bottom of the space. Draw vertical lines $\frac{1}{2}$-inch in from both sides of the lettering space to give a neat margin all around the lettering area. Then do the problems assigned from the group below. If no special assignment is made by the instructor, do them in the order given.

1. Fill one lettering space with ovals as shown at the right in Fig. 1. As an aid, sketch in first the parallelogram and then make the oval tangent at the middle point of each side. Note that the axis of the oval has a greater slant than the parallelogram. As skill is acquired, omit the parallelogram.

2. Fill one lettering space with alternate long and short straight stems as shown at the right in Fig. 1.

3. Fill one lettering space with the letters shown in Fig. 2.

Make first one line of each letter, and then for the remainder of the space repeat the letters in the order given.

4. Fill one lettering space with the letters shown in Fig. 3, repeating the letters in the order given.

5. Fill one lettering space with the letters shown in Fig. 4, repeating them in the order given.

6. Fill one lettering space with numerals as shown in Fig. 5. Make the last line of fractions. Include each number in the fractions.

7. Repeat any of the problems above using $\frac{3}{16}$-inch guide lines spaced $\frac{1}{8}$ inch apart.

Note: If a lettering triangle is used, the spacing of the guide lines may be as produced by the triangle instead of as given above.

GENERAL INSTRUCTIONS FOR ALL PROBLEM SHEETS

The layouts for the border line and title space of five different standard drawing sheets are shown in Figs. 7 and

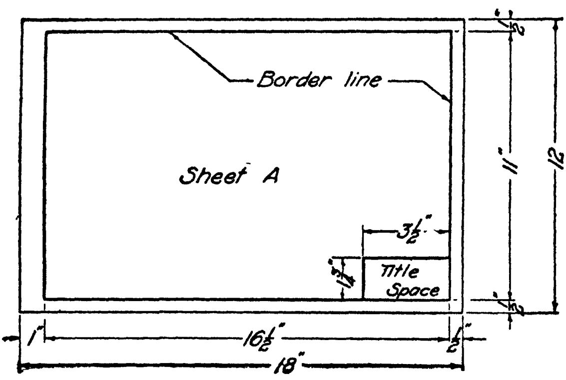


FIG. 7. Standard border line and title space for large sheets.

8. Your instructor will select the one you are to use. Study the dimensions carefully and memorize them so that you may lay out your sheets throughout the semester without continual reference to the figure.

To place the paper on the board. The paper should be placed about 4 or 5 inches from the bottom of the board and about 3 inches from the left-hand edge, as shown in Fig. 9. Place the T-square where you want the lower edge of the paper to be, then let the paper rest upon the T-square and fasten down the upper corners with thumb tacks. As soon as you have the tacks pushed down tight, check up with your T-square to see that the lower edge of the paper is in line. Then put the thumb tacks through the lower corners and push them all down firmly.

To lay out the border line. Having placed the paper on the board, lay out the standard border line and title space as selected by your instructor. Make the measurement with

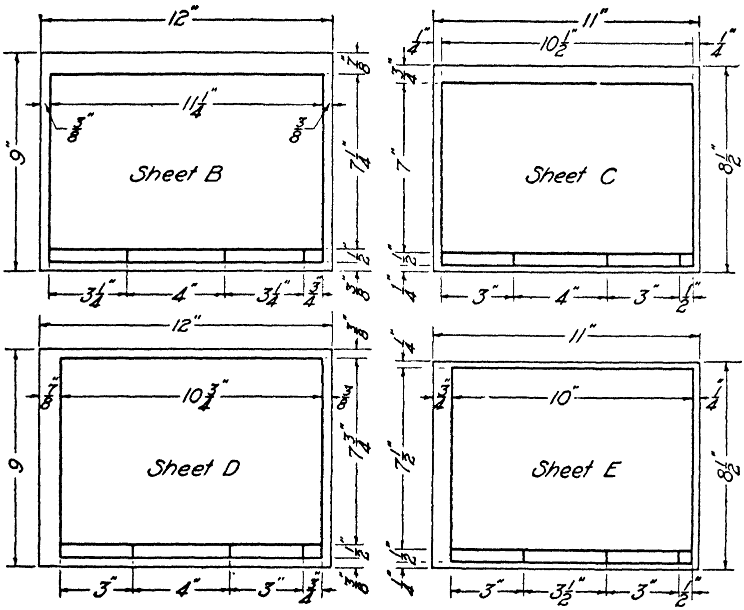


FIG. 8. Standard border lines and titles spaces for small sheets.

your scale first horizontally as shown in Fig. 9 and rule in the two vertical lines lightly with a 6H pencil. Second, make the vertical measurements and rule in the horizontal lines. Subdivide the title space as shown in Fig. 10 or 11, as the case may be.

Since the vertical lines were drawn first, these lines will over-run the corners. With your pencil-eraser remove all lines which extend beyond their proper limits. Now go over the entire layout with a 4H pencil, making the lines strong and firm but not grooving the paper. Be very careful not to over-run any of the corners. Letter in all parts of the title to the best of your ability, ruling guide lines to aid you as shown in Fig. 11. The name of the drawing will be determined by the problem which the instructor assigns.

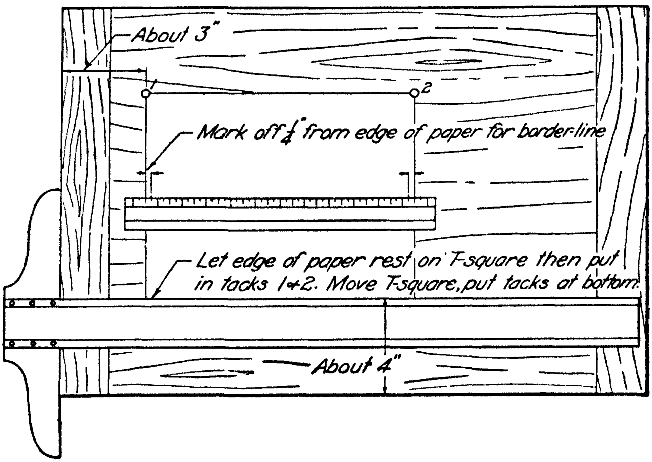


FIG. 9. Placing paper and marking border line.

After the border line and title layout are as nearly perfect as you can make them, both as to accuracy of measurement

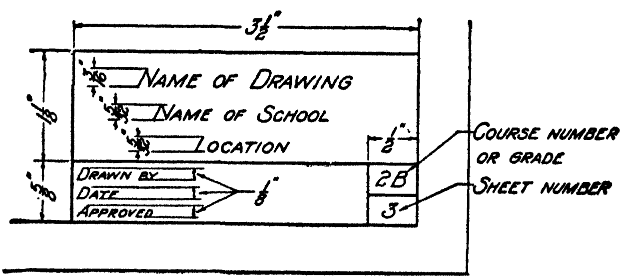


FIG. 10. Standard title form for large sheets.

and neat appearance, proceed upon the exercises assigned by the instructor.

Note: If the drawing paper as it comes to you is a little scant of the dimensions given in Fig. 7 or 8, let this shortage appear in the space inside the border line. In other words, always keep the margin between the border line and the

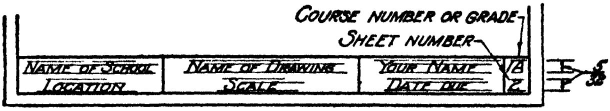


FIG. 11. Standard title forms for small sheets.

edge of the paper constant, since this will make the best appearing sheet.

UNIT II

GEOMETRICAL CONSTRUCTION. CONIC SECTIONS

PURPOSE OF UNIT II

It is the purpose of this unit to show what the conic sections are, some of their properties and uses and how they are constructed.

WHAT YOU SHOULD KNOW ABOUT CONIC SECTIONS

Meaning of the term. The term conic sections is applied to certain geometrical curves which may be formed by passing a cutting plane in various positions through a cone. The position of the cutting plane relative to the cone determines the type of curve which is generated.

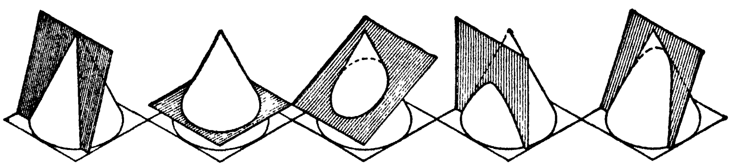


FIG. 1. Conic sections.

The circle. A circle is formed by passing a cutting plane parallel to the base of a right circular cone. To describe its position in another way, the plane may be said to be perpendicular to the axis of the cone. See Fig. 1.

The ellipse. An ellipse is formed by passing a cutting plane through a right circular cone at an angle with the axis as shown in Fig. 1. The plane must make an angle with the axis greater than the angle which the elements make with the axis.

The parabola. A parabola is formed by passing a cutting plane through a cone parallel to one of the elements, that is to say, it makes the same angle with the axis of the cone as do the elements. See Fig. 1.

The hyperbola. An hyperbola is formed by passing a cutting plane through a cone parallel to the axis of the cone. See Fig. 1. It should be noted that the cone may be extended on both sides of the vertex and hence it will be cut on both sides of the vertex by the plane, thus forming two branches of the curve.

It should be noted that, if the cutting plane passes through the vertex of the cone and makes an angle with the axis less than the vertex angle of the elements, it will cut along straight lines or elements of the cone as shown in Fig. 1.

DEFINITION AND USE OF CURVES

The circle. The circle may be defined as the path of a point moving in a plane at a fixed distance from a given fixed point called the center. The circle is the most commonly used of all the geometric curves since it is the basic curve of all wheels, gears, rollers, etc.

The ellipse. The ellipse may be defined as the path of a point moving in a plane in such a manner that the sum of its distances from two fixed points, called foci, is constant. The paths of planets around the sun are nearly circular ellipses; the comets move in long elliptical orbits. Approximations to the ellipse are found in many concrete arch bridges and arched doorways in houses.

The parabola. The parabola may be defined as the path of a point in a plane whose distances from a given line and a given point, called the focus, are always equal. The parabola is used as a basic curve for reflectors in headlights and searchlights. If the source of light is placed at the focus the reflected rays are parallel. It is also used as the transition curve in changing from one grade to another on highways and railroads.

The hyperbola. The hyperbola is the path of a point moving in a plane so that the difference of its distances from two fixed points, called foci, is constant.

HOW TO CONSTRUCT CONIC SECTIONS

The circle and the straight line are constructed by means of the compass and straight edge respectively, and hence need no discussion. The other three curves may be constructed in several different ways. All of them may be constructed by auxiliary projection from a cone which has

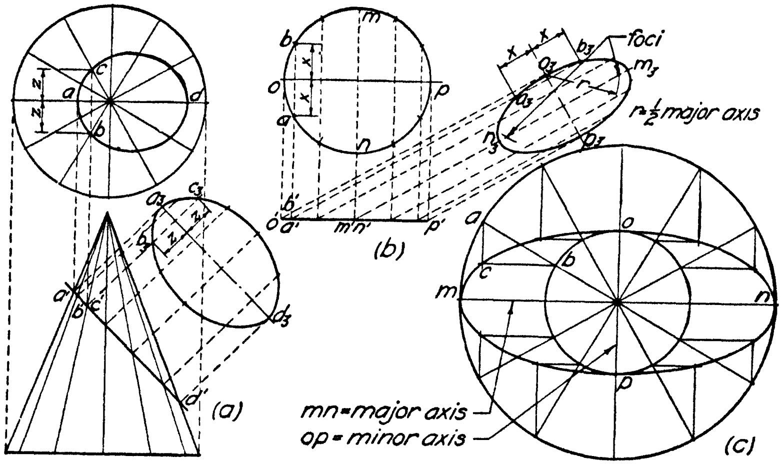


FIG. 2. Exact methods of constructing an ellipse.

been cut in the proper manner. They may also be constructed by plotting points in conformity to the definitions.

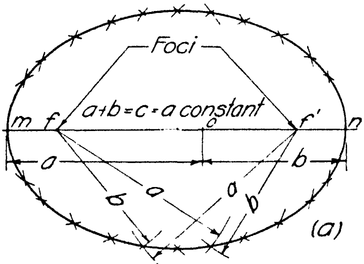
To construct an ellipse. To construct an ellipse by auxiliary projection from a truncated cone, draw the cone as shown in Fig. 2a with the cutting plane as shown edgewise in the front view at $a'b'c'd'$. Locate twelve equally spaced elements in the top view and project them to the front view. Find the curve of intersection in the top view. Next draw a center line a_3d_3 at a convenient place and parallel to the cutting plane $a'd'$. This center line corresponds to the horizontal center line in the top view. Draw perpendiculars from $a'b'c'd'$, etc., to the line a_3d_3. On these lines set off distances on opposite sides of the center line a_3d_3 equal to those in the top view like z–z for points b and c. Draw a smooth curve through the points thus obtained in the auxiliary view.

To construct an ellipse by projecting a circle on a plane which is inclined to the plane of the circle, draw the horizontal and vertical projections of the circle as shown in Fig. 2b. In the top view locate twelve equally spaced points on the circle and project them to the front view which is a straight line, or edgewise view of the circle. Draw the center line as o_3p_3, representing the auxiliary plane, at the desired angle with the front view of the circle, and erect lines from the points in the front view perpendicular to o_3p_3. On opposite sides of o_3p_3 set off distances such as x–x, obtained from the top view, to locate points a_3 and b_3 according to the usual rules of auxiliary projection. Draw a smooth curve through the points thus obtained.

To construct an ellipse when the major and minor axes are given, draw the major axis, as *mn*, Fig. 2c, and draw the minor axis through its center point, as *op*; using *mn* as a diameter draw a circle, and using *op* as a diameter draw another circle. With the triangles and T-square divide the circles into twelve equal parts, as shown. Where a dividing line cuts the circles, as at *a* and *b*, draw a vertical line through the point on the large circle and a horizontal line through the point on the small circle. The intersection of these two lines, as *c* is a point on the ellipse. Draw a curve through the points thus found.

To construct an ellipse when the distance between the foci and the sum of the distances from the foci to a point on the ellipse are given, first draw a line equal in length to the sum of the distances mentioned above. This is the major axis *mn* of the ellipse in Fig. 3a. Locate the foci f and f' on this line equidistant from the center of it. Divide the line between f and f' into one-fourth as many parts as you wish to have points on the curve. Set your compass to the two distances into which each of these points divides the major axis as illustrated for *a* and *b* and draw arcs with the centers at *f* and *f'*. Two arcs must be drawn on each side of the center line for each setting of the compass. Thus one division point between *f* and *f'* gives four points on the ellipse. After all points have been obtained draw a smooth curve through them with an irregular curve.

To draw an approximate ellipse when the enclosing rectangle or the two axes are given, draw the horizontal and vertical center lines *eb* and *cd* which become the major and minor axes, as shown in Fig. 3b, and connect *c* and *b*. With the intersection of the axes as center and a radius equal to



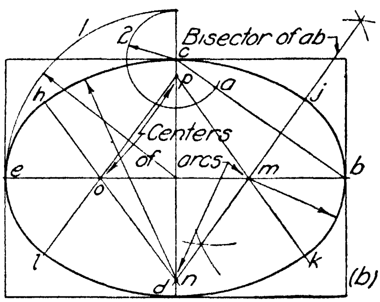


FIG. 3a. Exact method of constructing an ellipse.
FIG. 3b. Four-center approximate method of constructing an ellipse.

half the major axis draw arc 1 intersecting an extension of the minor axis. With the end of the minor axis *c* as center describe arc 2 locating *a* on *cb*. Erect the perpendicular bisector of *ab*. Where this bisector crosses the axes two centers are located as *m* and *n*. From these centers by symmetry locate the corresponding centers *o* and *p*. With *n* and *p* as centers respectively and the distance *nc* as radius draw the arcs *hj* and *lk*. Then with *m* and *o* as centers and *mb* as radius draw arcs *jk* and *lh*. This method is useful in laying out a semi-ellipse for a doorway.

To construct a parabola. To construct a parabola by using an auxiliary projection from the section of a cone, draw the *H* and *V* projections of a cone and find the projection in *H* of the section cut by the cutting plane shown edgewise in V, as in Fig. 4a. Follow the same procedure as described for the ellipse. Using distances marked x from the H projection, find the projection of the curve on an auxiliary plane placed parallel to the cutting plane as shown. Follow the usual rules for auxiliary projection in all respects.

To construct a parabola by plotting points by definition with the directrix and focus given. Draw a line through the focus perpendicular to the directrix. Step off a convenient number of points on this line and draw perpendiculars through these points. With the focus as center draw arcs

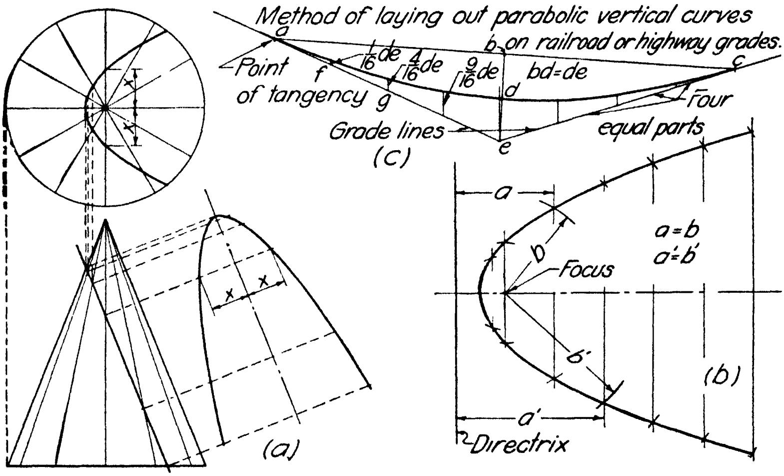


FIG. 4. Methods of constructing a parabola.

cutting the perpendiculars so that the points of intersection of arcs and perpendiculars are equidistant from the focus and the directrix in each case as indicated in Fig. 4b. Draw a curve through the points thus found.

To construct a parabola tangent to two intersecting lines, locate points like a and c on the lines and equidistant from e as in Fig. 4c. Draw a line connecting the points a and c and bisect it as at b. Draw a line from the midpoint b to e. Bisect this line be at d. The point d is on the parabola. Now the offset from a tangent to the parabola varies as the square of the distance along the tangent. If the offset at the center *de* is known the others can easily be found by dividing the distance between *a* and *e* into any convenient number of equal parts. If four are used as in Fig. 4c then the offset at *f* must be one-sixteenth of that at *e* since *f* is just one-fourth as far along the tangent from *a* as is *e*. One-sixteenth is the square of one-fourth. If five divisions had been used the first offset would have been one-twenty-fifth that at the center.

To construct an hyperbola. To construct an hyperbola by auxiliary projection proceed as in the constructions of

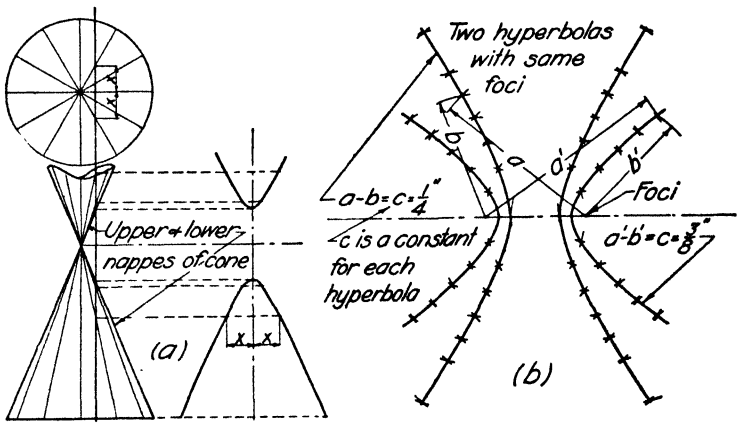


FIG. 5. Methods of constructing an hyperbola.

the ellipse and parabola as already described, and as shown in Fig. 5a.

To construct the hyperbola by plotting points when the foci are given and the difference of the distances from a given point on the curve to the foci is also given. Proceed as indicated in Fig. 5b, using the foci as centers and such radii as to make $a - b = c$ (a constant difference). Draw a smooth curve through the points found with an irregular curve. (Note that by changing the value of $a - b$ more than one pair of hyperbolas may be drawn from the same foci, as indicated in Fig. 5b.)

QUESTIONS

1. Name the curves which are called conic sections.
2. Why are the curves in this unit called conic sections?
3. Show by a sketch and explain how a plane must be passed to cut straight lines from a cone.
4. Explain how a plane must be passed to cut a circle from a right circular cone.
5. Show by a sketch and explain how a plane must be passed to cut an ellipse from a cone.
6. Show by a sketch and explain how a plane must be passed to cut a parabola from a cone.
7. Show by a sketch and explain how a plane must be passed to cut an hyperbola.
8. Show by a sketch how an ellipse may be constructed by projection from a circle.
9. Show by a sketch how an ellipse may be drawn by use of two circles.
10. What practical use is made of the parabola?
11. Define the ellipse as the path of a moving point.
12. Define the parabola as the path of a moving point.
13. Define the hyperbola as the path of a moving point.
14. Show by a sketch how to lay out an approximate ellipse for a doorway.

PROBLEMS

Lay out the standard border line and title space, then divide the drawing sheet into two equal spaces by means of a vertical line. In each space do one of the problems assigned from the group below:

1. Draw a cone having a base circle $2\frac{1}{2}$ inches in diameter and an altitude of 3 inches. By auxiliary projection construct an ellipse having a major axis of 2 inches. The cutting plane shall make a 45-degree angle with the base.

2. Draw a cone of the same size as in Prob. 1 and then construct a parabola by auxiliary projection. The cutting plane shall pass through the mid-point of the axis.

3. Draw a cone of the same size as in Prob. 1, then construct an hyperbola. Draw one branch only. The cutting plane shall pass $\frac{1}{2}$ inch away from the axis.

4. Construct an ellipse having a minor axis of $1\frac{1}{4}$ inches and a major axis of 3 inches by projection from a 3-inch diameter circle.

5. By means of two circles construct an ellipse having a minor axis of 2 inches and a major axis of 4 inches.

6. Draw two intersecting lines which make 120 degrees with each other, and then draw a parabola which shall be tangent to the two lines 2 inches from the point of intersection.

7. Draw a vertical line $\frac{1}{2}$ inch from the left edge of the drawing space, then draw the horizontal center line of the space and mark on it a point 1 inch to the right of the first line. With the vertical line as a directrix and the point as a focus construct a parabola according to definition. See Fig. 4b.

8. On the horizontal center line of the drawing space lay off two points $1\frac{1}{2}$ inches apart each $\frac{3}{4}$ inch from the middle of the center line; with these as foci construct both branches of an hyperbola when the constant difference from a point on the curve to the foci is $\frac{1}{2}$ inch. See Fig. 5b.

9. Construct an ellipse having a major axis of $3\frac{1}{2}$ inches and a minor axis of 2 inches by the four-center approximate method. See Fig. 3b.

10. A doorway is 5′–0″ wide and 7′–6″ high. Construct a pleasing and practical elliptical top for this opening by the approximate method.

UNIT III

LETTERING—COMPOSITION

PURPOSE OF UNIT III

It is the purpose of Unit III to give the rules for good lettering and to show how to make good lettering in titles and upon drawings of all kinds.

WHAT YOU SHOULD KNOW ABOUT LETTERING OF COMPOSITION

Rules for good lettering. The ability to do good lettering is not an inherited characteristic. Anyone can acquire the

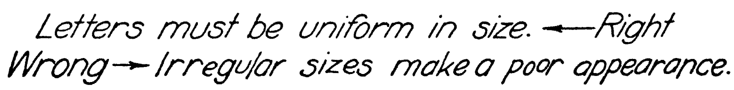


FIG. 1. Uniformity of size is necessary.

ability by the careful observance of a few rules while doing a little practise. The entire set of rules may be summarized under the one word uniformity. Good lettering requires uniformity of shape, size, slope, spacing, style and weight.

Uniformity of shape. Each letter must have the correct shape or form, and all letters of any one kind in a composition must be like all others of that kind, that is to say, all *a*'s will be alike, all *b*'s will be alike, and so on.

Uniformity of size. In addition to being alike, letters of a kind must be of the same size. They should always come fully up and down to the guide lines and should be of equal width. All letters based on the oval should have the ovals of exactly the same size. Correct and incorrect examples are shown in Fig. 1.

Uniformity of slope. For the letters having stems the stem determines the slope. For all others a center line or axis must be used to determine the slope. Figure 2 shows the proper slope.

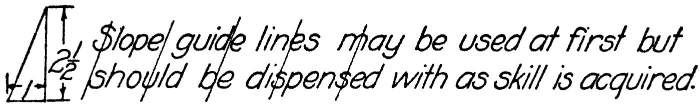


FIG. 2. Slope guide lines a help.

Uniformity of spacing. This rule means that the white areas between letters should be equal. This is accomplished by eye rather than by any attempt at measurement. Letters

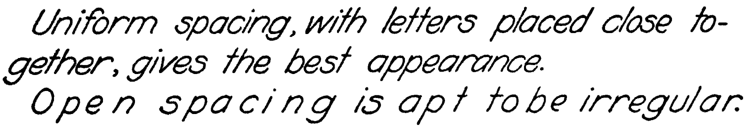


FIG. 3. Uniform close spacing best.

in words should be close together, as illustrated in Fig. 3. Open spacing is hard to read and makes the imperfections of each letter apparent.

Uniformity of style. This means that upper- and lower-case letters must not be mixed, except, of course, where the

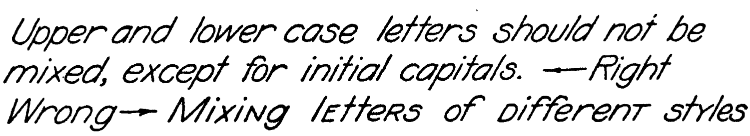


FIG. 4. Uniformity of style necessary.

initial letter of the word must be a capital. See Fig. 4 for correct and incorrect examples.

Uniformity of weight. This requirement means that the thickness of all strokes of the letters will be the same throughout any one composition. This weight must be determined by the pen. Use a heavy pen for heavy, large letters and a light pen for smaller and lighter letters. In general, it may be said that on drawings the lighter lettering is most pleasing. Gillot's pens Nos. 170, 303 and 404 are suitable for light work, as is also the Henry Tank pen No. 5. Tank pens Nos. 12 and 15 are suitable for heavier lettering.

Expanded and compressed lettering. When space demands, lettering may be either expanded or compressed from the normal width, which is four-fifths the height. Expanded, normal and compressed lettering are illustrated in Fig. 5. It should be observed that in the expanded lettering the space between letters is not expanded nearly as much as

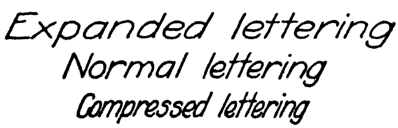


FIG. 5. Expanded, Normal and Compressed lettering.

the letters themselves, thus still retaining the advantage of close spacing.

HOW TO MAKE LETTERING COMPOSITION

To letter composition. Rule first the guide lines for the size of letters you desire to make, either by measurement or, preferably, by means of a lettering triangle. When the lettering is to be balanced within a given area, letter lightly in pencil one line of a length which seems proper for the space. Count the letters in this line and also in the total amount of material which is to be lettered. Compute how many lines this will take, and from this note whether you have begun your first line too high or too low or, perhaps, just right. If not exactly right to make a well-balanced piece of lettering erase the line and begin at the proper place. Keep in mind at all times the six rules regarding uniformity.

Precautions in ink lettering. When lettering in ink the following precautions should be observed in order to insure success.

1. See that the paper is free from all dust, dirt and lint which the pen might accidentally pick up.

2. See that the pen is not filled too full, and do not continue lettering until it is dry. Fill frequently and clean often.

3. Bear down just hard enough for the pen to produce its normal stroke. Do not spread the nibs of the pen.

QUESTIONS

1. What one word summarizes the rules for good lettering?
2. Explain and illustrate what is meant by uniformity of shape.
3. Explain and illustrate what is meant by uniformity of size.
4. Explain and illustrate what is meant by uniformity of slope.
5. What is the correct slope for slant lettering?
6. Explain and illustrate what is meant by uniformity of spacing.
7. Which is the better, compact or open spacing? Why?
8. What is meant by expanded lettering. Illustrate.
9. Explain what is meant by compressed lettering. Illustrate.
10. Explain what is meant by uniformity of style. Illustrate.
11. Explain what is meant by uniformity of weight.
12. What are some of the precautions to be taken when lettering in ink?

PROBLEMS

Lay out the standard border line and title space and then divide the space within the border line into four equal spaces by means of a vertical and a horizontal line. In these spaces, rule guide lines having a total height of $\frac{3}{16}$ inch as illustrated in Fig. 6. Then do the lettering exercises assigned from the following group. Balance the lettering in the center of the space both vertically and horizontally. Keep your mind on the job while lettering.

The good draftsman checks his own work before submitting it to his superior for approval.

FIG. 6.

Lettering practice should always be carried on with attention concentrated on correct letter forms.

FIG. 7.

A few minutes of thoughtful careful lettering practice is worth more than an hour of careless work.

FIG. 8.

Good lettering distinguishes the work of the master craftsman. His titles and notes are always carefully balanced.

FIG. 9.

A line must be parallel to a plane if the projection of the line on the plane shows the line in its true length.

FIG. 10.

Any plane face of an object must be parallel to one of the planes of projection if it is to show true shape in that plane

FIG. 11.

The lettering on a drawing shows whether a man is interested in his work or merely putting in time. It shows the character of the workman.

FIG. 12.

Two lines are said to be parallel when they are the same distance apart throughout their entire length. They are said to meet at infinity.

FIG. 13.

One line is perpendicular to another when the two make an angle of ninety degrees with each other Such lines are said to be at right angles to each other.

FIG. 14.

An orthographic projection is a projection which is made upon the basis that the projecting lines are perpendicular to the plane of projection.

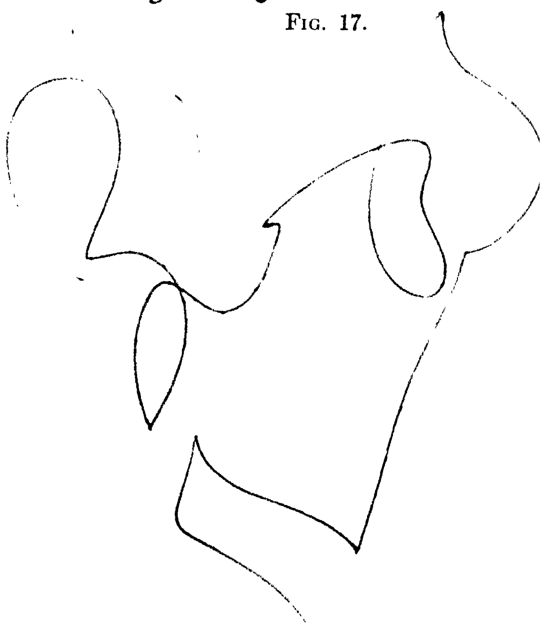
FIG. 15.

A projecting line or line of sight as it is sometimes called is an imaginary line extending from a point on the object to the plane of projection.

FIG. 16.

The third quadrant or angle is used exclusively in the U.S.A. for machine drawing. All quadrants are commonly used in descriptive geometry.

FIG. 17.



UNIT IV

INTERSECTION OF A PLANE WITH PRISMS AND PYRAMIDS

PURPOSE OF UNIT IV

It is the purpose of this unit to show how to find the intersection of a plane with a prism or pyramid.

WHAT YOU SHOULD KNOW ABOUT INTERSECTIONS

Practical uses. The intersection of various surfaces with each other is a problem which often confronts the draftsman

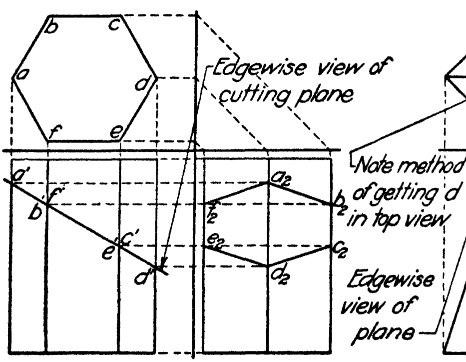


FIG. 1. Intersection of prism and plane.

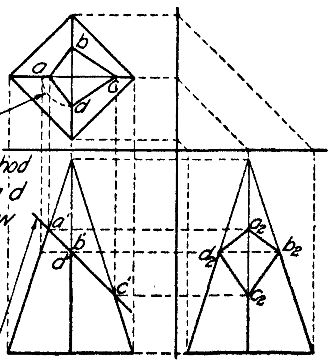


FIG. 2. Intersection of pyramid and plane.

and builder. The simplest form is the intersection of two plane surfaces, which is a straight line. In practical problems these surfaces usually occur in some more or less regular form, such as prisms and pyramids. Common examples are to be found in the hip and valley lines of the roof of a building.

The piercing point. The problem of finding the intersection of a plane and prism or pyramid resolves itself into the simpler one of finding the point where a line passes through a plane. This piercing point can be observed directly if an edgewise view of the plane is obtained as in Figs. 1 and 2. In both cases the cutting plane is perpendicular to the vertical plane and hence shows edgewise in the front view.

Geometric principles. The following geometrical facts about intersections will be of considerable use in obtaining and checking intersections for correctness and accuracy.

1. If the cutting plane intersects the axis of a prism or pyramid and does not cut across the base, the intersection will have the same number of sides as the base.

2. If the cutting plane is parallel to the base the intersection will be of the same shape as the base.

3. If two faces of a prism are parallel the lines of intersection of these faces with the plane are parallel.

Finding and joining points. The point where a line pierces a plane in one view having been found, its position in the other view can be determined by projection. The complete intersection is obtained by joining all the points where the edges of the prism or pyramid pass through the plane. Thus in Fig. 1 the point a' is found directly by observation and a_2 by projecting directly across to the corresponding line in the side view. The others are found in the same way and then connected. An examination of Fig. 2 will show the same method applied to the pyramid. Here the intersection shows as a separate group of lines in both the top and side views while in Fig. 1 the intersection coincides with the outline of the prism in the top view.

HOW TO FIND THE INTERSECTION OF A PLANE WITH A PRISM OR PYRAMID

The method of finding an intersection may be set down in a definite order of procedure.

1. Obtain first an edgewise view of the cutting plane. If such a view is not given in the original views a profile or auxiliary view must be made which will give it.

2. In the edgewise view note where each line or edge of the prism or pyramid pierces the plane.

3. Taking the lines one at a time obtain all projections of the *points* of intersection.

4. Finally connect these points and indicate properly the visible and invisible portions of the object, assuming the plane to be opaque or assuming the portion of the object cut off to be removed.

Several cases will be discussed to illustrate the method.

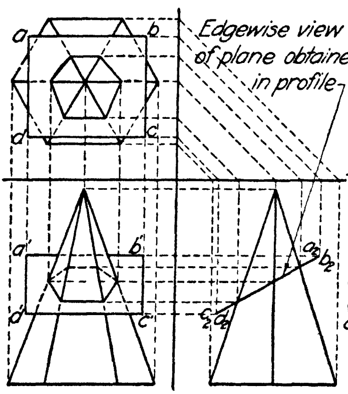


FIG. 3. Profile used to get edgewise view of plane.

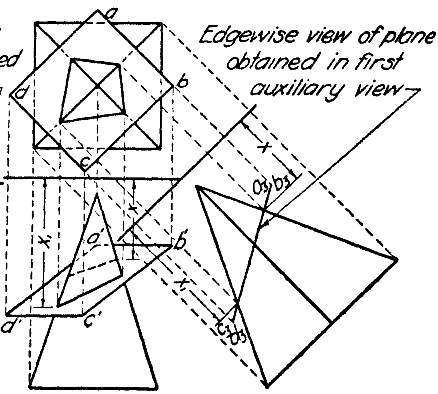


FIG. 4. Auxiliary plane used to get edgewise view of plane.

In Fig. 3 the plane $ABCD$* does not show edgewise in either the front or top view; it is necessary therefore, to get an edgewise view of the plane before attempting to find the intersection. Since the lines AB and CD are parallel to the horizontal and vertical planes the plane containing them will be perpendicular to the profile plane and hence a profile view will show the plane edgewise. The points on the intersection are then found by observation in the side view and projected to the front and top view where they are connected in proper order, thus showing the intersection.

* *Note:* Throughout the text, capital letters are used to designate points in space or on an object while the small letters with prime marks or subscripts are used to designate the projections of the points. This is the same method as was used in Book I.

In Fig. 4 the plane *ABCD* does not show edgewise in any of the three principal views, and hence an auxiliary view must be obtained which will show the cutting plane edgewise. It will be observed that the lines *AB* and *CD* are horizontal (see front view), and therefore an auxiliary plane can be set perpendicular to the horizontal plane and also perpendicular to the plane *ABCD* as shown in Fig. 4. The intersection is formed by observation in the auxiliary view and projected back to the top view and then to the front view in the usual manner.

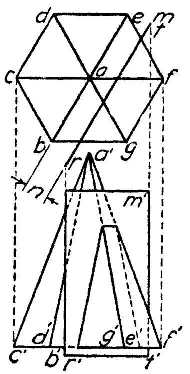


FIG. 5. Cutting plane parallel to edge AB.

In attacking problems which are given verbally it should be remembered that a plane which is perpendicular to the horizontal plane shows edgewise as a line in the top view. Likewise, a plane perpendicular to the vertical plane shows edgewise in the front view. Thus, in Fig. 5 the plane *MRT* may be described as perpendicular to the horizontal plane, parallel to the line *AB* and a distance *n* from it.

QUESTIONS

1. Give an illustration of a practical application of finding the intersection of a plane with prismatic or pyramidal surfaces.
2. Upon what simple process does the finding of an intersection depend?
3. What is the simplest method of finding where a line pierces a plane?
4. How do you distinguish between a prism and a pyramid?
5. How many faces not counting the upper and lower bases have the following prisms: square, pentagonal, heptagonal, octagonal and hexagonal?
6. If a cutting plane intersects the axis of a hexagonal prism or pyramid at right angles, how many edges will the intersection have?
7. If a cutting plane passes parallel to the base of a prism or pyramid, what will be the shape of the intersection?
8. If a cutting plane cuts two faces of a prism which are parallel,

what is the position of the two lines of intersection relative to each other?

PROBLEMS

Lay out the standard border line and title space, and then divide the space inside the border line into two equal rectangles by means of a vertical line.

Find the intersection of the plane and prism or pyramid assigned from the following group: Scale B, full size. Scale A, 2″ = 1″.

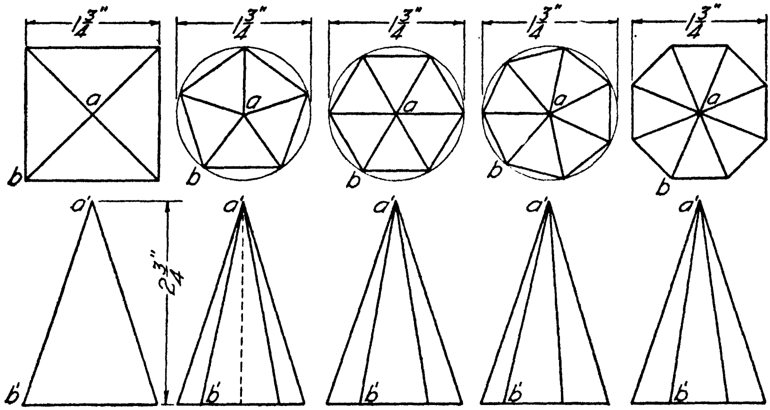


FIG. 6. FIG. 7. FIG. 8. FIG. 9. FIG. 10.

1 to 5. Find the intersection of a plane perpendicular to *V* passing through the mid-point of the axis of an assigned pyramid in Figs. 6 to 10. The plane shall make an angle of 60 degrees with the axis. Complete your drawing with the top part of prism removed.

6 to 10. Same as Probs. 1 to 5 except that the plane shall be perpendicular to *P*. The plane shall make 60 degrees with the axis of the pyramid and pass through its mid-point.

11 to 15. Find the intersection of a plane with a pyramid assigned from Figs. 6 to 10. The plane shall be perpendicular to *H*, parallel to the edge *AB* of the pyramid and ¼ inch from it toward the front. In your drawing show the pyramid with the part in front of the plane left off.

16 to 19. Find the intersection of the plane and pyramid assigned from Figs. 11, 12, 16 and 17. Note that the lines in the figure have been drawn in full. In your problem show the intersection and indicate properly all invisible lines. Assume the plane to be opaque. Leave the entire pyramid in your finished drawing.

20 to 25. Make three views of the small house diagrams assigned from Figs. 13 to 15 and 18 to 20 and show completely the roof lines. These are shown incomplete in the figure. Scale B, $\frac{1}{8}'' = 1'\text{-}0''$. Scale A, $\frac{3}{16}'' = 1'\text{-}0''$.

Note: Each problem of this group requires a full sheet, size *B*, *C* or *D*.

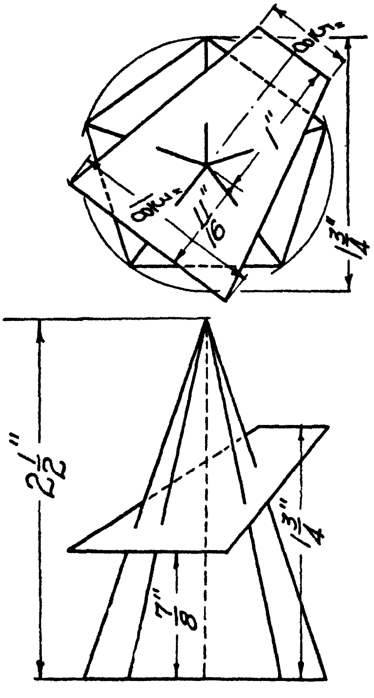


FIG. 11.

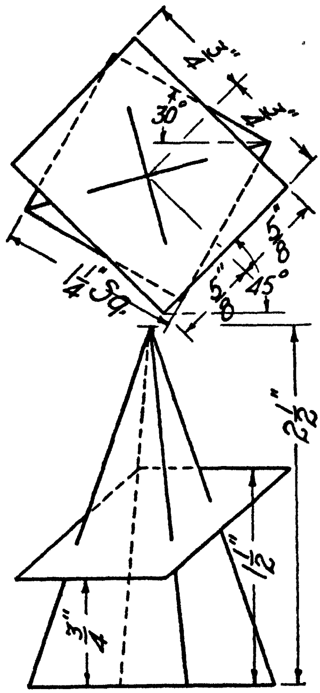


FIG. 12.

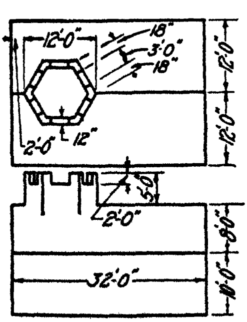


FIG. 13.

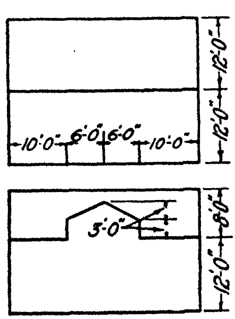


FIG. 14.

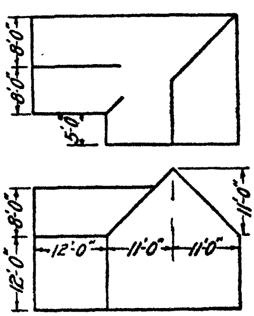


FIG. 15.

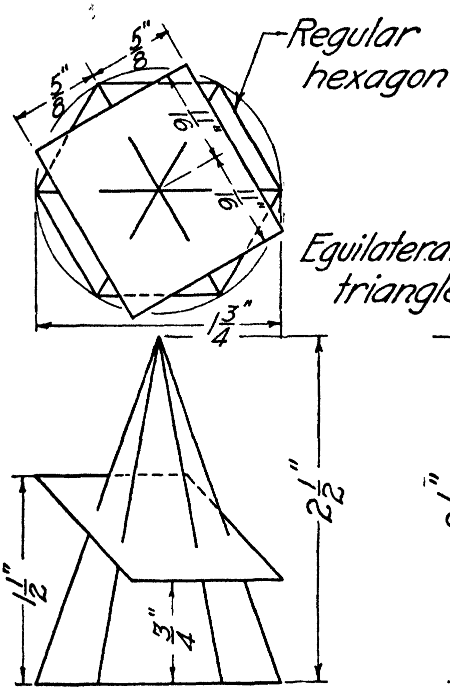


FIG. 16.

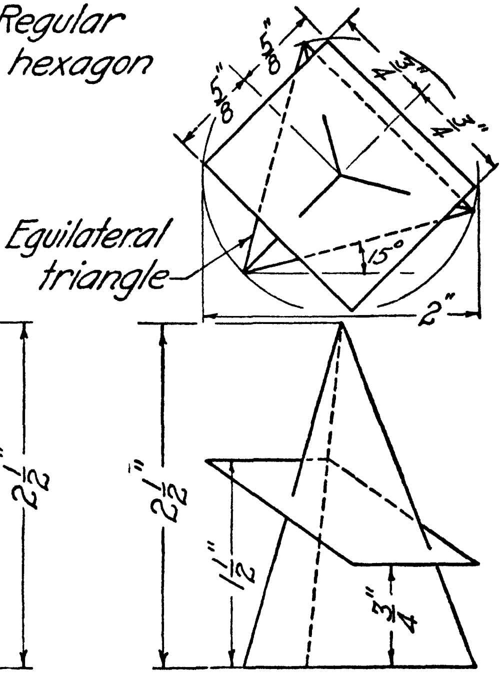


FIG. 17.

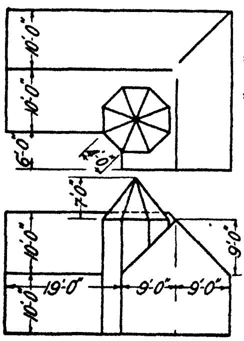


FIG. 18.

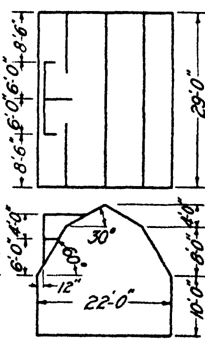


FIG. 19.

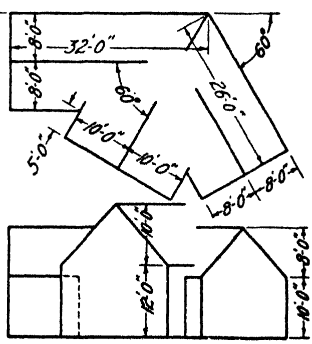


FIG. 20.

UNIT V

DEVELOPMENT OF PRISMS AND PYRAMIDS

PURPOSE OF UNIT V

It is the purpose of this unit to show what developments are, how they are used and how to make them for prisms and pyramids.

WHAT YOU SHOULD KNOW ABOUT DEVELOPMENTS

Definition. A development of a surface shows what the surface would look like if it were cut along some line and

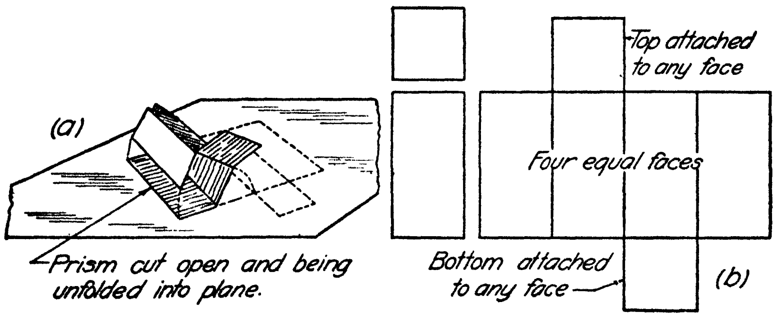


FIG. 1. Development of right prism.

then rolled out into a flat surface. It is the pattern which if properly creased, folded and fastened together will form the surface. Figure 1 shows a development of a right square prism.

Practical uses. Developments are necessary in all sheet-metal work, especially for curved surfaces such as cones and cylinders. In heavy plate work what amounts to a development is made, but each side or face is laid out by itself. This also applies to forms for concrete work. Hence, the fundamental principles of developments are quite useful in construction work.

Principles of development. Every line in a development must show the true length of the line of the object which it represents. This is comparatively simple for right prisms and pyramids since the true length of all lines is usually shown in one of the orthographic views. It should be remembered that lines show in their true length only when they are parallel to a plane of projection. Thus in Fig. 2 none of the slanting edges of the pyramid shows in true length, hence one of them, *AC*, must be turned until it is parallel to the *V* plane as represented in the figure. Then the true length shows in the *V* projection or front view. Since all the slanting edges are of the same length the true lengths of all lines composing the figure are known.

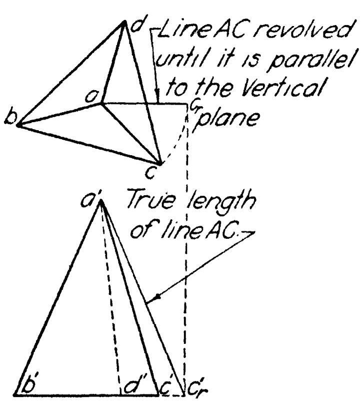


FIG. 2. ·True length of edge AC obtained by revolution.

Adjacent lines in a development must be in their true relationship to each other. This is readily accomplished with pyramids since the faces are triangles and can have only one shape, but more care is required for oblique prisms, as will be explained.

HOW TO MAKE DEVELOPMENTS

Right prisms. In Fig. 1a the right square prism is imagined to be cut along one vertical edge and to have the top and bottom cut along all but one edge. Hence to draw its development lay out its four sides the same size as in the orthographic views, and the top and bottom likewise, as shown in Fig. 1b. The top and bottom could be attached to any one of the four sides. This problem presents no difficulty since all faces of the prism are rectangular in shape.

Oblique prism. The oblique prism differs from the right prism in that the edges are not perpendicular to the base; hence the sides are not rectangles but parallelograms. In the development the true shape of each parallelogram must be maintained, and it must be joined to the neighboring parallelogram in proper order. The front view of Fig. 3

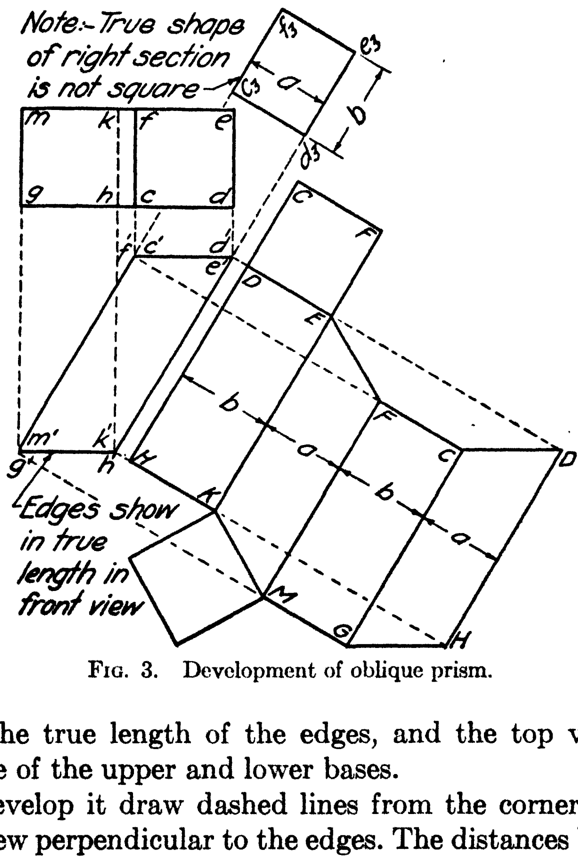


FIG. 3. Development of oblique prism.

shows the true length of the edges, and the top view the true size of the upper and lower bases.

To develop it draw dashed lines from the corners of the front view perpendicular to the edges. The distances between the pairs of parallel dash lines then are the true lengths of the edges. If the prism is cut along the line *DH* this line can be laid out at a convenient position as shown in Fig. 3. Make the distance *b* across the face *DEKH* the same as the line *de* in the top view and as d_3e_3 in the auxiliary view. Then lay out the rectangle *DEKH* as shown. Continue to the next face in a counterclockwise direction (in top view) making the edge *FM* offset from *DE* by the amount shown between the dash lines in the front view. Make the width of the face *EFMK* equal to f_3e_3 as indicated in the auxiliary view which shows a right section or the shape of a section cut at right angles to the edges. Lay out this measurement

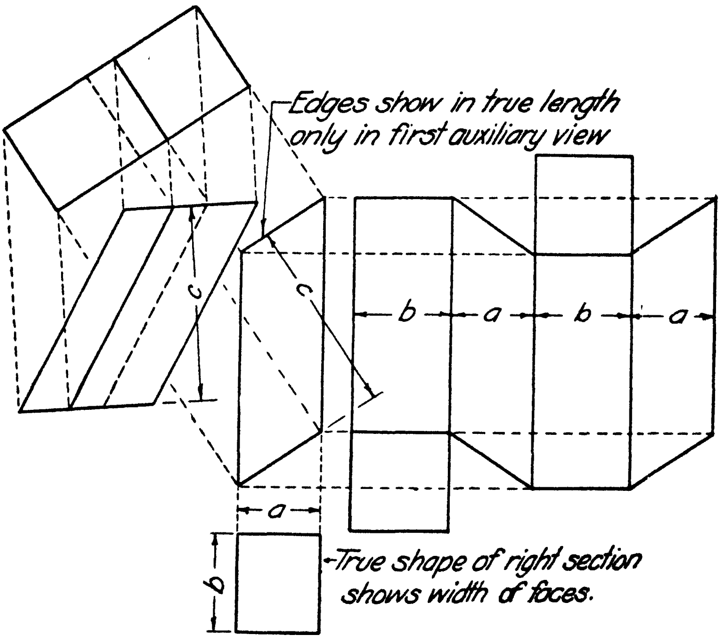


FIG. 4. Auxiliary plane used in development of oblique prism.

a at right angles to the line *EK* and complete the parallelogram as shown in the figure. Complete the development in the same manner. Be sure you understand every step you take.

If the oblique prism is in such a position that the true lengths of its edges do not show in either view, as in Fig. 4, then make first an auxiliary view which will show the true lengths of the edges. Next obtain a right section by auxiliary projection as shown in Fig. 4, after which proceed with the construction of the development in the usual manner as was indicated in Figs. 1b and 3, and treat the top view and first auxiliary view just as though they were the original top and front views.

Right pyramid. A right pyramid is one whose axis is perpendicular to the base. To develop a right pyramid obtain first the true length of one of the sloping edges as shown for *AB* in Fig. 5. The other edges are all this length. If the base is parallel to the horizontal or vertical planes, as is usually the case, then the edges of the base show in true length. Set your compass to the true length of one edge and describe

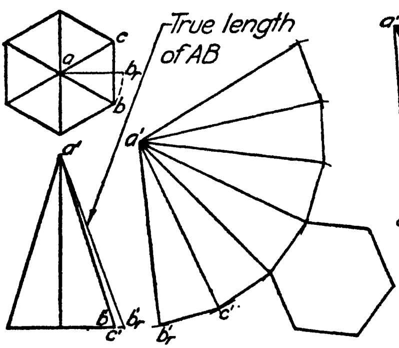


FIG. 5. Development of right pyramid.

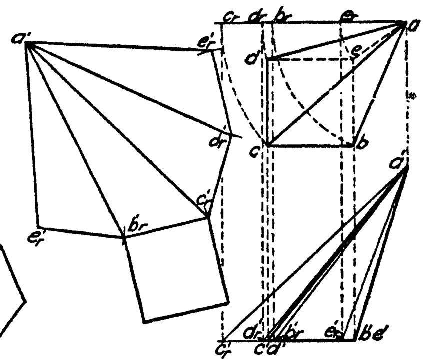


FIG. 6. Development of oblique pyramid.

an arc of indefinite length. At some convenient place draw the line $a'b_r'$, with a' the center of the arc, and b_r' upon the arc. Now set your compass to the true length of the edge of the base as *bc*; step off this distance at $b_r'c'$ and continue the proper number of sides as shown in Fig. 5. The entire arc is not shown in the figure since it comes so close to the straight lines. Connect these points with the apex a' and with each other, thus forming a series of triangles which are of the same shape as the faces of the pyramid. On one of the edges construct the base by the usual method of transferring a plane figure.

Oblique pyramid. An oblique pyramid is one whose axis is not perpendicular to the base. To develop an oblique pyramid obtain first the true length of each edge of the pyramid by the usual method as shown in Fig. 6. All these edges will, as a rule, be of different lengths. If the base is not parallel to the horizontal or vertical plane obtain the true shape of the base by auxiliary projection and thus the true length of its edges.

Cut the pyramid at any edge, say *AE* as in Fig. 6. Draw this line in true length as $a'e_r'$ at any convenient place on the paper. Then with a' as a center and the true length of the next edge $a'b_r'$ as a radius describe an arc. With e_r' as a center and the true length of the base edge *BE* as a radius describe another arc cutting the first one. This intersection represents the corner b_r'; connect b_r' with a' and e_r', thus completing the first face of the development. Now with a' as a center and the true length of *AC* as a radius describe another arc. Then with b_r' as a center and the true length of *BC* as a radius describe another arc intersecting the first one, and thus locate c_r' in the development. Connect c_r' with b_r' and a' and proceed as before until the entire figure is developed including the base, as shown in Fig. 6.

Models. Models of these geometric figures can be made from paper if a pasting strip is left along the edges which have been imagined cut to make the development, as, for example, the edge $a'e_r'$ and the three sides of the square base in the development in Fig. 6.

QUESTIONS

1. What is meant by the development of a surface?
2. Why are developments of surfaces made?
3. What are some of the practical cases in which developments or partial developments are used?
4. Under what conditions does a line show in its true length in an orthographic projection?
5. Make a sketch showing one way of determining the true length of a line which does not show in true length in any one of the three principal views.
6. What is the difference between a right and an oblique prism?
7. How do you distinguish between a right and an oblique pyramid?

8. What two things must we know or find out about every line used in a development?

9. If a paper model is to be constructed what addition must be made to the development?

PROBLEMS

Lay out the standard border line and title space, then make the development of the object assigned from the following group: Scale full size, for sheet size B. Scale A, $1\frac{1}{2}'' = 1''$.

1 to 6. Make the front and top views of a right prism $2\frac{1}{2}$ inches high with a regular base which can be inscribed in a $2\frac{1}{2}$-inch diameter circle. Then make a complete development of the surface. Place the views at the left and the development at the right. The base shall have the shape assigned by the instructor from the following list:

1. Triangle
2. Square.
3. Pentagon.
4. Hexagon.
5. Heptagon.
6. Octagon.

7 to 12. Make the development of a right pyramid under the same conditions as to height and shape of base specified in Probs. 1 to 6.

13 to 16. Make the development of the larger part of the truncated pyramid as assigned by the instructor from Figs. 11, 12, 16 and 17 of the preceding unit. Draw the views at the left of your sheet. Then find the intersection; then make the complete development. Lastly, lay off on the whole development the line of intersection and make the development for the larger portion heavier.

UNIT VI

INTERSECTIONS OF PRISMS

PURPOSE OF UNIT VI

It is the purpose of this unit to show how to find the intersections of prisms with each other.

WHAT YOU SHOULD KNOW ABOUT THE INTERSECTIONS OF PRISMS

The intersection of two prisms is composed entirely of straight lines. These straight lines must always begin and end upon the edges of one or the other of the two prisms. The intersection will be visible only when it is on the near side of both prisms; it will be invisible if it is on the far side of either one of the two.

Importance of edgewise view. Since prisms are enclosed entirely by plane surfaces the best method of procedure is to get an endwise view of one prism in order to see where the edges of the other prism go through the sides or surfaces of the first. In other words, if we get an endwise view of one prism we can see where the edges of the other prism go through these surfaces and then locate some of the points on the intersection. If then we repeat the process and get an endwise view of the second prism we can see where the edges of the first penetrate its sides, thus locating the remaining points on the intersection. By properly connecting the points and indicating the visibility, the line of intersection may be determined. This general method will now be described in detail for two cases.

Types of intersections. Four distinct types of intersections are possible, as illustrated in Fig. 1. The plan or top view shown above each pictorial intersection is a key to the type of intersection and should be thoroughly studied so that you will know from the orthographic views what general type of intersection you are going to get before you even begin to locate any points. The pictorial views are dimetric projections and, of course, must not be thought of as being in projection with the top view. They simply represent pictorially what is shown in the plan.

Locating points. Assume two prisms as in Fig. 2 whose intersections are to be formed. The top view shows the endwise view of the vertical prism, and we can see where the

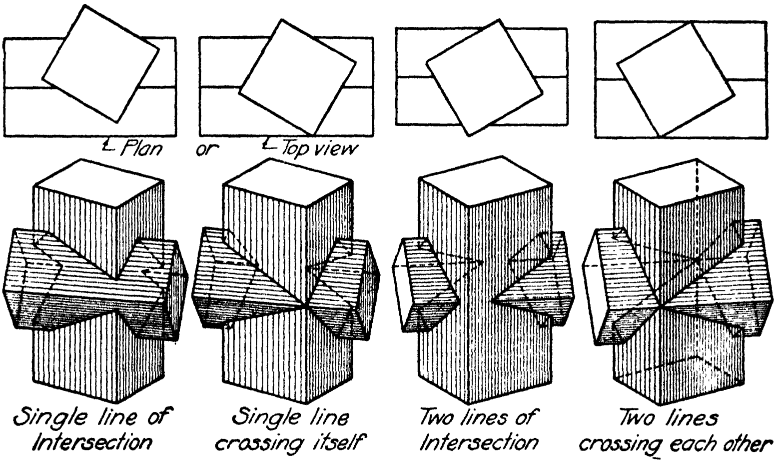


FIG. 1. Four types of intersections illustrated.

four horizontal edges *AJ*, *BN*, *CM* and *DK* of the horizontal prism pierce the faces of the vertical prism at *1*, *3*, *4* and *5* on the right and *7*, *8*, *10* and *12* on the left. These points can then be projected to the front view by locating them on the corresponding lines. Thus the points *3* and *8* which are on edge *A* project to *3'* and *8'* on *a'j'*. The other points are located in the same manner. From the top view, however, we cannot tell where the vertical lines from *FP* and *HS* of the vertical prism pass through the horizontal prism. If, however, we make a profile view as shown in Fig. 3 the horizontal prism is shown edgewise and we can locate where the edges *FP* and *HS* of the vertical prism pierce it at 2_2, 6_2, 9_2

and 11_2. These points are projected across to the front view onto the proper lines *h′s′* and *f′p′*.

It now remains to connect these points in their proper order and to indicate which lines are visible and which are invisible.

Connecting the points. From an inspection of the top view it can be seen that the horizontal prism passes entirely through the vertical prism. There will, therefore, be two separate lines of intersection, as in case 3, Fig. 1. To connect the points, begin at the foremost point as shown in one of the edgewise views, like *1* in the top view of Fig. 3, and

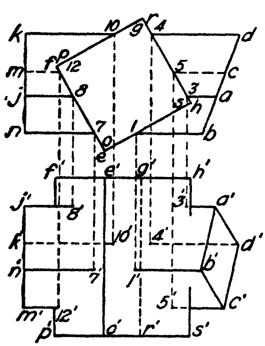


FIG. 2. Finding points on intersection.

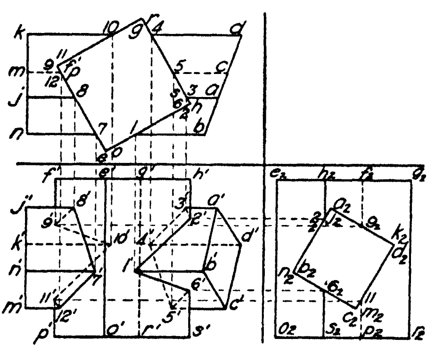


FIG. 3. Profile view used to complete intersection.

trace back along the face of the edgewise prism until an edge of either prism is encountered, like *hs* in Fig. 3. Connect the two corresponding points *1′* and *2′* on the front view by a visible line if it lies in a visible face of both prisms. From point *2* continue tracing along the faces of the edgewise prism until the next edge *aj* is crossed, thus giving the point *3*. Then connect *3′* with the preceding point *2′*. The line will be invisible if it lies in an invisible face on either prism. Continue in like manner until you return to the original point *1′*, as shown in Fig. 3. Draw the lines of intersection *7′8′*, *8′9′*, *9′10′*, *10′11′*, *11′12′* and *12′7′* in the same manner.

In order to get an edgewise view of both prisms an auxiliary view is sometimes necessary. Thus in Fig. 4 the square prism has four edges parallel to *V* and inclined to *H* and *P*. It will not, therefore, show edgewise in the profile view. An auxiliary view made on a plane perpendicular to *V*, however, will give the desired endwise view as shown.

This view was necessary to find where the edge *AB* of the triangular prism passed through the faces of the square prism. This can be seen at once at 6_3 and 8_3 in the auxiliary view. The distances $a_3 6_3$ and $a_3 8_3$ are taken back to the top

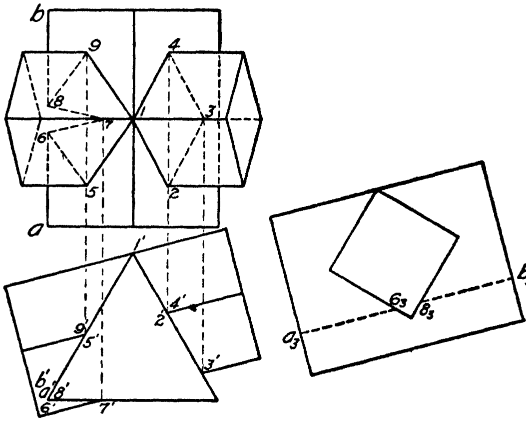


FIG. 4. Auxiliary view used to get intersection.

view by dividers, thus locating points *6* and *8* on ***ab***. All other points can be obtained from the front and top views.

Another method not requiring an edgewise view may be used. This is explained in the next unit but it may be applied with equal success to problems of the type discussed in this unit.

HOW TO FIND THE INTERSECTION OF TWO PRISMS

First, obtain views of the prisms such that each prism is shown endwise in at least one view. This is accomplished by making a profile or one or more auxiliary views as conditions may require.

Second, on the endwise views mark where the edges of one prism pierce the faces of the other and project the points to the remaining views.

Third, connect the points in proper order and show the visible and invisible portions of the intersection as solid and dotted lines respectively.

QUESTIONS

1. Upon what lines must the lines which form an intersection begin and end?

2. When is a line of intersection visible?

3. Under what conditions is a line of intersection invisible?

4. What method is used for finding where the edges of one prism pass through the faces of another?

5. After having found where the edges of one prism penetrate the faces of another, what must one do as the next step toward completing the intersection?

6. After all points in which the edges of each prism pierce the other have been found, what is the next step in the procedure?

7. If the endwise views of both prisms cannot be obtained in the customary three views, what may be done to obtain them?

PROBLEMS

Lay out the standard border line and title space, and divide the space into two equal parts by a vertical line. Find the intersection of the prisms assigned from the following group.

The prisms are shown incomplete, but it should not be assumed that the lines end exactly where shown in the figures. Scale full size, for sheet size B. Scale A, $1\frac{1}{2}'' = 1''$.

Note: In Figs. 8 to 13 inclusive a profile or auxiliary view must be made before the front view can be completed. Where difficulties arise, enough of the auxiliary view has been suggested in the figure to make the construction clear. One corner has been identified by letters. Your auxiliary view will, of course, have to show both prisms and must be farther from the top view than shown in the text.

