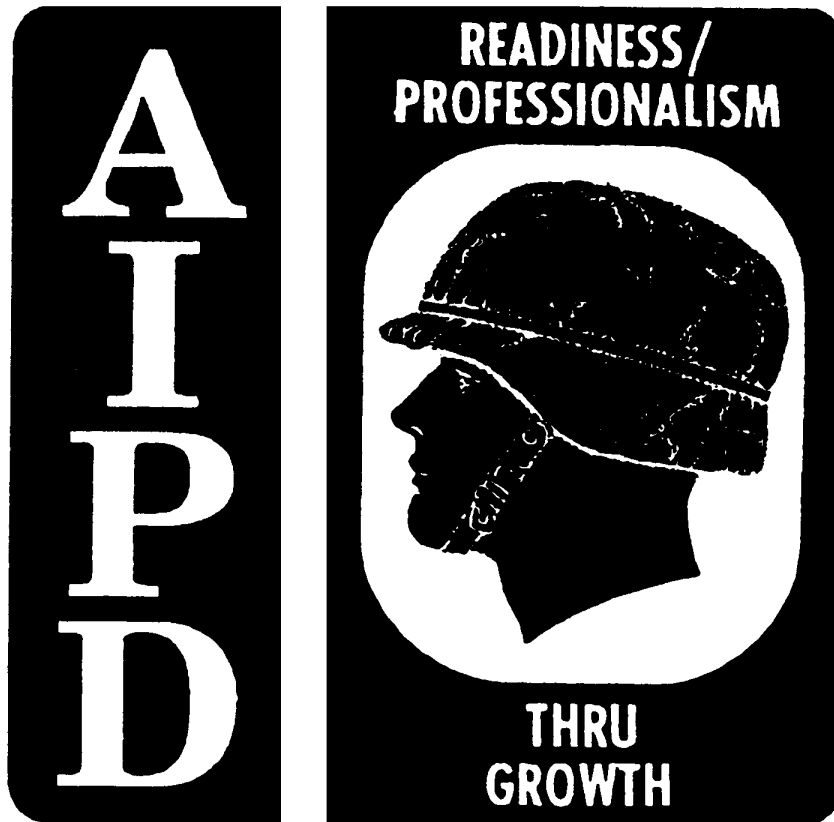

PRINCIPLES OF DRAFTING AND SHOP DRAWINGS



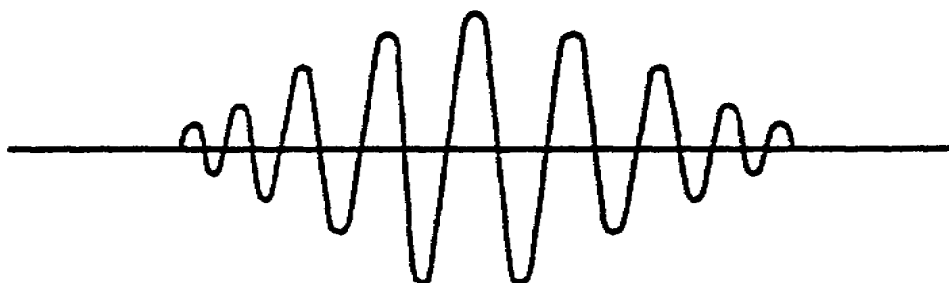
**THE ARMY INSTITUTE FOR PROFESSIONAL DEVELOPMENT
ARMY CORRESPONDENCE COURSE PROGRAM**



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US ARMY REPAIR SHOP TECHNICIAN WARRANT
OFFICER ADVANCED CORRESPONDENCE COURSE

MOS/SKILL LEVEL: 441A

PRINCIPLES OF DRAFTING AND SHOP DRAWINGS

SUBCOURSE NO. OD1641
EDITION 8
US Army Correspondence
Course Program

6 Credit Hours

NEW: 1988

GENERAL

This subcourse is designed to introduce the student to the principles of drafting and shop drawings. It describes the primary types of mechanical drawings used for shop drawings. It endeavors to teach the students how to read shop drawings through visual identification of lines, symbols, etc.

Six credit hours are awarded for successful completion of this subcourse

Lesson 1: DRAFTING AND SHOP DRAWING FUNDAMENTALS

TASK 1: Describe orthographic projection theory and freehand drafting.

TASK 2: Describe drafting instruments and the fundamentals of geometric construction.

TASK 3: Describe the theory and fundamentals of pictorial drawings: oblique and isometric projection.

TASK 4: Identify shop terms, abbreviations, and dimensioning elements.

TASK 5: Interpret a shop drawing.

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STUDENT NOTES

LESSON 1

DRAFTING AND SHOP DRAWING FUNDAMENTALS

TASK 1. Describe orthographic projection theory and freehand drafting.

CONDITIONS

Within a self-study environment and given the subcourse text, without assistance.

STANDARDS

Within one hour

REFERENCES

No supplementary references are needed for this task.

1. Introduction

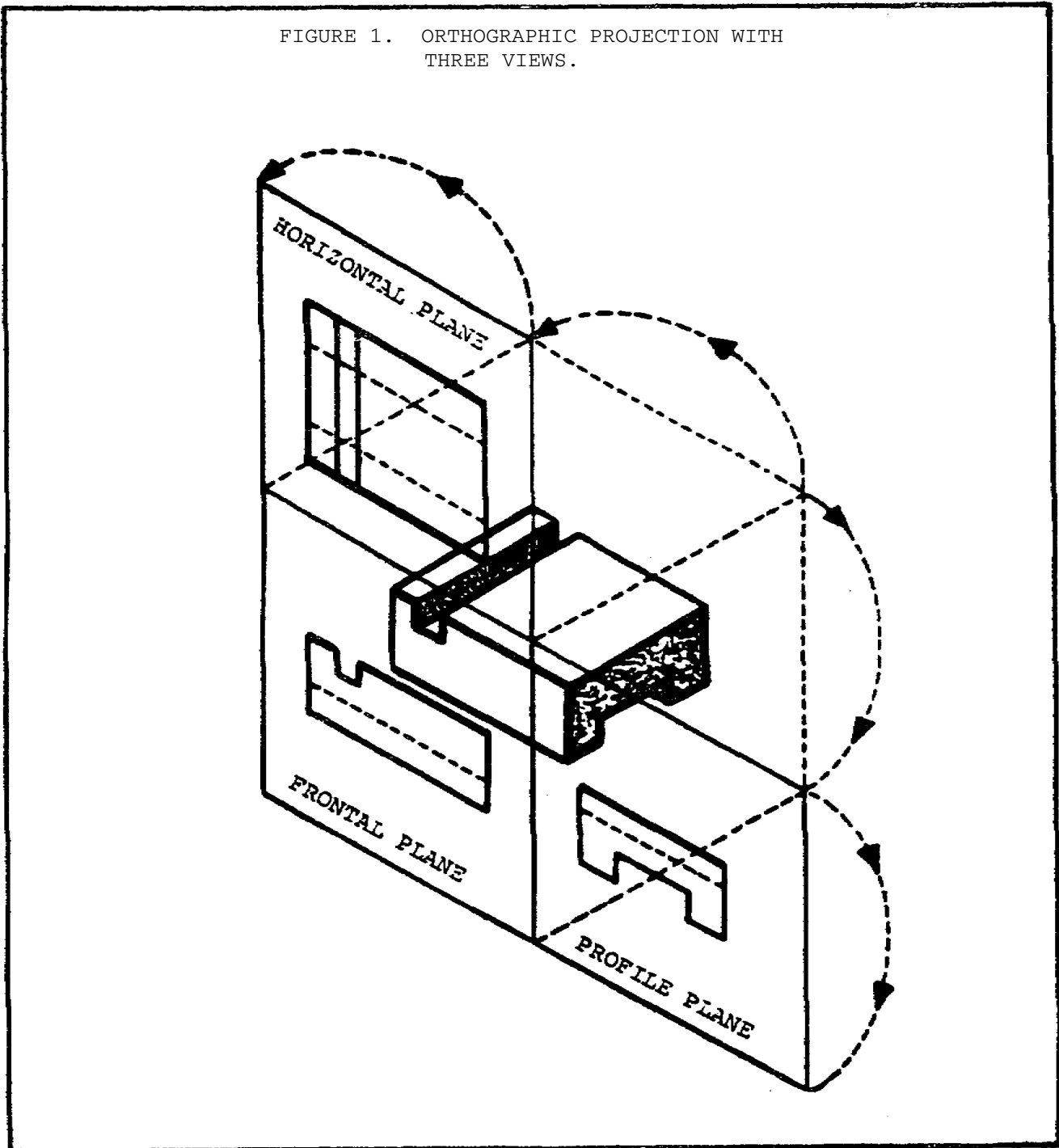
Most work done in a metalworking repair shop is detailed through the use of blueprints and shop drawings. In order to interpret these drawings into workable plans, the repair shop technician must be familiar with the fundamentals of drafting and shop drawings.

That is the purpose of this subcourse, to introduce the student to the fundamentals of drafting and shop drawings. Task one of this subcourse will cover the theory of orthographic projection and freehand drafting.

2. Orthographic Projection

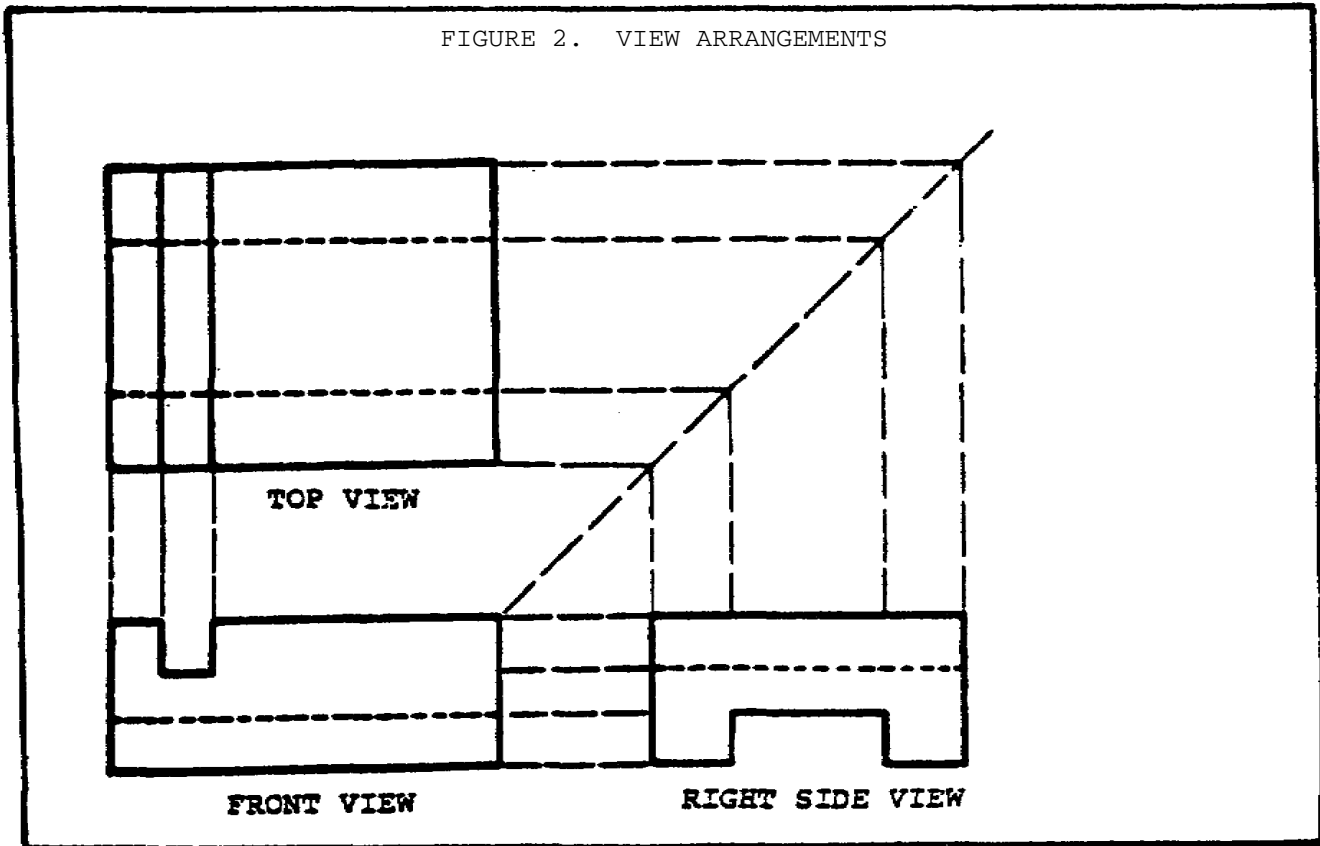
Accurate orthographic drawings are the foundation of all construction drawings. They furnish complete information for construction and repair, as well as present an object in its true proportions as to shape and size. Third-angle orthographic projection is the standard for all mechanical drawings. These drawings have very little pictorial value but are so superior to all

other forms of drawings, from the standpoint of the workman and the draftsman, that nearly all working drawings are made in this form.



a. Views. Orthographic projection is the method of representing the exact shape of an object in two or more views, on planes generally at right angles to each other, by extending perpendiculars from the object to the planes. One of these views is referred to as the "plane" or top view and

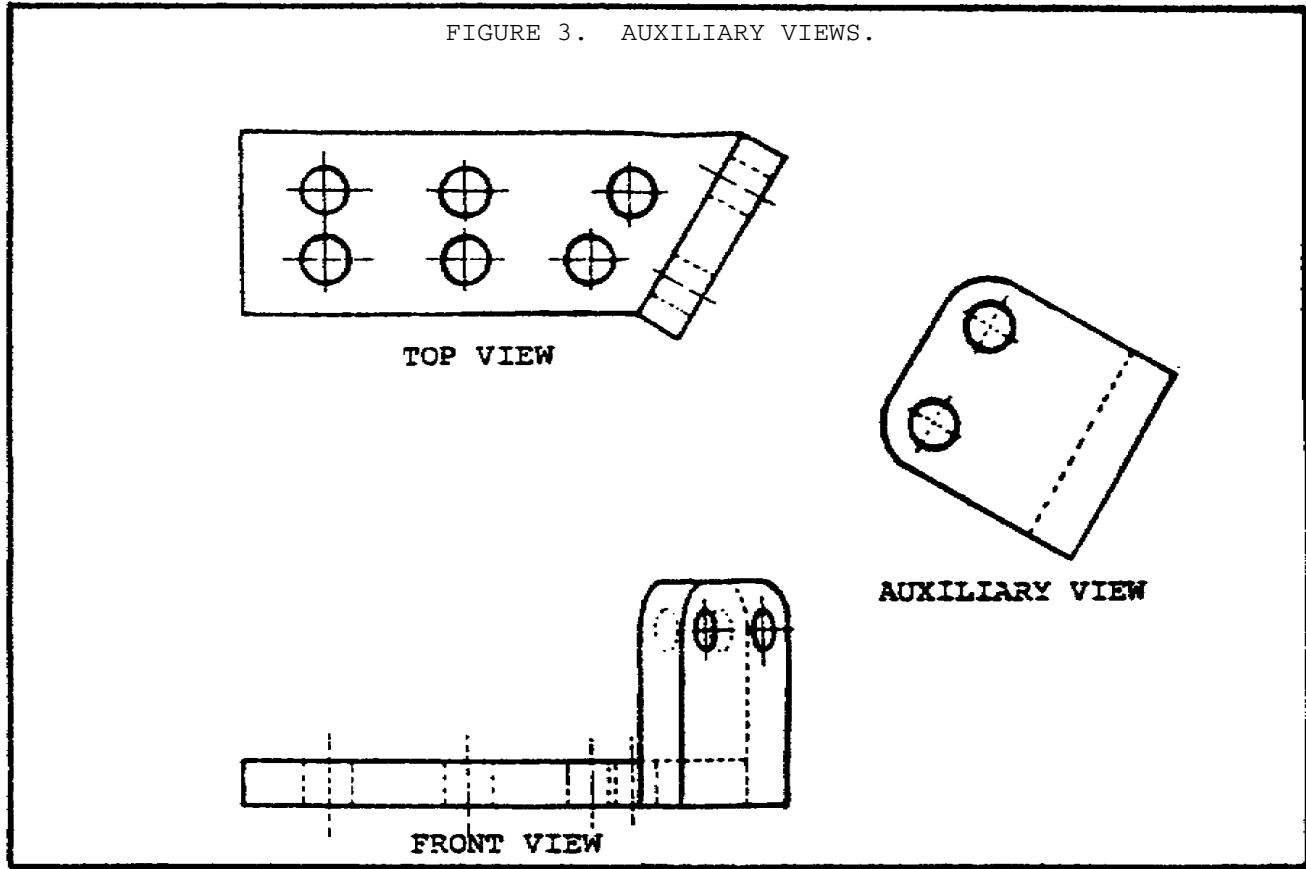
represents the object as it appears from directly overhead. Another is known as the "elevation" or front view and represents the object as it appears directly from the front. Still another, designated as "side elevation" or side view, supplements the top and front views by giving information not given in these views. Figure 1 (on the previous page) depicts an orthographic projection with three views. There are three additional views that are sometimes, though rarely, used. These views are the bottom, rear, and left side view.



b. *View Arrangement.* When views of the various surfaces of an object are placed on paper, their proper relationship is maintained by the proper arrangement of views. Study the arrangement of the three views in figure 2. The front view is the starting place. It was selected for the front view because it shows the most characteristic feature of the object. The right side view is projected directly to the right of the front view. Some of the lines in the right side view lie along extension lines from the front view. Notice that the top view is placed directly above the front view and that some of its lines lie along extensions of lines from the front view. After

studying each view, try to imagine or visualize the appearance of the object. Figure 1 on page 2 indicates how the views are pulled from the object.

c. *Auxiliary Views.* Objects having inclined faces, or other features that are not parallel to any of the three principal planes of projection, require auxiliary views to show the true shape of such features. The auxiliary view is arranged as though the auxiliary planes were revolved into the plane of the paper by considering it hinged to the plane with which it is perpendicular (figure 3).



d. *Principal Plane Line.* Drawings are divided into zones. Each zone contains one orthographic view, together with all information pertinent to that view. The zones are separated by crossed (90°) construction lines called *principal plane lines* which are similar to a mathematical coordinate system. They are omitted on finished drawings, but their presence is understood. Principal plane lines are defined in figure 4 (on the following page). Figure 5 (on the following page) shows how principal plane lines were initially developed.

FIGURE 4. PRINCIPAL PLANE LINES.

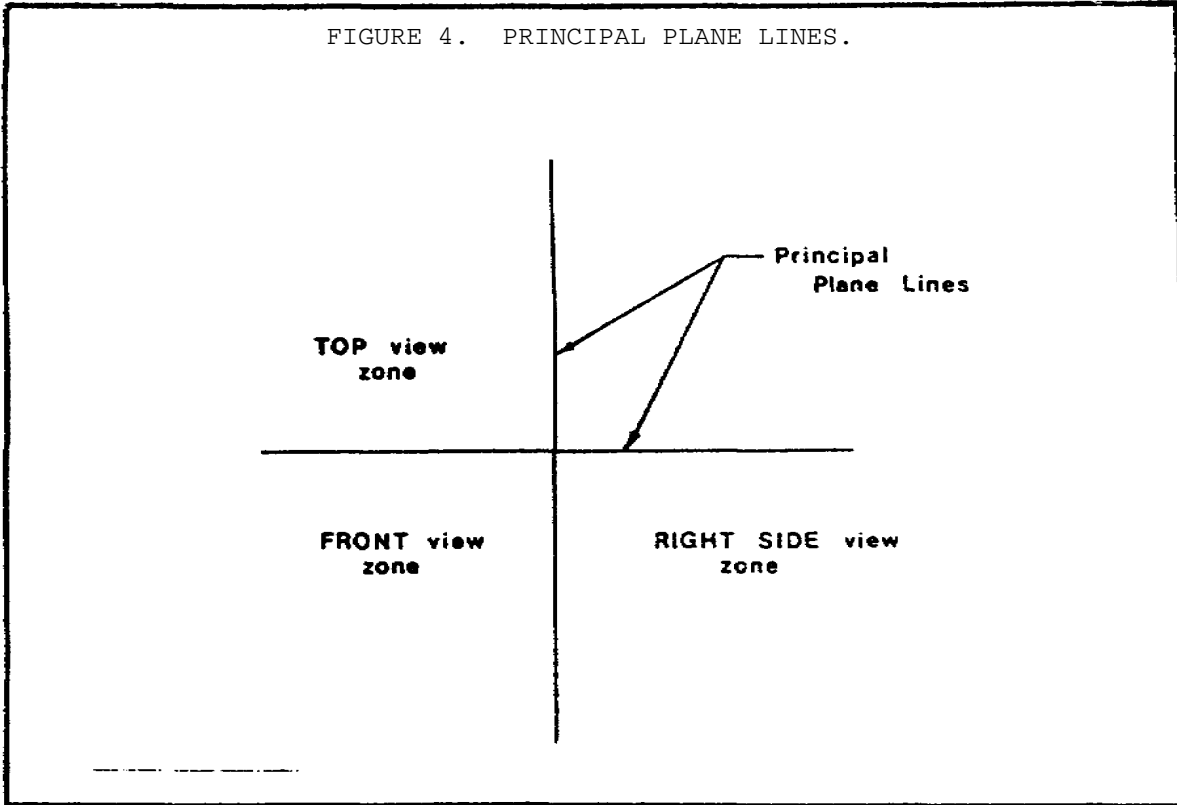
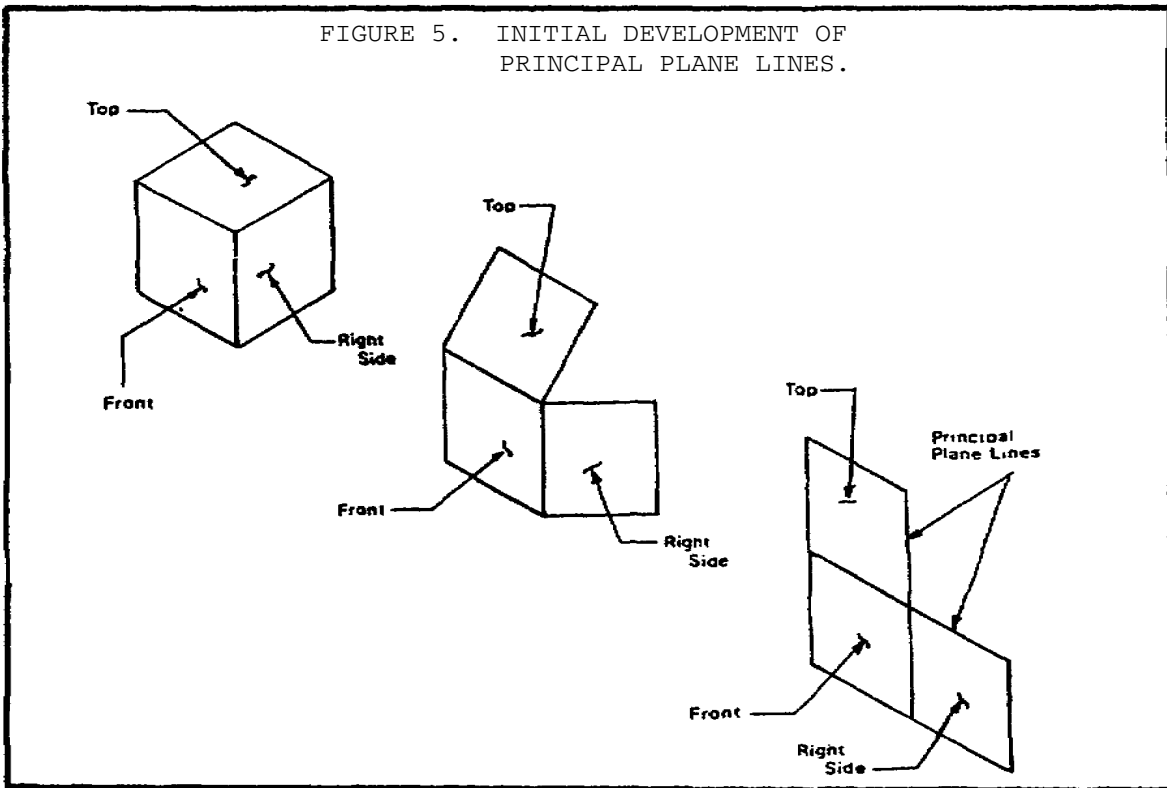


FIGURE 5. INITIAL DEVELOPMENT OF PRINCIPAL PLANE LINES.



e. *Points.* Projection theory is the study of how to transfer information from one orthographic view to another. Often, two views of an object may be visualized, or parts of each view may be drawn, but the completed drawing remains unclear. Projection theory enables the bits and pieces to be used together to arrive at a finished drawing.

Reduced to its simplest form, projection theory may be used to transfer a single point from one view to another. Figure 6 presents the problem of finding the right side view of a point where the front and top views are given.

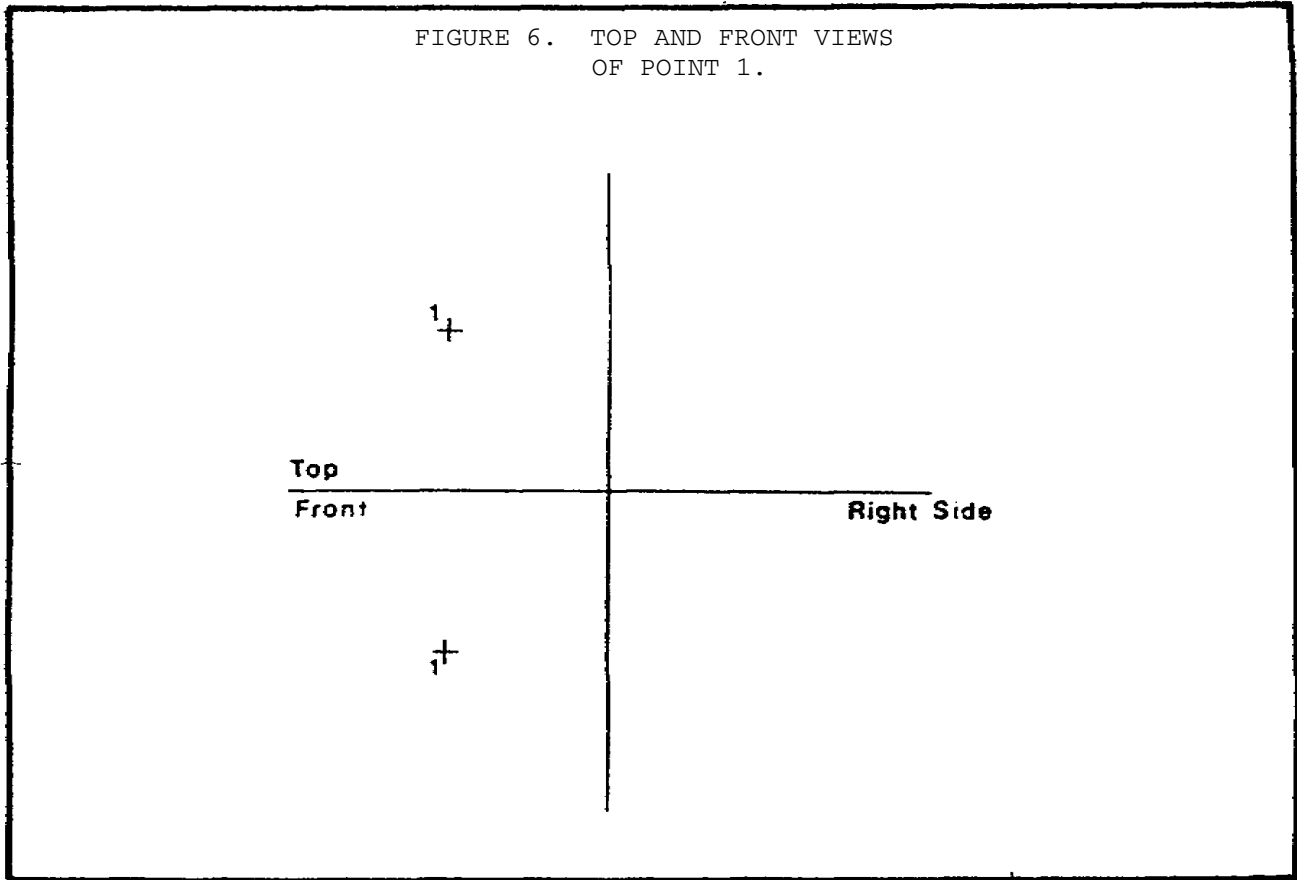
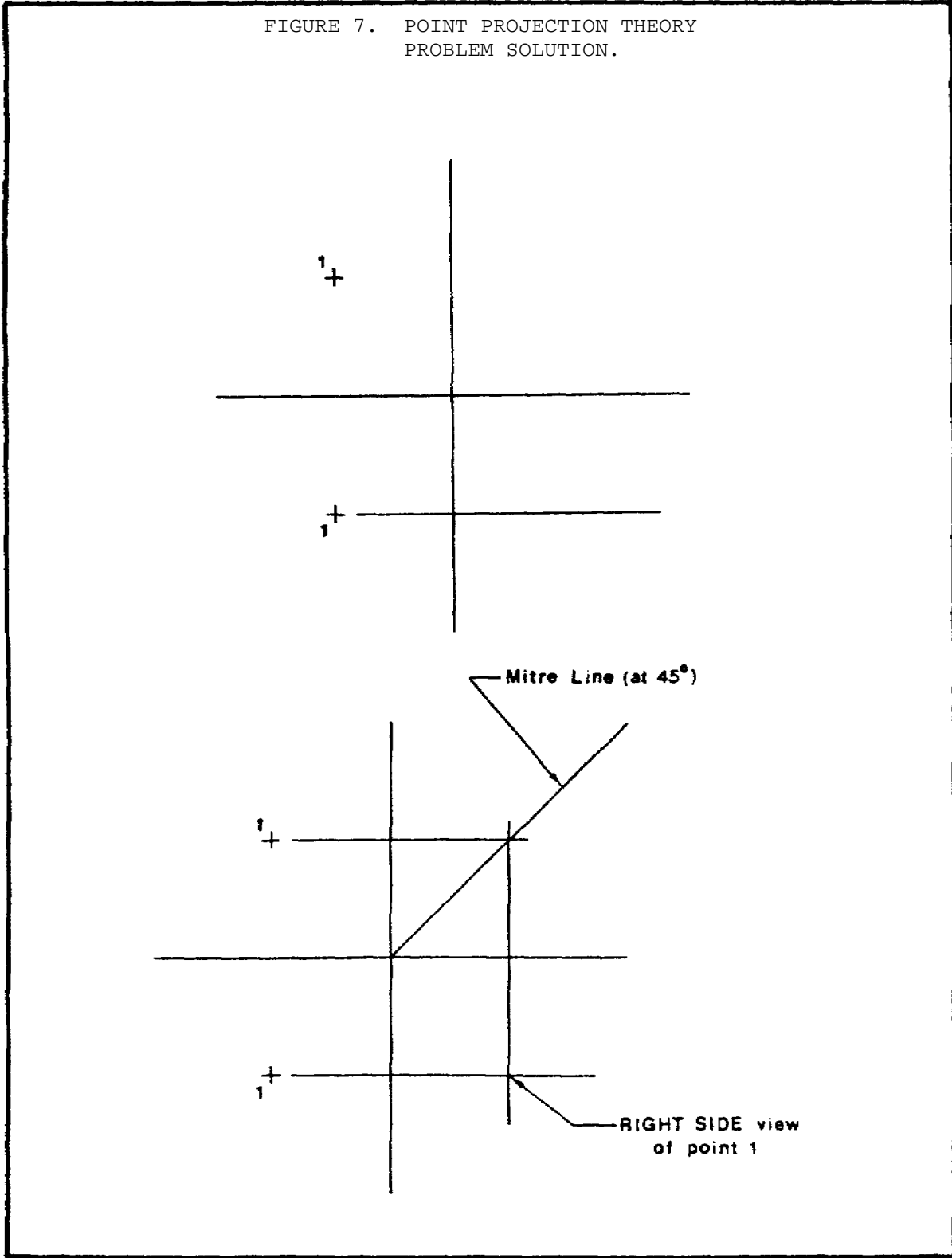


Figure 7 (on the following page) shows the solution. Project the front view of point 1 into the right side view zone. This is done by drawing a horizontal construction line parallel to the horizontal principal plane line. The tendency here is to draw the projection line too short, meaning extension may be required later on. All we know at this time is that the right side view is somewhere along the projection line.