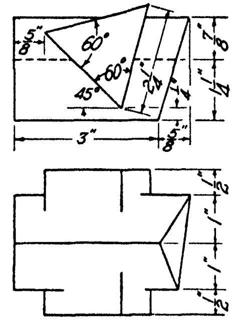


FIG. 5.

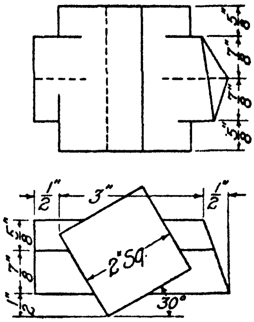


FIG. 6.

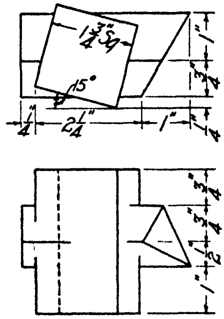


FIG. 7.

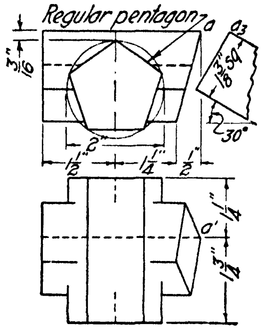


FIG. 8.

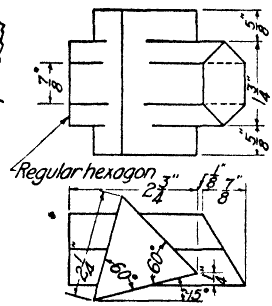


FIG. 9.

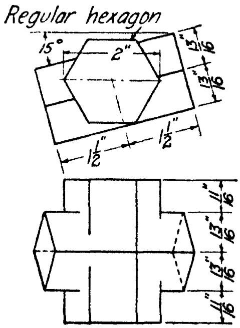


FIG. 10.

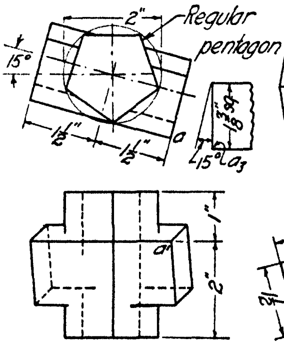


FIG. 11.

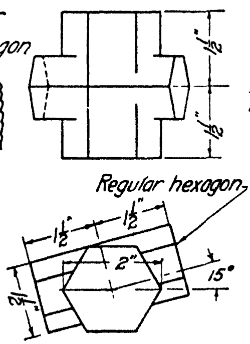


FIG. 12.

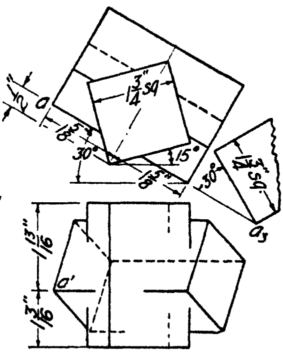


FIG. 13.

UNIT VII

INTERSECTION OF PRISMS AND PYRAMIDS

PURPOSE OF UNIT VII

It is the purpose of this unit to show how to find the lines formed by the intersection of prisms with pyramids.

WHAT YOU SHOULD KNOW ABOUT THE INTERSECTIONS OF PRISMS AND PYRAMIDS

The intersections of prisms and pyramids can be arranged in four groups just like those of Fig. 1 in Unit VI. The type

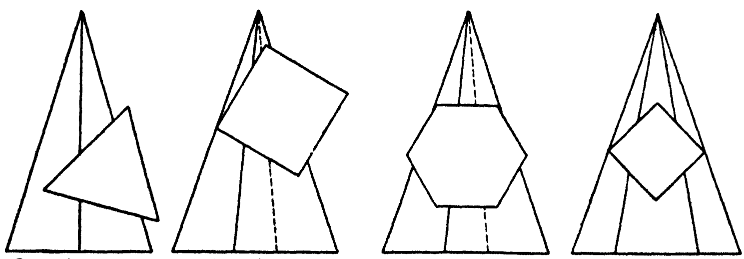


FIG. 1. Method of identifying types of intersection.

of intersection to be expected can be recognized before beginning construction if an endwise view of the prism is obtained. The four situations are shown in Fig. 1.

A more general method for finding intersections than that used in Unit VI will now be explained. This method is particularly useful when endwise views cannot be obtained, as with two pyramids.

Suppose that we wish to find where the edge *AB* of the horizontal triangular prism in Fig. 2 pierces the faces of the pyramid. If we imagine a projecting plane like *EF* passed through the line *AB* this will cut the faces of the prism in two lines, *MN* and *MO*. A projecting plane is a plane which is perpendicular to any one of the three principal planes. Now since the lines *MN* and *MO* and the edge of the prism *AB* all lie in the same plane *EF*, these lines will intersect unless, perchance, they should be parallel. In Fig. 2 the edge *AB* intersects the faces of the pyramid in the points *1* and *2* which are the points of intersection between *a′b′* and *m′o′* and *m′n′* respectively as found in the *V* plane. The

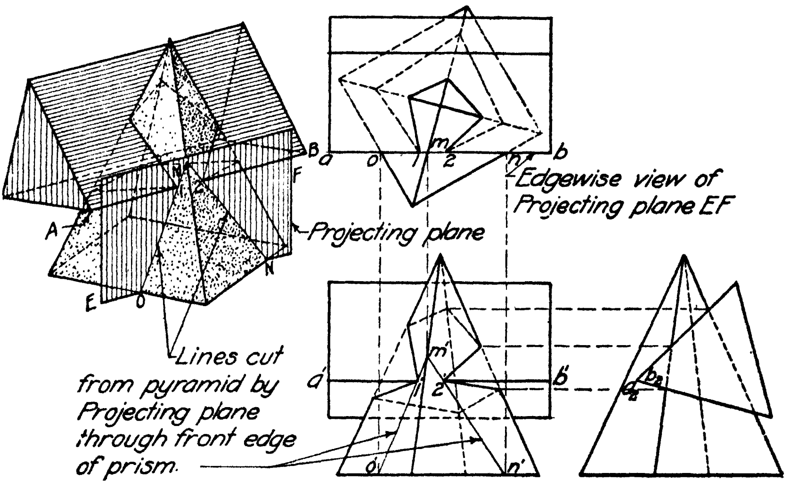


Fig. 2. Finding line of intersection.

same thing may then be done for the other edges of the prism.

The points where the edges of the pyramid pierce the faces of the prism may be found in the same way or by finding the endwise view of the prism, which of course, is preferable when possible.

HOW TO FIND THE INTERSECTION BY MEANS OF PROJECTING PLANES

Follow the steps of the procedure outlined below for each line or edge whose piercing points you need to find.

First, in any convenient view draw a projecting plane through the lines, as for example line *AE* in Fig. 3. Since this plane shows edgewise in the top view (being an *H*-projecting plane, that is, a plane which is perpendicular to *H*), the points where the edges *MN*, *NO* and *NQ* of the pyramid go through this plane can be seen at once in the top view. Project these points *r*, *s* and *t* to the front view. Connect these points and thus establish lines in which the projecting plane cuts the faces. Where the projection *a′e′* crosses these lines *r′s′* and *s′t′* gives the points *1′* and *2′* on the line of

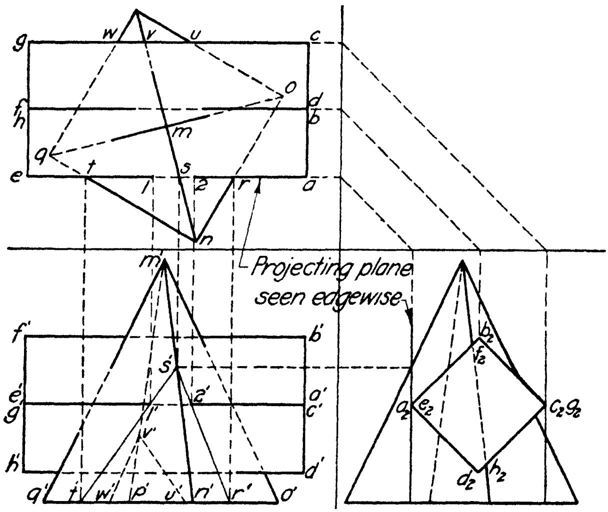


FIG. 3. H-projecting plane used to determine points on line of intersection.

intersection. The process is then repeated for the other lines, *BF* and *DH*.

If the side view had not been drawn one could not tell from the front or top view whether the line *CG* pierced the pyramid or not. Upon attempting to find its piercing point by the method above, it will be seen that the two lines *u′v′* and *v′w′* do not cross *c′g′* and, hence, the line does not pierce the faces of the pyramid.

The side view or an auxiliary projection giving an endwise view of the prism should, however, always be made by the beginner as an aid in visualizing the type of intersection to be expected and in determining the visibility of the line of intersection.

The rules for determining visibility given in Unit VI apply in the intersections of this unit as well as in all others. The line to be visible must be on the near side of both objects.

QUESTIONS

1. What is meant by a projecting plane?
2. Outline the steps in finding where the edge of one object pierces the faces of another by the use of the projecting plane.
3. What is the field of especial usefulness of the "projecting plane" method?
4. State the rule for determining the visibility of a line of intersection.
5. Illustrate by a sketch the position of a pyramid and prism to give a single line of intersection.
6. Illustrate by a sketch the position of a pyramid and prism to give a single line of intersection which crosses itself.
7. Show by a sketch the position of a pyramid and prism to give two lines of intersection.
8. Show by a sketch the position of a pyramid and prism to give two lines of intersection which cross each other.
9. Since the intersection can be found without the endwise view of the prism what advantage, if any, is there in making such a view?

PROBLEMS

Lay out the standard border line and title space, and then reproduce the views of the objects assigned from the following group and find the line of intersection. Show properly the visible and invisible portions. Scale full size, for sheet size B. Scale A, $1\frac{1}{2}'' = 1''$.

Make the development of both objects upon a second sheet if so directed by the instructor. Scale full size, for sheet size B. Scale A, $1\frac{1}{2}'' = 1''$.

In laying out Figs. 6, 9, 10, 11 and 12 it will be necessary to construct the profile or auxiliary view before the front or top view can be completed.

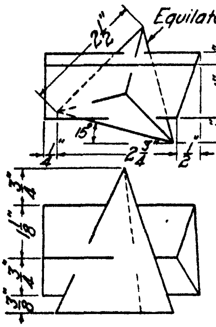


FIG. 4.

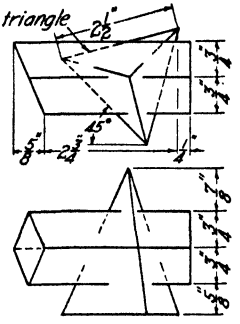


FIG. 5.

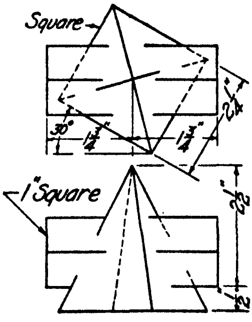


FIG. 6.

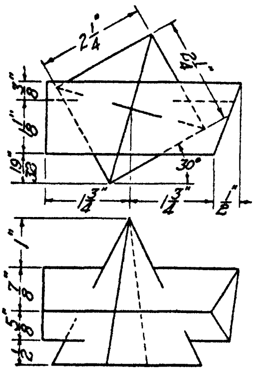


FIG. 7.

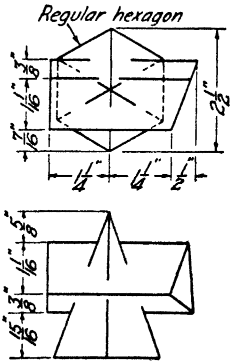


FIG. 8.

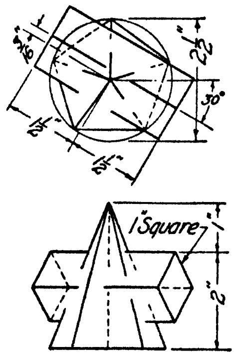


FIG. 9.

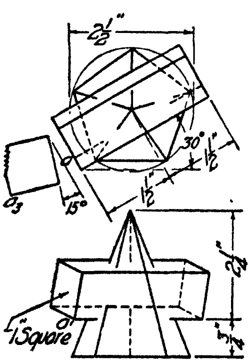


FIG. 10.

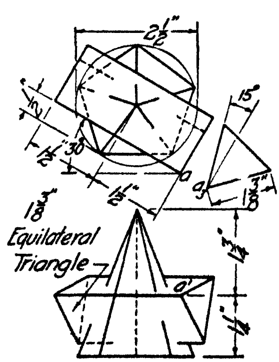


FIG. 11.

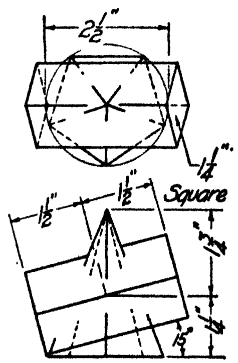


FIG. 12.

UNIT VIII

SQUARE AND ACME THREADS

PURPOSE OF UNIT VIII

It is the purpose of this unit to teach the proportions of square and acme threads, their fields of especial usefulness and how to represent them upon drawings.

WHAT YOU SHOULD KNOW ABOUT SQUARE AND ACME THREADS

As its name implies, the profile of the so-called square thread is a square as shown in Fig. 1. This thread is just as

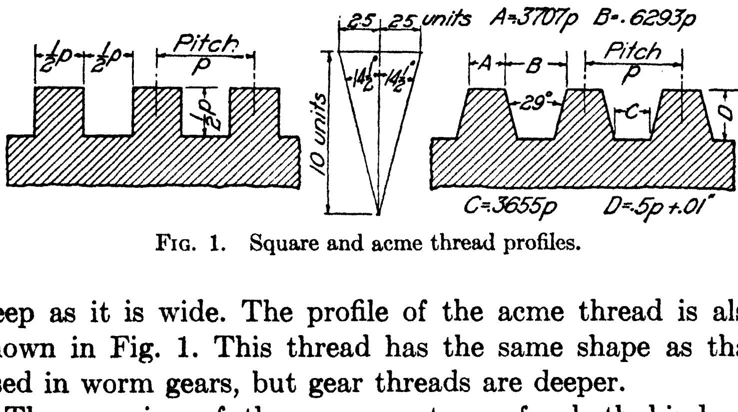


FIG. 1. Square and acme thread profiles.

deep as it is wide. The profile of the acme thread is also shown in Fig. 1. This thread has the same shape as that used in worm gears, but gear threads are deeper.

The meaning of the common terms for both kinds of threads is shown in Figs. 2 and 3. The pitch is the distance from center to center of adjacent threads, or from the edge of one thread to the corresponding edge of the next. The term minor diameter refers to the diameter at the root or base of the threads; the major diameter is the overall outside diameter.

The term "lead" applies only to multiple threads. It is the distance from the center of a thread to the center of the same thread as it comes around again or the distance the screw travels in one revolution. For a double thread the lead is twice the pitch, and so on. Multiple threads are

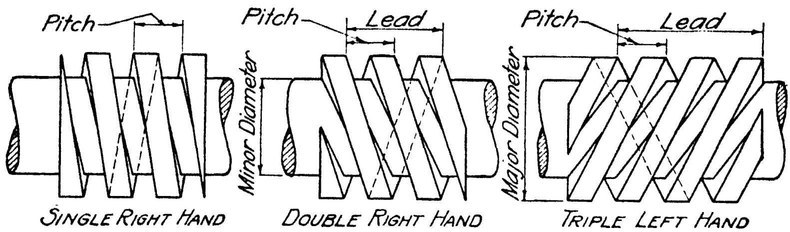


FIG. 2. Square threads.

shown in Figs. 2 and 3. A right-hand thread advances when turned clockwise; a left-hand thread advances when turned counter-clockwise. Square and acme threads are used in situations where heavy loads are to be handled, as for ex-

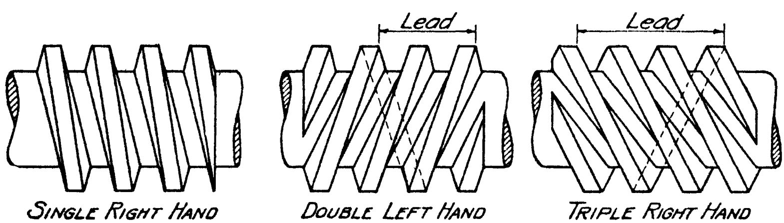


FIG. 3. Acme threads.

ample in screw jacks, presses, etc. Acme threads are also commonly used in water and steam pipe valves.

HOW TO DRAW SQUARE AND ACME THREADS

To draw square threads. The pitch and major diameter of the threads being given, draw two parallel lines *a* and *b* a distance apart equal to the major diameter, as shown in Fig. 4a. Then draw two other lines *c* and *d* inside of *a* and *b* respectively and at a distance from them equal to one-half the pitch. Mark off on one outside line a series of points at intervals equal to one-half the pitch. At these points draw light lines as at *e* in Fig. 4a at right angles to the first lines, thus forming a series of little squares on each side. For a single thread draw slanting lines as *f* which connect points on the outside lines to those next ahead of the corresponding points on the opposite side. These lines represent the top of the thread. Next draw slanting lines as *g* from all points on the inner line *d*. These lines should be drawn only to the center, since only one-half of the root line, or base, of the thread is visible. Complete the thread by drawing the short slanting lines *h* representing the back turn of the thread. Find the slant of *h* by the same method as used to draw *f*. Examination of Fig. 4 will make the steps in the process clear.

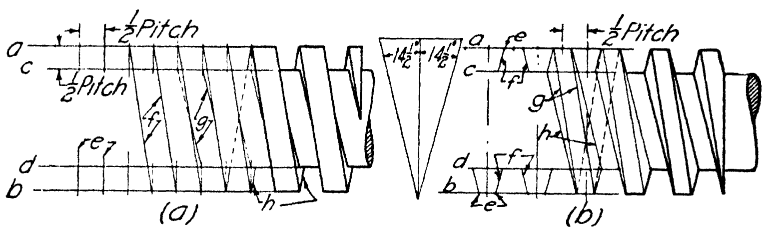


FIG. 4. Construction of square and acme threads.

To draw acme threads. The acme thread is slightly wider at the top of the thread than at the bottom of the groove, ($A = 0.3707p$; $C = 0.3655p$), but for purposes of drawing this can be ignored and the groove and thread made alike. The depth also can be made equal to one-half the pitch since the additional one-hundredth of an inch clearance given in the value at *D*, in the formula, need not be shown in a drawing.

Therefore, first draw lines *a* and *b* as in Fig. 4b representing the major diameter, and then lines *c* and *d* representing the minor diameter inside of lines *a* and *b* at a distance equal to one-half the pitch.

Next mark off points at intervals of one-half the pitch on opposite sides of the thread. With these points as centers, mark off points *e* to show the top of the thread. The width *e* is computed from the formula in Fig. 1. Then draw the sloping lines *f* to represent the sides of the thread. This will locate the bottom of the groove. When these lines are all drawn put in the lines *g* as shown in Fig. 4b and then the lines *h* representing the top and bottom of the threads respectively. The dotted lines indicate the return of the thread on the back of the screw. In drawing double and triple acme threads, parts of these return lines show and the side of the thread need not be drawn, except to find the bottom points of the groove and to locate the sloping lines *h* as indicated in Fig. 4b.

When drawing double threads notice that crest is opposite crest, whereas in triple threads, crest is opposite root, and the slope is increased one additional thread, as shown in Figs. 2 and 3.

QUESTIONS

1. Make a sketch showing the shape of the square thread profile. Give dimensions in terms of the pitch.

2. Show by a large sketch a single right-hand square thread. Show four or five turns, and indicate by dotted lines the invisible part of one turn.

3. Which way must a right-hand thread be turned to make it advance into a threaded hole?

4. How can you tell a single from a double thread in a drawing?

5. How does the depth of the acme thread compare with the depth of the square thread of the same pitch and diameter?

6. What is the width of the top of the acme thread in terms of the pitch?

7. What is the width of the top of the groove in an acme thread in terms of the pitch?

8. What is meant by the term "lead" as applied to screw threads?

9. What is the relationship, if any, between the lead and pitch of a double thread?

10. What is the angle included between the sides of an acme thread?

11. Show by a sketch how an angle of $14\frac{1}{2}$ degrees may be laid out.

12. Name some of the uses of square and acme threads. Why are such threads used in the places you have just named?

PROBLEMS

Lay out the standard border line and title space, and then divide the space inside the lines into four equal rectangles by means of vertical and horizontal lines. In these spaces draw four problems assigned from the group below. In each case make the threaded part 2 inches long and have a cylinder $\frac{1}{2}$ inch longer and equal to the minor diameter extending beyond each end. Break off the cylinder in the usual conventional manner. Letter neatly in lower-case letters under each thread a brief description of it.

1. Make a single right-hand square thread of $2\frac{1}{2}$-inch major diameter and $\frac{3}{4}$-inch pitch.

2. Make a single left-hand square thread of $2\frac{1}{4}$-inch major diameter and $\frac{1}{2}$-inch pitch.

3. Make a double right-hand square thread of $2\frac{1}{2}$-inch major diameter and $\frac{5}{8}$-inch pitch.

4. Make a double left-hand square thread of 3-inch major diameter and $\frac{3}{4}$-inch pitch.

5. Make a triple right-hand square thread of 3-inch major diameter and $\frac{7}{8}$-inch pitch.

6. Make a triple left-hand square thread of 2-inch major diameter and $\frac{1}{2}$-inch pitch.

7 to 12. Repeat the above problems, making acme instead of square threads.

UNIT IX

FASTENERS

PURPOSE OF UNIT IX

It is the purpose of this unit to teach the principal facts concerning fasteners of different kinds and to show how to represent them and specify them on drawings.

WHAT YOU SHOULD KNOW ABOUT FASTENERS

Kinds of fasteners. Fasteners may be divided roughly into two classes, namely, those used in holding metal parts

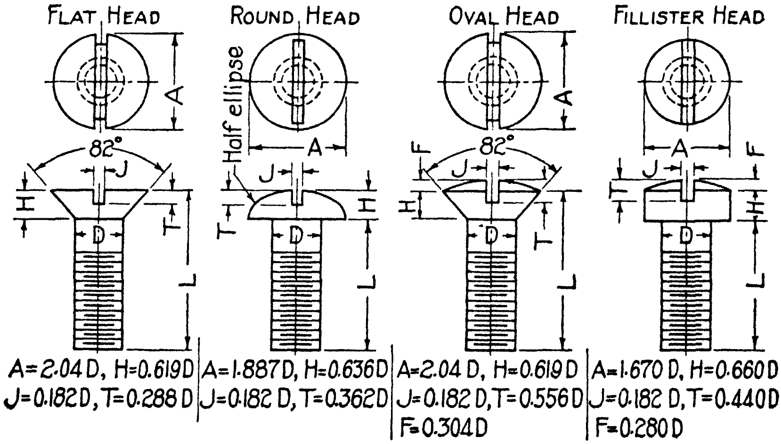


FIG. 1. A. S. M. E. machine screws.

together and those used with wood. Since those used exclusively in woodwork are usually not shown in drawings they present no drawing problem and will not be shown. This unit, therefore, concerns itself chiefly with the other group. The more common metal fasteners consist of bolts, machine screws, cap screws, set screws, rivets, keys, taper pins and cotter-pins. Bolts were discussed in Unit XXV, Vol. I, and will not be dealt with here.

Machine screws. Four A.S.M.E. standard shapes of machine-screw heads are shown in Fig. 1. The actual dimensions of machine screws are best obtained from tables. Those shown in the figures and used for drawings are based upon the diameter of the screw. These proportions are shown in Fig. 1.

Machine screws are specified by numbers up to 12 and then by the diameters as in the case of bolts. A list of these sizes with the corresponding diameters, threads per inch and tap-drill diameters is given in Table I. The tap drill is the drill used to make the hole which is to be threaded to receive the screw. Its diameter is roughly equal to that of the root diameter of the screw.

The lengths of machine screws vary from $\frac{1}{8}$ inch to 3 inches, changing by $\frac{1}{16}$ inch from $\frac{1}{8}$ to $\frac{1}{2}$ inch, by $\frac{1}{8}$ inch from $\frac{1}{2}$ to 1 inch and by $\frac{1}{4}$ inch for the other lengths. The threaded length is not less than $1\frac{1}{4}$ inches for all screws over that length. For shorter screws the threads are extended as near the head as possible. Machine screws may be obtained with

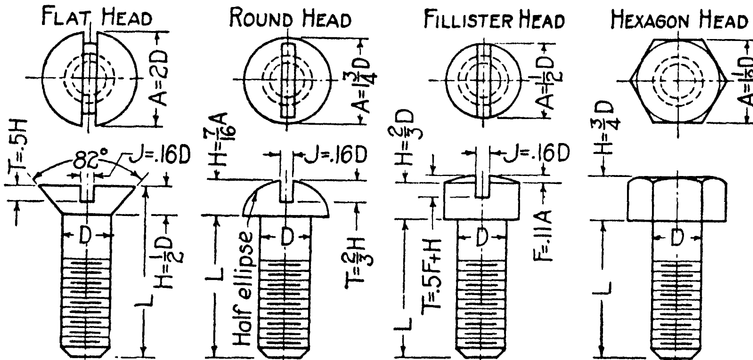
TABLE I

A.S.M.E. STANDARD MACHINE SCREWS

Size		Threads per Inch		Tap-drill diameter Sizes		Size		Threads per Inch		Tap-drill diameter Sizes	
No.	Dia.	Coarse	Fine	Coarse	Fine	No.	Dia.	Coarse	Fine	Coarse	Fine
2	0.086	56	64	50	50	10	0.190	24	32	25	21
3	0.099	48	56	47	45	12	0.216	24	28	16	14
4	0.112	40	48	43	42	$\frac{1}{4}$	0.250	20	28	7	3
5	0.125	40	44	38	37	$\frac{5}{16}$	0.3125	18	24	F	I
6	0.138	32	40	36	33	$\frac{3}{8}$	0.375	16	24	$\frac{5}{16}$	Q
8	0.164	32	36	29	29						

either the coarse or fine threads. The coarse threads are more common.

Cap screws. The shape of common cap-screw heads is shown in Fig. 2. The sizes are specified by diameters which vary by sixteenths from ¼ to ⅝ inch and by eighths from ⅝ inch to 1¼ inches. Formulas are not available for the proportions of the heads, but tables of dimensions can be found in various textbooks and handbooks, to which the student is referred.* The approximate formulas shown in Fig. 2 may



Exact dimensions of Cap Screws must be obtained from tables. Approximate formulae above may be used when tables are not available

Fig. 2. Cap screws.

be used when tables are not available. Cap screws may be obtained in lengths from ¼ inch to 6 inches, varying by eighths up to 1 inch, then by quarter inches up to 4 inches and then by ½ inch up to 6 inches.

The threaded length of cap screws is two diameters plus ¼ inch. When the screw is too short for this formula to apply, it is threaded as close to the head as practicable. Cap screws are regularly threaded with the National coarse thread.

* "Machinery's Handbook," Industrial Press, New York.
"Engineering Drawing," by Jordan and Hoelscher, Third Edition, John Wiley & Sons, New York.

Set screws. Set-screw heads and points usually furnished are illustrated in Fig. 3. The American Standard coarse-thread series is used on set screws, and they are always threaded for the full length. These screws are used to pre-

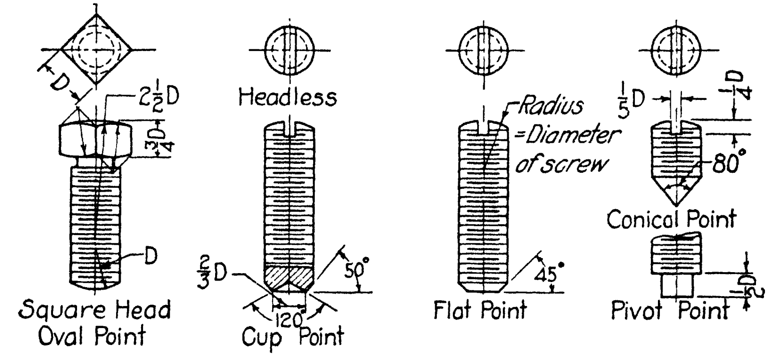


FIG. 3. Set screws.

vent machine parts from rotating or sliding out of position on a shaft. In drawings they are represented as shown in Fig. 3, and are specified by giving the diameter, length, kind of point and head.

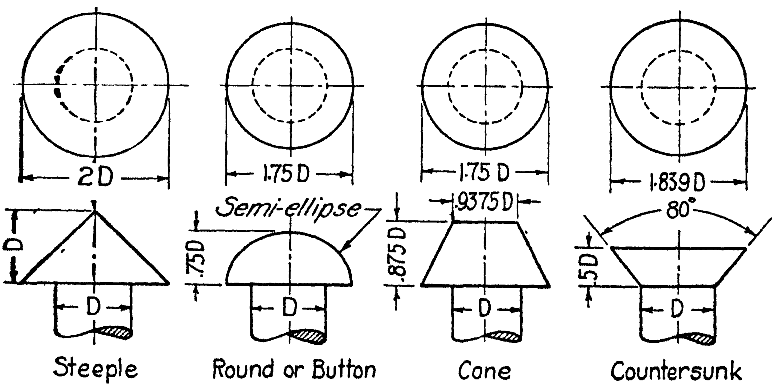


FIG. 4. Rivet heads.

Special bolts and screws. Many other kinds and types of bolts and screws are manufactured. For the sizes, dimensions and shapes of these the student should refer to the handbooks mentioned earlier in this unit.

Rivets. Bolts and screws are used if it may be desirable to remove them. Rivets are used for making permanent connections. Eighteen or more types of heads are used; four of the most common are shown in Fig. 4. On large-scale drawings rivets may be represented as shown in this figure, but on small-scale drawings ($1\frac{1}{2}'' = 1'-0''$ and under) for structural work they are represented by symbols as shown in Fig. 5.

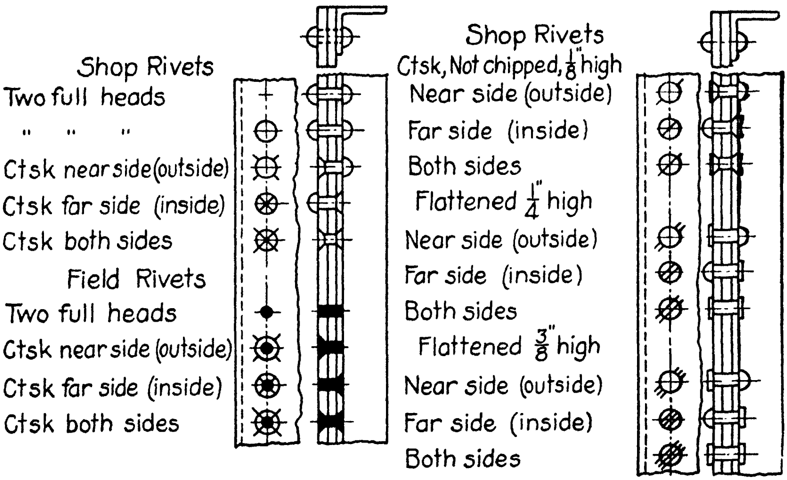


FIG. 5. Rivet symbols.

Rivets are driven by machine while they are white hot through holes previously punched to receive them, and are used principally in structural work such as bridges, buildings and heavy machine frames. In order to obtain clearance, rivets are sometimes countersunk or merely flattened where there is not room for the full round head.

Keys. Keys are used to prevent gears and pulleys, couplings, etc., from rotating or slipping upon their shafts. Several of the more common types of keys are shown in Fig. 6. A groove called a keyway must be made in both the shaft and the gear or pulley so that the key itself extends into each part thus preventing one turning without the other. The dimensions of keys of all kinds and of various sizes of shafting are given in handbooks.

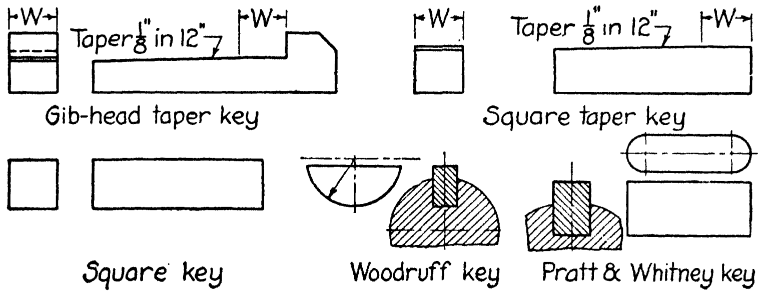


FIG. 6. Common types of keys.

Taper pins. Taper pins, as their name implies, are smaller at one end than at the other and fit into holes which have been similarly shaped to fit them. See Fig. 7. Both the slope, or taper, and the common sizes of these pins have been standardized.

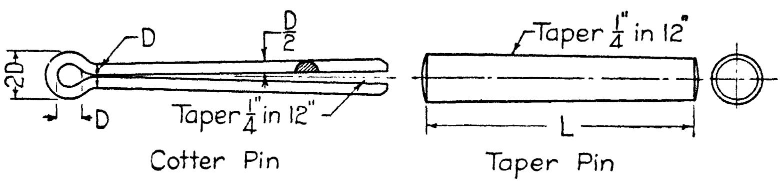


FIG. 7. Cotter-pin and taper pin.

Cotter-pins. Cotter-pins are illustrated in Fig. 7. The most common purpose of cotter-pins is to prevent nuts from

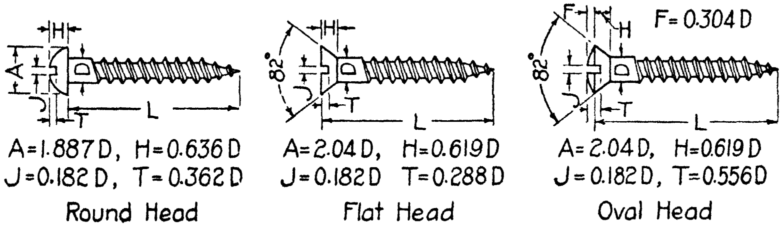


FIG. 8. Wood screws.

turning on a bolt. They are used on automobiles and other moving machine parts where vibration might cause a nut to work loose. Sizes and dimensions of cotter-pins vary from

$\frac{3}{32}$-inch diameter and $\frac{1}{2}$-inch length to $\frac{5}{8}$-inch diameter and 4-inch length.

HOW TO DRAW FASTENERS

Except in very unusual cases where a specially designed fastener is specified, show all fasteners by symbols. To draw them, study carefully the figures given in this unit and those shown in handbooks or other textbooks. With a table of sizes before you, draw the fasteners as shown in the figures. Lay out center lines first and step off dimensions on the center lines. Then draw the outlines of the symbols representing the required fasteners. Heads of round-head screws are elliptical in shape. Use the four-center approximate method to draw the semi-ellipse. In drawing unusual fasteners for which there are no accepted symbols, draw accurate orthographic drawings just as you would for any other object. To draw the threads follow the procedures used in Units XXIV and XXV of Book I, dealing respectively with screw threads and with bolts and nuts.

QUESTIONS

1. Name the common types of machine screws.
2. What kind of threads are used on machine screws?
3. What is meant by a tap drill?
4. How are machine screws specified?
5. Make a sketch showing a fillister-head cap screw.
6. Make a sketch of an oval fillister-head cap screw.
7. Name four types of cap screws.
8. How are cap screws specified?
9. What kind of threads are used on cap screws?
10. What are set screws used for?
11. Sketch two kinds of set-screw points.
12. How are rivets driven?
13. How are rivets represented on small-scale drawings?
14. Show the symbol for a rivet countersunk on the near side.
15. What are keys used for?
16. Name three common types of keys.
17. What is the amount of taper per inch used on standard taper pins?
18. Make a sketch of a cotter-pin.

PROBLEMS

Lay out the standard border line and title space; divide the drawing sheet into four equal parts by means of horizontal and vertical center lines, and then draw the screws or other fasteners assigned from the following list. Scale full size for sheet size B.

1. A flat-head machine screw $\frac{3}{8}$ inch in diameter, 2 inches long.
2. A round-head machine screw $\frac{5}{16}$ inch in diameter, $1\frac{3}{4}$ inches long.
3. An oval-head machine screw $\frac{1}{4}$ inch in diameter, 2 inches long.
4. A fillister-head machine screw $\frac{3}{8}$ inch in diameter, $2\frac{1}{4}$ inches long.
5. A flat-head cap screw $\frac{3}{4}$ inch in diameter, $2\frac{1}{2}$ inches long.
6. A button-head cap screw $\frac{5}{8}$ inch in diameter, $2\frac{1}{4}$ inches long.
7. A fillister-head cap screw 1 inch in diameter, $2\frac{3}{4}$ inches long.
8. A hexagon-head cap screw 1 inch in diameter, $2\frac{1}{2}$ inches long.
9. Draw the symbol for full head and countersunk-head rivets for field rivets and shop rivets, scale 1″ = 1′–0″.
10. Draw a Woodruf key in a $1\frac{1}{2}$-inch shaft.
11. Draw a Pratt & Whitney key in a 2-inch shaft.
12. Draw a Gib head key for a $1\frac{3}{4}$-inch shaft.

Consult handbooks for sizes in Probs. 10, 11 and 12.

UNIT X

PIPING DRAWINGS

PURPOSE OF UNIT X

The purpose of this unit is to give information about pipes and pipe fittings needed to make piping drawings and to show how to make such drawings.

WHAT YOU SHOULD KNOW ABOUT PIPES AND PIPING DRAWINGS

Pipe systems. All the pipes which, taken together, serve to supply a house with water and to take away waste water are called the plumbing system of the house. Likewise all the pipes which serve to circulate hot water or steam for the purpose of heating a house are called the heating system. The pipes used in a system vary greatly in size, in the materials of which they are made and in the manner of connecting them to other pipes. Supply pipes are usually made of wrought iron, steel, brass or copper. Waste pipes are usually made of cast iron or lead. The parts used to join pipes are called fittings. There are numerous standardized fittings. Fig. 1 shows the standard malleable-iron fittings. Figs. 2 and 4, with the accompanying tables, give the shapes and dimensions of malleable screw fittings.

Pipe threads. Pipe threads are usually cut on a taper of 1 to 16 and are shaped as shown in Fig. 3. The sides of the threads are cut at an angle of 60 degrees with one another, and the crests and roots of the threads are truncated so that the depth of the thread is eight-tenths of the pitch. By cutting the threads on a taper it is possible to make the connections much tighter than they would be if cut on a cylinder because the farther the fitting moves along the thread the tighter it becomes. Because of this it is necessary

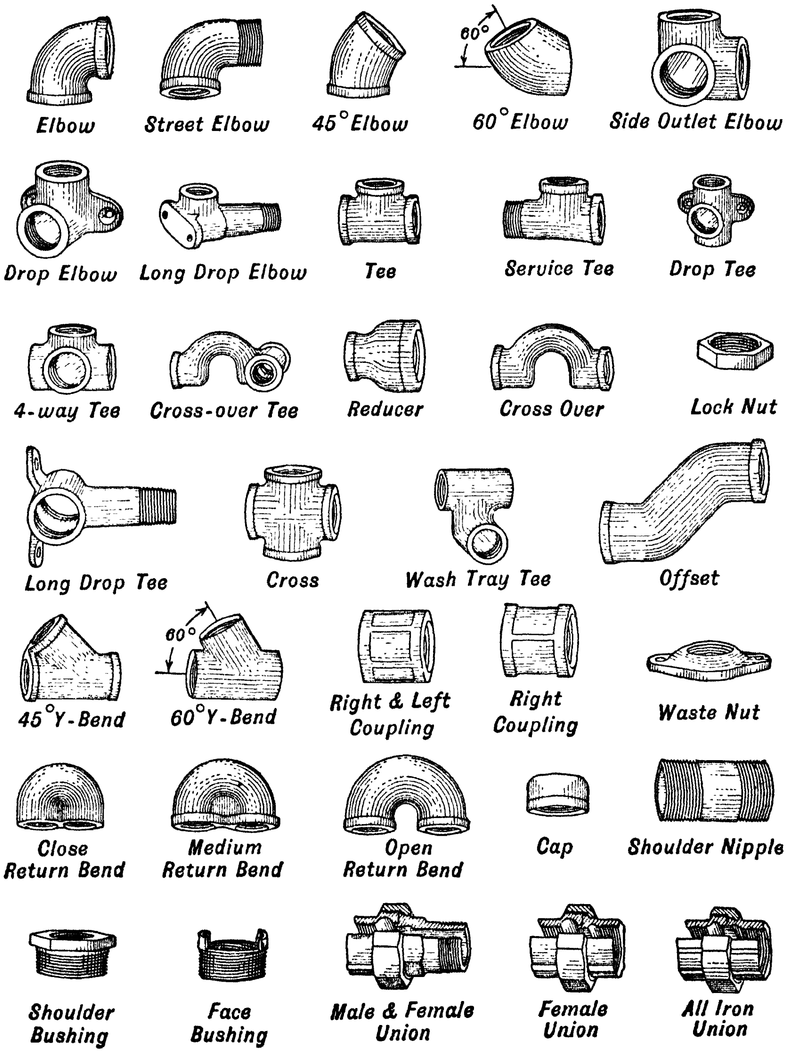
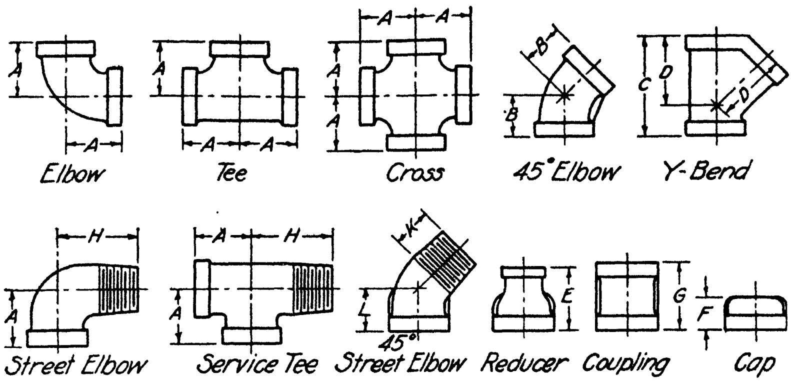


FIG. 1. Malleable iron fittings.

to lubricate pipe threads when tightening a fitting. A very common lubricant is white lead or red lead, and oil. It not only lubricates the threads but it also prevents rust and, when dry, aids in sealing the joint.



Size, Inches	1/8	1/4	3/8	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	3 1/2	4
A.........	11/16	13/16	15/16	1 1/8	1 5/16	1 7/16	1 3/4	1 15/16	2 1/4	2 11/16	3 1/8	3 7/16	3 3/4
B.........		3/4	13/16	7/8	1	1 1/8	1 5/16	1 7/16	1 11/16	1 15/16	2 3/16	2 3/8	2 5/8
C.........			2 1/8	2 1/2	2 7/8	3 7/16	4 1/16	4 1/2	5 7/16	6 1/4	7 1/4		8 7/8
D.........			1 7/16	1 11/16	2	2 7/16	2 15/16	3 5/16	4 1/16	4 11/16	5 9/16		6 15/16
E.........		1	1 1/8	1 1/4	1 7/16	1 11/16	2 1/16	2 5/16	2 13/16	3 1/4	3 11/16	4	4 3/8
F.........	17/32	5/8	3/4	7/8	1 1/16	1 3/16	1 1/4	1 5/16	1 7/16	1 5/8	1 3/4	1 15/16	2
G.........		1 1/16	1 3/16	1 5/16	1 1/2	1 11/16	1 15/16	2 1/8	2 1/2	2 7/8	3 3/16	4 1/8	4 1/2
H.........	1 1/8	1 5/16	1 7/16	1 5/8	1 7/8	2 1/8	2 1/2	2 11/16	3 3/16	3 13/16	4 1/2	5 1/8	5 11/16
K.........		15/16	1 1/16	1 3/16	1 5/16	1 1/2	1 11/16	1 7/8	2 1/4		3		3 3/4
L.........		5/8	11/16	13/16	15/16	1 1/16	1 1/4	1 3/8	1 11/16		2 1/8		2 1/2

FIG. 2. Malleable iron fittings.

Pipe joints. Other means of joining pipes are by leaded joints, where bell-and-spigot cast-iron pipes are used; by wiped joints, where lead pipes are joined, and by flanged fittings where screw fittings or leaded joints cannot conveniently be used or are otherwise undesirable. Figs. 5, 6 and 7, respectively, show these fittings and joints.

Wiped joints. Wiped joints are commonly used where lead pipes are joined. They are made by first spreading the end of one pipe and tapering the end of the other to fit into the spread end. Then melted solder is poured around the connected ends and molded to an oval shape by means of a greased wiping cloth, or mole skin, held in the hand. Much skill is required to make this joint. See Fig. 5.

Leaded joints. Leaded joints are commonly used on cast-iron pipes. They are also called bell-and-spigot joints. They are made by placing the "spigot" end of one pipe into the "bell" end of another pipe. Then a piece of oakum, made of hemp which has been soaked in a preparation of tar or creosote, is tightly calked around the spigot. Over this is

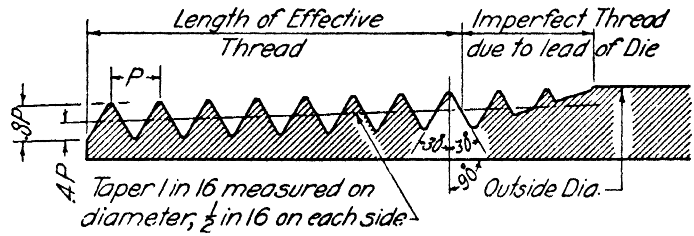
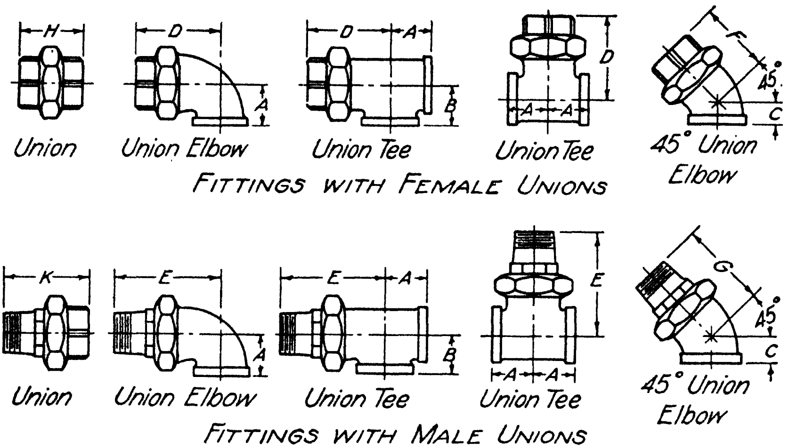


FIG. 3. A. S. A. pipe thread.

then poured molten lead which is calked tight as it begins to cool, because lead shrinks when it cools. See Fig. 6.

Flanged joints. Flanged joints are formed by bolting together the flanges at the ends of pipes. They are bolted together with a gasket between the flanges to make the joint water tight. These gaskets are commonly made of rubber, rubberized cloth, copper or asbestos composition. See Fig. 7.

Plumbing systems. The conditions of a satisfactory plumbing system are: there must be an adequate and continuous supply of pure water, and there must be an efficient set of waste pipes properly trapped so that unpleasant sewer gases do not enter any fixtures. All traps must be so vented that unequal air pressures in the waste lines will not "unseal" the traps by pushing the water out of them. All supply pipes must be laid so as to drain to the lowest point in the system in order that no water will remain in the system when the main supply valve is closed to cut off the supply. Likewise all waste lines must drain toward their outlets.



Size, Inches	1/8	1/4	3/8	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	3 1/2	4
A.........		13/16	15/16	1 1/8	1 5/16	1 7/16	1 3/4	1 15/16	2 1/4	2 11/16	3 1/8		
B.........		13/16	15/16	1 1/8	1 5/16	1 7/16	1 3/4	1 15/16	2 1/4	2 11/16	3 1/8		
C.........		3/4	13/16	7/8	1	1 1/8	1 5/16	1 7/16	1 11/16				
D.........		1 13/16	2 1/16	2 5/16	2 5/8	3	3 7/16	3 13/16	4 3/8	4 7/8	5 5/8		
E.........		2 7/16	2 3/4	3 1/16	3 1/2	3 15/16	4 7/16	4 3/4	5 3/8	6	6 15/16		
F.........		1 9/16	1 11/16	1 7/8	2 1/8	2 7/16	2 3/4	3 1/16	3 1/2				
G.........		2 3/16	2 3/8	2 11/16	3	3 3/8	3 3/4	4	4 1/2				
H.........	1 1/2	1 5/8	1 3/4	1 7/8	2 1/8	2 3/8	2 5/8	2 15/16	3 1/4	3 9/16	3 15/16	4 5/16	4 5/8
K.........		2 1/4	2 7/16	2 11/16	3 1/16	3 5/16	3 11/16	4	4 5/16	4 11/16	5 5/16		
L.........		3/4	13/16	7/8	15/16	1 1/16	1 3/16	1 5/16	1 1/2	1 5/8	1 13/16	2	2 1/4

FIG. 4. Fittings with unions.

Heating systems. The arrangement of pipes in a heating system depends upon the particular type of system used, and the types are numerous. In general, the problem in any system is to convey the heat-bearing substance, whether steam or water, as quickly and efficiently as possible to the radiators throughout the building and to return it, as it gives off its heat, to the boiler where it can be recharged

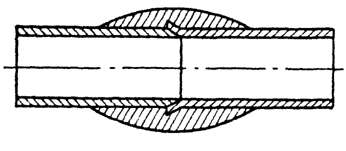


FIG. 5. Wiped joint.

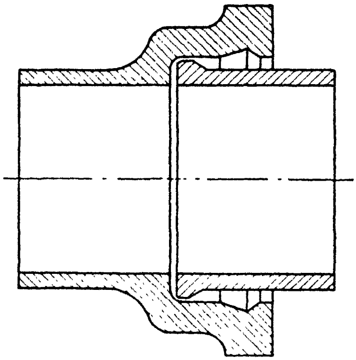
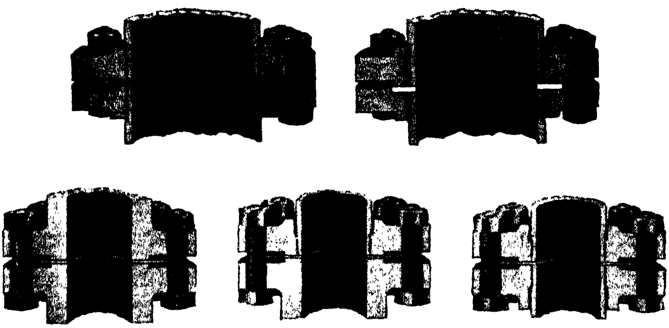


FIG. 6. Bell and spigot joint.

with heat and sent back to the radiators. This must be a continuous process. The essential parts of such a system are: (1) the *boiler*, which heats the water, (2) the *supply*



Courtesy of the Crane Co.

FIG. 7. Common types of flanged unions.

mains leading from the boiler to the points where (3) the *risers* take the water or steam up to (4) the *radiators* which give off the heat and from which (5) the *returns* carry the cooled water or condensed steam back to the boiler. Along such a route there will be many fittings such as tees, elbows, reducers, valves, etc., and various sizes of pipe.

Pipe layouts. Pipe layouts are drawings which show the sizes and arrangement of the pipes in a plumbing or a heating system. Such a drawing may be made on the floor plan of a building or it may be an isometric or a cabinet drawing

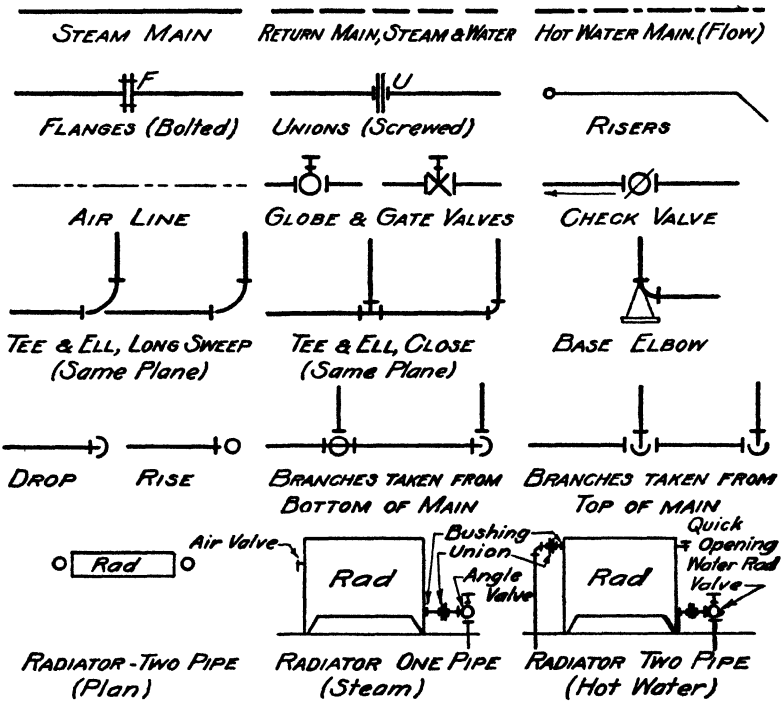


FIG. 8. Single line pipe and valve symbols.

showing pictorially the relative positions of all pipes in the system. Architects' drawings are usually plan drawings. In all small-scale drawings, pipes are indicated by single lines, and fittings by standard symbols. These symbols are shown in Fig. 8. In large-scale details the pipes are drawn to scale, with double line symbols as shown in Fig. 9, and exact dimensions are used for all fittings and fixtures. Architects rarely show water-supply pipes in pipe layouts. The location and size of water pipes are usually described in the specifications, and their layout is so generally understood by contractors and plumbers that drawings are not often required. Waste pipes and pipes used for the heating systems of houses are usually shown in layouts.

Pictorial layouts are frequently used. These have the advantage of showing the relative positions of the pipes and

DOUBLE LINE PIPE AND VALVE SYMBOLS

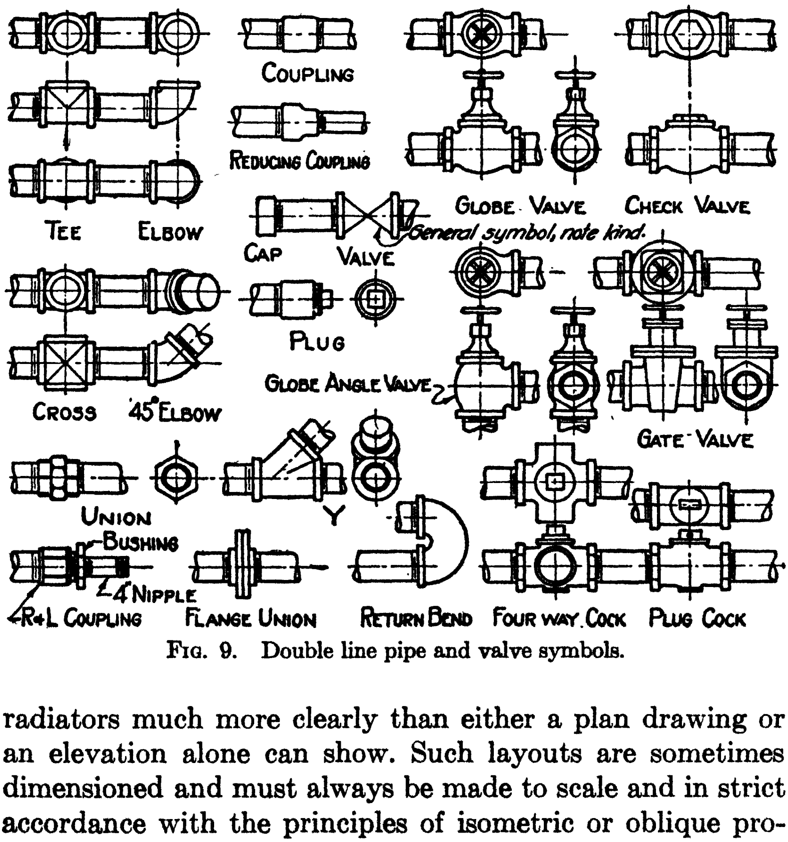


FIG. 9. Double line pipe and valve symbols.

radiators much more clearly than either a plan drawing or an elevation alone can show. Such layouts are sometimes dimensioned and must always be made to scale and in strict accordance with the principles of isometric or oblique projection. Unless these rules are followed even the relative position of parts will not be properly shown. They are used chiefly for illustrations in books and magazines, for advertisements, and for purposes of studying relative positions of the members of a system. Such pictorial layouts are sometimes used as working drawings.

HOW TO MAKE PIPING DRAWINGS

Plumbing layouts. To draw pipe layouts or plan drawings of a plumbing system locate on the plan the various outlets, then study the possible ways of connecting these locations with branch supply lines so as to avoid unnecessary piping and fittings. Next sketch in lightly what seems to be the most desirable location of the main supply line which leads to the service pipe outside the building. After determining the location of the main supply line, sketch in the branches which run from it to the pipes which lead to outlets. Next, refer to a chart of symbols, and draw, in their proper locations, the symbols representing the outlet fixtures. Then draw the lines representing pipes. Place in these lines, at the proper locations, the symbols representing fittings. Proceed in the same order to draw in waste lines. Work from fixtures, such as kitchen sinks, bath tubs, wash basins, etc., to branch lines, then locate main waste pipes and connect the branch lines to them. Draw waste pipes with dotted lines.

To draw heating layouts. To draw heating layouts locate first the radiators, then the furnace. Next decide on the location of risers and returns and locate the main feed and the main return lines. Draw symbols to indicate radiators and the furnace. Draw lines showing main feed branches and risers, then draw in returns in the same order. Place symbols for fittings in both feed and return lines. In a single-line drawing make feed lines solid and return lines dotted. Study Figs. 10 and 16.

To make a pictorial layout of a heating system. To make a pictorial layout of a heating system, first draw a symbol to represent the furnace, then draw the radiator symbols, in their proper position to scale, and decide on the location of the main feed lines, branches and returns. Next draw main feed lines, branches (if any) and returns from radiators.

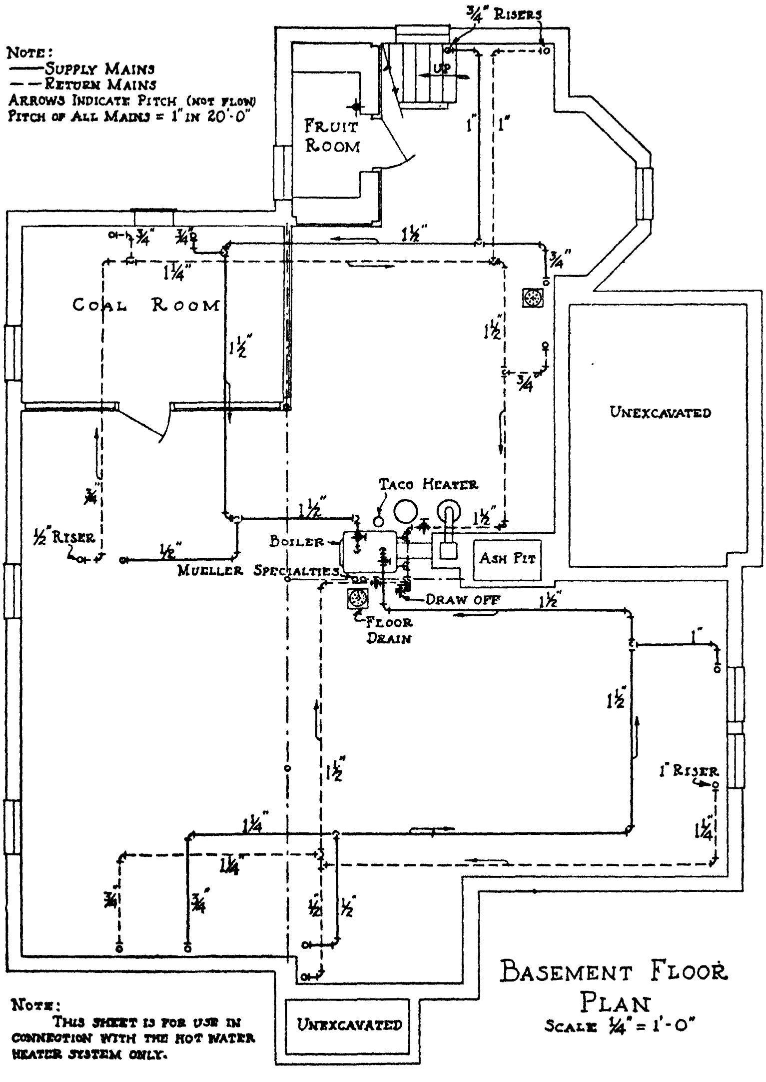


FIG. 10. Pipe layout for heating system.

Draw in symbols for fittings throughout the system of piping. Draw the symbols for the fittings so that they lie in the same plane with the pipes which they connect. Study Fig. 11. Make main feeds, branches and risers solid lines and all returns dotted. Make main lines heavier than branches, and branches heavier than lines connecting them

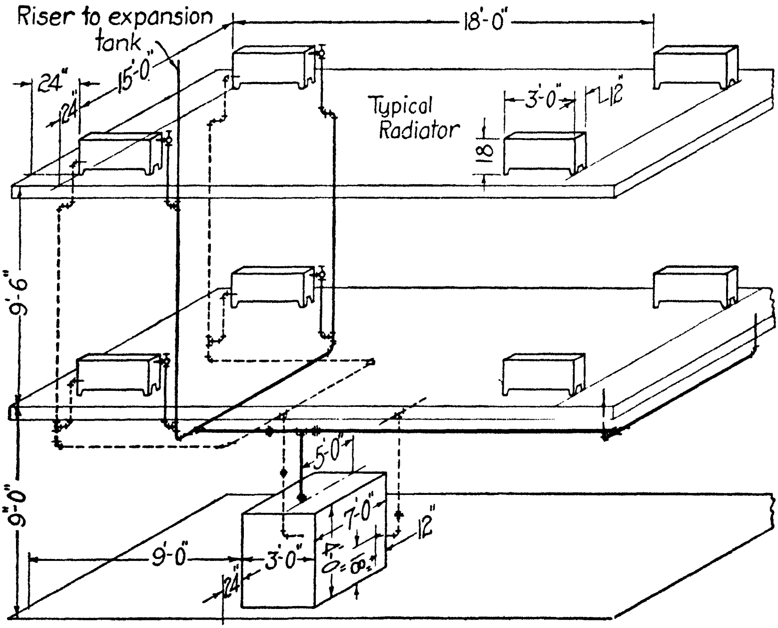


FIG. 11. Pipe layout in oblique projection.

with radiators. If the pictorial drawing is to be used for a working drawing give the sizes of pipes and dimension the drawing.

To make large-scale orthographic drawings for illustrative purposes. To make large-scale illustrative or "show" drawings, first draw the center lines of all pipes and fittings, then make all pipes with double lines. Sketch all fittings so as to show their shape and appearance. Draw the large arcs with a compass and the small fillet curves freehand. Keep all parts of fittings in correct proportion by measurements obtained from tables. Lay out to scale the details such as pipe size, fittings, radiators, etc., but not the larger distances between them. See Fig. 12. Make the drawing show clearly the pipe arrangement and the relative position of fittings and other parts of the layout by giving as many views as necessary. Unless such drawings are working drawings do not place dimensions on them. Examine carefully Fig. 13.

Large-scale isometric drawings. If the drawing is to be isometric, first lay out the center lines for all pipes and

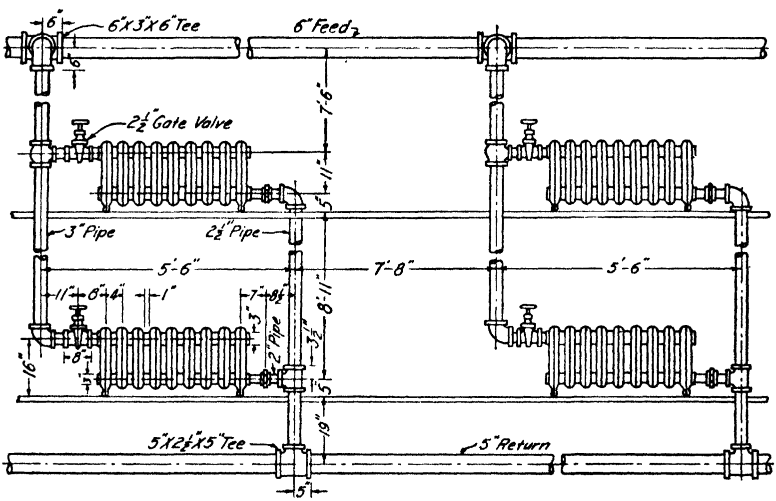


FIG. 12. Radiator layout.

fittings. Run the horizontal center lines at 30 degrees to right or left. Then draw double lines showing pipes. The distance between double lines is obtained by drawing the two lines tangent to the circle that represents the end of the pipe. See Fig. 14. Next sketch, free hand, all fittings. It is best to block out fittings in rectangular blocks which just enclose them and which are of the proper size. The fitting can then be accurately sketched inside the block. Make the fittings show as clearly as possible their shape, location and relative sizes by using dimensions given in tables to lay out the blocks. Clearness of arrangement is the important factor. Examine Fig. 14.

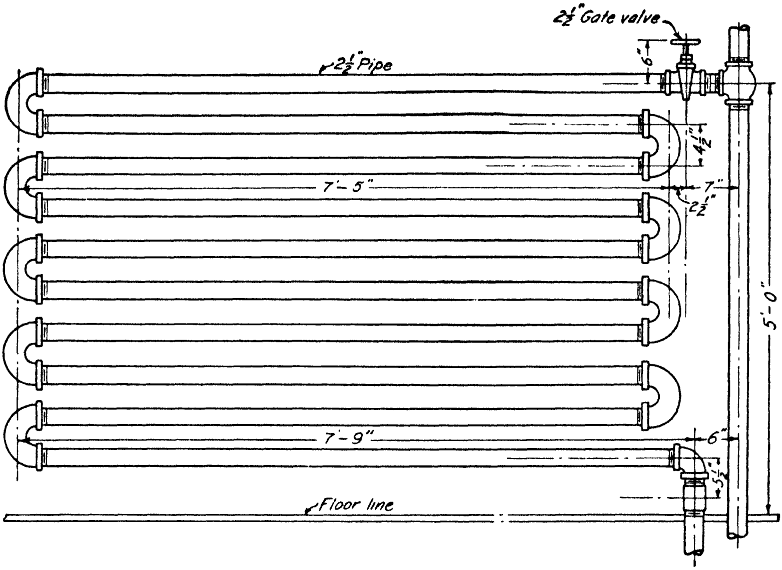


FIG. 13. Steam coil.

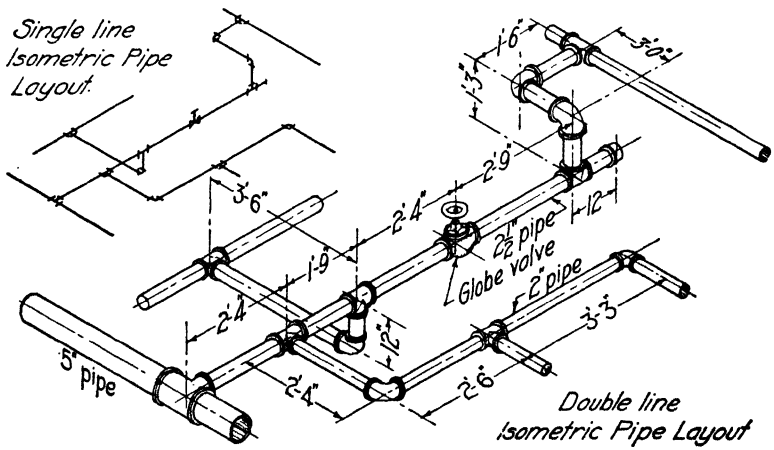


FIG. 14. Single and double line pipe layout in isometric.

To draw large-scale details. To draw large-scale details, either as a plan drawing or an elevation, use two lines for pipes and make them exactly to scale. Refer to a table of pipe sizes for outside diameters of pipes. Likewise draw fittings as accurately as possible. Refer to a table of fittings for outside dimensions, and sketch details of the fittings from a chart of large-scale symbols or from a line drawing in a manufacturer's catalogue. Lay out first all center lines of pipes, then the center lines of all fittings and draw in outlines about the center lines. Make all measurements along

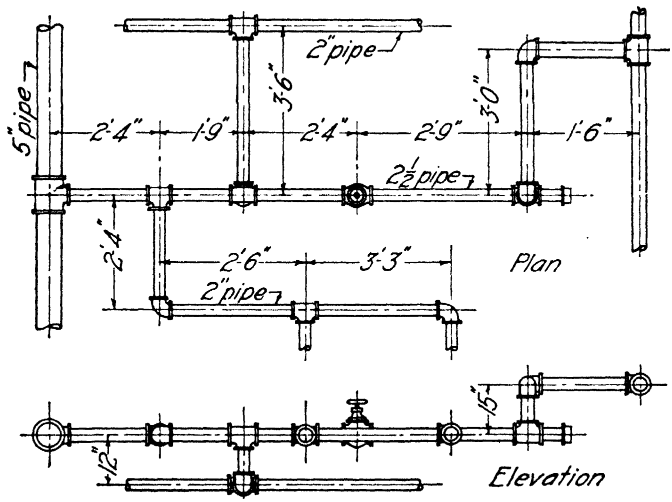


FIG. 15. Orthographic layout of pipes shown in Fig. 14.

center lines and from center line to center line. Mark all dimensions from center line to center line of fittings. Examine Figs. 12, 13 and 15.

QUESTIONS

1. What is a pipe system?
2. What are the names of the different parts of a plumbing system?
3. What are the names of the different parts of a heating system?
4. Of what materials are waste pipes made?
5. Of what materials are water and steam pipes made?
6. Why do plumbing fixtures have to be trapped and vented?
7. What are pipe fittings?
8. What different types of fittings are used in piping?

9. Why are pipes in a house system never laid perfectly level?

10. Why are pipe threads cut on a taper? What is the amount of taper used?

11. Why is some substance such as lead and oil used on pipe threads when fittings are screwed on?

12. Why is lead calked as it cools when making a bell-and-spigot joint?

13. What are pictorial layouts used for?

14. Why are plumbing systems seldom shown on house plans?

15. What steps would you take in drawing a heating system layout?

16. How should large-scale drawings be dimensioned?

REFERENCES FOR FURTHER STUDY

American Society of Heating and Ventilating Engineers' Guide, New York.

The American Society of Heating and Ventilating Engineers, Vol. 8, 1930.

BABBITT, HAROLD E.: Plumbing, McGraw-Hill Book Company, New York, 1928.

SNOW, WILLIAM G.: Pipe Fitting Charts, David Williams Company, New York, 1912.

SVENSEN, CARL LARS: Handbook on Piping, D. Van Nostrand Company, New York.

PROBLEMS

1. Draw the steam coil shown in Fig. 13. Consult the table of pipe sizes for outside diameters of pipes, and the table of fittings for over-all dimensions of fittings. Copy as accurately as you can the outlines of the fittings from the chart of symbols, Fig. 5. Draw small curves and fillets freehand but the larger ones with a compass. Give all needed dimensions and notes. Scale 1″ = 1′–0″. Title: Return Bend Steam Coil.

2. Draw the heating arrangement shown in Fig. 12. Consult the table on pipe sizes for outside diameters of pipe. Other dimensions given are not standard but are made to insure a pleasing drawing which will show a certain type of heating arrangement. This is not to be a working drawing; therefore, omit all dimensions and notes. Scale $\frac{1}{2}$″ = 1′–0″. Title: Down-feed Two-pipe System. Place drawing in center of sheet horizontally and nearer the top margin vertically.

3. Make a working drawing of a pipe arrangement similar to that shown in Fig. 15. Make a plan and elevation, and dimension carefully. Bring into use ten of the fittings assigned by your instructor from Fig. 9. Indicate pipe sizes and types of valves in notes. Use your own imagination in making the layout but see that your sheet is finally well balanced. Refer to tables for pipe

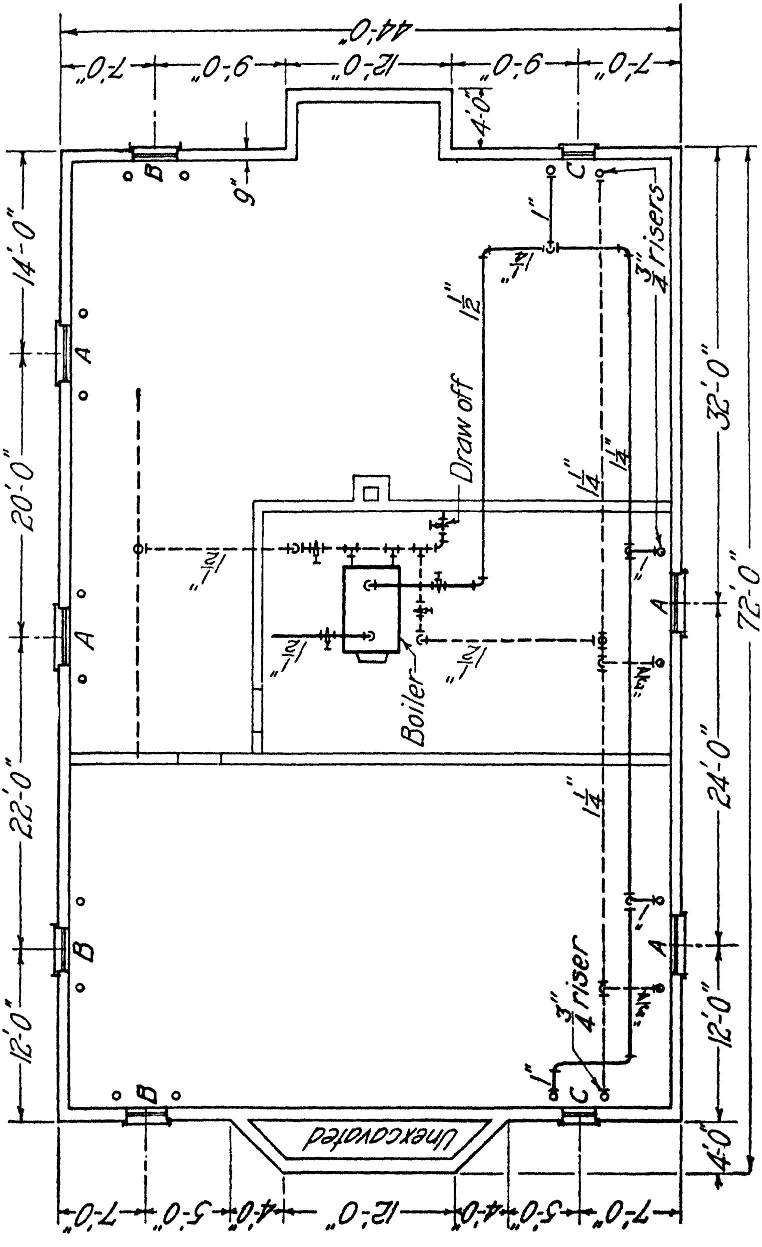


Fig. 16. Pipe layout problem. Heating system.

sizes and fitting dimensions. Copy outlines of fittings from Figs. 2 and 3. Scale $\frac{3}{4}'' = 1'\text{-}0''$. Title: Supply Pipe Arrangement.

4. Make the pictorial layout shown in Fig. 11 and complete the piping to the four unconnected radiators, so that their connections correspond exactly to those of the other radiators. Consult the chart of symbols, Fig. 8. Title: Heating Layout. Scale ¼″ = 1′–0″.

5. Copy the drawing shown in Fig. 16 and complete the heating system connections. Draw basement plan to scale, ⅛″ = 1′–0″. Since this is only a heating layout omit the dimensions of the basement plan. Place the boiler as shown, near the center of the basement. Locate pipes approximately as shown; their exact location to scale is not necessary. Make boiler about 4′–0″ x 5′–0″. All window-openings marked *A* are 4 feet wide, all marked *B* are 3 feet and those marked *C* are 2 feet. Title: Heating System. Basement Plan.

Dimensions and Weight of Standard Pipe

(National Tube Co.)

Nominal Size	Diameters		Thickness	Weight per Foot, Pounds		Threads per Inch
	External	Internal		Plain Ends	Threads and Couplings	
⅛	0.405	0.269	0.068	0.244	0.245	27
¼	0.540	0.364	0.088	0.424	0.425	18
⅜	0.675	0.493	0.091	0.567	0.568	18
½	0.840	0.622	0.109	0.850	0.852	14
¾	1.050	0.824	0.113	1.130	1.134	14
1	1.315	1.049	0.133	1.678	1.684	11½
1¼	1.660	1.380	0.140	2.272	2.281	11½
1½	1.900	1.610	0.145	2.717	2.731	11½
2	2.375	2.067	0.154	3.652	3.678	11½
2½	2.875	2.469	0.203	5.793	5.819	8
3	3.500	3.068	0.216	7.575	7.616	8
3½	4.000	3.548	0.226	9.109	9.202	8
4	4.500	4.026	0.237	10.790	10.889	8
4½	5.000	4.506	0.247	12.538	12.642	8
5	5.563	5.047	0.258	14.617	14.810	8
6	6.625	6.065	0.280	18.974	19.185	8
7	7.625	7.023	0.301	23.544	23.769	8
8	8.625	8.071	0.277	24.696	25.000	8
8	8.625	7.981	0.322	28.554	28.809	8
9	9.625	8.941	0.342	33.907	34.188	8
10	10.750	10.192	0.279	31.201	32.000	8
10	10.750	10.136	0.307	34.240	35.000	8
10	10.750	10.020	0.365	40.483	41.132	8
11	11.750	11.000	0.375	45.557	46.247	8
12	12.750	12.090	0.330	43.773	45.000	8
12	12.750	12.000	0.375	49.562	50.706	8

UNIT XI

PRODUCTION DIMENSIONING

PURPOSE OF UNIT XI

It is the purpose of this unit to show how to dimension parts which must be produced in quantities under definite specifications and which must fit interchangeably.

WHAT YOU SHOULD KNOW ABOUT PRODUCTION DIMENSIONING

Classes of fit. All machines have moving parts which must fit closely or loosely, depending upon the function which the parts must perform. These fits vary all the way from very loose free fits to those very tight ones in which the parts must be forced together under heavy pressure and are then permanently joined together.

The various classes of fits have been standardized through the cooperation of many engineering societies and manufacturers. These standards are given in Bulletin B–4a–1925 of the American Standards Association. A brief outline of them is given below.

Definition of terms. Before discussing the classifications of fits it is necessary to define terms which are commonly used and which have a definite technical meaning.

Basic size. The exact theoretical size from which all limiting variations are made is called the *basic size.* It is the minimum size of the external member regardless of the kind of fit.

Allowance (Neutral zone). An intentional difference in the dimensions of mating parts, or the minimum clearance space which is intended between mating parts, is called allowance. It represents the condition of the tightest permissible fit, or the largest internal member mated with the smallest external member. It is to provide for different classes of fit. When the internal member is larger than the external member the allowance is said to be negative. It is also referred to as interference.

Limits. By limits is meant the extreme permissible dimensions of a part. The amount of variation permitted in the size of a part is called tolerance. For example, if a hole is dimensioned 0.750 inch and a shaft 0.749 inch the allowance is 0.001 inch. In manufacturing such parts, however, it is impossible to make them all exactly to the dimension specified. Some variation must be tolerated, but this variation must be controlled so that in all cases the parts will fit together. Thus the hole may vary from 0.750 to 0.751 inch, which would be a tolerance of 0.001 inch, and the shaft might be permitted to vary from 0.749 to 0.748 inch, thus also giving a tolerance of 0.001 inch. In assembling these parts, then, the loosest fit would have a clearance of 0.003 and the tightest one a clearance of 0.001 inch, which was the allowance originally set for the parts.

The greater the tolerance on parts the cheaper it is to manufacture them, since fewer pieces must be rejected. Hence, designers endeavor to secure the greatest tolerance consistent with proper working of the parts. With the larger tolerance (classes 1 to 4 inclusive) assembly is interchangeable, that is, any two mating parts picked up at random will go together. This process is more rapid than where selective assembly is necessary. Eight classes of fits have been established. The following paragraphs are quoted from A. S. A. Bulletin B–4a–1925.

Loose fit (Class 1)—large allowance. This fit provides for considerable freedom and embraces certain fits where accuracy is not essential.

Examples: Machined fits of agricultural and mining machinery; controlling apparatus for marine work; textile, rubber, candy and bread machinery; general machinery of a similar grade; some ordnance material.

Free fit (Class 2)—liberal allowance. For running fits with speeds of 600 r.p.m. or over, and journal (bearing) pressure of 600 pounds per square inch or over.

Examples: Dynamos, engines, many machine tool parts, and some automotive parts.

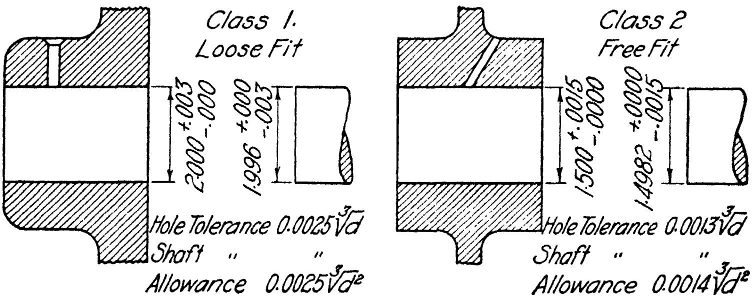


Fig. 1. A. S. A. fits. Class 1 and 2.

Medium fit (Class 3)—medium allowance. For running fits under 600 r.p.m. and with journal pressures less than 600 pounds per square inch; also for sliding fits; and the more accurate machine tool and automotive parts.

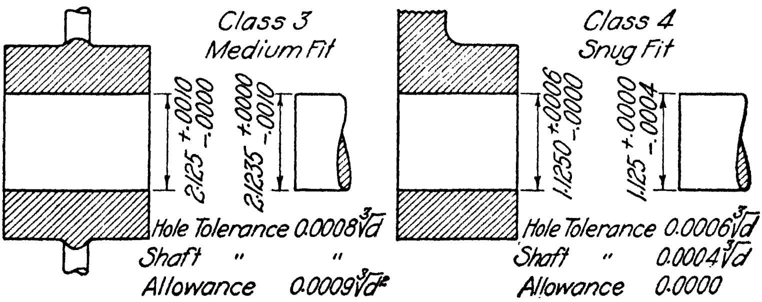


Fig. 2. A. S. A. fits. Class 3 and 4.

Snug fit (Class 4)—zero allowance. This is the closest fit which can be assembled by hand and necessitates work of considerable precision. It should be used where no perceptible shake is permissible and where moving parts are not intended to move freely under a load.

Wringing fit (Class 5)—zero to negative allowance. This is also known as a "tunking fit," and it is practically metal to metal. Assembly is usually selective and not interchangeable.

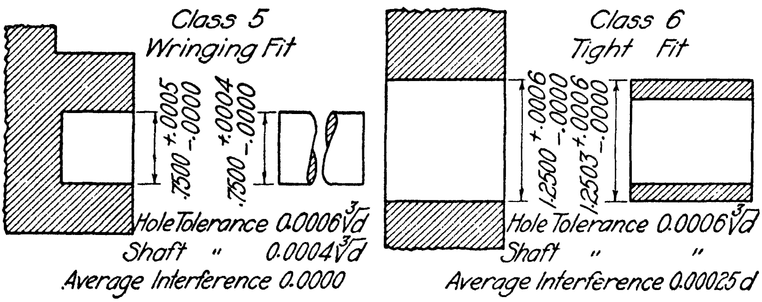


FIG. 3. A. S. A. fits. Class 5 and 6.

Tight fit (Class 6)—slight negative allowance. Light pressure is required to assemble these fits and the parts are more or less permanently assembled, such as fixed ends of studs for gears, pulleys, rocker arms, etc. These fits are used for drive fits in thin sections or extremely long fits on very light sections. Used in automotive, ordnance and general machine manufacturing.

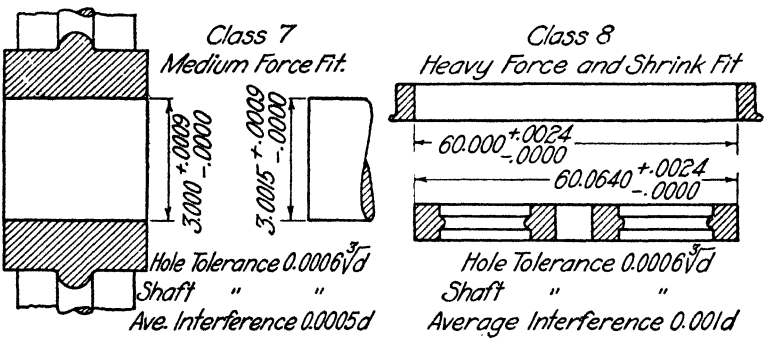
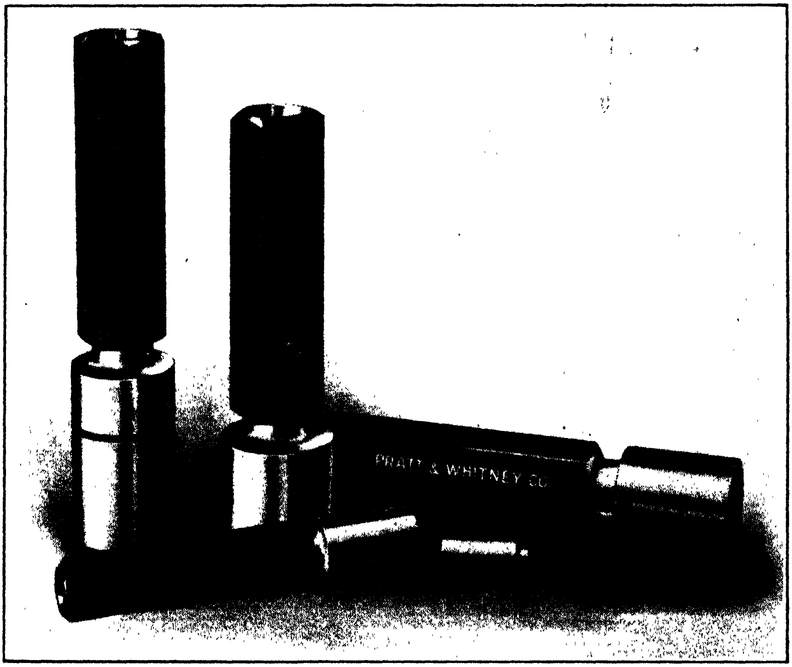


FIG. 4. A. S. A. fits. Class 7 and 8.

Medium force fit (Class 7)—negative allowance. Considerable pressure is required to assemble these fits, and the parts are considered permanently assembled. These fits are used in fastening locomotive wheels, car wheels, armatures of dynamos and motors, and crank disks to their axles or shafts. They are also used for shrunk fits on medium sections or long fits. These fits are the tightest which are recommended for cast-iron holes or external members as they stress cast iron to its elastic limit.



Courtesy of Pratt & Whitney Co.

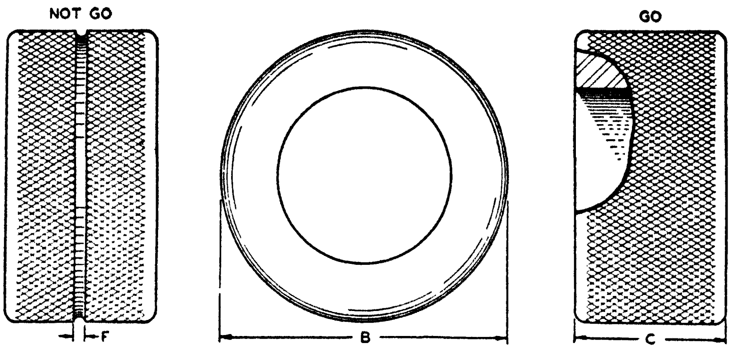
FIG. 5. Plug gages.

Heavy force and shrunk fit (Class 8)—considerable negative allowance. These fits are used for steel holes where the metal can be highly stressed without exceeding its elastic limit. These fits cause excessive stress for cast-iron holes. Shrunk fits are used where heavy force fits are impracticable, as on locomotive wheels, tires, heavy crank disks of large engines, etc.

Gages. In order to determine whether parts come within the limits specified, instruments called gages are used.

There are many types of gages, several of which are indicated in Figs. 5 to 9.

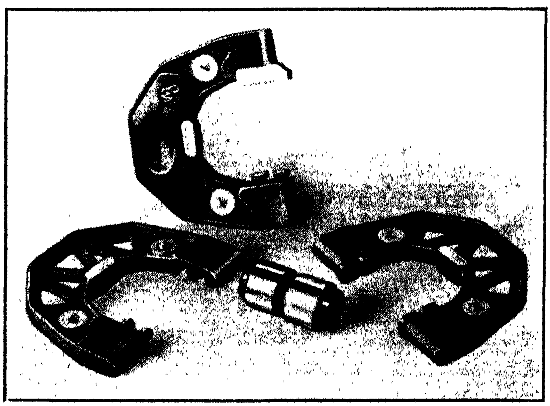
The ring gage is one whose inside measuring surface is circular in form. A plug gage is one whose outside surface



Courtesy Pratt & Whitney Co.

FIG. 6. Ring gages.

is arranged to verify the specified uniformity of holes. Master gages are used to check the gages in use and to see

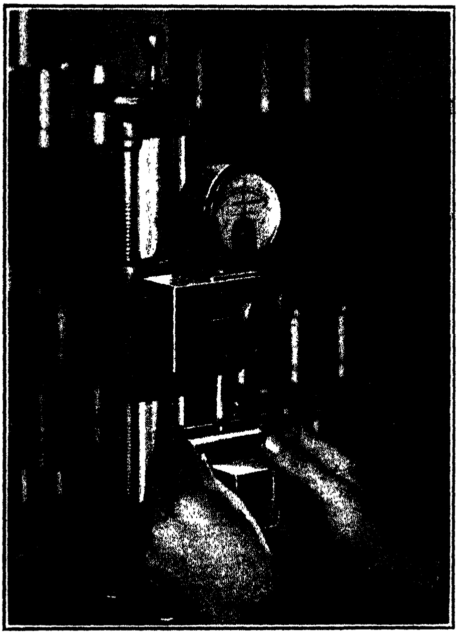


Courtesy Pratt & Whitney Co.

FIG. 7. Snap gages

that they do not depart from the true requirements by reason of wear while in constant use.

The electrolimit gage shown in Fig. 8 combines mechanical gaging with electrical magnification to obtain either external or internal measurements. It can be set to any limits desired, ranging from ordinary shop thousandths to mil-



Courtesy Pratt & Whitney Co.

FIG. 8. Electro-limit gage.

lionths, and is an excellent inspection instrument for selective assembly.

HOW TO DIMENSION

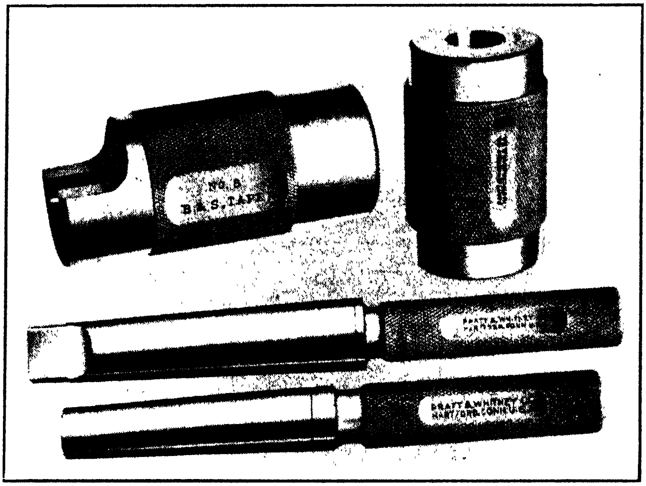
The problem of dimensioning for production with certain definite tolerances introduces no new drafting problem except that of allowing a little more room than usual for dimensions.

Mark dimensions on the object as illustrated in Figs. 1 and 2, or specify the exact upper and lower limits as shown in Fig. 10. Both methods are in use.

In attempting to put in dimensions like this always rule guide lines so that a workman-like appearance is obtained.

Make the decimal point clear and strong so that it cannot by any chance be overlooked.

Compute the actual allowances and tolerances on parts from formulas given in Figs. 1 to 4. These computations are



Courtesy Pratt and Whitney Co.

FIG. 9. Taper plug and ring gages.

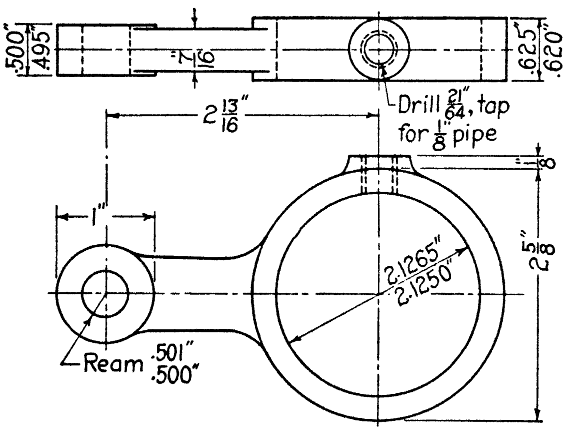


FIG. 10. Another method of giving limit dimensions.

best made by the use of logarithms. Tables are given in the A.S.A. bulletin from which the allowances and tolerances may be taken directly.

QUESTIONS

1. Explain clearly the meaning of the term allowance.
2. What is meant by tolerance?
3. What is meant by basic size?
4. From the equations given in Figs. 1 and 4 compare the allowance in the first four classes of fits.
5. Which class has the greatest positive allowance?
6. What is meant by a negative allowance?
7. Other things being equal, which object is the cheapest to manufacture, one with a large or one with a small tolerance? Why?
8. How are the sizes of objects checked to see whether they fall within the limits specified?
9. What is meant by the term "limits"?
10. What is meant by interference?
11. Show by a sketch two ways of specifying the limits in dimensioning.

PROBLEMS

Lay out the standard border line and title space. Divide the sheet into four equal rectangles. In each rectangle letter neatly the solution of the problems assigned from the following group. In each case, compute the allowance, and tolerance on the inside and outside piece. Show class of fit, formulas and resulting dimensions, giving limits on both parts.

1. A bronze bushing which is held in place by its own pressure in a hole in a cast-iron part. The basic size of the hole is 2 inches.

2. A bearing for a shaft which makes 400 r.p.m. and has a bearing pressure 150 pounds per square inch. The shaft is 3 inches in diameter (basic size).

3. A bearing in a binder (agricultural machine). The basic size of the shaft is $1\frac{1}{2}$ inches.

4. A pump piston; basic size $1\frac{1}{2}$ inches. A pump does not have packing rings, hence a snug fit is required.

5. A dynamo bearing, basic shaft size 3 inches. Speed 1800 r.p.m.

6. The stud in a rocker arm which is held in place by its own pressure. Basic size 2 inches in diameter.

7. A sliding part on a commercial bread mixer, basic size (square) $1\frac{1}{4}$ inches.

8. Guide for a sliding rod on an accurate machine tool. Moves back and forth 10 times per minute, bearing pressure 300 pounds per square inch. Basic size $3\frac{1}{2}$ inches.

9. A crank disk and shaft; basic diameter 5 inches. Disk stays in place by its own pressure.

10. On the standard drawing sheet make a working drawing of an object assigned by your instructor from the group below. Use the method of giving limit dimensions designated by your instructor. Use the scale given in the figure.

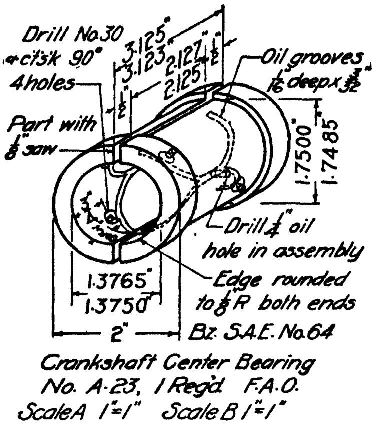


FIG. 11. Camshaft center bearing.

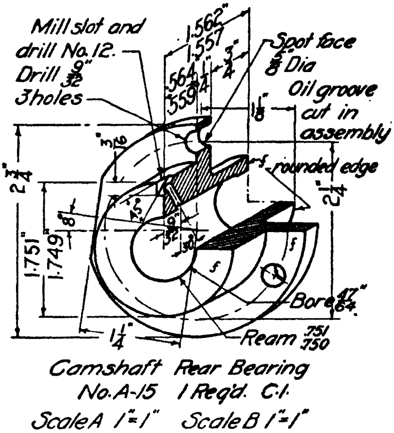
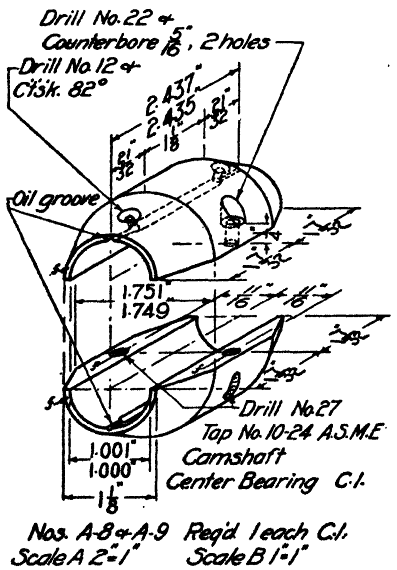
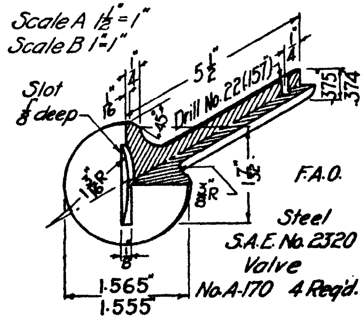


FIG. 12. Camshaft rear bearing.





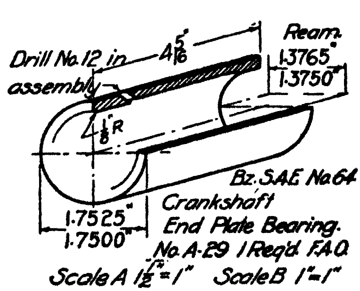


FIG. 13. Camshaft center bearing.

FIG. 14. Valve.

FIG. 15. Crankshaft endplate bearing.

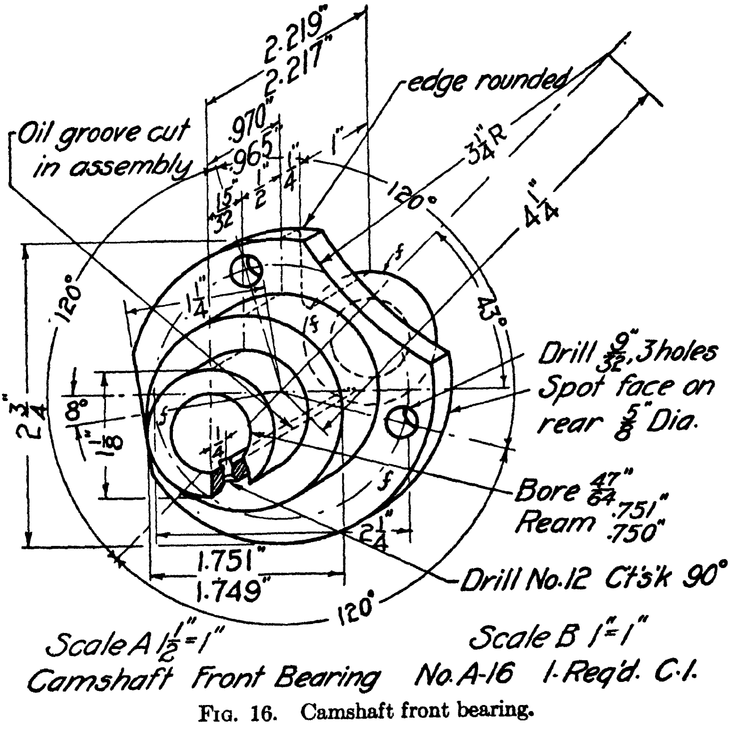


FIG. 16. Camshaft front bearing.

UNIT XII

ASSEMBLY DRAWINGS

PURPOSE OF UNIT XII

It is the purpose of this unit to teach the uses and characteristics of assembly drawings and how to make detail drawings from them.

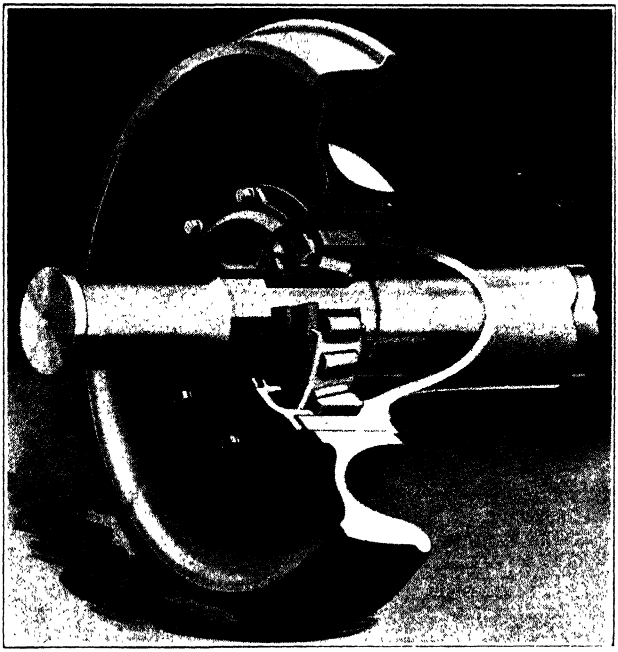
WHAT YOU SHOULD KNOW ABOUT ASSEMBLY DRAWINGS

Uses of assembly drawings. Assembly drawings are used for (1) preliminary and final design, (2) advertising and sales work, (3) erection in the field, (4) assembly in the shop.

For design. An assembly drawing for design purposes may be a mechanical drawing or a freehand sketch which shows the general proportions and function of a machine or other structure. From this assembly the size required of various parts to give the necessary strength may be computed, required clearances may be determined and other information may be obtained to make the detail drawings of the parts.

For advertising. For sales and advertising purposes the assembly drawing is used to show how a machine works. This type of drawing is usually sectioned as shown in Fig. 1, and it may be colored to help distinguish one part from another. The parts are usually named or numbered so that they may be identified when replacements are necessary.

For shop assembly. For erection or assembly in shop the drawing frequently consists of only one view which is sectioned in such a manner as to reveal all parts in their proper working order. Fig. 2 illustrates this type of drawing. An assembly drawing, then, may be defined as one or more views of a machine or structure adequately sectioned to reveal all parts in their proper working order and containing sufficient dimensions and notes for the purpose intended.



Courtesy American Steel Foundries and Simmons-Boardman Pub. Co.
FIG. 1. Car wheel assembly. Roller bearing unit.

HOW TO MAKE DETAIL DRAWINGS FROM ASSEMBLY DRAWINGS

In this unit we shall use assembly drawings only for the purpose of making detail drawings. Since complete dimensions for all parts cannot be shown on such a drawing many of the dimensions must be determined by a sense of proportion based upon some of the dimensions in the drawing which are known.

The valve shown in Fig. 2 is quite elaborately dimensioned. Ordinarily the size of the valve, size of pipe, the overall length and height would be the principal dimensions given. From dimensions given, by a sense of proportion, determine the minor details such as radii of curved parts, length of threaded parts, etc.

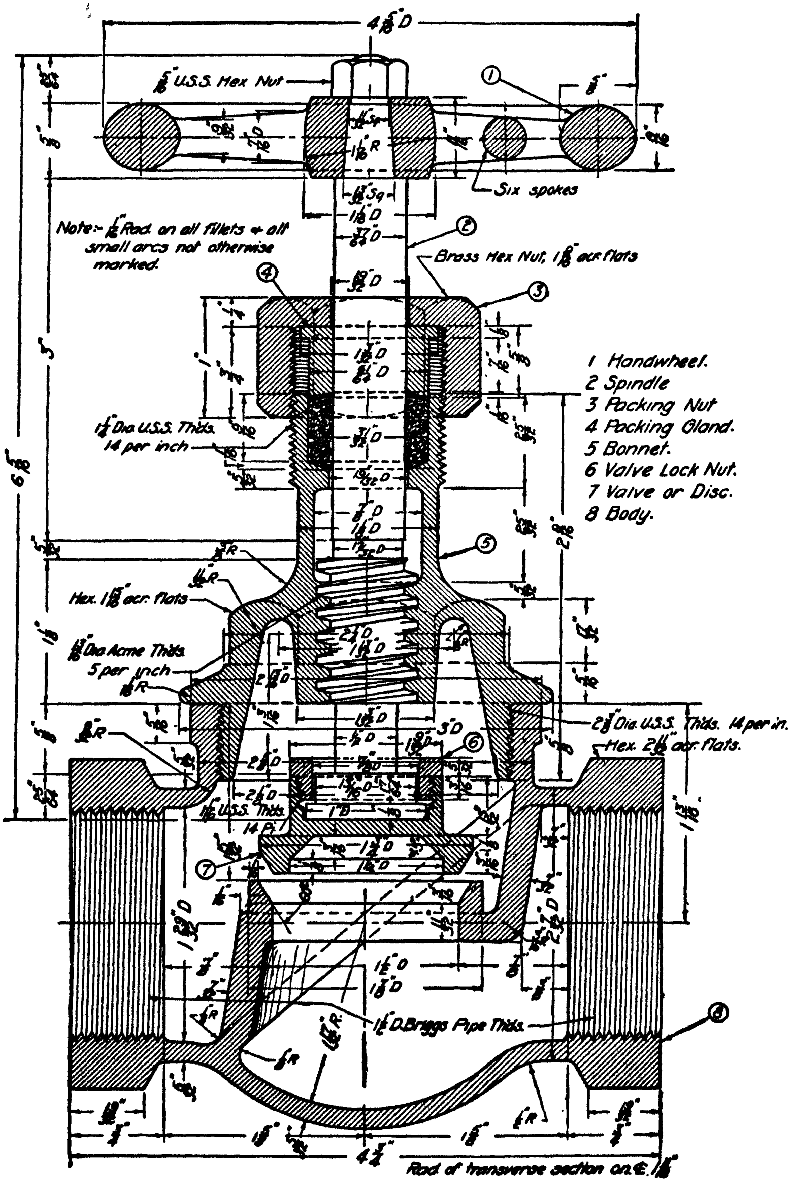


FIG. 2. Valve assembly.

Provide clearance where necessary for moving parts and determine proper allowance and tolerance for parts that must fit accurately, as, for example, the packing gland of Fig. 2.

When all parts have been detailed, carefully check them to see that:

1. They can actually be assembled.
2. They fit properly where they belong and have the proper fasteners to keep them in place.
3. They are properly dimensioned to be assembled interchangeably, if that is desirable (this is usually the case in quantity production).
4. Standard parts such as bolts, screws, keys and pins have been used, rather than special types.

QUESTIONS

1. Define the term "assembly drawing."
2. What are assembly drawings used for?
3. Why are parts named and numbered in some assembly drawings?
4. What is the meaning of the term clearance as used in this unit?
5. Why are assembly drawings usually elaborately sectioned?
6. When details are made from an assembly drawing how are dimensions which are not specified in the drawing determined?
7. What is meant by having parts made to be assembled interchangeably?
8. Is a class I fit capable of interchangeable assembly?

PROBLEMS

Make a complete set of details from the object assigned from the following group. Put the drawing of each piece upon a separate sheet; use small sheets $8\frac{1}{2}$ x 11 or 9 x 12, unless otherwise instructed by your teacher. Use your own judgment based upon the definitions (see Unit XI) in determining the class fit for the various parts. Scale A permits all parts to be put on one sheet size A, if carefully arranged. "Scale B select" means to choose the proper scale for each piece. They need not all be to the same scale when placed on different sheets.

After your drawings are completed, check all parts to see that they will go together and operate as intended.

Note: The different parts of an object may be assigned to different pupils if a complete set of details is desired in a short space of time.

The more complicated assemblies must be examined very carefully to find all the dimensions since it is a very difficult task to get so many dimensions upon an assembly. If a dimension finally proves to be missing make a careful estimate of what the dimension ought to be by comparison with other parts. The drawings are all to scale.

Screw threads are all specified in the standard form—the first number of the thread note gives the crest diameter, and the

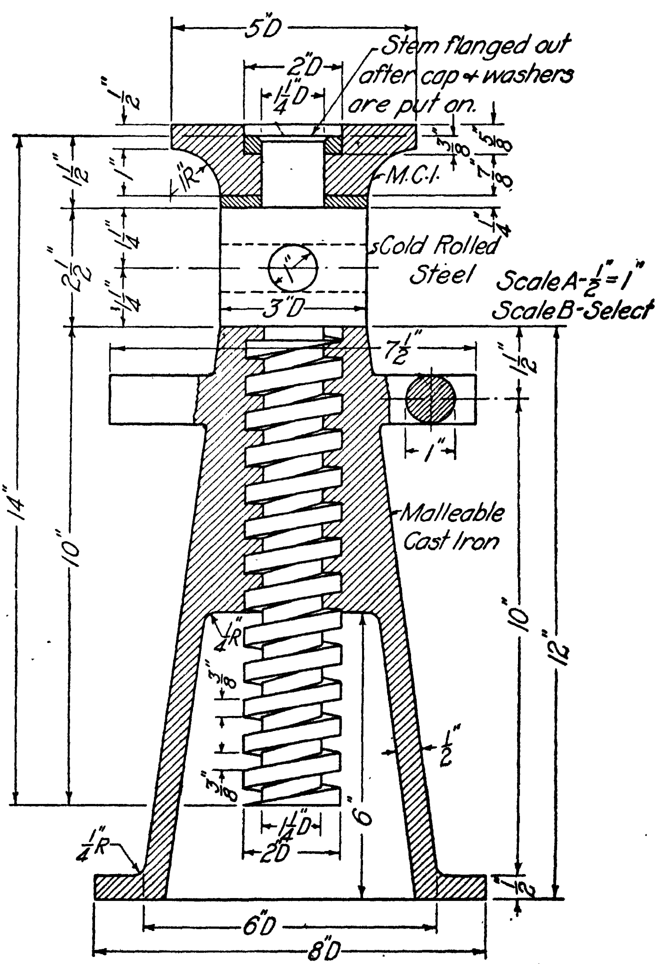


FIG. 3. Screw jack.

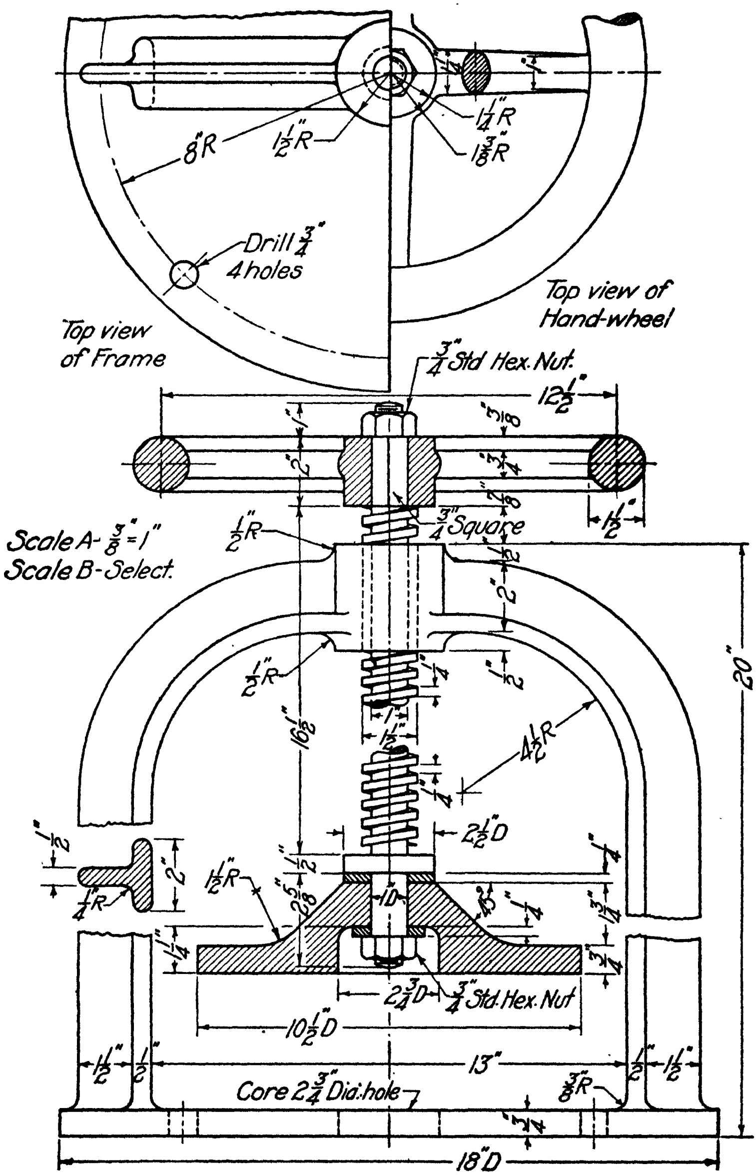


FIG. 4. Screw press.

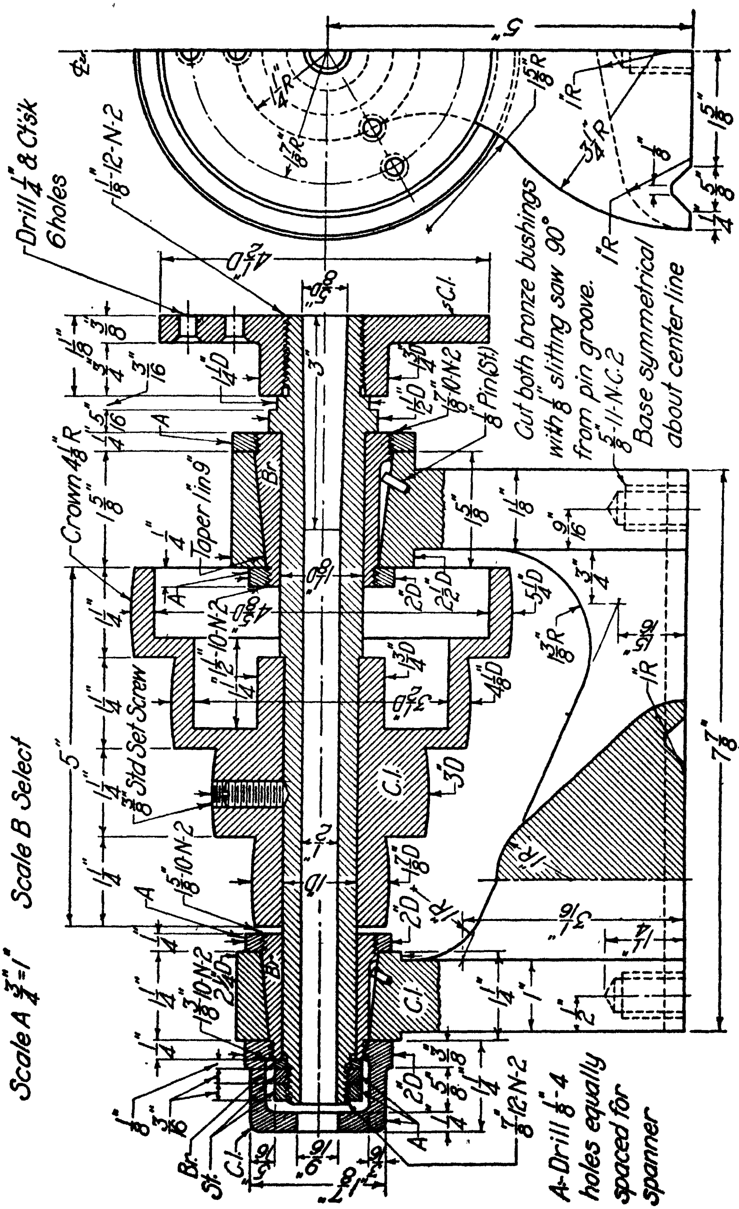


FIG. 5. Lathe head stock.

second, the number of threads per inch. The remaining letters and numbers indicate the type of thread and the class of fit respectively.

The valve in Fig. 2 has been dimensioned so that it may be used as a problem if desired.

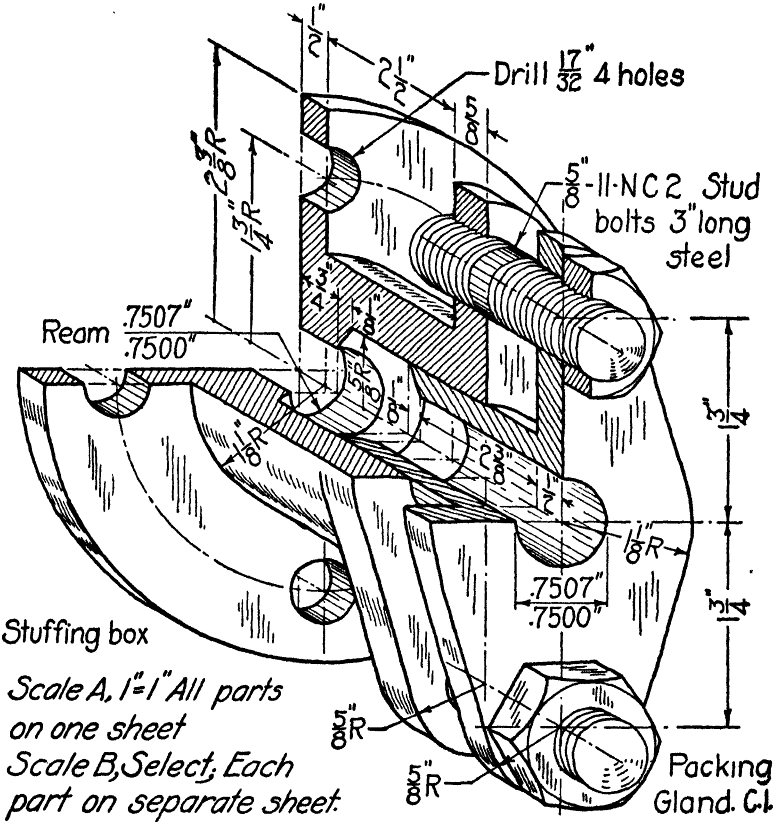


FIG. 6. Stuffing box.

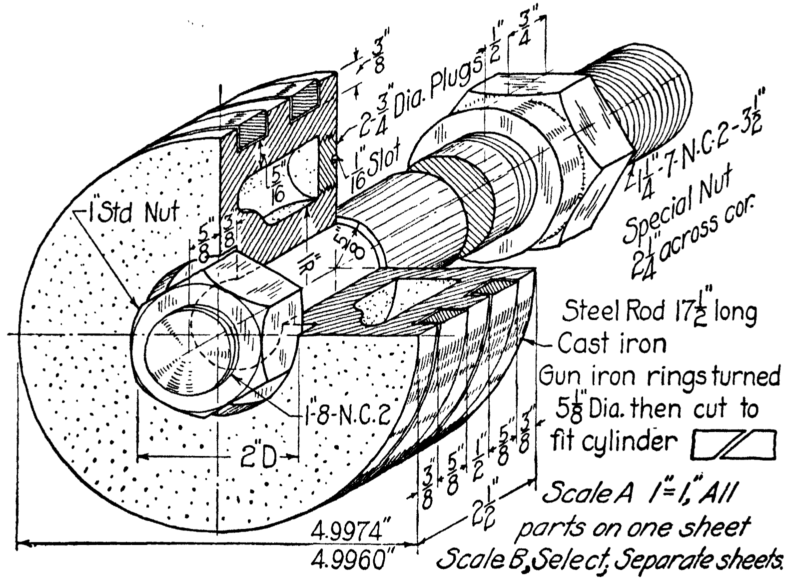


FIG. 7. Piston and rod.

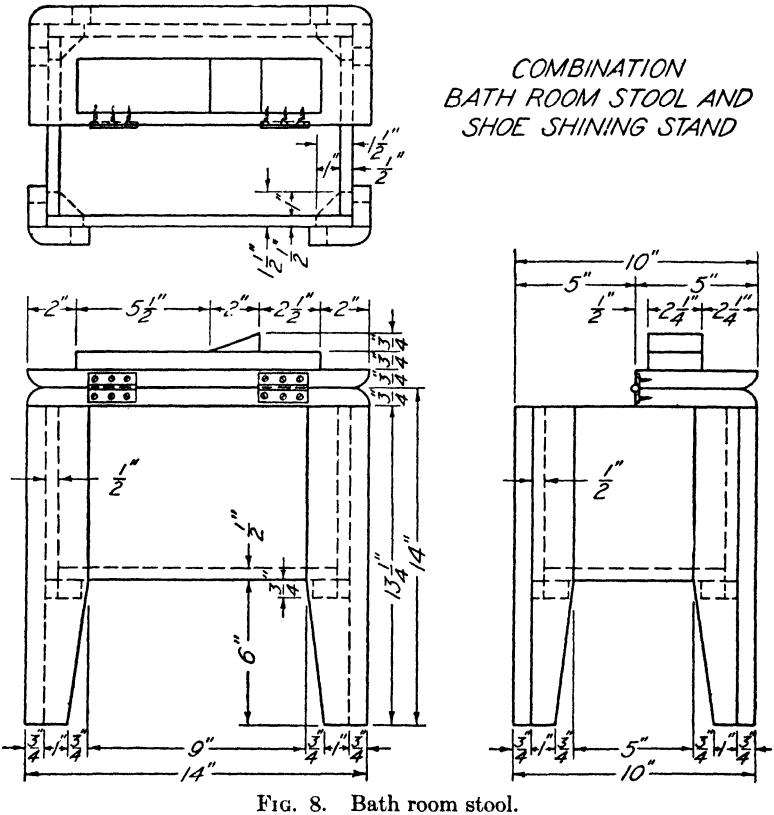


FIG. 8. Bath room stool.

UNIT XIII

ASSEMBLY DRAWINGS

PURPOSE OF UNIT XIII

It is the purpose of this unit to show how to make assembly drawings from details.

WHAT YOU SHOULD KNOW ABOUT ASSEMBLY DRAWINGS

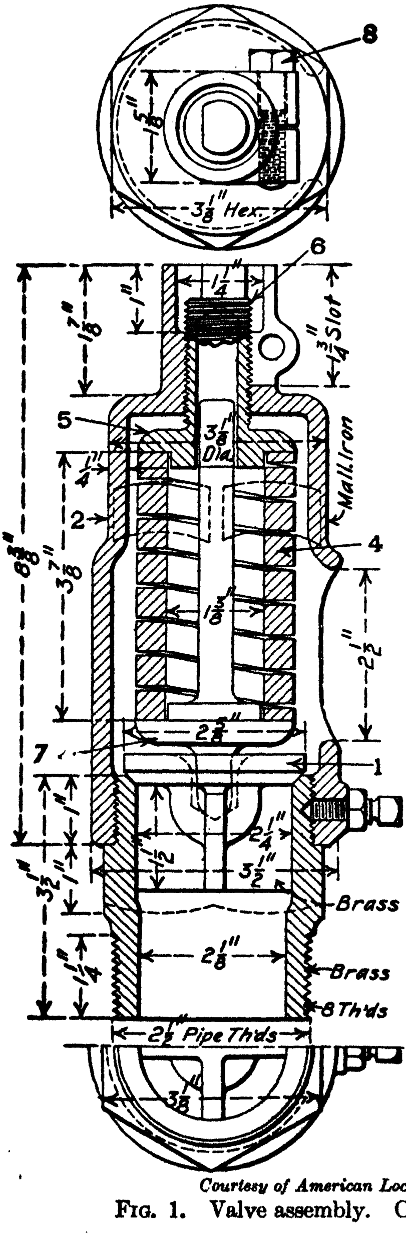
Purpose of assembly drawings. In the process of production after details have been prepared it is frequently desirable to make a new assembly drawing from the dimensioned parts, first as a check upon their accuracy and proportions, and second, as a guide in bringing the parts together in a finished machine.

In making such an assembly drawing for simple machines the proper place for each part can usually be determined by inspection and a comparison of the dimensions. For more complicated machines a knowledge of the operation of the machine is necessary. In this unit only the simple types of machines will be given.

Sectioning and noting. Assembly drawings of this type are usually made in half or full section and should show each part in sufficient detail so that it may be identified. Each part should be named or numbered with an arrow leading from the name or number to the part. As a rule, only general over-all dimensions need be given. See Fig. 1.

HOW TO MAKE AN ASSEMBLY DRAWING FROM DETAILS

To plan the assembly. Study the detail drawings carefully and with special attention to the dimensions of various parts; attempt to figure out in your imagination how the parts work together. Take advantage of all perfectly obvious



1. Valve.
2. Body.
4. Pressure spring.
5. Pressure spring cap.
6. Adjusting screw.
7. Pressure spring seat.
8. Adjusting screw clamp bolt.

Courtesy of American Locomotive Co. and Simmons-Boardman Pub. Co.

FIG. 1. Valve assembly. Cylinder head relief valve.

Note:—The types of arrowhead and dimension lines used in this figure are not standard practice and are not approved.

relationships to speed up this process. Thus, for example, a shaft necessarily calls for a bearing; one gear calls for another; a threaded rod calls for a threaded hole or a nut; a keyway must have a key, and a gear, pulley, clutch or coupler to go with it, etc.

To draw the assembly. Having determined the proper order in which the parts should be assembled, draw first, in light outline, the main part or body of the object, and study carefully whether a half section or full section will best show all parts. It may be necessary to combine partial or broken sections with the half or full section. This can be determined only as the drawing progresses.

Having drawn the main part, draw in other parts in about the same order as you would put the parts together if you had the actual objects at hand to assemble. When the outlines have been drawn cross-hatch the parts, taking care to change the direction of the cross-hatching to distinguish the adjacent parts from each other.

To ink. When inking, make the outlines heavy so that they will stand out clearly above the cross-hatching, which should be made very light.

QUESTIONS

1. Why is it desirable to make an assembly from finished detail drawings?
2. Name some of the obvious relationships which can be used as an aid in making an assembly drawing from details.
3. Besides the obvious relationship of parts such as gear to gear, what item in the detail drawings must be the final governing factor in putting parts together?
4. How should one proceed to make an assembly drawing after having determined mentally the position of each piece?
5. What general order should one follow in drawing in all the parts?
6. Upon what basis is the choice of half, full or other sectioning determined?
7. Which lines in the drawing are made heaviest?

PROBLEMS

Lay out the standard border line and title space and then make an assembly drawing of one of the objects assigned from the following pages.

Determine the scale for each drawing by carefully estimating the over-all dimension and selecting the largest scale that will appropriately fit the sheet. The number of views to be made should be sufficient to show how the parts go together and, if it is a machine, how it works.

The little pictures with Figs. 4, 6 and 8 show objects somewhat similar but not exactly like those given in the details. These will assist you in making your assembly. Note that these three objects require two figures each in the text to represent all the parts.

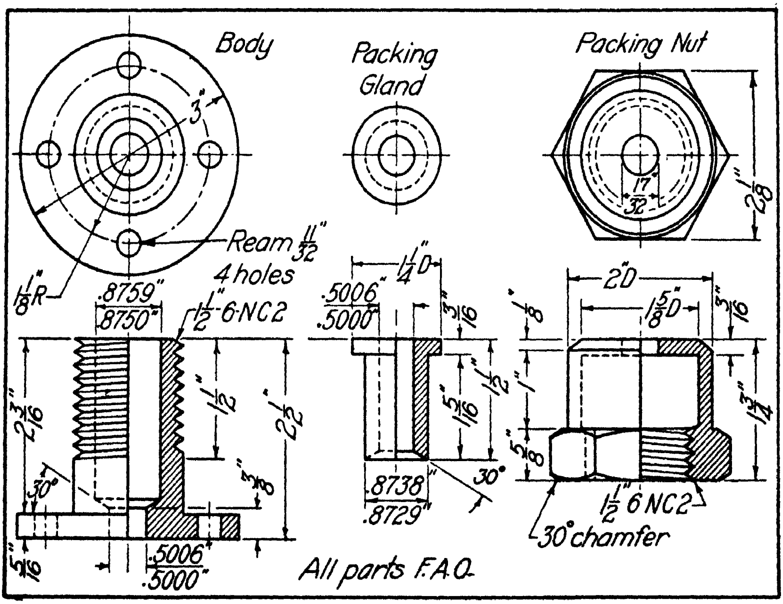


FIG. 2. Details of stuffing box.

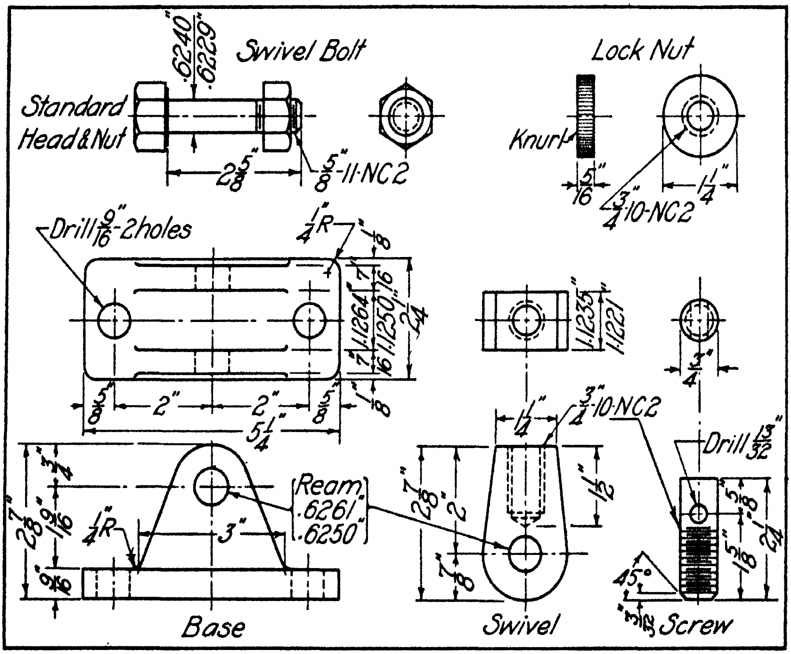


FIG. 3. Details of machinist's jack.

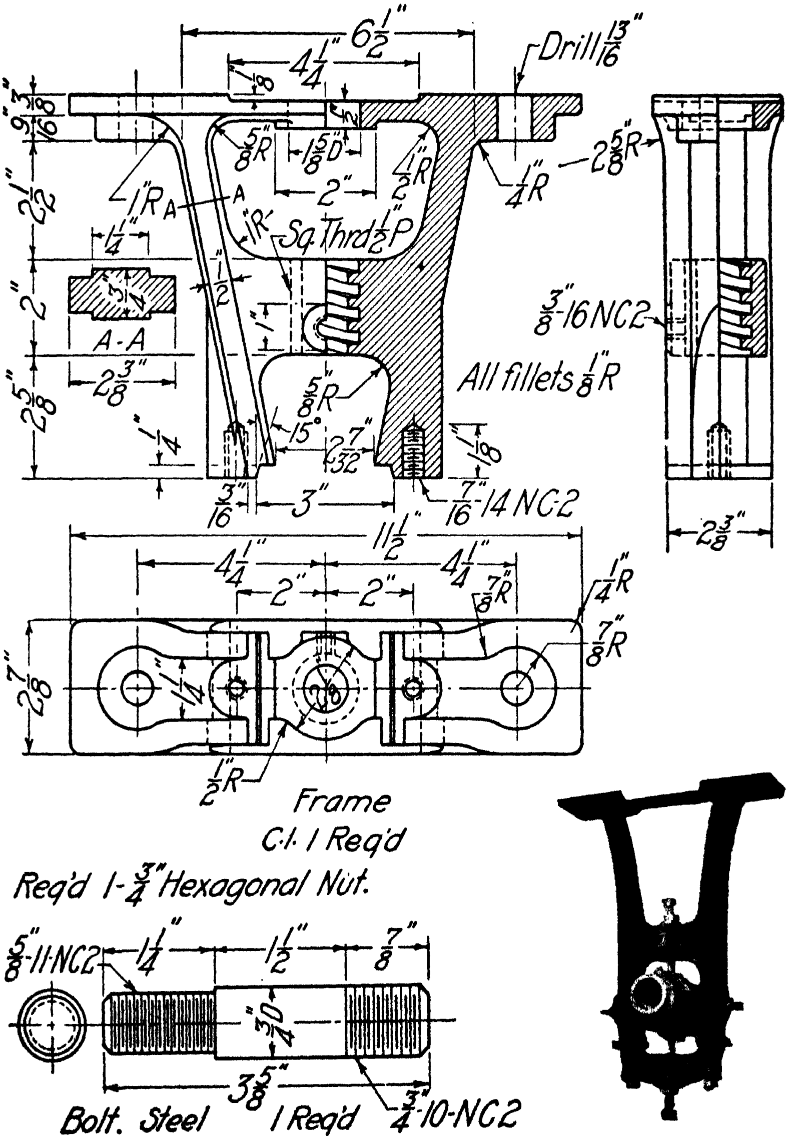


Fig. 4. Details of shaft hanger.

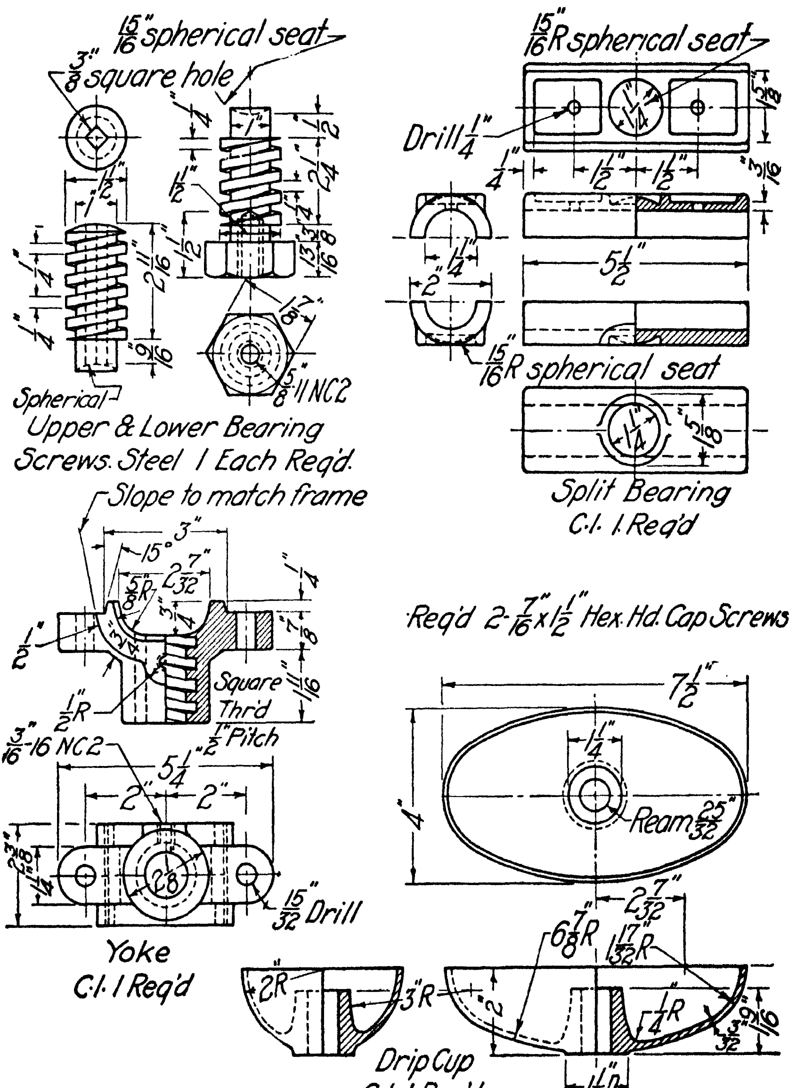


Fig. 5. Details of shaft hanger.