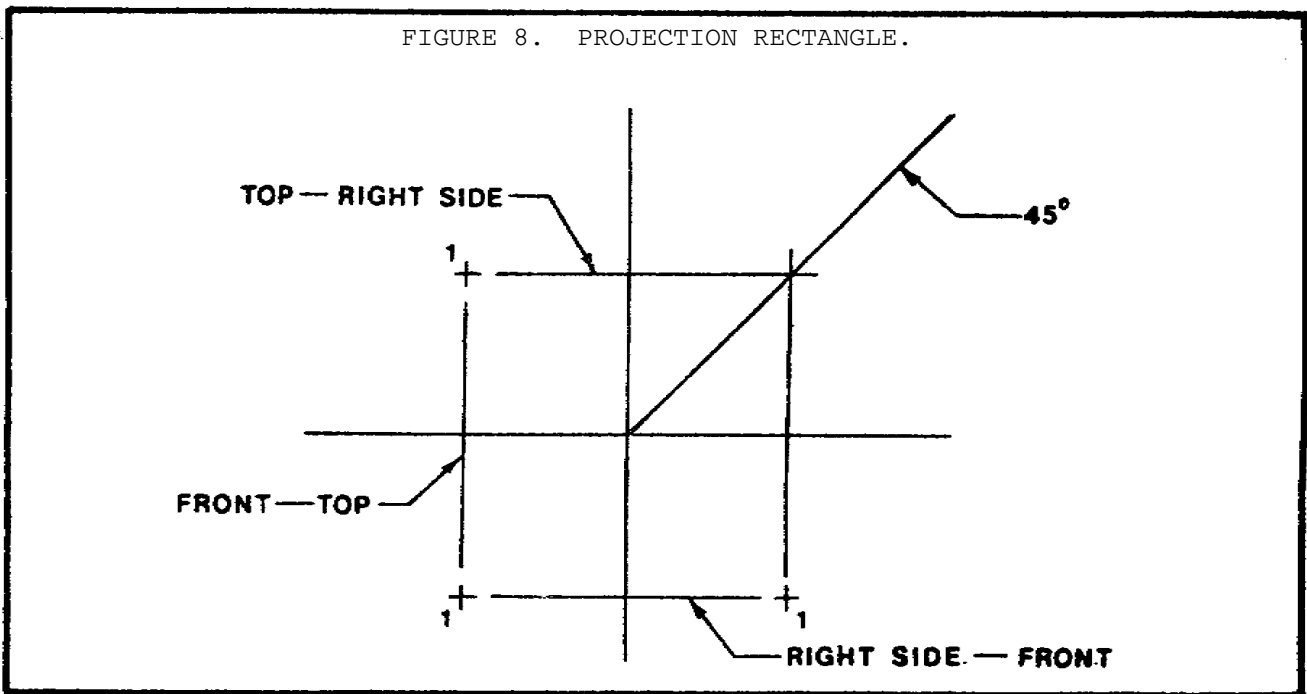
FIGURE 7. POINT PROJECTION THEORY
PROBLEM SOLUTION.



Draw a line 45° up and to the right from the intersecting point of the principal plane lines.

This is called a mitre line. Project the top view of point 1 into the right side view zone. This is done by drawing a horizontal construction line to the right, parallel to the principal plane line until it touches the 45° mitre line. When the projection line touches the mitre line, it turns the corner, i.e., it goes from horizontal to vertical. To continue the projection line, draw a vertical construction line, parallel to the vertical principal plane line, extending down into the right side view zone. As before, don't be stingy with the lead; draw the projection line through and beyond the horizontal projection line. The intersection of the two projection lines is the right side view of point 1. Label it.

Several additional points should be made before leaving this problem. The location of the front view of point 1 in relation to the top view is not random. The vertical line between the front and top views is parallel to the vertical principal plane line. Figure 8 shows three views of point 1 and the projection lines used to go from view to view. The point views and lines form a perfect rectangle (four sided figure with four right angles). This *projection rectangle* enables the draftsman to find any third view of a point when he is given the two other views. This means that if we consider only three principle views (top, front, and right side), there are only three possible projection problems.



f. *Lines.* The projection of lines between views follows directly from the point projection theory. If we consider the axiom:

To a draftsman, a line is a visible line that connects two or more points.

It follows then that lines may be projected by projecting the points that define them.

Figure 9 presents the problem of finding a right side view when the front and top views are given.

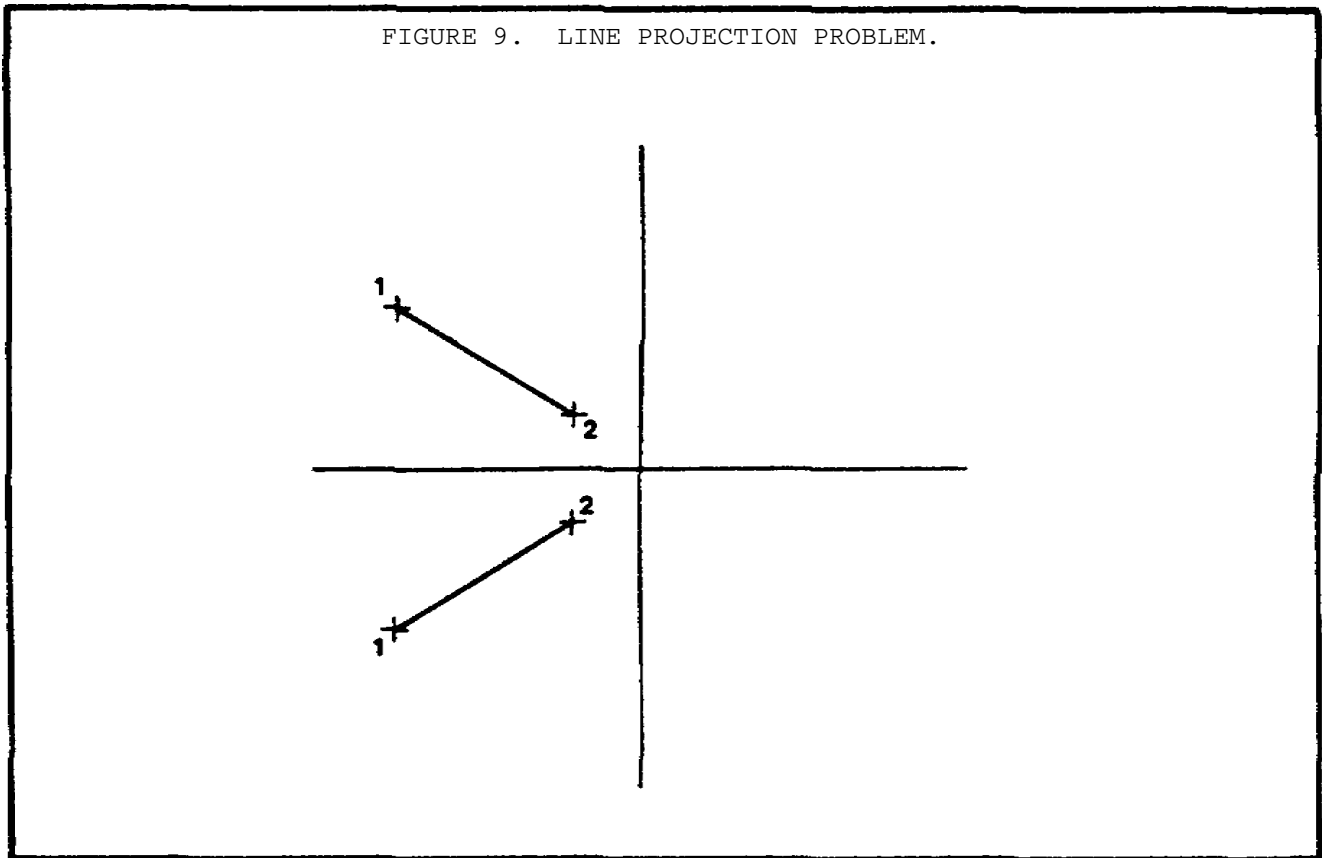
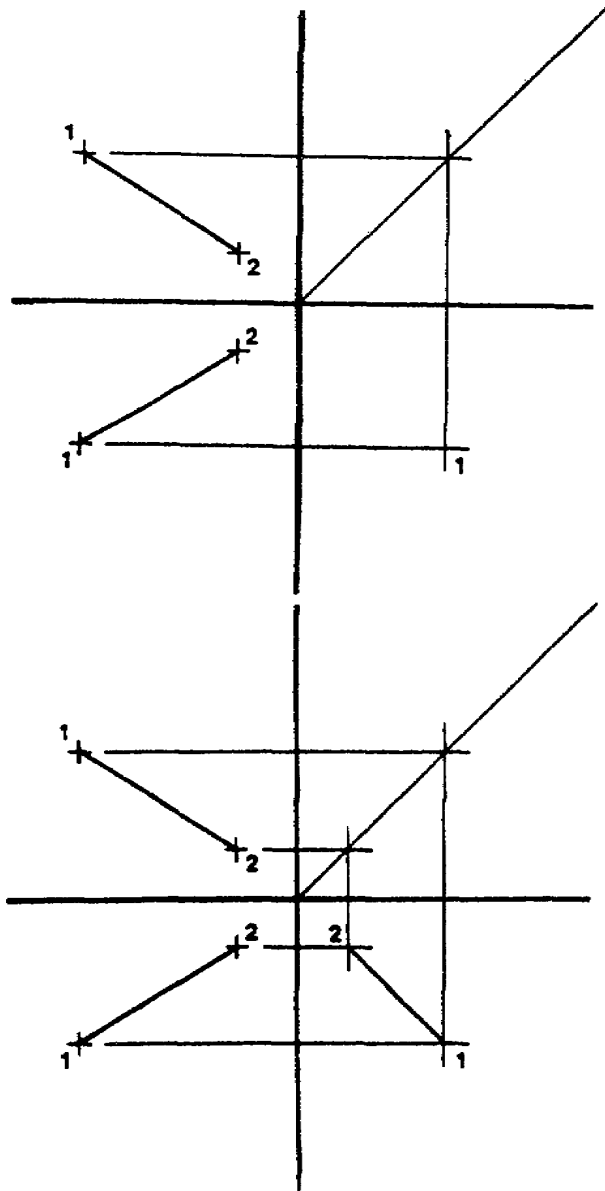


Figure 10 (on the following page) is the solution and was arrived at by the following:

- Step 1. Projecting point 1 into the right side view.
- Step 2. Projecting point 2 into the right side view.
- Step 3. Connecting points 1 and 2 with an object line.

FIGURE 10. LINE PROJECTION PROBLEM SOLUTION.



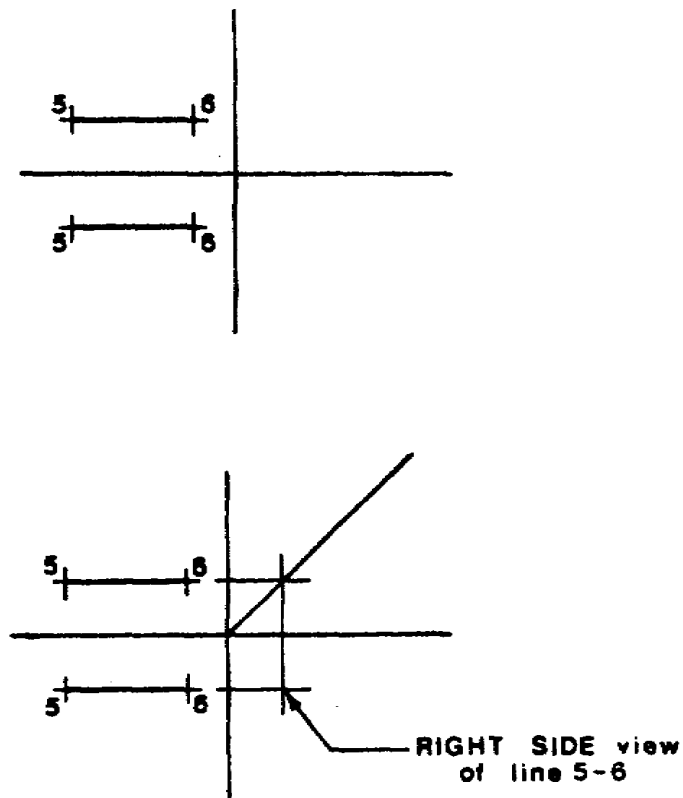
Step 3 is the right side view of line 1-2. One aspect of line projection that could cause

confusion is a double-point projection. This is clarified by the following axiom:

The end view of a straight line is a point (really a double-point).

Figure 11 is an example of a double-point projection. The solution is derived exactly as shown in figure 10 (on the previous page), except for step 3. Points 1 and 2 cannot be joined by an object line because the line extends into the paper and, therefore, appears as a double point. This may be visualized if you hold a pencil horizontal to the ground and rotate it until you are looking directly at the point, with the eraser end directly behind the point. If the point represents point 1 and the eraser represents point 2, you now have a model of the end view of a line.

FIGURE 11. END VIEW OF A LINE.



g. *Planes.* As the line projection theory was derived from the point projection theory, so the plane projection theory follows directly from the line projection theory. If we consider the following axiom:

To a draftsman, a plane is the area enclosed within a series of lines interconnected end to end.

This differs from the geometric concept of planes in that it considers a plane a finite area, that is, an area with known boundaries. Figure 12 gives the front and top views of plane 1-2-3-4 and asks for the right side view.

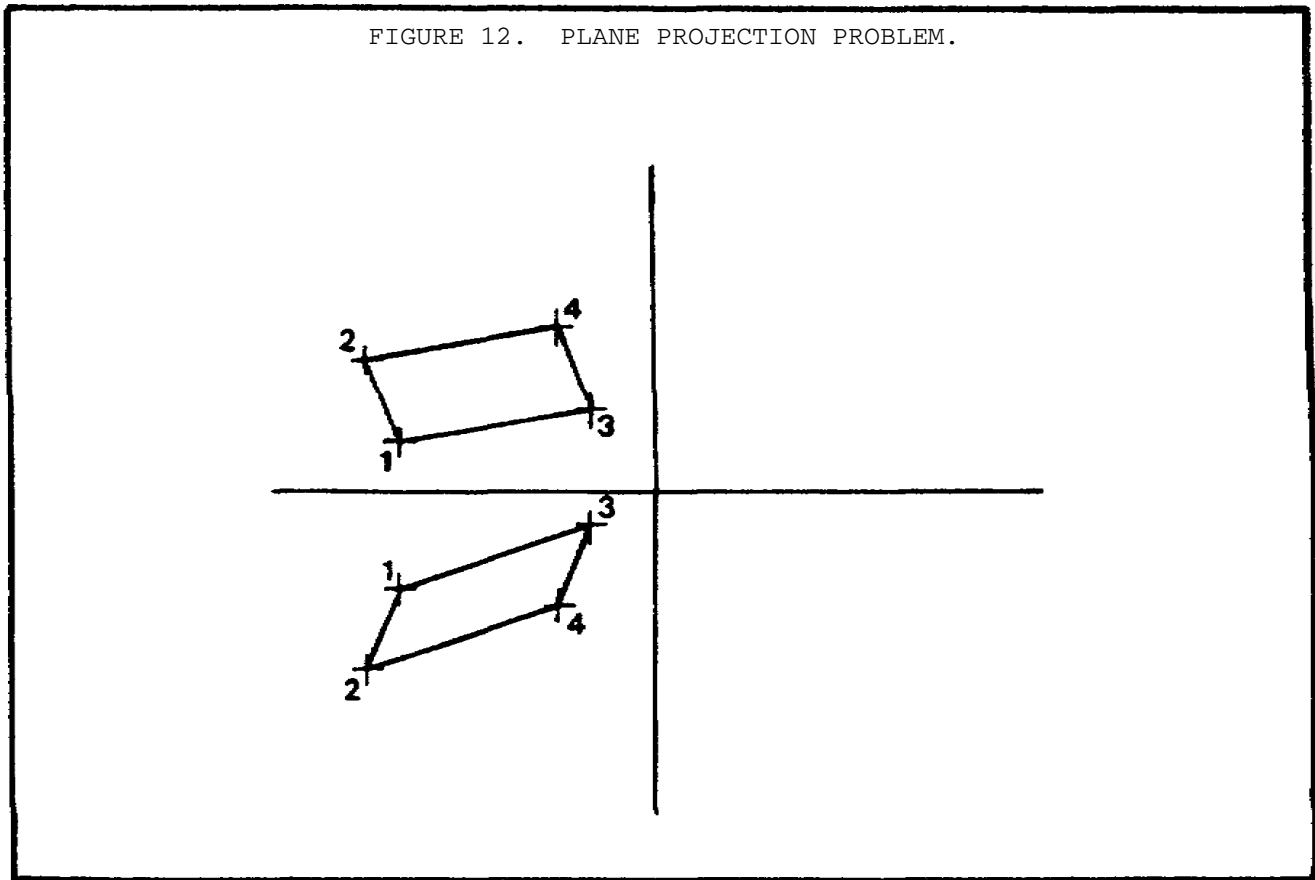
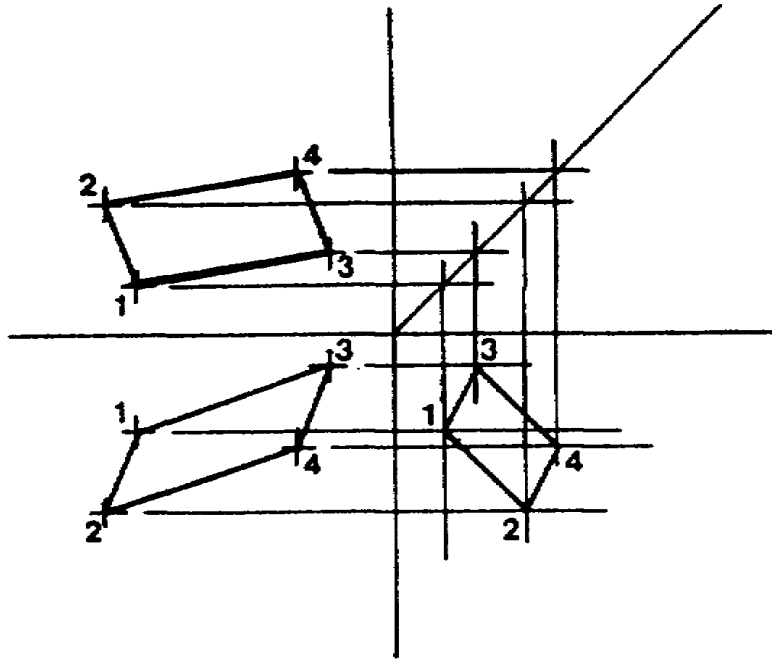


Figure 13 (on the following page) shows the solution, which was derived at by the following:

- Step 1. Identify the lines that define plane 1-2, 2-4, 4-3, and 3-1.
- Step 2. Project the individual points 1, 2, 3, and 4 into the right side view.
- Step 3. Draw in, with object lines, the lines that define the plane.

FIGURE 13. PLANE PROJECTION PROBLEM SOLUTION.



The lines drawn in step 3 define the right side view of plane 1-2-3-4.

In line theory we found that the end view of a line was a double-point. A similar situation appears in the plane theory, which is explained by the following axiom:

The end view of a plane is a line (really several lines directly behind each other).

This may be verified by holding a sheet of paper horizontal to the ground and rotating it until you are looking directly at one edge. Although it is a plane, the sheet appears as a line.

h. *Curves.* So far, we have considered only straight lines. Point, line, and plane projection theory may be extended to include curved lines if we consider the following axioms:

To a draftsman, a curved line is a visible line connecting three or more points which form a smooth, nonlinear line.

To a draftsman, the accuracy of a curve is a function of the number of points used to define the curve.

To draw a perfectly accurate curve would require an infinite number of points. To do this is not only impossible, it is also impractical. Most curves may be very closely approximated by a finite number of points, and it is up to the draftsman to determine what level of accuracy is required and how many points he needs to achieve this level. Circles and perfect arcs are exceptions to the axioms because they may be drawn with perfect accuracy using a compass.

Figure 14 is an example of the curved line projection problem, while figure 15 (on the following page) offers the solution to this problem.

FIGURE 14. CURVED LINE PROJECTION PROBLEM.

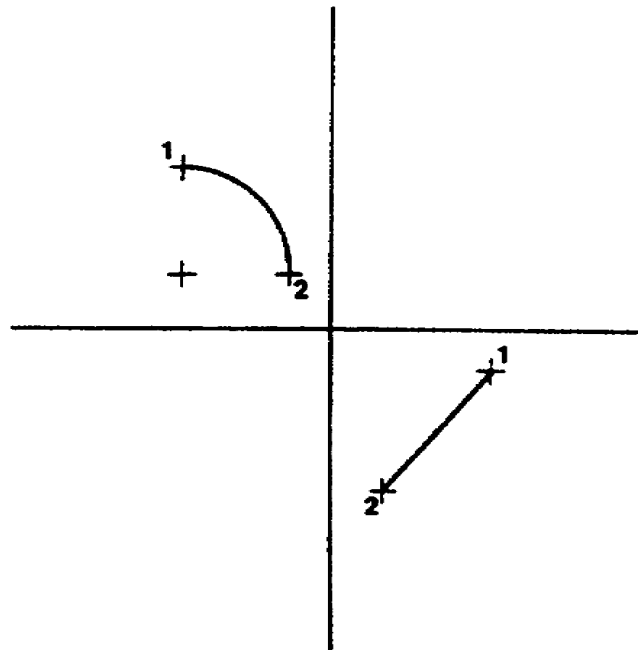
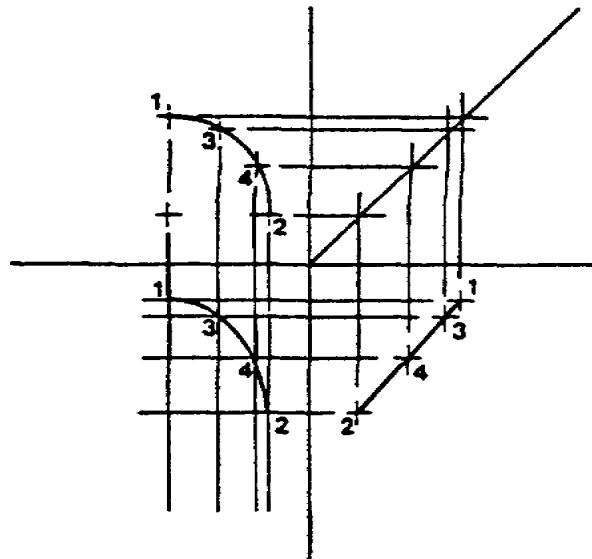
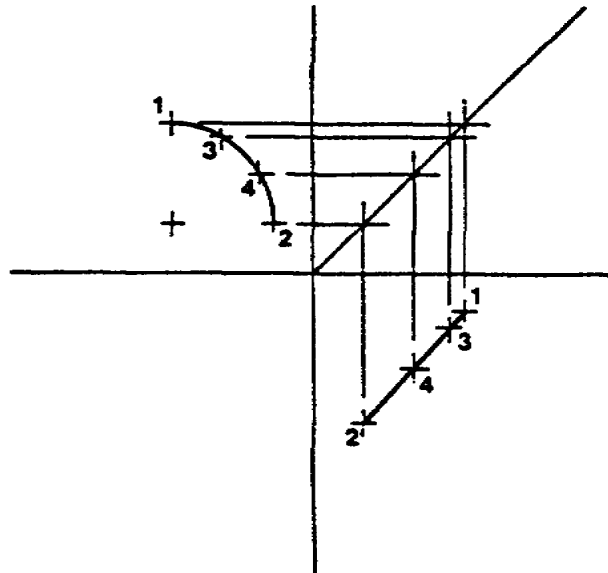


FIGURE 15. CURVED LINE PROJECTION PROBLEM SOLUTION.



3. Freehand Drafting

In the machine shop, the sketch or freehand drawing is a quick, accurate, and clear method of conveying ideas. Although sketching is not essential to the reading of a shop drawing, it is helpful in learning the language of mechanical drawings.

Sketches are made rapidly and usually without the aid of drawing instruments, but they must be accurate and complete. Omissions and mistakes that would be discovered in making a scale drawing might easily be overlooked in a freehand sketch. Extreme care, therefore, must be taken to ascertain that all information is accurate and that nothing has been omitted.

a. *Kinds of Sketches.* Sketches are divided into two general classes as follows:

(1) *Class I.* Class I sketches include sketches made before the project is started.

(a) *Idea.* Used in studying and developing the arrangement and proportion of parts.

(b) *Computation.* Used in connection with mathematical calculations for motion and strength.

(c) *Executive.* Drawn by the inventor or engineer to give instruction for special arrangements or ideas that must be embodied in design.

(d) *Design.* Used for putting ideas into form from which the design drawing can be started.

(e) *Working.* Used as substitutes made from finished project.

(2) *Class II.* Class II sketches include sketches made from the finished project.

(a) *Detail.* Made from existing drawings or parts with complete notes and dimensions. They must include information essential to the making of parts, or mechanical drawings of the parts.

(b) *Assembly.* Made from an assembled project to show the relative position of the various parts, with center and location dimensions, or sometimes with complete dimensions and specifications.

(c) *Diagrammatic.* Usually made for the purpose of locating and setting up projects.

b. *Equipment and Materials.* In the following paragraphs, some of the materials required to make a good sketch of an object will be discussed.

(1) *Paper.* Either plain or cross-section (grid) will be used.

(2) *Pencil.* Medium, sharpened to a long conical point, not too sharp.

(3) *Eraser.* Art gum or regular, but to be used only when a clean, clear job can be accomplished.

(4) *Measuring Devices.*

(a) Rule or scale

(b) Calipers

(c) A square, thread gage, and micrometer, on occasions where more accurate sketches are required.

c. *Technique.* In drawing any straight line between two points, keep the eyes on the point to which the line is to go rather than on the point of the pencil. Do not try to draw the complete line in a single stroke. Usually, it is advisable to draw a light line first, and then correct any discrepancies in the light line with a heavy line. Accuracy of direction is more important than the smoothness of the line. To obtain this accuracy, hold the pencil freely, not too close to the point, and draw the different lines as follows:

(1) *Vertical Lines.* Draw downward with a finger movement in a series of overlapping strokes.

(2) *Horizontal Lines.* Draw with either a wrist or forearm motion.

(3) *Inclined Lines.* When running downward from right to left, draw with the same motion used for vertical lines. When they run downward from left to right, turn the paper and draw them as horizontal lines.

PRIN. OF DRAFTING AND SHOP DRAWINGS - OD1641 - LESSON 1/TASK 1

(4) *Circles.* Draw by marking the radius on each side of the center lines, then sketch the circumference.

d. *Procedure.* A systematic order of application should be followed for both idea sketches and sketches from objects. It is outlined as follows:

(1) *Visualize Object.* This is essential so that the mental image is definite and clear and a good graphical description can be developed.

(2) *Determine Views.* The views may or may not be the same as for a scale drawing, depending upon the purpose of the sketch; e.g., a note in regard to the thickness or shape of the section will often be used to save a view.

(3) *Determine Size.* A sketch should be in proportion to the sheet of paper. It should be large enough to show all detail clearly, but allow plenty of room for dimensions, notes, and specifications.

(4) *Locate Center Lines.* Always locate the center lines first when beginning a sketch.

(5) *Block in Main Outlines.* Watch carefully the proportions of width to height in this step. Select one edge as a unit from which to estimate the proportionate lengths of the other edges.

(6) *Complete Detail.* After the main outline is satisfactory, fill in the details in correct proportion.

(7) *Dimension Lines and Arrowheads.* When the shape of the object has been completely described, the dimension lines and arrowheads should be added. No measurements are taken until this step is completed.

(8) *Dimensions.* Now the sketch is ready to have dimensions inserted on it. These dimensions are obtained with a rule or a steel cable. All measurements should be taken from finished surfaces.

(9) *Titles and Notes.* These should be inserted together with the date so that, in the case of new inventions, it is possible to prove priority.

(10) *Check.* The sketch should be given a final check. Be sure this is done very carefully.

4. Conclusion

This concludes task one, which dealt with orthographic projection and freehand drafting. In task two, we will cover drafting instruments and the fundamentals of geometric construction.

LESSON 1

DRAFTING AND SHOP DRAWING FUNDAMENTALS

TASK 2. Describe drafting instruments and the fundamentals of geometric construction.

CONDITIONS

Within a self-study environment and given the subcourse text, without assistance.

STANDARDS

Within one hour

REFERENCES

No supplementary references are needed for this task.

1. Introduction

In task one of this subcourse, we covered orthographic projection and freehand drafting. In this task, we will cover drafting instruments and the fundamentals of geometric construction.

2. Drafting Instruments

In the following paragraphs, we will cover some of the drafting instruments that may be encountered and used; however, we will not cover such common instruments as pencils and erasers.

a. *Scales.* Scales are used for linear measuring. The scale most commonly used by a draftsman is one with its inches graduated into sixteen divisions, with each division measuring one-sixteenth of an inch. Figure 16 (on the following page) shows part of a "16 to the inch" scale, together with some sample measurements. Unlike a real scale, the scale in figure 16 has the first inch completely labeled to help you become familiar with the different fractional values. Measurements more

FIGURE 16. A 16-TO-THE INCH SCALE WITH SOME SAMPLE MEASUREMENTS.

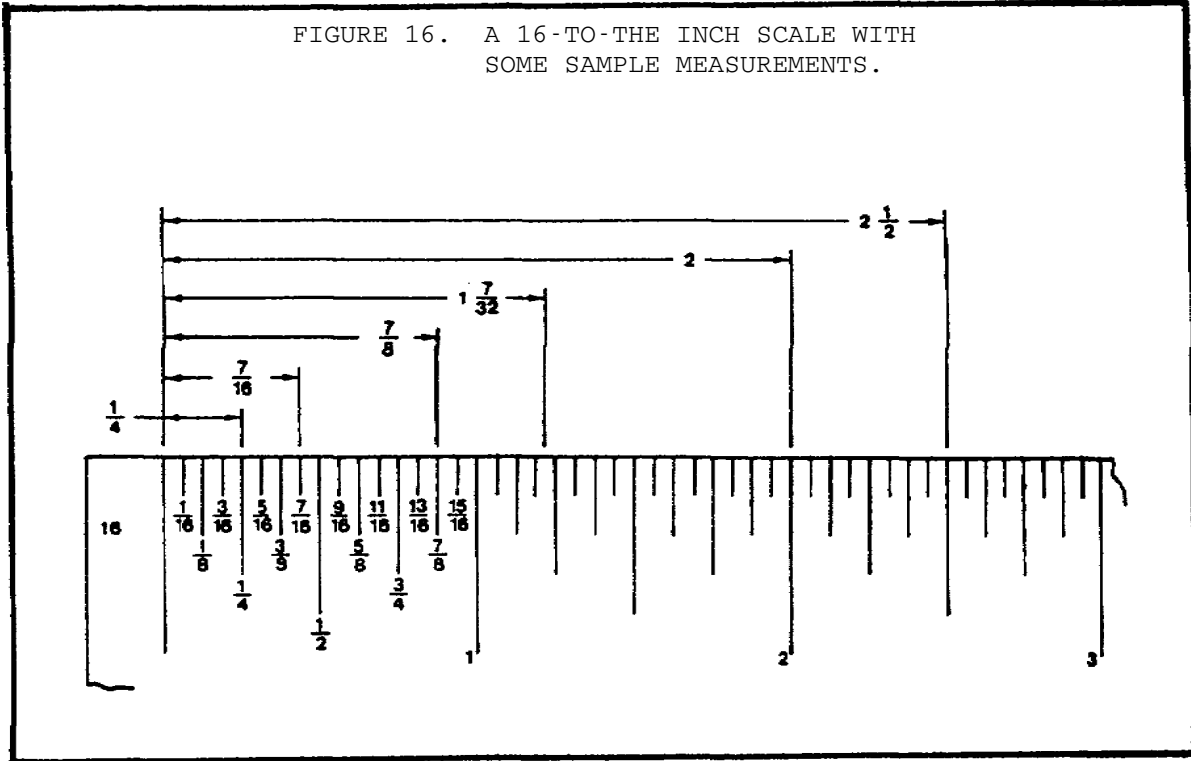
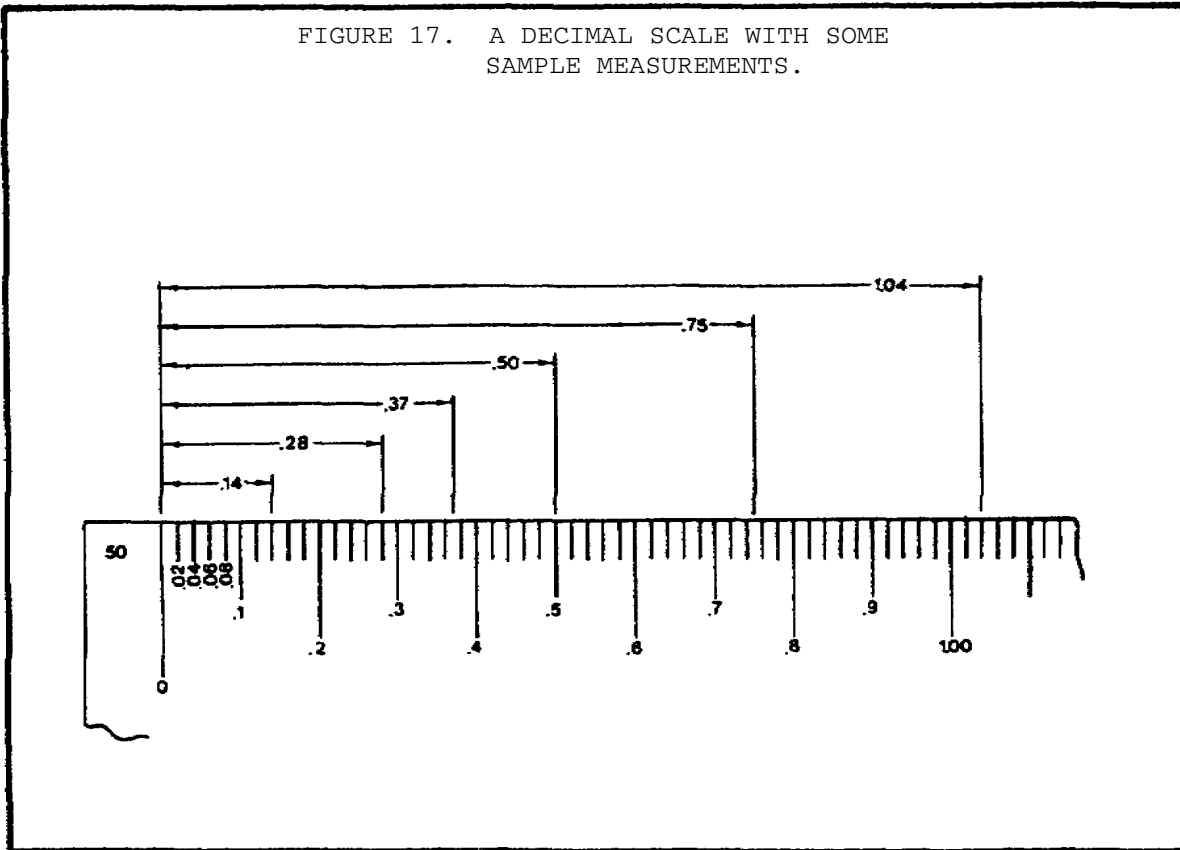


FIGURE 17. A DECIMAL SCALE WITH SOME SAMPLE MEASUREMENTS.