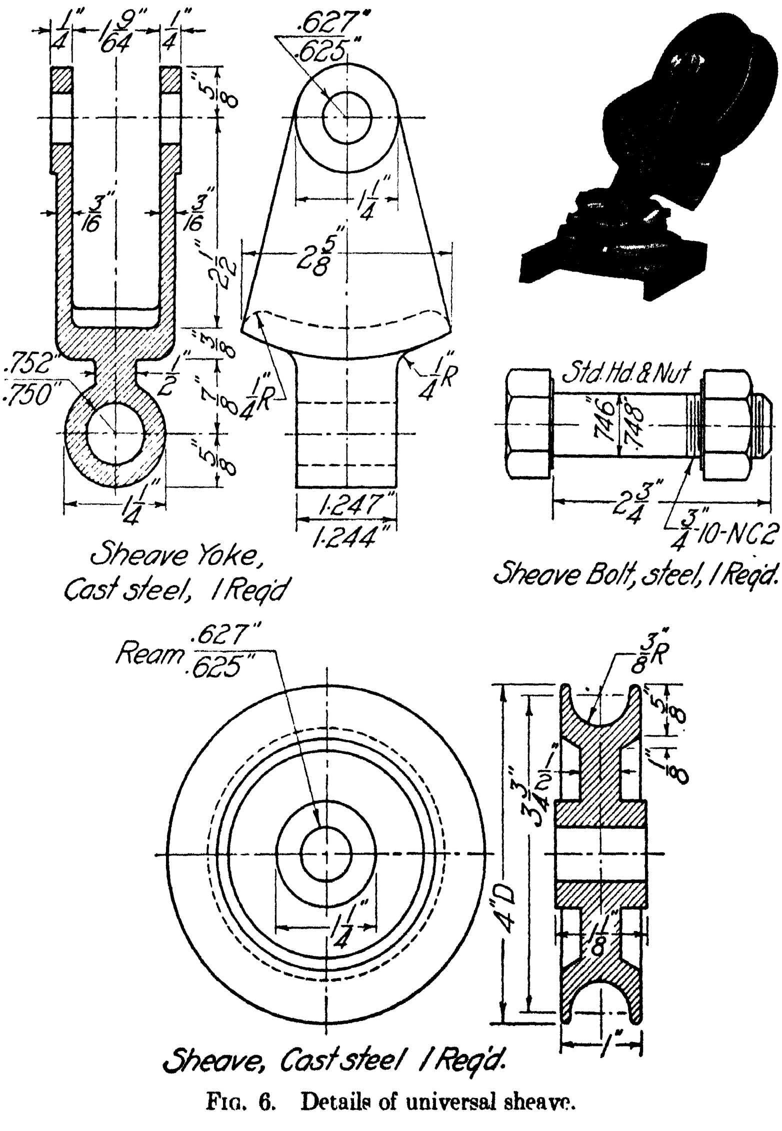


FIG. 6. Details of universal sheave.

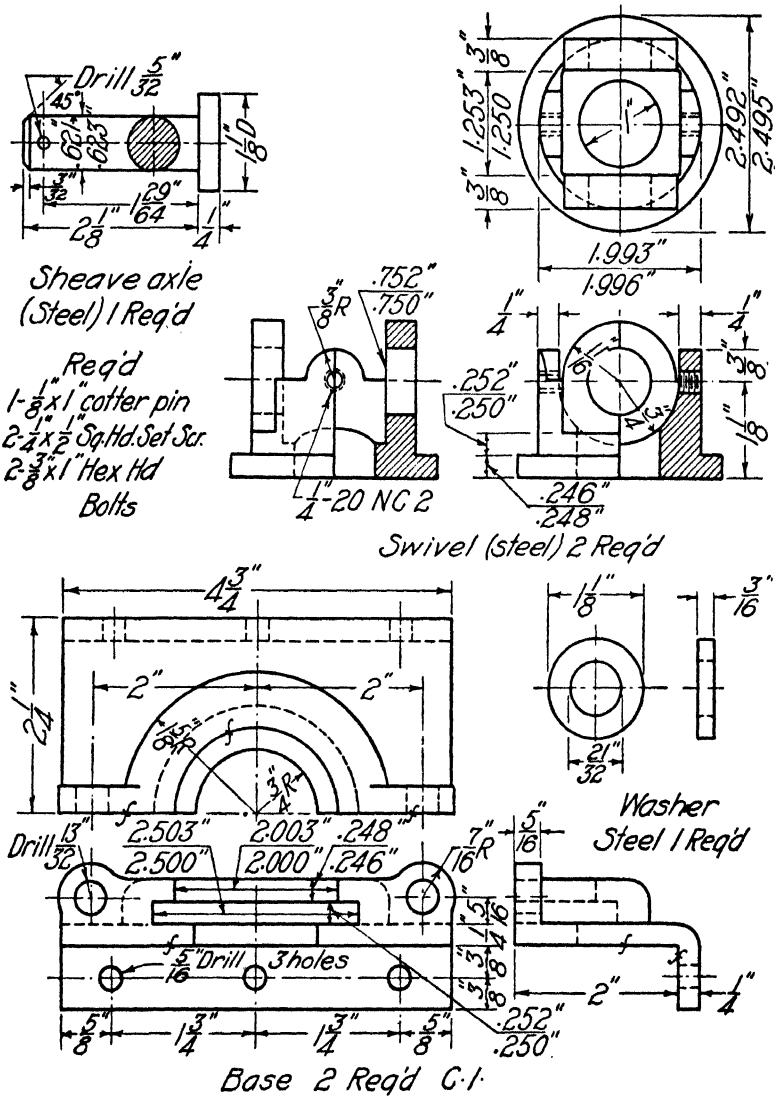
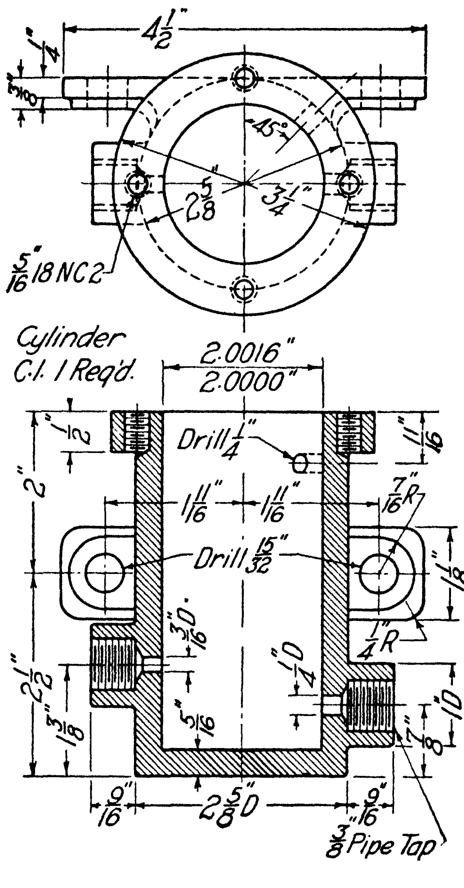
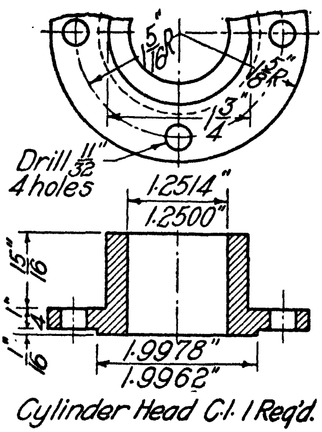
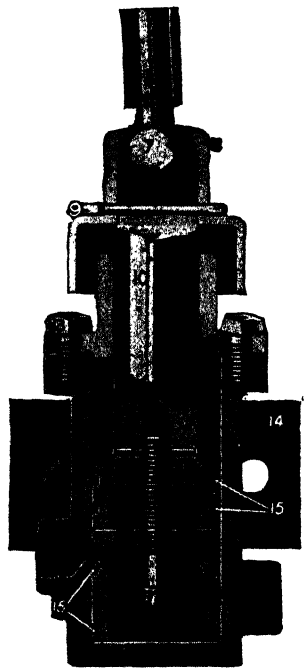


FIG. 7. Details of universal sheave.







Half tone cut of Gollmar Bell Ringer. Courtesy of The United States Metallic Packing Co. and the Simmons-Boardman Pub. Co.

Fig. 8. Details of bell ringer.

7. Connecting Rod
8. Thimble
9. Spring Cotter for Thimble
10. Piston
12. Cylinder Head
13. Cylinder Head Cap Screw
14. Cylinder
15. Packing Rings
16. Valve Stem Pin
17. Valve Stem
18. Valve

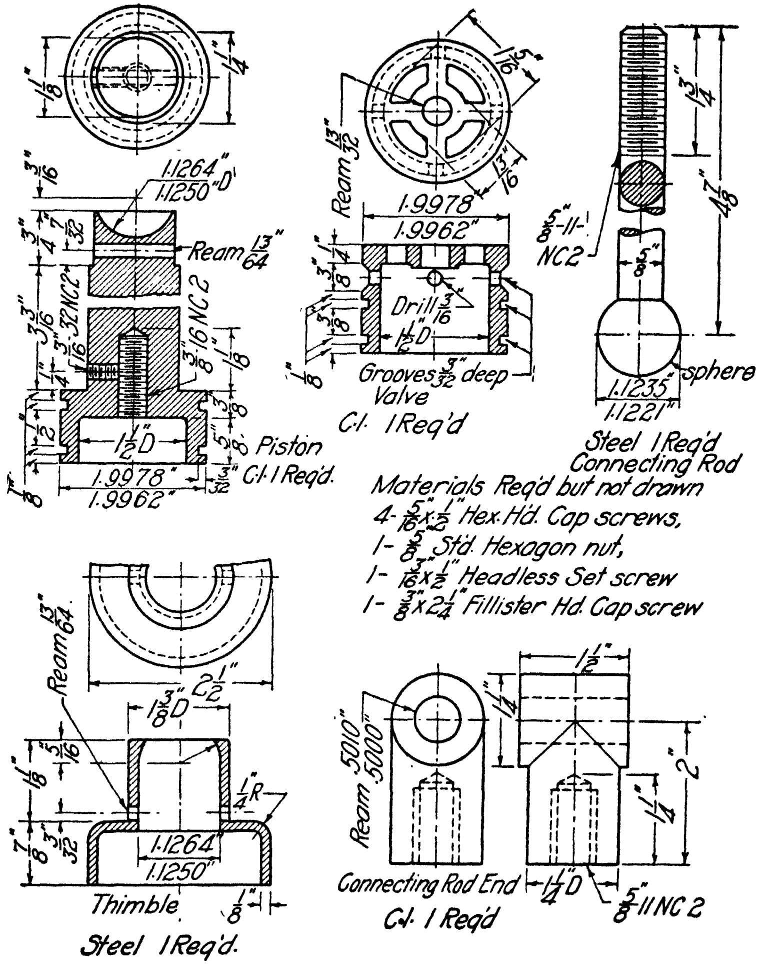


FIG. 9. Details of bell ringer.

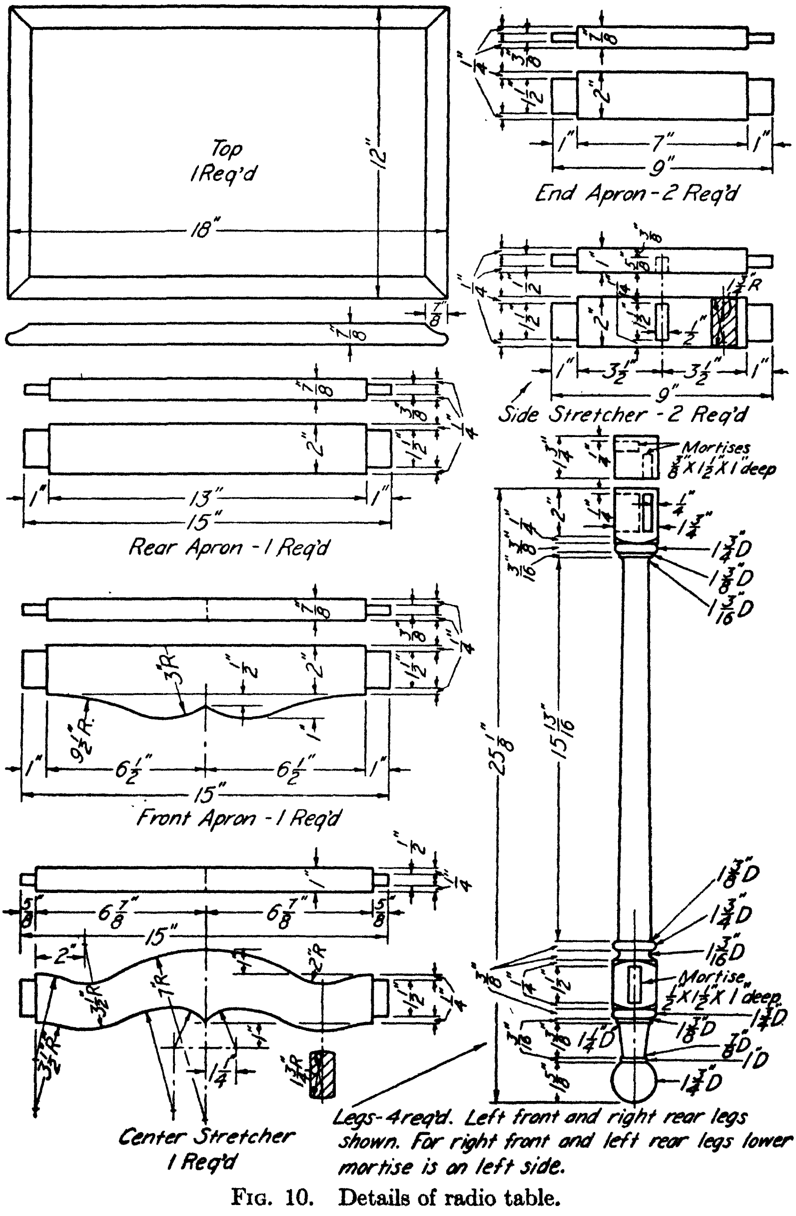


Fig. 10. Details of radio table.

UNIT XIV

ELECTRIC WIRING DIAGRAMS

PURPOSE OF UNIT XIV

The purpose of this unit is to show how to draw electric wiring diagrams and how to indicate circuits on house plans.

WHAT YOU SHOULD KNOW ABOUT WIRING DIAGRAMS

Purpose of diagrams. Electric-wiring diagrams are used by electric-wiring contractors, electrical engineers and architects to study methods of meeting the requirements of lighting, signal systems and power-distribution jobs, and to estimate costs of the wiring and the installing of electric equipment in buildings or other structures. Three types of wiring diagrams are in common use. The first, used by architects, shows only the location of electric outlets and switches and which outlets are controlled by the switches. The second is used by architects and electricians to show the electrical circuits, that is, which lights, outlets or receptacles and switches are on the same circuit. All but the smallest houses have several circuits. The third kind of wiring diagram shows the actual electrical wiring and connections and makes clear the operation of the circuits. These diagrams are also used by teachers and students in courses on electricity in technical schools and colleges.

Nature of a diagram. A wiring diagram is a drawing which shows the scheme of arrangement of wires, switches, lights, power units and power-consuming devices of various kinds. Diagrams are rarely scale drawings, since the parts of a system of wiring and power distribution are perfectly standardized, and the only purpose of the diagram is to indicate the relative positions and the types of wires, switches, lights, motors, etc., which are to be used. Hence every part of an electric-wiring diagram is a standardized symbol and not an accurate working drawing of the objects shown. Figure 1 shows a diagram of a main power line running from a dynamo, or generator, to several lights, a motor and a heating device. This is quite clear and indicates how the various parts are related to one another, but no effort

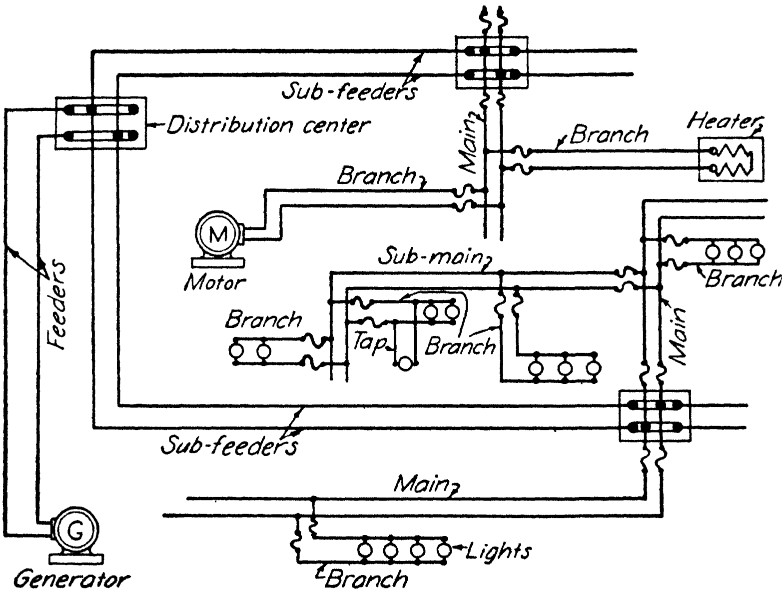


FIG. 1. Meaning of common electrical terms.

is made to give dimensions or to use scale drawings. It may be five miles from the generator to the lights and a mile from the lights to the motor, but to indicate that on the diagram and draw it to scale would be of no value to one who merely wanted to study the arrangement of wires and the flow of electric current.

Definitions. An electrical worker must know many technical terms, and a draftsman should be familiar with as many of them as are necessary to make a correct drawing of a wiring diagram or a plan. The meaning of at least the following terms should be learned before trying to draw diagrams.

Electric circuit. An electric circuit is the complete path of a current of electricity.

Feeder. A feeder is a wire or conductor connecting the source of electric energy with a distributing center.

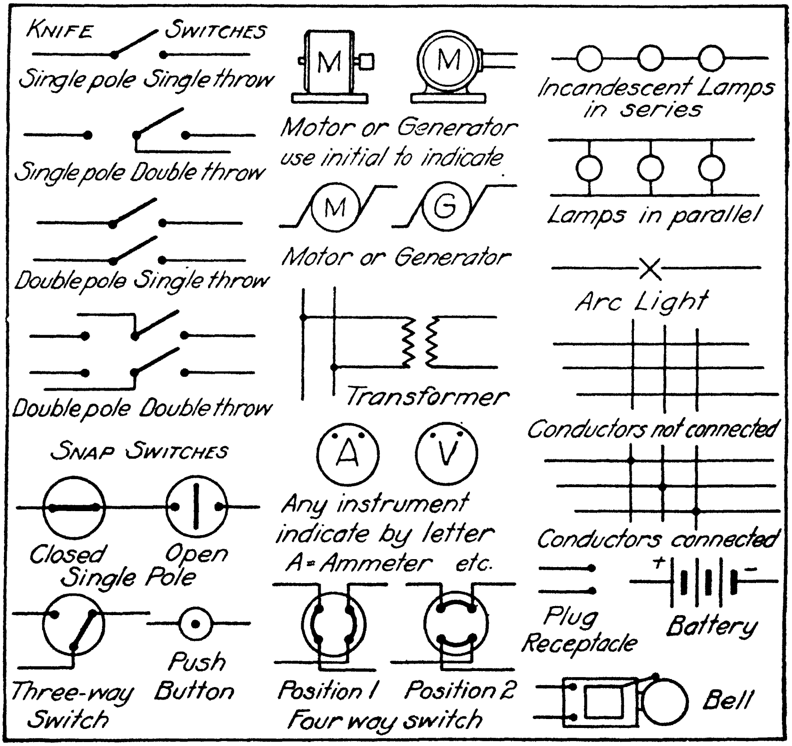


FIG. 2. Wiring diagram symbols.

Distributing center. A distributing center is a part of a wiring system at which current is distributed from feeders to mains, from mains to sub-mains, or to branches. A panel of switches in a house system of wiring is a distributing center.

Sub-feeder. A sub-feeder is a wire connecting one distributing center with another.

Main. A main is a wire which runs from a distributing center and to which energy-consuming circuits are connected by fuses or circuit breakers.

Sub-main. A sub-main is a secondary main which is connected through a cutout to a main and to which branch circuits are connected.

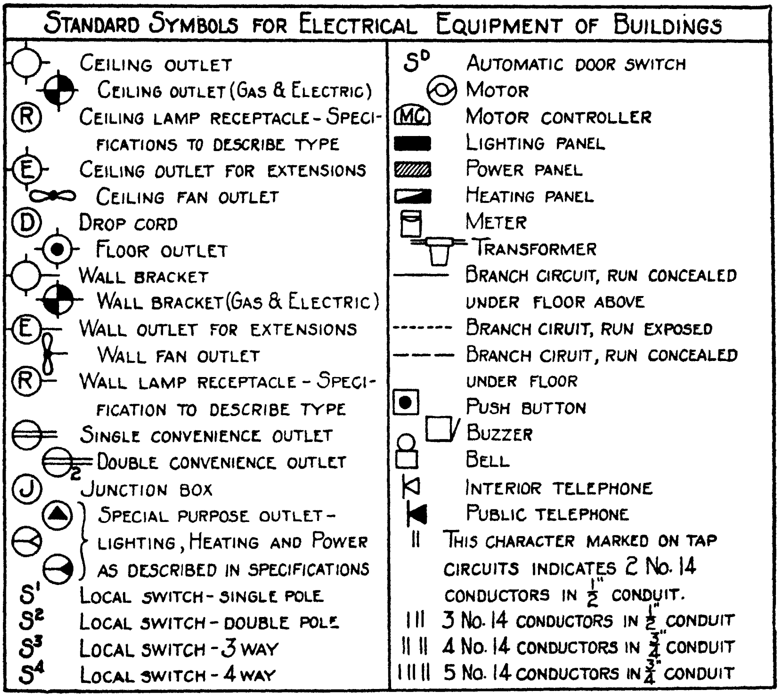


FIG. 3. Wiring symbols for architectural plans.

Branch. A branch circuit is a set of wires leading off from a main or sub-main and supplying current directly to lights, motors, etc.

Service wires. Service wires are the wires running underground or on poles from a power station to houses or other places using electric current. Figure 1 illustrates these terms. Figure 2 shows commonly used wiring-diagram symbols. Figure 3 shows small-scale symbols used by architects in building plans to indicate circuits, and the many types of outlets in common use.

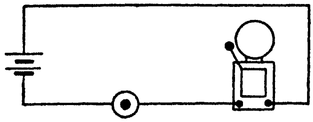


FIG. 4. Simple circuit.

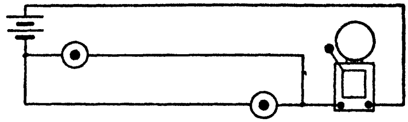


FIG. 5. Bell circuit with two push buttons.

Special uses of diagrams. An important use of wiring diagrams is to show the operation of different kinds of switches. There are many possible arrangements of switch

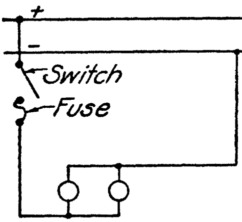


FIG. 6. Lights in simple circuit.

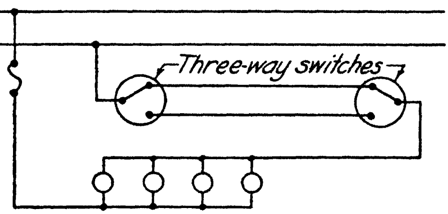


FIG. 7. Lights controlled from two points.

control. A switch may be used to control a single light, a group of lights or a whole system of lights and other energy-consuming devices. Switches may be designed and placed

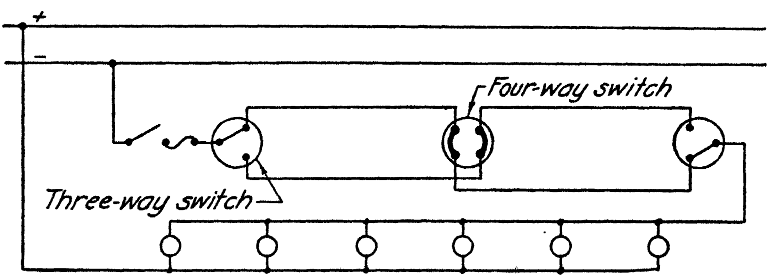


FIG. 8. Lights controlled from three points.

so that the same lights can be controlled by several different switches in different parts of a house. All these various arrangements call for special schemes of wiring and of switch connection. Figures 4, 5, 6, 7, 8 and 9 show some of the many possible arrangements of switch control. These should be studied until they are thoroughly understood and can be reproduced from memory with the lamps, switches, etc., in various positions.

A very common use of diagrams is the wire plan for a house. In architects' plans the location of switches and outlets, or electric devices, is usually all that is shown, though occasionally the wires are indicated also. Figure 10 shows a typical architectural layout of lights and switches as used

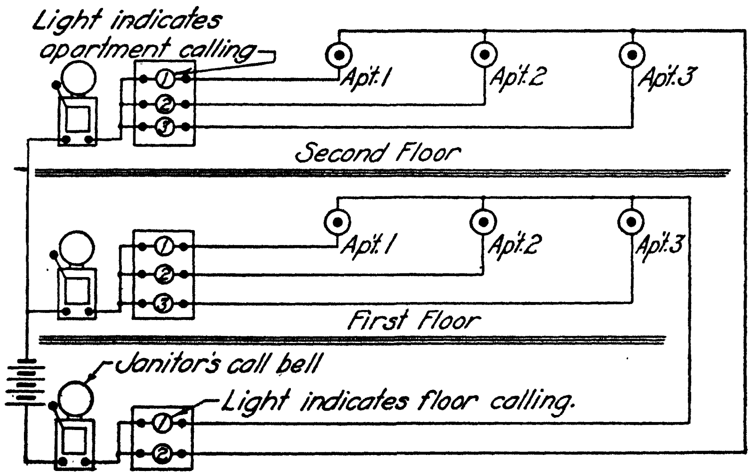


FIG. 9. Annunciator layout for apartment building.

in ordinary floor plans of buildings. On such drawings, switches are always connected by dashed lines with the outlets they control. Fig. 11 indicates another more complete method used by architects to indicate wiring. This scheme shows the actual circuits and what circuit each outlet belongs to. It does not show the actual wiring or its location in the building.

HOW TO DRAW DIAGRAMS

In order to explain how to make wiring diagrams the three kinds must be handled separately.

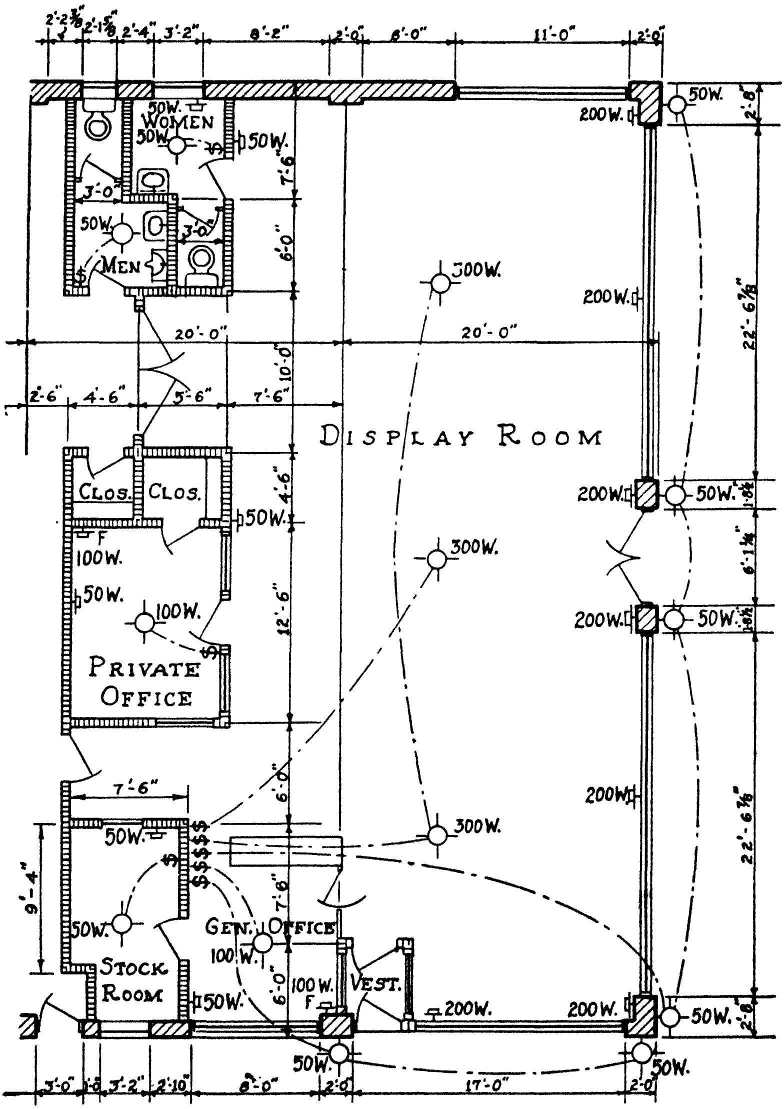


FIG. 10. Architects' indication of electrical equipment.

Architectural plans. *Outlets and switches only.* This is the simplest type. Indicate by proper symbols (see Fig. 3) on the floor plans the location of all electric outlets. Locate all switches by symbol on the plan, and then connect the switch symbol by a smooth dash line with the symbol of the outlet which it controls. Plug outlets in wall or floor, since they are not operated by a switch, have no connections of any kind indicated. Beside each outlet, letter the capacity in watts for which the outlet is to be wired, as 100 w, 250 w, etc.

Architectural plans. *Circuit layout.* As in the preceding case, locate by symbol on the plan all outlets and switches. In addition show the location of the distribution panel. Divide the lights and other outlets into circuits of approximately the same load and in groups for economy of wiring. (The regulations as to loads, wires, conduits, fuses, etc., are presented by the Electrical Code of the National Fire Underwriters and also quite frequently by city building codes. The drawing of circuits rather than design is the function of this text, hence the design according to any code is not attempted.) Draw a heavy line from the distribution panel to all the lights, receptacles and switches of any one circuit as shown in Fig. 11.

Wiring diagrams. The wiring diagram proper shows the actual wires and connections. Again lay out the electric outlets by large-scale symbols (use those of Fig. 2) in their proper place on the plan and connect them with the switches and with the distribution panel. Use straight lines following the outlines of the house in making your diagram. It is a common practise to use tracing paper for this purpose and trace the house outlines very lightly upon it from the original architect's plan. Then the wiring is shown in medium-weight lines. See Fig. 12 as an illustration. Such wiring diagrams are also frequently made without the skeleton of the architectural plans.

For ordinary house and small building work use a medium weight of line throughout. For power house, sub-stations

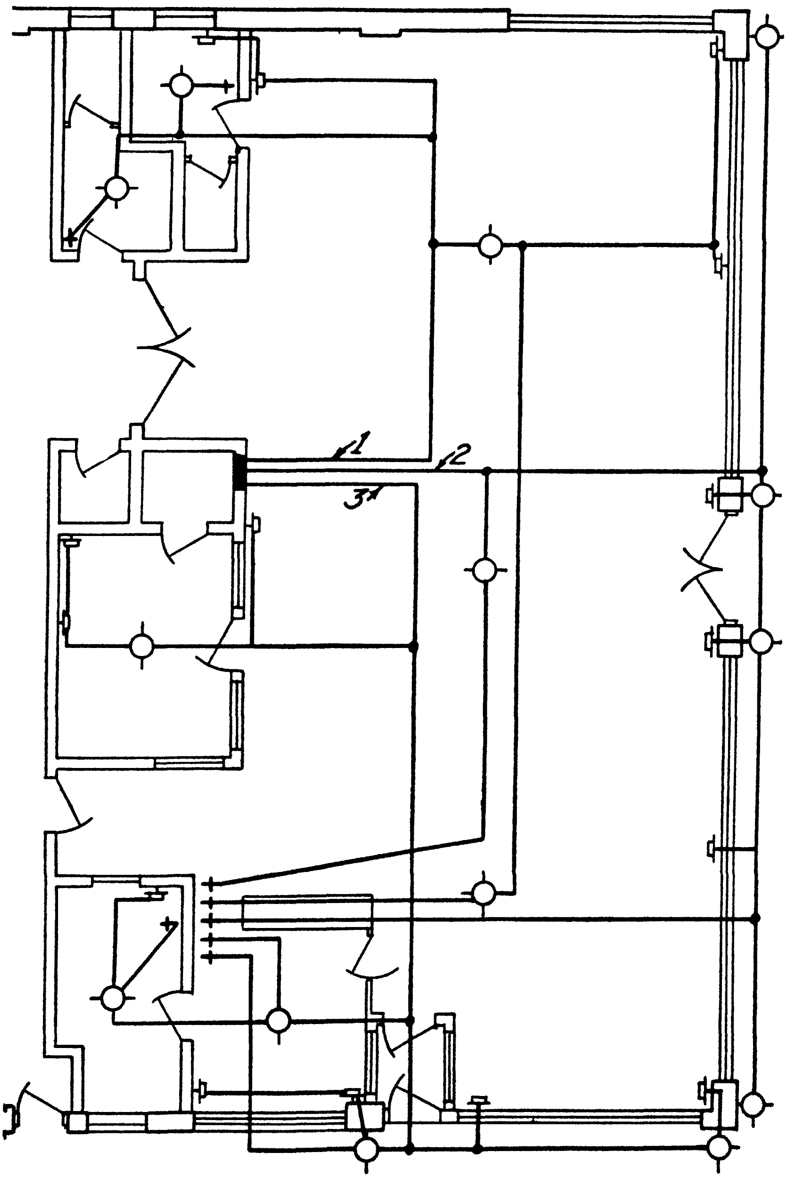


FIG. 11. Circuit diagram of plan in Fig. 10.

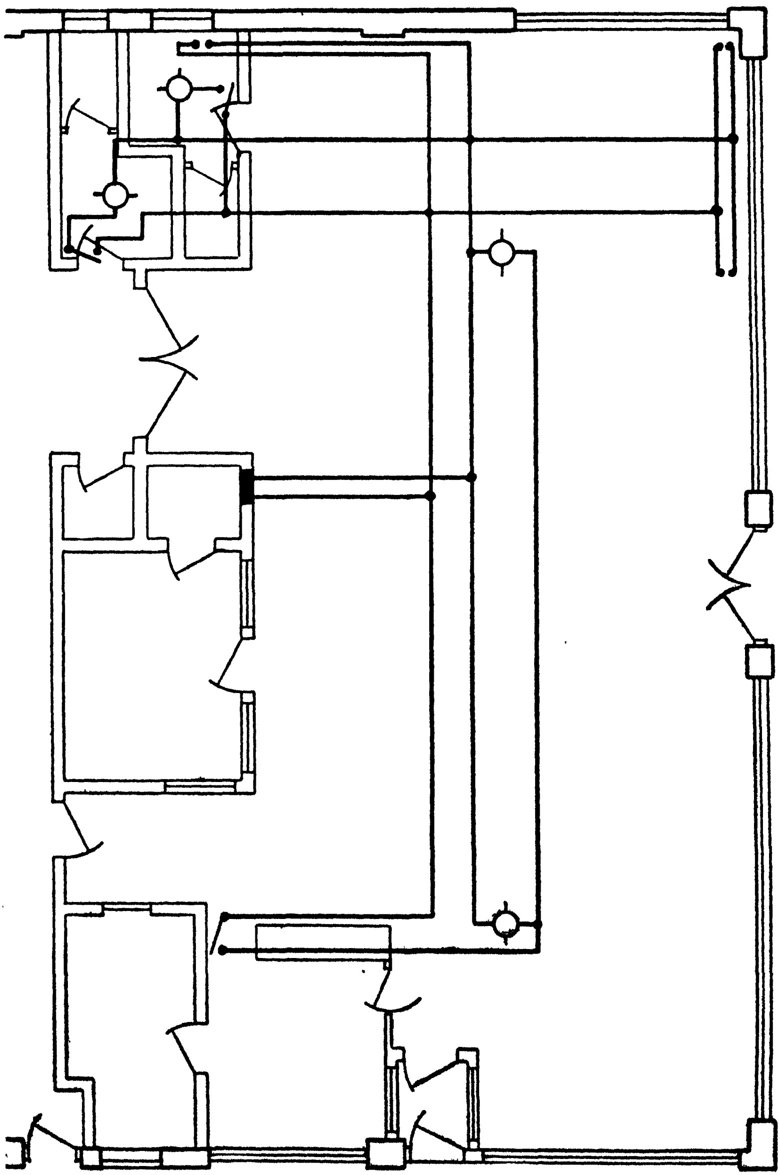


FIG. 12. Wiring diagram of circuit No. 1 in Fig. 11.

and buildings having a heavy power load use heavy lines for feeders, somewhat lighter lines for sub-feeders, mains and sub-mains and light lines for branch circuits.

Wiring diagrams are not dimensioned. Where the wires are placed in conduits a loop is put around the lines which go in the same conduit. In making the layouts all plug receptacles must be connected to "hot wires," that is to say, there must be no switch control of such outlets. All lights operated by one switch must be on the same circuit with the switch.

QUESTIONS

1. What three kinds of wiring diagrams are there?
2. What are the uses of each of the three kinds of wiring diagrams?
3. What is meant by the term electric circuit?
4. What is a distributing center?
5. What do the following terms mean: feeder, main, branch circuit, sub-feeder, sub-main, outlet, switch, generator?
6. What vocations make use of wiring diagrams?
7. Why are wiring diagrams rarely made to scale?
8. How do architects indicate the location of switches and the outlets they control? How do they indicate that two switches control the same outlets?
9. Why are wiring diagrams not dimensioned?
10. How do you proceed to draw a wiring diagram which shows the actual electrical connections?
11. Make a diagram showing how a lamp may be operated from two different stations.

PROBLEMS

1. Copy the wiring diagram in Fig. 13. Use dimensions shown in laying out the diagram but do not place any dimensions on your drawing. Title: Diagram of Single-pole Master-switch Arrangement. On a 3 x 5 card, letter a description of what occurs when (1) M_1 is closed and M_2 is open; (2) M_2 is closed and M_1 is open. In each case state in what position the three-way switches must be to turn on lights and to shut off lights by means of M_1 or M_2. Attach the lettered card to your sheet when finished.

2. Copy the drawing in Fig. 14. Make a diagram for the wiring in the right-hand store room similar to that in the left-hand room. Arrange wiring so that the switch does not control the two front lights or the light marked *B*, but controls all the other lights.

Put in a second switch at the front door to control these three lights. Use the dimensions given to make the drawing, but do not mark any dimensions on your drawing. Complete the plan of the right-hand store, making it correspond exactly to the left-hand room. Title: Wiring Diagram for Two-store Building.

3. Copy the annunciator layout problem in Fig. 15 to the scale and dimensions given, but do not dimension your drawing. By reference to the diagram of Fig. 9 make the wiring diagram so that closing switch 1 on the third floor rings the annunciator on that floor and the one in the basement and also lights lamp 1 on the third floor and lamp 3 in the basement. Title: Annunciator System for Three-story Apartment Building.

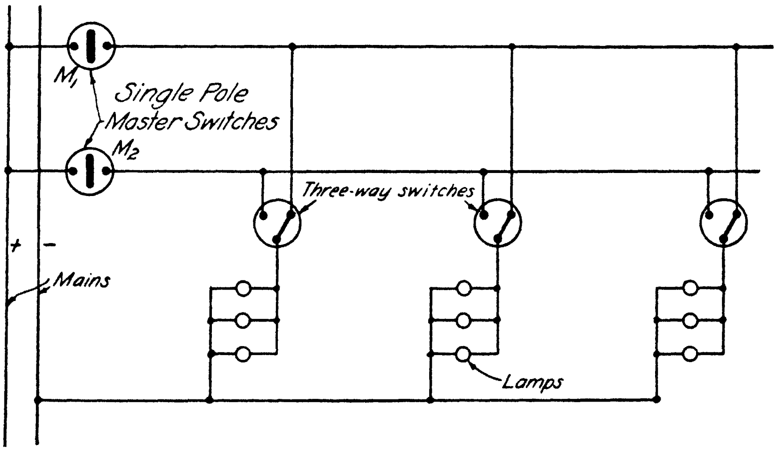


FIG. 13. Two point control with master switches.

4. Make a wiring diagram for a door bell operated by current from a bell transformer which can be rung from either the front or back door of a house. Consult Fig. 2 for symbols, and study the other figures of the text for suggestions.

5. Copy the store building of Fig. 14 to the dimensions and scale given, but do not dimension your drawing. Put in the lamp symbols as shown, but do not put in the wiring. Lamps marked 1 are to be controlled by one switch, those marked 2 by another and those marked 3 by a third. Indicate the switches near the distribution panel and then connect the switches and lamp as an architect would show it on his plans.

6. Same as Prob. 5 but make a circuit diagram instead of using the architect's method of indicating lights and switches. Show all circuits starting from the distribution panel.

7. Make a wiring diagram for each of the three circuits described in Prob. 5. The building need not be reproduced. The circuits may be laid out without reproducing the building plan.

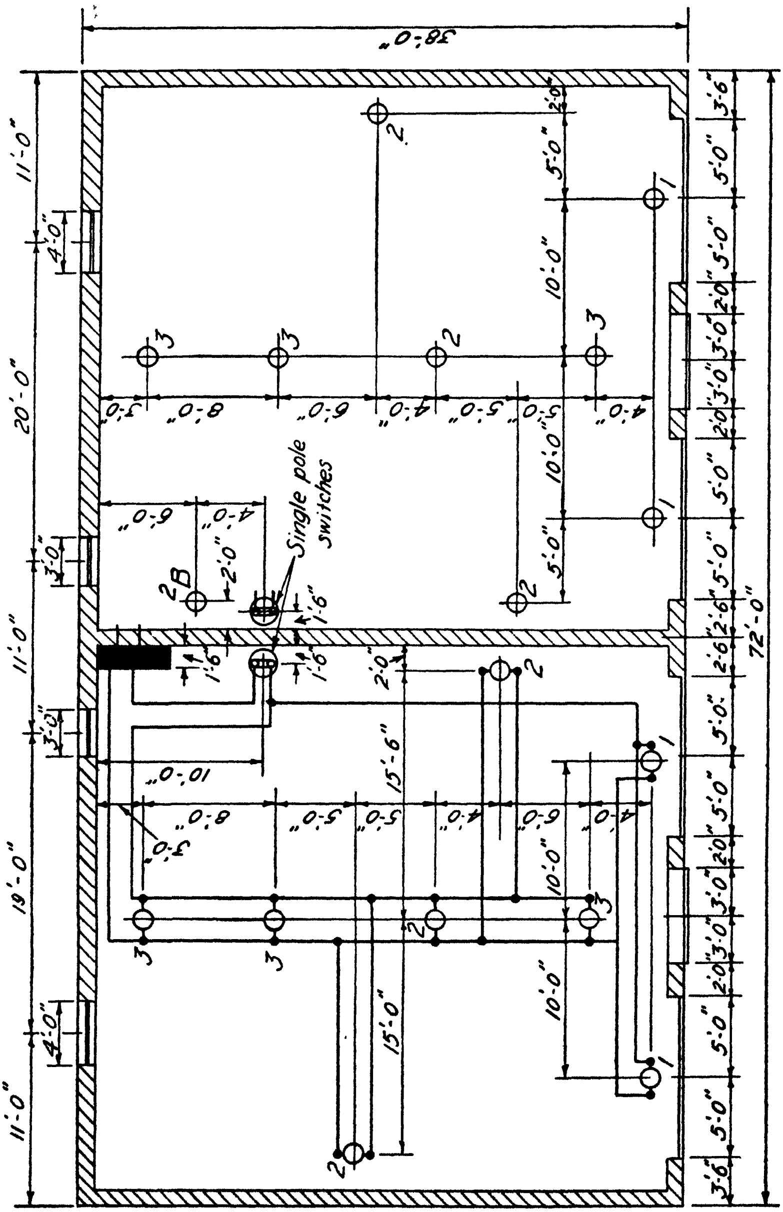


FIG. 14. Wiring problem.

8. Make a plan of the store building shown in Fig. 14 and indicate outlets, circuits and switches as an architect shows them on floor plans, according to the following specifications: (1) three wall bracket lights on each side wall of each store, (2) three 300-watt ceiling lights equally spaced through the center of the store,

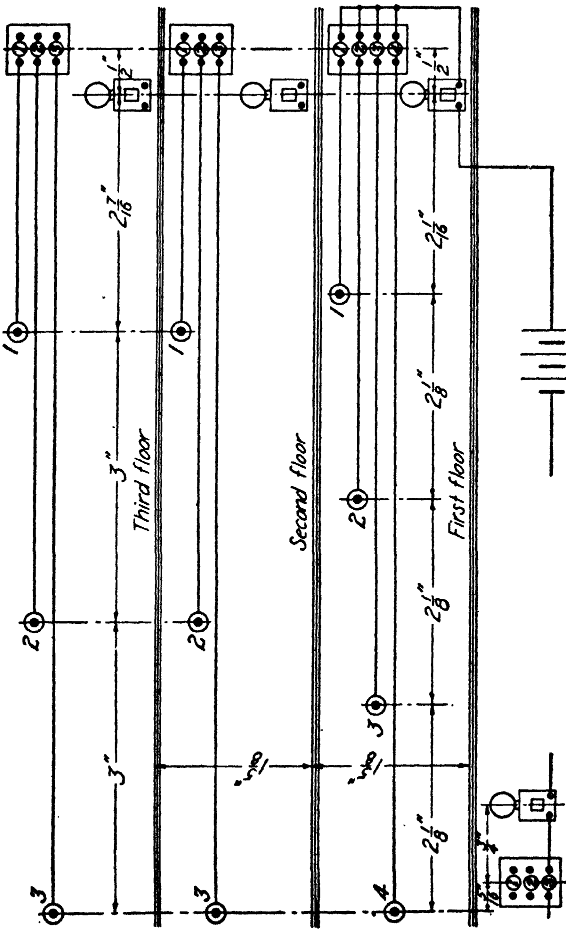


Fig. 15. Annunciator wiring problem.

(3) four ceiling fans equally spaced among the center ceiling lights, (4) two floor outlets on the back wall, one to be 1 foot to left of the smaller window and the other 1 foot to right of larger window, (5) in the right-hand store also place a wall fan in the center of the partition wall between stores and a motor near the back right-hand corner. Place ceiling lights in each store on one

circuit, and show where you would place the switch. Place wall bracket lights on one circuit and locate their switch; place show-window (front) lights (as shown in Fig. 14) on one circuit and locate their switch. Title: Electric Outlet Layout for Store Building.

9. Make a circuit diagram for the lights and electrical equipment of Prob. 8. Use four circuits in each store.

10. Make a wiring diagram of an assigned circuit laid out in Prob. 9.

11. Make the wiring diagram for circuit 2 in Fig. 11. Reproduce the outline of the building in light lines. Show the lights, outlets and switches on circuit 2 only and then make the wiring diagram. See circuit 1 in Fig. 12 as an example.

12. Make the wiring diagram for circuit 3 in Fig. 11. Follow the instructions of Prob. 11.

13. Make a wiring diagram for circuit 2 in Fig. 11. Include in the circuit an additional switch located in the vestibule to control the center light in the display room. Follow the instructions of Prob. 11.

UNIT XV

SHADE LINING

PURPOSE OF UNIT XV

The purpose of this unit is to point out the uses of shade lining in mechanical drawing and to tell how to draw shade lines.

WHAT YOU SHOULD KNOW ABOUT SHADE LINING

Show drawings. It sometimes becomes necessary for a draftsman to make what is called a show drawing. Such a

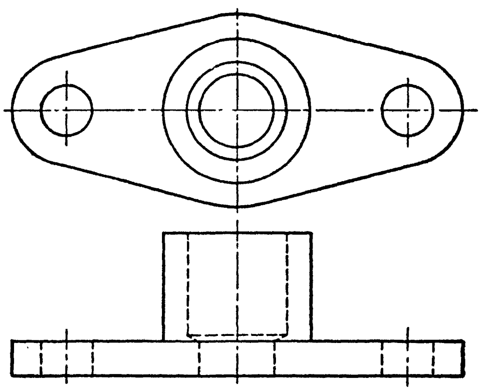


FIG. 1. Orthographic projection.

drawing is used to represent an object in a striking and pleasing manner for purposes of illustration, explanation or of attracting special attention. Illustrations for engineering books and magazines, advertisements of machines and machine parts and U. S. Patent Office drawings are examples of such drawings. Since the purpose is to present the object in an attractive manner rather than to give necessary information for making it, dimensions are omitted from show drawings, and where one view can be made to give a clear idea of the object, only that view is drawn. More than one view, however, may be shown when necessary. A very common method of making a drawing attractive and causing it to appear to "stand out" on the paper is to use shade lining.

Shade lining. To shade-line a drawing is to make certain lines much heavier than others so as to indicate the appearance of the object drawn when the light falls upon it at an

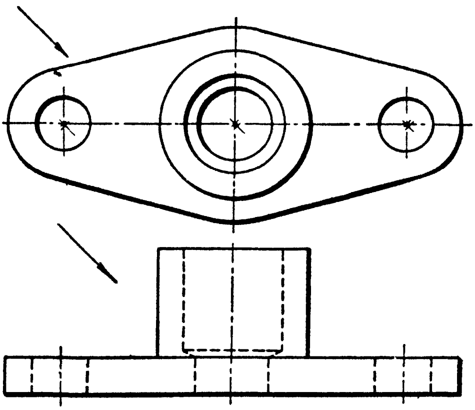


FIG. 2. Orthographic projection shade lined

angle of 45 degrees from the upper left, as shown by the arrows in Fig. 2. The heavy lines represent the edgewise views of the surfaces which would not be in the light. This device gives the drawing the appearance of having depth or of standing out as the object itself does. Note the difference of the two drawings, Figs. 1 and 2, which show the same object. By thinking of each view by itself and considering the light to come in the direction of the arrow one can determine at a glance which surfaces are in the shadow.

HOW TO DRAW SHADE LINES

To shade-line straight objects. To shade-line a solid body having straight edges make the top and left-hand lines, which represent edges of surfaces which are in the light, with light lines. Make the lower and right-hand lines, which represent the edges of surfaces which are in shadow, about three times as heavy as the light lines. To shade-line a hole having straight edges make the upper and left-hand lines about three times as heavy as the lower and right-hand lines. See Fig. 3.

To shade-line circular objects. To shade-line the edges of a circular solid move the center of the compass along a radius drawn at 45 degrees toward the lower right-hand part of the object, and without changing the radius of the

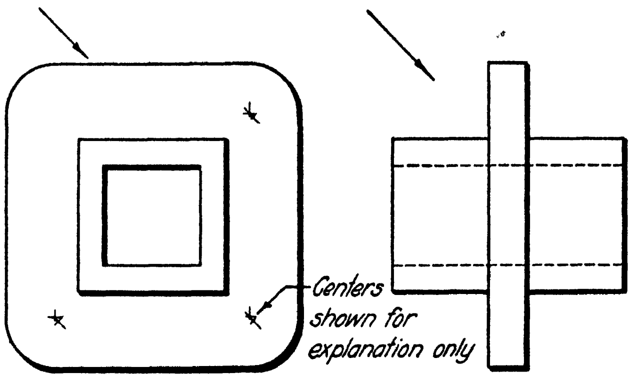


FIG. 3. Shade lining.

compass make the lower right-hand part of the circumference heavier than the upper left-hand part. Make the thickest place of the lower right-hand arc about three times as heavy as the upper left-hand arc of the circle. See Fig. 2. To shade-line a circular hole move the center point of the compass along a 45-degree line toward the lower right-hand as in the case of a solid, but make the upper-left hand part of the circumference of the hole about three times as heavy as the lower-right-hand part. See Fig. 2. Always draw the additional thickness of a shaded line outside the edge of the object.

QUESTIONS

1. What is shade lining?
2. When is shade lining used?
3. How heavy should a shade line be?
4. How can you know what lines to make heavy?
5. How are drawings of straight-edged solid objects shade-lined?
6. How are drawings of circular objects shade-lined?
7. How are holes shade-lined? Why?
8. Why is the center point of the compass moved down toward the right-hand when shade-lining either a hole or a circular solid?

PROBLEMS

Lay out the standard border line and title space, and then make two or three views of the object assigned by your instructor from the group below. Decide for yourself upon the proper number of views. After completing the views, shade-line all of them according to the rules of this unit. Do not dimension. The title of the sheet will be "Shade Lining." Letter the name of the object under the views in large and small caps.

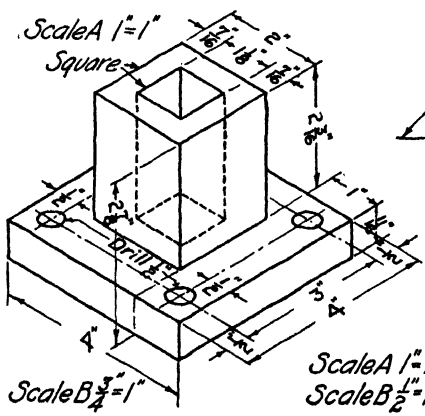


Fig. 4. Block.

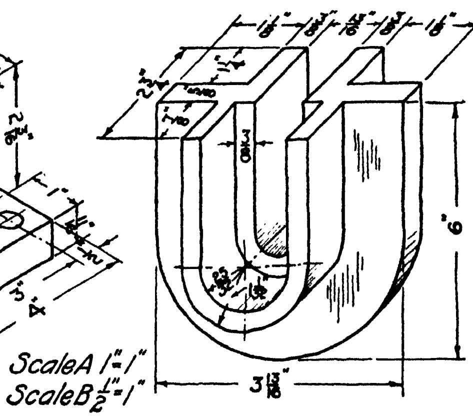


Fig. 5. U-block.

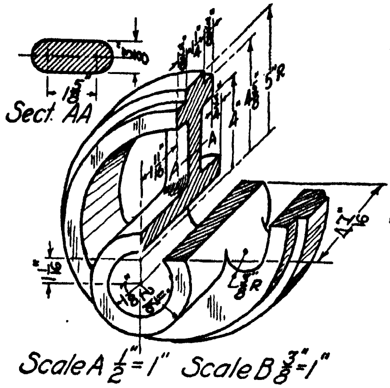


FIG. 6. Eccentric.

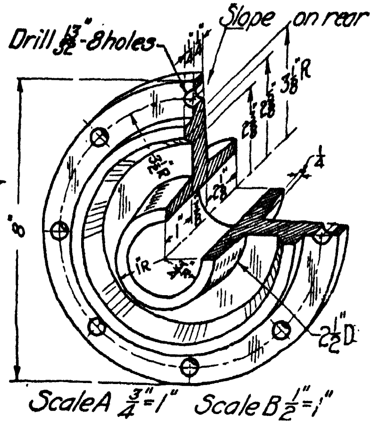


FIG. 7. End bearing plate.

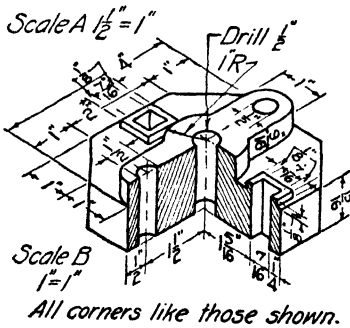


FIG. 8. Block.

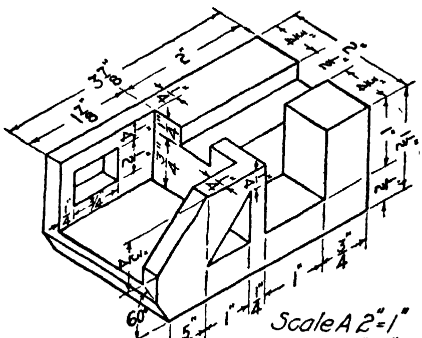


FIG. 9. Block.

UNIT XVI

CHARTS AND DIAGRAMS

PURPOSE OF UNIT XVI

The purpose of this unit is to show a few of the uses of charts and diagrams and how to draw the simpler kinds.

WHAT YOU SHOULD KNOW ABOUT CHARTS AND DIAGRAMS

Use of charts and diagrams. One of the divisions of mechanical drawing is that of charts and diagrams. This field has nothing to do with the theories of projection. Whereas all the other kinds of drawing you have studied have been concerned with the representation of objects, this field concerns itself with the representation of facts. Again as in all drawing the purpose is to make the facts clear and unmistakable to the reader of the drawing. Usually a relationship exists between pairs of facts. These pairs are spoken of as variables. One is usually independent, as for example, time, and is referred to as the independent variable while the other fact is called the dependent variable. The independent variable is always placed on the horizontal or X axis.

TABLE I

SCHOOL ATTENDANCE IN THE UNITED STATES, AGES 5 TO 20 YEARS

Year	Attendance
1850	4,089,507
1860	5,692,954
1870	6,596,466
1880	9,956,608
1890	11,674,878
1900	13,367,147
1910	18,009,891
1920	21,763,275

Charts and diagrams are used for the following purposes.

1. As a means of analyzing masses of data which would be difficult to grasp in tabular form.

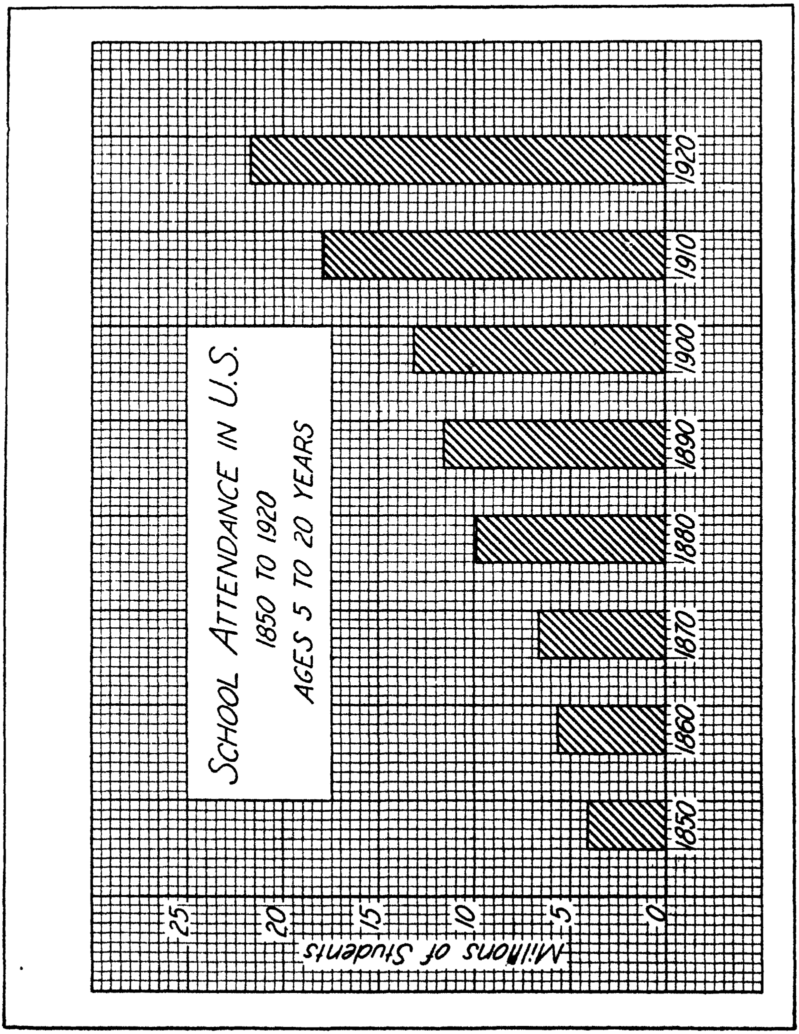


FIG. 1. Barograph of school attendance.

2. To determine trends in current events.

3. To assist in determining scientific laws and in reducing them to mathematical statements.

4. To save time in computation where the same equation must be solved repeatedly.

5. In advertising and in other ways to make clear to large numbers of people facts which otherwise might be obscure.

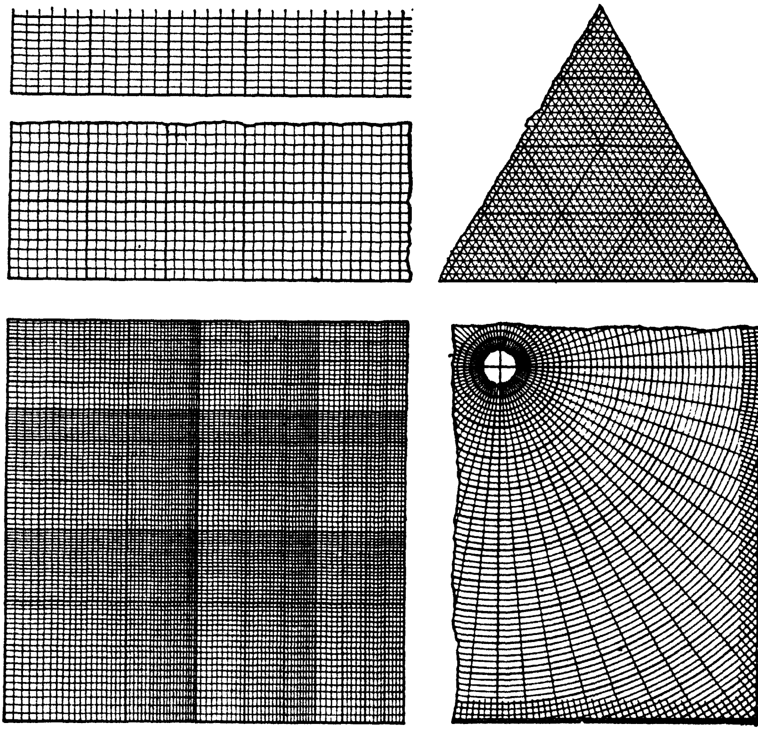
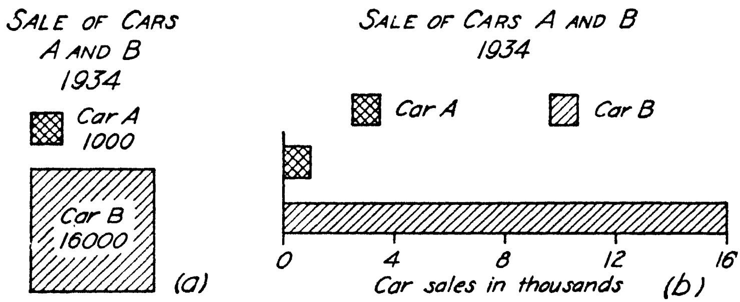


FIG. 2. Co-ordinate papers.

Only a few of these uses can be discussed in this text. As an illustration of points 1 and 2 above, the facts given in Table I showing that the school attendance of persons between the ages of five and twenty years increased from 4,089,507 in 1850 to 21,763,275 in 1920 do not give one a very good grasp of the trend. On the other hand, the barograph in Fig. 1 representing these same facts graphically gives a much clearer picture of the situation.

Co-ordinate papers. In the business office, drafting room, statistician's office or engineering office, charts are usually drawn upon commercial co-ordinate papers which can be obtained in a great many forms. The most common kind is called rectangular co-ordinate paper. This may be obtained in many different rulings. Other types are polar co-ordinate paper, logarithmic paper, semi-logarithmic, trilinear, etc. See Fig. 2.

Choice of kind of chart. *The barograph.* The purpose for which the chart is to be used will determine the kind selected. It is possible either intentionally or innocently to give a very



a. Poor type of chart. b. Correct method for same chart.

FIG. 3.

false impression by choosing a bad type of chart or by exaggerating the co-ordinates upon what might otherwise be a good form. For example, if it is desired to show in a striking manner that one quantity is sixteen times as great as another quantity, two squares may be drawn as in Fig. 3a. It is probable that most readers will merely compare the length of the sides of the squares which have the ratio of one to four, and will not think of the areas of the squares which compare as one to sixteen. Two bars, one sixteen times as long as the other, would be a better means of showing the relationship of the two quantities as illustrated in Fig. 3b. This latter form is called a barograph.

Besides the barograph, other useful kinds of charts are the plane curve and the sector or pie diagram.

Plane curves. Plane curves may serve exactly the same purpose as a barograph. They have the advantage of taking less time to draw, but coupled with it the disadvantage of

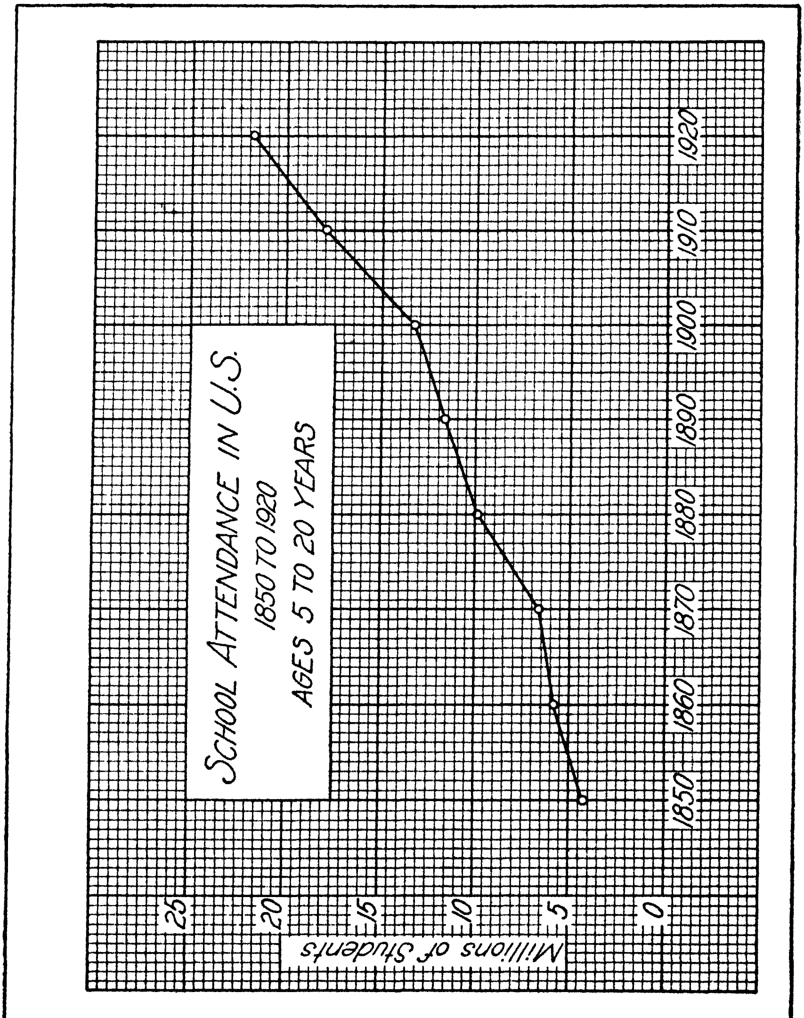


FIG. 4. Plane curve showing school attendance.

not being quite so easily understood by the uninitiated. For example, if it is desired to show the increase in school attendance from 1850 to 1920, either a barograph or a plane curve may be used as in Fig. 1 or Fig. 4. Since the attendance at school is reported annually and actually increases by jumps in September and February the points on the curve

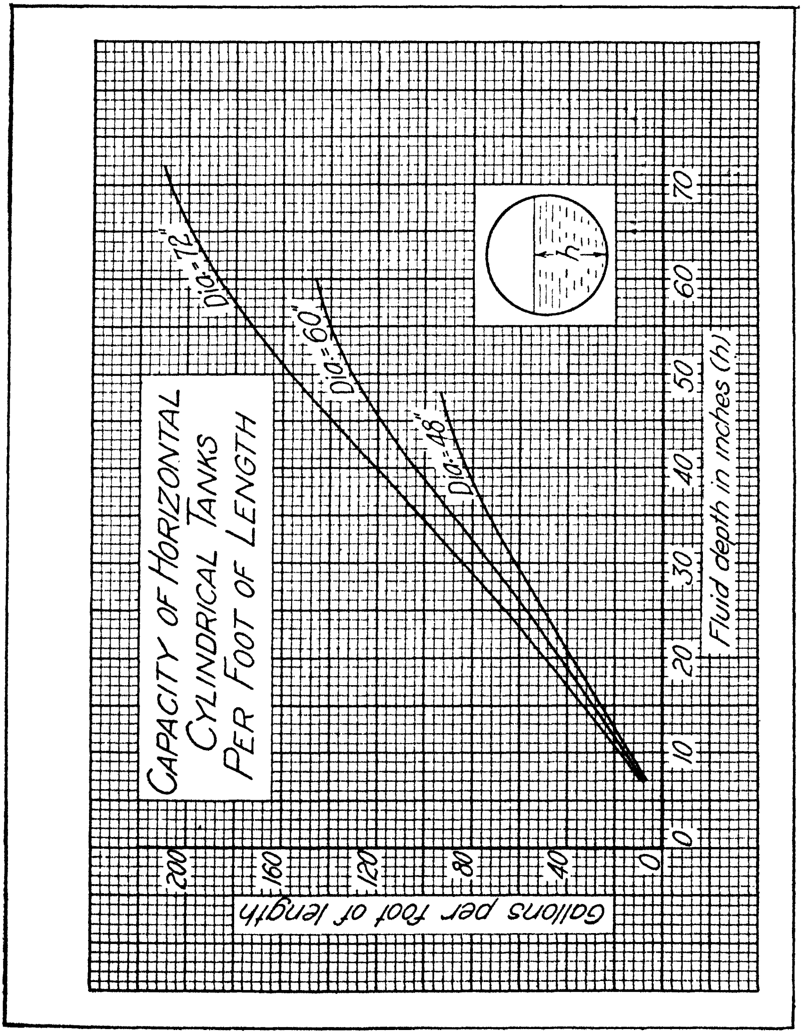


FIG. 5. Plane curves showing a continuous relationship of two variables.

are joined by straight lines which serve merely to tie the points together as a whole. Intermediate values on the straight line have no significance.

Plane curves, on the other hand, may be used where barographs would not do at all. Thus, for example, if the relationship between two variables is changing continuously, that is by small regular increments and not by big periodic jumps, then the plane curve serves most usefully. Thus one might plot the relationship between the contents and depth of a liquid in a cylindrical tank lying with its axis horizontal, as shown in Fig. 5. This relationship is perfectly continuous and can be represented only by a smooth curve.

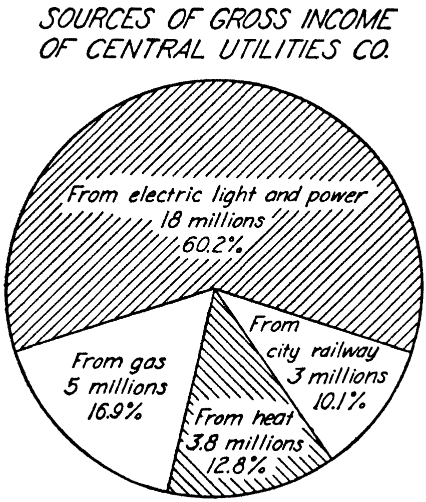


FIG. 6. Pie or sector diagram.

Sector diagrams or pie diagrams. A very commonly used diagram is the sector diagram. This is quite effective where parts of a whole are to be shown for comparison among themselves, and with the whole. A typical example is a diagram such as Fig. 6 which shows the sources of gross income of a power company as given in Table II.

TABLE II

SOURCES OF GROSS INCOME OF POWER COMPANY

Source	Amount	Per Cent of Total	Part of Circle in Degrees
From electric light and power.....	$18,030,000	60.2	217
From gas..........................	5,050,231	16.9	61
From city railway................	3,020,137	10.1	36
From heat.........................	3,840,281	12.8	46
	$29,940,649	100.0	360

Here one can easily note the relationship among the items of income from various sources.

Importance of clarity. In chart drawing as in orthographic projection, clarity of meaning is the most important consideration. For clearness, charts must contain certain things if they are to be intelligible to the reader. These items may be enumerated as follows.

Title. Every chart must have a neatly lettered title stating exactly what the chart represents.

Co-ordinates. The co-ordinates must be clearly marked numerically on both axes of a chart so that the exact value of either variable may be determined, at a glance.

Legends. The meaning of the co-ordinates, that is what the numerical marking represents, must be clearly indicated by a legend placed along the axis to which it refers. For example, if the horizontal axis gives time the legend must indicate whether this is in minutes, hours, days, weeks or years.

Keys. Where more than one curve or bar is plotted on a sheet the meaning of each curve or bar must be clearly indicated by a key or key note along the curve. See Fig. 8.

Sketches. In some cases sketches are necessary to make the meaning of a chart clear. See Fig. 5.

HOW TO DRAW CHARTS AND DIAGRAMS

To draw a plane curve chart. To draw a plane curve chart which represents successive relationships of two varying quantities, such as time and growth, use a piece of co-ordinate paper, and lay off near the lower border a horizontal line. This line is called the *X* axis. Then draw a vertical line intersecting the *X* axis near the lower left-hand corner of your paper. This line is the *Y* axis. Make these axes far enough from the border to allow room for numbering the co-ordinates and putting in a legend stating what they are. This usually requires from ½ to 1 inch of space. Along the *X* axis lay off spaces or co-ordinates representing time, and along the *Y* axis lay off co-ordinates representing growth. The size of space used for the units along both axes must be determined by the size of the paper and the size of the quantities which must be shown. Make both as large as possible. Then from your table of data plot the points showing the changes in growth by years. When all points have been plotted draw the curve through them. This curve may be either a smooth curve through all points or a series of straight lines, depending upon the data shown. For example, suppose you are trying to show, on a chart, the increase in business of an electric power company and the data are as shown in Table III.

TABLE III

POWER SALES, UNION ELECTRIC POWER CO.

Year	Output in Kilowatt-hours	Year	Output in Kilowatt-hours
1916	215,150,000	1925	375,123,000
1917	225,250,000	1926	410,200,000
1918	240,400,000	1927	435,160,000
1919	250,000,000	1928	465,370,000
1920	265,150,000	1929	510,354,000
1921	285,230,000	1930	570,436,000
1922	300,100,000	1931	646,370,000
1923	325,200,000	1932	742,336,000
1924	345,197,000	1933	890,128,000

Starting at the lower left hand of your chart lay off the years along the horizontal or X axis, and on the vertical Y axis lay off units representing millions of kilowatt-hours as shown in Fig. 7. Starting on the vertical line representing 1916 place a dot at the level of 215 million; on the 1917 line place a dot at the 225-million level; on the 1918 line place a dot at the 240-million level, this being two-tenths of the distance from the 200- to the 400-million line. Continue in this way, estimating accurately about the distance between intervals which would properly represent the amounts of kilowatt-hours given in the table. Accurate estimates of distance are made by computing the exact value of the smallest divisions on the paper and using these values to get the correct level. When dots are located on all the vertical lines which represent years, sketch a smooth curve through the dots, as shown in Fig. 7. A smooth curve should be

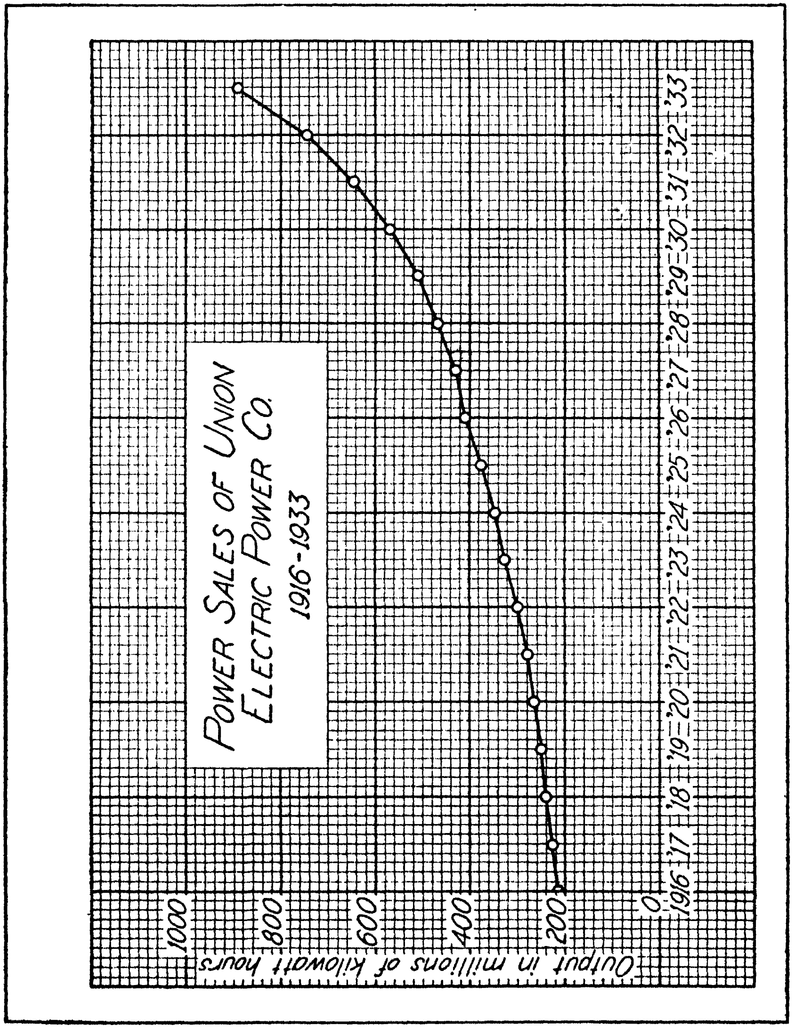


FIG. 7. Plane curve.

drawn in this case, for the growth of business is a daily, almost hourly, affair, and points on the curve other than those plotted have a real meaning.

To draw a barograph. To draw a barograph use co-ordinate or "cross-section" paper as for plane curves. Draw first the X axis and the Y axis intersecting near the lower left-hand

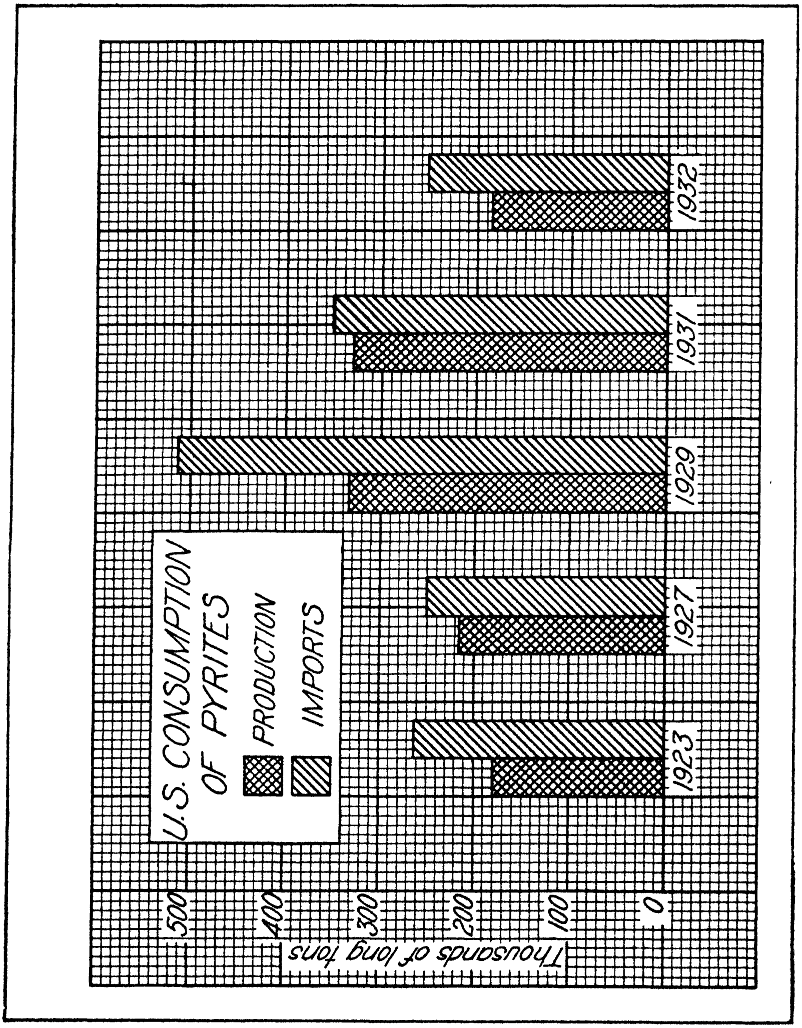


FIG. 8. Barograph showing annual variation of two quantities.

corner of the paper. Allow room for numbers and legends between axes and border. Lay off intervals on the Y axis to represent the dependent variable. On the X axis note first how many bars you will have to make. Determine the approximate width of bars by taking half the available space along the X axis and dividing it by the number of bars. Mark off twice as many spaces as there are bars and then use the alternate spaces. When two or more bars are to be put side by side as in Fig. 8 the width of both bars must be the unit.

Always make the bars come on the lines of the coordinate paper. Do not make the bars come to the edge of the coordinate area.

TABLE IV

UNITED STATES CONSUMPTION OF PYRITES

Year	Production	Imports
1923	181,628	263,695
1927	215,786	250,794
1929	333,465	514,336
1931	330,848	352,066
1932	186,485	253,248

For example, if the data of Table IV are to be shown in the form of a barograph as illustrated in Fig. 8, locate the axes 1 inch from the bottom and left-hand edges of the coordinate area to allow room for the numbers and legends. This allows 6 inches for the ordinates. Since the largest number in the table is 514,336, make the ordinates 100,000 to the inch and mark them as shown in Fig. 8.

Nine inches of space are available on the horizontal axes for the bars and spaces between them. This gives 90 small divisions on the paper. From the table we note that there must be five double bars. One-half the number of divisions available is 45, which divided by 5 gives nine divisions for a double bar. This would make the single bar come on a half division. It would also bring the last bar to the edge of the coordinate area; hence make the double bar eight divisions wide and the space between double bars eight units wide.

Begin over one space (eight small divisions), and make a single bar four divisions wide and of a height equal to the first number in the production column. Next to it make a bar four divisions wide of a height equal to the first number in the imports column, and continue for each year until all the data are plotted as shown in Fig. 8. After all the bars have been outlined, cross-hatch them to distinguish the two quantities "production" and "imports" from each other. Put in the co-ordinate markings, legends, title and a key to indicate what the cross-hatching means as illustrated in Fig. 8.

To make a sector diagram. To make a sector diagram draw a circle of a size which will fit conveniently the space available on the drawing paper. Next, for example, from Table II, compute the relative sizes of the quantities to be represented in terms of their percentage of the whole. These percentages have been computed and are shown in the table for convenience. Then compute the same percentages of the 360 degrees in the whole circle, as given in the last column of the table. Beginning at some convenient place, with a protractor mark off the circle into arcs of the proper number of degrees, as just computed, to represent the various parts. Letter in each part, horizontally if possible, what it represents, and give in figures the percentage of the total. Finally cross-hatch the areas in different directions to distinguish one part from another. Leave the space around the lettering clear. Put the title above the circle.

Another very convenient way to make sector diagrams is to use polar co-ordinate paper which may be obtained already marked off in degrees. By using this paper a protractor is not needed. Paper may also be obtained with circles divided into 100 parts. On such paper percentages may be laid off directly.

QUESTIONS

1. What are the uses of charts and diagrams?
2. What is a barograph? What kinds of facts does it show best?
3. What is a plane curve diagram? What kinds of facts does it show best?
4. When is it desirable to use larger spaces on the Y axis than on the X axis in drawing plane curves?

5. What is a sector diagram? What kinds of facts does it show best?

6. Name the things which must appear on a chart besides the plotted data to make it clear in meaning.

7. How do you judge the quality of a diagram or chart?

8. When is it best to connect points with a curved line on a plane curve diagram? When should straight lines be used?

9. Watch the papers, magazines, pamphlets and advertisements which come to your home, and make a list of the different kinds of charts and diagrams you find in them.

10. Why is it not best to use circles or squares of different sizes to represent different quantities to be compared? Illustrate your answer.

PROBLEMS

Use a sheet of standard co-ordinate paper with 10 co-ordinates to the inch in both directions. Paper printed in green or neutral tint is best. Omit the usual standard border line on printed papers but put your signature in the lower right-hand corner as usual. Do one of the problems assigned from the group below. You must work out your own scales and all other details. Do not, however, have any lettering outside of the printed co-ordinate area except your signature.

1. Make a barograph of the following data:

CHART OF GAS CONSUMPTION, 1916 TO 1930 INCLUSIVE

Year	Consumption in Billions of Cubic Feet	Year	Consumption in Billions of Cubic Feet
1916.........	1,930,262	1924.........	2,500,000
1917.........	1,500,000	1925.........	2,600,000
1918.........	1,620,000	1926.........	3,200,000
1919.........	1,750,000	1927.........	3,510,000
1920.........	1,860,000	1928.........	4,100,000
1921.........	2,000,000	1929.........	5,000,000
1922.........	2,250,000	1930.........	5,450,000
1923.........	2,370,000		

2. Make a plane curve diagram showing the following facts:

NUMBER OF GAS CONSUMERS, 1916 TO 1930 INCLUSIVE

Year	Number	Year	Number
1916	52,000	1924	76,000
1917	53,500	1925	78,000
1918	57,500	1926	85,000
1919	60,000	1927	87,500
1920	63,000	1928	92,000
1921	67,500	1929	97,000
1922	70,000	1930	82,500
1923	73,400		

3. Make a sector diagram of the following data:

PUBLIC EXPENDITURES BY PHILIPPINE GOVERNMENT

Items	Percentage of Total
Public education	23.77
Public health	5.03
Public works	12.07
Other purposes	59.13
Total	100.00

4. Make a sector diagram of the following data:

POPULATION OF THE DISTRICT OF COLUMBIA, 1930

Race	Per Cent
White	72.7
Negro	27.1
Other color	0.2
Total	100.0

5. Make a suitable diagram to show the following data:

ANNUAL COST OF INSULAR GOVERNMENT OF PUERTO RICO

Items	Per Cent
General government	14.4
Protection	9.6
Education	29.4
Social welfare	9.7
Highways and streets	13.7
Economic development	5.8
Public utilities	10.2
Debt service	7.2
Total	100.0

6. Make a suitable diagram to show the following data:

FEDERAL APPROPRIATIONS FOR VOCATIONAL EDUCATION

Year	Amount	Year	Amount
1918	1,700,000	1925	6,200,000
1919	2,400,000	1926	7,200,000
1920	3,100,000	1927	7,200,000
1921	3,700,000	1928	7,200,000
1922	4,200,000	1929	7,200,000
1923	4,700,000	1930	7,200,000
1924	5,200,000		

7. Make a suitable diagram to show the following data:

INVESTMENT OF TRUST FUNDS

Securities	Amount	Per Cent
Farm mortgages	$ 58,841	18.2
City property mortgages	12,500	4.0
Railroad and utility bonds	208,730	64.6
Industrial bonds	20,105	6.2
Other securities	22,798	7.0
	$322,974	100.0

8. Make a suitable diagram to show the following data. The independent variable will be the capacity of the pipe in gallons per minute. The friction loss will be the dependent variable. Make a separate curve for each of the three sizes of pipe. After your curves have been completed determine from the chart what will be the pressure drop in 50 feet of 1¼-inch pipe delivering 27 gallons of water per minute.

CARRYING CAPACITY AND FRICTION LOSS (PRESSURE DROP) FOR STANDARD WROUGHT-IRON PIPE

Gallons per Minute	Friction Loss in Pounds per Square Inch per 100 Feet of Pipe Size of pipe		
	1¼″	1½″	2″
5	0.28	0.13	0.04
10	1.00	0.46	0.13
15	2.12	0.97	0.28
20	3.65	1.65	0.47
25	5.50	2.50	0.72
30	7.80	3.50	1.00

9. Make a suitable diagram to show the following data:

HOMICIDE RATE IN 31 CITIES OF THE UNITED STATES

Year	Rate per 100,000 Population	Year	Rate per 100,000 Population	Year	Rate per 100,000 Population
1900	51	1910	81	1920	85
1901	49	1911	83	1921	98
1902	49	1912	83	1922	95
1903	53	1913	88	1923	106
1904	56	1914	85	1924	113
1905	66	1915	86	1925	113
1906	77	1916	91	1926	103
1907	86	1917	91	1927	103
1908	70	1918	84	1928	103
1909	73	1919	91	1929	101

10. Consult a copy of the U. S. Census Bureau report and make a diagram showing the increase in population from 1880 to 1920 inclusive.

UNIT XVII

BLUELINE, OZALID AND PHOTOSTAT REPRODUCTIONS OF DRAWINGS

PURPOSE OF UNIT XVII

It is the purpose of this unit to describe the methods of reproducing drawings by means of blueline, ozalid and photostat prints.

WHAT YOU SHOULD KNOW ABOUT METHODS OF REPRODUCING DRAWINGS

Blueline prints. Blueline prints can be made in two ways, namely, the direct method and the indirect method. In the direct method a tracing may be used as the source of the print but a special paper and chemical developer are required. The indirect method requires a sepia print as the source instead of a tracing, but it is made upon ordinary blue print paper and is handled in all other respects just like a blueprint. It has the advantage of having blue lines on a white background and hence may be corrected and noted very easily. It also looks more like an original drawing since it has dark lines on a white background.

Ozalid prints. The ozalid print offers another method of reproducing engineering and other kinds of drawings. It has some advantages which other types of prints do not have. It has a maroon-colored line upon a creamy white background and so has all the advantages of a blueline print.

The print is developed dry and therefore has the advantage of being just as true to scale as the original tracing, since the shrinkage due to wetting the paper, which occurs with blueprints, is avoided. Being developed dry, these prints are ready to use or to mail as soon as finished. The paper itself is of good quality and makes possible rendering in pencil, ink or water colors.

Photostat prints. Photostat prints are made primarily as a matter of record rather than for use in the shops. Unless

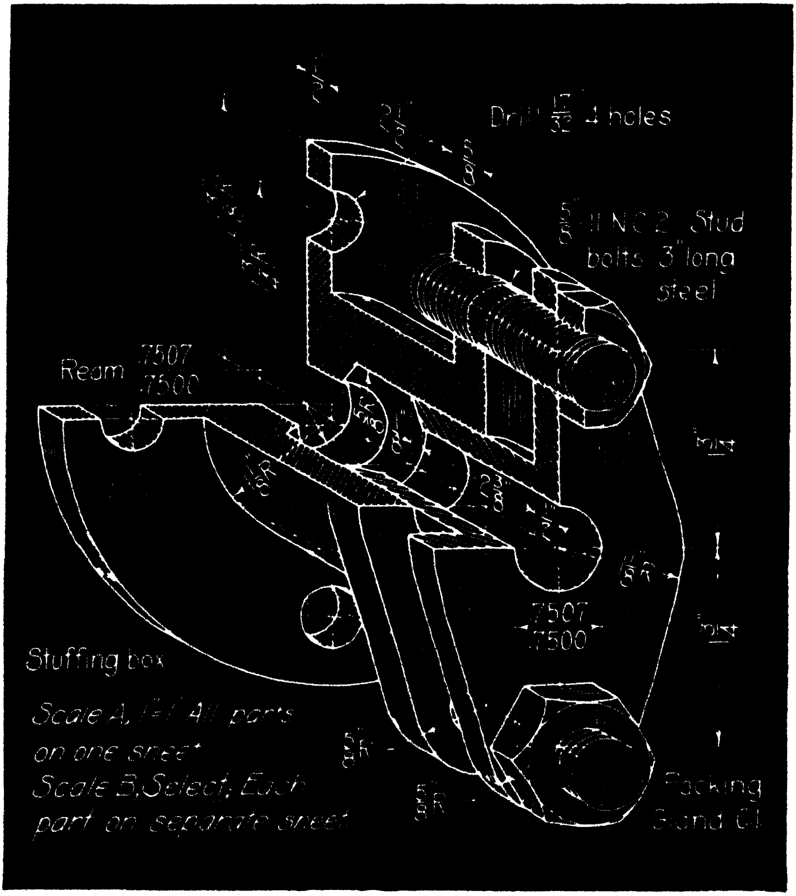
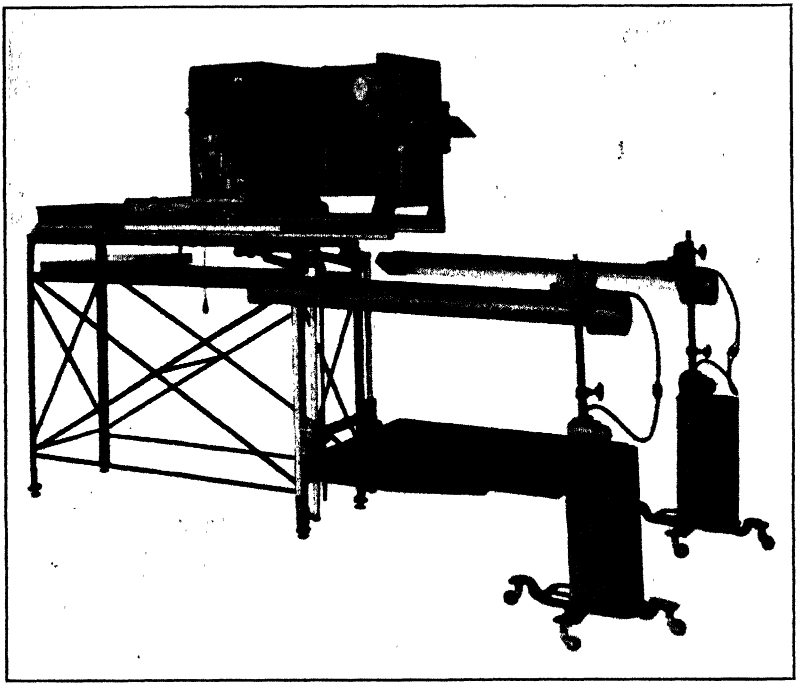


FIG. 1. Photostat print.

the original drawing is small, about 12″ x 16″ in size, the reproduction must be smaller than the original. The copies are black with white lines, which is just the reverse of the original, as shown in Fig. 1. Positive prints, however, may be made by copying the first reproduction.

The process of making a photostat requires a machine like that shown in Fig. 2, which is essentially a camera. Instead of using a film, however, the image is made directly upon the paper. The paper is then developed in the machine and also passes through a fixing bath after development,



Courtesy Photostat Corporation

FIG. 2. Photostat.

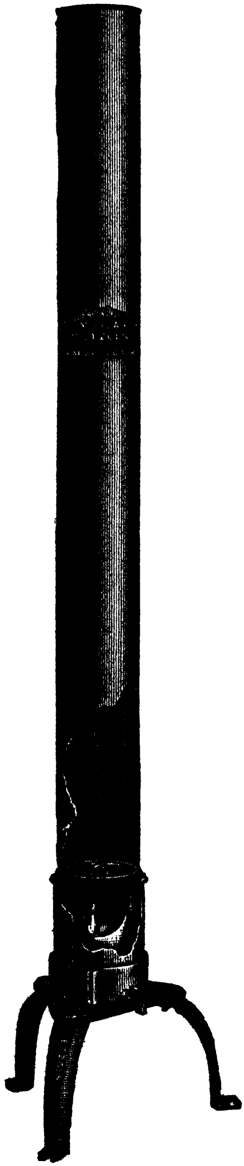
just like a camera print. The entire process is completed within the machine except for washing the print in water and drying.

HOW TO MAKE PRINTS

To make blueline prints. Place the sepia print* which has been properly transparentized upon the blueprint paper exactly as you would a tracing. Expose to sunlight or an

* Sepia prints are discussed in Basic Units of Mechanical Drawing, Book I.

electric arc light. The time of exposure must be determined by trial. Sunlight varies considerably, but an electric arc will require only from one to two minutes.



Courtesy Eugene Dietzgen Co.
FIG. 3. Ozalid developer.

After exposure lay the sepia print aside and wash the paper in water for three to five minutes, keeping the water in motion so that all the excess chemical will be washed off. Rinse in clear water and hang up to dry.

If the print has been over-exposed wash it in an oxidizing solution such as sodium bichromate, then rinse it off in clear water and hang up to dry.

To make ozalid prints. Place the tracing upon the ozalid paper with the ink lines away from the paper. Expose to light in the same manner as for a blueprint or blueline print. Determine the length of exposure by trial. After exposure lay the tracing aside and place the print in a tank containing ammonia gas. See Fig. 3. The time required for development must also be determined by trial. The strength of the ammonia gas is the determining factor. About three to five minutes is the usual time. When properly developed the print is ready to use. The ammonia gas adhering to the print soon disappears.

If the entire print turns a maroon color then the exposure to light was not long enough. There is little danger of spoiling the print by over-development.

The tanks for developing can be obtained from the manufacturers of the paper or may be made in a tin shop.

Place liquid ammonium hydroxide in the bottom and provide a screen to keep the prints from falling into the liquid. A tube divided into two parts which fit tightly together may be used, in which case have the lower part large enough to hold about a pint of liquid below the screen, and the upper part big enough to hold the print. If not rolled too tightly together a number of prints may be developed at the same time in this manner.

To make photostat prints. The process of making photostat prints is entirely a machine operation and cannot be practised without the machine, hence the process is not described here. The process is essentially the same as making a camera film except that sensitized paper is used instead of film. The steps are: (1) exposure, (2) development, (3) fixing, (4) washing and drying.

PART II

UNIT XVIII

INTERSECTIONS

PLANE WITH CONE OR CYLINDER

PURPOSE OF UNIT XVIII

It is the purpose of this unit to show how to draw the line of intersection formed by a plane and a cone or a cylinder.

WHAT YOU SHOULD KNOW ABOUT INTERSECTIONS

Cones and cylinders. A cone is a surface generated by a line which passes through a fixed point called the vertex

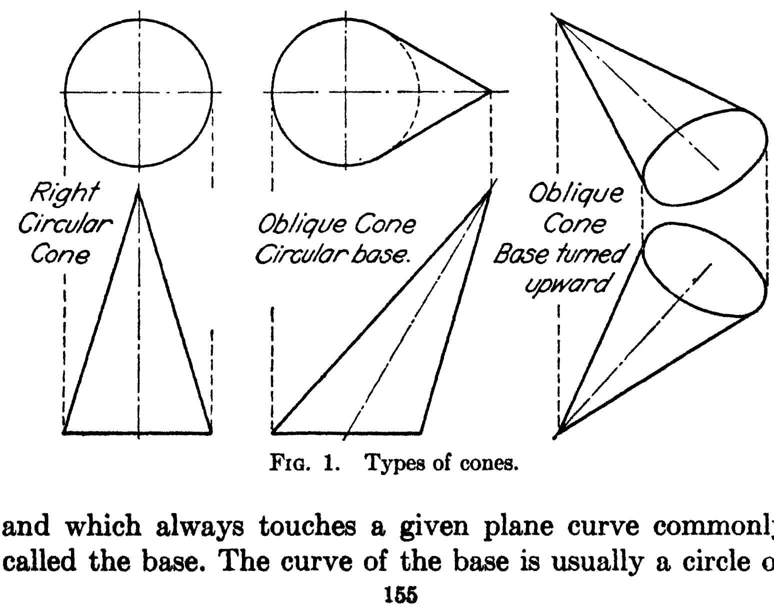


FIG. 1. Types of cones.

and which always touches a given plane curve commonly called the base. The curve of the base is usually a circle or an ellipse, although it may have any form. The cone is called a right cone when the line joining the vertex and the center of the base is at right angles to the base. Figure 1 illustrates several types of cones.

A cylinder is generated by a line moving in such a manner that it remains parallel to its original position and always touches a given plane curve called the base. The curve of the base may be any plane curve, but in practical work it is usually a circle or ellipse. A right cylinder is one in which

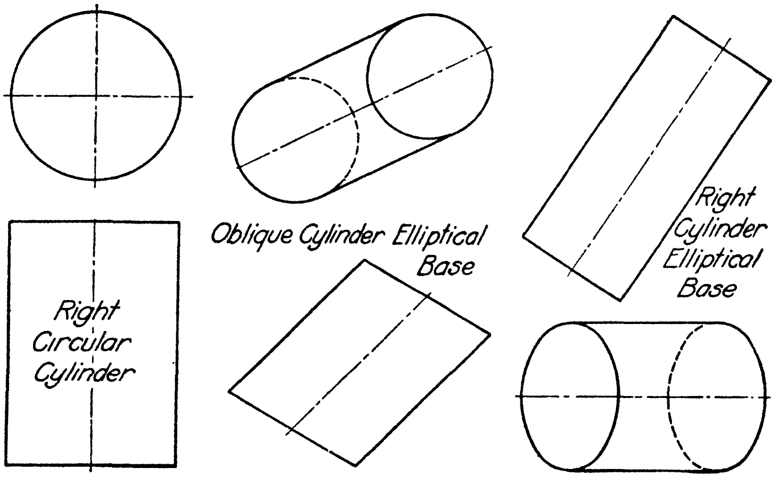


FIG. 2. Types of cylinders.

the generating line is at right angles to the plane of the base. Several cylinders are illustrated in Fig. 2. If the vertex of a cone were removed to infinity the cone would become a cylinder.

Lines of intersection. The conic sections discussed in Unit II give the possible types of intersection which may be formed by a plane and cone or cylinder when the base of either is circular or elliptical. These are the only types which will be considered in this unit.

If the base is circular the following facts may be observed to be true:

1. If the cutting plane is parallel to the base the line of

intersection is a circle. (In any case the line of intersection is similar to the base.)

2. If the plane is inclined to the axis the line of intersection will be an ellipse.
3. If the plane is parallel to the axis the line of intersection will be an hyperbola in the case of a cone and two parallel straight lines in case of a cylinder.
4. If the plane is parallel to an element of a cone the curve of intersection will be a parabola.

These facts should be kept in mind when finding an intersection and should be used to correct errors in points which are obviously not in the proper position to give correct results.

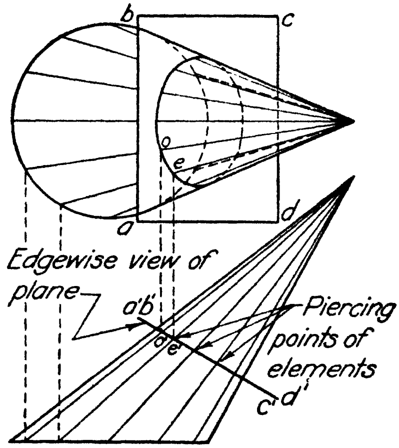


FIG. 3. Intersection of cone and plane.

The intersection of a cone or cylinder with a plane is determined by finding where the elements of the cone or cylinder pass through the plane. In most cases it will be sufficient to use twelve equally spaced elements of the surface. The point where the element passes through the surface may best be found by obtaining an edgewise view of the plane. In this view the piercing point can be observed by inspection, as shown in Fig. 3.

If the plane does not show edgewise in one of the original views then an auxiliary view of the cone and plane must be made which will show the plane edgewise, as illustrated in Fig. 4.

HOW TO GET AN INTERSECTION

When cutting plane shows edgewise. Divide the base of the cone or cylinder into twelve equal parts if it is a circle, and twelve approximately equal parts if it is elliptical or of other shape. Draw the elements one at a time in all views. By inspection locate the point where the element passes through the edgewise view of the plane and project this point onto the other views of the element. Having completed this for one element proceed with the next in the same manner, and then the next until the piercing points of all elements have been found. Then with an irregular curve draw a smooth curve through the points in each view. Show properly whether the curve is visible or invisible.

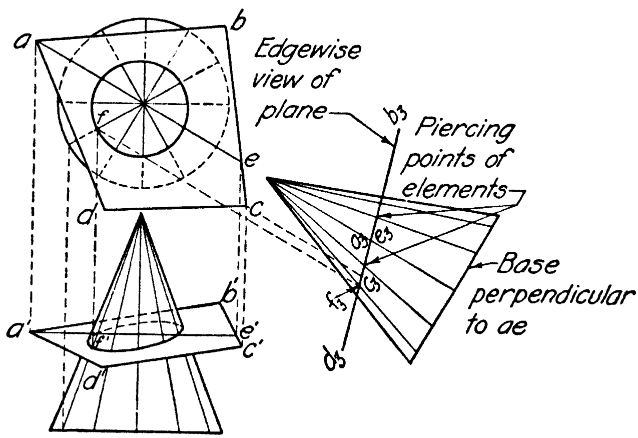


FIG. 4. Auxiliary view used to get edgewise view of plane.

When cutting plane does not show edgewise. If the cutting plane does not show edgewise get an edgewise view by means of an auxiliary projection in the following way. First, draw a horizontal line in the plane by drawing its vertical projection horizontally from one corner across to another side, as for example *a′e′* in Fig. 4. Get the horizontal projection or top view of this line in the usual manner and then set up the auxiliary ground line perpendicular to this line as in Fig. 4. The ground line has not been drawn in Fig. 4 since the base of the cone will serve the same purpose and is more convenient. This view will show the cutting plane edgewise. From this point on, the construction is like the preceding one except that there are three views and the elements must be shown in all three and the piercing points located on all three projections.

QUESTIONS

1. How is a cone generated?
2. Define a right circular cone.
3. How is a cylinder generated?
4. If the vertex of a cone is moved an infinite distance away from the plane of the base, what does the surface become?
5. How must a plane be passed to cut a circle from a circular cone?
6. How must a plane be passed to cut an hyperbola from a cone?
7. How must a plane be passed to cut a parabola from a cone?
8. How must a plane be passed to cut straight lines from a cylinder?
9. Describe the method of finding the intersection of a plane and cone.
10. How can an edgewise view of an inclined plane be found? Illustrate by a sketch using a triangular-shaped plane.

PROBLEMS

Lay out the standard border line and title space. Reproduce the views of the cone or cylinder assigned from the group below, and then find the intersection of the plane and cone or cylinder. Note that the location of the object from the center of the drawing area is given. Scale B, full size. Scale A, $1\frac{1}{2}'' = 1''$.

Note: Only one problem can be done on sheet sizes B, C and D. The last four problems require the use of auxiliary projection.

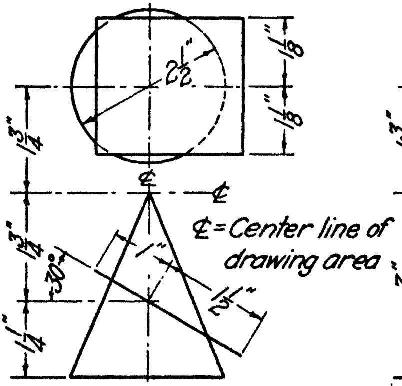


FIG. 5.

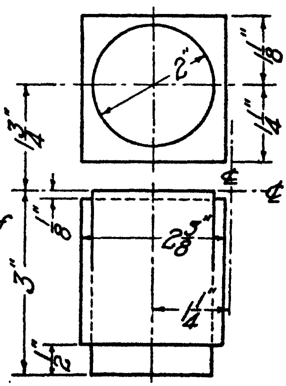


FIG. 6.

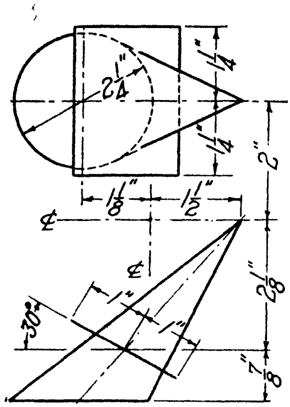


FIG. 7.

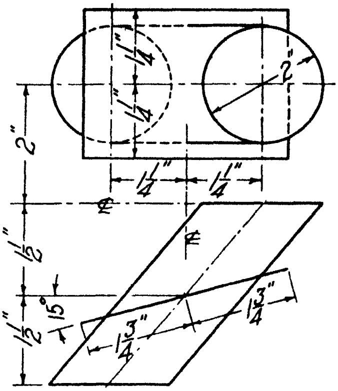


FIG. 8.

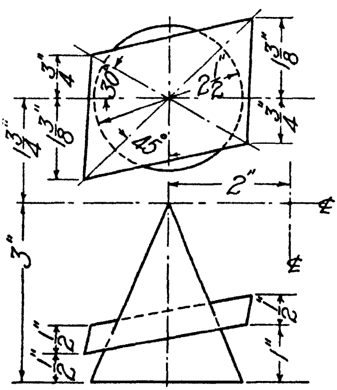


FIG. 9.

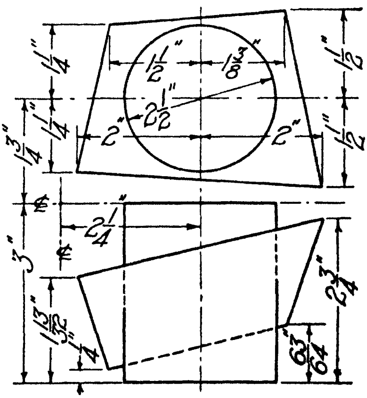


FIG. 10.

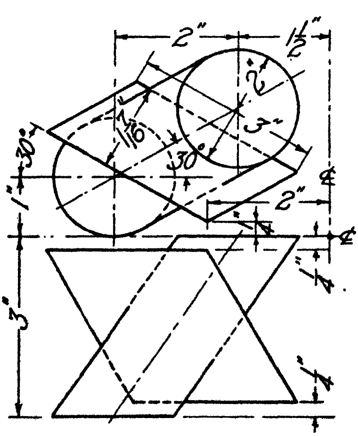


FIG. 11.

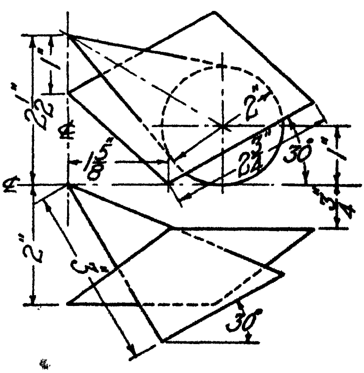


FIG. 12.

UNIT XIX

DEVELOPMENT OF CONES AND CYLINDERS

PURPOSE OF UNIT XIX

It is the purpose of this unit to show how to make a development of a cone or cylinder.

WHAT YOU SHOULD KNOW ABOUT DEVELOPMENTS

Use of developments. The process of the manufacture of objects made of sheet metal, whether the metal be thin like

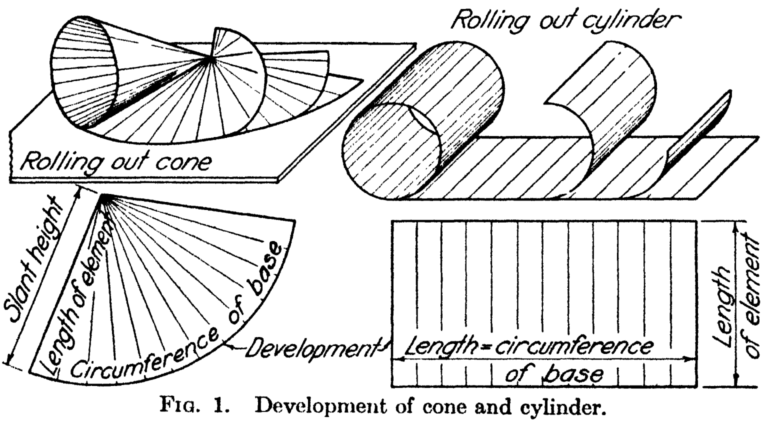


FIG. 1. Development of cone and cylinder.

a 28-gage copper gutter or whether it be of heavy steel plate as in water and gas tanks, always begins with a flat plate or sheet. The flat plate must be cut to such shape that when it is formed it will produce exactly the shape desired. Such a flat shape is called a development of the surface which will be formed from it. If a surface is imagined to be rolled out into a flat sheet it is said to be developed. The flat sheet is sometimes spoken of as a pattern.

Non-developable surfaces. Not all surfaces can be developed, that is to say, some surfaces cannot be formed by simply bending a flat sheet of metal of the proper shape. The sphere, for example, cannot be formed in this manner without stretching the plates. It therefore is said to be non-developable. Cones and cylinders, however, can be developed, and it is with them that this unit is primarily concerned.

Right circular cone. If a right circular cone is split along one of its elements and rolled out it will take the shape of a sector of a circle as shown in Fig. 1. The radius of the sector is equal to the slant height of the cone, and the length of the arc is equal to the circumference of the base of the cone.

Right circular cylinder. A right circular cylinder will develop as a rectangle one of whose sides is equal in length to the elements of the cylinder and the other of which is equal to the circumference of the base, as shown in Fig. 1.

Oblique cones and cylinders. Oblique cones and cylinders develop into odd shapes resembling only in a very general way the right circular cone and cylinder. Illustrations are shown in Figs. 3 and 5.

HOW TO DEVELOP CONES AND CYLINDERS

To develop a cone. In the drawing room the cone is developed by using a series of triangular figures which approximate the cone. For ordinary purposes twelve such triangles will be sufficient. For more accurate work a greater number must be used. Figure 2 illustrates the process for a right circular cone. First, locate twelve equally spaced elements on the cone. Then draw an arc of indefinite length having a radius OA equal to the slant height of the cone. Then, beginning at any point A, step off twelve spaces equal to the chords into which the base of the cone was divided by its twelve elements. This brings the end of the development to the point M. Connecting A and M with the center O completes the development.

In order to obtain an accurate construction it is necessary to set the dividers to the length of the chord on the base of the cone, or cylinder, and then step off this value on the base circle six times and see if it checks out on the half circle. If it does not, adjust the dividers slightly (one-sixth the error) and try again until six steps will just make one-half the circle. With this final setting, step off the twelve spaces on the development of the cone or cylinder.

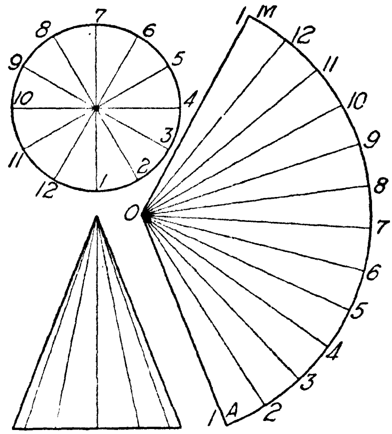


FIG. 2. Development of right circular cone.

To develop an oblique cone. In the case of the oblique cone again divide the surface into twelve parts. This time, however, the length of the elements is not constant, and hence you must find the

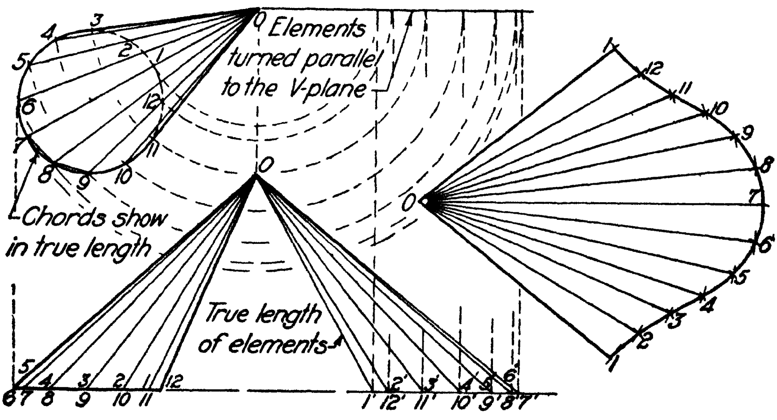


FIG. 3. Development of oblique cone.

true length of each one, for the development must show all parts of the surface in their true size. Figure 3 shows the development of an oblique cone. To find the true length of each element turn it until it is parallel to the vertical plane, as shown in the figure. The true length of the chords will show in the top view since the base is parallel to the horizontal plane. If the base were inclined then the true length of the chords would also have to be determined.

When the base of a cone or cylinder is not parallel to one of the planes of projection and hence does not show in its true shape, the chords subtending the arcs into which the base has been divided will not show in their true length. In such cases the best way to get the true length of the chords is to get the true shape of the base by auxiliary projection.

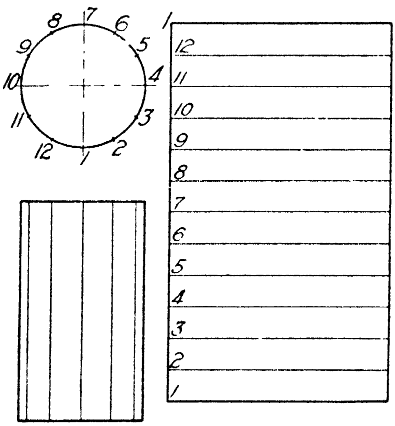


FIG. 4. Development of right circular cylinder.

To make the development, then, split the cone along the shortest element and lay out the first triangle on one side as *0, 1, 2* in Fig. 3, and then on this lay out the next one, *0, 2, 3*, and so on until the entire figure is completed. Draw a smooth curve through the points *1, 2, 3, 4*, etc. If the cone has a plane of symmetry, only half of the development need be made since the other half will be just like it only reversed.

To develop a cylinder. To develop a right circular cylinder step off the twelve chords of the base on a straight line and draw the first and last elements as shown in Fig. 4.

The accuracy of the setting of the dividers for chord length should be checked as noted above in the paragraph concerning the cone.

To develop an oblique cylinder. The base of an oblique cylinder will not develop as a straight line and its exact shape will be unknown, hence it is necessary, as the foundation for the development, to use another line which will develop as a straight line. Such a line is formed by any right section, that is, a section at right angles to the elements.

To obtain the true shape and length of the right section make an auxiliary projection as shown in Fig. 5. Also find the true length of all elements if they are not shown in true length in the original views. Do this also by drawing an auxiliary view as shown in Fig. 5.

To make the development then lay out a straight line and on it step off the true length of the right section. Erect

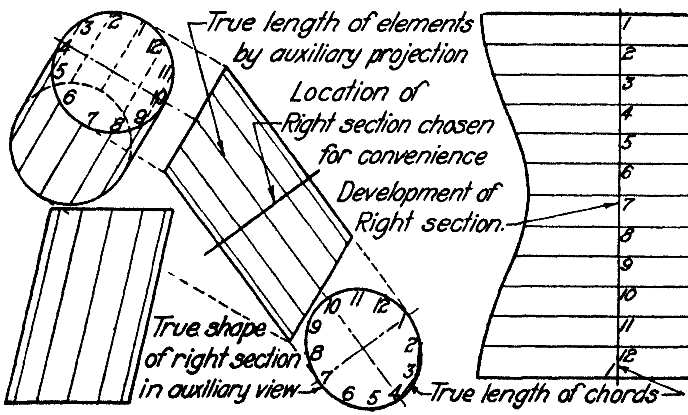


FIG. 5. Development of oblique cylinder.

perpendiculars to the line at each point, and on them lay off the true lengths of the elements on each side of the right section.

It is best to number the elements in the various views and in the development in order to avoid confusion.

QUESTIONS

1. What is the shape of the development of a right circular cone?
2. What is the shape of the development of a right circular cylinder?
3. What is the length of the radius of the development of a right circular cone in terms of dimensions of the cone?
4. What are the dimensions of the development of a right circular cylinder in terms of the dimensions of the cylinder?

5. Explain how to get the true length of an element of an oblique cone.

6. What is the most convenient way to get the true length of the elements of an oblique cylinder?

7. What circumferential line on an oblique cylinder will develop as a straight line?

8. How may the true length of the right section of an oblique cylinder be determined?

9. Explain what is meant by a development?

10. When are surfaces developable?

PROBLEMS

Lay out the standard border line and title space. Then reproduce the views of an object assigned from the following group and make a development of the surface. When a cutting plane is indicated upon the cone or cylinder make a development of the entire cone or cylinder and the developed line of intersection of the cutting plane. Show all construction lines lightly in pencil. The entire drawing is to be done in pencil or ink as assigned by the instructor. Scale B, full size. Scale A, $1\frac{1}{2}'' = 1''$.

Place the views of the object well to one side of the sheet in order to allow for the development. Two problems may be solved on sheets A, but only one on sheets B, C or D.

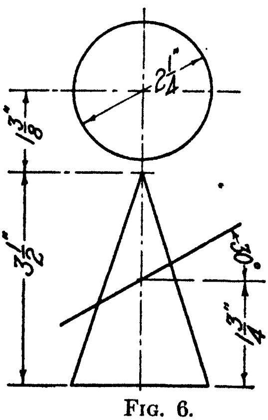


FIG. 6.

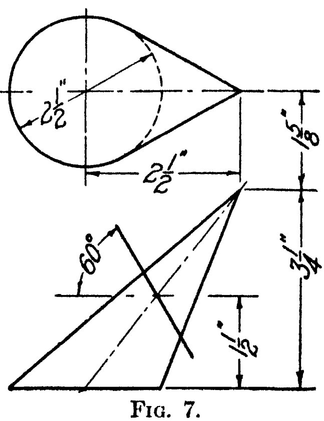


FIG. 7.

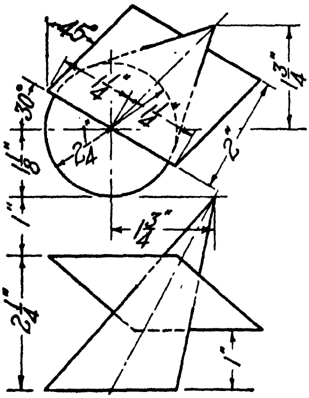


FIG. 8.

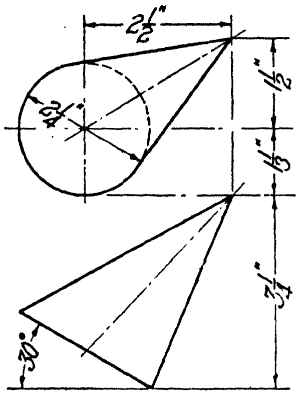


FIG. 9.

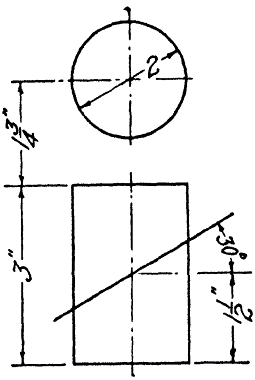


FIG. 10.

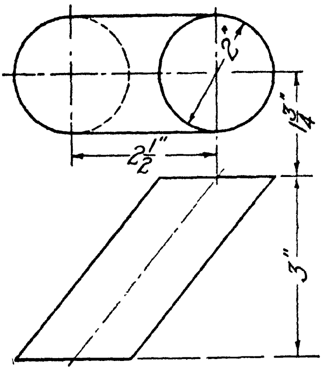


FIG. 11.

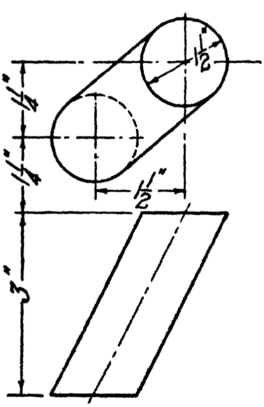


FIG. 12.

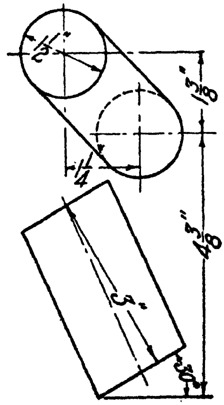


FIG. 13.

UNIT XX

INTERSECTIONS OF CYLINDERS

PURPOSE OF UNIT XX

It is the purpose of this unit to show how to find the line of intersection of two cylinders.

WHAT YOU SHOULD KNOW ABOUT INTERSECTIONS

Types of intersections. Cylinders may intersect each other to form four different kinds of intersections, as illustrated in

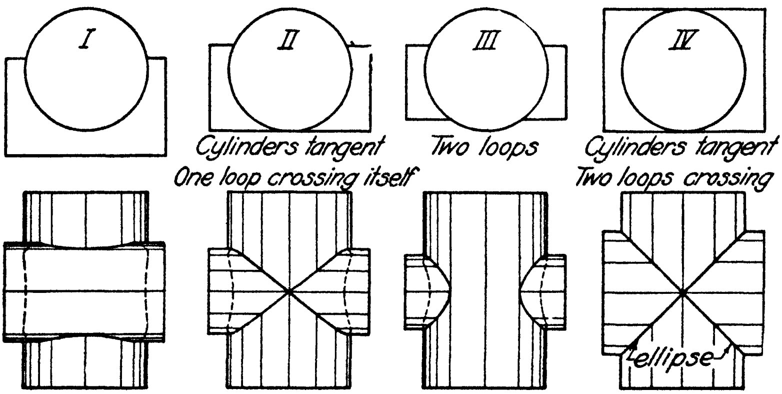


FIG. 1. Four types of intersections illustrated.

Fig. 1. The type to be expected should be recognized by the relative positions and sizes of the cylinders as revealed by the endwise view of either cylinder. This knowledge should be used as a guide in finding the intersection. The endwise view of either cylinder will give the same information as that given by the other. In case I, Fig. 1, it will be noted that each cylinder cuts partly through the other. In case II the two cylinders are tangent to each other on one side. In

case III one cylinder passes completely through the other, and in case IV the two cylinders penetrate each other and are tangent to each other on both sides. The general method of finding the intersection of any two surfaces consists of passing a cutting plane through the two surfaces in such a way that it will cut lines from both surfaces the projections of which can be found. The intersection of these lines will locate points in the curve of intersection. Lines cut by such

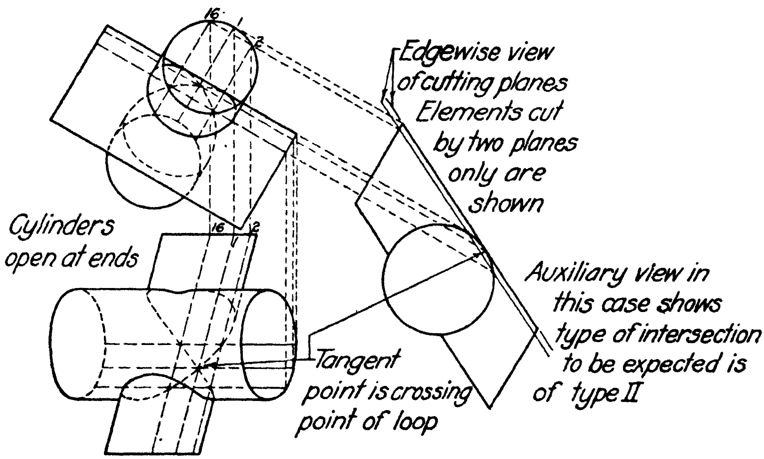


FIG. 2. Auxiliary view used to get intersection.

planes will be either circles or straight lines. Usually the straight line is preferable.

Use of endwise views. In the case of two cylinders the easiest method of finding the position of a plane that will cut straight lines or circles from the two cylinders is by obtaining an endwise view of one of the cylinders. If not already shown in the views given, this may always be accomplished by auxiliary projection, as shown in Fig. 2. Occasionally a second auxiliary view may be necessary.

Visibility of curves. The visibility of the curve will depend upon where it lies upon the surfaces. To be visible a point must be upon the intersection of two visible elements. If either element upon which the point lies is invisible then the point is invisible. One other fact should be observed, namely, that the curve of intersection changes visibility only at a point of tangency with the outstanding elements of the cylinders. See Fig. 2.

HOW TO FIND THE INTERSECTION OF TWO CYLINDERS

To find curve of intersection. Obtain first an endwise view of one of the cylinders by auxiliary projection if necessary. The auxiliary plane must be perpendicular to the elements of the cylinder. In this endwise view pass cutting planes one at a time and determine the elements cut from each of

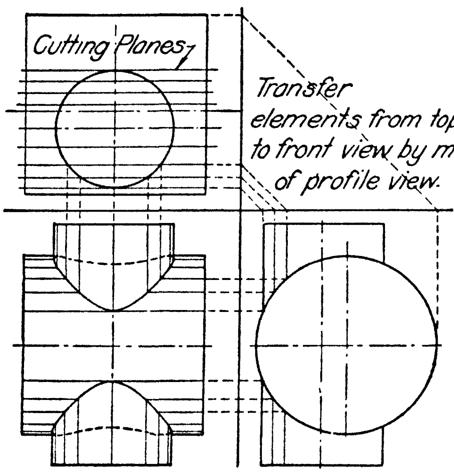


FIG. 3. Profile view used to find intersection.

the cylinders. Find where these elements intersect; indicate by a dot the visible points and by a very small cross the invisible points. Locate the points obtained by one cutting plane in all views before passing another plane. In passing the cutting planes begin at one side and work across the cylinder. Connect the points by a very light freehand line as you locate them. This will assist in determining the final shape of the curve. Draw the curve of intersection finally with an irregular curve.

When one of the cylinders is horizontal and the end of it shows as a straight line in both top and front views, transfer the elements obtained by cutting planes in either view to the other view by means of the profile view, as illustrated in Fig. 3. A common error of students is to space the elements in the second view just as they are in the first, forgetting that the two views are rotated 90 degrees with reference to each other.

QUESTIONS

1. Tell briefly how to determine the visibility of any point on a curve of intersection.
2. At what points only can the curve of intersection change visibility?
3. Name the four types of intersections which may occur.
4. How may the endwise view of a cylinder be obtained?
5. Illustrate by a sketch the relative position and size of two cylinders which will give an intersection composed of two closed curves which intersect each other twice.
6. Illustrate by a sketch the relative position and size of two cylinders which will give an intersection composed of two separate closed curves.
7. Illustrate by a sketch the relative position and size of two cylinders which will give an intersection which is a single closed curve that crosses itself.
8. Explain briefly the general method for finding the intersection of any two surfaces.
9. State which of the four types of intersections will be found in any of the problems assigned from the group below.

PROBLEMS

Lay out the standard border line and title space and then do the problem assigned by your instructor from the group below. Leave all construction lines in until your work has been checked. Show properly the visibility of the outlines of the cylinders and the curve of intersection. The outstanding elements of the cylinders do not stop as shown in the figure. These must be obtained as a part of the intersection. Scale A, $1\frac{1}{2}'' = 1''$. Scale B, $1'' = 1''$.

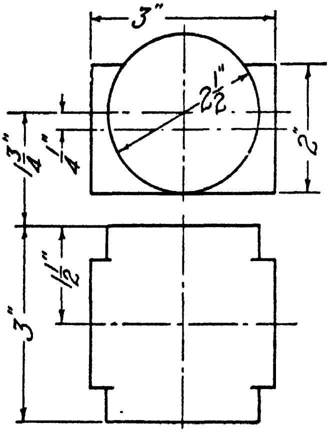


Fig. 4.

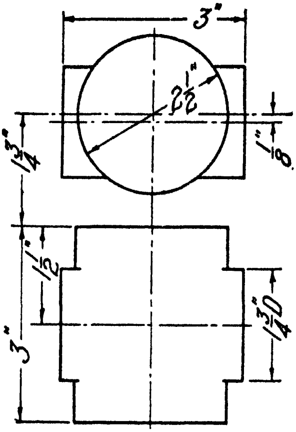


Fig. 5.

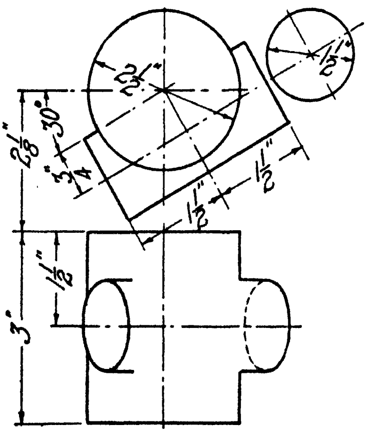


Fig. 6.

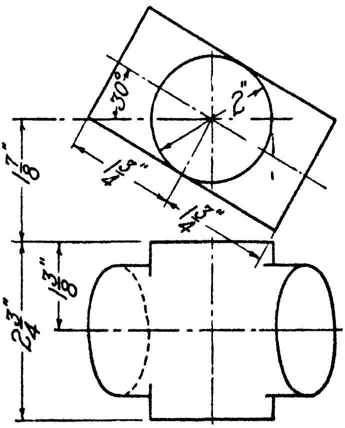


Fig. 7.

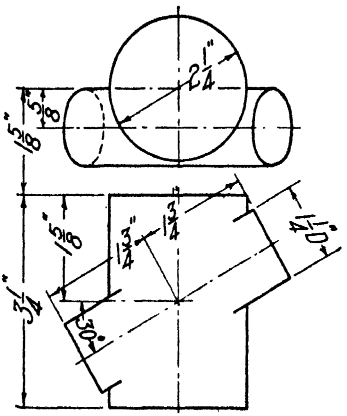


Fig. 8.

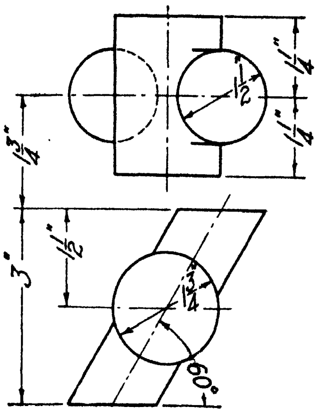


Fig. 9.

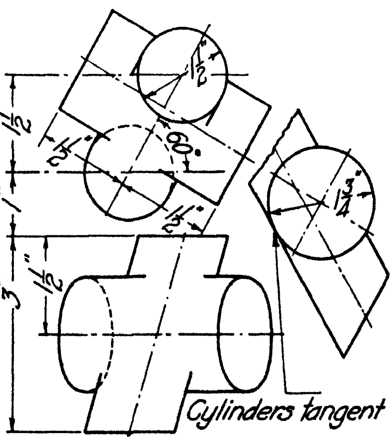


Fig. 10.

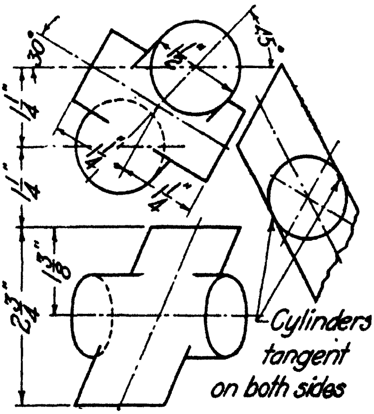


Fig. 11.

UNIT XXI

INTERSECTION OF CONES

PURPOSE OF UNIT XXI

It is the purpose of this unit to show how to find the line of intersection of two cones and of a cone and a cylinder.