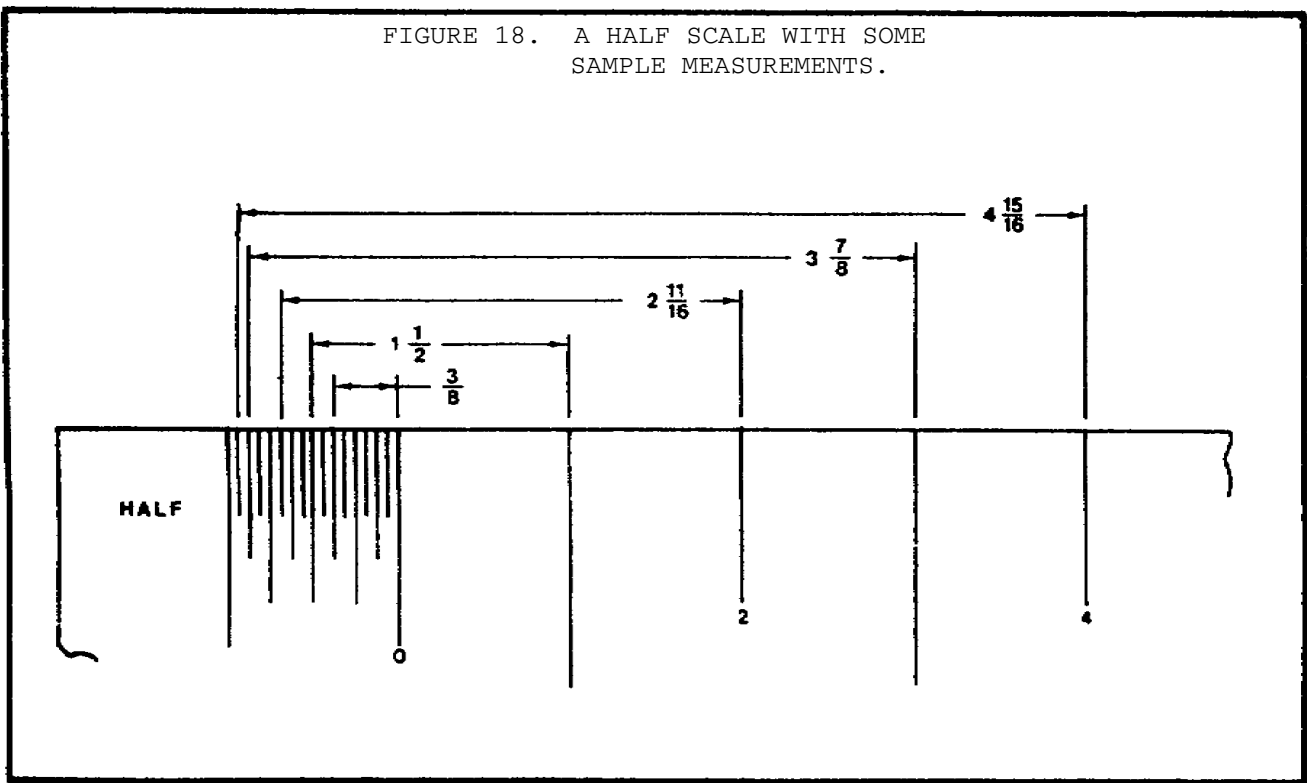


accurate than one-sixteenth must be estimated. For example, $1/32$ is halfway between the 0 and the $1/16$ marks.

Figure 17 (on the previous page) shows part of a decimal scale. Each inch is divided into 50 equal parts making it possible to make measurements within 0.01 inch (hundredth of an inch) accuracy. Several sample readings have been included and the first 0.10, unlike a real decimal scale, has each graduation mark labeled.

Many scales are set up for other than full-sized drawings. For example, the $1/2$ scale enables a half-sized drawing to be made directly without having to divide each dimensional value by 2. Three-quarter scales enable direct $3/4$ sized drawings to be made, and so on.

All fractional scales are read as shown in figure 18. Only one of the sections representing an inch is graduated into fractional parts. This graduated section is located to the left of the "0" mark. When making a reading (for example $3 \frac{7}{8}$) on a fractional scale, read the whole (3) part of the number to the right of the "0" and the fractional part ($7/8$) to the left. See figure 18 for an example of a $3 \frac{7}{8}$ reading on a half-scale.



b. *T-Square and Triangles.* A T-square is used as a guide for drawing horizontal lines and as a support for the triangles which, in turn, are used as guides for drawing vertical and inclined lines. To use a T-square or triangle as a guide for drawing lines, pull the pencil along the edge of the straight edge from left to right. (These directions are for right-handed people. Left-handed people should reverse the directions.) Rotate the pencil as you draw so that a flat spot will not form on the lead. Flat spots cause wide, fuzzy lines of uneven width. Always remember to keep your drawing lead sharp.

When using a T-square, hold the head (top of the T) firmly and flat against the left edge of the drawing board. Use your left hand to hold the T-square still and in place while you draw. When you move the T-square, always check to see that the head is snug against the edge of the drawing board before you start to draw again.

When a T-square and a triangle are used together to create a guide for drawing, the left hand must not only hold the T-square firmly in place; it must also hold the edge of the triangle firmly and flat against the edge of the T-square. To accomplish this, use the heel of your hand to hold the T-square in place and your fingers to keep the triangle against the T-square.

It is important that all your tools be accurate. A T-square, for example, must have a perfectly straight edge. If it does not, you will draw wavy lines and inaccurate angles with the triangles. To check a T-square for accuracy, draw a long line by using the T-square as a guide. Then flip the T-square over and, using the same edge just used as a guide, see if the T-square edge (now upside down) matches the line. If it does not, the T-square is not accurate.

Triangles should be checked for straightness in the same manner used to check a T-square, but, in addition, they must be checked for "squareness." To check a triangle for squareness, align the triangle against the T-square and draw a line by using the edge of the triangle which forms a 90° angle to the T-square as a guide. Holding the T-square in place, flip the triangle over, and see if the triangle edge matches the line. If it does not, the triangle is not square, meaning either

that the 90° angle is not 90° , or that the edge of the triangle is curved, or that the edge of the T-square is curved.

To use the T-square and the triangle as a guide for drawing a line parallel to a given inclined line, align the long leg of the triangle with the given line and then align the T-square to one of the other legs of the triangle. By holding the T-square in place with your left hand, you can slide the triangle along the T-square and the long leg will always be parallel to the originally given line.

c. *Compass.* A compass is used to draw circles and arcs. The three basic kinds of compass are drop, bow, and beam. The bow is the most common.

To use a compass, set the compass opening equal to the radius of the desired circle or arc by using a scale. Then place the compass point directly on the circle center point and, using only one hand, draw in the circle.

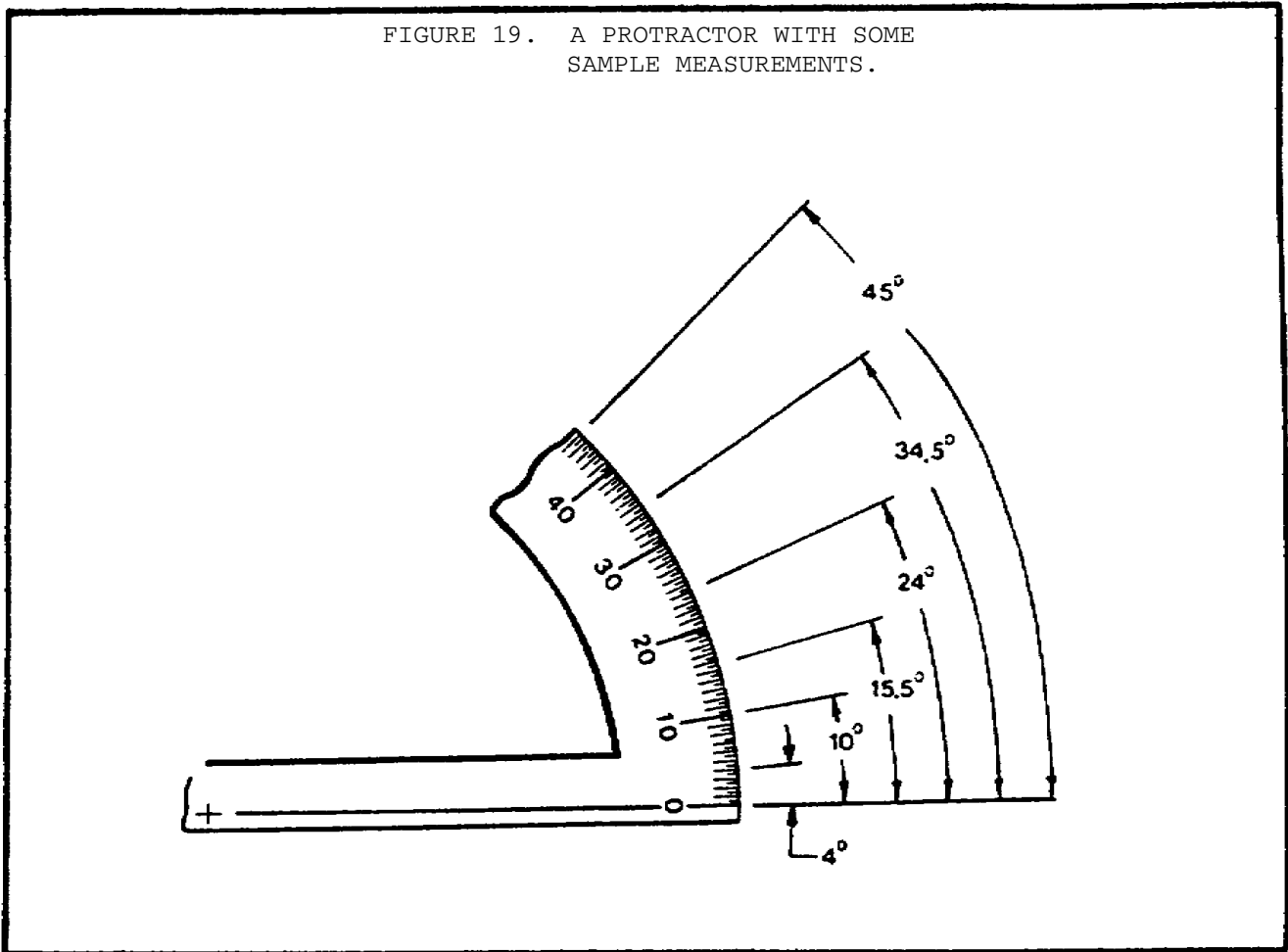
d. *Protractors.* A protractor is used to measure angles. The edge of a protractor is calibrated into degrees and half-degrees. Figure 19 (on the following page) shows part of a typical protractor edge, together with some sample measurements. Measurements more accurate than half a degree (0.5°) must be estimated.

To measure an angle, place the center point of the protractor on the origin of the angle so that one leg of the angle aligns with the 0° mark on the protractor. Read the angle value where the other leg of the angle intersects the calibrated edge of the protractor.

e. *Curves.* Curves are used to help draw noncircular curved shapes. Draftsmen refer to them as *French curves* or *ship's curves*, depending on their shapes (ship's curves look like the keel of a ship).

Noncircular shapes are usually defined by a series of points and a curve is used to help join the points with a smooth, continuous line. Using a curve to help create a smooth line is difficult and requires much practice.

FIGURE 19. A PROTRACTOR WITH SOME SAMPLE MEASUREMENTS.



f. *Templates.* Templates are patterns cut into shapes useful to a draftsman. They save drawing time by enabling the draftsman to accurately trace a desired shape. Some templates provide shapes that are difficult to draw with conventional drawing tools (very small circles, for example). Other templates provide shapes that would be tedious and time-consuming to layout and draw (ellipses, for example).

The most common template used in mechanical drafting is the circle template. The holes of a circle template are labeled by diameter size and are generally made slightly oversized to allow for lead thickness. Always check a circle template before initial use to see if lead allowance has been included.

To use a circle template, locate the center point of the future circle with two lines 90° to each other. Align the template with the two 90° lines by using the four index marks printed on the edge of the template hole. Draw in the circle. Keep

the leadholder vertical and constantly against the inside edge of the hole pattern. Check the finished circle with a scale.

g. *Other Tools.* There are many tools, other than the ones already presented, which are used to help create technical drawings. One such tool is an adjustable curve or snake, which is useful when drawing unusually shaped curves.

Another tool is the drafting machine. A drafting machine is a combination T-square, triangle, protractor, and scale which, when used properly, will greatly increase drawing efficiency. The information previously presented for using a T-square, triangle, protractor, and scale may be directly applied to using a drafting machine.

This concludes the discussion on drafting tools. In the following paragraphs, we will discuss the fundamentals of geometric construction.

3. Geometric Construction

Geometric constructions are the building blocks of drafting. Every drawing, regardless of its difficulty, is a geometric shape. A rectangle is four straight lines and four right angles. A cam is a series of interconnected arcs of various radii. Every repair shop technician must have a fundamental knowledge of geometric constructions if he is to progress to more difficult work.

In the following paragraphs, we will discuss some of the geometric constructions that may be encountered.

a. *Points and Lines.* A point, to a draftsman, is defined as the intersection of two construction lines (figure 20 on the following page).

NOTE

A dot should not be used to define a point because a dot may be easily confused with other marks on the drawing and thereby cause errors.

FIGURE 20. POINTS.

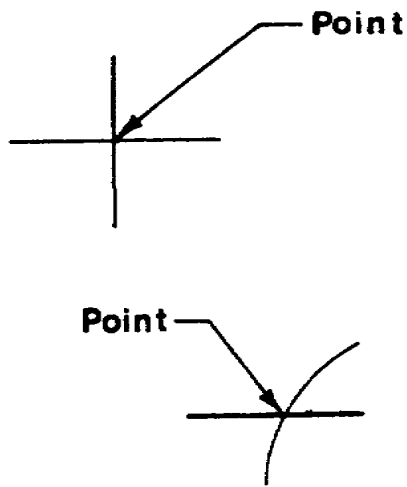
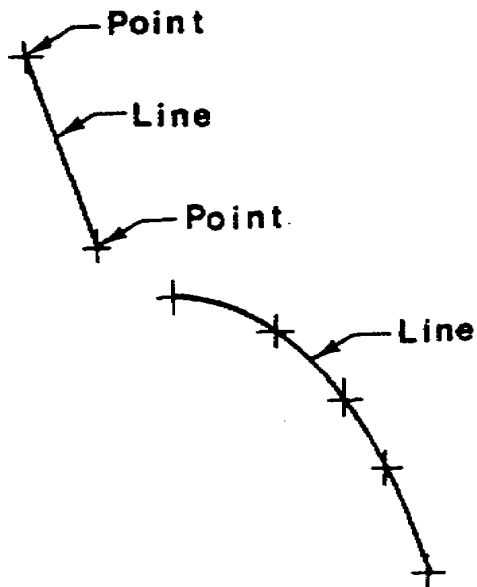


FIGURE 21. LINES.



A line, to a draftsman, is an object line connecting two or more points (figure 21 on the previous page).

NOTE

The accuracy of a curved line depends on the number of points used to define it. The number of points used depends on the accuracy required for the particular curve.

b. *Bisecting*. Bisecting is the geometric way of finding the center of a line or an angle. In the following subparagraphs, we will discuss the two procedures for bisecting a line and the procedure for bisecting an angle.

(1) *Bisect a Line - First Method* (figure 22 on the following page). Let's assume we are given a line (1-2, view A). Our problem is that we have to divide this line into two equal parts. To divide the line into two equal parts, perform the following steps:

Step 1. Construct an arc of radius R. Use point 1 as the center. R = any radius of greater length than 1/2 of line 1-2 (view B).

Step 2. Construct an arc of radius R. Use point 2 as the center (view C).

Step 3. Define the intersection of the arcs as points 3 and 4 (view C).

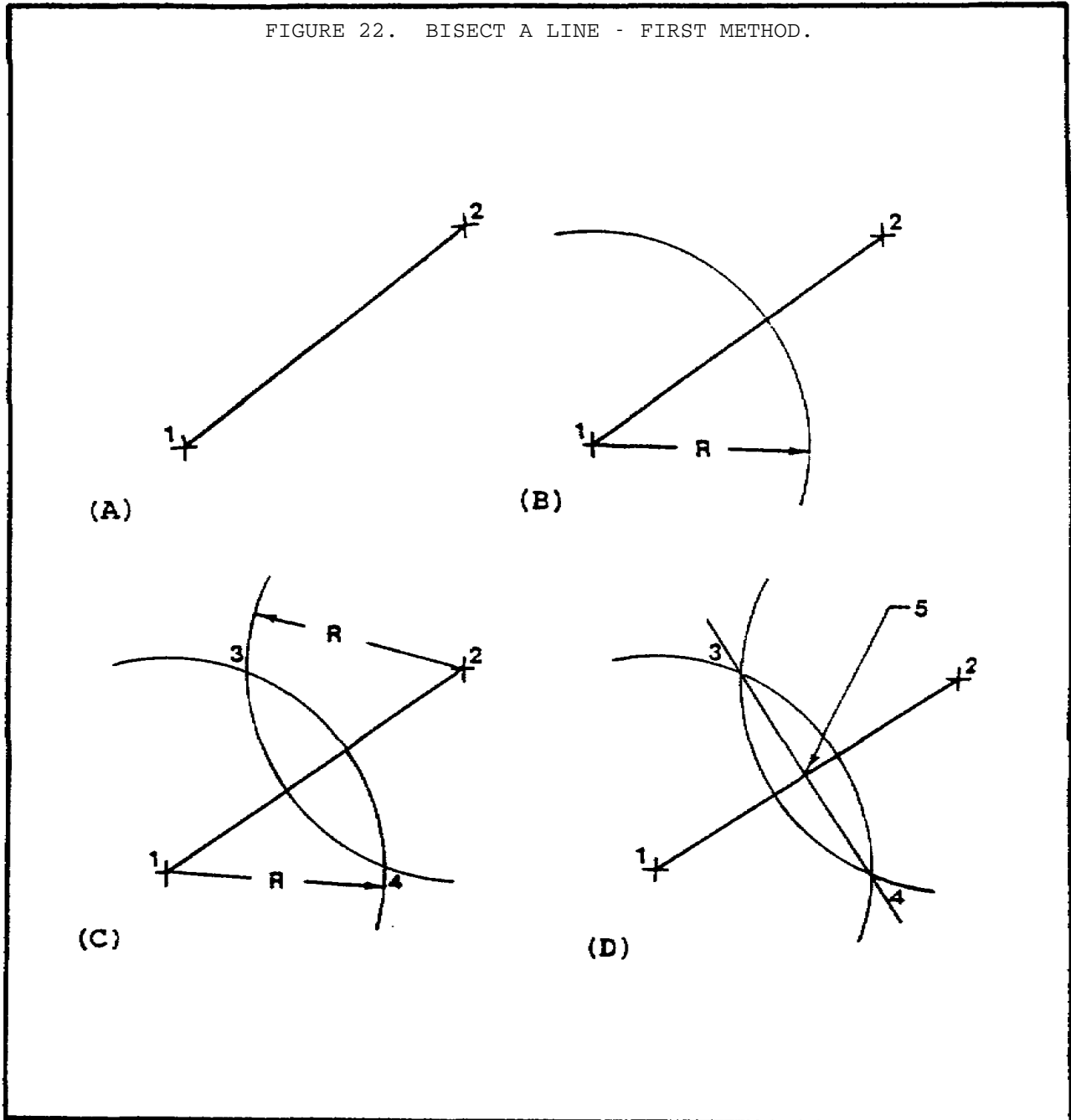
Step 4. Connect points 3 and 4 with a construction line (view D).

Step 5. Define point S where line 3-4 intersects line 1-2. Line 1-5 is equal to line 5-2

NOTE

This is the classical method as taught in plane geometry.

FIGURE 22. BISECT A LINE - FIRST METHOD.

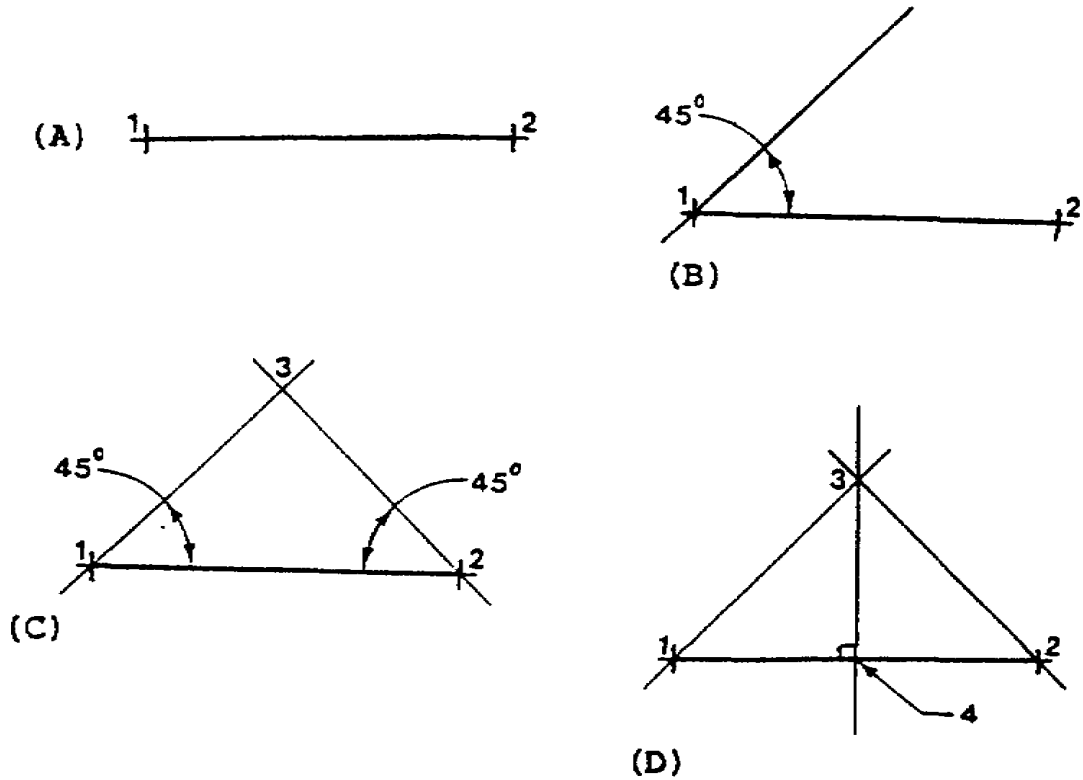


(2) *Bisect a Line - Second Method*, (figure 23 on the following page). Let's assume that we have a line (1-2, view A). Again our problem is to divide the line into two equal parts. To divide this line into two equal parts, perform the following steps:

NOTE

This method relies on drafting equipment for completion. Any angle may be used in steps 1 and 2 as long as they are equal.

FIGURE 23. BISECTING A LINE - SECOND METHOD.



Step 1. Align the T-square with line 1-2 and, using a 45-45-90° triangle as a guide, construct a line 45° to line 1-2 through point 1 (figure 23, view B)

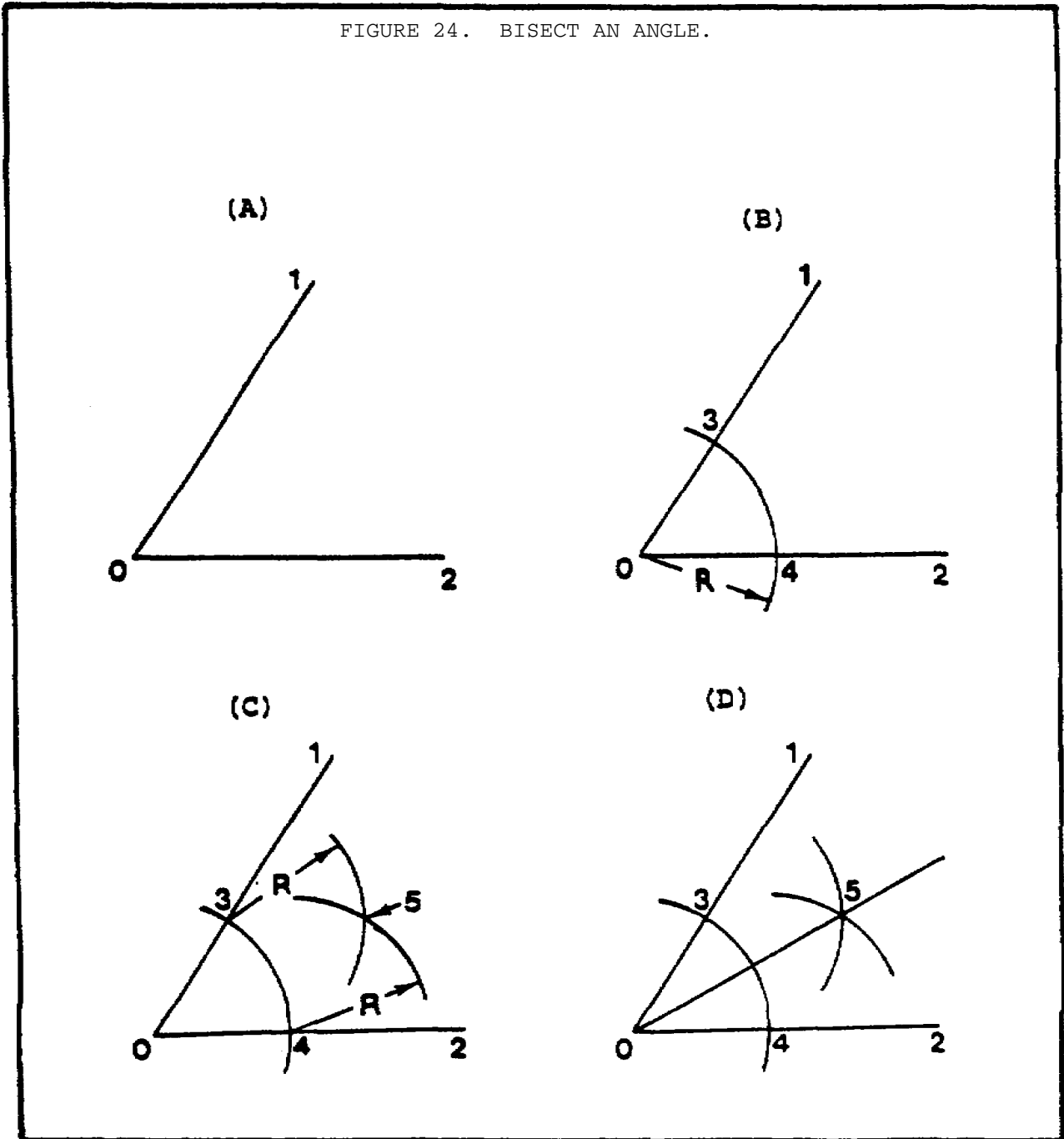
Step 2. Repeat step 1, this time constructing the 45° line through point 2 (view C).

Step 3. Define the intersection of the construction line as point 3 (view C).

Step 4. Draw a line through point 3 perpendicular to line 1-2 which intersects line 1-2 (view D).

Step 5. Define point 4 as shown in view D. Line 1-4 is equal to line 4-2.

(3) *Bisect an Angle*, (figure 24). Let's assume that we have an angle (1-0-2, view A). Our problem is that we have to bisect this angle. To bisect this angle, perform the following steps:



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- Step 1. Construct an arc of radius R. Use point 0 as the center (view B).
- Step 2. Define points 3 and 4 where the arc intersects lines 0-1 and 0-2 (view B).
- Step 3. Using points 3 and 4 as centers, construct two more arcs of radius R as shown in view B.
- Step 4. Define the intersection of the two arcs as point 5 (view C).
- Step 5. Construct a line 0-5. Angle 1-0-5 is equal to angle 5-0-2 (view D).

c. *Divide a Line.* In the following subparagraphs, we will discuss the procedures for dividing a line into any number of equal parts and dividing a line into proportional parts.

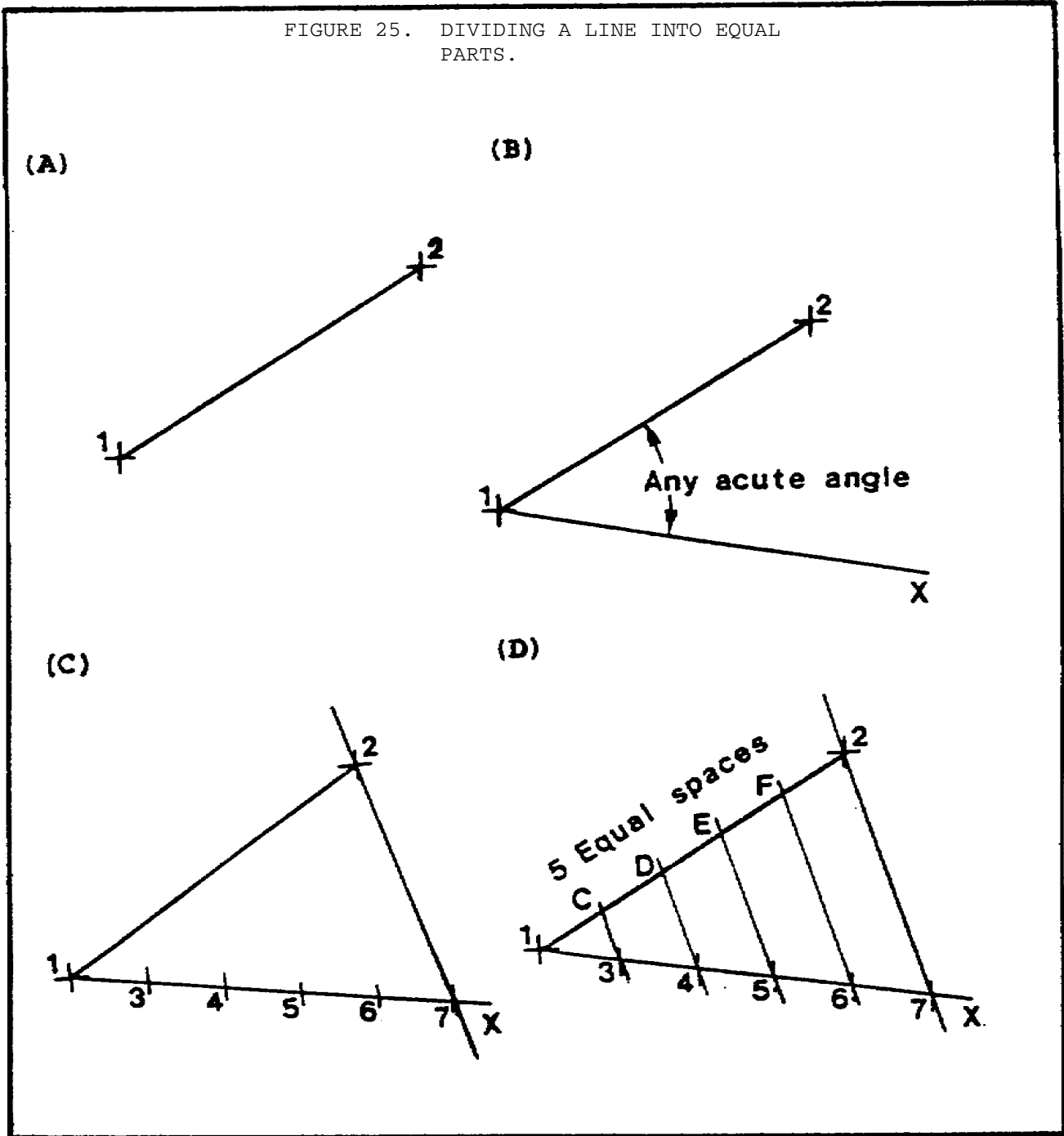
(1) *Divide a Line into Equal Parts,* (figure 25, on the following page). Let's assume that we have a line 1-2 (view A). We have to divide this line into five equal parts. To divide the line perform the following steps:

- Step 1. Construct a line A-X at any angle to line 1-2 (figure 25, view B).
- Step 2. Mark off five equal spaces along line 1-X and construct a line 2-7 (view C).

NOTE

Any size space may be used as long as they are all equal in length.

- Step 3. Draw lines 6-F, 5-E, 4-D, and 3-C parallel to line 2-7 (figure 25, view D).



(2) *Divide a Line into Proportional Parts*, (figure 26, on the following page). Let's assume that we have a line 1-2 (view A) and that we need to divide this line into proportional parts of 1, 3, and 5. To do this, perform the following steps:

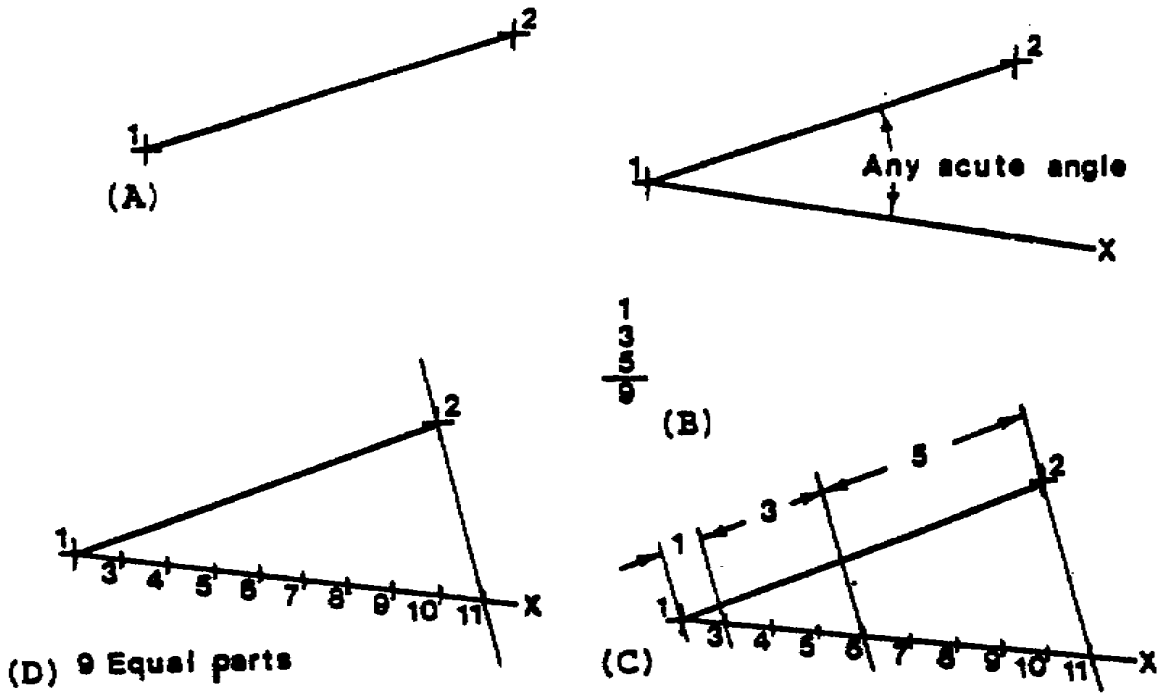
Step 1. Add up the total number of proportional parts required and use the total number derived as if the problem were to divide the line into equal parts (figure 26, view B).

Step 2. Refer back to the procedures contained in paragraph 3c(1) on page 32, to divide the line into equal parts (view C).

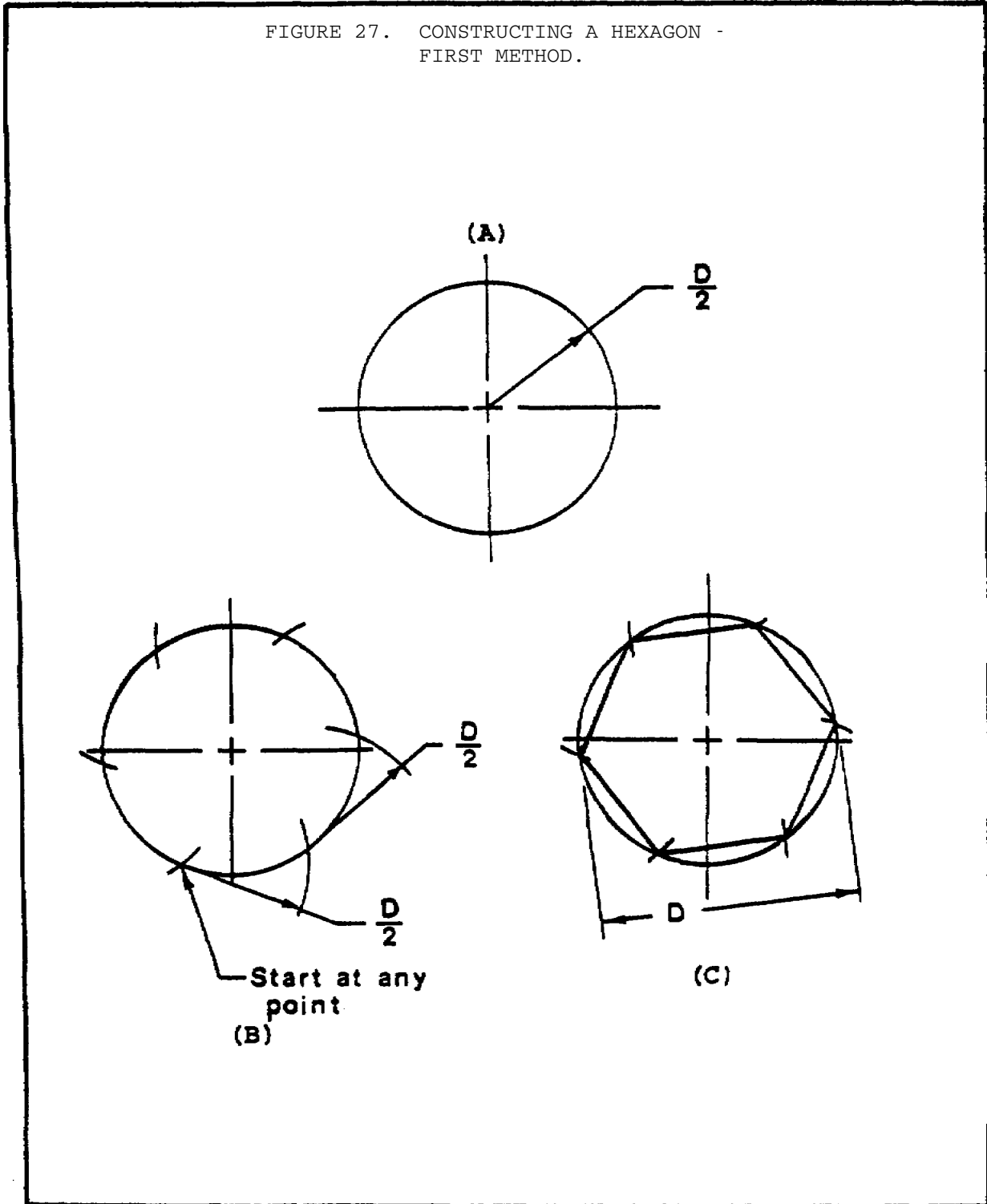
Step 3. Then, mark off the required proportional parts (view D).

d. *Hexagon.* In the following subparagraphs, we will discuss the five procedures for constructing a hexagon.

FIGURE 26. DIVIDE A LINE INTO PROPORTIONAL PARTS.



(1) *Construct a Hexagon - First Method*, (figure 27). Let's assume that we have to draw a hexagon D across the opposite corners. To construct a hexagon, perform the following steps:



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Step 1. Construct a circle of diameter D. $\text{Diameter}/2 = \text{radius}$. Set a compass to the radius dimension (view A).

Step 2. Using the compass, mark off six distances $D/2$ as shown in view B.

Step 3. Draw in the hexagon (view C).

This is the classical geometric method and is not generally used by draftsman because it makes positioning of the hexagon difficult.

(2) *Construct a Hexagon - Second Method*, (figure 28 on the following page). We will construct a hexagon S across the opposite corners by performing the following steps.

Step 1. Construct a circle of diameter S (view A).

Step 2. Define points 2 and 3 as shown in view A (figure 27 on the previous page).

Step 3. Using points 2 and 3 as the center, construct two arcs of radius $S/2$ (view B).

Step 4. Define points 4, 5, 6, and 7 as shown in view C.

Step 5. Draw in the hexagon (view C).

(3) *Construct a Hexagon - Third Method*, (figure 29 on page 38). Let's assume that we have to construct a hexagon A across the opposite corners. Construct it by performing the following steps:

Step 1. Construct a circle of diameter A.

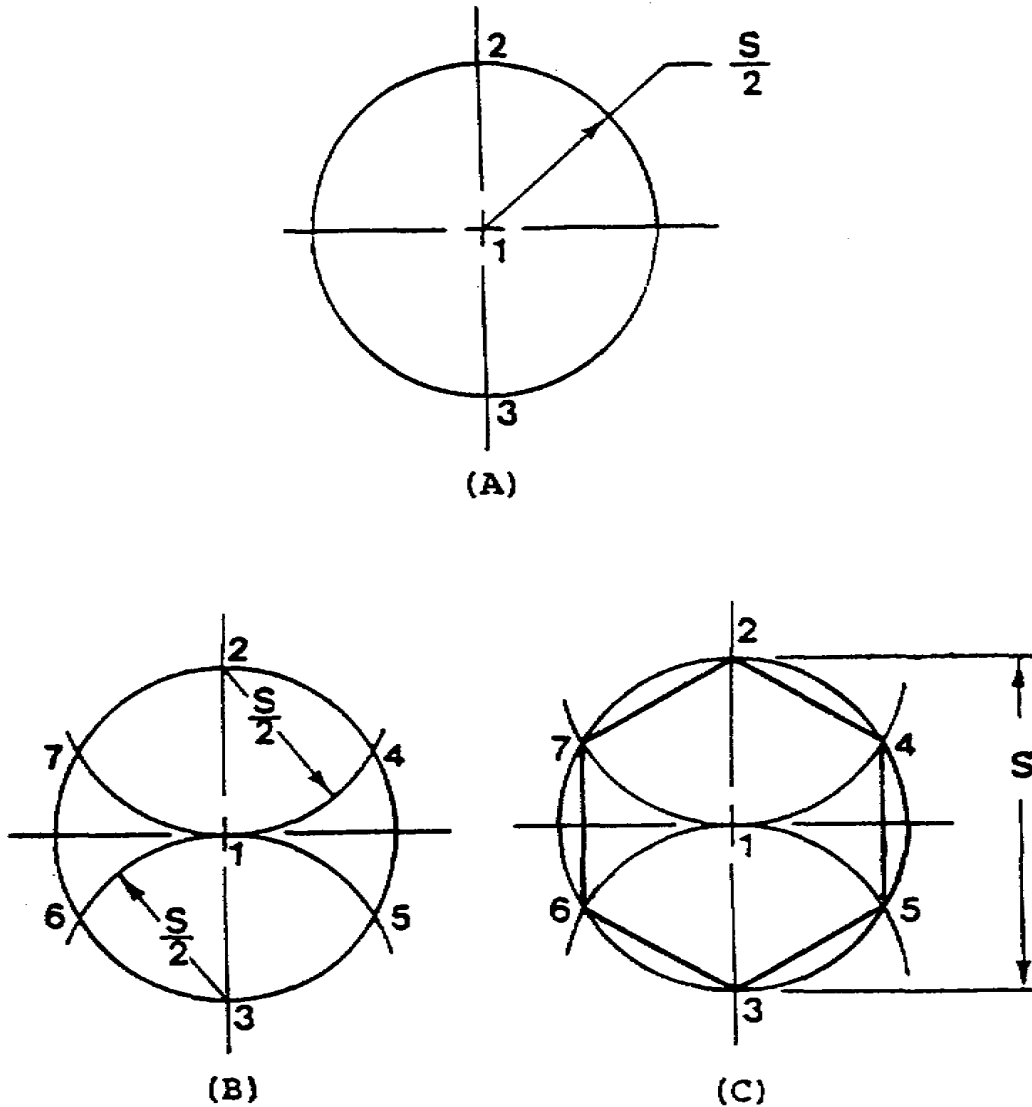
Step 2. Using a 60° triangle, construct lines 60° to the horizontal as shown in view A.

Step 3. Define points 1, 2, 3, and 4 (view A).

Step 4. Construct lines 1-2 and 3-4 (view B).

Step 5. Draw in the hexagon (view C).

FIGURE 28. CONSTRUCT A HEXAGON - SECOND METHOD.

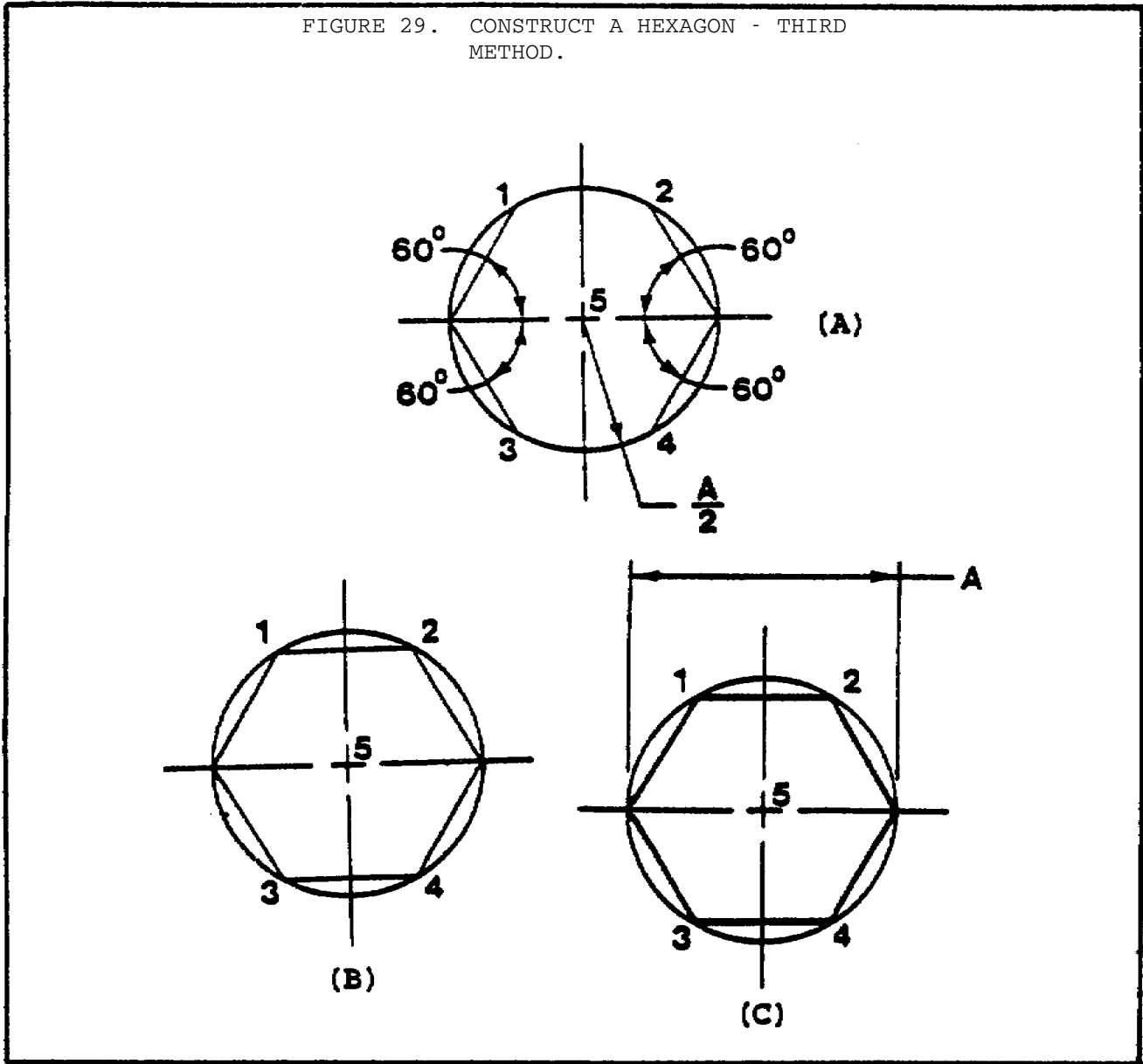


(4) *Construct a Hexagon - Fourth Method*, (figure 30 on page 39). In this problem we have to construct a hexagon B across the opposite corners. To construct this hexagon, perform the following steps:

Step 1. Construct a circle of diameter B.

Step 2. Using a 30° triangle, construct lines 30° to the horizontal as shown in figure 30, view A, on the following page.

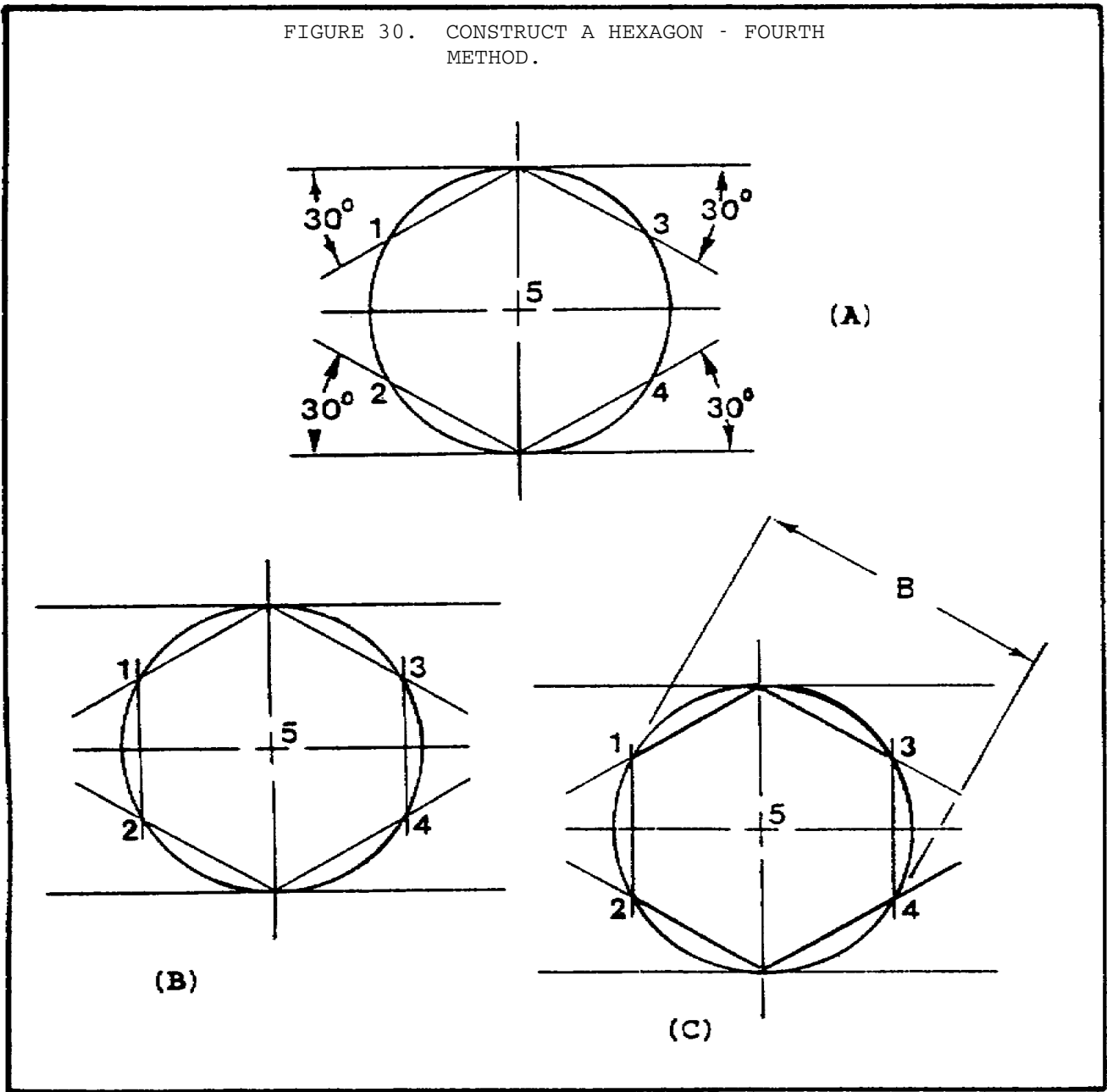
Step 3. Define points 1, 2, 3, and 4 (view A).



Step 4. Construct lines 1-2 and 3-4 (figure 30, view B).

Step 5. Draw in the hexagon (view C).

FIGURE 30. CONSTRUCT A HEXAGON - FOURTH METHOD.



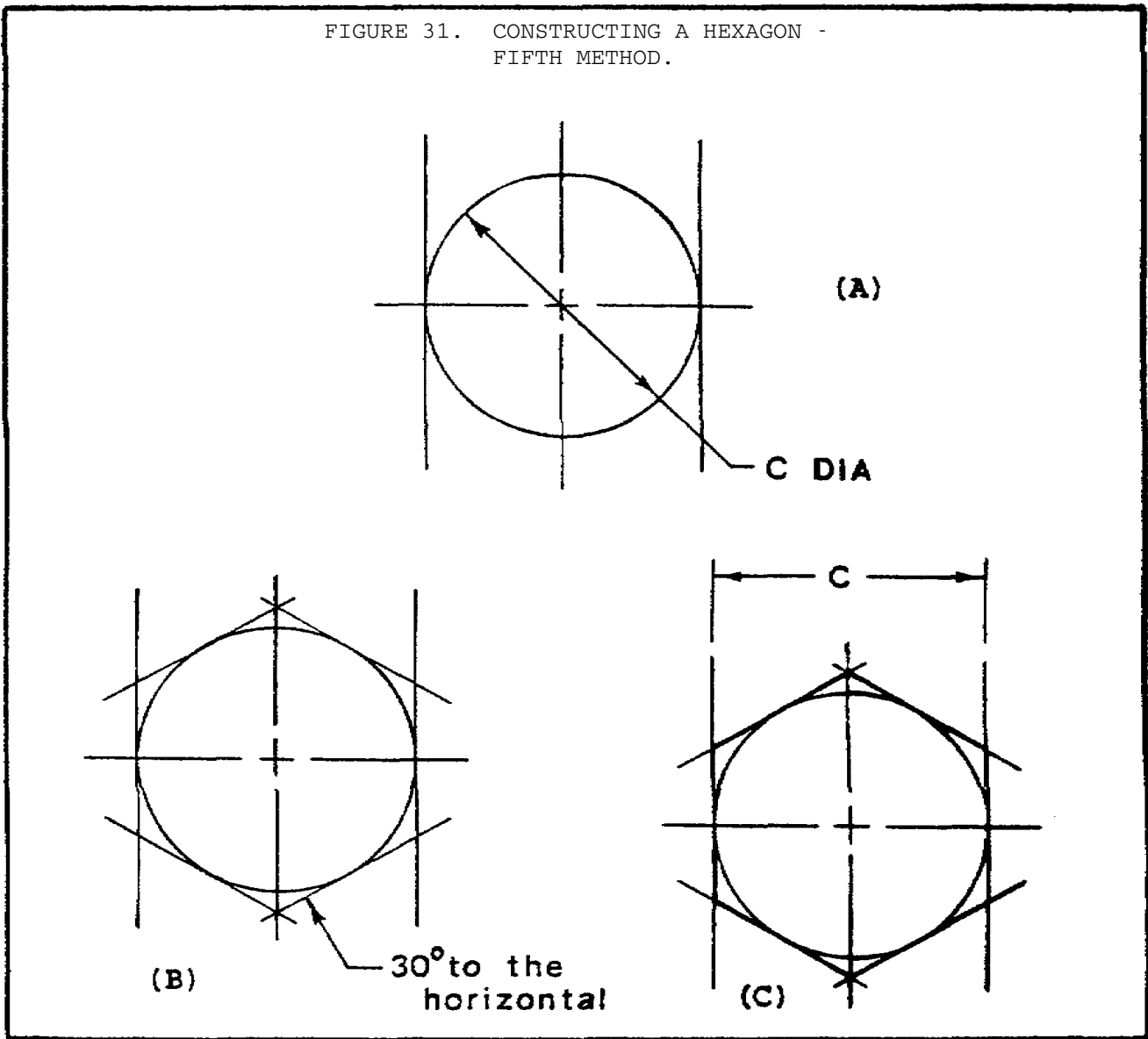
(5) *Construct a Hexagon - Fifth Method*, (figure 31 on the following page). We have to construct a hexagon C across the flats. To construct this hexagon, perform the following steps:

Step 1. Construct a circle of diameter C (view A).

Step 2. Construct two vertical lines tangential to the circle (view A).

Step 3. Using a 30° triangle, construct lines tangential to the circle, and 30° to the horizontal as shown in view B.

FIGURE 31. CONSTRUCTING A HEXAGON - FIFTH METHOD.



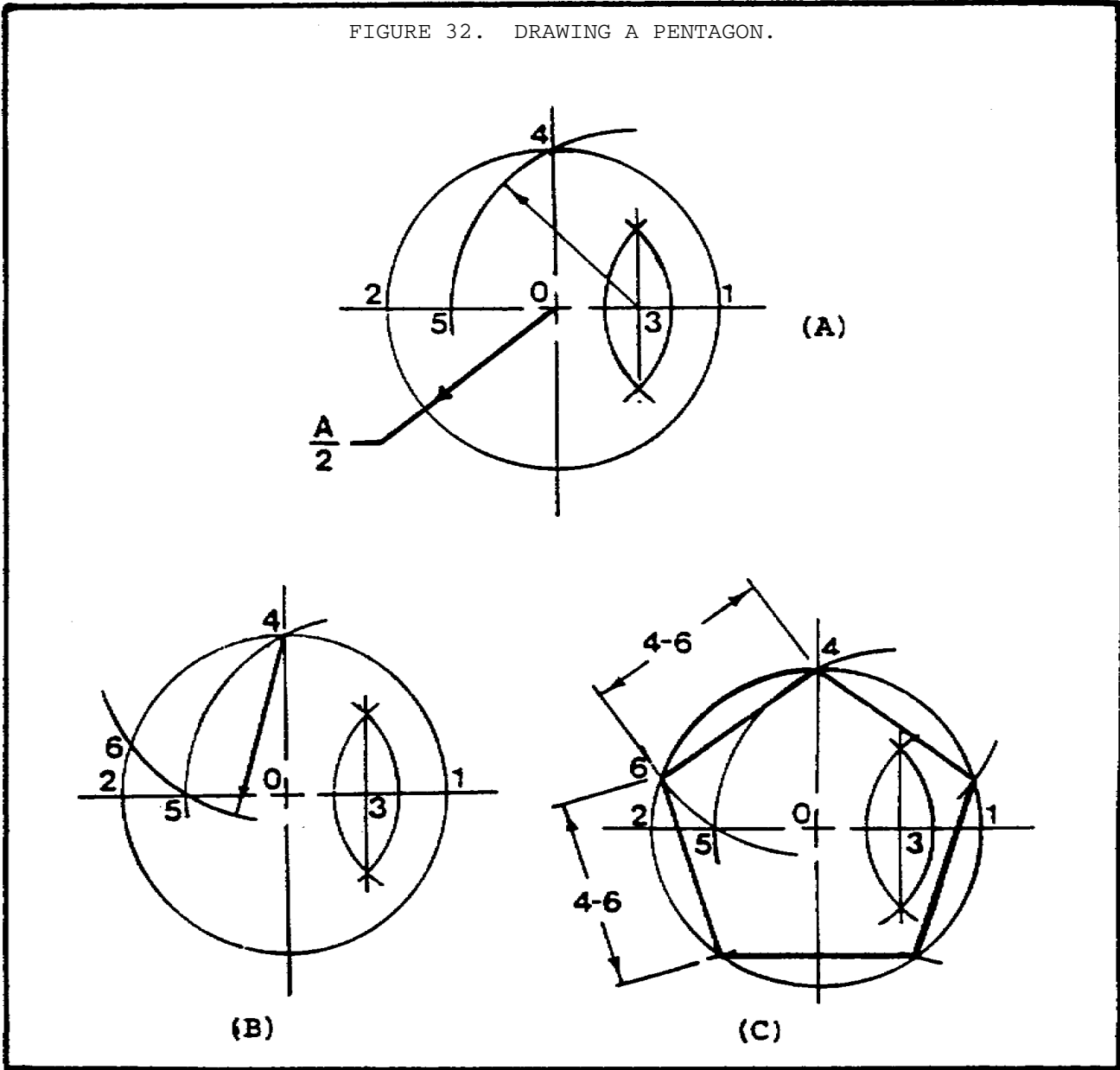
Step 4. Draw in the hexagon (figure 31, view C).

e. *Pentagon*, (figure 32 on the following page). In the following subparagraphs, we will discuss the procedures for constructing a pentagon. We have to draw a pentagon inscribed in a circle of diameter A. To draw this pentagon, perform the following steps:

Step 1. Construct a circle of diameter A.

Step 2. Define points 0, 1, and 2 as shown in view A.

FIGURE 32. DRAWING A PENTAGON.



Step 3. Bisect line 0-1 and define the midpoint as point 3 (figure 32, view A).

Step 4. Define point 4 as shown in view A.

Step 5. Using a compass set on point 3, construct an arc through point 4 and line 2-0.

Step 6. Define the intersection of the arc and line 2-0 as point 5.

Step 7. Using a compass set on point 4, construct an arc through point 5 and the edge of the circle (view B).

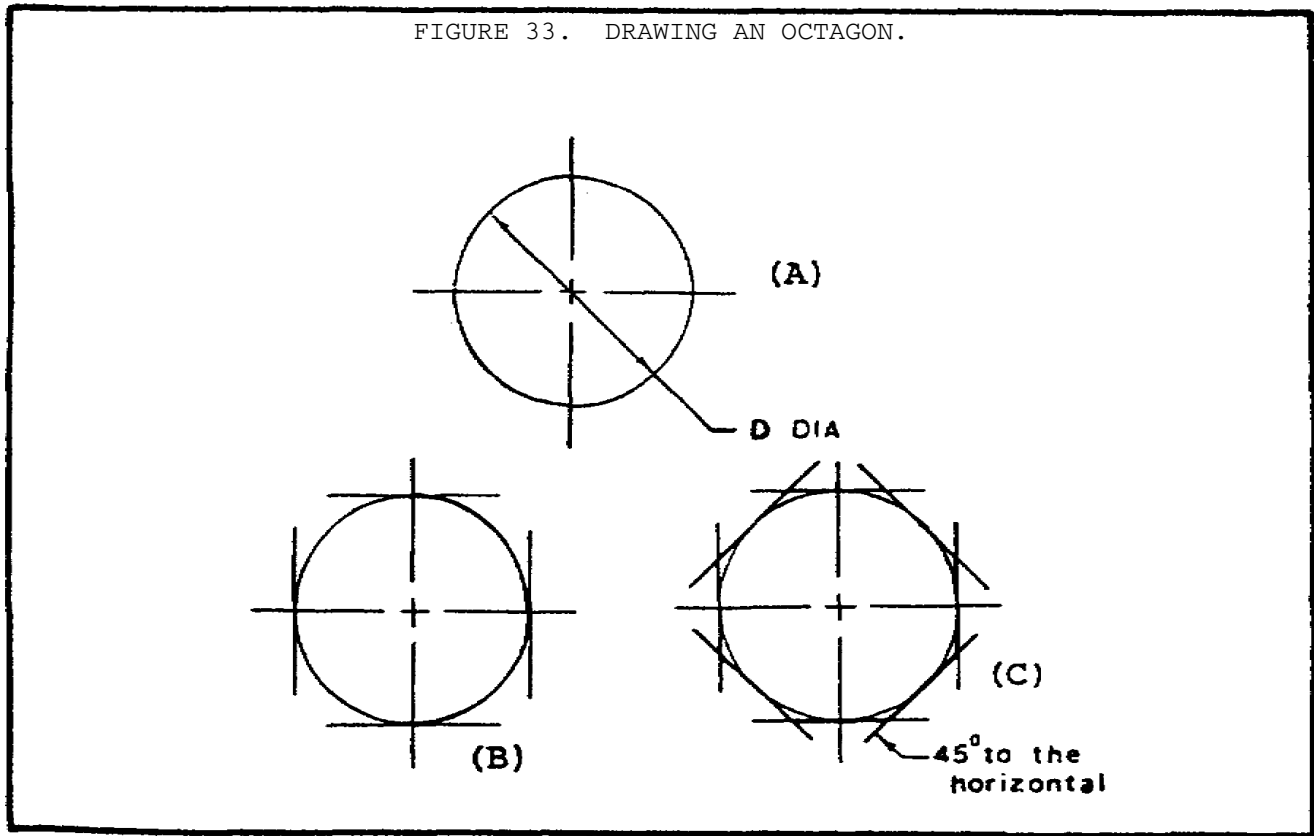
PRINCIPLES OF DRAFTING AND SHOP DRAWINGS - OD1641 - LESSON 1/TASK 2

Step 8. Define the intersection of this arc and the circle as point 6 (figure 32, view C, on the previous page).

Step 9. Using a compass, mark off the distance 4-6 around the circumference of the circle as shown in view C.

Step 10. Draw in the pentagon (view C).

f. *Octagon*, (figure 33). In this problem we have to draw an octagon D across the flats. To draw this octagon, perform the following steps:



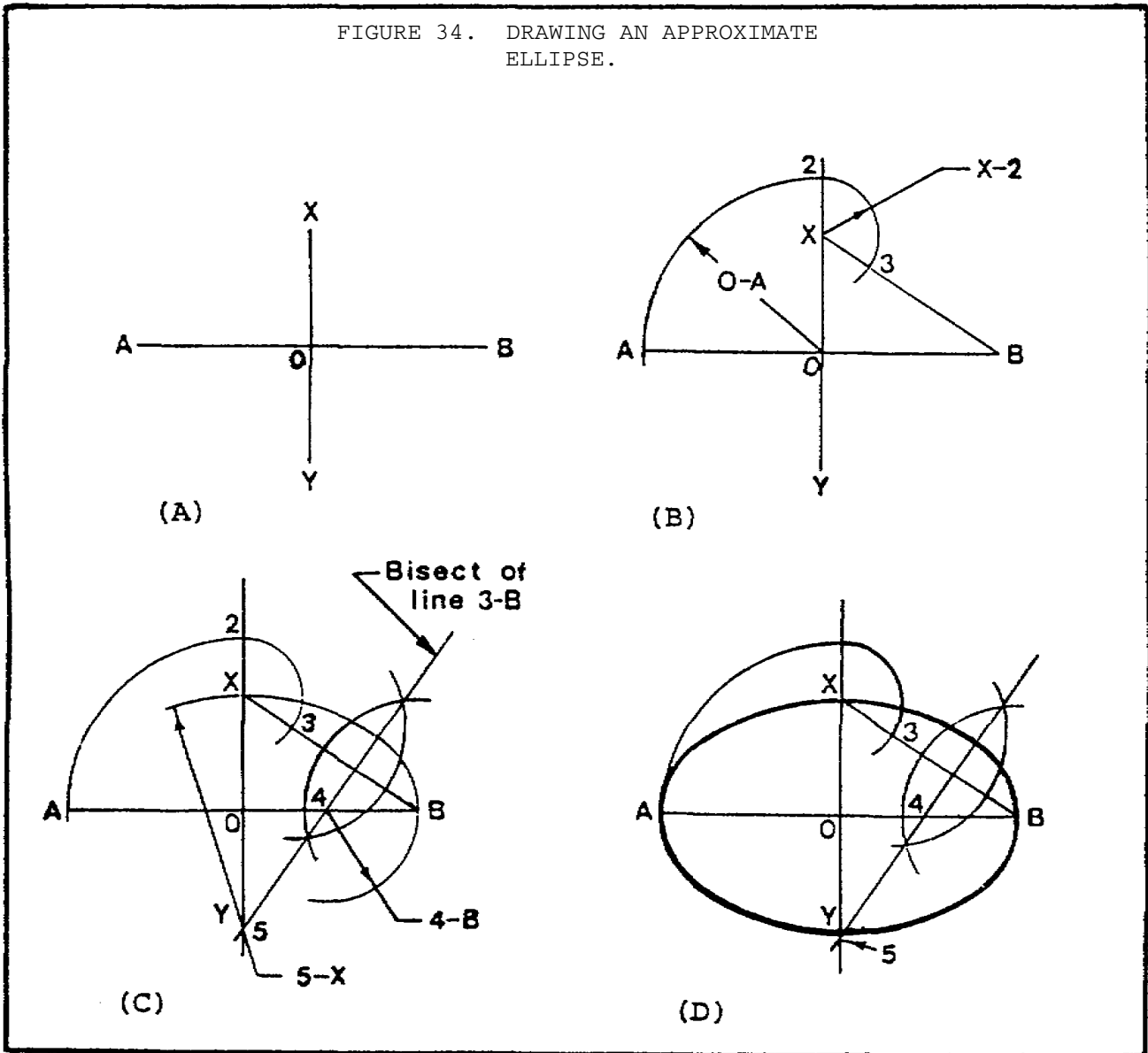
Step 1. Draw a circle of diameter D (view A).