WHAT YOU SHOULD KNOW ABOUT INTERSECTIONS

Intersection of cones. Cones like cylinders may intersect to form four different types of curves of intersection. In Fig. 1 the positions and relative sizes of cones which will produce each of the types of curves of intersection are illustrated. The projection which gives an endwise view of the line joining the vertices of the cones is the one which tells the story. In each case of Fig. 1 this is the profile view. In some problems this endwise view might occur only in an auxiliary projection. The profile view in Fig. 1a shows that the cones may be of any size but must partially overlap to get a curve of one loop. Figure 1b shows that one cone must be smaller than the other and that they must be tangent to each other on one side to get one loop crossing itself. Figure 1c shows that one cone must be smaller than the other and the projection of the smaller must lie entirely within the projection of the other to get two loops. Figure 1d shows that the two cones must be tangent to each other on opposite sides to get two loops which are plane curves and cross each other twice.

The general method of finding the intersection of two cones is the same as with cylinders. It consists in passing through the two cones a series of planes which will cut lines on the cones whose projections can be found. The points where these lines intersect are on the curve of intersection.

A sufficiently large number of such points must be found to determine the curve. An examination of the lines cut by the one cutting plane shown in Fig. 2 will make this clear.

In the statement above, the expression "cut lines on the cones whose projections can be found" limits these lines to

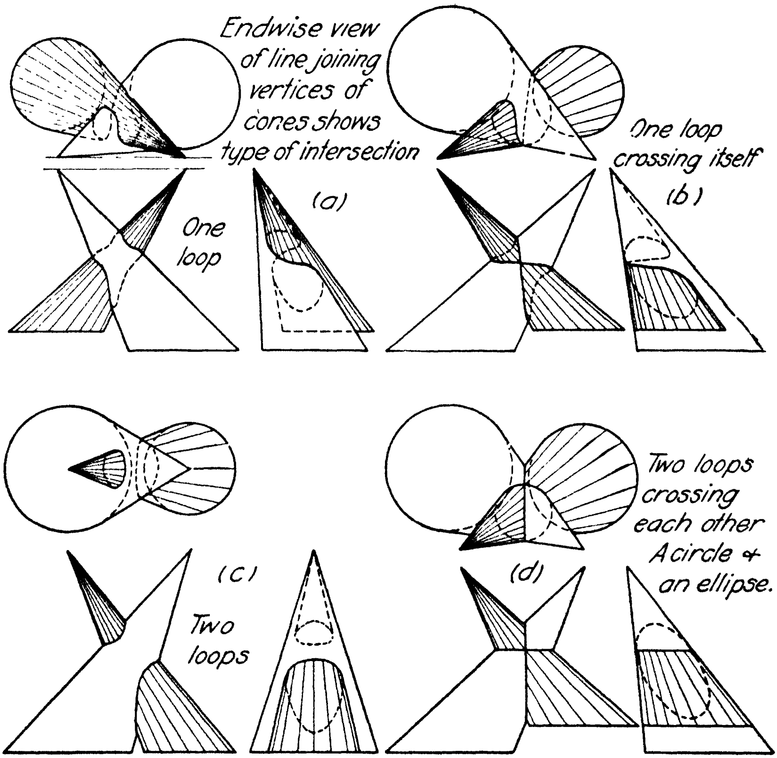


FIG. 1. Method of identifying four types of intersections.

straight lines. The problem then is to find the position of planes that will cut straight lines from both cones. In the discussion on conic sections it is shown that a plane must pass through the vertex of a cone if it is to cut straight lines from it. Hence for two cones the cutting planes must pass through the vertices of both cones and therefore through the line joining the vertices of both cones.

This is most easily accomplished by getting an endwise view of the line joining the vertices of the cones by means of an auxiliary projection, as illustrated in Fig. 2.

A complete discussion of the subject of intersections may be found in texts on descriptive geometry.*

Intersections of cones and cylinders. The intersections of cones and cylinders also fall into four distinct types of the

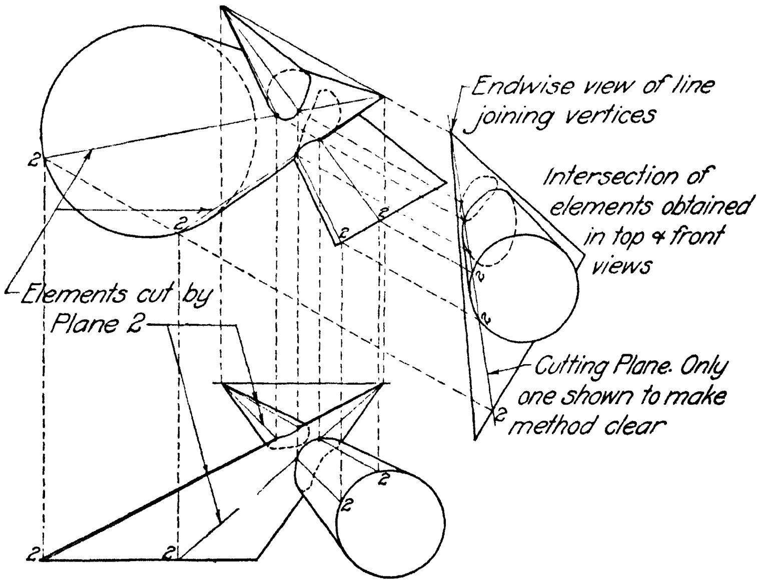


FIG. 2. Auxiliary view used to find intersection.

same character as illustrated for cones in Fig. 3 and for cylinders in Unit XX. The cutting planes must pass through the vertex of the cone and also cut elements from the cylinder. This is most easily accomplished by making an endwise view of the cylinder using an auxiliary projection, if necessary.

HOW TO FIND THE LINE OF INTERSECTION

To find the intersection of two cones. First, get an endwise view of the line joining the vertices of the two cones by means of an auxiliary projection, if it is not already shown

* For a thorough treatment of the subject, see Jordan and Porter, "Descriptive Geometry," Ginn and Company, Boston.

in one of the principal views. Make complete projections of both cones in the auxiliary view. Then pass a series of cutting planes as shown in Fig. 2, and find the elements cut by each plane. Locate the points of intersection of these elements, and indicate the visible points by a dot and the invisible ones by a very small cross. Begin at one side of the figure and work across, completing all the work for any one plane in all views before drawing the next plane.

Always work systematically and carefully. Choose a sufficient number of cutting planes to give points of intersection

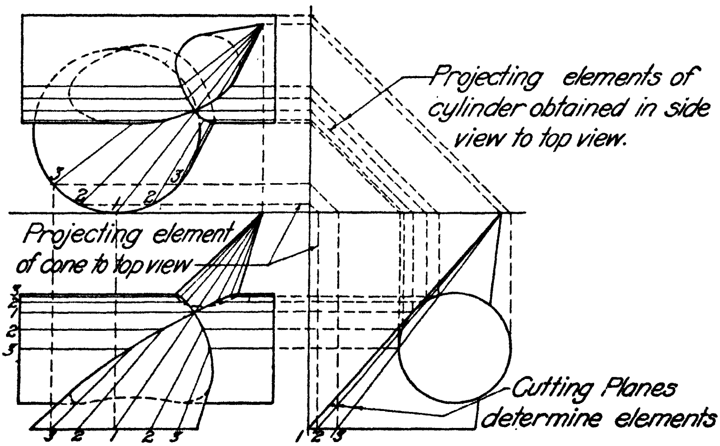


FIG. 3. Profile view used to find intersection.

that are close together. Connect the points of intersection by a light, freehand line as an aid in drawing the final curve. Make the final curve carefully with an irregular curve.

To find the intersection of a cone and cylinder. Get an endwise view of the cylinder showing the complete cone, as in the side view of Fig. 3. Pass the cutting planes in this view to determine the elements. Begin at one side and work across systematically. Pass the planes at small intervals. Be sure to draw the elements cut by each plane, and find the points of intersection of each before drawing the next cutting plane. Indicate visible and invisible points in the usual manner; connect the points, as you find them, by a light freehand line. When the intersection is complete draw it in carefully with an irregular curve.

QUESTIONS

1. Describe the general shape (i.e., one loop, etc.) of each of the four types of intersections which may be produced by two cones.
2. Can the intersection of two cones ever be a plane curve—that is, a curve that lies entirely in one plane?
3. How must a plane be passed to cut straight lines from a cone?
4. How must a plane be passed so that it will cut straight lines from each of two intersecting cones?
5. What method may be used to locate the planes which cut straight lines from two intersecting cones?
6. Under what conditions is a point on the curve of intersection of two cones visible?
7. When is a point on the curve of intersection of two cones invisible?
8. What is meant by a right cone; an oblique cone?
9. Why is it important to pass cutting planes at frequent intervals when finding a curve of intersection?

PROBLEMS

Lay out the standard border line and title space and find the intersection of the cones, or of cone and cylinder, assigned from the group below. Scale A, $1\frac{1}{2}'' = 1''$. Scale B, $1'' = 1''$.

Show all construction lines lightly. Indicate properly the visible and invisible portions of the curve. It is recommended that sheet size A be used for intersections.

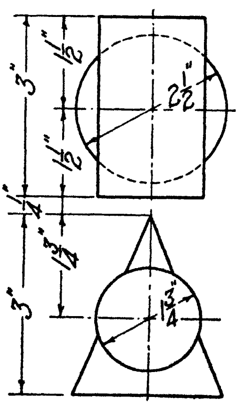


Fig. 4.

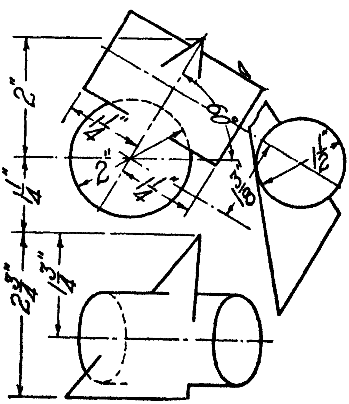


Fig. 5.

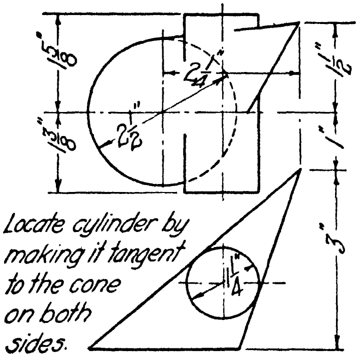


FIG. 6.

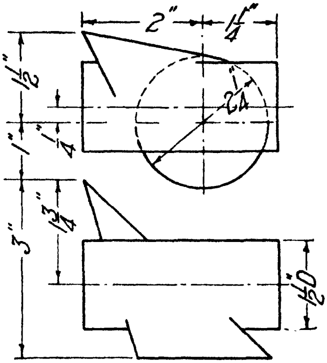


FIG. 7.

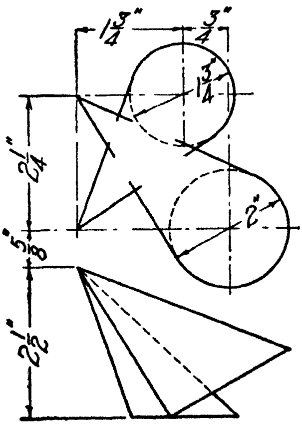


FIG. 8.

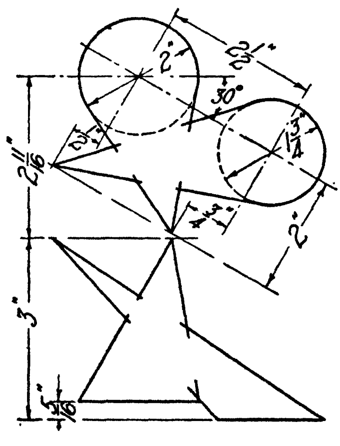


FIG. 9.

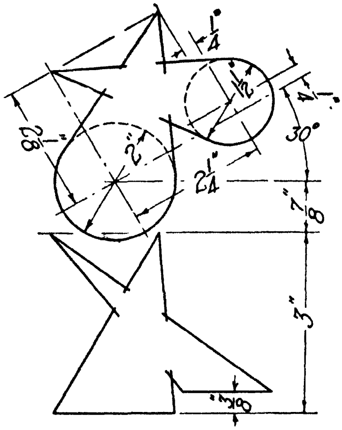


FIG. 10.

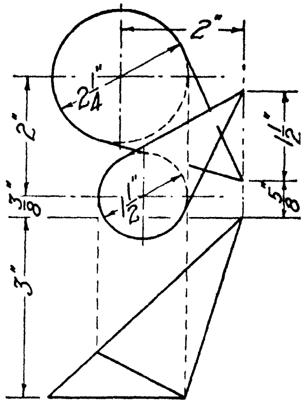


FIG. 11.

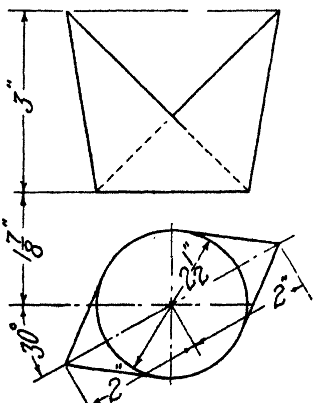


FIG. 12.

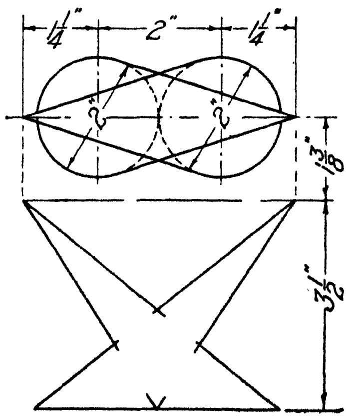


FIG. 13.

UNIT XXII

DEVELOPMENT OF PRACTICAL PROBLEMS

PURPOSE OF UNIT XXII

It is the purpose of this unit to show how to recognize the types of surface occurring in practical work and how to make the developments of such surfaces.

WHAT YOU SHOULD KNOW ABOUT COMMON SURFACES AND THEIR DEVELOPMENT

Types of surfaces. The five types of surfaces commonly met in commercial practice are: (1) the plane surface, (2)

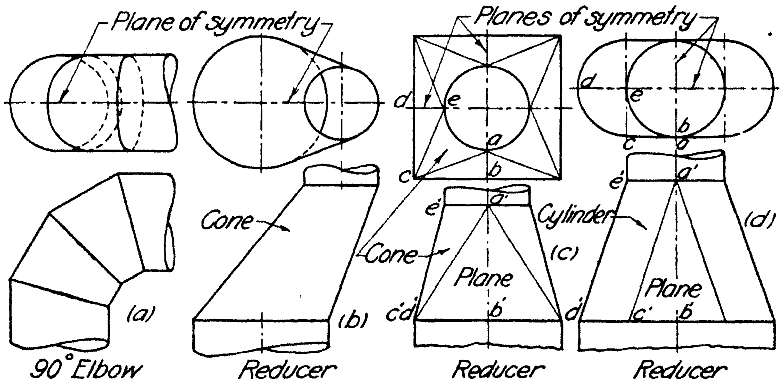


FIG. 1. Common types of surfaces used in practical work.

the prism, (3) the pyramid, (4) the cone and (5) the cylinder. The prism and pyramid, of course, are simply combinations of plane surfaces and may be dealt with as such. Their development was discussed in Unit V.

Combinations of surfaces. Combinations of the cone and cylinder and of the cone, cylinder and plane surface occur frequently in sheet-metal work, in both heavy and light materials. Illustrations of a few of these combinations are shown in Fig. 1. Others will be found in the problem section of this unit. In order to identify the various types of surfaces involved in a piece of work one must keep in mind the definitions of the cone and cylinder. Thus, Fig. 1a can be seen to be a series of cylinders; Fig. 1b consists of two cylinders and a part of a cone; and Fig. 1c consists of a prism, a cylinder, parts of four cones, with the vertices at the four corners of the prism, and triangular plane surfaces between the cones. Figure 1d consists, at the bottom, of two half cylinders, and two planes; the reducer is composed of two half cylinders and two triangular planes; and the top part is a cylinder. In the last two figures the light lines marking the edges of the plane surfaces would not ordinarily be shown in working drawings. They are given here to assist in determining the exact composition of the surfaces.

HOW TO DEVELOP COMPLEX SURFACES

To determine planes of symmetry. First study the surface carefully to see whether it can be broken up into developable surfaces. If so, draw in these parts in light lines and, if possible, locate a plane of symmetry. A plane of symmetry divides an object into two parts which are exactly alike except that they are right and left. The planes of symmetry are indicated in Fig. 1 by center lines.

Tc develop the parts. Having determined the plane, or planes, of symmetry proceed to develop a symmetrical half or quarter, as the case may be. Begin at one plane of symmetry and end on the next, if there are two planes, and upon the same one if there is only one. Develop each portion of a cone, or cylinder, prism or pyramid just as you would if that formed the whole problem. Then join the parts in proper order. Figures 2, 3, 4 and 5 illustrate the development of each of the surfaces shown in Fig. 1.

To develop an elbow. In Fig. 2 since the parts *M* and *N* are not right circular cylinders obtain, first, the true shape of the right section. Since the true lengths of all elements show in the front view, develop the cylinders in the convenient, simple manner shown in Fig. 2.

To develop reducers. In Fig. 3 only the reducing section needs to be developed. This is a part of an oblique circular cone with its vertex at A. Develop this cone in the usual way. Be sure to find the true length for each element. Develop only one of the symmetrical halves.

In Fig. 4 develop only one-fourth of the reducing section. This can then be used as a pattern to make the other three-fourths of the development. Determine carefully the true

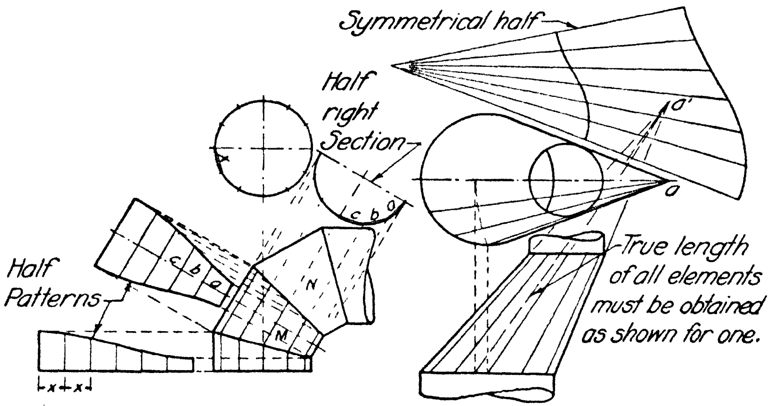


FIG. 2. Development of elbow.

FIG. 3. Development of conical reducer.

length of every line in the figure. Develop first the triangle ABC, then the cone ACD and then the triangle ADE, thus completing the figure $BAEDC$ as shown in Fig. 4.

Draw only one-fourth of the reducer in Fig. 5. Lay out first the triangle ABC, which shows in true size in the front view. Next develop one-fourth of a cylinder as at *1–2–3–4* in Fig. 5. The true lengths of the elements of the cylinder show in the front view. Determine the true shape of the right section by an auxiliary projection as illustrated in Fig. 5.

Note: If objects such as these are to be fabricated of sheet metal, make allowance for overlapping the joint along which the material is cut, so that it may be riveted or soldered. If models are made of paper, make a similar allowance for gluing. In any case, make the development by exact theoretical methods between planes of symmetry. Then allow the necessary additional strip on the finished pattern.

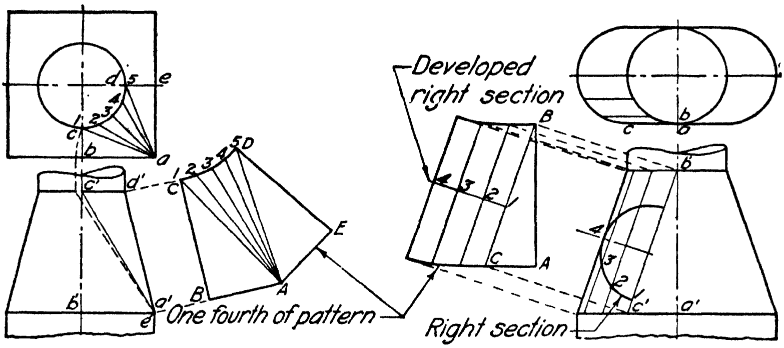


FIG. 4. Development of reducer. FIG. 5. Development of reducer.

QUESTIONS

1. What is the first step to take in the development of a complicated sheet-metal problem?
2. Of what developable surfaces are most sheet-metal objects composed?
3. What is meant by a plane of symmetry?
4. If there is one plane of symmetry, how much of an object needs to be developed?
5. If there are two planes of symmetry, what portion of an object should be developed?
6. In developing a cylindrical part when the cylinder is oblique, what two things must be obtained before development can be begun?
7. Does a line in a development show in the same length as in the orthographic views? If not, what length must show in the development?
8. Must every line used in a development show in its true length? Why?
9. What two methods are used in fastening the two ends of a development together in fabricating the object?
10. How is the needed allowance for fastening provided for?

PROBLEMS

Lay out the standard border line and title space and then make a development of one of the objects assigned from the following group:

Reproduce the orthographic views first, to the scale indicated, and then make the development. Show all construction lines lightly but clearly. In each case lay out the orthographic views at the left of the sheet so that there will be room for the development at the right.

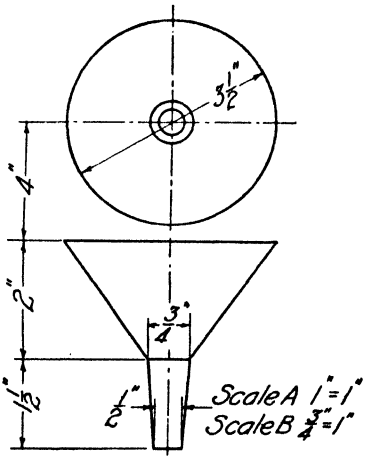


FIG. 6. Funnel.

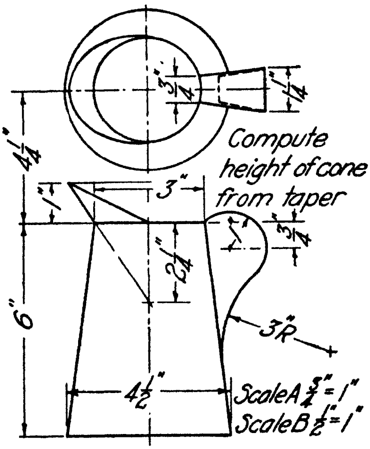


FIG. 7. Measuring vessel.

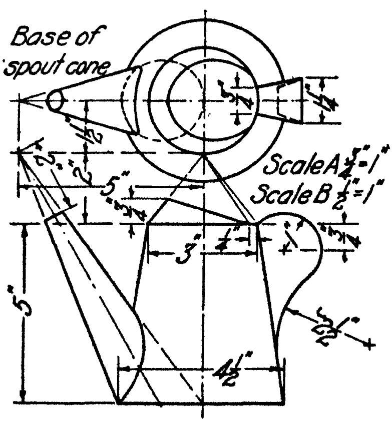


FIG. 8. Oil can.

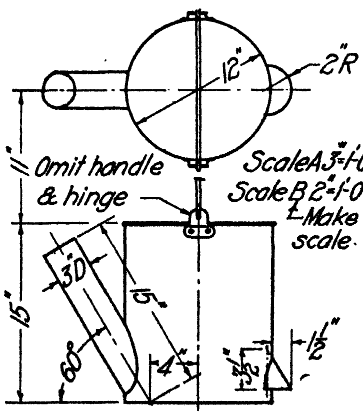


FIG. 9. Sand bucket.

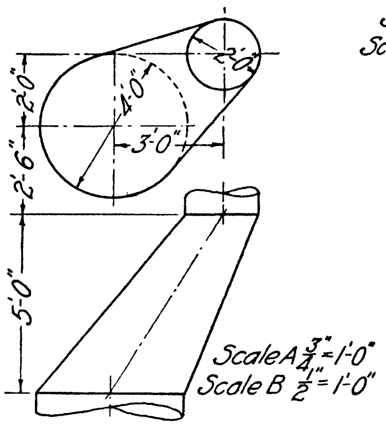


FIG. 10. Reducer.

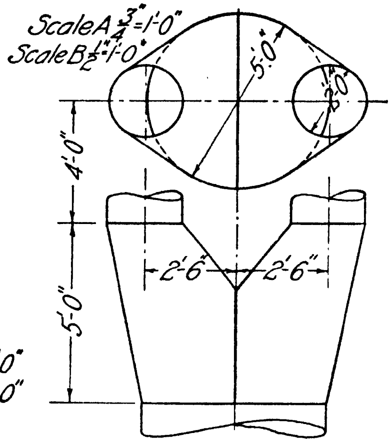


FIG. 11. Y-reducer.

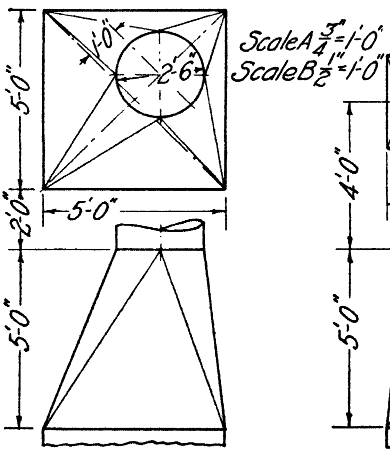


FIG. 12. Reducer.

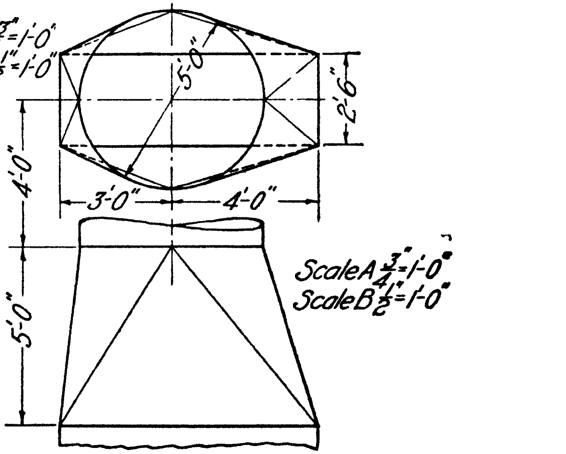


FIG. 13. Reducer.

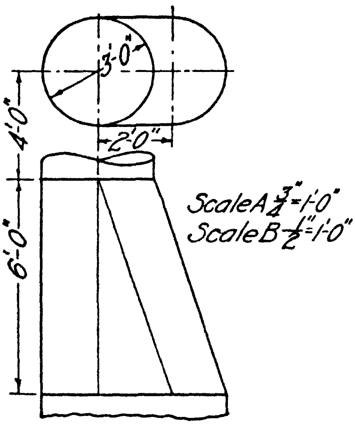


FIG. 14. Reducer.

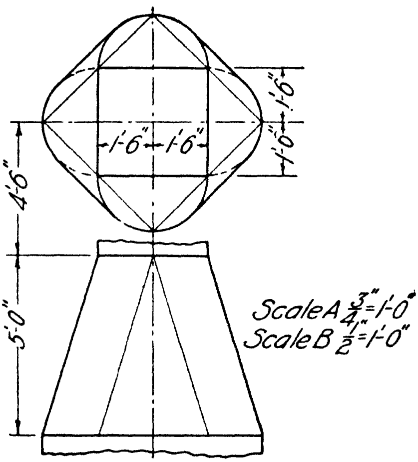


FIG. 15. Reducer

UNIT XXIII

ISOMETRIC. STRAIGHT-LINE OBJECTS

PURPOSE OF UNIT XXIII

It is the purpose of this unit to teach the principles of isometric drawing and how to make isometric drawings of objects composed entirely of straight lines.

WHAT YOU SHOULD KNOW ABOUT ISOMETRIC DRAWING

Meaning of isometric projection. Isometric projection is one of the forms of orthographic projection because by definition an orthographic projection is any projection in which the projecting lines are at right angles to the plane of projection. It may be defined as an orthographic projection upon the isometric plane. An isometric plane is one that makes equal angles with the three principal planes as shown in Fig. 1. Therefore, such terms as horizontal projection, vertical projection and isometric projection are similar in that each refers to an orthographic projection upon some specified plane. If an object, for example a cube, is placed in its usual position for projection upon the principal planes and one looks at it in a direction perpendicular to the isometric plane, he will see not one face at a time but three faces. In the cube these faces will all show in the same amount, as in Fig. 2.

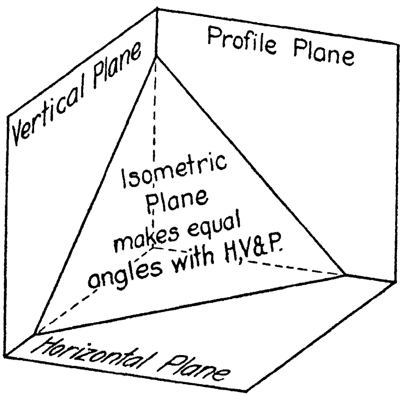


FIG. 1. Position of isometric plane.

The isometric scale. Since the isometric plane makes equal angles with the principal planes it will also make equal angles with the faces of the cube and with the edges of the cube. Hence since the edges of the cube are all the same length their isometric projections will all be the same length, but, of course, shorter than the true length. The exact length of the projection may be determined by noting that the angle which the edges make with the isometric plane is 35 degrees and 16 minutes. If a line is laid out at this angle with another line and then projected upon it, the length of

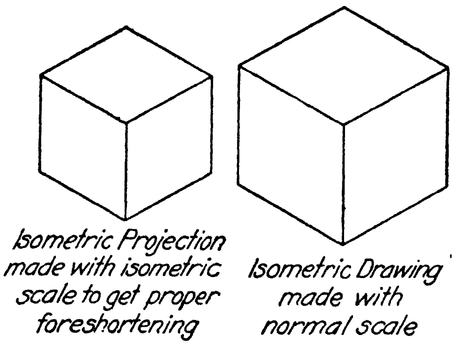


FIG. 2. Comparison of isometric projection and isometric drawing.

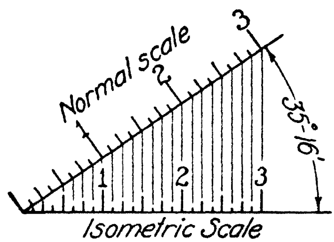


FIG. 3. Construction of isometric scale.

the isometric projection is found. This gives a method of constructing an isometric scale, as shown in Fig. 3.

Isometric drawings. Since all the edges of a cube are equally foreshortened there is actually no need to make a real projection. If the edges of the cube were laid out at 120 degrees with each other, which is their true position in the projection, and their lengths made the same as their true lengths, a view would be obtained which would be just like the true isometric projection, except that it would be larger. The isometric drawing and the isometric projection of the same cube are shown in Fig. 2. The drawing made with the regular scale is called an isometric drawing to distinguish it from the isometric projection. In the remainder of this text we shall deal only with isometric drawings since

Isometric lines. The word isometric means equal measure. The three original lines of the cube and any lines which are drawn parallel to them are called isometric lines, since they are the only ones on which measurements can be made to scale; this fact is very important in construction and should be carefully noted. Lines not parallel to isometric lines are called non-isometric lines. Non-isometric lines will not make the same angle with the plane of projection as the isometric lines, and their projections will not be equally foreshortened; therefore, only isometric lines can be measured or laid off to scale. This fact forms the basis of construction for isometric drawings.

HOW TO MAKE AN ISOMETRIC DRAWING

To draw a cube. Lay out three lines making 120 degrees with each other, and mark off on each line, from their com-

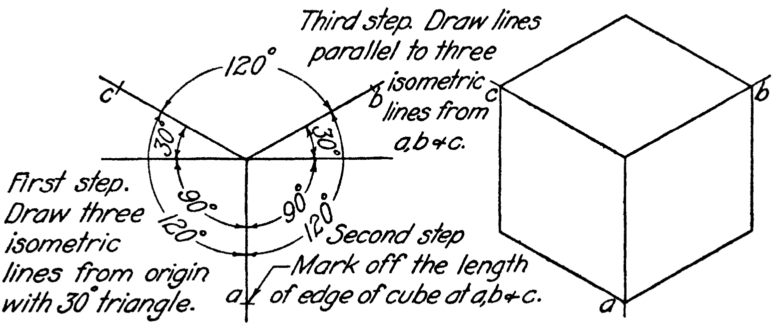


FIG. 4. Steps in making isometric of a cube.

mon point of intersection, the length of the edges, as shown in Fig. 4. From the three points *a*, *b* and *c* thus determined, draw lines parallel to the original lines, thus completing the cube. The invisible edges are not drawn unless they are absolutely necessary for a clear understanding of the object.

To draw a rectangular prism. To make an isometric drawing of a rectangular prism proceed in exactly the same manner as for a cube. The edges, however, now will not all be of the same length, but lay them out to scale just as for the cube. Figure 5 shows the same prism turned in four different positions. These positions enable one to show the right or left side, top or bottom as desired. The only difference in the construction is the position of the three original

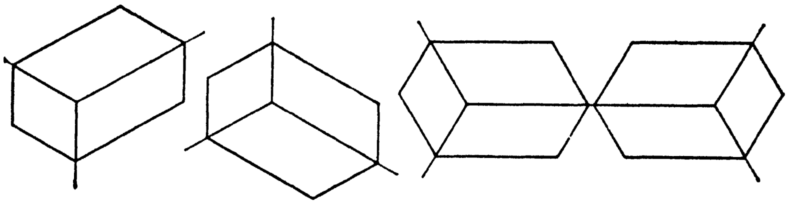


FIG. 5. Convenient positions of the isometric axes.

isometric lines which are indicated in Fig. 5 by the longer over-running lines.

To draw various rectangular objects. To make an isometric drawing of the object shown in Fig. 6a, construct

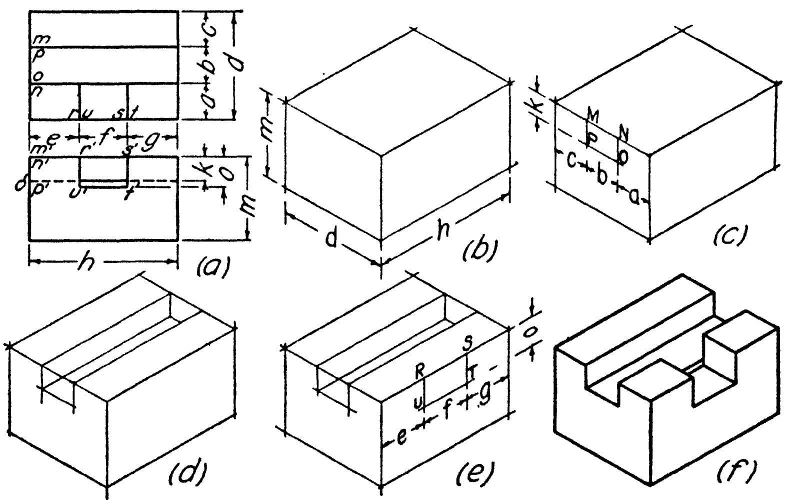


FIG. 6. Construction of an isometric drawing having isometric lines only.

first an isometric of a prism, or block, that will just exactly enclose it as shown in Fig. 6b. Next lay off the distances *a*, *b* and *c*, as shown in the top view, along the corresponding edge in the isometric drawing, as shown at Fig. 6c, and locate M and N. From M and N draw vertical isometric lines and make MP equal to $m'p'$ and NO equal to $n'o'$ in the front view. Complete the isometric rectangle $MNOP$. Next draw the lines across the top of the figure as shown in Fig. 6d. Then in similar manner construct the rectangle $RSTU$ as at Fig. 6e. Then complete the figure as at Fig. 6f. Rub out unnecessary lines.

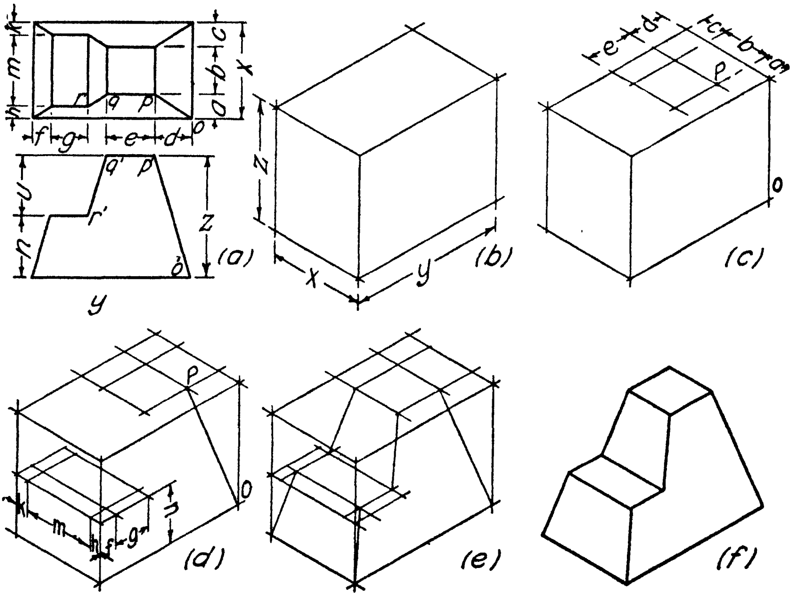


FIG. 7. Construction of an isometric drawing having non-isometric lines.

To draw objects with non-isometric lines. To draw non-isometric lines determine the end points of the lines by measuring along isometric lines as shown in Fig. 7. Thus to draw line OP in Fig. 7a locate P by making measurements along isometric lines as shown in Fig. 7c. Then connect the points P and O as illustrated in Fig. 7d. A careful study of the figures will make the steps clear. Obtain all measurements directly from the two orthographic views, and set them off along isometric lines only. Measurements cannot be made along any other lines, nor can angles be measured in any way except by plotting points.

QUESTIONS

1. Describe the location of the isometric plane.
2. What is the relationship of the projecting lines to the isometric plane in making an isometric projection?
3. What is the difference between an isometric projection and an isometric drawing?
4. Why are isometric drawings made rather than isometric projections?
5. Show by a sketch how to construct an isometric scale.
6. Show by a sketch and explain the meaning of the term isometric lines.
7. Along which lines must measurements be made in isometric drawing? Why?
8. What are non-isometric lines?
9. Show by a sketch how to draw an angle of 45 degrees in isometric.
10. Explain how to draw non-isometric lines.
11. What does the word isometric mean?

PROBLEMS

Lay out the standard border line and title space. Make an isometric drawing of an object assigned from the following group. In the case of Figs. 10, 11, 12 and 13 separate the two parts of the joint, and show them in proper position relative to each other. If it is desired to use sheet size A, increase the scale to the next standard one above that given for scale B.

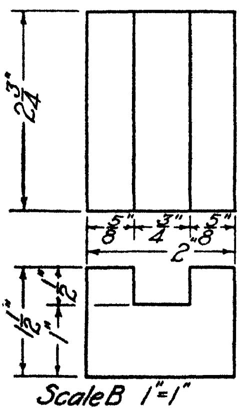


FIG. 8. Block.

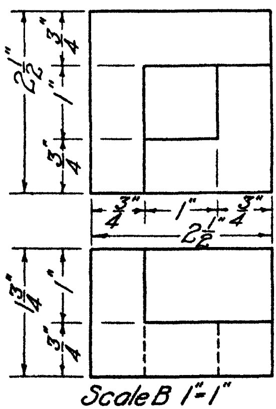


FIG. 9. Block.

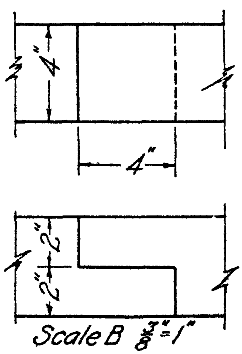


FIG. 10. Lap joint.

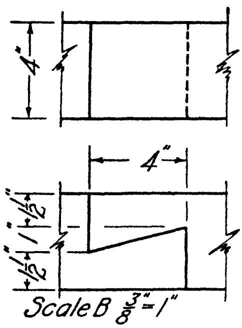


FIG. 11. Beveled lap joint.

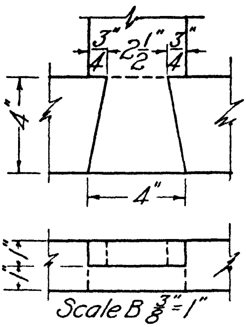


FIG. 12. Dovetail joint.

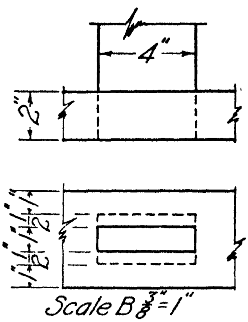


FIG. 13. Mortise and tenon.

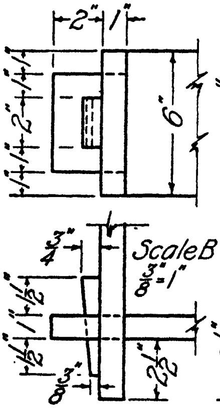


FIG. 14. Keyed mortise and tenon.

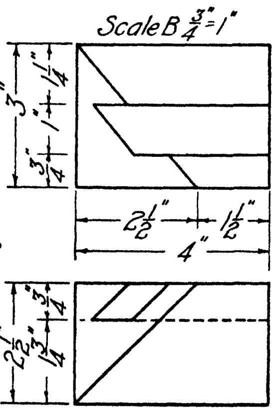


FIG. 15. Block.

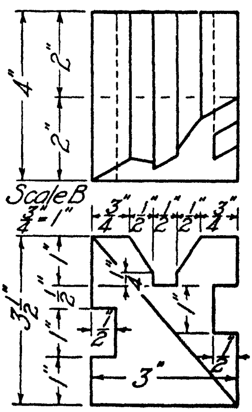


FIG. 16. Block.

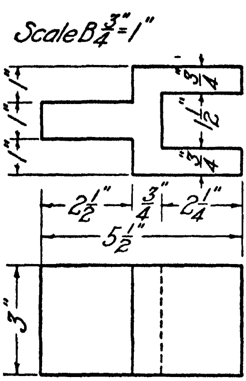


FIG. 17. Block.

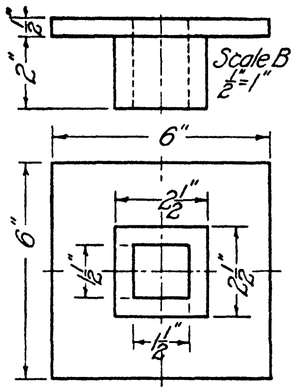


FIG. 18. Block.

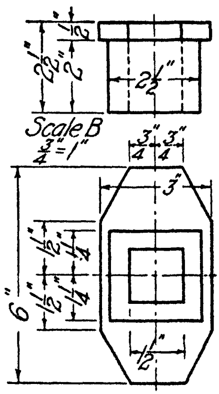


FIG. 19. Block.

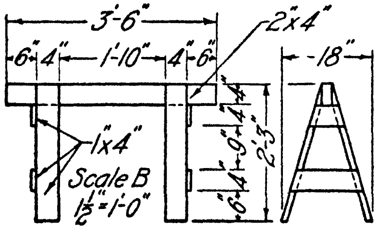


FIG. 20. Carpenters' horse.

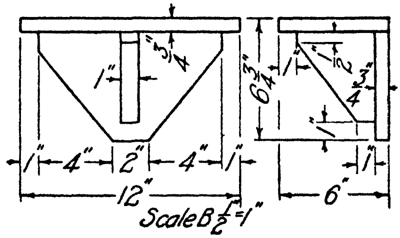


FIG. 21. Shelf.

UNIT XXIV

ISOMETRIC OF CURVED OBJECTS

CURVES IN ISOMETRIC PLANES

PURPOSE OF UNIT XXIV

It is the purpose of the unit to show how to represent objects which contain curved outlines which lie in isometric planes.

WHAT YOU SHOULD KNOW ABOUT DRAWING CURVED LINES IN ISOMETRIC

Methods of drawing curves. Many simple objects are composed of curved or circular parts. Circles may be drawn

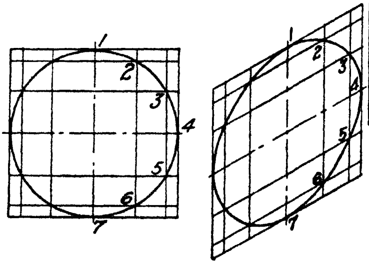


FIG. 1. Circle in isometric. Exact method.

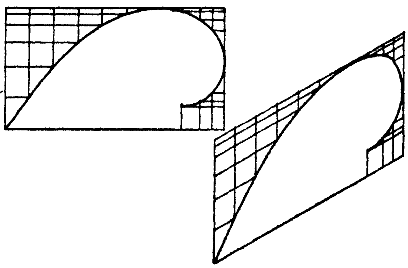


FIG. 2. Curve plotted in isometric.

in isometric in two ways, one of which is exact and the other only approximate. The exact method consists of plotting a series of points and then drawing the ellipse which represents the circle through the points with an irregular curve, as illustrated in Fig. 1. Curves other than circles can be drawn only by plotting points and then drawing the curve with the irregular curve as illustrated in Fig. 2.

Approximate method. The approximate method of drawing a circle in isometric consists of drawing a series of circular arcs which closely approximate the ellipse, as shown in Fig. 3. In Fig. 4 the error of the approximate method is shown by placing the exact and the approximate ellipses together. The dotted line represents the exact method, from which it may be noted that the approximate method gives an ellipse that is too broad and somewhat shorter than it ought to be. In most objects the errors of the approximate method are so small that it may be used without attracting attention.

HOW TO DRAW CURVES AND CIRCLES IN ISOMETRIC

To draw a circle by the exact method. First enclose the circle in a square. Divide the circle into twelve equal parts and draw rectangular co-ordinates through these twelve points, as shown in Fig. 1. Make an isometric drawing of the enclosing square. Draw the co-ordinates in the isometric square and plot the twelve points. Through the points thus found draw the ellipse with an irregular curve. The isometric square may be drawn in any of the three possible positions by using the same method.

To draw any curve by the exact method. Follow the same procedure as that used for the circle. First, enclose the curve in a rectangle, select a sufficient number of points to determine the curve and then draw the co-ordinates through them. Next draw the rectangle in its proper isometric position. Draw the co-ordinates in the isometric rectangle and plot the points as illustrated in Fig. 2. Draw the curve through the points. It is necessary to draw only one of the co-ordinate lines for each point and then step off on this line the other co-ordinate distance with a divider. If two parallel curves are to be drawn the second may be obtained from the first by stepping off the constant distance between them at each point along isometric lines, as shown in Fig. 6.

To draw a circle by the approximate method. Draw first the isometric square in the required position, which will be either horizontal, or vertical sloping to the right, or vertical sloping to the left. Draw the long diagonal of the isometric square. Erect perpendiculars at the mid-points of the sides.

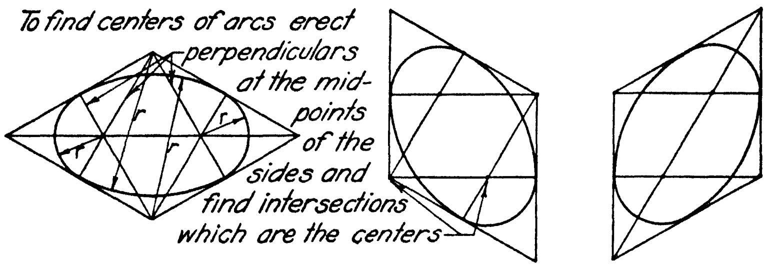


FIG. 3. Circles in isometric by the four-center approximate method.

These four perpendiculars intersect in pairs, and their intersections locate the centers of the four arcs which are tangent to the sides, as shown in Fig. 3. If the long diagonal is used, only two of the perpendiculars need be erected from the sides, as shown at the right in Fig. 3. The four perpendiculars at the mid-points of the sides may be used without the long diagonal. See middle diagram in Fig. 3.

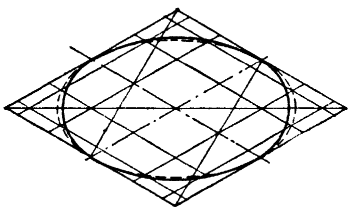


FIG. 4. Difference between exact and approximate methods.

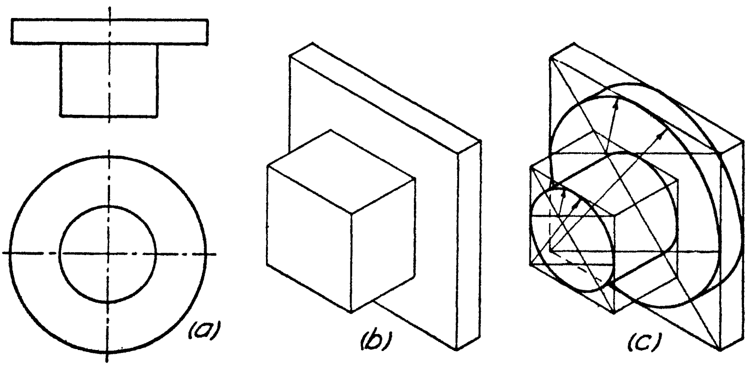


FIG. 5. Steps in making an isometric drawing of a cylindrical object.

To draw curved objects in isometric. To draw an object like that in Fig. 5a first lay out the enclosing rectangular blocks. See Fig. 5b. Then draw the circles in the proper planes by the methods described above and as shown in Fig. 5c. Connect the circles on opposite ends of a cylinder by isometric lines tangent to the circles as shown in Fig. 5c. Such tangent lines must always be drawn no matter how short or shallow the cylinder is, since they represent the outstanding elements.

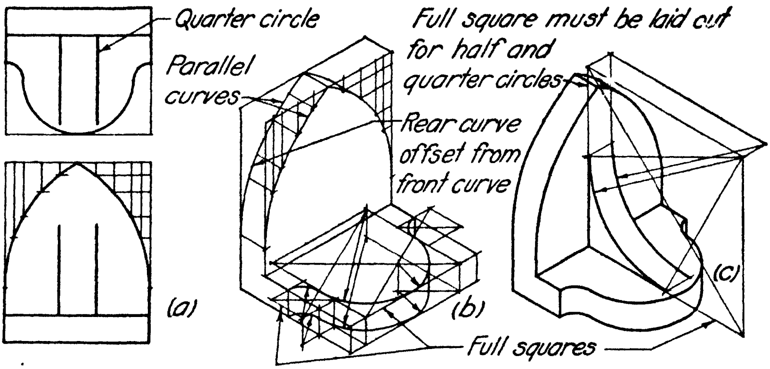


FIG. 6. Steps in construction of an isometric with curves in three planes.

The method for drawing an object in which curves occur in each of the three isometric faces is illustrated in Fig. 6.

QUESTIONS

1. Show by a sketch how to draw an isometric circle by the coordinate method.

2. Show by a sketch how to draw an isometric circle by the four-center approximate method.

3. How does the ellipse produced by the approximate method differ from the true ellipse?

4. Show by a sketch how to draw an isometric square in a horizontal position.

5. Show by a sketch how to draw an isometric square in a vertical position representing the left face of an object.

6. How is a curve other than a circle drawn in isometric?

7. How are two parallel curves drawn in isometric?

8. Along what lines only may measurements be made in isometric drawing?

9. How are the straight lines which bound cylindrical objects located in isometric drawings?

PROBLEMS

Lay out the standard border lines and title space and make an isometric drawing of an object assigned from the following group. Use the four-center method for complete circles and semicircles, and the co-ordinate method for long-radius arcs.

Proceed in the usual way by first laying out in isometric the enclosing rectangular figure and then making all construction from points on the enclosing figure. Leave all construction lines until the work is approved by your instructor.

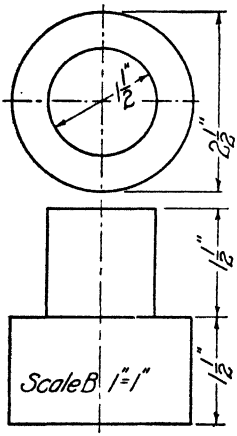


FIG. 7. Block.

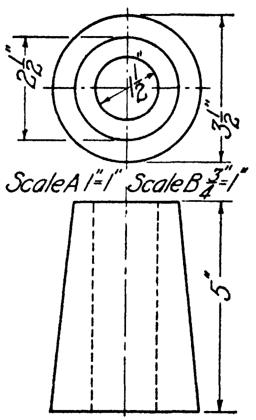


FIG. 8. Block.

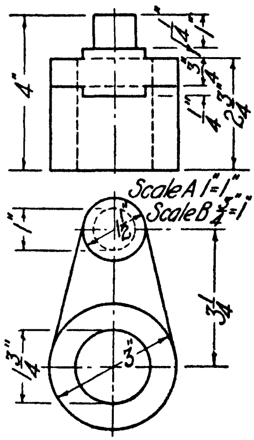


FIG. 9. Rocker arm.

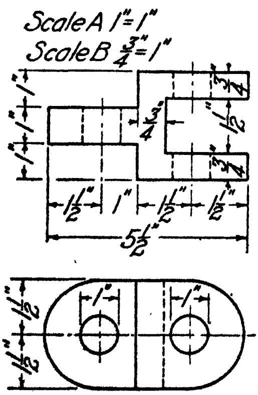


FIG. 10. Link.

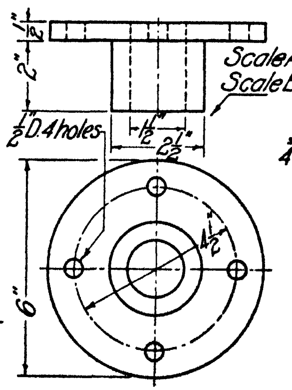


FIG. 11. Cylinder end.

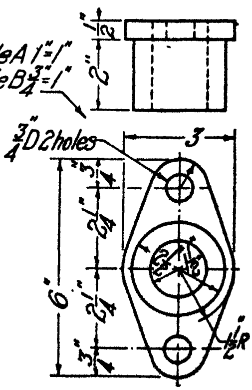


FIG. 12. End bearing.

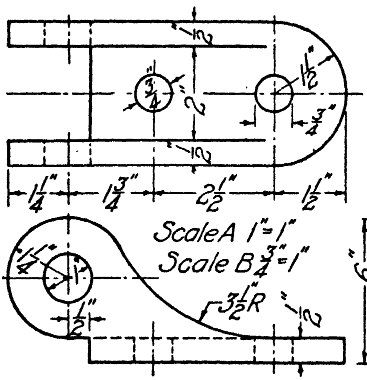


FIG. 13. Hinge.

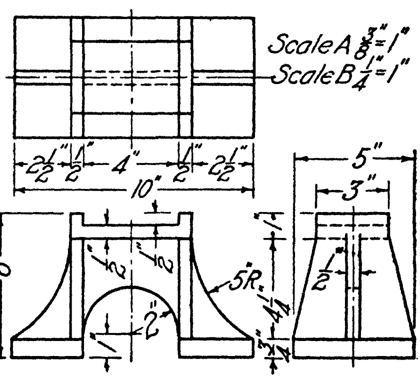


FIG. 14. Bearing floor stand.

UNIT XXV

ISOMETRIC OF CURVED OBJECTS

CURVES NOT IN ISOMETRIC PLANES

PURPOSE OF UNIT XXV

It is the purpose of this unit to show how to draw objects which are in part composed of curved lines that do not lie in isometric planes.

WHAT YOU SHOULD KNOW ABOUT DRAWING CURVES

Use of co-ordinates. Curves which do not lie in isometric planes must be plotted by using three co-ordinates, as shown for the helix in Fig. 1. These co-ordinates are always isometric lines. Two of the measurements may be made in one face of the enclosing block, as for example the distance AB vertically on the front edge of the block in Fig. 1, and then the distance BC horizontally in the right face. The third measurement CD is then made on an isometric line which represents a perpendicular to the face of the block in which the other two dimensions lie.

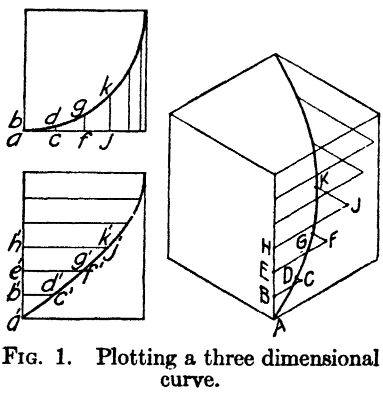


FIG. 1. Plotting a three dimensional curve.

Plane curves. If the curve is a plane curve, that is one lying wholly in a plane, then the three co-ordinates may be laid out as shown in Fig. 2. Study this figure carefully.

Here measurements across the right face are obtained by drawing the projections of the planes in which the curves lie. This is more convenient than taking the measurement from the orthographic views with dividers, although this may be done in the usual way.

Hidden lines. Invisible lines should not be drawn when the object is more or less symmetrical and the hidden parts can be assumed to be like those in front. If the concealed part differs from the parts shown and the drawing is not clear in meaning without them, then the hidden lines should

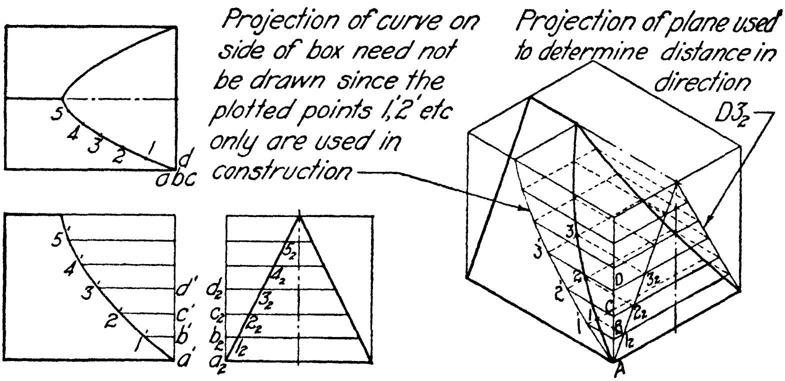


FIG. 2. Plotting a curve in a non-isometric plane.

be shown. As in all drawing, clearness of meaning is the criterion which determines the best practise.

HOW TO DRAW AN ISOMETRIC OF A CURVE NOT LYING IN AN ISOMETRIC PLANE

To draw the enclosing block. First, draw the orthographic view and then draw a rectangular block around the view that will enclose the object, as shown in Fig. 3a. The orthographic views must be to the same scale as that desired for the isometric drawing. Second, make an isometric of the block in the position desired and draw in the parts which are not curved, as shown in Fig. 3b.

To complete the drawing. In the orthographic views lay out the co-ordinates of the curve, as shown at *a*, *b*, *c*, *d*, *e*, etc., in Fig. 3a. With a divider lay off these co-ordinates as

AB, *BC*, *CD* and *CE* along isometric lines in the block as shown in Fig. 3c. Since the object is symmetrical use the same dimensions for laying out the curve on the other side, as shown in Fig. 3c. Leave all construction lines in the work

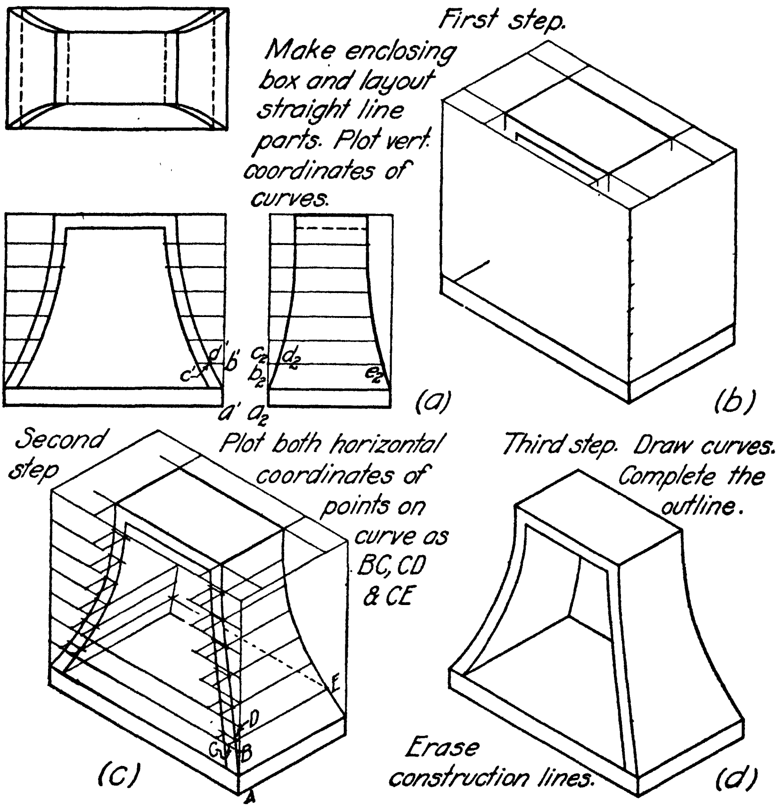


FIG. 3. Steps in constructing an isometric drawing with three dimensional curves.

until it has been checked. After the drawing is checked, erase construction lines and retouch the drawing to give it "life" and "snap." Make the outlines clear, sharp and bold. Study Fig. 3 very carefully.

QUESTIONS

1. Make an isometric sketch of a block and then sketch in the co-ordinates of a point 1 inch up from the bottom, 1½ inches back

from the left end and ¾ inch in from the right face. Indicate the dimensions on the co-ordinates.

2. How many co-ordinates are necessary in making isometric curves which do not lie in an isometric plane?

3. What are the steps to be taken in drawing an object which has curved lines which do not lie in an isometric plane?

4. Should hidden lines ordinarily be shown in isometric drawings? Why?

5. Why is it desirable to use the projections of a plane of a curved line on the faces of the enclosing block?

6. How may a curve which lies in a plane but not an isometric plane be drawn in isometric?

7. What kind of lines should be used to make an isometric drawing appear clear-cut and attractive?

PROBLEMS

Lay out the standard border line and title space. At one side of the sheet lay out the orthographic views of the object assigned, and at the other make the isometric drawing of the object. Draw first the enclosing block, and show clearly all construction lines used in plotting the curves.

In all cases choose the position of the object which will show it to best advantage.

The object of Fig. 11 will require the orthographic views to be made on a separate sheet.

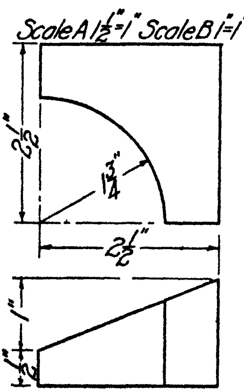


FIG. 4. Block.

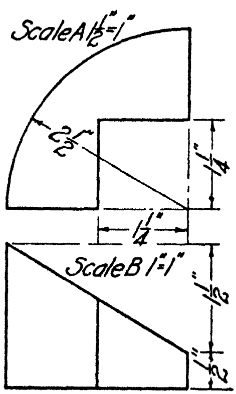


FIG. 5. Block.

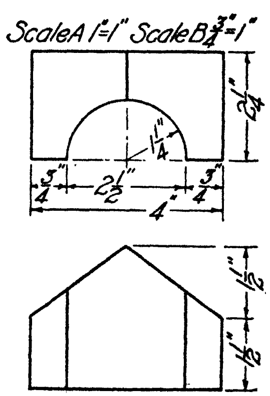


FIG. 6. Block.

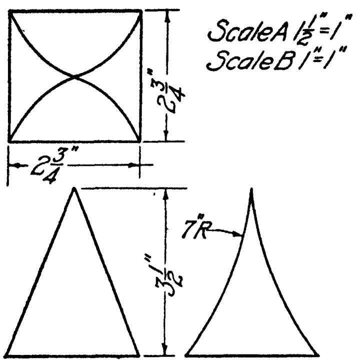


FIG. 7. Pyramid with two curved faces.

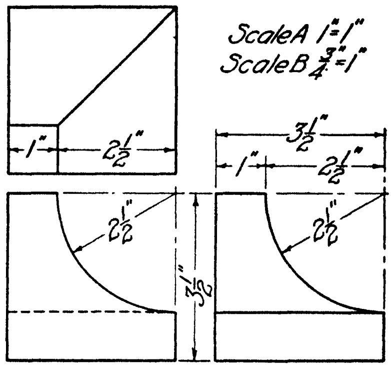


FIG. 8. Block.

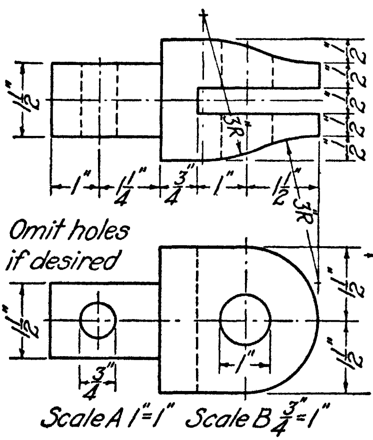
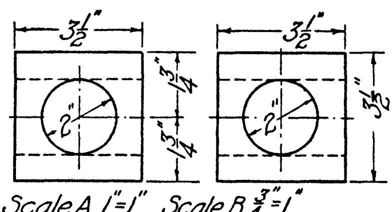


FIG. 9. Link.



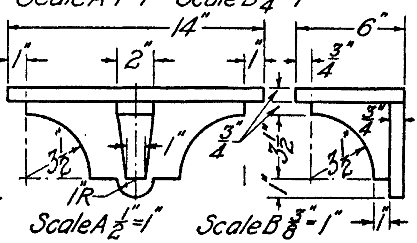


FIG. 10. Drilled cube.
FIG. 11. Shelf.

UNIT XXVI

SECTIONAL VIEWS AND DIMENSIONING IN ISOMETRIC DRAWING

PURPOSE OF UNIT XXVI

It is the purpose of this unit to show how to make sectional views in isometric and how to dimension isometric drawings.

WHAT YOU SHOULD KNOW ABOUT SECTIONAL VIEWS AND DIMENSIONING

Kinds of sectional views. The same kinds of sectional views as are used in two- and three-view orthographic pro-

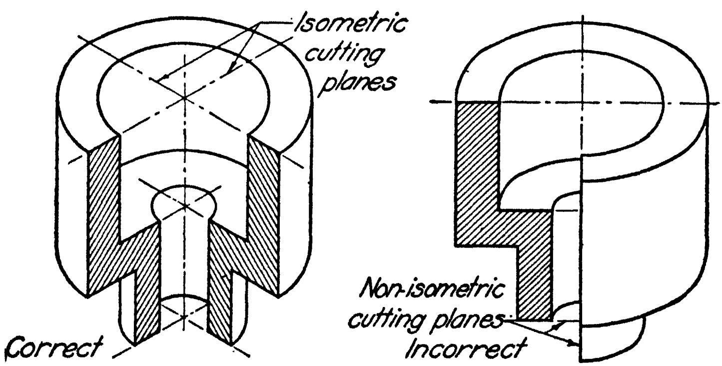


FIG. 1. Correct and incorrect methods of passing section planes.

jection may also be used in isometric drawing. Thus there may be full sections, half sections, broken sections, etc. The half and the broken sections are the most commonly used. When half and full sections are made, the cutting planes should be isometric planes, as shown in Fig. 1.

Cross-hatching. The cross-hatching should, in general, follow the same principles as in two- and three-view drawing. However, in the case of the half section the same parts on opposite sides of the center line of the section should be cross-hatched in such a way that the lines would coincide if revolved together, as shown in Fig. 2. The cross-hatching

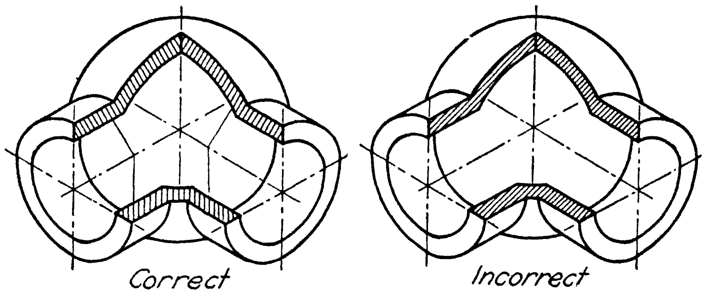


FIG. 2. Correct and incorrect cross-hatching.

lines if extended would meet on the center line at approximately the same angle. Different parts should be distinguished by a change in slope of the cross-hatching.