Step 2. Construct four tangent lines as shown in view B.

Step 3. Construct four lines, 45° to the horizontal, tangential to the circle as shown in view C.

Step 4. Draw in the octagon (view C).

g. *Approximate Ellipse*, (figure 34). In this problem we have to draw an approximate ellipse from the following given information: we have a major axis A-O-B and a minor axis of X-O-Y (view A). To construct this ellipse, perform the following steps:



Step 1. Draw an arc of radius O-A, using point O as a center, such that it intersects point A and an extension of line Y-O-X (view B).

Step 2. Draw a straight line between points X and B (view B).

Step 3. Draw arc X-2 as shown in view B.

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Step 4. Define the intersection of arc (X-2) and line X-B as point 3 (figure 34, view B, on the previous page).

Step 5. Bisect line 3-B and draw the bisect line so that it intersects an extension of the line X-O-Y. Define this intersection as point 5 (view C).

Step 6. Define the intersection of the bisect line and line O-B as point 4 (view C).

Step 7. Using point 5 as center, draw an arc of radius 5-X as shown in view C. Also draw an arc of radius 4-B as shown in view C. These two arcs will generate half of the ellipse. Draw the other half by symmetry (view D).

4. Conclusion

In this task, we covered drafting instruments and the fundamentals of geometric construction. In the next task, we will discuss the theory and fundamentals of pictorial drawings: oblique and isometric projection.

LESSON 1

DRAFTING AND SHOP DRAWING FUNDAMENTALS

TASK 3. Describe the theory and fundamentals of pictorial drawings: oblique and isometric projection.

CONDITIONS

Within a self-study environment and given the subcourse text, without assistance.

STANDARDS

Within one hour

REFERENCES

No supplementary references are needed for this task.

1. Introduction

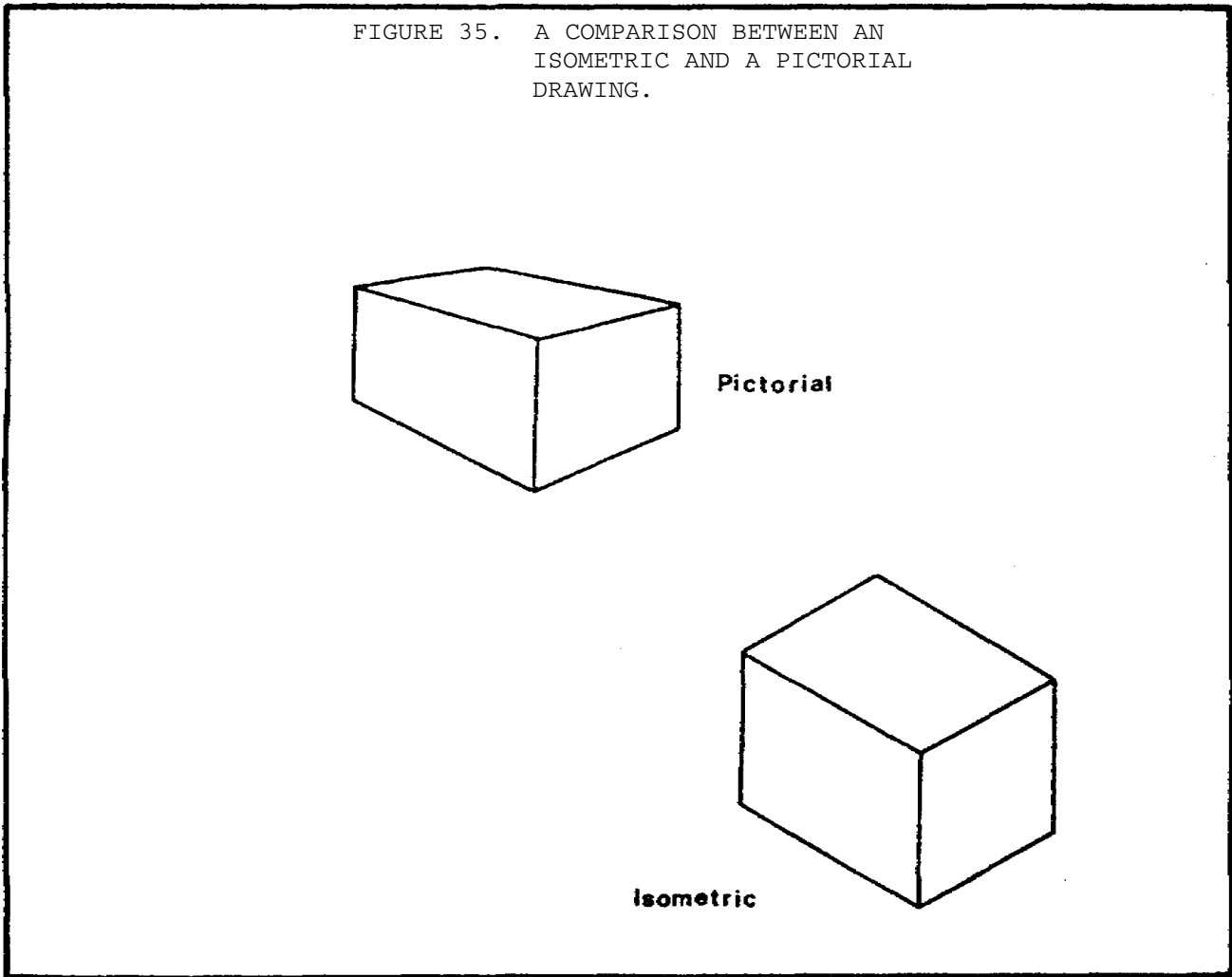
In the previous two tasks of this subcourse, we discussed orthographic projection, freehand drafting, drafting instruments, and geometric construction. In this task, we will discuss pictorial drawings: oblique and isometric.

Shop drawings are divided into two main categories of projection, pictorial and orthographic. These two main categories are further subdivided into various types. For instance, under pictorial drawings there are four subdivisions, perspective, oblique, isometric, and cabinet. In this task, we will only be discussing two of these subdivisions, oblique and isometric.

2. Isometric Drawings

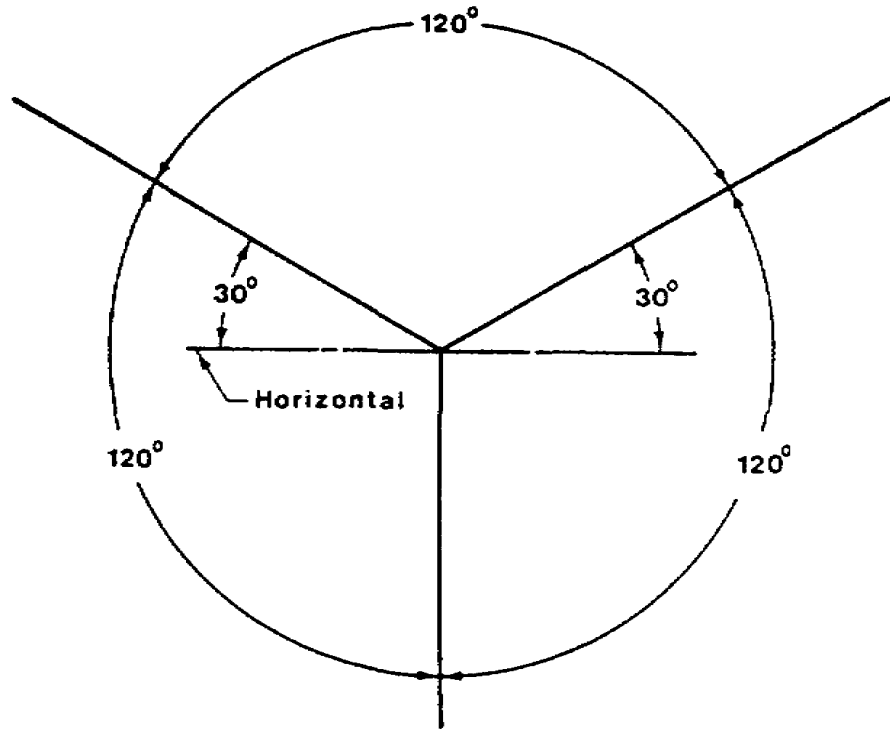
Isometric drawings are technical pictures that can be drawn by using instruments. They are not perfect pictures because their axes do not taper

as they approach infinity. Figure 35 shows a comparison between an isometric drawing of a rectangular box and a pictorial drawing (such as an artist would draw) of the same object; it demonstrates the distortion inherent in isometric drawings. Note how the back corner of the isometric appears much larger than the back of the pictorial drawing. Despite the slight distortion, isometric drawings are a valuable way to convey technical information.



The basic reference system for isometric drawings is shown in figure 36 (on the following page). The three lines are 120° apart and may be thought of as a vertical line and two lines 30° to the horizontal, which means that they may be drawn by using a 30-60-90 triangle supported by a T-square. All isometric drawings are based on this axis system.

FIGURE 36. THE BASIC REFERENCE SYSTEM FOR ISOMETRIC DRAWINGS.

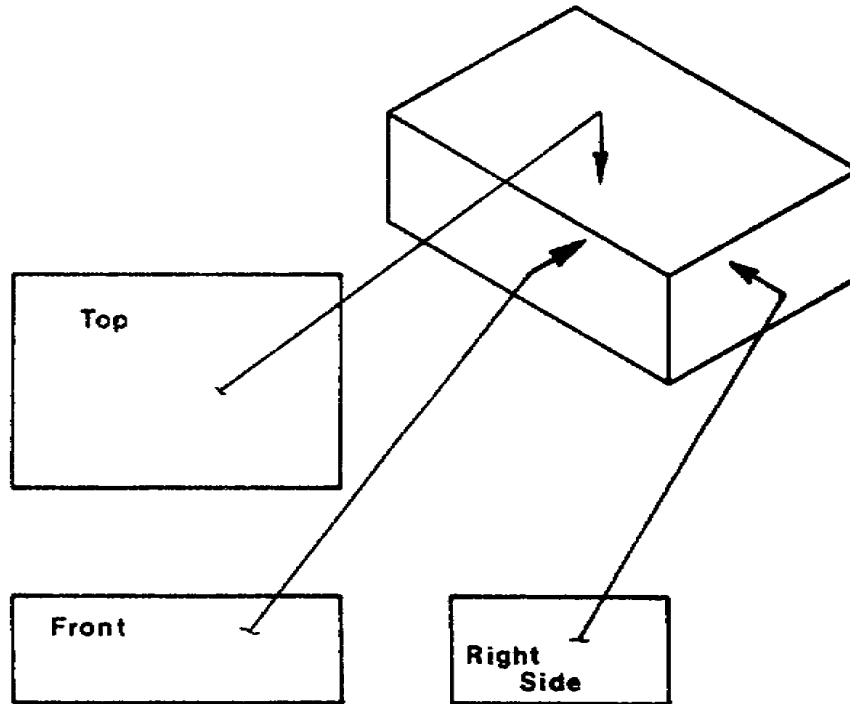


Normally, an isometric drawing is positioned so that the front, top, and right side views appear, as shown in figure 37 (on the following page). This may be varied according to the position that the draftsman feels best shows the object.

Dimensional values are transferable from orthographic views only to the axis, or lines parallel to the axis, of isometric drawings. Angles and inclined dimensional values are not directly transferable and require special supplementary layouts which will be explained later (page 50, paragraph 2b) in this task.

Isometric drawings do not normally include hidden lines, although hidden lines may be drawn if special emphasis of a hidden surface is required.

FIGURE 37. THE RELATIONSHIP BETWEEN THE FRONT, TOP, AND SIDE VIEWS AS DRAWN ORTHOGRAPHICALLY AND ISOMETRICALLY.



a. *Normal Surfaces.* Figure 38 (on the following page) is a sample problem that requires you to create an isometric drawing from given orthographic views. Since all surfaces in the problem are normal (90° to each other), all dimensional values may be transferred directly from the orthographic views to the isometric axis, or lines parallel to the isometric axis. The basic height, width, and length of the object are $1 \frac{1}{2}$, 2, and 3, respectively, in both the isometric and orthographic drawings. In figure 38 we are given the front, top, and side views of an orthographic projection. Our task is to draw an isometric drawing from this information.

FIGURE 38. ISOMETRIC DRAWING PROBLEM.

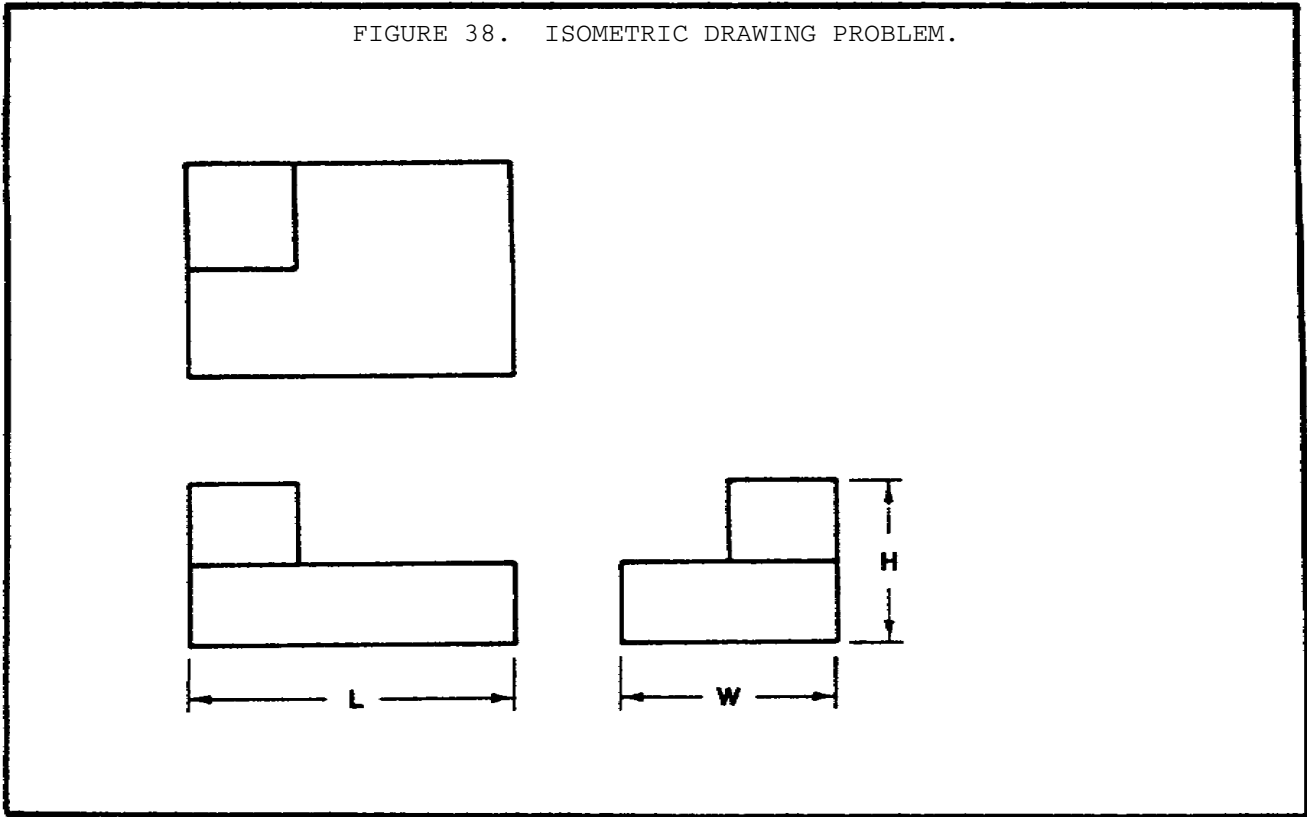


Figure 39 (on the following page) is the solution to figure 38 and was derived by the following procedures:

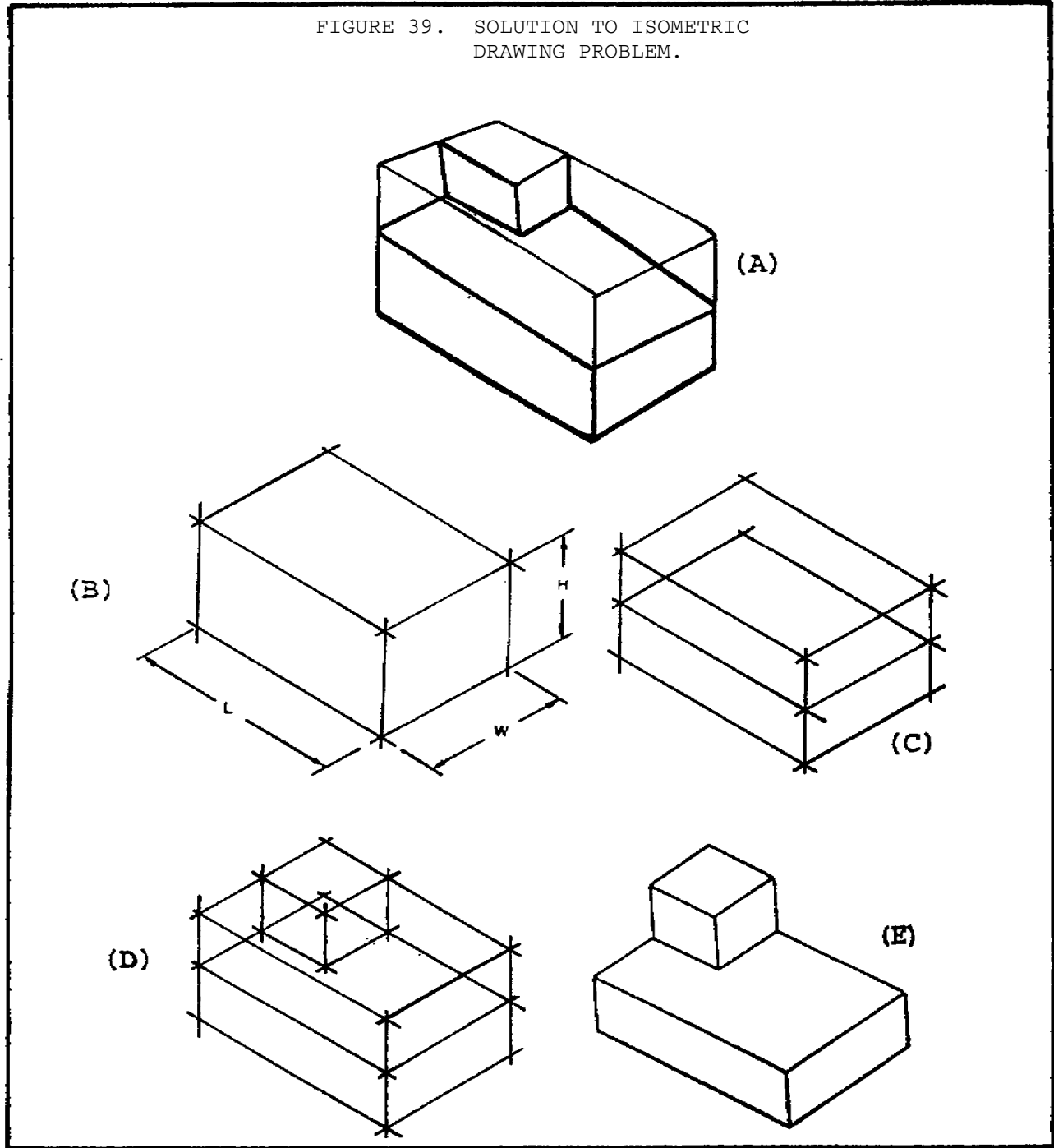
Step 1. Make, to the best of your ability, a freehand sketch of the solution. Remember that since it is easier to make corrections and changes on a sketch than on a drawing, you should make your sketch as complete and accurate as possible (figure 39, view A).

Step 2. Using very light lines, lay out a rectangular box whose height, width, and length correspond to the height, width, and length given in the orthographic views (view B).

Step 3. Again, using very light lines, lay out the specific shape of the object. Transfer dimensional values directly from the orthographic views to the axis, or lines parallel to the axis, of the isometric drawing (views C and D).

Step 4. Erase all excess lines and smudges, carefully check your work, and darken in all final lines to their proper color and pattern (view E).

FIGURE 39. SOLUTION TO ISOMETRIC DRAWING PROBLEM.



b. *Slanted and Oblique Surfaces.* Figure 40 (on the following page) is a sample problem that involves the creation of an isometric drawing from given orthographic views that contain a slanted surface. The slanted surface is dimensioned by using an angular dimension. That presents a problem because angular dimensions cannot be directly transferred from orthographic views to isometric drawings.

FIGURE 40. ISOMETRIC DRAWING PROBLEM CONTAINING A SLANTED SURFACE.

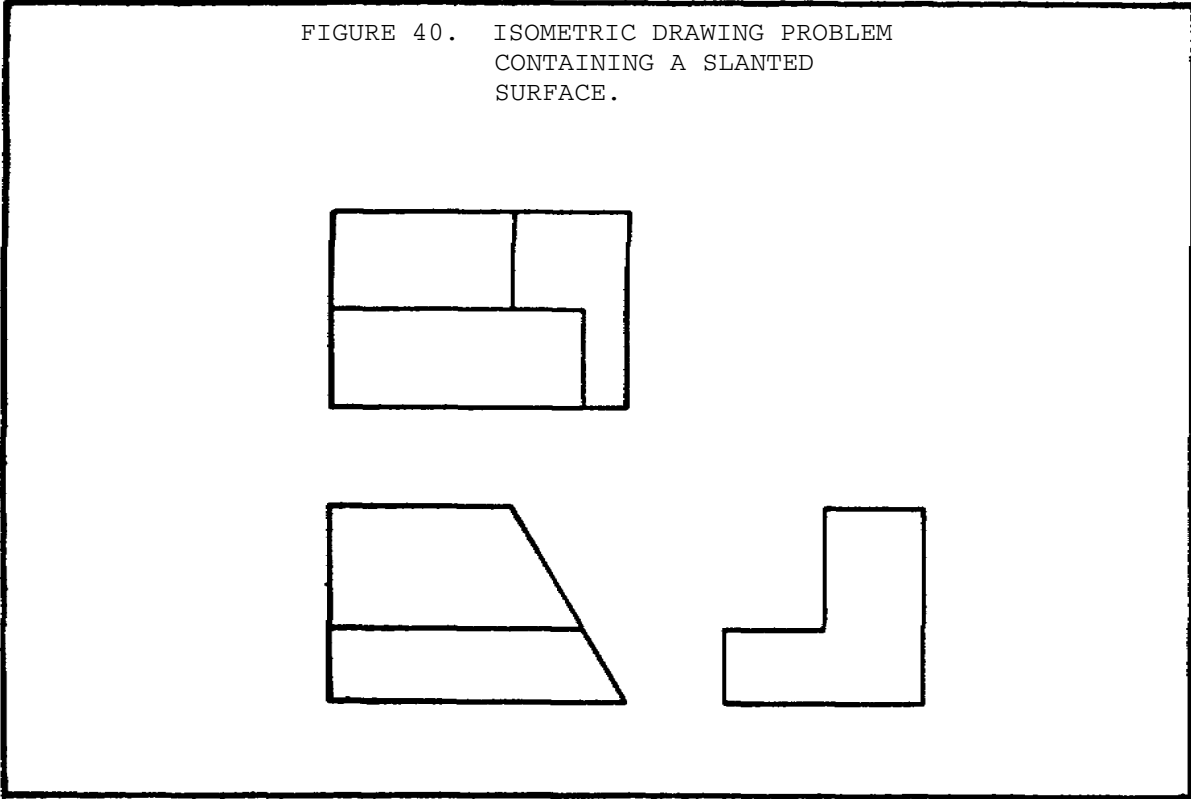
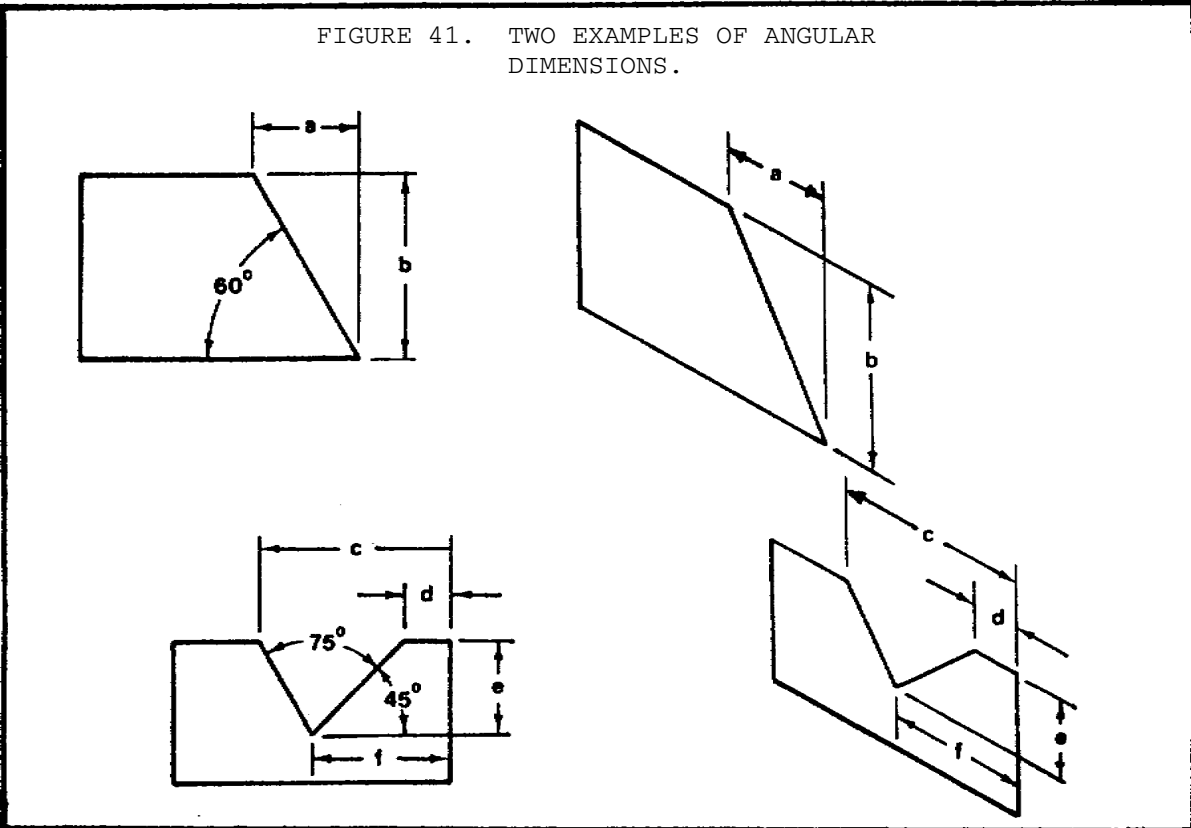


FIGURE 41. TWO EXAMPLES OF ANGULAR DIMENSIONS.



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To transfer an angular dimensional view from an orthographic view to an isometric drawing, convert the angular dimensional value to its component linear value and transfer the component values directly to the axis of the isometric drawing. Figure 41 (on the previous page) illustrates this procedure by showing two angular dimensions that have, been converted to their respective linear values, then showing how these values are transferred to the isometric axis. Normally, a draftsman simply measures his full-sized orthographic views and then transfers the information. If the information is not available, they make a supplementary layout from which the necessary values may be measured. Supplementary layouts may be made on any extra available piece of paper and should be saved for reference during the checking of the drawing.

Figure 42 (on the following page) is the solution to the problem in figure 40 and was derived by the following procedures:

Step 1. To the best of your ability, make a freehand sketch of the solution (view A).

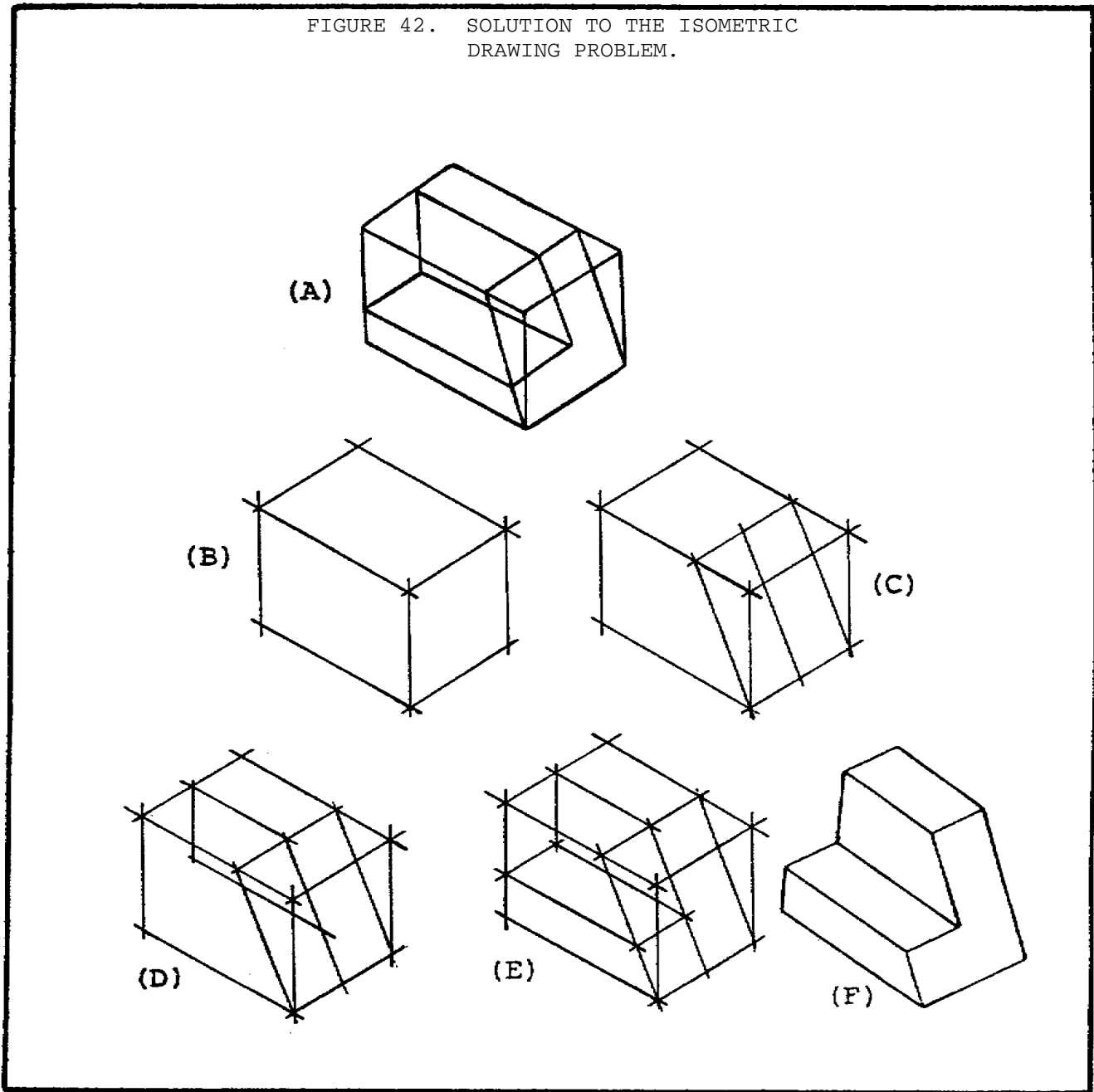
Step 2. Using very light lines, lay out a rectangular box whose height, width, and length correspond to the height, width, and length given in the orthographic view (view B).

Step 3. Using very light lines, lay out the specific details of the object. Where necessary, make supplementary layouts that furnish the linear component values which can transfer to the isometric axis. In this case, the 30° component layout is shown in figure 41 (on the previous page).

Step 4. Erase all excess lines and smudges, check your work, then draw in all lines to their proper color and pattern.

c. *Holes in Isometric Drawings.* There are two basic methods for drawing holes in isometric drawings. One method is to use instruments and draw the holes by using the four-center ellipse

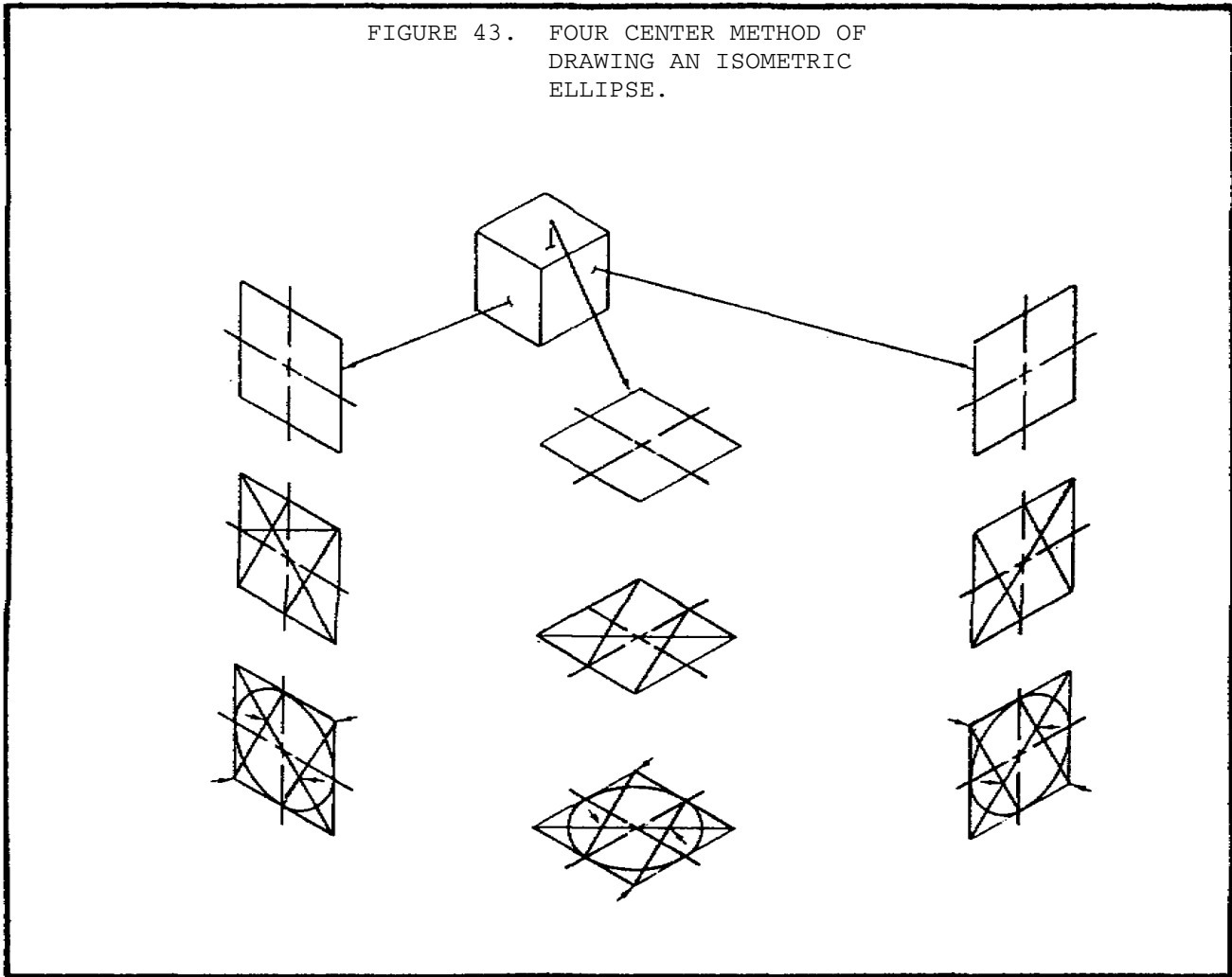
FIGURE 42. SOLUTION TO THE ISOMETRIC DRAWING PROBLEM.



method. The other method is to use an isometric hole template as a guide. The template is much easier and faster to use, but templates are available only in standard hole sizes. Very large or odd-sized holes may only be drawn by using the four-center ellipse method.

The four-center ellipse method is presented in figure 43 (on the following page). When you use this method, be careful that the four centers are

located accurately. If the centers are not located properly, the four individual arcs will not meet to form a smooth, continuous ellipse. A good practice that will help you draw a smooth, continuous ellipse is to lightly construct the ellipse, then check it for accuracy before drawing in the final heavy arcs.



An isometric hole template may be conveniently used as a guide for drawing the hole size for which it is cut. To align the template for drawing, first draw in the hole center lines, then align the guidelines printed on the template adjacent to the desired hole with the center lines on the drawing. If you are still unsure of how to position the template, draw in the center lines and the major and minor axes of the ellipse as shown in figure 44 (on the following page). Then align the template

with the four intersections formed by the center lines as they cross the major and minor axes (labeled points 1, 2, 3, and 4 in figure 44) and draw in the ellipse.

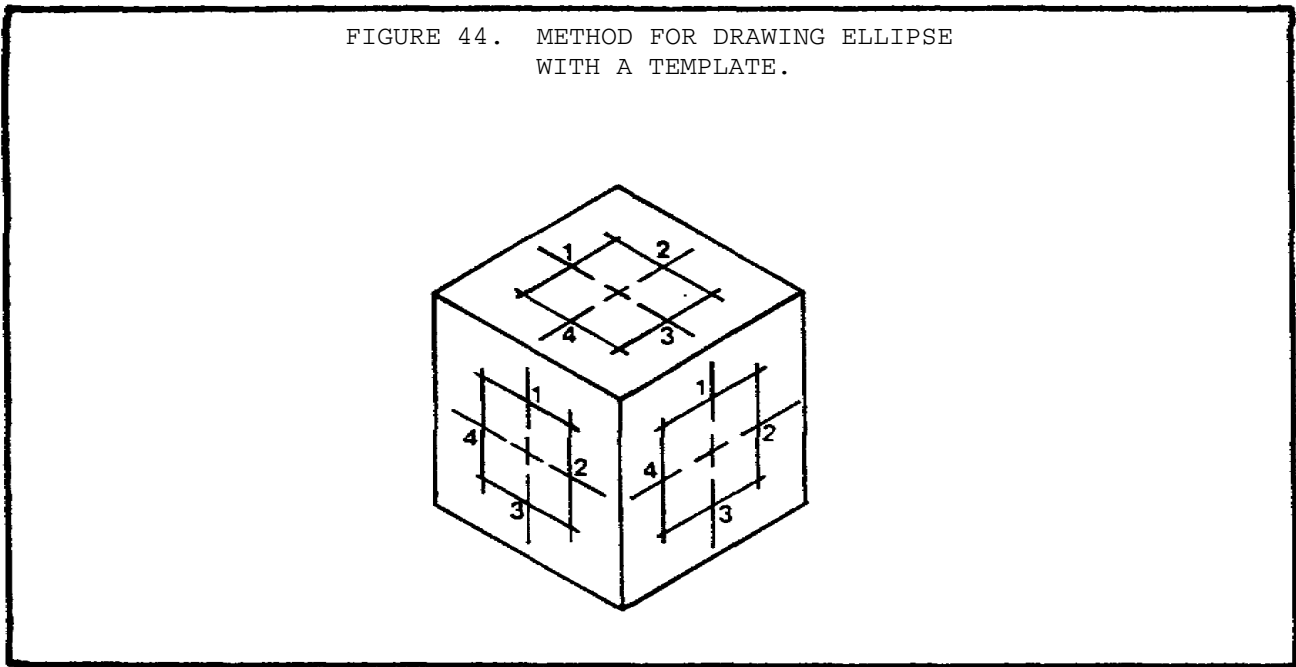
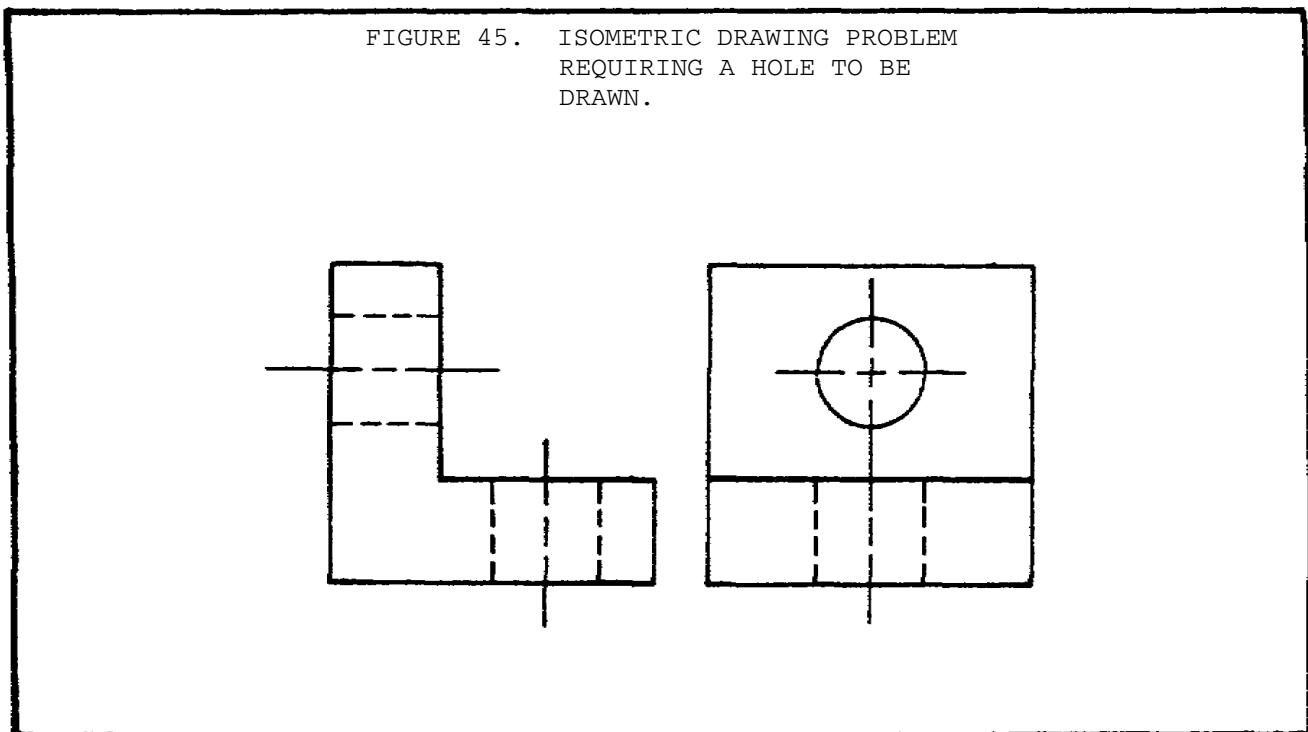


Figure 45 is a problem that requires you to draw a hole in an isometric drawing. Figure 46 (on the following page) is the solution using the four-



center ellipse method, and figure 47 (on the following page) is the solution using an isometric hole template.

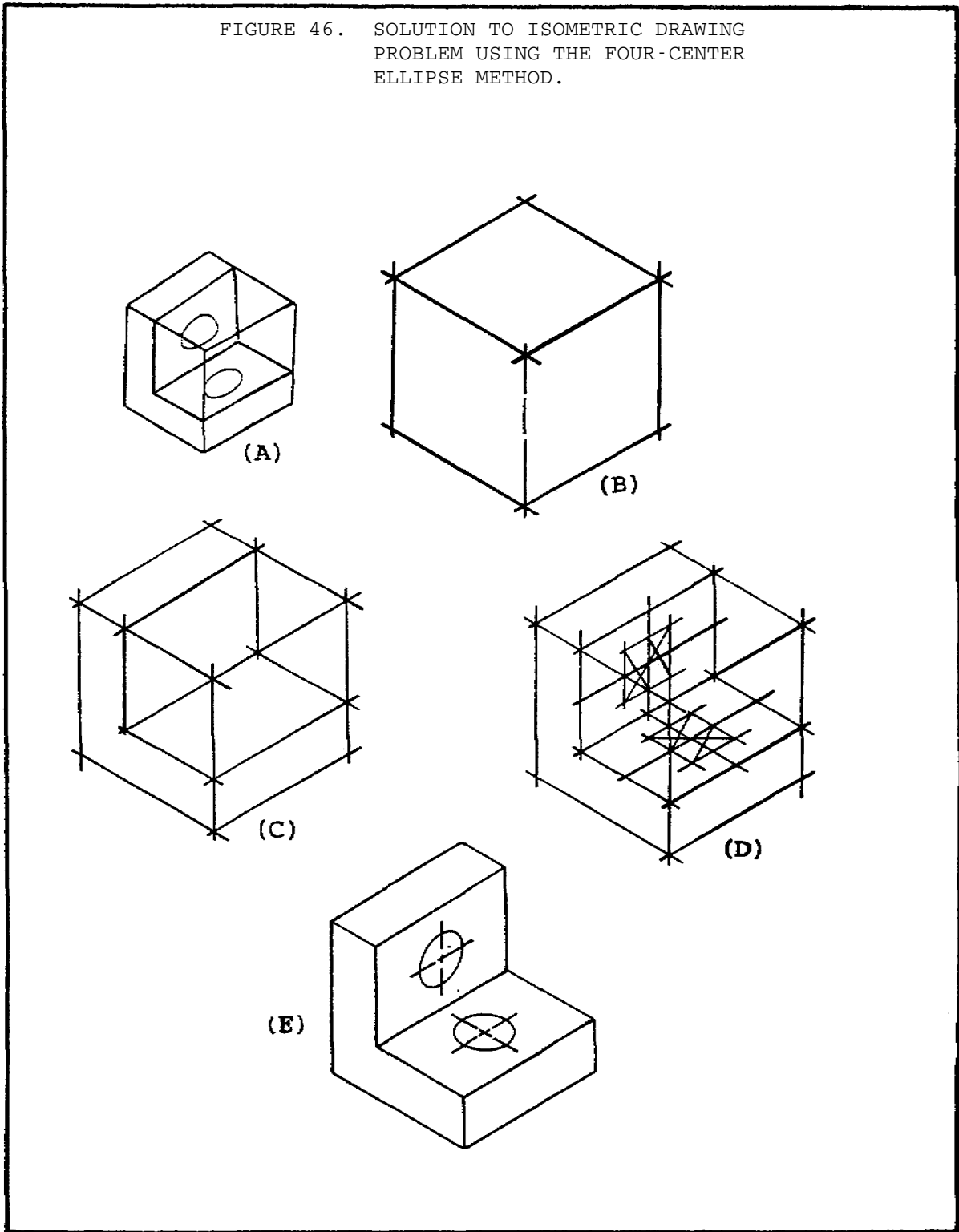
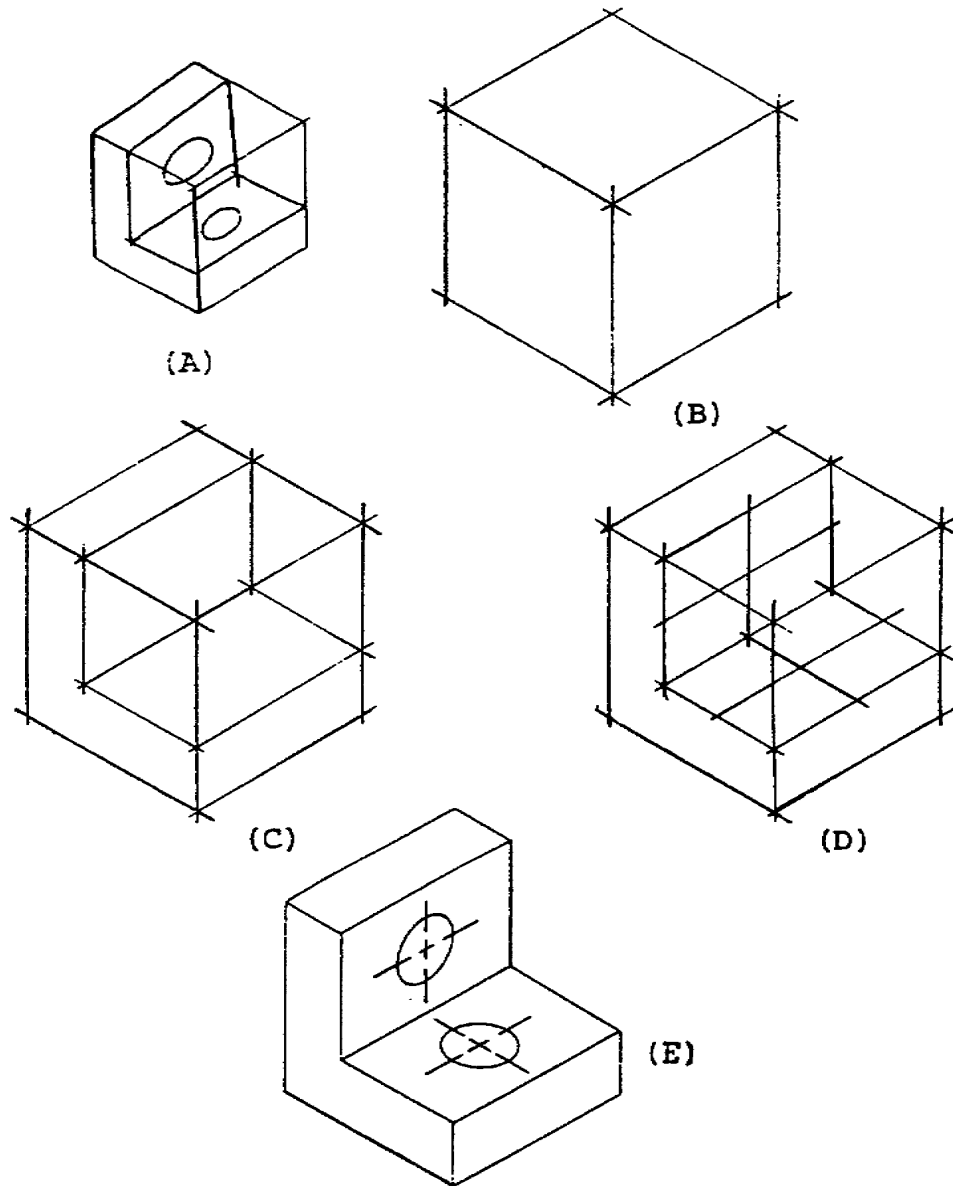


FIGURE 47. SOLUTION TO ISOMETRIC DRAWING PROBLEM USING AN ISOMETRIC HOLE TEMPLATE.



In drawing a hole for an isometric drawing, there arises the question of whether or not the bottom edge of the hole can be seen. If it can be seen, how much of it can be seen? Figure 48 (on the following page) illustrates the problem.

FIGURE 48. SHOWING THE BOTTOM EDGE OF A HOLE IN AN ISOMETRIC DRAWING.

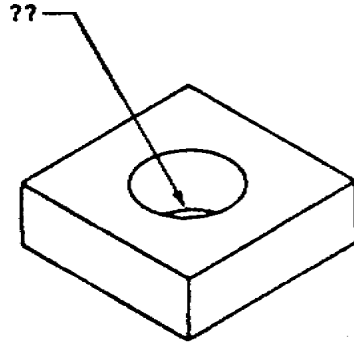
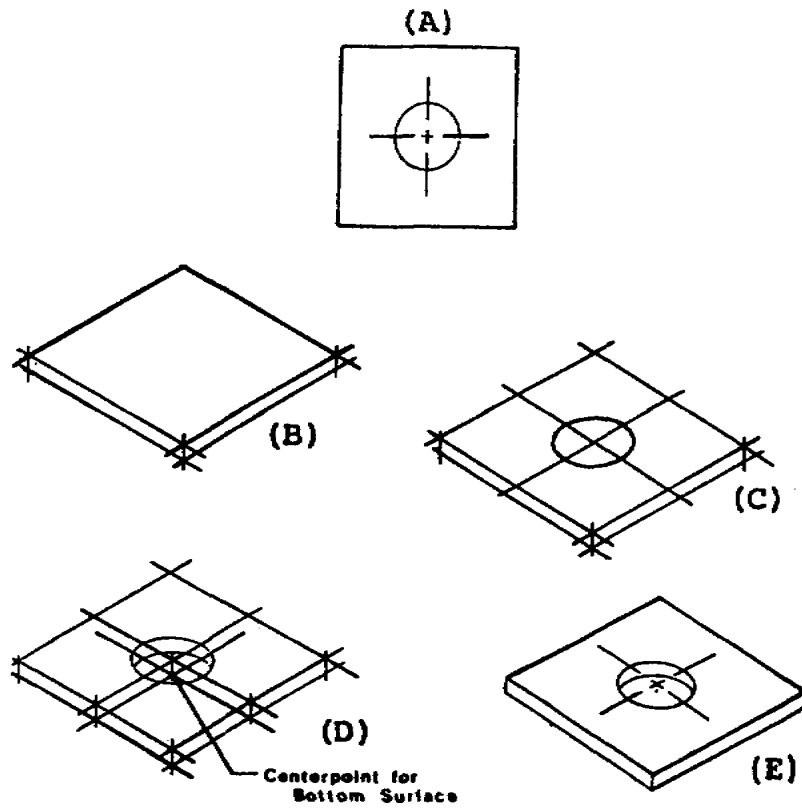


FIGURE 49. SAMPLE PROBLEM SHOWING HOLE.



To determine exactly if and how much of the bottom edge of the hole should be drawn, locate the center point of the hole on the bottom surface and draw the hole by using the same procedure you used for the hole on the top surface. If the hole drawn on the bottom surface appears within the hole on the top surface, it should appear on the finished drawing. If the hole drawn on the bottom surface does not appear within the hole on the top surface, it should not appear on the finished drawing. Figure 49 (on the previous page) presents a sample problem that illustrates this procedure.

d. *Round and Irregular Surfaces.* Figure 50 is a sample that requires you to create an isometric drawing from given orthographic views that contain a round surface. To make an isometric drawing of a round surface, use either an isometric template for a guide or the point method.

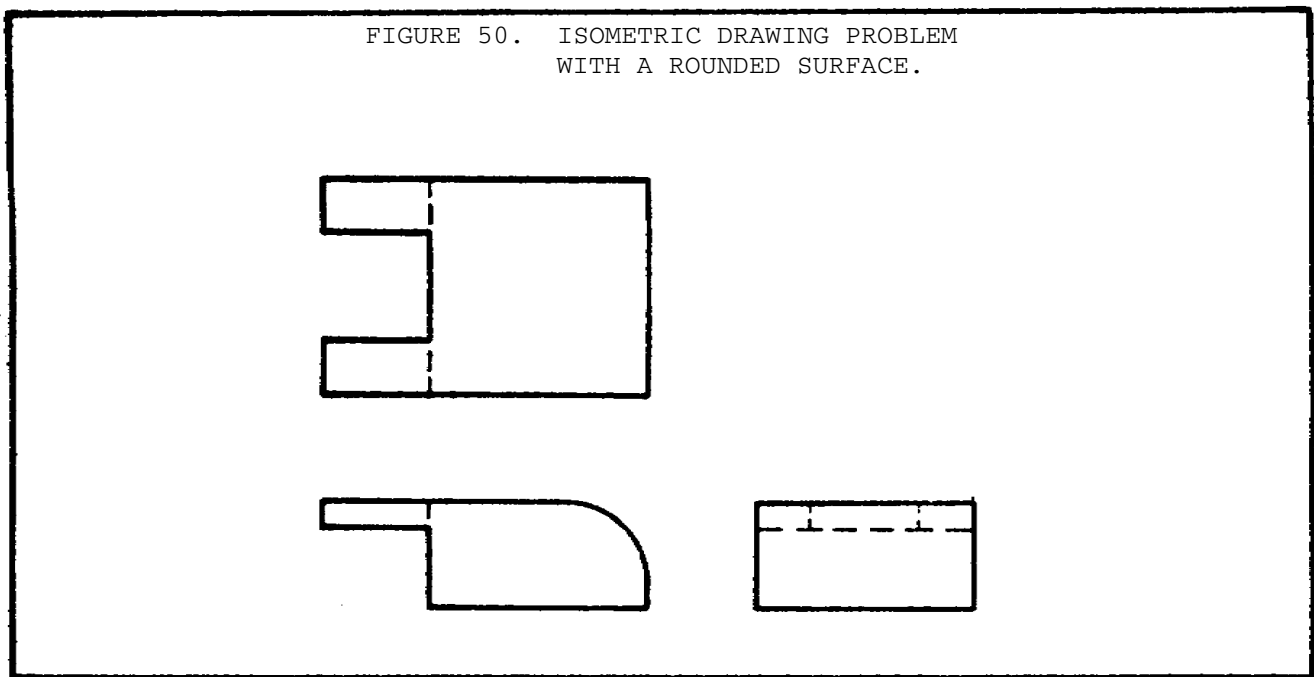
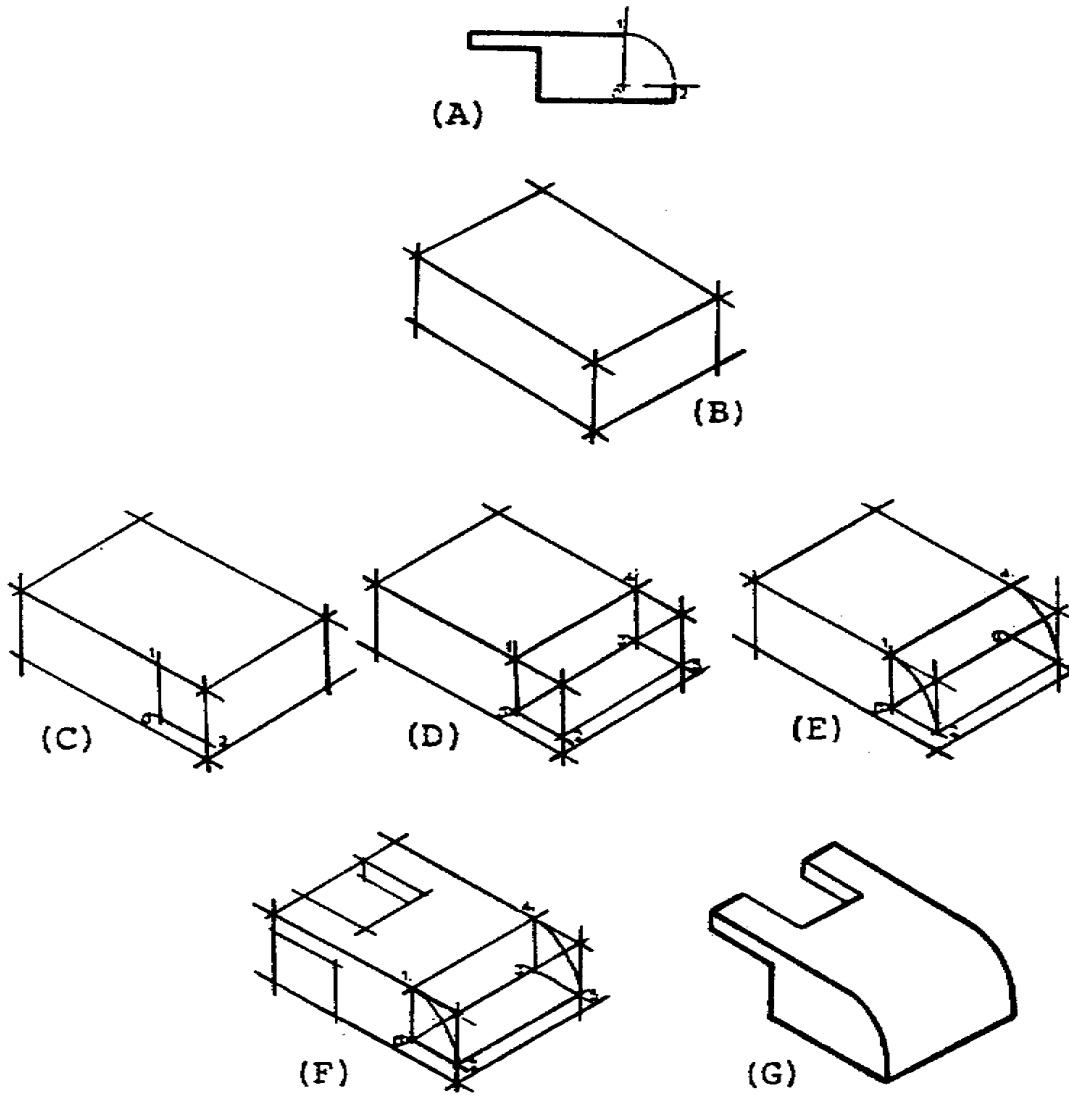


Figure 51 (on the following page) is the solution that was derived by using an isometric template.

(1) To draw a round surface by using an isometric ellipse template, perform the following steps:

Step 1. Define on one of the orthographic views (the one that shows the round surface as part of a circle) the center point of the round surface and the intersections of the center lines with the surfaces of the object. In this example the center

FIGURE 51. SOLUTION TO ISOMETRIC DRAWING PROBLEM USING AN ISOMETRIC TEMPLATE.



point is marked "0", and the two intersections are marked points 1 and 2 (figure 51, view A).

Step 2. Draw a rectangular box and transfer the points 1, 2, and 0 to the front plane of the isometric drawing (views B and C).

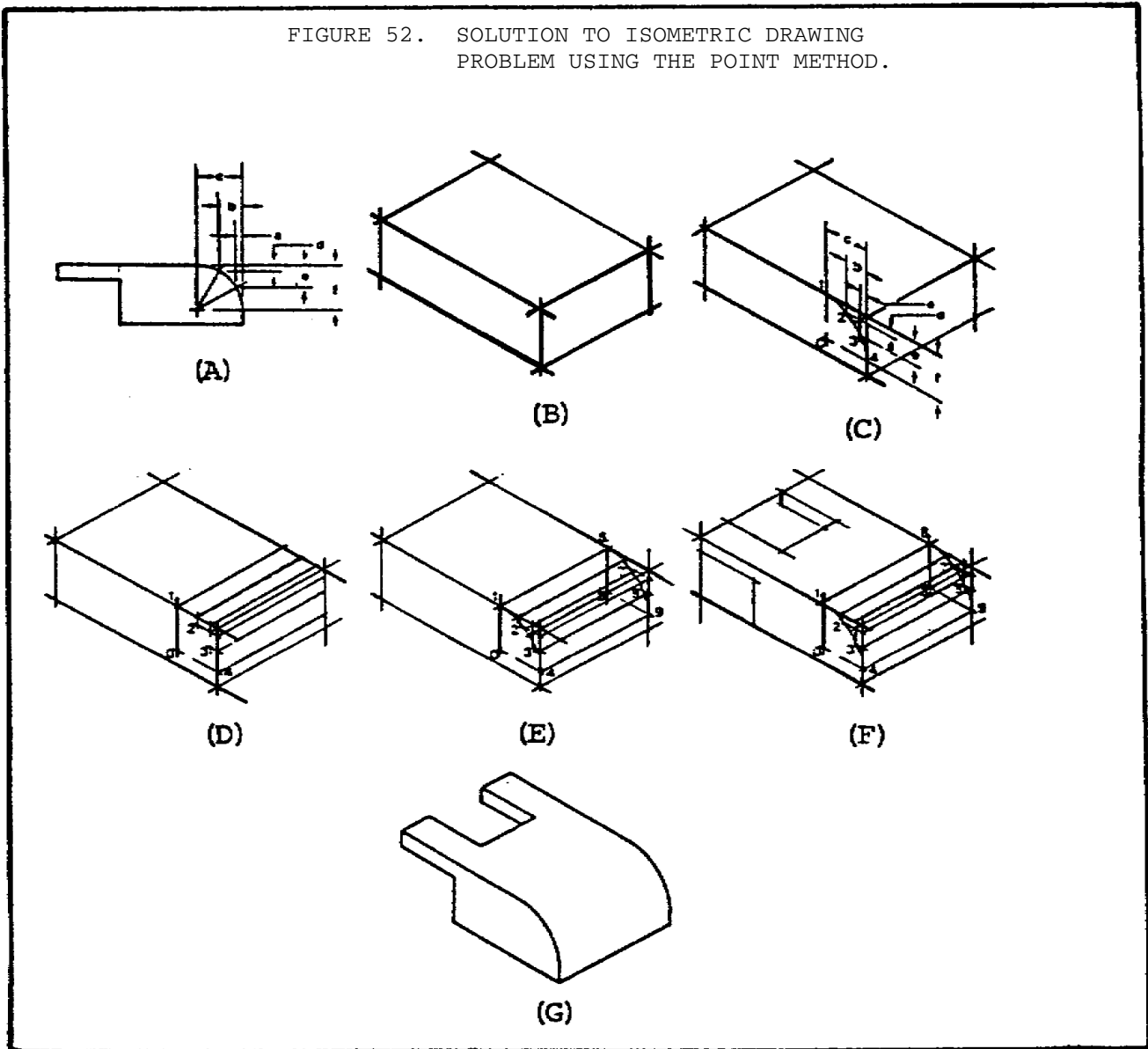
Step 3. Project the points in the front plane across the isometric drawing to the back plane (view D), and label them 3, 4, and 5.

Step 4. Align the proper hole in the isometric ellipse template with the center lines on the front

of the isometric surface, and draw in the isometric arc. Repeat the same procedures for the back plane (figure 51, views E and F, on the previous page).

Step 5. Erase all excess lines and smudges, check your work, draw in the remaining lines of the object lightly at first, then darken them to their proper color and pattern (view G).

Figure 52 is the solution that was derived by using the point method.



(2) To draw a round surface by using the point method, perform the following steps:

Step 1. On one of the orthographic views (the one that shows the round surface as part of a circle) mark off a series of points along the rounded surface (figure 52, view A, on the previous page). The points need not be equidistant. The more points you take, the more accurate will be the final isometric ellipse. If necessary, make a full-sized supplementary layout

Step 2. Draw a rectangular box (view B).

Step 3. Dimension each point horizontally and vertically as shown (view C).

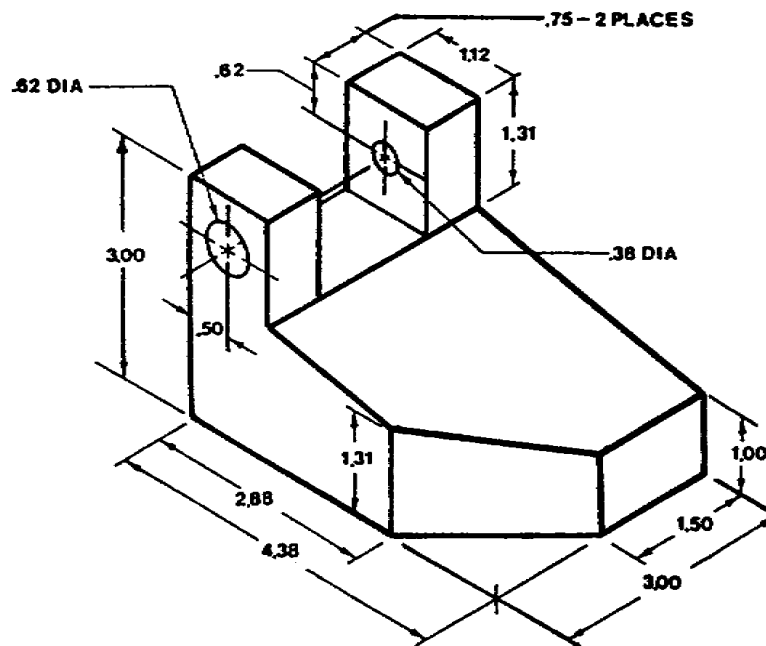
Step 4. Transfer the dimensional values to the isometric axis as shown (view D).