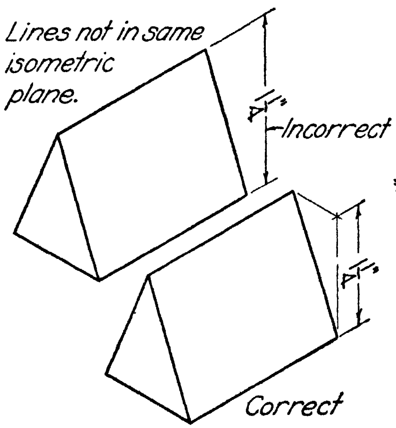


FIG. 3. Correct and incorrect dimensioning.

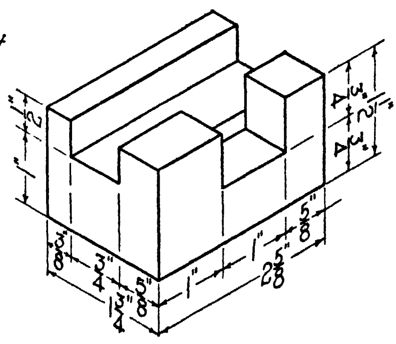


FIG. 4. Dimensioned isometric drawing.

Dimensioning. The rules for dimensioning working drawings apply, in general, to isometric drawing and should be reviewed at this time. In addition, the following rules should be observed.

1. All dimension and witness lines must be isometric lines.

2. The witness and the dimension lines must lie in the same isometric plane. This point is illustrated in Fig. 3, which shows a common error on the left and the correct method on the right.

3. So far as possible, all dimensions should read from one point of view, as illustrated in Fig. 4.

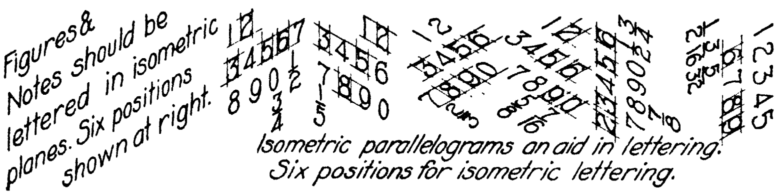


FIG. 5. Lettering in isometric.

4. All numerals must be made to lie in isometric planes. To this end only vertical lettering should be attempted. Correct numerals are illustrated in Fig. 5.

HOW TO MAKE SECTIONAL VIEWS AND HOW TO DIMENSION DRAWINGS

To make sectional views. Lay out first the enclosing block as in Fig. 6a. Then draw the center lines across the top and in the faces of the block which mark out the cutting planes, as illustrated in Fig. 6b. With these lines as a basis proceed to draw in the portions of the object which have been cut by the planes, as shown in Fig. 6c. Then complete the remaining three-fourths, or one-half, of the object, as the case may be, as shown in Fig. 6d.

In some instances it may be best to draw the whole object and next draw upon it the center lines representing the cutting planes and then erase the remainder. The objection to this method is the fact that unnecessary drawing is done, and also, in erasing, some parts will be removed which will have to be replaced.

To dimension drawings. After the object has been completed in isometric, draw the witness lines and dimension lines according to the rules given above. Check carefully to see that all necessary dimensions are given. Keep them off the object itself as far as possible. This cannot always be done as easily as in two- and three-view drawing and frequently requires much scheming to accomplish the best results. See Fig. 4 for a dimensioned drawing.

Until skill in isometric lettering is acquired, to make numerals and letters lie in isometric planes sketch for each

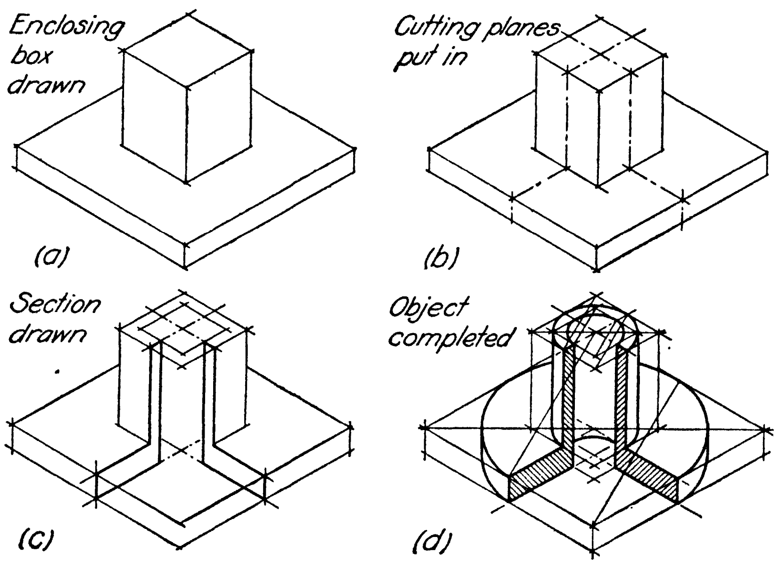


Fig. 6. Steps in making a sectioned isometric drawing.

number or letter a small enclosing isometric parallelogram, as shown for a few of the numerals in Fig. 5. Horizontal and vertical strokes of letters or numerals must always be isometric lines.

Make the numerator and denominator of a fraction lie on the same vertical center line.

QUESTIONS

1. How should the cross-hatching be drawn on the two sides of a half section when the part is all one piece?
2. What are the rules governing dimensioning in isometric?

3. Explain and illustrate how to make figures appear to lie in isometric planes.

4. Make in isometric the figures from 1 to 9.

5. Make a sketch of a rectangular block and give its three dimensions showing the best arrangement of position of the figures.

6. What must be the position of cutting planes used in making a sectional view, i.e., to what planes are they parallel?

7. How must fractions be made in isometric?

8. How do you proceed to draw sectionalized isometric drawing?

9. What method other than the one you gave to answer Question 8 can be used?

PROBLEMS

Lay out the standard border line and title space, then make a dimensioned isometric drawing of an object assigned from the following group. In each case a sectional view is to be shown. Since there are no curves to be plotted the orthographic views need not be drawn.

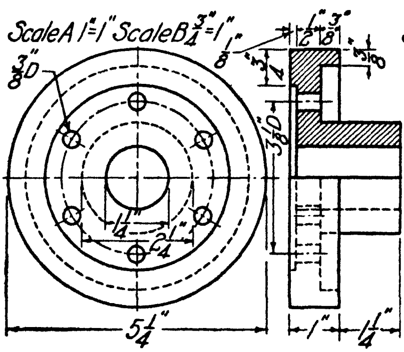


FIG. 7. Flanged coupler.

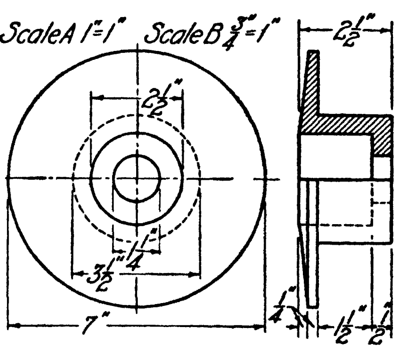


FIG. 8. Shield for bolt head.

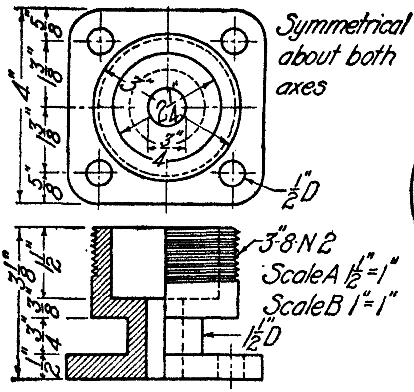


FIG. 9. Flexible coupler body.

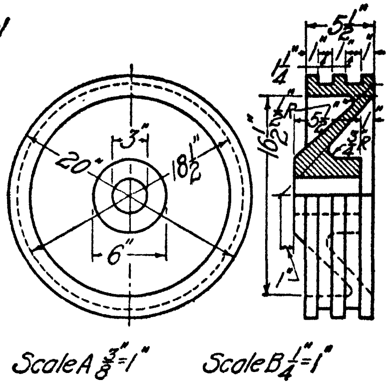


FIG. 10. Piston.

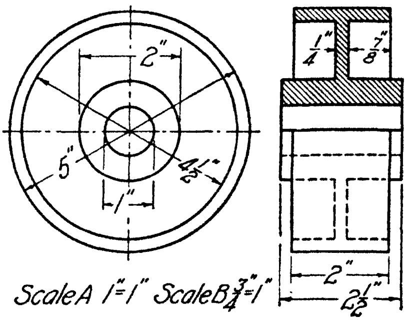


FIG. 11. Pulley.

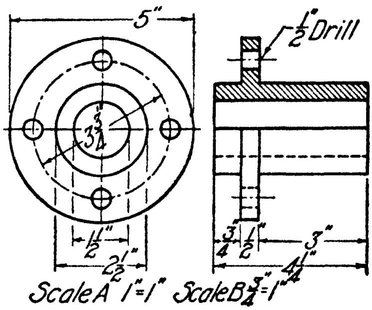


FIG. 12. Bearing.

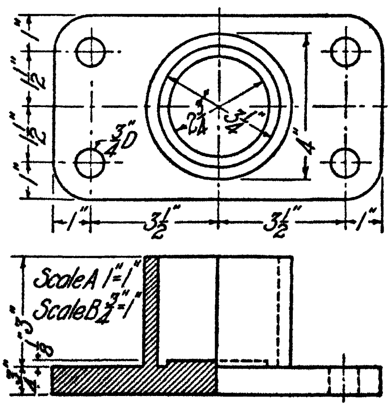


FIG. 13. Base of step bearing.

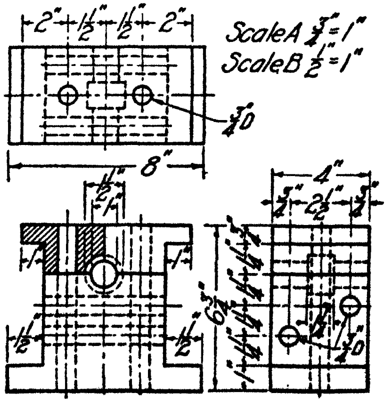


FIG. 14. Bearing take-up end support.

UNIT XXVII

DIMETRIC DRAWINGS

PURPOSE OF UNIT XXVII

It is the purpose of this unit to teach the underlying principles of dimetric projection and how to make dimetric drawings of objects.

WHAT YOU SHOULD KNOW ABOUT DIMETRIC DRAWINGS

Dimetric angles. In isometric drawing the three edges of the enclosing cube or block make equal angles with the

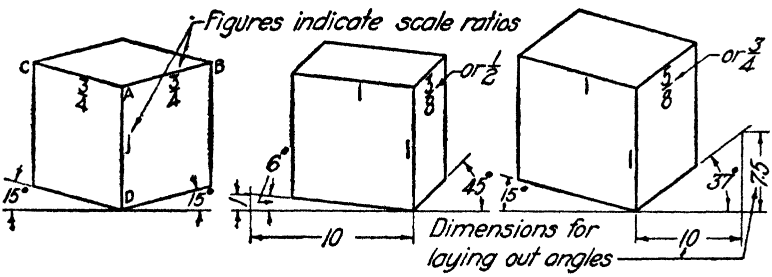


FIG. 1. Three positions of axes in dimetric projection.

plane of projection and are consequently projected in equal measure. In dimetric projection two edges of the cube or block are at the same angle with the plane of projection while the third is at a different angle. For example, in Fig. 1 edges *AB* and *AC* are at the same angle with the vertical plane while *AD* is at a different angle. As a result the same scale may be used on the two edges which make the same angle with the projection plane but a different scale must be used on the third.

Dimetric axes. The three positions of the axes shown in Fig. 1 have been found fairly accurate, pleasing and comparatively easy to draw. The angles shown can be accurately laid out on very thin board with the dimensions given, and wooden or celluloid triangles constructed which will be a great convenience in drawing. Dimetric drawings require more time for their construction than isometrics, but they present a much more pleasing appearance and are, therefore, more desirable than isometrics.

Dimetric drawings. The general process of construction consists of locating points on the object by means of three co-ordinates parallel to the three edges of the enclosing block in the same way as for isometric drawing. The only difference is in the different slopes of the axes and the use of two scales instead of one.

HOW TO CONSTRUCT A DIMETRIC SCALE AND MAKE DIMETRIC DRAWINGS

To construct a scale. The ordinary boxwood scale does not contain odd scales such as $\frac{5}{8}'' = 1''$ and $\frac{7}{8}'' = 1''$. A

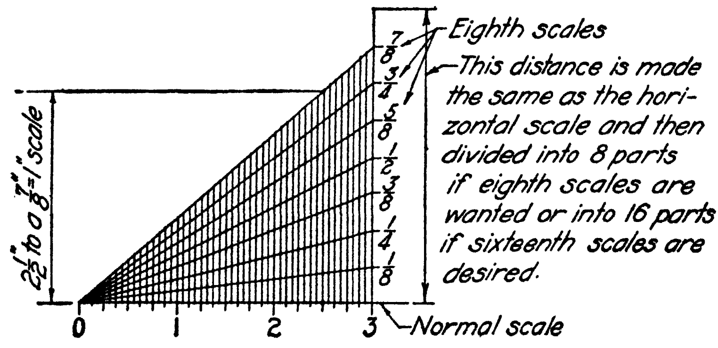


FIG. 2. Scale chart.

complete set of such scales may be constructed quite readily as illustrated in Fig. 2. Lay off a horizontal scale of 3 inches, 6 inches, 8 inches or other convenient length and mark off the sixteenth-inch divisions as illustrated. At the end of the line erect a perpendicular of the same length as the base scale. Divide this perpendicular into eighths and draw lines to the beginning of the horizontal scale. These sloping lines will give scales of $\frac{1}{8}$, $\frac{1}{4}$, $\frac{3}{8}$ inch, etc. That is, the vertical distance from the horizontal scale to one of the sloping lines, say the fifth from the bottom, will give this distance to a $\frac{5}{8}'' = 1''$ scale. To make scales varying by one-sixteenth divide the upright line into sixteenths instead of eighths. Hence, to convert any distance on a full-size orthographic drawing to a different scale set the divider to that distance on the drawing, then step off this distance from the zero point of the horizontal scale and pivot the divider so that the end which was formerly on 0 of the horizontal scale will be vertically above the pivot point and touch the slant line which represents the desired scale. For example, if the distance is to be changed to $\frac{7}{8}$ scale, the point of the divider resting on 0 will be pivoted to a position vertically over the other point and extended to touch the slant line which runs from 0 to $\frac{7}{8}$ on the dimetric scale as shown in Fig. 2.

HOW TO MAKE A DIMETRIC DRAWING

To make dimetric drawings. Construct first the necessary orthographic views to the same scale as the largest one to be used in the dimetric drawing. Enclose it in a rectangular block which will just contain it. Construct the dimetric drawing of the block in the desired position. Within it plot the defining points of the object. One set of dimensions may be set off with a divider directly from the orthographic views; the others must first be reduced to the proper scale as described above.

Lay off all measurements parallel to the three axes and exercise great care to see that the proper one is used. Circles cannot be drawn by the approximate method as in isometric drawings but must be plotted in all faces which have two scales. In a face which has the same scale on both sides the four-center method used in isometrics may be used. For the method of locating these centers see Fig. 3. In all other respects proceed in the same general manner as in isometric drawing.

When drawing section planes make them parallel to the faces of the enclosing dimetric block. Draw all dimension lines parallel to the dimetric axes, and make all figures lie in the dimetric planes.

Choice of position of object. When an object has circles in one face and not in others, as is often the case, make this

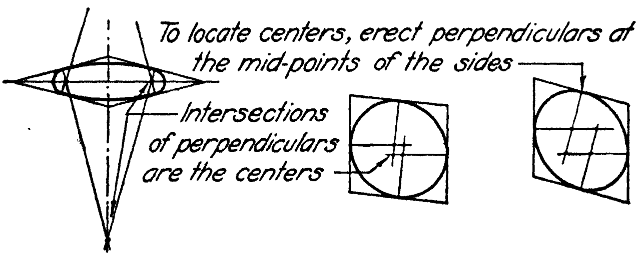


FIG. 3. Four-center method of drawing circles in dimetric drawing.

face with the same scale on both edges, then draw the circle by the four-center method. This will save considerable time.

QUESTIONS

1. How does a dimetric drawing differ from an isometric drawing?
2. What is the advantage of a dimetric drawing over an isometric?
3. Explain how you would construct a series of odd scales such as $\frac{5}{8}'' = 1''$ etc.
4. If an object has circles in one face only, in what position would it be most advantageous to draw the object?
5. How are the centers of a circle to be drawn by the four-center approximate method located?
6. When a sectional view is to be made, what should be the position of the cutting planes?
7. In what planes must dimensions and dimension lines lie?
8. How must section planes be located in dimetric drawing?

PROBLEMS

Lay out the standard border line and title space. Then make a dimetric drawing of the object assigned from the following group. The scales specified with each figure are for the larger equal axes. The shorter scale for the third axis must be computed according to one of the arrangements of Fig. 1. Thus, if the scale specified is $\frac{3}{4}'' = 1''$ and the second position in Fig. 1 is chosen, then the scale on the shorter axis would be $\frac{3}{8}$ of $\frac{3}{4}$ which is $\frac{9}{32}$. Hence use either $\frac{9}{32}'' = 1''$ or $\frac{5}{16}'' = 1''$. (The next larger sixteenth scale should be used in place of the scales which come out as thirty-seconds.) Leave all pencil construction lines until the drawing is checked by your instructor.

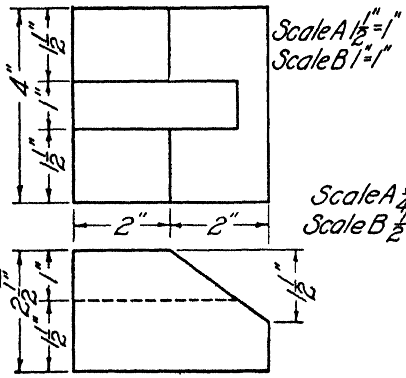


FIG. 4. Block.

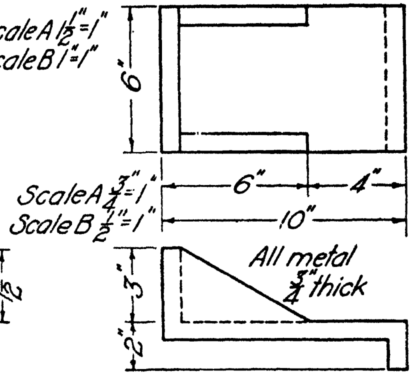


FIG. 5. Truss end block.

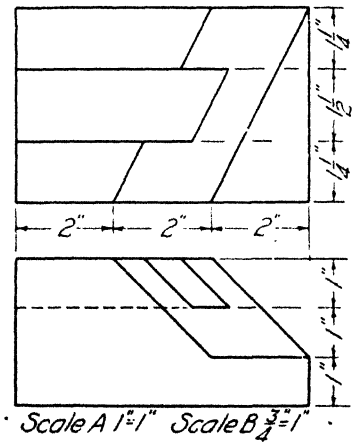


FIG. 6. Block.

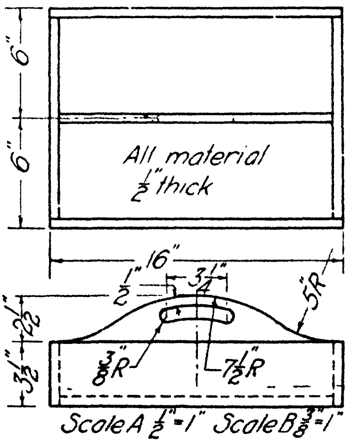


FIG. 7. Knife box.

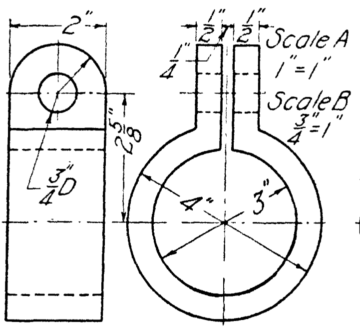


FIG. 8. Collar clamp.

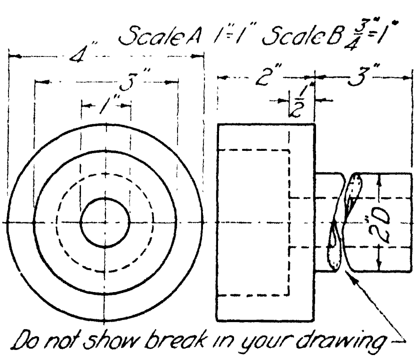


FIG. 9. Chuck blank.

UNIT XXVIII

OBLIQUE PROJECTION. STRAIGHT-LINE OBJECTS

PURPOSE OF UNIT XXVIII

It is the purpose of this unit to teach the underlying principles of oblique projection and the rules for drawing oblique projections which may be derived therefrom; to teach what cavalier projections are, and how to make them.

WHAT YOU SHOULD KNOW ABOUT OBLIQUE PROJECTION

Oblique projection. Oblique projection differs from all other types of drawing in one fundamental principle only. In all drawing presented heretofore in this book, including isometric, the projecting lines have been perpendicular to the plane of projection, and the drawings were therefore called orthographic projections. As the name implies, the drawings of this chapter are to be made with the projecting lines oblique to the plane of projection. The angle which the projecting line makes with the plane of projection may have any value except 90 degrees. Forty-five degrees is the one most commonly used.

Cavalier projection. When the projecting lines make 45 degrees with the plane of projection the oblique drawing has certain properties which oblique drawings made with other angles do not have. It is given the name cavalier projection. Figure 1 shows a cavalier projection constructed from orthographic views.

At the left in Fig. 1 three orthographic views are shown with the projecting lines making 90 degrees with the planes of projection. At the right the same views are shown with the projecting lines making 45 degrees with the vertical plane on which the oblique projection is constructed. The

45-degree angle, however, does not show in its true size in any one of the views. Its true value is found by revolving one of the projecting lines like AB about the orthographic projecting line AC of the end A until it is parallel to the profile plane as shown in Fig. 1 at a_2 b_{2r}.

Certain facts will now be observed to be true, namely:

1. Lines which are parallel to the plane of projection show in their true length.

2. In cavalier projection, lines which are perpendicular to the plane of projection also show in true length because

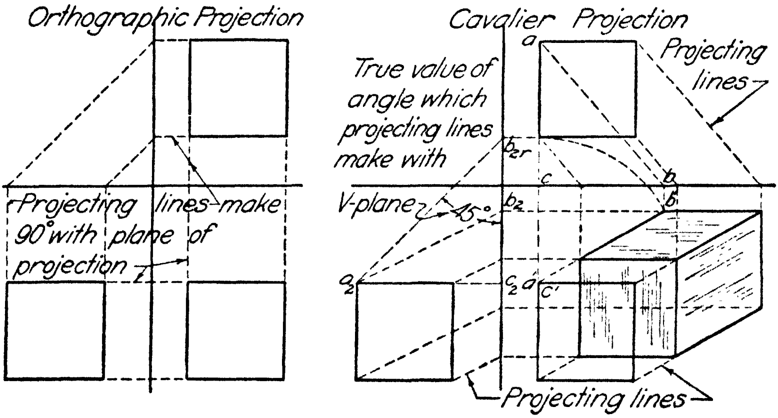


FIG. 1. Oblique projection from orthographic views.

they are projected at 45 degrees and the two sides of a 45-degree triangle are equal. See Fig. 2.

3. The projection of a perpendicular line may have any desired position relative to the horizontal. See Fig. 2.

From statement 1 above, it will be observed that the front face of a cube (see Fig. 1) or other object will show in its true shape exactly as in an orthographic projection.

From statement 2 we see that the receding edge of the cube or other object must be drawn to the same scale as the other two edges since all of them project in true length.

From statement 3 we note that the receding axis may have any number of positions relative to the horizontal. Figure 3 illustrates a few of the more convenient ones. It is again pointed out that the fact that the projecting line makes 45 degrees with the plane of projection does not necessitate the receding axis being 45 degrees to the horizontal. Figure 2 should be studied carefully until the difference between a projection and a projecting line is clear. At

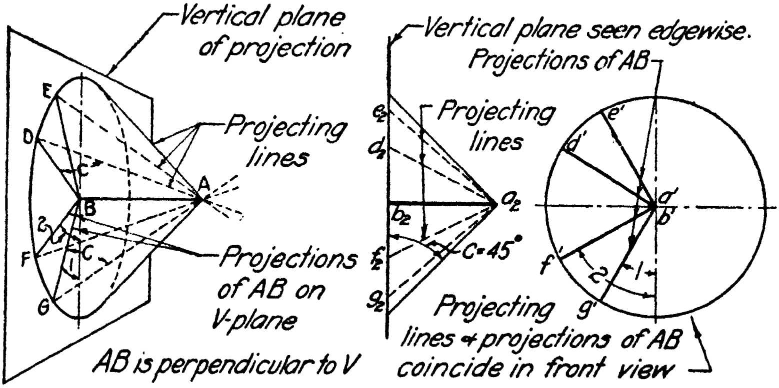


Fig. 2. Cavalier projection of a line.

the left in Fig. 2 is a pictorial drawing and at the right the orthographic views of the same situation.

With these facts before us we are now prepared to make cavalier projections by a much shorter method than the construction shown in Fig. 1 from which our rules are derived.

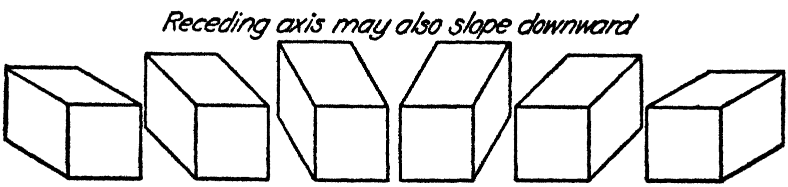


Fig. 3. Position of axes in oblique projection.

Eliminating distortion. Cavalier projections, it will be noted, have a somewhat distorted appearance. This becomes quite pronounced if an object which is longer in one dimension than the other two has this long dimension placed on the receding axis. To avoid this as far as possible, objects which are of this character should have the longest dimension in the front face rather than on the receding axis.

HOW TO MAKE A CAVALIER PROJECTION

To make a cavalier projection. Draw first the orthographic view of the object and then enclose it in a rectangular block. Draw the cavalier projection of the block in the position desired and then proceed to lay out the object within the block by measurements, using the same scale on all three axes, as illustrated in Fig. 4. Begin by laying out

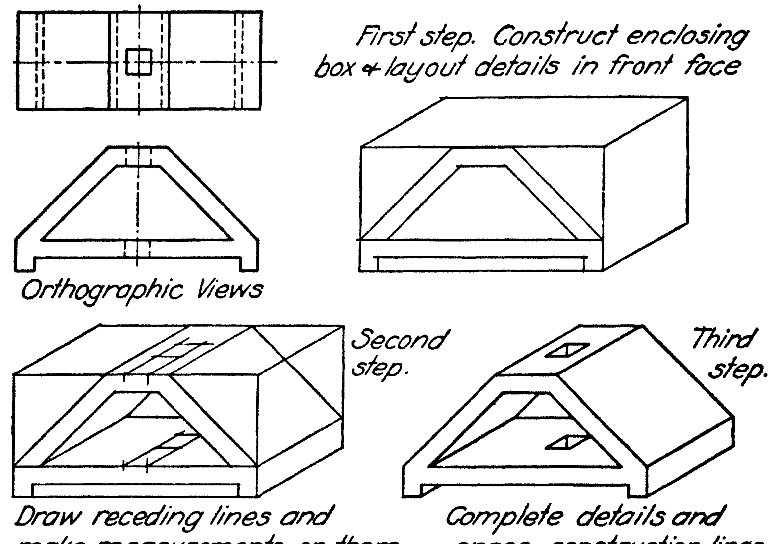


FIG. 4. Construction of an oblique projection.

the details of the front face just as you would in the orthographic front view. Then draw the receding lines and lay out the details behind the front face by measurement along these lines. The scheme for plotting points and constructing the view is exactly the same as in isometric, except for the different position of the three axes.

In the front face, or in any face parallel thereto, measurements may be made in any direction. Angles may also be laid out in their true value in this face.

QUESTIONS

1. How does oblique projection differ in principle (not appearance) from the other kind of drawing you have studied?
2. What distinguishes cavalier projections from other oblique projections as regards the position of the theoretical projecting line?
3. How does an oblique projection differ from an isometric projection in appearance? Illustrate with a sketch.
4. What angle do the projecting lines make with the plane of projection in cavalier projection?
5. At what particular angle with the horizontal, if any, must the receding axis of a cavalier projection be drawn?
6. What distinguishes cavalier projection from other oblique projections as regards the scales used?
7. When one dimension of an object is longer than the other two, which of the three dimensions should be placed on the receding axis?

PROBLEMS

Lay out the standard border line and title space, and then make a cavalier projection of the object assigned from the group below. Draw the enclosing block in the position indicated with each figure. For example, "30° *R*" following the scale means that the receding axis shall be drawn 30 degrees up from the horizontal to the right.

Reproduce first the orthographic views and then from them construct the cavalier projection.

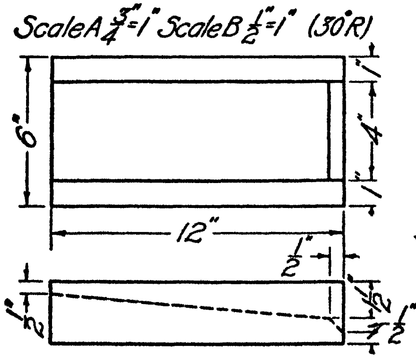


FIG. 5. Bearing wedge.

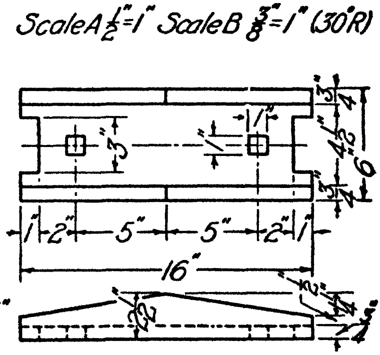


FIG. 6. Anchor block.

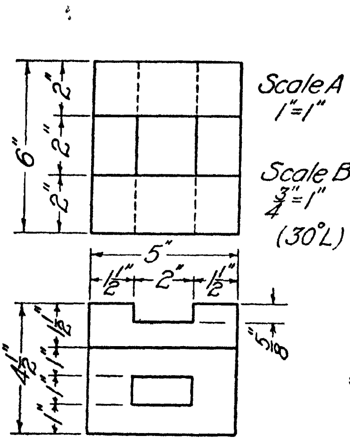


FIG. 7. Block.

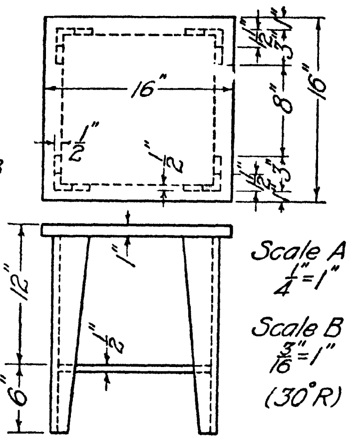


FIG. 8. Taboret.

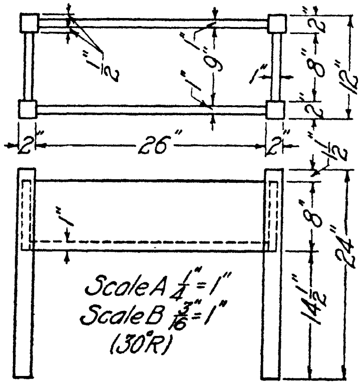


FIG. 9. Fern box.

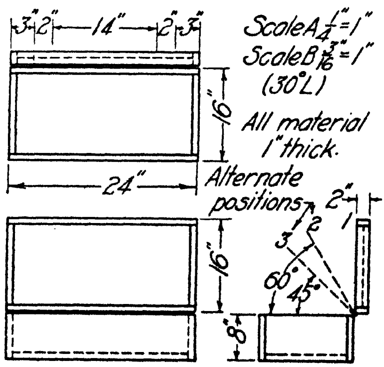


FIG. 10. Box.

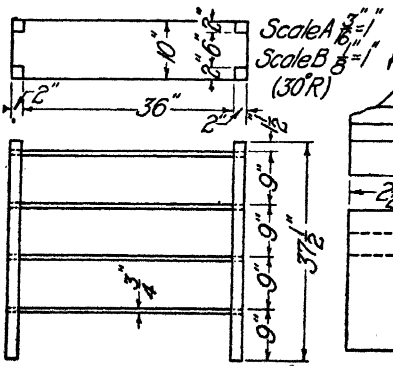


FIG. 11. Book rack.

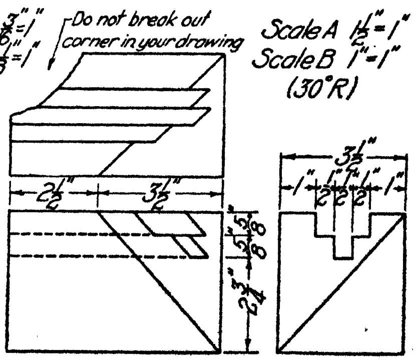


FIG. 12. Beveled block.

UNIT XXIX

OBLIQUE PROJECTION. CURVED OBJECTS

PURPOSE OF UNIT XXIX

It is the purpose of this unit to show the advantages of oblique projection and how to draw oblique projections of curved objects.

WHAT YOU SHOULD KNOW ABOUT OBLIQUE PROJECTIONS

Advantages of oblique projection. Oblique projection possesses several distinct advantages over isometric draw-

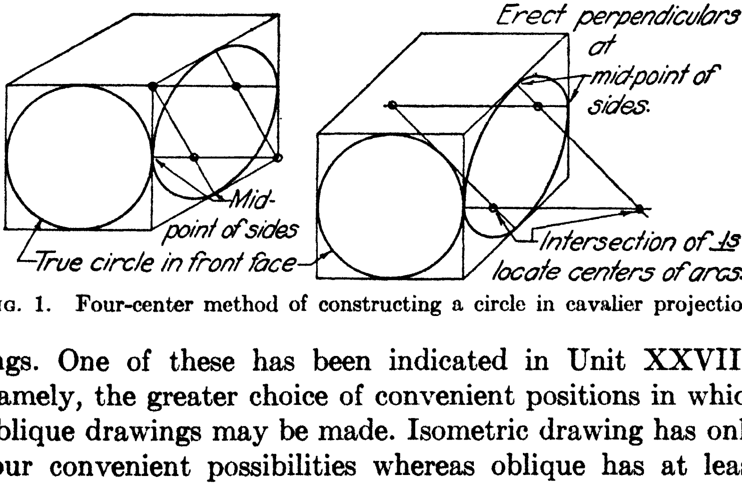


FIG. 1. Four-center method of constructing a circle in cavalier projection.

ings. One of these has been indicated in Unit XXVIII, namely, the greater choice of convenient positions in which oblique drawings may be made. Isometric drawing has only four convenient possibilities whereas oblique has at least twelve.

In addition to this, oblique projection possesses the advantage of having the front face similar to a true orthographic projection. For objects having circular holes or circular faces on one side this is a distinct advantage since the circles can be drawn as true circles if this face of the object is made the front face. If there are circles in other faces also, then the one having the most circles should be made the front while the others are placed in the side and top and may there be drawn by the four-center method. The method of finding centers for the approximate method is illustrated in Fig. 1.

Curves in oblique drawing. Curves other than circles or arcs of circles may be drawn in any face by the method of plotting two co-ordinates. Arcs of circles may be conveniently drawn in the front face just as they would be in orthographic projection. Circles and arcs in planes parallel to the front

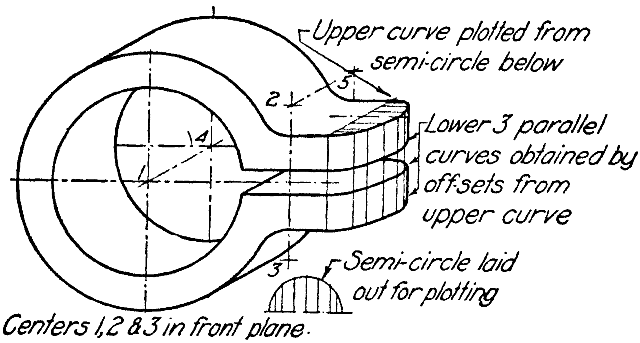


FIG. 2. Curves in oblique projection.

face may also be drawn as true circles and arcs by simply locating the center in the proper plane. This is illustrated in Fig. 2.

HOW TO DRAW AN OBLIQUE PROJECTION

To use center lines. Instead of drawing an enclosing block for simple objects to be reproduced in oblique projection it is sometimes more convenient to draw the principal center lines, when there are such lines, as illustrated in Fig. 3. Draw first the center lines for the circles in the front face and then through their intersections draw the receding center line at the desired slope, as shown in Fig. 3b. Measure off the depth of the object along this receding center line, or axis, and thus establish also the center of the rear face. Then extend the center lines horizontally to the small end, and by measurement establish the center of the front circle. Draw next the receding center line at the small end and lay off the centers, as shown in Fig. 3c.

Now draw the circles of the front face and then the circles of the rear face, and finally the tangent lines, connecting them as shown in Fig. 3d.

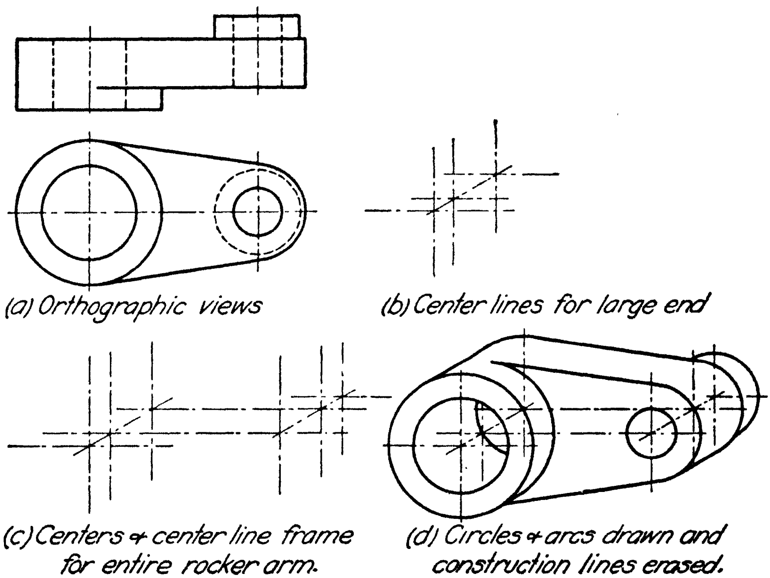


FIG. 3. Centerline method of construction.

To draw small circles in receding faces. When circular holes are to be drawn in the receding faces of the object and these holes are too small to be drawn by the four-center method they may be made freehand by drawing first the enclosing parallelogram (see side faces in Fig. 1) and also the center lines of the parallelogram in both directions and then drawing the ellipse which represents the circle, freehand.

QUESTIONS

1. Name two advantages of oblique projection over isometric drawing.
2. Show by a sketch how circles may be drawn in the top or receding side of a cavalier projection by the four-center method.

3. What other scheme besides that of the enclosing block may be used to lay out the skeleton structure of oblique drawings?

4. How may a curve which is not an arc of a circle be laid out? Illustrate.

5. Explain how to locate the centers for circles which are not in the front face but parallel to it.

6. When an object has circles in one or more parallel faces but not in the others, which face should be made the front face in oblique projection? Why?

7. By what method can curves which are not circular be drawn in the receding faces of an object?

PROBLEMS

Lay out the standard border line and title space, and then make a cavalier projection of the object assigned from the following group.

Draw the orthographic views first at one side; then construct the oblique projection to the scale given and with the axes as indicated following the scale.

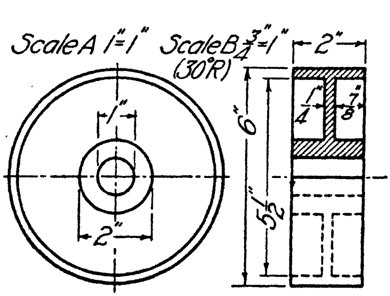


Fig. 4. Pulley.

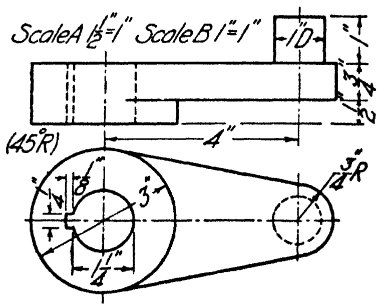


Fig. 5. Crank.

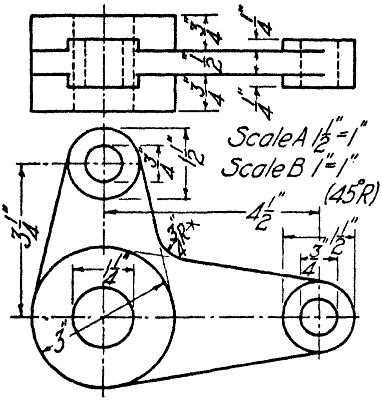


FIG. 6. Rocker arm.

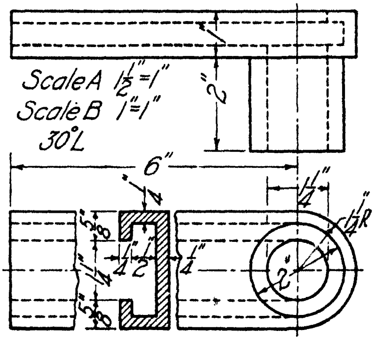


FIG. 7. Tool rest.

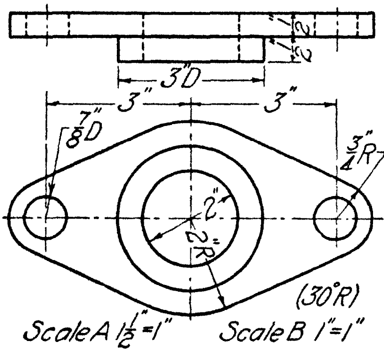


FIG. 8. Coupler.

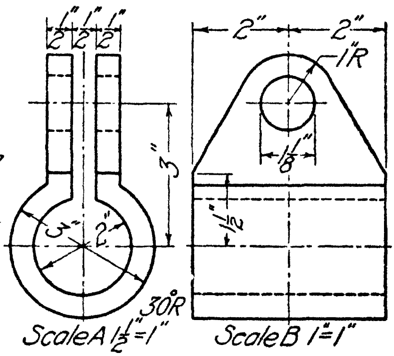


FIG. 9. Clamp.

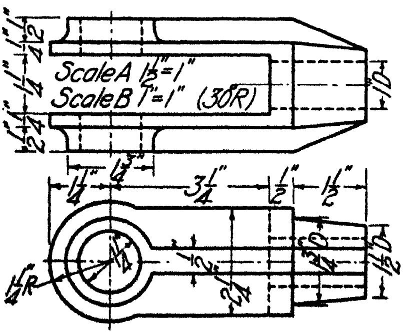


FIG. 10. Clevis.

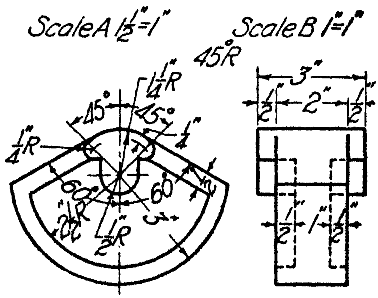


FIG. 11. Rocker.

UNIT XXX

OBLIQUE PROJECTION. THREE-DIMENSIONAL CURVES. SCREW THREADS. SECTIONAL VIEWS

PURPOSE OF UNIT XXX

It is the purpose of this unit to show how to plot curves which do not lie parallel to any of the oblique planes; also how to represent sectional views and screw threads in oblique.

WHAT YOU SHOULD KNOW ABOUT SECTIONAL VIEWS, SCREW THREADS, AND PLOTTING CURVES

Plotting curves. Curves which do not lie in or parallel to one of the three principal oblique planes must be plotted

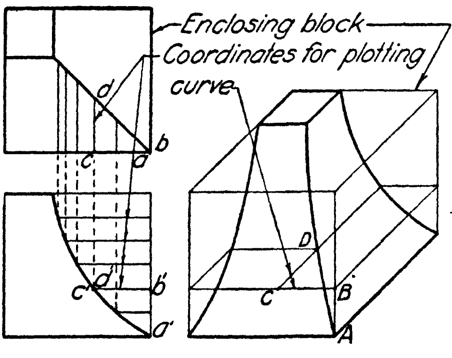


FIG. 1. Three dimensional curves in oblique projection.

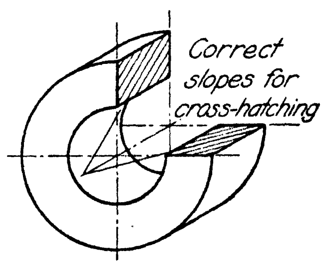


FIG. 2. Cross-hatching a sectional view.

by means of three co-ordinates. The procedure is exactly the same as in isometric except that the three axes along which measurements are made are not 120 degrees apart. One corner of the enclosing block is assumed as the origin. From this, one must measure up and then across the front face and then perpendicular to the front face, that is, parallel to the receding axis. Figure 1 illustrates the method for point *D* on the object shown. The dimensions *ab*, *bc* and *cd* are obtained from the orthographic views by means of dividers and stepped off as *AB*, *BC* and *CD* in the oblique drawing.

Sectional views. The cutting planes for sectional views should be taken parallel to the principal oblique planes, when showing a half or full section. For broken or partial sections they may be taken in other convenient positions. The cross-hatching should be in such directions, on opposite sides of a half section, that they will appear to coincide if folded together, as shown in Fig. 2.

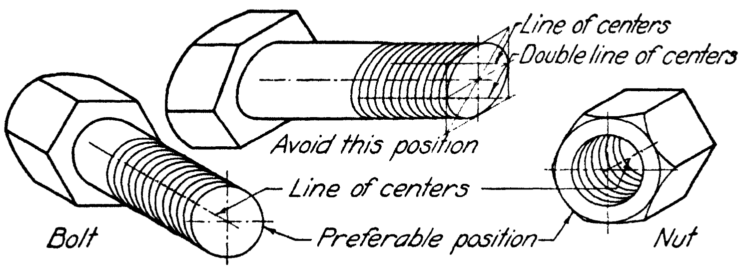


FIG. 3. Screw threads in oblique projection.

Screw threads. Unless it is entirely impossible to do so, screw threads should always be shown with the axis of the screw parallel to the receding oblique axis, as illustrated in Fig. 3, since this makes it possible to represent the threads by circular arcs. For screws parallel to any other axis the four-center, approximate method must be used. This is much more cumbersome and should be avoided if possible.

HOW TO DRAW THREE-DIMENSIONAL CURVES, SECTIONAL VIEWS AND SCREW THREADS

To draw three-dimensional curves. Draw first the orthographic views and enclose them in a rectangular block. Draw the necessary co-ordinates in these views to plot the curves as illustrated in Fig. 1. When one view of the object is a circle in the orthographic views the construction may be carried out as in Fig. 4. Draw first the enclosing cylinder and mark off the co-ordinates of the curve as in Fig. 4a. Then draw the center lines of the front and rear faces and the axis as in Fig. 4b. Draw also the radial lines which thus establish two co-ordinates of the points on the curve. From the intersections of the circle and radial lines in the front face draw lines parallel to the receding axis and lay off the

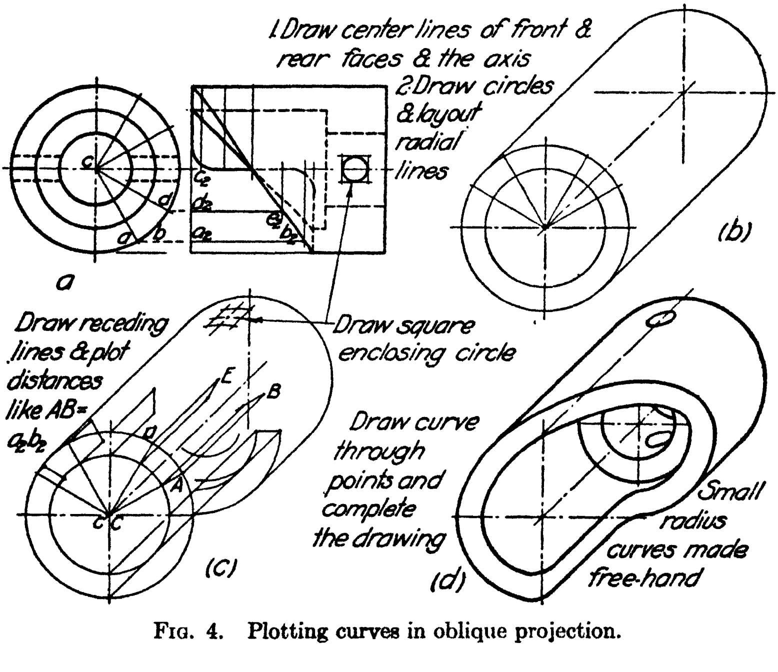


FIG. 4. Plotting curves in oblique projection.

third co-ordinate of the points, as in Fig. 4c. When the points have all been plotted draw a smooth curve through them and complete the remaining parts in the usual manner. Circles which are too small to be drawn with an irregular curve are made freehand by first drawing the enclosing square and its center lines as a guide, as in Fig. 4a, 4c and 4d.

To draw sectional views. For objects requiring sectional views the best procedure will be to draw first the enclosing block, then the center lines of the faces where the section planes are to be passed. Next construct the sectioned parts and then put in the rest of the object as shown in the various steps of Fig. 5. Finally cross-hatch the sectional areas in the proper manner. Note that corresponding cross-hatching lines in the two parts would meet on the center line if extended. See Fig. 2.

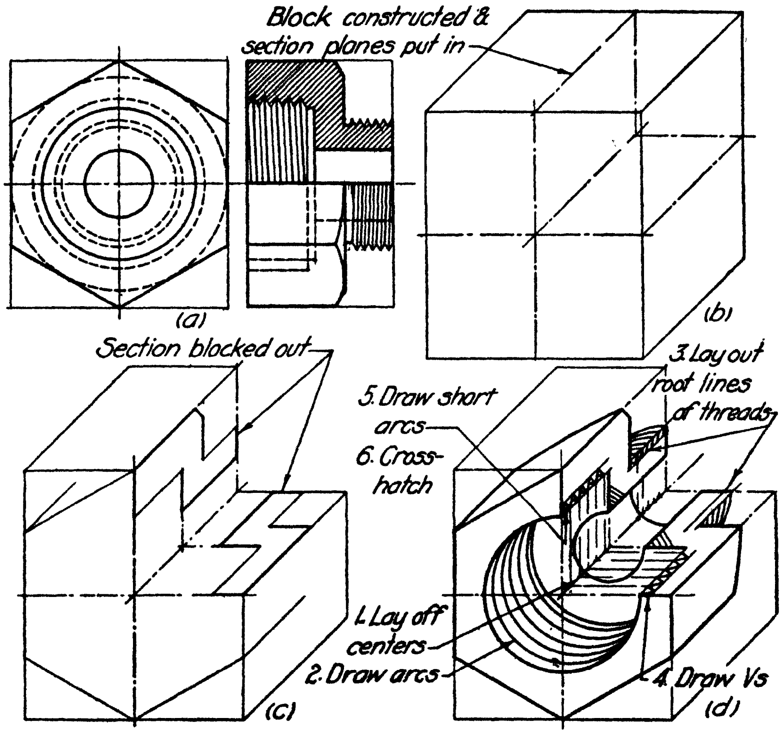


FIG. 5. Constructing sectional view and threads in oblique projection.

To draw screw threads. Draw the line representing the axis of the thread, which, if possible, should always be parallel to the receding axis, and then step off on it the distances representing the pitch of the thread, as shown in Fig. 5d. Then with a compass set to give the proper crest-diameter draw a series of circular arcs, as shown in Fig. 5d. If the thread is sectioned, the V-grooves must be shown as illustrated. The arcs are drawn first and then the grooves put in to fit. When the exact number of threads is too large to make a neat appearance a smaller number may be used. Thus, if the drawing were being made to a $\frac{3}{4}'' = 1''$ scale and there were 16 threads per inch, 12 might be used instead. In laying out screw threads follow the five steps indicated in Fig. 5d, in the order 1 to 5.

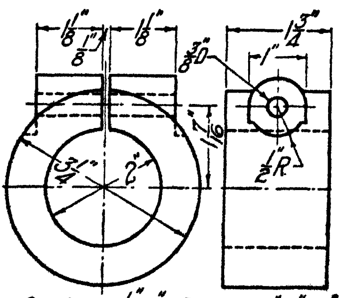
QUESTIONS

1. Show by a sketch and explain how to draw a three-dimensional curve in oblique projection.
2. What is the general order of procedure in drawing an oblique projection of an object which has curves not lying in a single plane?
3. In what position should the cutting plane for a half or full sectional view be passed?
4. What is the better method of procedure in making a sectional view in oblique projection?
5. How should section lining be drawn in oblique sectioning?
6. In what position is it best to place the axis of a screw thread? Why?
7. If a screw thread is sectioned what else must be done besides drawing the arcs for the crest of the threads? Illustrate with a sketch.
8. What is the advantage, if any, of using the receding axis as the axis of a screw?

PROBLEMS

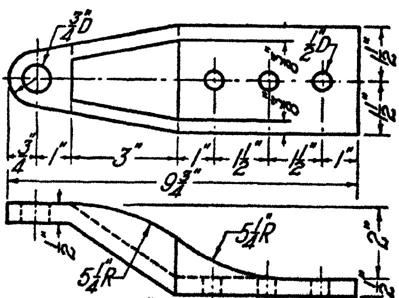
Lay out the standard border line and title space, and then make an oblique projection of the object assigned from the following group.

Draw first the orthographic views at one side of the sheet and then from them construct the oblique projection. Use the scale and position of axes as given in each figure.



Scale A $1\frac{1}{2}'' = 1''$ Scale B $1'' = 1''$ (30R)

Fig. 6. Collar clamp.



Scale A $1'' = 1''$ Scale B $\frac{1}{2}'' = 1''$ (30R)

Fig. 7. Bracket.

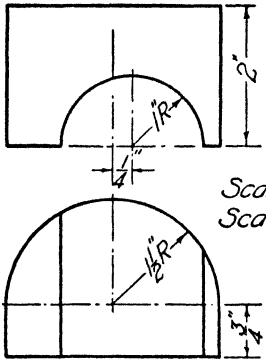


FIG. 8. Block.

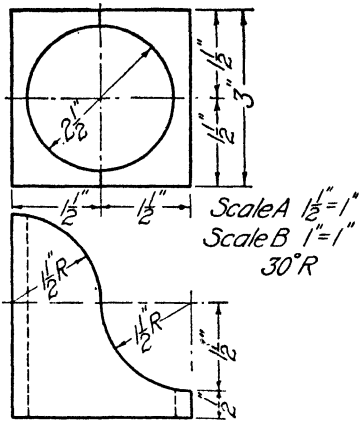


FIG. 9. Block.

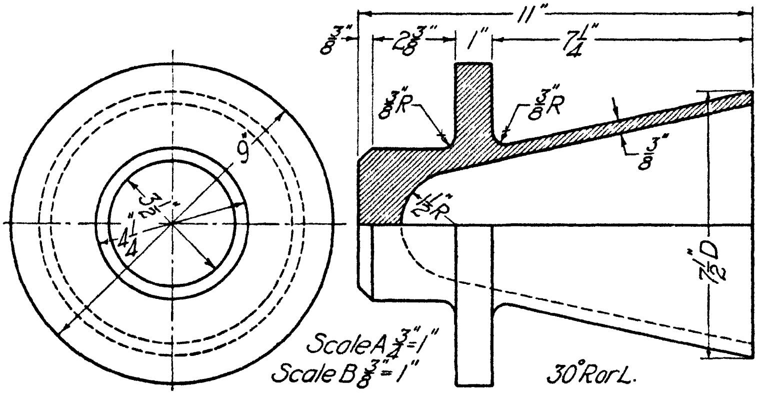


FIG. 10. Truck centering device.

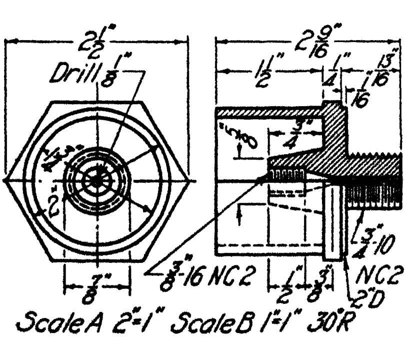


FIG. 11. Grease cup.

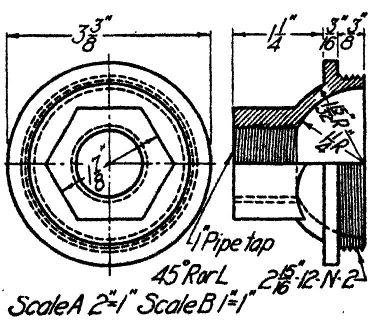


FIG. 12. Flexible coupler.

UNIT XXXI

CABINET DRAWING

PURPOSE OF UNIT XXXI

It is the purpose of this unit to teach the meaning of the term cabinet drawing, how it differs from a cavalier projection and other oblique projections and how to make cabinet drawings.

WHAT YOU SHOULD KNOW ABOUT CABINET DRAWINGS

A cabinet projection. A cabinet drawing is an oblique projection in which the projecting lines make an angle of 63°26′

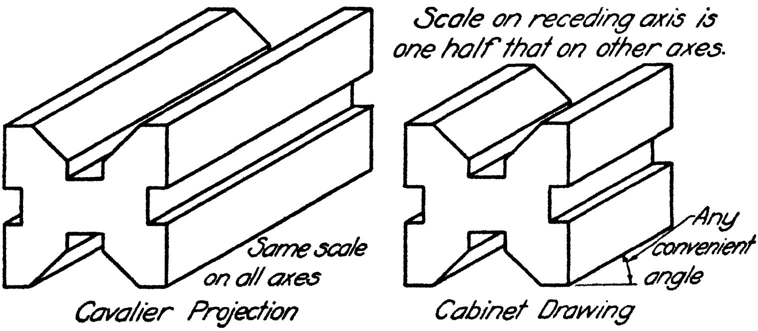


FIG. 1. Cabinet and cavalier projections compared.

with the plane of projection. This means that the lines which are parallel to the plane of projection still show in their true length, whereas those that are perpendicular to the plane of projection show just one-half their true length.

The only difference, then, in appearance between a cavalier projection and a cabinet drawing is the length of the projection of lines perpendicular to the plane of projection. The perpendicular lines are represented by the sloping or receding lines in the oblique projection. These receding lines, then, are just one-half as long in cabinet drawing as in a cavalier projection, as shown in Fig. 1. This simply means that in laying out such a drawing two different scales must be used: one scale on the two axes which are at 90 degrees to each other, and another scale just half as long on the sloping axis. In other words, if the scale used in the front face is $\frac{3}{4}'' = 1''$ then the scale used on the receding axis must be $\frac{3}{8}'' = 1''$.

Advantages of cabinet drawings. The receding axis in both cabinet drawings and other oblique projections may

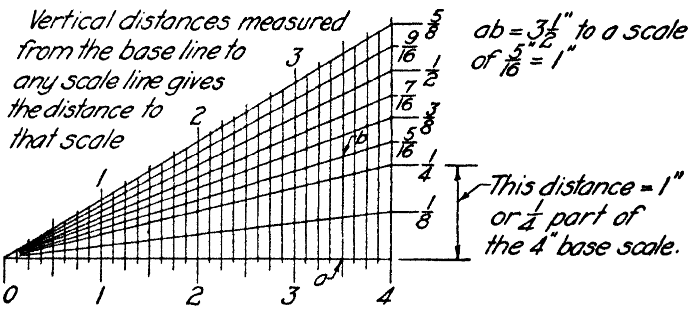


FIG. 2. Scale chart.

make any desired angle with the horizontal. The advantage of the cabinet drawing lies in the fact that it overcomes the unpleasant distortion of the cavalier projection and makes the object look more as it naturally appears to the eye. With the one exception of the use of two different scales the cabinet drawing is made just like the cavalier projection.

Other oblique projections or pseudo-perspectives. When a change from cavalier to cabinet drawing does not seem to give pleasing results, other scales can be employed. Thus, for example, if the scale on the front face is $1'' = 1''$, that on the receding axis might be made $\frac{5}{8}'' = 1''$ or $\frac{3}{4}'' = 1''$. Such drawings sometimes are called pseudo-perspectives, or simply oblique projections. A scheme for obtaining any desired scale is shown in Fig. 2.

Summary of advantages. Oblique projections, then, have the following advantages over isometric drawing:

1. A greater choice of positions is possible.
2. They are easier to draw because the front face is similar to an orthographic view and circles may be drawn as true circles in it.
3. The distortion apparent in isometrics may be overcome by shortening the receding axis to any convenient scale.

HOW TO MAKE A CABINET DRAWING

To make cabinet drawings. Make first the orthographic views of the object to the same scale as that desired for the

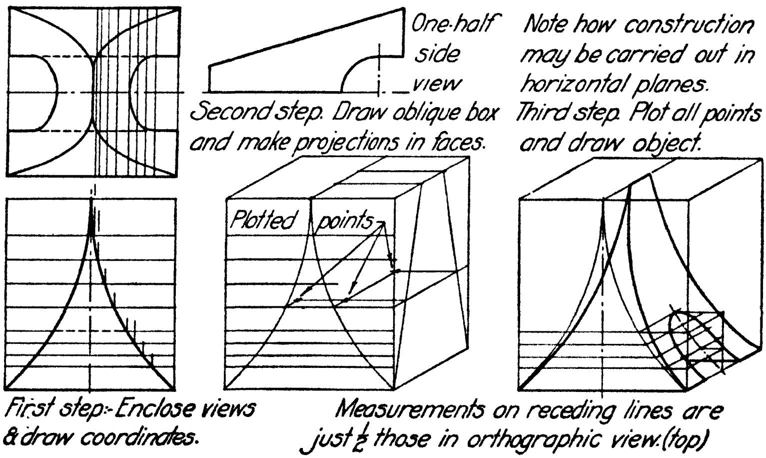


FIG. 3. Plotting curves in cabinet drawing.

front face of the oblique drawing. Decide which dimension of the object shall be upon the receding axis. Draw the enclosing block in oblique, remembering to make the receding edge just one-half as long as on the orthographic view, as shown in Fig. 3.

Proceed, then, in the same manner as for cavalier projection, remembering that each dimension laid off on, or parallel to, the receding axis, or edge, must be just one-half its size as shown on the orthographic drawings.

It should be noted that circles cannot be drawn in either receding face of a cabinet drawing by the four-center, approximate method because of the foreshortening of the scale on the receding axis. Since the enclosing parallelogram does not have equal sides it is impossible to draw an arc tangent at the mid-point of two adjacent sides. See Fig. 4. Circles

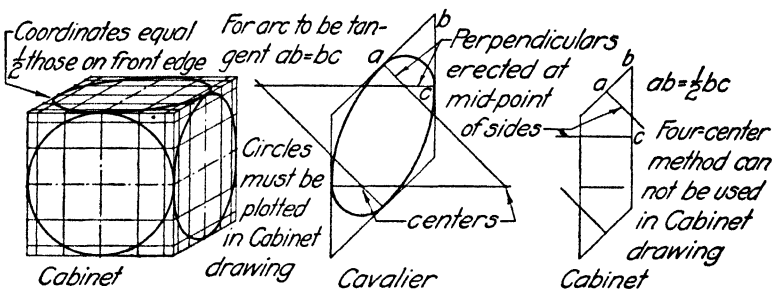


FIG. 4. Circles in cabinet drawing.

in the side or top face must be plotted by the method shown at the left in Fig. 4.

QUESTIONS

1. How does a cabinet drawing differ in appearance from a cavalier projection?

2. What difference is there in the position of projection lines by which a cavalier and a cabinet projection would be produced?

3. What is the advantage of a cabinet drawing over a cavalier projection?

4. Name the three advantages of oblique projection over isometric.

5. How can you tell an oblique projection from an isometric drawing?

6. How can you tell a cabinet drawing from a cavalier projection?

7. How can you tell a dimetric drawing from an isometric?

8. Does the receding axis in a cabinet drawing make any particular angle with the horizontal?

9. Can a circle be represented in the side or top of a cabinet drawing by the four-center approximate method? Why?

10. What difference, if any, is there in the methods of making a cabinet drawing and a cavalier projection? Be specific in your answer.

PROBLEMS

Lay out the standard border line and title space, and then make a cabinet drawing of the object assigned from the following group.

Make first the orthographic views at one side of the sheet to the same scale as that assigned for the front face of the object, then construct the cabinet drawing. The scales specified are for the front face.

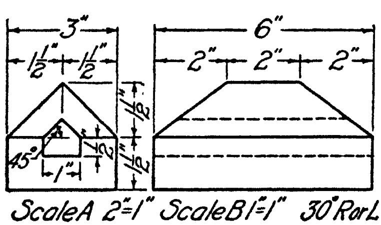


FIG. 5. Block.

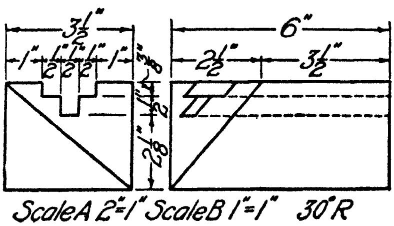


FIG. 6. Block.

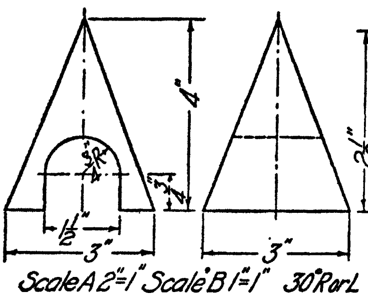


FIG. 7. Pyramid.

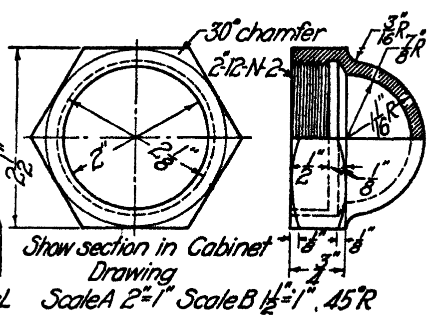


FIG. 8. Stay bolt end.

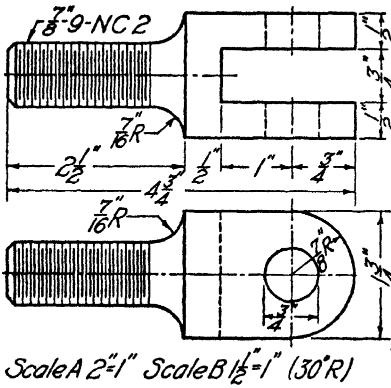


FIG. 9. Connecting rod end.

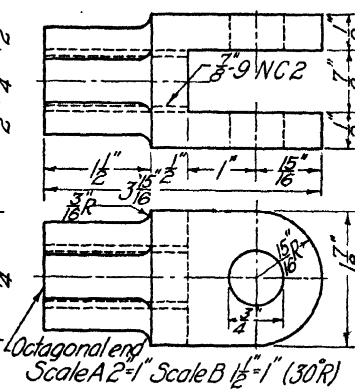


FIG. 10. Connecting rod end.