Step 5. Using a French curve as a guide, draw in the isometric arc (view E).

Step 6. Transfer the points to the back surface and, again using a French curve as a guide, draw in the isometric arc (view F).

Step 7. Erase all excess lines and smudges, check your work, draw in the remaining lines of the object lightly at first, then darken them to their final color and pattern (view G).

FIGURE 53. ISOMETRIC DIMENSIONS.

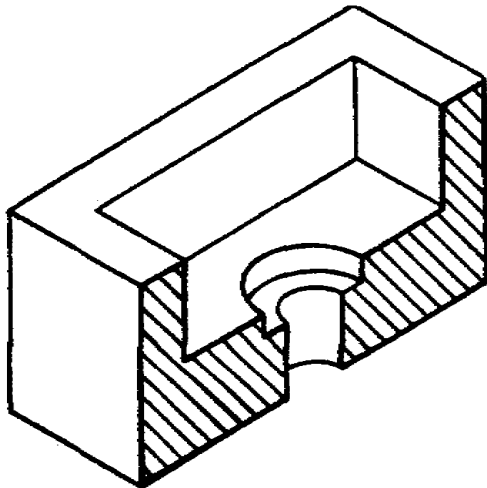


e. *Isometric Dimensions.* Isometric drawings may be dimensioned by using either the aligned system or the unidirectional system.

Regardless of the system used, the leader lines must be drawn in the same isometric plane as the surface they are defining. The guidelines for the dimensions in the aligned system are drawn parallel to the edge being defined, while the guidelines for the unidirectional system are always horizontal. Figure 53 (on the previous page) is another example of the unidirectional system. The numbers are drawn either 1/8 or 3/16 inch in height in both systems.

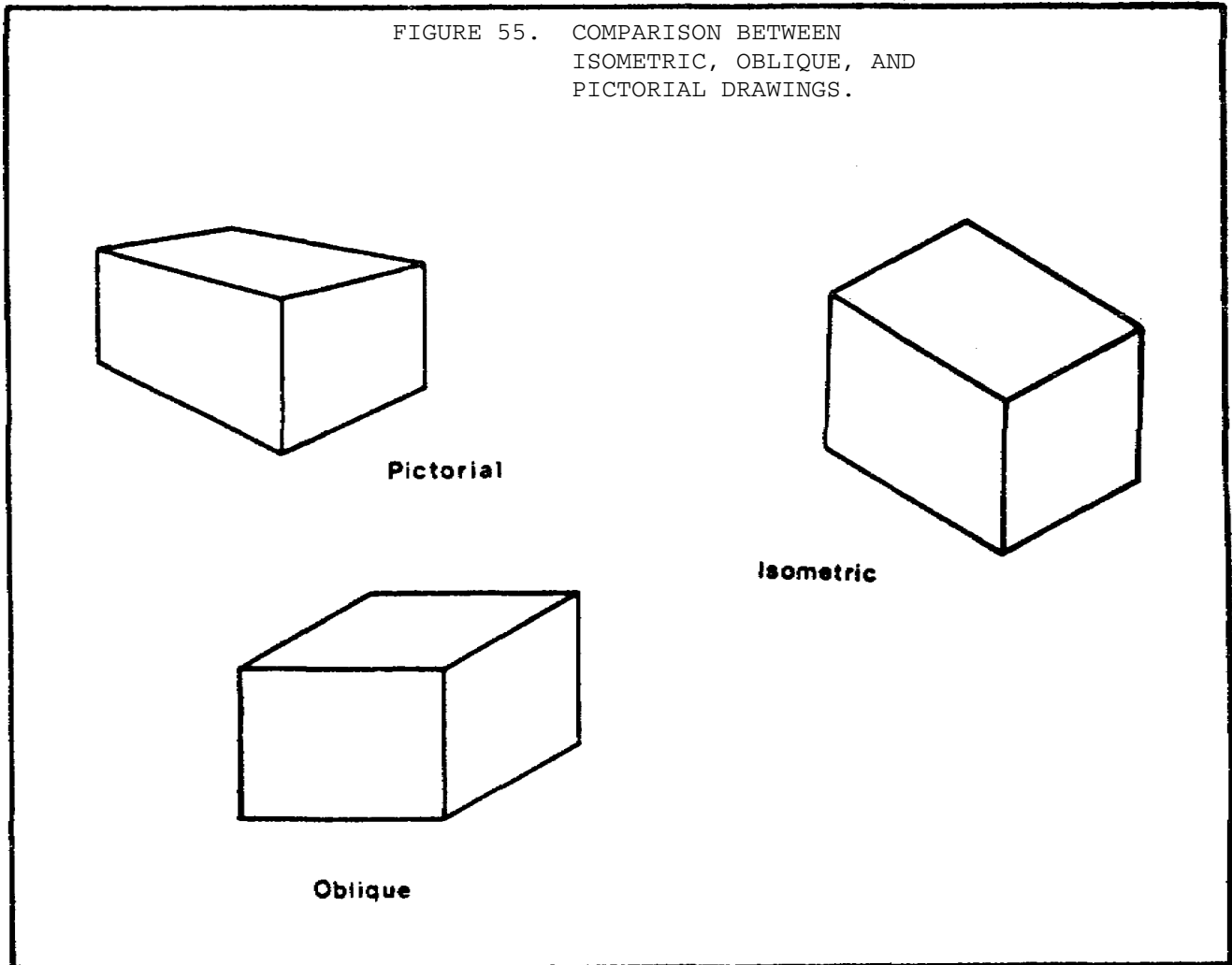
f. *Isometric Sectional Views.* Isometric sectional views are used for the same reasons that orthographic sectional views are used, to clarify objects by exposing important internal surfaces that would otherwise be hidden from direct view. Figure 54 shows a full isometric sectional view and a half isometric sectional view. Note that, as with orthographic sectional views, hidden lines are omitted and the cross-hatching lines are drawn medium to light in color, 3/32 apart at an inclined angle. Isometric sectional views do not require a defining cutting plane and are usually presented as individual pictures with no accompanying reference drawing. Dimensions are placed on an isometric sectional view in the same way they are for regular isometric drawings.

FIGURE 54. ISOMETRIC SECTION CUT.



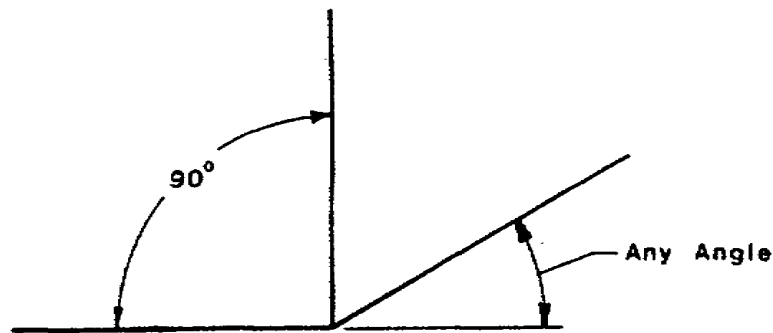
3. Oblique Drawings

Oblique drawings are technical pictures that can be drawn with instruments. They are easier to draw than isometric drawings, but they contain more inherent visual distortion. Figure 55 compares oblique, isometric, and pictorial drawings of the same object and illustrates the visual differences among the three.



The basic reference system for oblique drawings is shown in figure 56 (on the following page). The most distinct characteristic of the oblique axis is the 90° relationship between the left-hand axis and the vertical axis. Because of this 90° relationship, the front view and all surfaces parallel to it are almost identical to the front view of an orthographic drawing. This makes it very easy to transfer information between the two different front views.

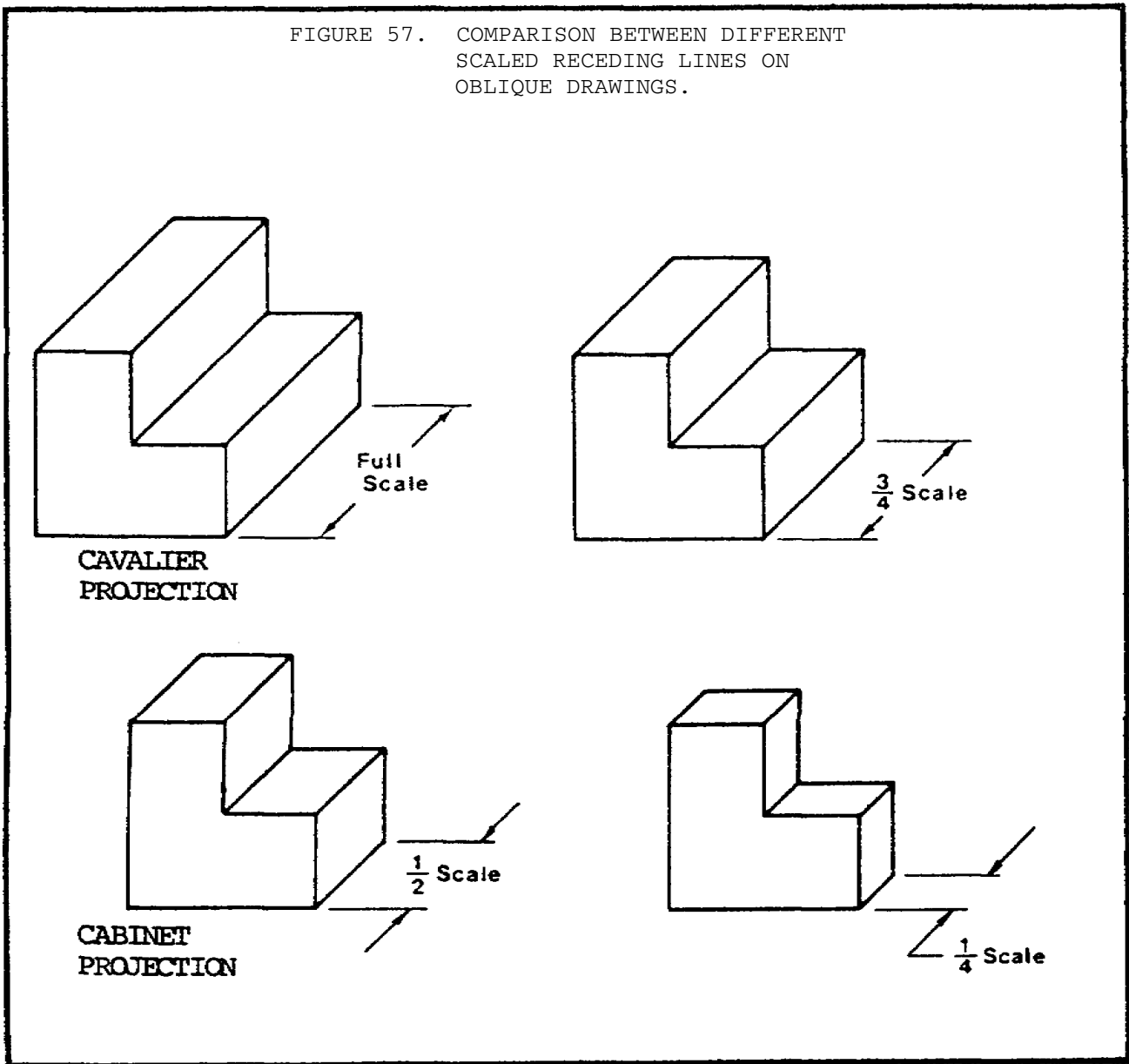
FIGURE 56. THE REFERENCE SYSTEM FOR
OBLIQUE DRAWINGS.



The receding lines may be drawn at any convenient angle. Upward and to the right at either 30° or 45° are most commonly used because these angles may be drawn with standard triangles. The choice of which receding angle to use depends on which angle best shows the object involved.

Dimensional values are directly transferable from the front view of the orthographic drawing to the front view of the oblique drawing. Circles transfer as circles, not as ellipses as in isometric drawings, and angles transfer as the same angles. Dimensional values in all other views are not directly transferable. They can only be transferred from the orthographic views to the receding axis of the oblique drawing.

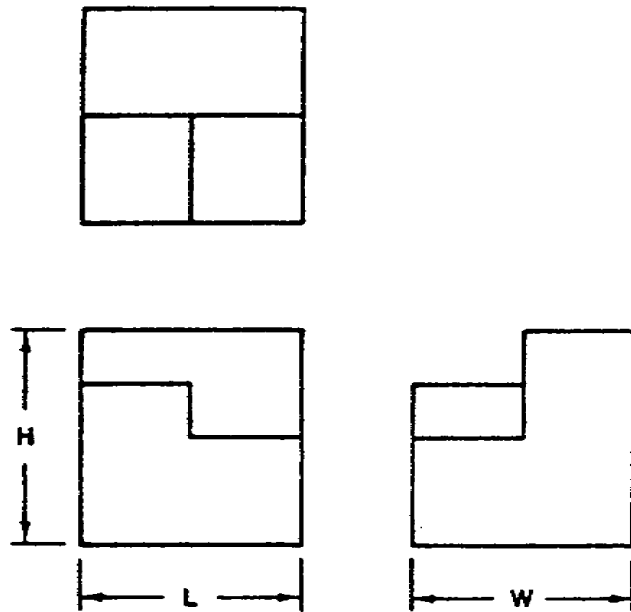
Sometimes, when dimensional values are transferred to the receding axis of the oblique drawing, they are redrawn at a reduced scale. The scale reduction improves the visual quality of the drawing. Note that in figure 57 (on the following page) the reduced scale of the receding axis changes the way the object looks. Although any scale reduction may be used, the most common is the half-scale reduction called a *cabinet projection*. If the dimensional values are transferred full-scale, the resulting oblique drawing is called a *cavalier projection*.



Oblique drawings do not normally include hidden lines, although they may be used if special emphasis is required.

a. *Normal Surfaces.* Figure 58 (on the following page) is a sample problem that involves creating an oblique drawing from given orthographic views. Since all surfaces in the problem are normal (at 90° to each other), all dimensional values may be directly transferred from the orthographic views to the axis of the oblique drawing.

FIGURE 58. NORMAL SURFACE OBLIQUE
DRAWING PROBLEM-ORTHOGRAPHIC
VIEWS.

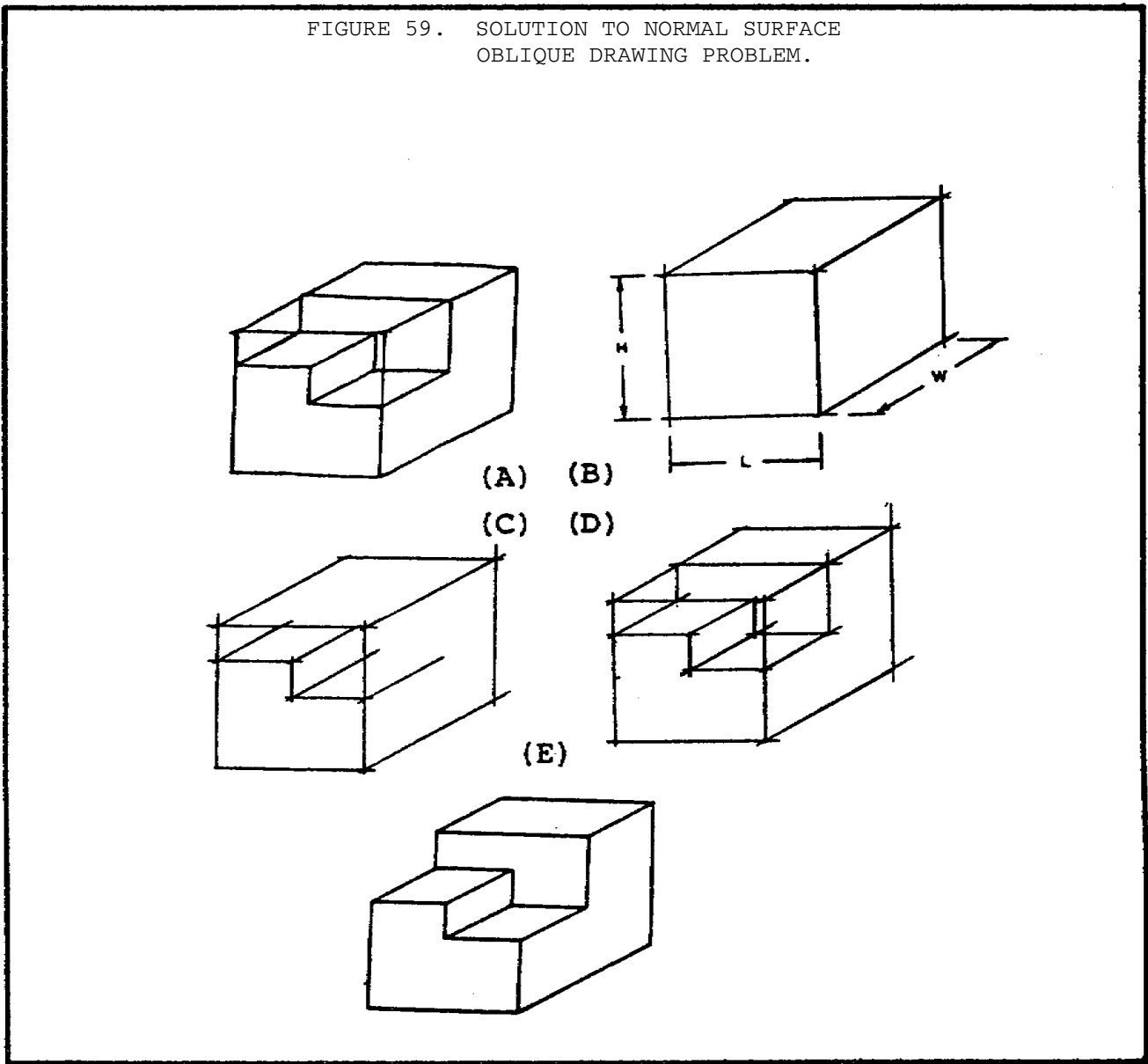


All values are to be transferred at full value, which means that the resulting oblique drawing is a cavalier projection. Figure 59 (on the following page) is the solution to this problem and was derived by using the following procedure:

Step 1. To the best of your ability, make an oblique freehand sketch of the proposed solution (view A).

Step 2. Using very light lines, lay out a rectangular box whose height, width, and length correspond to the height, width, and length given in the orthographic views. In this case, a receding axis of 30° was chosen (view B).

Step 3. Using very light lines, lay out specific details of the object. Transfer the dimensional values directly from the orthographic views to the axis of the oblique drawing. For example, use a pair of dividers and verify all other dimensional values (views C and D).



Step 4. Erase all lines and smudges, check your work, and draw in all lines to their final color and configuration (figure 59, view E).

b. *Inclined and Oblique Surfaces.* Figure 60 (on the following page) is a sample problem that involves creating an oblique drawing from given orthographic views that contain an inclined surface. Unlike isometric drawings, angular dimensions may be directly transferred from the front orthographic view to the front oblique view, thereby eliminating the need for supplementary layouts. Remember that the direct transfer only works on the front view and on surfaces parallel to the front view.

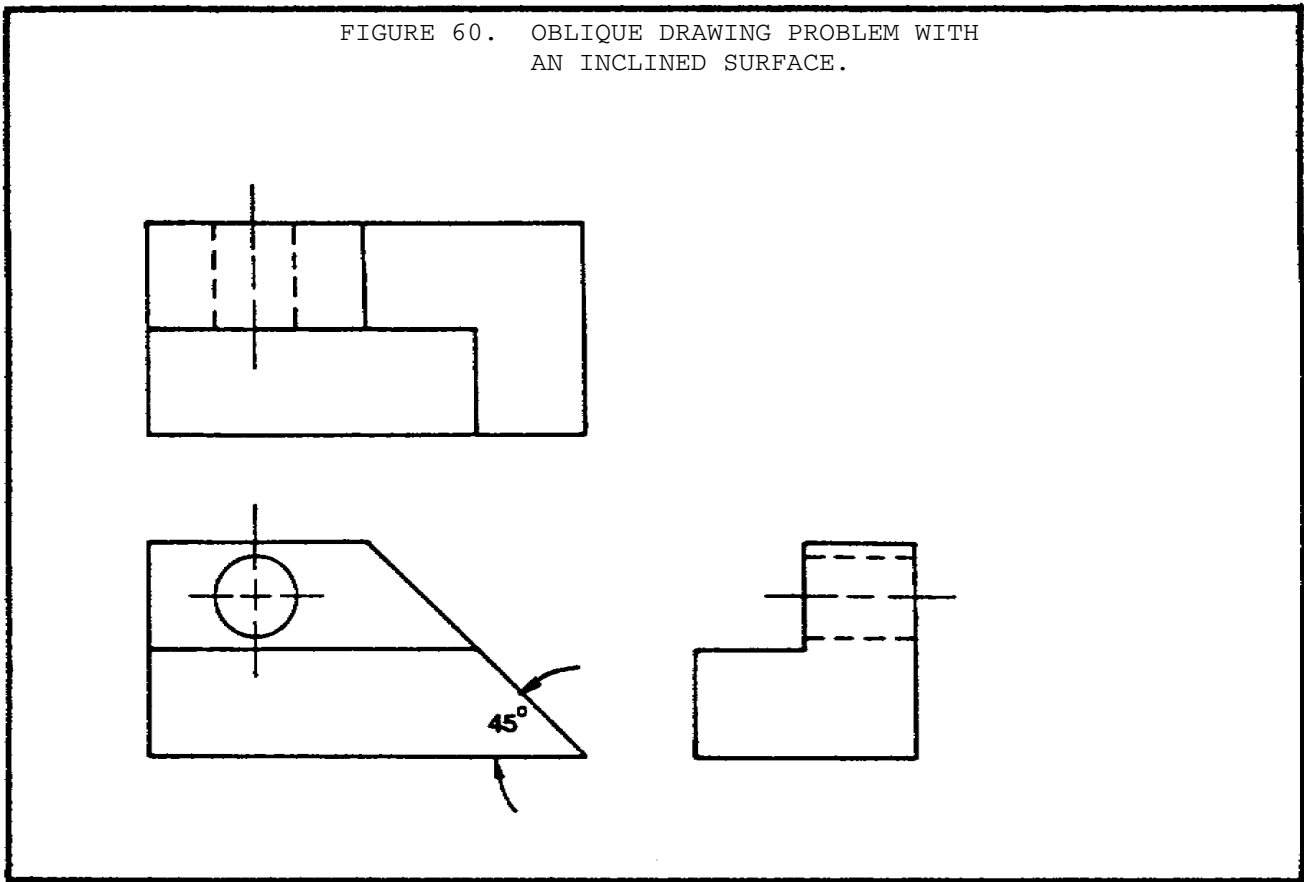


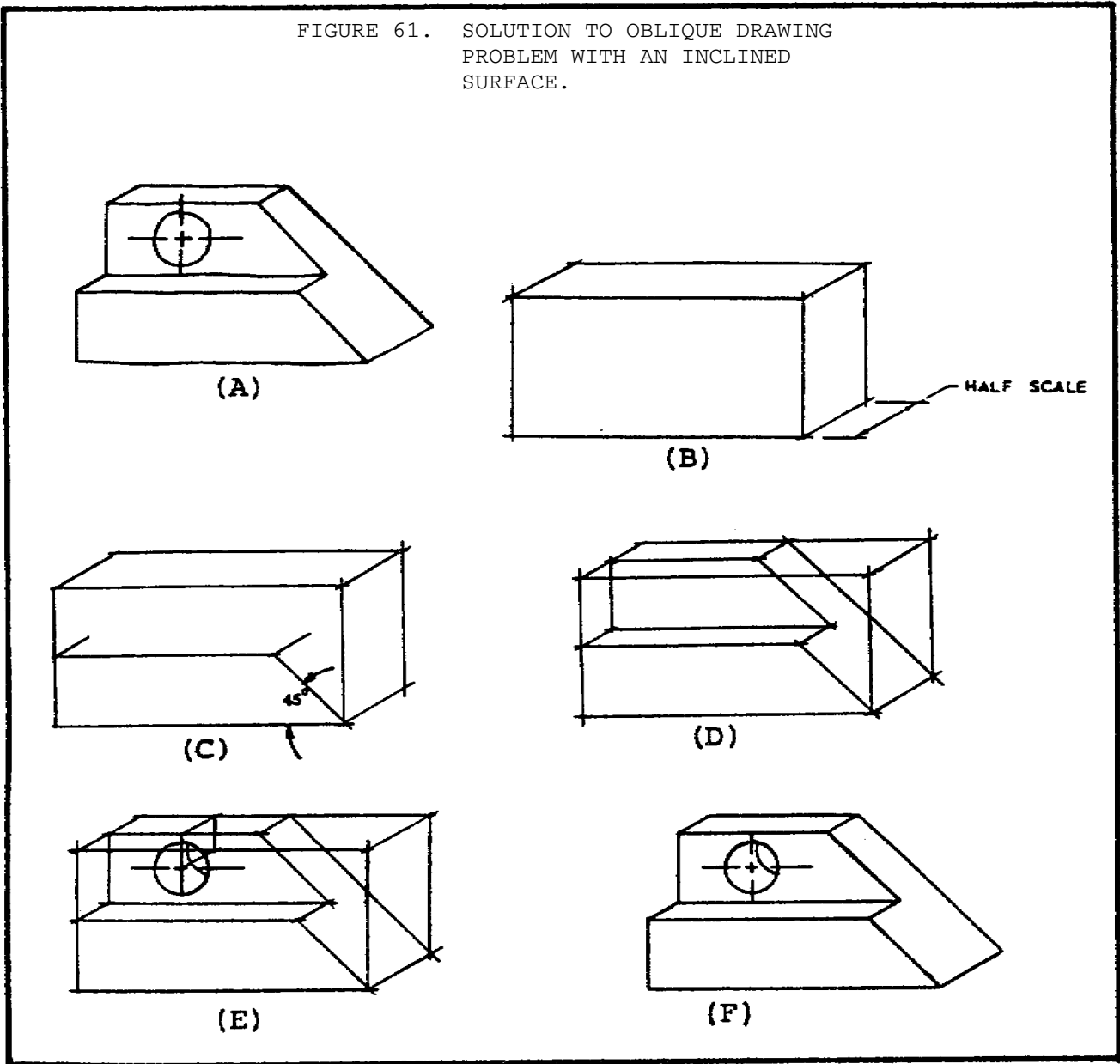
Figure 61 (on the following page) is the solution for this problem and was derived using the same procedures as for normal surfaces.

Step 1. To the best of your ability, make an oblique freehand sketch of the proposed solution (view A).

Step 2. Using very light lines, lay out a rectangular box whose height, width, and length correspond to the height, width, and length given in the orthographic views. In this case, a receding axis of 30° was chosen (view B).

Step 3. Using very light lines, lay out the specific details of the object. Transfer the dimensional values directly from the orthographic views to the axis of the oblique drawing (views C, D, and E).

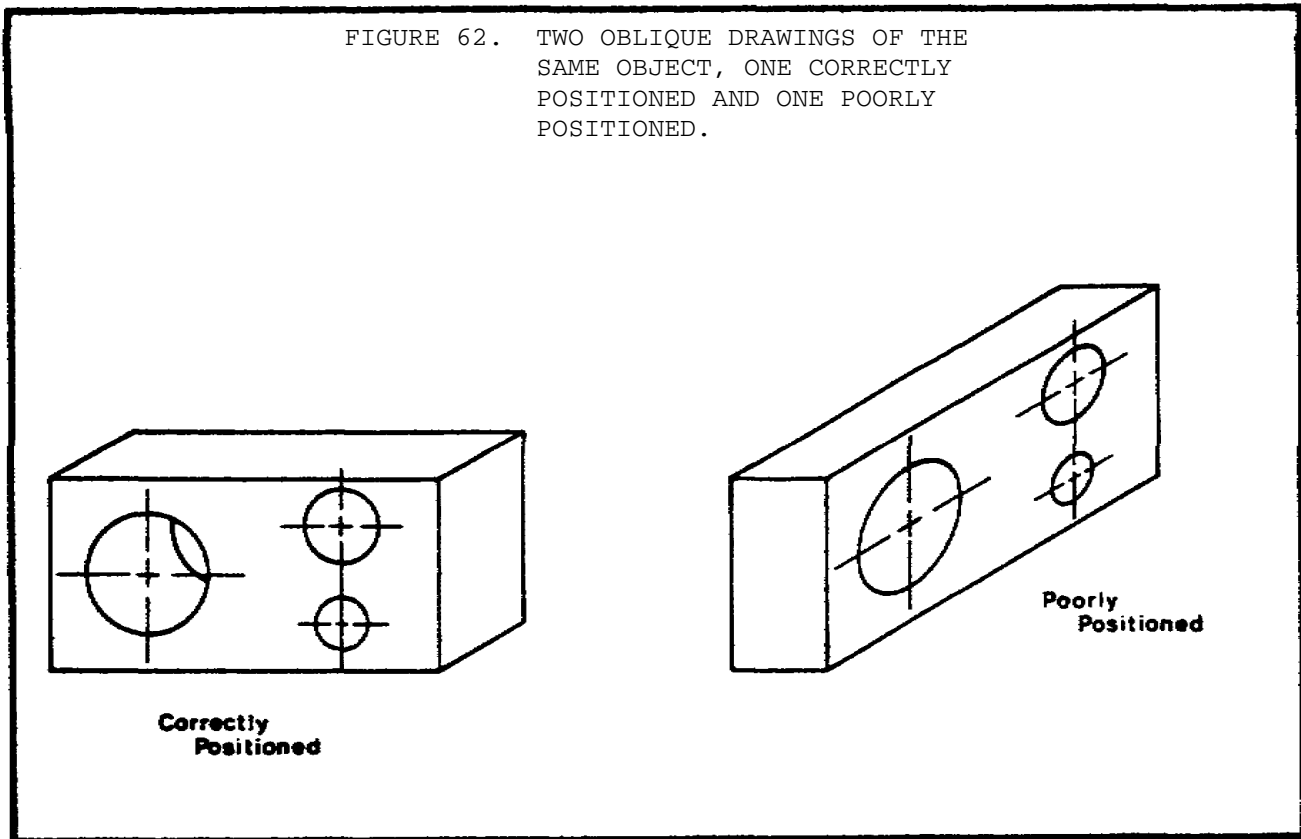
Step 4. Erase all lines and smudges, check your work, and draw in all lines to their final color and configuration (view F).



c. *Holes in Oblique Drawings.* The techniques required to draw holes in oblique drawings vary according to the surface on which you are working. On the front surface, and on all surfaces parallel to the front surface, holes are perfectly round and may be drawn with the aid of a compass or a circle template. On any other surface, elliptical holes must be drawn. Elliptical holes may be drawn by using either the four-center ellipse method or by using an elliptical template. Use only a template cut to the correct hole size, at the correct angle, which has been correctly aligned to the elliptical hole's center line.

When you are creating oblique drawings, take advantage, if possible, of the unique

characteristics of the front view by positioning the object with as many holes as possible located in the front view. Figure 62 shows two oblique drawings of the same object and demonstrates the value of correct positioning. In the drawing on the left, the object is positioned so that all holes are located in the front view; in the drawing on the right, the object is positioned so that the holes are located in one of the receding surfaces. This difference of positioning enables the left drawing to be drawn by using circles for holes; the right drawing requires elliptical holes. Because of the elliptical hole requirement, the drawing on the right takes about four times as long to draw as the drawing on the left. In addition, there is no appreciable gain in technical clarity: It is, however, important to remember that in positioning an object, your first consideration should be technical clarity and ease of understanding for the reader and not ease of drawing for the draftsman.



d. *Rounded and Irregular Surfaces.* Figure 63 (on the following page) is a sample problem that involves creating an oblique drawing from given orthographic views that contain a rounded surface.