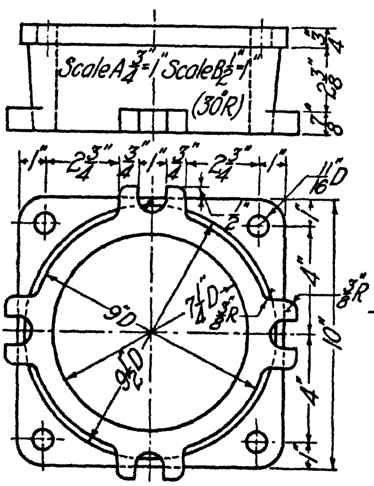


FIG. 11. Exhaust nozzle.

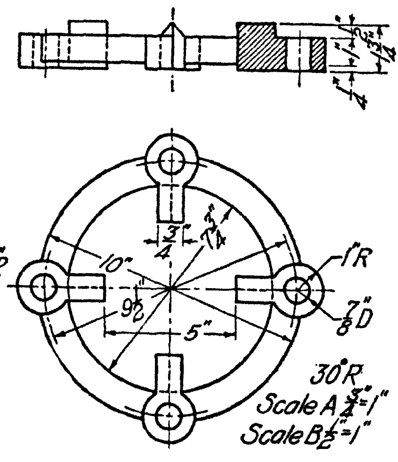


FIG. 12. Exhaust nozzle break up wedges.

UNIT XXXII

PARALLEL PERSPECTIVE

PURPOSE OF UNIT XXXII

It is the purpose of this unit to teach the underlying principles of projection upon which parallel perspective is based, and how to make parallel perspectives.

WHAT YOU SHOULD KNOW ABOUT PARALLEL PERSPECTIVE

Advantage of perspective. Of the three forms of pictorial drawing, perspective comes the nearest to representing an object as it actually appears to the eye rather than as it really is, as shown by an orthographic projection.

Vanishing points. In nature, long parallel lines appear to the eye to come together. This is expressed in another way in geometry by saying that parallel lines meet at infinity. We call the point where the parallel lines come together the vanishing point.

Parallel perspective. Parallel perspective derives its name from the position in which the object is placed relative to the plane of projection, or picture plane, as it is frequently called. The principal face of the object is placed parallel to the picture plane, hence the term parallel perspective. Horizontal and vertical lines which are parallel to the picture plane have no vanishing point, so in general only one set of lines on an object (assuming it to be more or less rectangular in shape), namely, those perpendicular to the picture plane, have a vanishing point. Hence, there is only one principal vanishing point, and, therefore, parallel perspective is frequently called one-point perspective.

Fundamentals of projection. Perspective like isometric and oblique projection is a one-plane projection, that is to say, three sides of an object are shown in one view upon a single plane, whereas in orthographic projection three planes would be required to show three sides. While three sides are shown in one view, usually on the vertical plane, the horizontal and profile planes are used as aids in construction. All construction for a perspective is purely orthographic projection using two or more planes, but the final result, the perspective, is a projection on the vertical plane only.

Point of sight. In all other types of drawing studied heretofore the point of sight has been at infinity, thus making

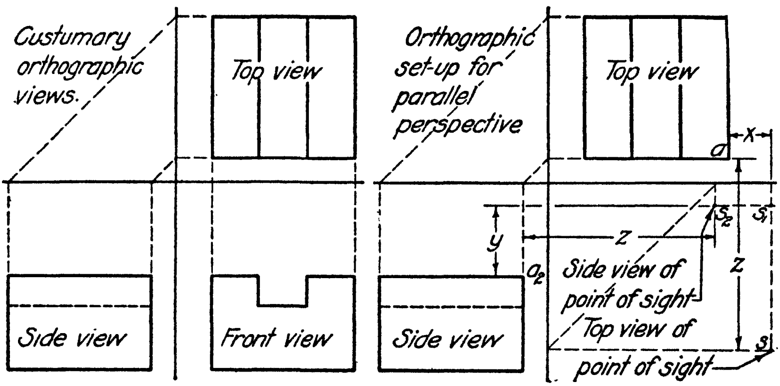


FIG. 1. Orthographic projection of object and point of sight.

the projecting lines, or lines of sight, parallel to each other. In perspective the point of sight is assumed to be at a finite, or definite, distance from the object, thus making the projecting lines converge to this point. This is the one fundamental and only difference in theory between perspective and other types of drawing you have studied.

In setting up any problem, then, one must specify not only the object and its position relative to the picture plane, but also the exact location of the point of sight relative to the object. When not shown in a drawing this is usually done by means of three co-ordinates or dimensions which are referred to some particular point on the object. The distance of the point of sight to the right or left of some point on the object is specified as plus or minus x.

The distance above or below the same point on the object is indicated by plus or minus y, and the distance in front of the same point of reference on the object by z, this quantity always being plus.

Construction of perspectives. In constructing a perspective two views are always necessary. Any two views could be used, but since the perspective is made on the vertical plane it would overlap the front view, hence it is customary to use the top and side views, as shown in Fig. 1 at the right.

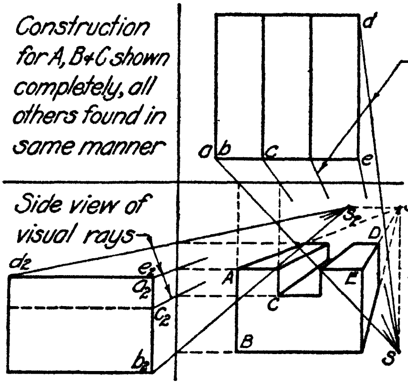


FIG. 2. Perspective constructed from top and side views.

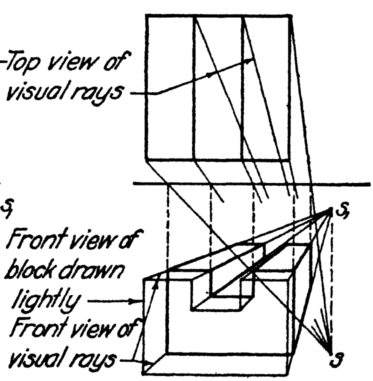


FIG. 3. Perspective constructed from top and front views.

With the object, picture plane and point of sight drawn, as in Fig. 1, it is a simple matter to draw lines of sight from the point of sight to the various corners of the object, find where they pass through the picture plane and thus determine the perspective, as illustrated for the points A and B in Fig. 2.

Piercing points. Since the picture plane appears edgewise in both the top and side views, the point where the line of sight pierces it can be seen by inspection in both views. Drawing perpendiculars from each of these points locates the vertical projection of the piercing point which is the perspective of the point on the object from which the line of sight came.

It will be noted that the edges like DE in Fig. 2, which are perpendicular to the picture plane, actually converge to a point called the vanishing point. This point was not used in the construction of Fig. 2.

Point of sight as vanishing point. The same perspective might have been drawn by using the front and top views of the object and point of sight, as illustrated in Fig. 3. In this figure it will be noted that the vertical projection of the point of sight is the vanishing point for lines perpendicular

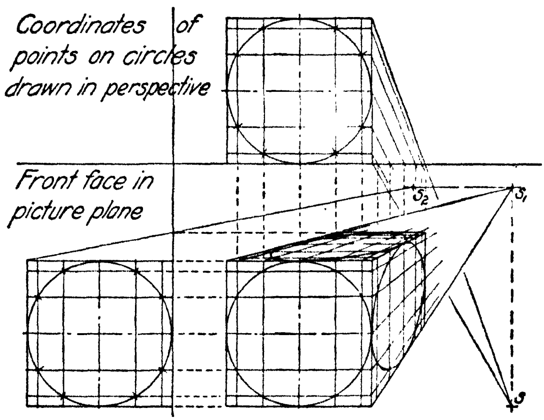


FIG. 4. Perspective of circles.

to the picture plane. This fact is always true and may sometimes be used to advantage. The overlapping of the front view and perspective is illustrated in Fig. 3, which explains why the top and side views are more frequently used for construction.

Visual-ray method. The method of construction here shown is sometimes called the visual-ray method. It is the simplest to understand although not the best method to use for practical problems.

When the face of an object is parallel to the picture plane the perspective of the face will be similar to the orthographic view but smaller, unless the face is actually in the picture plane, in which case it is exactly the same as the orthographic view. Thus, the perspective of a circle parallel to the picture plane will be a circle. This follows from the geometry of the situation since the visual rays to the circle form a cone which is cut by the picture plane parallel to the base of the cone; hence, the section cut, which is the perspective, will be a figure similar to the base, namely, a circle. This applies, of course, not only to circles but also to any plane figures.

When a circle occurs in the side or top of an object, to be made in parallel perspective, its shape is elliptical and it must be made by plotting points as shown in Fig. 4 or Fig. 5.

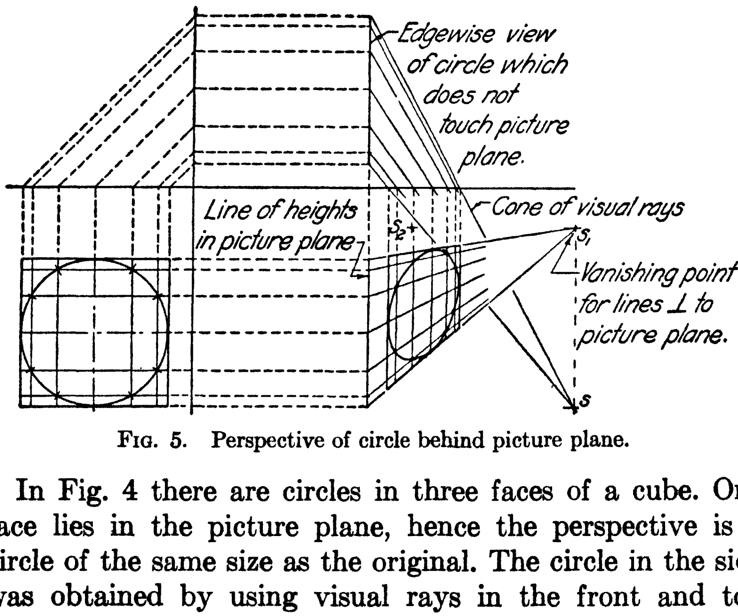


FIG. 5. Perspective of circle behind picture plane.

In Fig. 4 there are circles in three faces of a cube. One face lies in the picture plane, hence the perspective is a circle of the same size as the original. The circle in the side was obtained by using visual rays in the front and top views. The co-ordinates for the circle in the top were carried around from the side.

In Fig. 5 a circle which lies in a plane perpendicular to the picture plane is drawn in perspective. The line marked "line of heights" is really the front view of the circle, and the visual rays are again shown in the front and top views.

Summary. To sum up the matter the perspective of an object is found by getting the perspective of all the points which define it. The perspective of a point is obtained by drawing a visual ray from the point on the object to the point of sight and finding where this visual ray passes through the picture plane.

HOW TO MAKE A PARALLEL PERSPECTIVE

To draw parallel perspectives. Draw the two ground lines representing the top and side views of the picture plane.

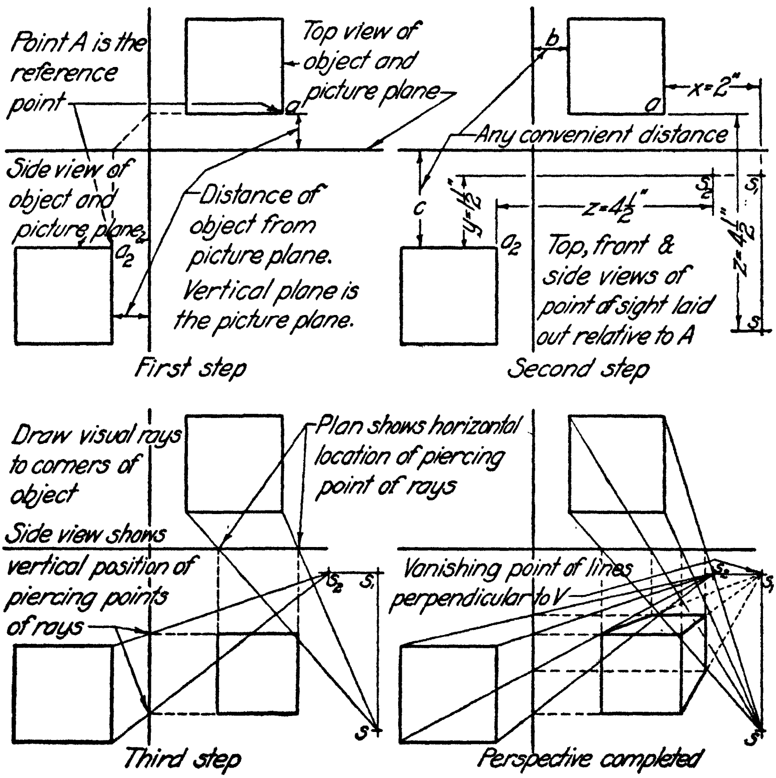


FIG. 6. Steps in constructing a perspective.

Next draw the top and side views of the object in the proper, or specified, position relative to picture plane and horizontal plane. Third, locate the top and side views of the point of sight in their proper position relative to the object and picture plane. Finally, draw the visual rays to each point of the object, one at a time, and get the perspective of each point. Connect these points in the proper order to give the entire perspective of the object. The successive steps are shown in Fig. 6.

QUESTIONS

1. In what one fundamental principle of projection does perspective differ from other kinds of drawing you have studied?
2. What does the name parallel perspective signify?
3. What is another name for parallel perspective?
4. What is the significance of the term one-point perspective?
5. How does a parallel perspective differ in appearance from a cabinet drawing?
6. Where, in general, is the point of sight assumed to be in perspective?
7. What effect does the location of the point of sight have upon the relationship of the projecting lines or lines of sight to each other?
8. How many orthographic views are needed to construct a perspective?
9. Why are the top and side views generally used to construct a perspective?
10. Could the side and front views be used to construct a perspective?
11. What is the shape of the perspective of a circle which is parallel to the picture plane?

PROBLEMS

Lay out the standard border line and title space, and then construct a perspective of the object assigned from the following group.

Three orthographic views of the object and of the point of sight are shown in each figure. Reproduce the top and side views of the object and the top and side views of the point of sight. If the object has one face in the picture plane, reproduce as much of the front view of the object as actually lies in the picture plane since this will be a part of the perspective. The vertical projection of the point of sight may be used in construction if desired since it is the vanishing point for perpendiculars. The locations of the drawings in the text are not to scale in the figures below. All dimensions should be drawn to the scale specified.

Note: The objective of this unit is to learn the principles of perspective as well as merely to get a perspective made, hence all your construction lines should be drawn in lightly so that your instructor may check the accuracy of your work. Draw lightly, since you may have to erase. Note in the problems that s_2 is just as far in front of the vertical plane in the side view as s is in front of it in the top view. This must be true since both represent the same point in space.

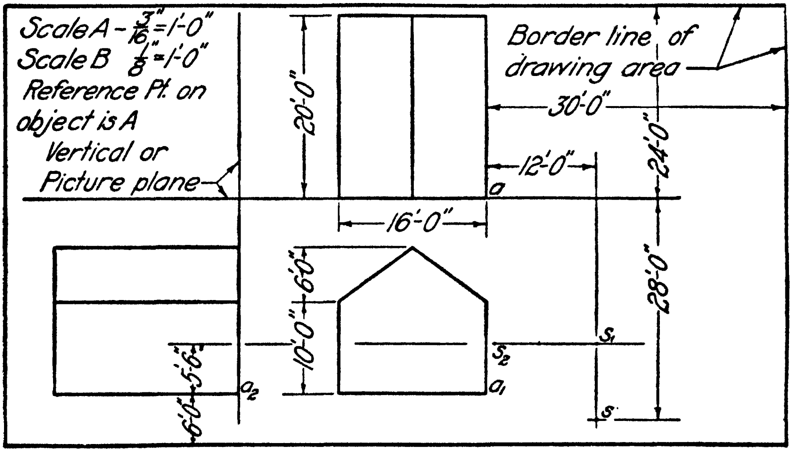


FIG. 7. Garage outline.

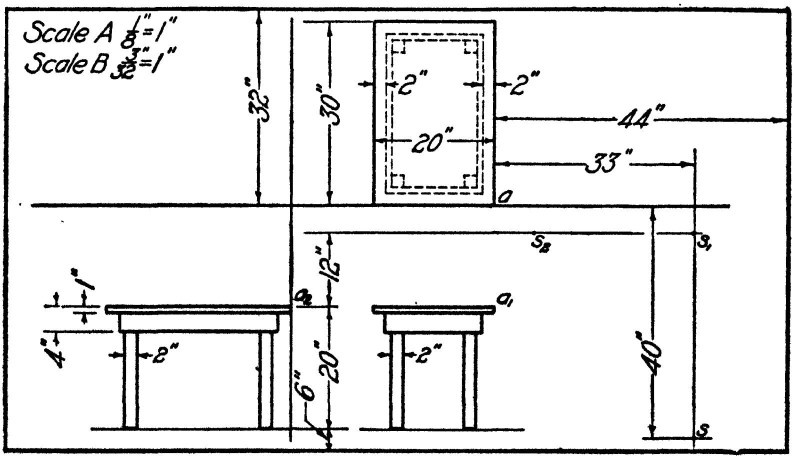


FIG. 8. Table.

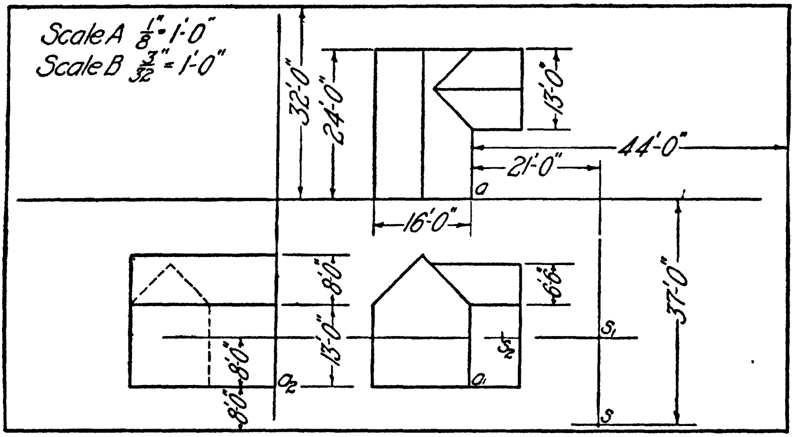


FIG. 9. Ell house outline.

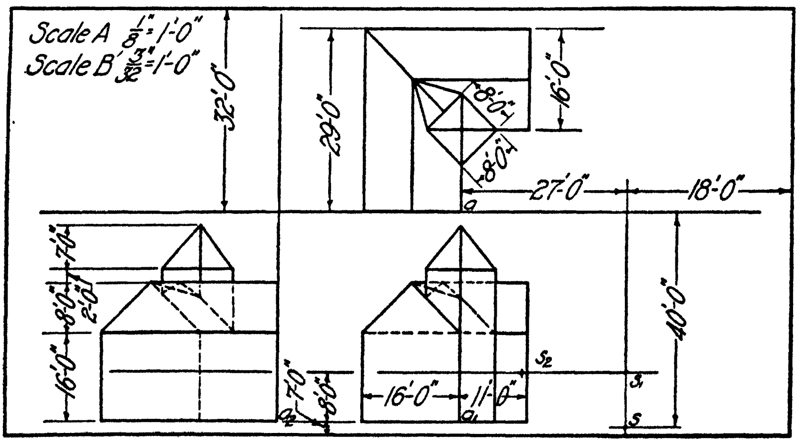


FIG. 10. Church outline.

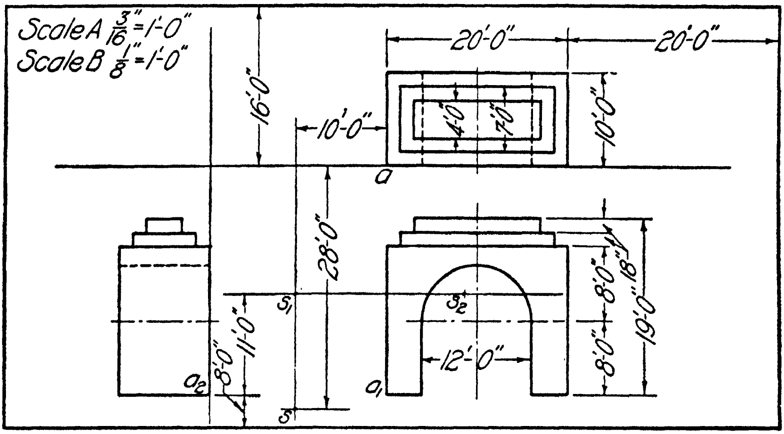


FIG. 11. Memorial arch.

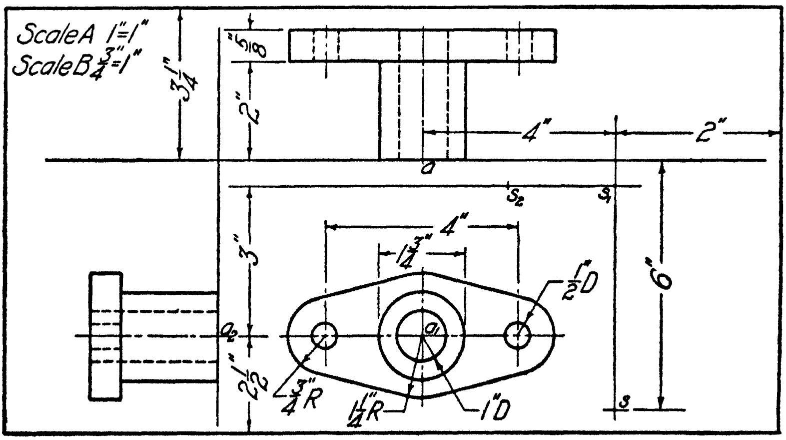


FIG. 12. Bearing.

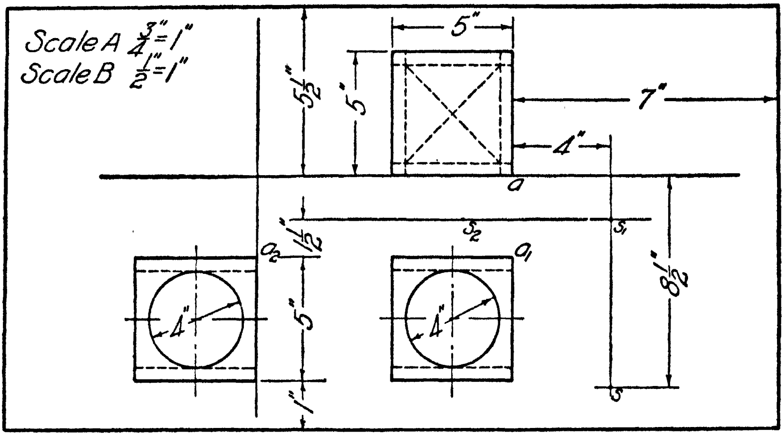


FIG. 13. Drilled cube.

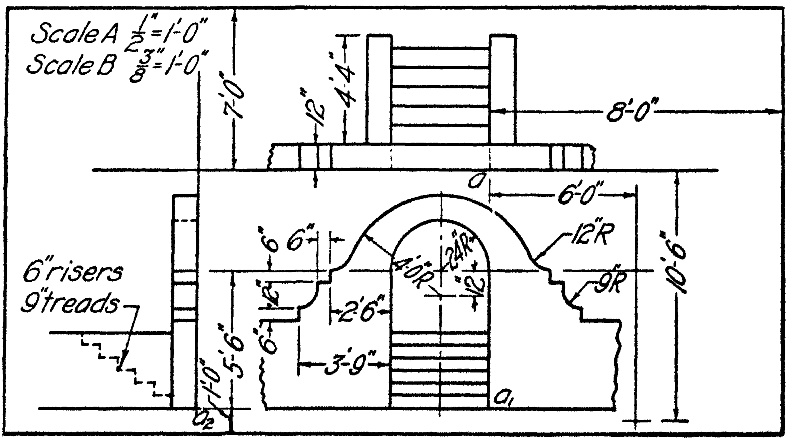


FIG. 14. Garden gate.

UNIT XXXIII

ANGULAR PERSPECTIVE

PURPOSE OF UNIT XXXIII

It is the purpose of this unit to teach the principles of projection underlying angular perspective, how to find vanishing points and how to use them in the construction of angular perspective.

WHAT YOU SHOULD KNOW ABOUT ANGULAR PERSPECTIVE

Angular perspective. Angular perspective differs from parallel perspective only in the one respect indicated by its name, i.e., that the object is placed with its principal faces at an angle with the picture plane. For rectangular objects this leaves only the vertical lines parallel to the picture plane, hence there are two principal vanishing points. For this reason angular perspective is sometimes called two-point perspective.

Construction of two-point perspectives. A two-point perspective may be constructed in exactly the same manner as a parallel perspective by the visual-ray method, as shown in Fig. 1; but a more effective way, especially for larger problems, is to use the so-called vanishing-point method which will now be described.

Before taking up the vanishing-point method we shall review certain facts and rules of projection which must be known and used in this method.

1. A straight line is determined by two points.

2. Two intersecting straight lines determine a point.

3. If two lines are parallel their corresponding projections on any and all planes are parallel.

4. Two projections or views are always necessary to represent either a point or a line. One view is never enough.

5. If a point is on a line the projections of the point are on the projections of the line.

6. Parallel lines meet at infinity. This is called their vanishing point. The perspective of this point on the drawing is also referred to as the vanishing point.

These facts are true and useful not only in the geometry class room and the drafting room, but also in the shop and field, in fact, wherever engineers and mechanics work.

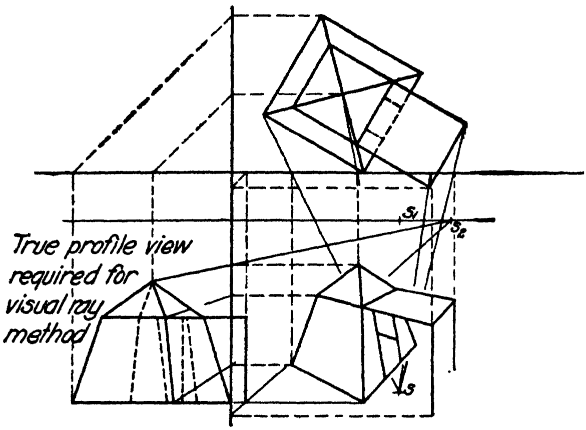


Fig. 1. Angular perspective by the visual ray method.

General procedure. The general procedure for finding a perspective by the vanishing-point method is as follows:

1. The perspective of a line on the object will be obtained by determining two points in it (rule 1 above), one of which is always its vanishing point and the other of which is where the line itself, if extended, passes through the picture plane.

2. The perspective of a point on an object will in general be obtained by the intersection of two lines (rule 2 above). These lines are usually edges of the object.

Since the vanishing point of a line must be used in finding its perspective the first problem is to learn how to find the vanishing point for any group of parallel lines. Before beginning this, however, it should be noted that all the lines in a group of parallel lines have a common vanishing point. Horizontal lines have their vanishing point in the horizon. The horizon is a horizontal line in the perspective which passes through the vertical projection of the point of sight.

Inclined lines have vanishing points also, but these are not in the horizon. Such vanishing points are found in exactly the same manner as horizontal lines, but the process will not be treated in this text.*

HOW TO FIND A VANISHING POINT AND HOW TO MAKE A PERSPECTIVE

To find the vanishing point at the right. To find the vanishing point for any group of parallel lines follow the two steps given below:

1. Draw a line through the point of sight parallel to the group of parallel lines. See rules 3 and 4 above. It should be recalled that it takes two projections to determine this line. One projection is not enough.

2. Find where this line goes through the picture plane. The vertical projection of the point where the line pierces the picture plane is the so-called vanishing point for the whole group of parallel lines.

These steps are illustrated in Fig. 2 where the vanishing point for lines *AB* and *CD* is found by (1) drawing a line from s parallel to ab, and from s_2 parallel to a_2b_2, and (2) erecting perpendiculars from the points n and n_2 where these projections are seen to pierce the picture plane in the two views, thus locating the vertical projection of the piercing point n_1. This is the vanishing point, and it is lettered *V.P.* It may be noted that the method just described is simply the visual-ray method applied to a point at infinity, where the parallel lines in question are said to meet.

* For a more complete discussion see the chapter on perspective in "Engineering Drawing" by Jordan and Hoelscher, or other advanced texts.

It may also be noted that the line through s_2 parallel to any horizontal line in the side view is always horizontal itself and therefore always coincides with the horizon line, hence it is not necessary to have both s, and s_2.

To find the perspective of a line. Since two points always determine a line, and one point has been found as the vanishing point, find another by extending the line itself until it pierces the picture plane. Since this point lies in the picture plane it is its own perspective. For example, produce the line AB in Fig. 2 until it passes through the vertical plane

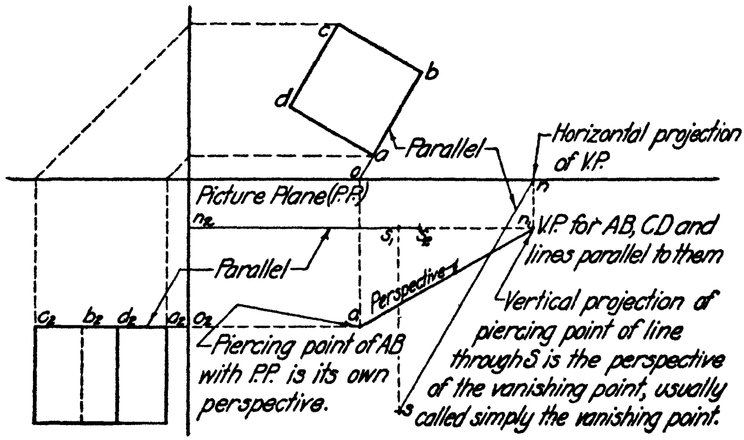


FIG. 2. Locating the right hand vanishing point.

as at o. To do this extend ab in the top view and a_2b_2 in the side view. Then project in from where these two projections cross the picture plane; the intersection of the two projection lines gives the perspective o_1 of the end of the line AB where it touches the plane.

Join the point o_1 just found with the vanishing point. This gives the perspective of the entire line from the picture plane back to infinity. Find the perspectives of the other three edges parallel to AB in the same way, as shown in Fig. 3.

To find the vanishing point at the left. To find the vanishing point for lines AD, BC, etc., proceed in the same manner;

see Fig. 4. Draw a line from s parallel to ad, and from s_2 parallel to a_2d_2. Erect perpendiculars from the points n and n_2 where these lines cross their respective ground lines

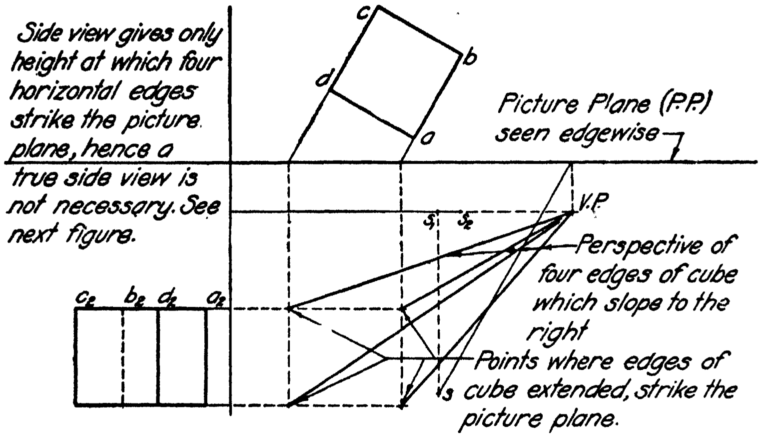


FIG. 3. Vanishing point used to draw edges of cube.

(picture plane edgewise); the intersection of these perpendiculars is the vanishing point for this set of lines. See

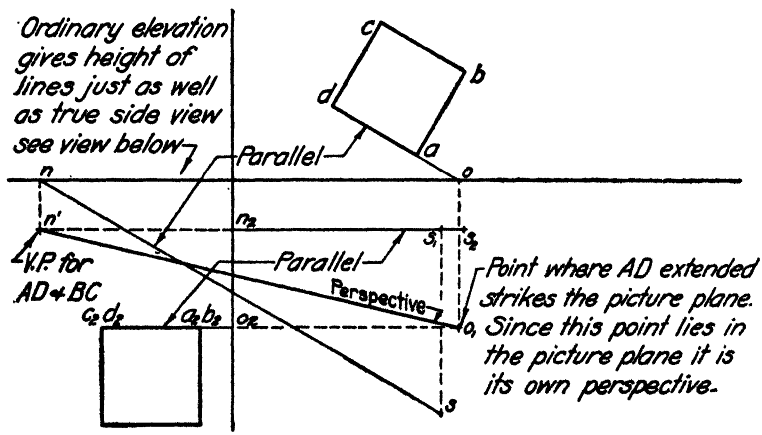


FIG. 4. Locating the left hand vanishing point.

Fig. 4. Next extend ad and a_2d_2 until they cross the picture plane at o and o_2 and again erect perpendiculars from these crossing points. The intersection of the perpendiculars is

the piercing point of *AD* with the picture plane. Connect this point o_1 with the vanishing point just found at the left. This gives the perspective of the entire line *AD*. Perspec-

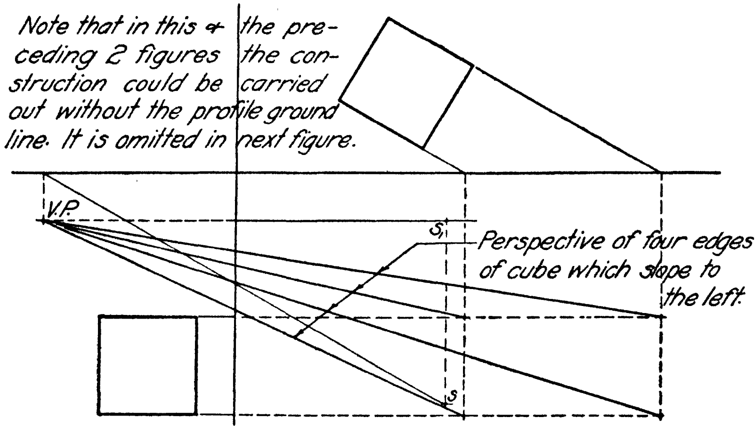


FIG. 5. Vanishing point used to draw edges of cube.

tives of lines parallel to *AD* may be found in a similar manner as in Fig. 5.

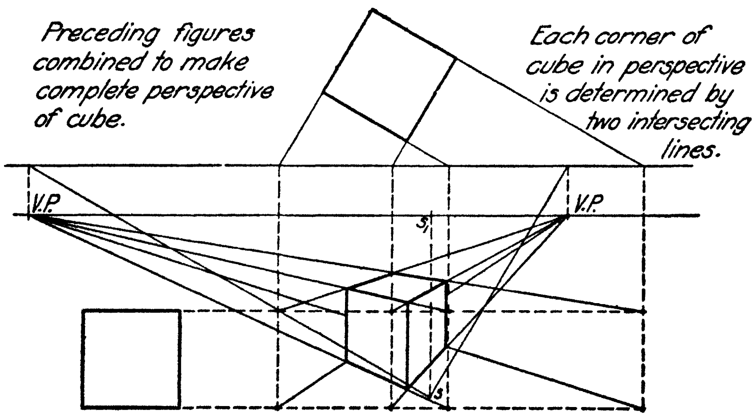


FIG. 6. Perspective of cube completed. (Figs. 3 and 5 combined.)

The perspective of all the horizontal edges of the cube having been found these will be observed to intersect in the four upper and lower corners of the cube. Draw the vertical edges between these intersections, thus completing the perspectives of the cube, as shown in Fig. 6.

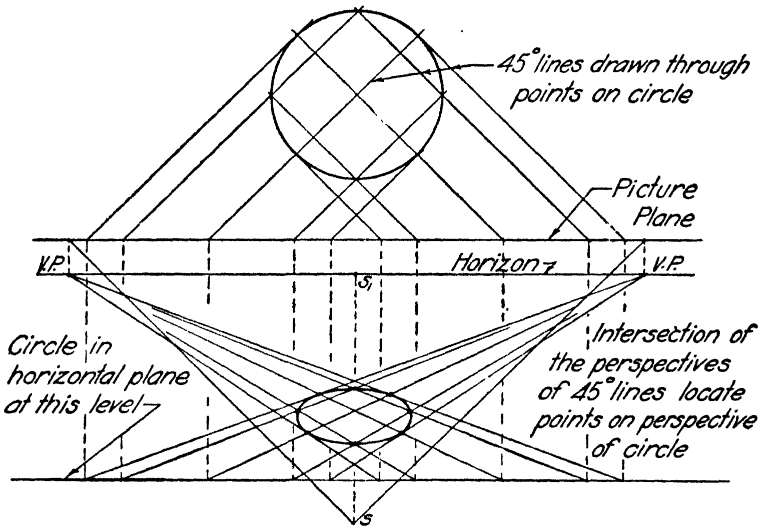


FIG. 7. Perspective of a horizontal circle. Vanishing point method.

The perspective of any point can always be found by drawing two intersecting lines through the point. The per-

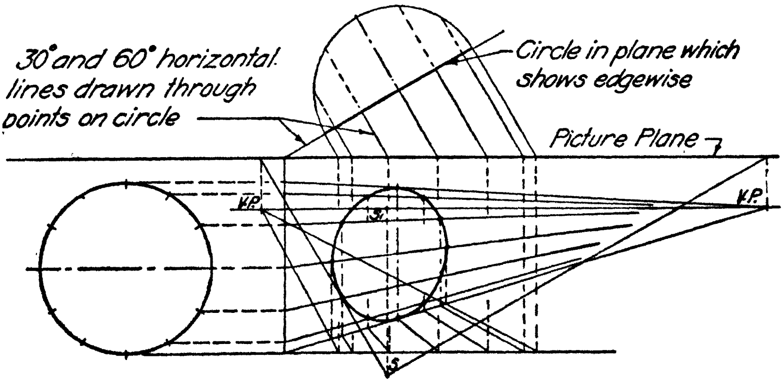


FIG. 8. Perspective of a vertical circle. Vanishing point method.

spectives of these two lines are then obtained, and their intersection gives the perspective of the point.

To find perspective of a circle. To find the perspective of a curve or circle draw lines through points on the circle in two directions as shown in the horizontal projection in Fig. 7. Then find the perspectives of these lines. The intersections of the perspectives of these lines give points which are in the perspective of the circle, as shown in Figs. 7 and 8. Draw a smooth curve through the points found.

QUESTIONS

1. Explain the meaning of the term angular perspective.
2. How does angular perspective differ from parallel perspective?
3. How is the name two-point perspective derived?
4. Can an angular perspective be constructed by the visual-ray method?
5. How is a straight line determined?
6. How is a point determined?
7. If two lines are parallel, what do we know about their orthographic projections?
8. If a point is on a line, where must the projections of the point appear?
9. Explain briefly how to find the vanishing point for a line. Give each of the two steps clearly.
10. Where will the vanishing point for horizontal lines always be found?
11. What is the horizon?
12. Explain briefly how the perspective of a line is found by the vanishing-point method.
13. Explain how the perspective of a circle may be found. Illustrate with a sketch.
14. How many projections are always necessary to determine a point or a line completely?

PROBLEMS

Lay out the standard border line and title space, and then make an angular perspective of the object assigned from the following group.

The position of the entire layout of each problem is shown and dimensioned in the figures relative to the border lines of the standard drawing sheets. The size of object, its position relative to the picture plane, location of the point of sight and all other details are given. All dimensions should be laid out according to the scale used. The figures in the text themselves, however, are not exactly to scale.

Show all construction lines lightly in pencil so that the accuracy and corrections of your work may be checked. After inking, pencil construction lines may be removed.

Note: The problems of the preceding unit may be used as angular perspective by changing the position of the object and point of sight. The choice of position may be left to the student.

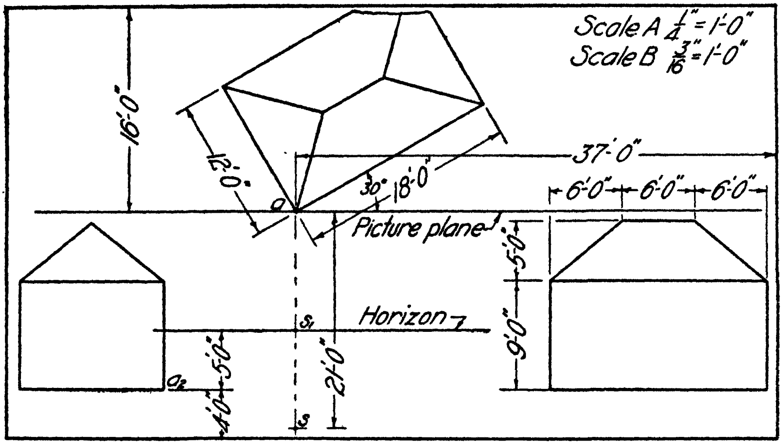


FIG. 9. Garage outline.

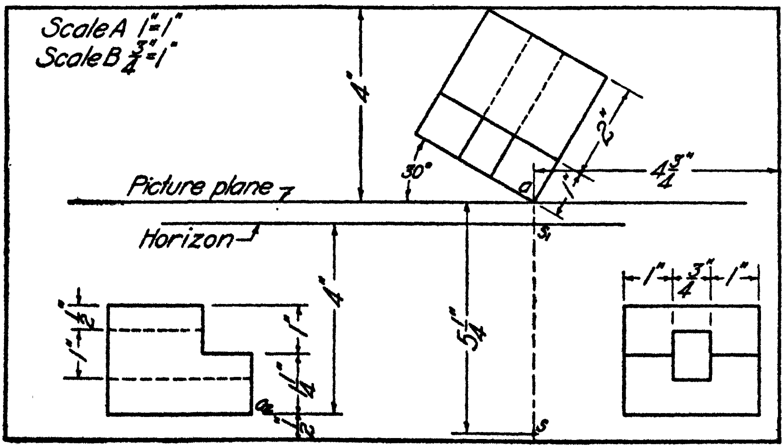


FIG. 10. Stepped block.

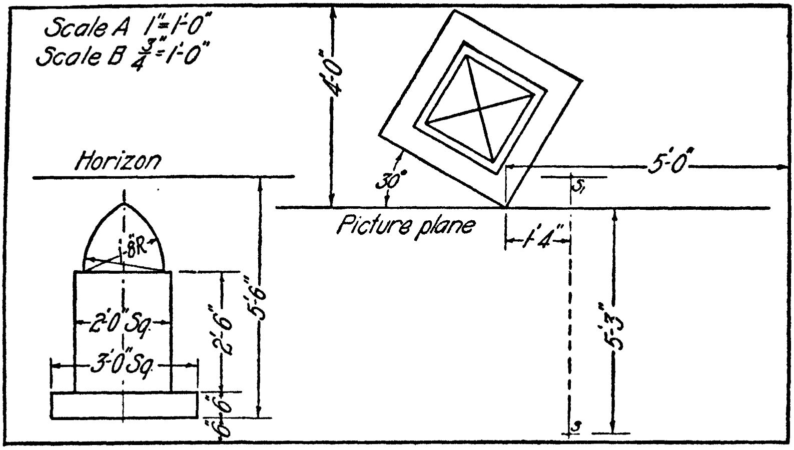


FIG. 11. Monument.

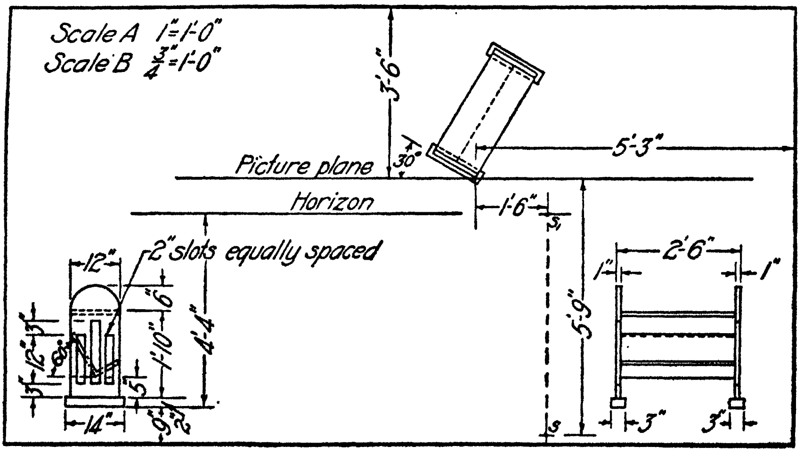


FIG. 12. Book rack.

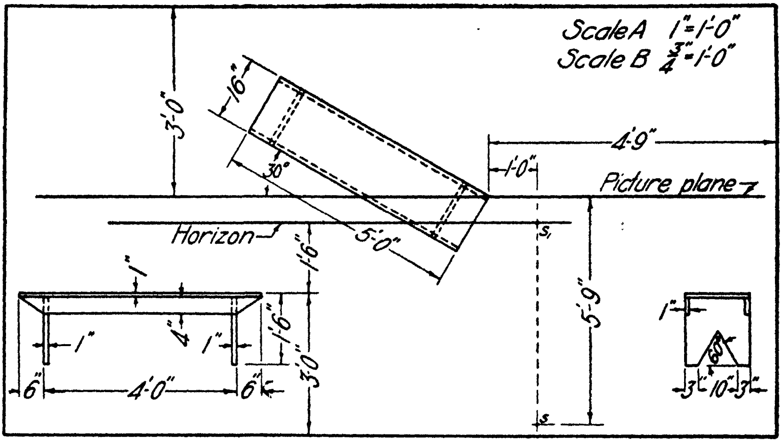


Fig. 13. Bench.

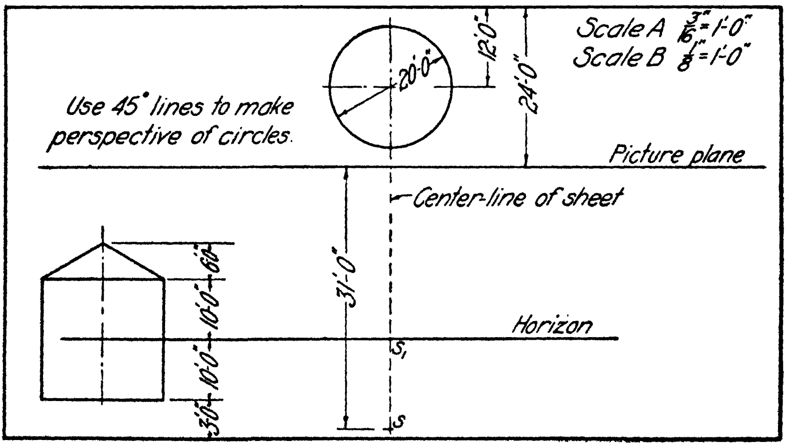


Fig. 14. Tank.

UNIT XXXIV

RENDERING DRAWINGS

PURPOSE OF UNIT XXXIV

It is the purpose of this unit to show how to render ortho-graphic and pictorial drawings to make them appear more realistic. Only pencil and ink work will be considered in this unit.

WHAT YOU SHOULD KNOW ABOUT RENDERING DRAWINGS

Purpose of rendering. The purpose of both orthographic and pictorial drawings is to make clear to an observer the

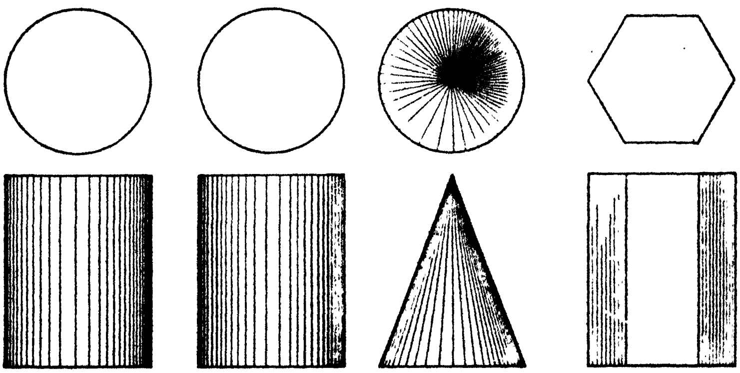


Fig. 1. Ruled line rendering on orthographic views.

shape of an object. This can be more easily done if the drawings are treated in such a way as to have the same depth, texture and qualities of light and shade as the object would have if actually in existence. The purpose of rendering and shade lining is therefore to give these qualities of realism to a drawing. The light is assumed to come from the upper left, that is to say, over the draftsman's left shoulder. It may also be assumed to come from the upper right if the position of the object makes this lighting better.

Rendering with ruled lines. Orthographic views may be made more realistic if the curved surfaces such as cones, cylinders and spheres are shaded with ruled lines to bring out the curvature by means of light and shade. This may be accomplished in two ways: one method consists of using a uniform weight of lines and changing the spacing, the other requires a change in both spacing and weight. This method is illustrated in Fig. 1.

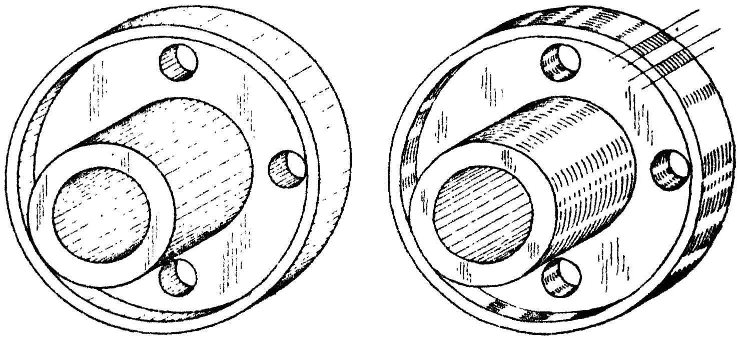


FIG. 2. Line rendering on pictorial views.

Pictorial views. Pictorial views may be rendered by line shading in much the same manner as orthographic drawings. Although the pictorial drawing does show the curvature of surfaces its appearance can be enhanced by shading. Cylindrical surfaces may be shaded with either straight-line elements or by circular elements as illustrated in Fig. 2.

Ruled lines are appropriate with mechanical drawing, but with freehand work the shading should also be made freehand.

Pencil tones. Pencil drawings may be rendered by using various pencil tones as shown in Fig. 3. When well done this forms a very effective means of giving life and realism to a drawing.

Stippling. Another way of rendering pictorial drawings is by stippling, which is a method of producing tones by means of more or less densely scattered dots, as shown in Fig. 4. These dots may be put on by pencil or pen. This is a slow process, but satisfactory when the tone is to be light and the amount of work to be done is not extensive. It may also

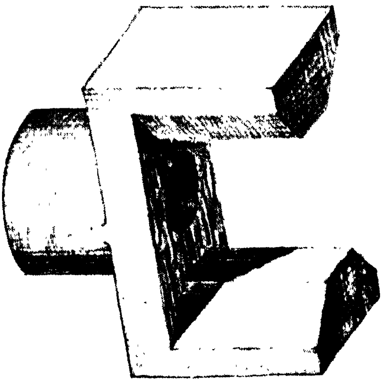


FIG. 3. Rendering with pencil tones.

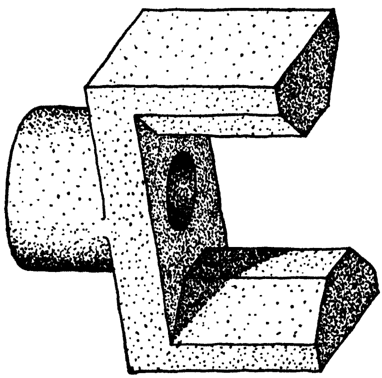


FIG. 4. Hand stippling.

be done by means of a tooth brush, wire screen and mats, or by means of mats and the air brush, which is the best method when equipment is available. A mat is a piece of stiff paper with a hole cut out which is just the shape of the

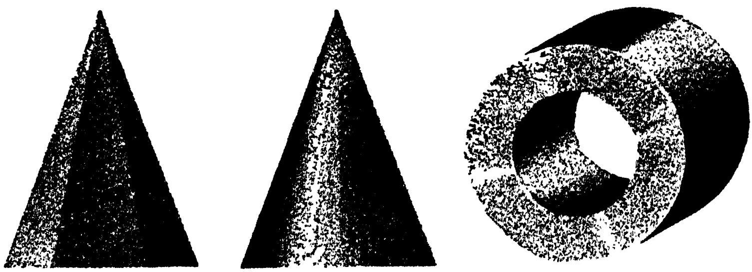


FIG. 5. Stippling with screen and brush.

area to be stippled. The method of using mats is the same regardless of the means used to apply the stipple, so the instructions given below suffice for either method. Figure 5 is an illustration of stippling with brush and screen.

HOW TO RENDER DRAWINGS

To render orthographic views by ruled lines. Use ruled-line rendering chiefly on cylindrical and conical surfaces in orthographic views. Place the high light, or brightest spot, on the cylinder or cone a little to one side of the center. Leave this area white. As you work from the white area make the lines regularly closer together with the closest spacing just at the edges of the figures. See Fig. 1. Be careful to maintain a regular variation in the spacing; otherwise the effect of uniform curvature will be destroyed.

To render pictorial drawings. The same general rule applies also to pictorial drawings when shaded with straight lines. When curved elements are to be used, break these into short arcs of varying length and spacing, as illustrated in Fig. 2. Make the centers of the arcs fall along the receding center line and space them uniformly. Start and stop the arcs upon lines which are parallel to the receding axis as illustrated by the lines in the left-hand view of Fig. 2. Until you become skilful draw in the lines lightly as a guide in making arcs. Follow the same procedure in mechanical or freehand work. Do freehand work very carefully and slowly so that the arcs are accurately parallel.

To render in pencil tones.* To produce pencil tones successfully you will need at least three soft pencils in addition to the harder pencils used for regular drafting work. These may be in the grade of B, 2B or 3B, and 4B or 5B. Sharpen all pencils used for rendering as shown in Fig. 6, so that it will be possible to make either a wide line or, by turning the pencil in the hand, a narrow line. In order to secure a satisfactory pencil tone put considerable pressure on the pencil. If the tone is too dark, use a harder pencil and the same pressure, but do not reduce the pressure used. Do not attempt to use a very soft pencil and very light pressure, for

* The paragraphs on pencil tones and the illustrations accompanying them were prepared by Mr. J. T. Lendrum of the Department of General Engineering Drawing at the University of Illinois.

this gives a tone which is irregular and rough, having more of the quality of a crayon drawing.

With the proper selection of pencils you can make any tone, from the very lightest to a rich black. Notice the first two squares in Fig. 6 which show four tones, made with pencils sharpened as shown. The grades of pencils used, with equal pressure on all, were 2H for the lightest, F, B and 4B in the order named. The other three squares show how tones used on rendered drawings may be built up from lines made by correctly sharpened pencils. The center square in Fig. 6 shows a graded tone, the change from light

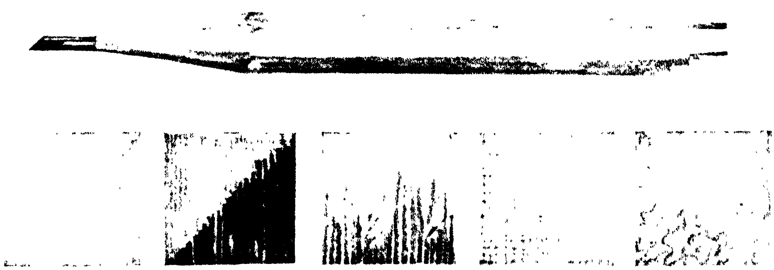


FIG. 6. Pencil tones.

to dark being made by a change in pressure. In this case it would be impossible to obtain the desired effect by changing pencils and using a constant pressure on each.

The fourth square shows another method of obtaining a graded tone. Here each line is of uniform weight, all being made by one pencil and a constant pressure. The effect of a graded tone is obtained by running a second set of lines at right angles to the first. There is no reason why this cross-hatching could not be continued, and another series of lines drawn at an angle of 45 degrees, if it were necessary to produce a desired result. The last square represents an entirely different texture, perhaps a material with a rougher surface. This tone must not be made by a series of short lines. It is one continuous line, the pencil should not be lifted from the paper until the whole is finished. The grading is accomplished by varying the pressure.

In any tone, however light or dark, always leave some white areas between some of the strokes, so that the paper itself is seen. This gives a transparent, luminous quality to the pencil work that can be obtained in no other way.

To render by stippling with pencil or pen. Bring out the high lights and dark areas by means of tones produced by dots. Leave the brightest spot without dots, and gradually increase the density or number of dots as darker shades are to be produced, as shown in Fig. 4. For heavy dark tones make the dots larger and as black as possible.

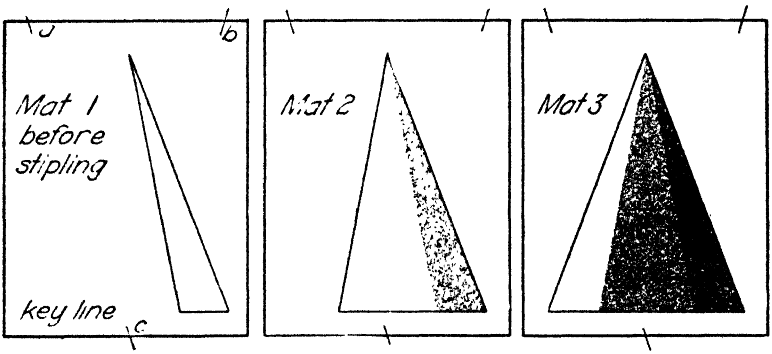


FIG. 7. Mats for stippling.

To stipple with brush and screen. Draw first the projection of the object, either pictorial or orthographic as desired, upon a piece of stiff paper which is not too thick to cut readily with a sharp knife. Upon a trial drawing decide upon the shading which is desired, by producing tones with soft pencils of varying degree of hardness, as discussed above. Then with a sharp knife cut out of the drawing made upon the stiff paper first the portion that is to have the darkest tone. Then place the mat (that is the piece of stiff paper out of which you have cut the area to be shaded) on the final drawing sheet at the desired position to make a well-balanced sheet when finished. Hold the mat in place by weights and "key" it to the drawing sheet by drawing lines across the edge in at least three places, as at *a*, *b* and *c* in Fig. 7, which shows the mats for the hexagonal pyramid of Fig. 5. Stipple the area showing through the opening in the mat by dipping brush in ink and then rubbing it across a piece of screen which is held over the area. Be careful to shake out the brush so that the bristles are comparatively dry; otherwise a drop of ink may fall through the screen and ruin your work. Do not make the tone as dark as it is finally to be. The mat itself, of course, becomes covered with stippling, but for the sake of clearness this is not shown in the figure. Protect all portions of the drawing sheet with pieces of paper except that portion under the opening in the mat where the stipple is desired.

Next, cut off the second portion of the mat as indicated in Fig. 7, and stipple over the area of the drawing sheet left exposed by the enlarged opening in the mat. Finally, cut out the remaining portion as in Fig. 7, and again stipple over the entire area exposed, producing the hexagonal pyramid as shown in Fig. 5.

To stipple a cylinder or cone. Cut out of a mat the entire area to be stippled and place a piece of paper over it so as to expose only as much of the area at one time as desired. To make a smooth gradation of tone, shift the piece of paper by small amounts and stipple lightly each time you move it. Be careful to keep the edge of the movable paper parallel to the elements of the cone or cylinder. A special series of mats must be worked out for each problem.

QUESTIONS

1. What kinds of rendering may be used on orthographic drawing?
2. What is meant by ruled-line rendering? Illustrate.
3. Show by a sketch how a cylinder in pictorial form may be rendered with curved lines.
4. What is meant by stippling?
5. What are some of the ways in which stippling may be made?
6. What is the purpose of rendering?
7. From what direction is the light assumed to come, in rendering objects?

8. What grade of pencils should be used for making pencil tones?
9. How are the different qualities of pencil tones produced?

PROBLEMS

Lay out the standard border line and title space, then do the problems assigned from the group below.

1. Reproduce a pyramid assigned from Figs. 8 to 11 and render it with hand stippling in ink.

2. Reproduce a prism or cylinder assigned from Figs. 12 to 15 and render it with ruled rendering.

3. Same as Prob. 1 rendered with brush and screen stippling.

4. Same as Prob. 2 rendered with brush and screen stippling.

5. Make an isometric drawing of an object assigned from Figs. 16 to 21 and render it as directed by your instructor.

6. Make an oblique drawing of an object assigned from Figs. 16 to 21 and render it as directed by your instructor.

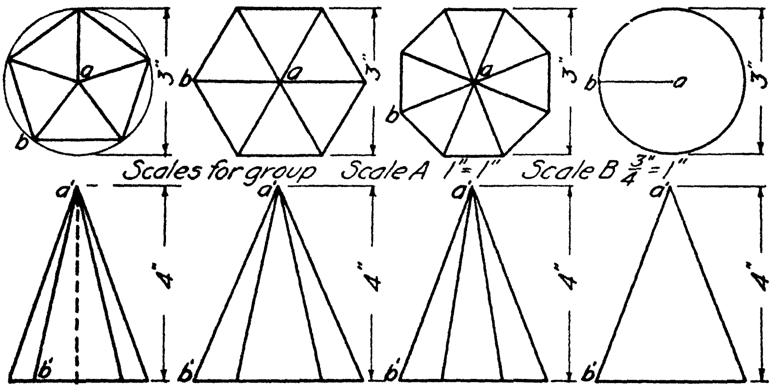


FIG. 8. FIG. 9. FIG. 10. FIG. 11.

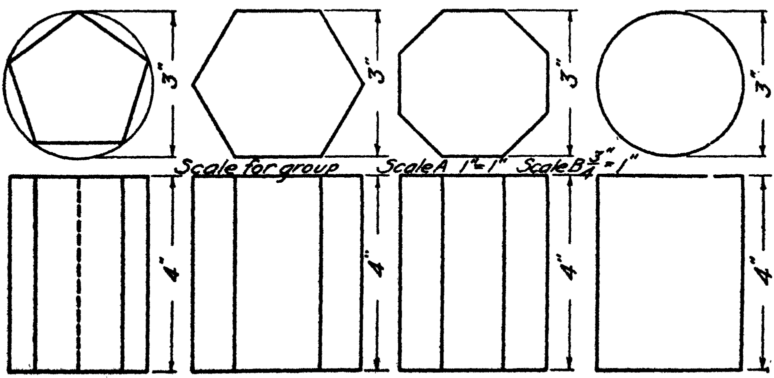


FIG. 12. FIG. 13. FIG. 14. FIG. 15.

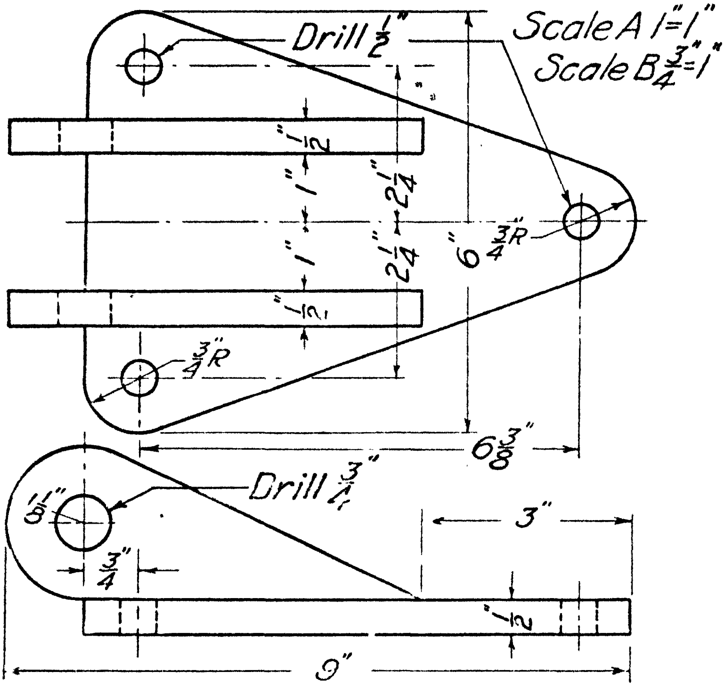


Fig. 16. Hinge.

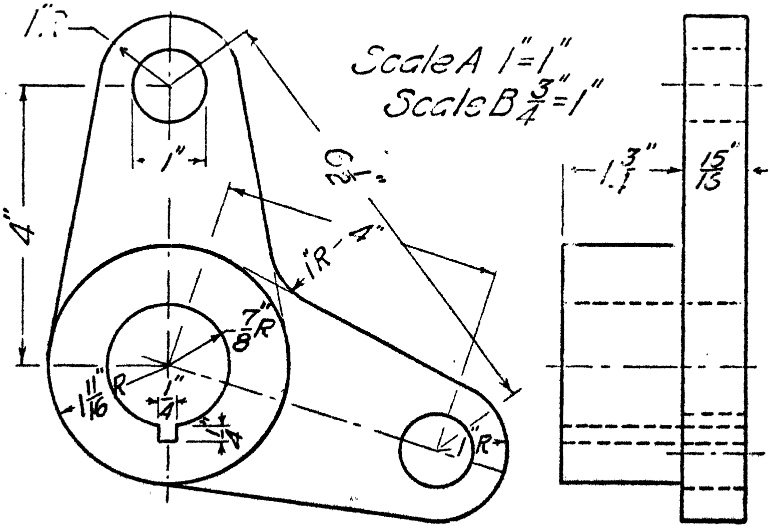


Fig. 17. Rocker-arm.

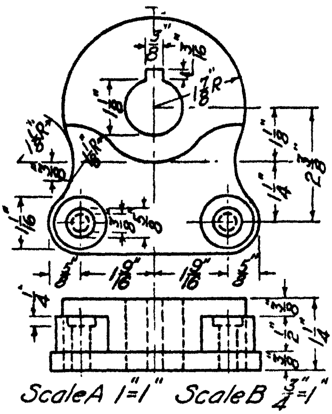


FIG. 18. Cam follower.

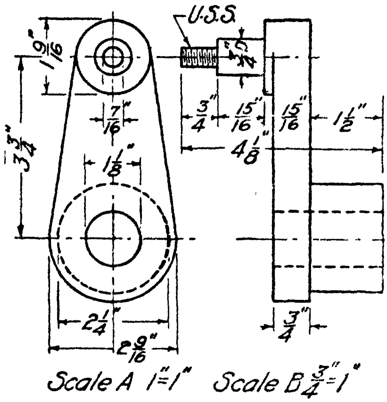


FIG. 19. Crank.

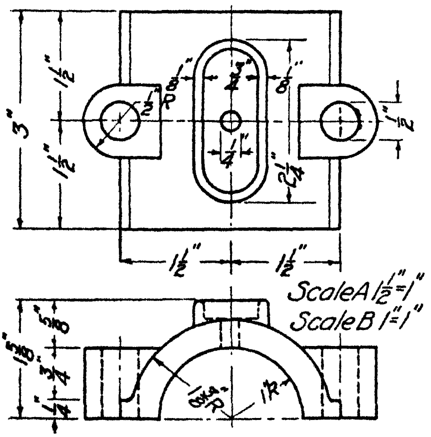


FIG. 20. Bearing cap.

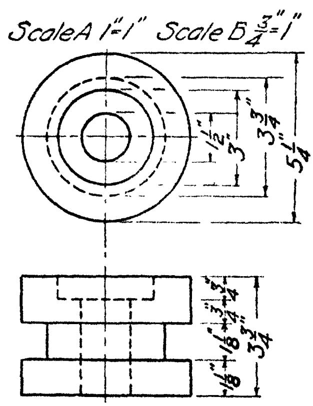


FIG. 21. Circular block.

INDEX