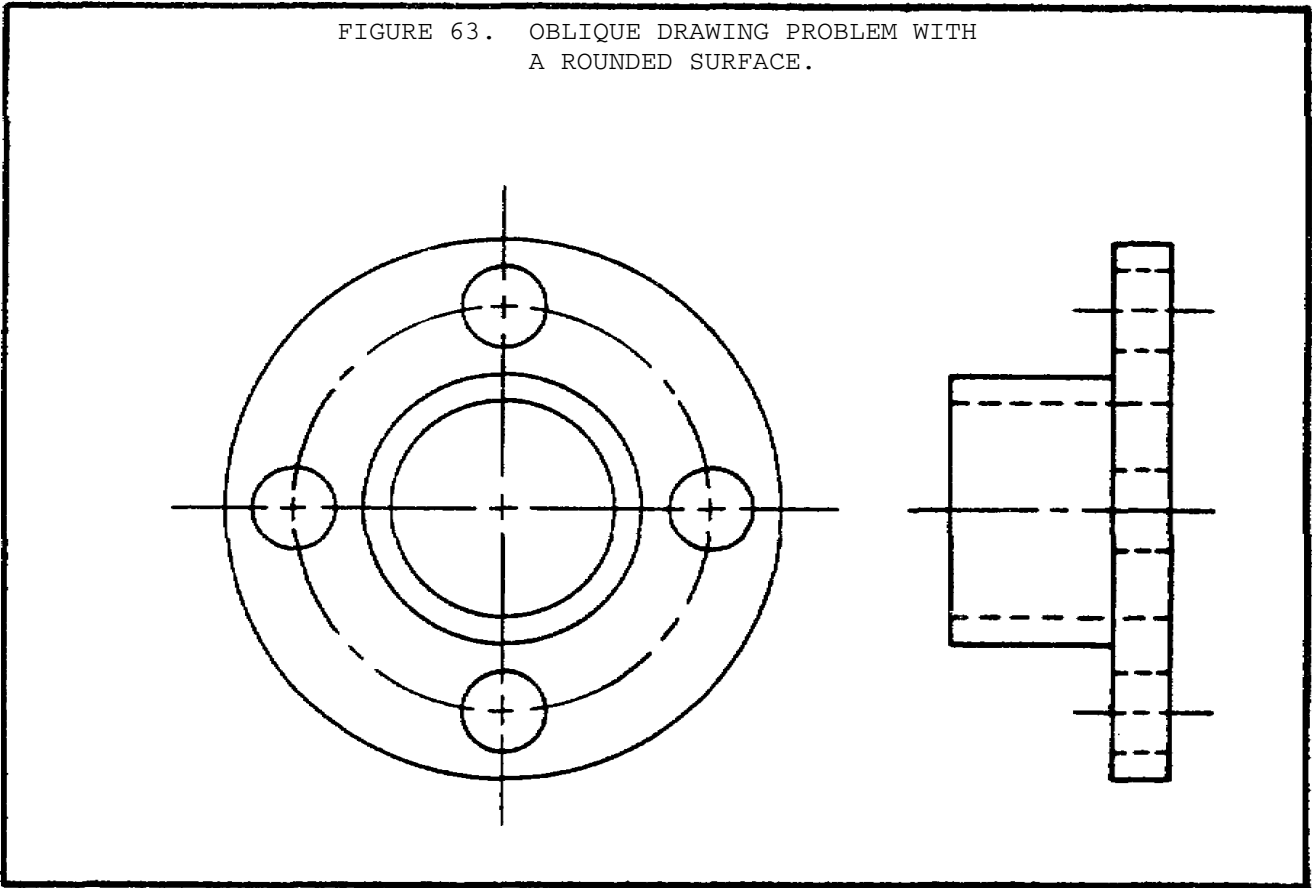


Figure 64 (on the following page) is the solution and was derived by performing the following steps:

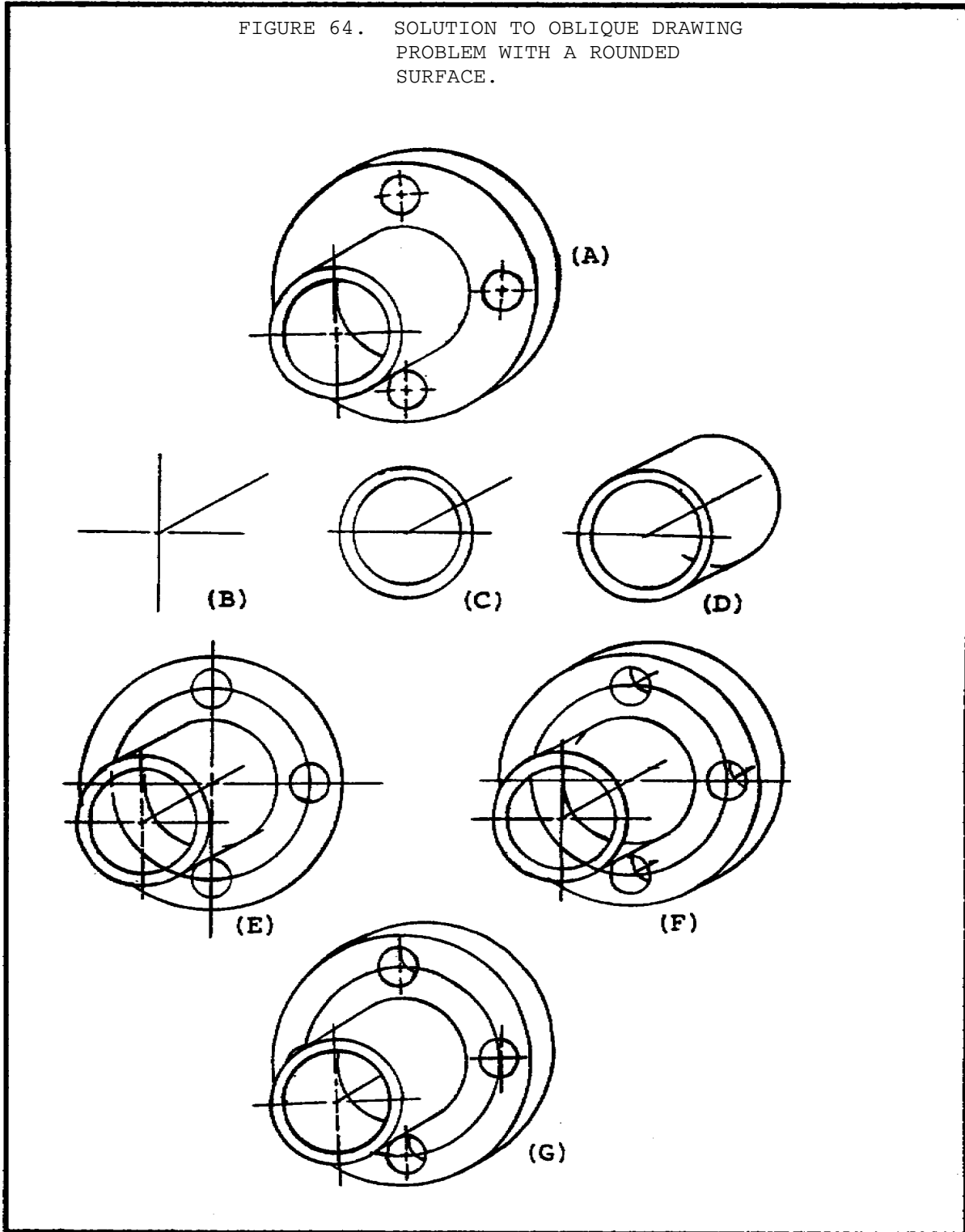
Step 1. To the best of your ability, make a freehand sketch of the solution (view A).

Step 2. Using very light lines, lay out a rectangular box whose height, width, and length corresponds to the height, width, and length given in the orthographic views. In this example, a basic cylinder shape was substituted for the rectangular shape (views B, C, and D).

Step 3. Using very light lines, lay out the specific details of the object. In this example, the round portions of the object are all positioned so that they appear in the front view or in views parallel to the front view. This positioning makes the object easier to draw (views E and F).

Step 4. Erase all excess lines and smudges, check your work, and draw in all lines to their final color and configuration (view G).

FIGURE 64. SOLUTION TO OBLIQUE DRAWING PROBLEM WITH A ROUNDED SURFACE.



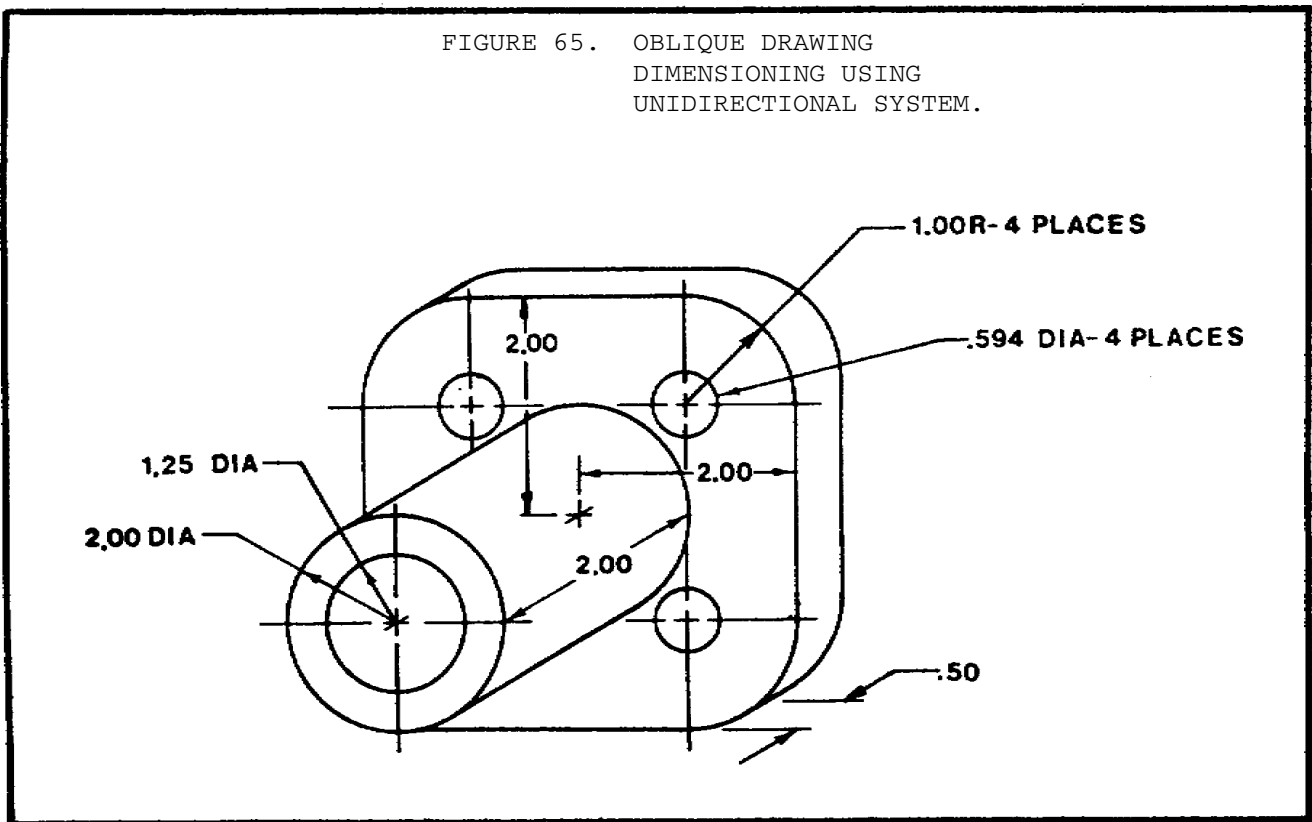
e. *Dimensioning an Oblique Drawing.* Oblique drawings may be dimensioned by using either the unidirectional or aligned systems. The front views and all other surfaces parallel to it are

dimensioned in the same way that they were in the orthographic views, but dimensions along the receding axis must be drawn in the same oblique plane as the surface they are defining.

In the aligned system, guidelines for dimensions that define receding surfaces must be drawn parallel to the receding axis. Guidelines for dimensions that define surfaces in the front view, or any surface parallel to the front view, are drawn either horizontally or vertically depending on whether they are defining horizontally or vertically.

In the unidirectional system, all guidelines are drawn horizontally. In both systems, all letters and numbers are drawn either 1/8 or 3/16 in height.

Figure 65 is an example of an oblique drawing that has been dimensioned by using the unidirectional system.



f. *Oblique Sectional Views.* Figure 66 (on the following page) illustrates a full-oblique sectional view, and figure 67 (on the following page) illustrates a half-oblique sectional view. Oblique sectional views are drawn in the same

sectional views are drawn. Since the only difference between the two sectional views is the defining axis system, the information given in paragraph 2f, page 63, may also be applied to oblique sectional views.

FIGURE 66. A FULL OBLIQUE SECTION CUT.

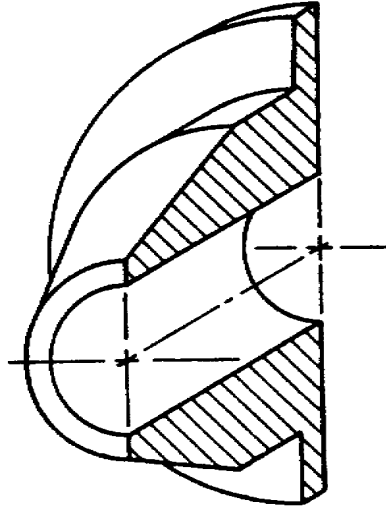
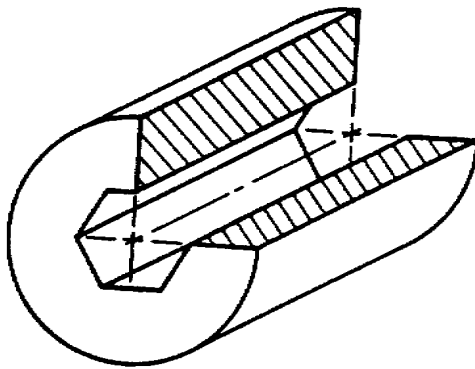


FIGURE 67. A HALF OBLIQUE SECTION CUT.



4. Conclusion

This concludes our discussion of the theory and fundamentals of: oblique and isometric pictorial drawings. In the next task, we will identify shop terms, abbreviations, and dimensioning elements.

LESSON 1

DRAFTING AND SHOP DRAWING FUNDAMENTALS

TASK 4. Identify shop terms, abbreviations, and dimensioning elements.

CONDITIONS

Within a self-study environment and given the subcourse text, without assistance.

STANDARDS

Within one hour

REFERENCES

No supplementary references are needed for this task.

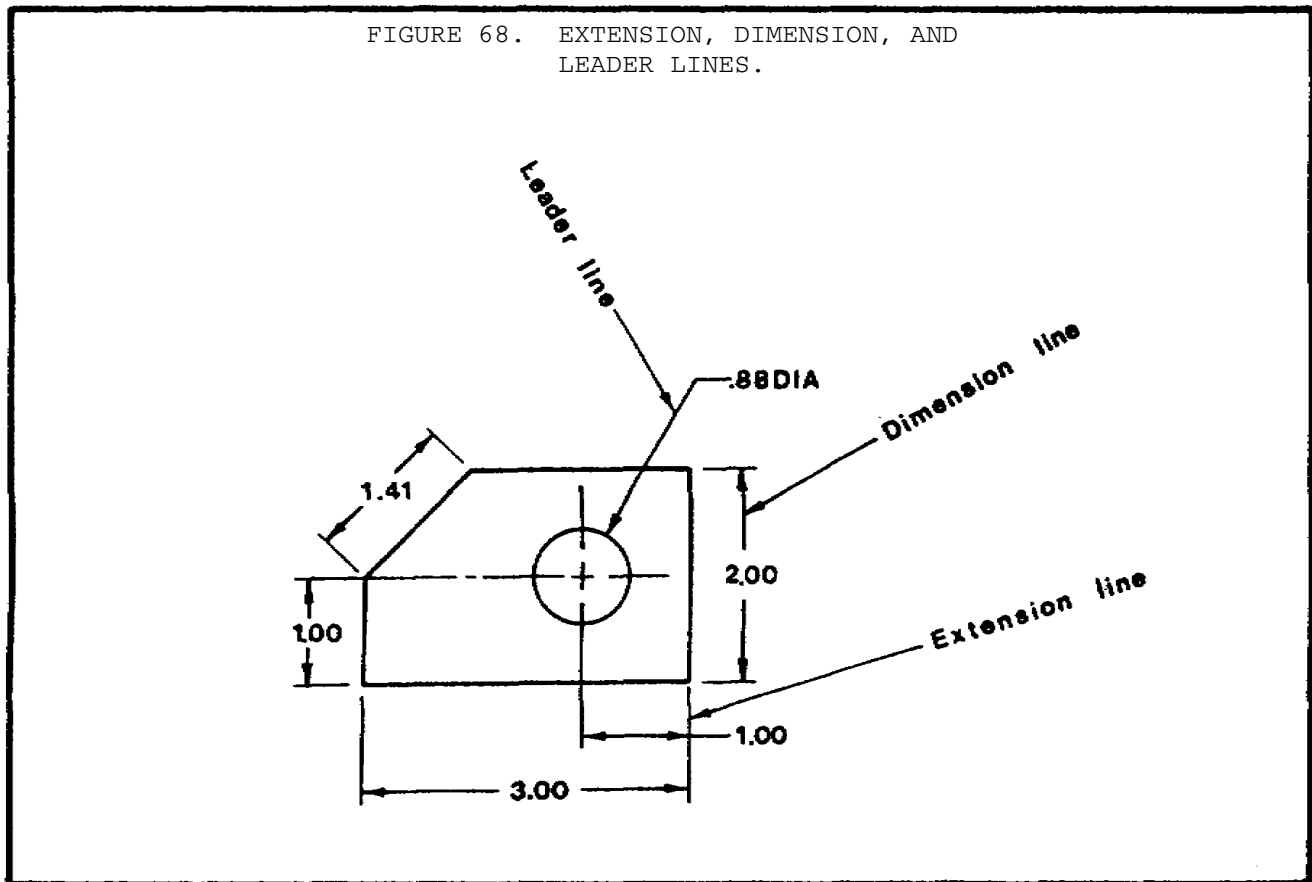
1. Introduction

In the previous three tasks, we covered orthographic projection, freehand drafting, drafting instruments, geometric construction, and pictorial drawings: oblique and isometric. In this task, we will identify shop terms, abbreviations, and dimensioning elements found on shop drawings. A shop drawing is the drawing one uses to work from, since it contains all of the information necessary to make an object.

2. Dimensions, Tolerances, and Allowances

In the following paragraphs, we will discuss dimensions, tolerances and allowances. The picture portion of a drawing defines the shape of the object, the dimensions define the size, and the tolerances define the amount of variance permitted in the size. All three pieces of information are needed to form a clear, understandable, manufacturable drawing.

a. *Dimensions.* Dimensions are placed on a drawing by using a system of extension lines, dimension lines, leader lines, and arrowheads. Figure 68 illustrates how these various kinds of lines are used for dimensioning.



(1) *Types of Lines.* The lines are defined as follows:

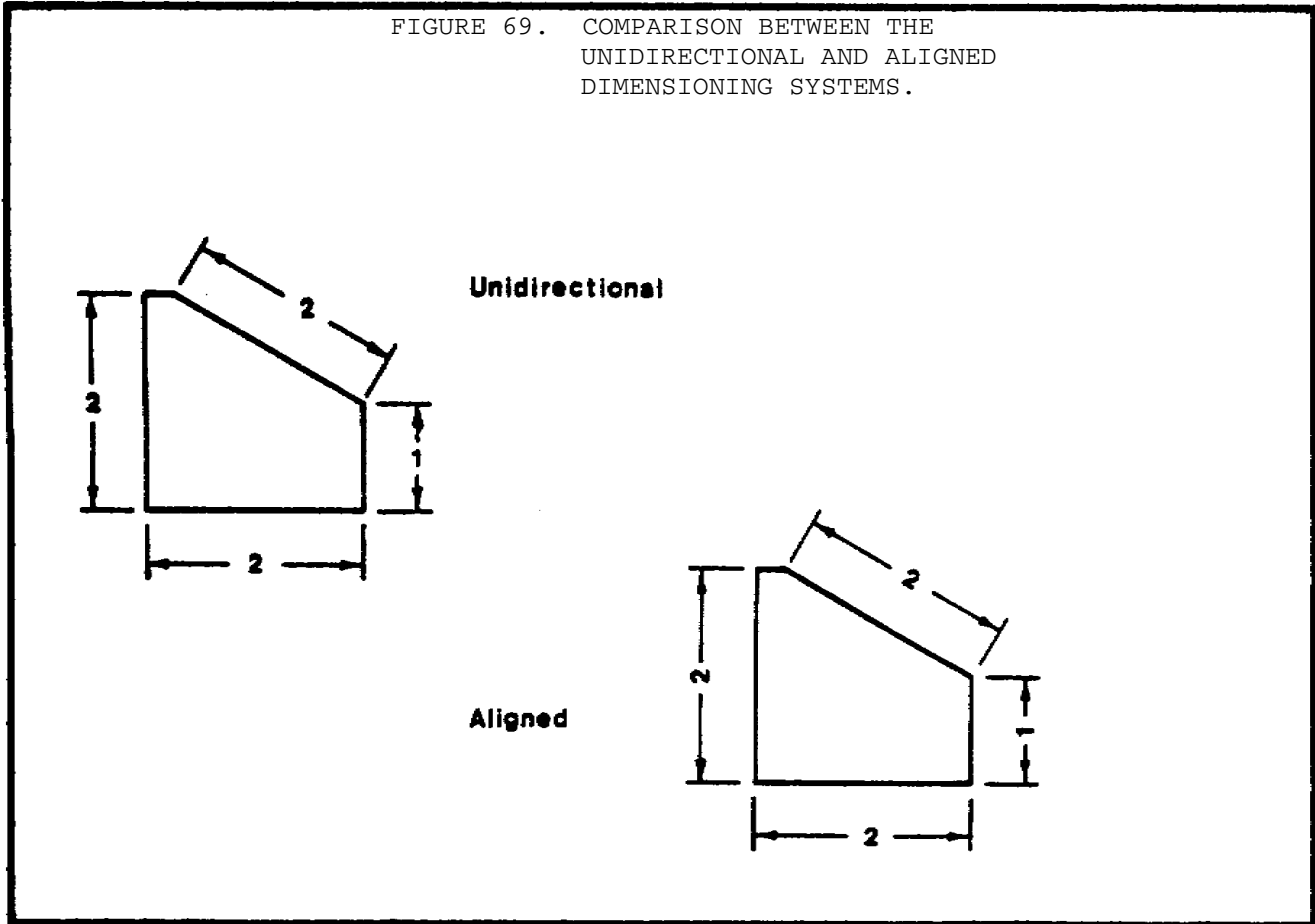
(a) Extension lines are used to indicate the extension of an edge or point to a location outside the part outline.

(b) Dimension lines show the direction and extent of dimension.

(c) Leader lines are used to direct an expression, in note form, to the intended place on the drawing. The leader line should terminate in an arrowhead or dot.

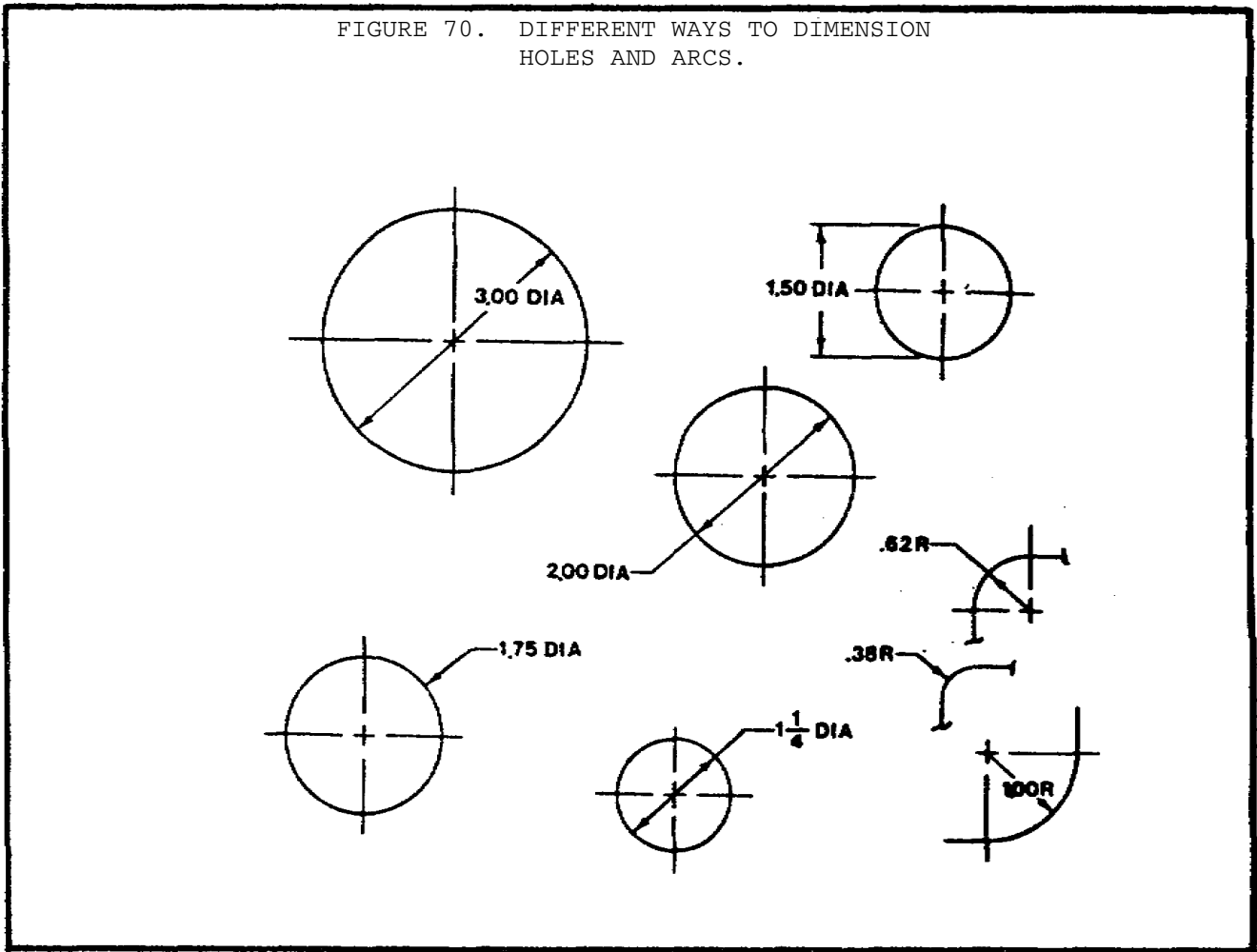
(d) Arrowheads are used to indicate the ends of the dimension lines and the ends of some of the leader lines.

(2) *Dimensioning Systems.* Dimensions may be positioned on a drawing by using either the unidirectional or the aligned system. The unidirectional system is the preferred system. In the unidirectional system, all dimensions are placed so that they can be read from the bottom of the drawing, that is, with their guidelines horizontal. In the aligned system, dimensions are placed so that they may be read from either the bottom or the right side of the drawing, that is, with their guidelines parallel to the surface that they are defining. Figure 69 illustrates the difference between the two systems.



(3) *Dimensioning Holes.* Figure 70 (on the following page) illustrates several ways to dimension holes. Holes are usually dimensioned to their diameters because most drills, punches, and boring machines are set up in terms of diameters. Arcs are usually dimensioned according to radii.

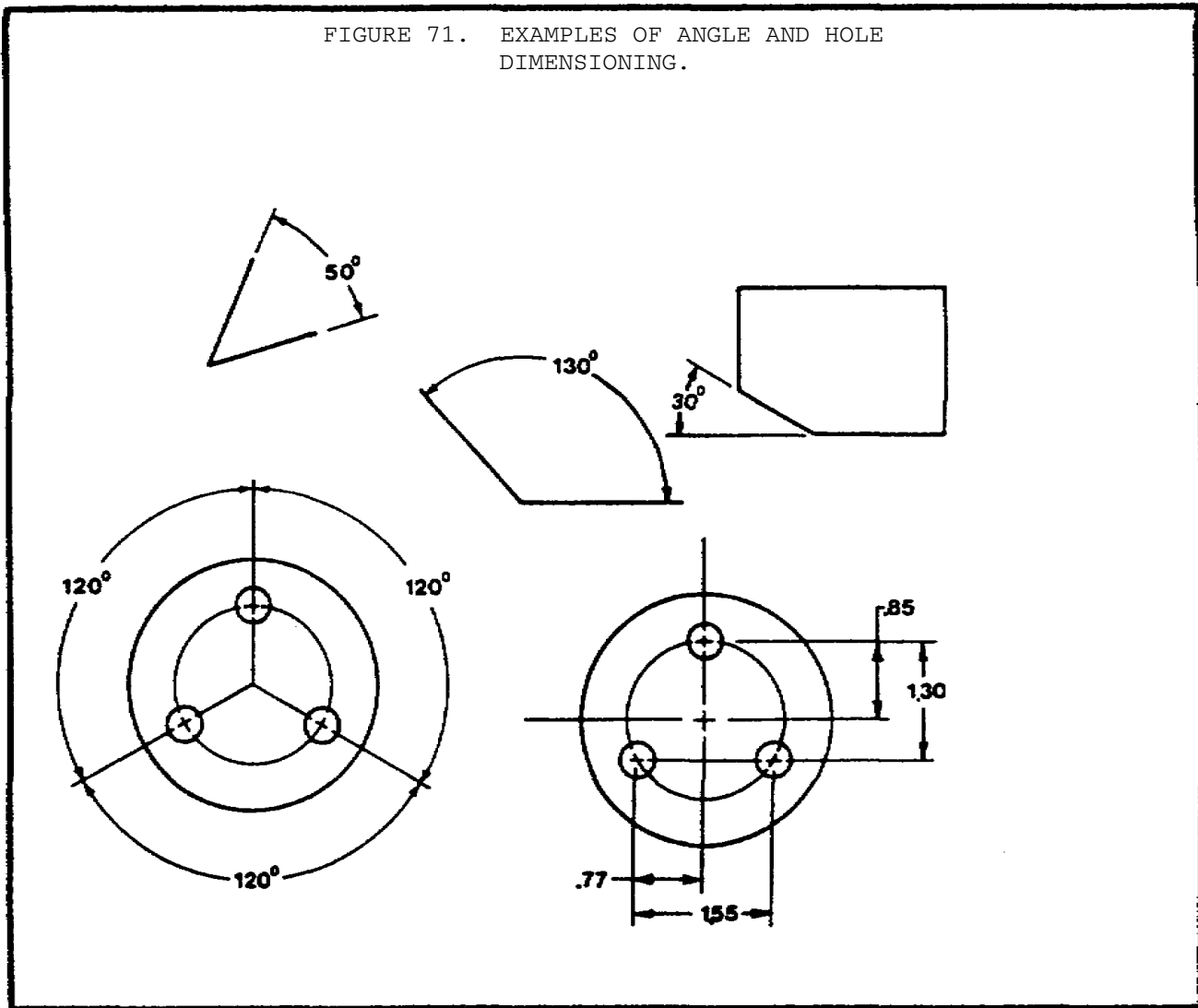
Always locate a hole by dimensioning to its center point. Make sure that the center point of the hole is clearly defined by crossing the short sections of the center lines. The long sections of the center lines may be dimensioned as if they were extension lines.



When using leader lines, always point the arrow end of the line at the center point of the hole. Always finish the non-arrow end with a short horizontal section that will guide the reader's eye into the dimension note. Always place dimension notes so that they may be read from the bottom of the drawing.

(4) *Dimensioning Angles and Holes.* Figure 71 (on the following page) illustrates several different ways to dimension angles. It also illustrates the angular (dimensioned with angles) and the coordinate (dimensioned using the center lines as base lines) systems of dimensioning holes on an object.

FIGURE 71. EXAMPLES OF ANGLE AND HOLE DIMENSIONING.



(5) *Dimensioning Small Distances and Small Angles.* When dimensioning a small distance or a small angle, always keep the lettering at the normal height of either 1/8 or 3/16. The temptation is to squeeze the dimensions into the smaller space. This is unacceptable because crowded or cramped dimensions are difficult to read, especially on blueprints which are microfilmed. Figure 72 (on the following page) shows several different ways to dimension small distances or angles and still keep the dimensions at the normal height.

FIGURE 72. DIFFERENT WAYS TO DIMENSION SMALL DISTANCES AND ANGLES.

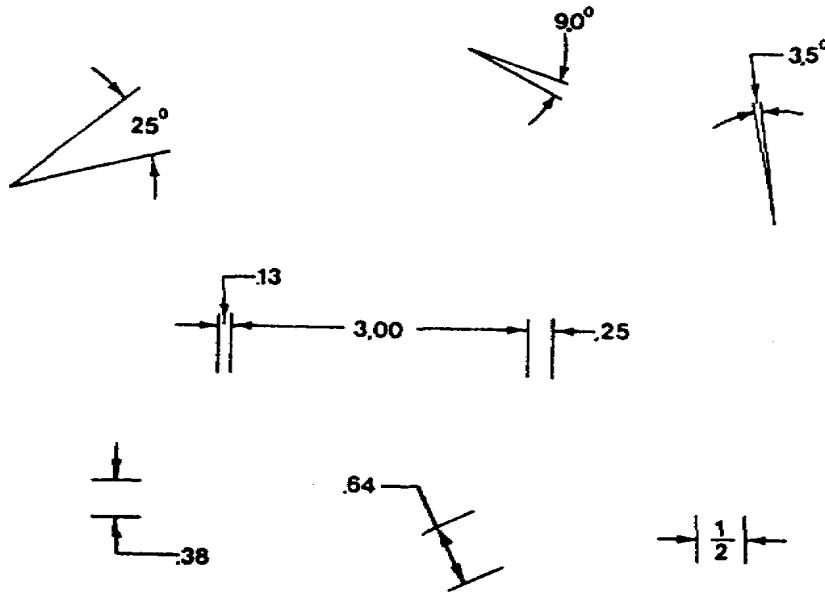
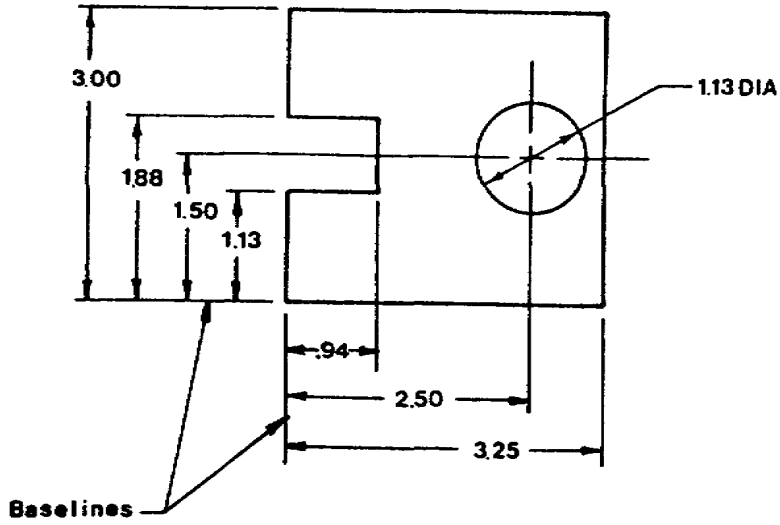


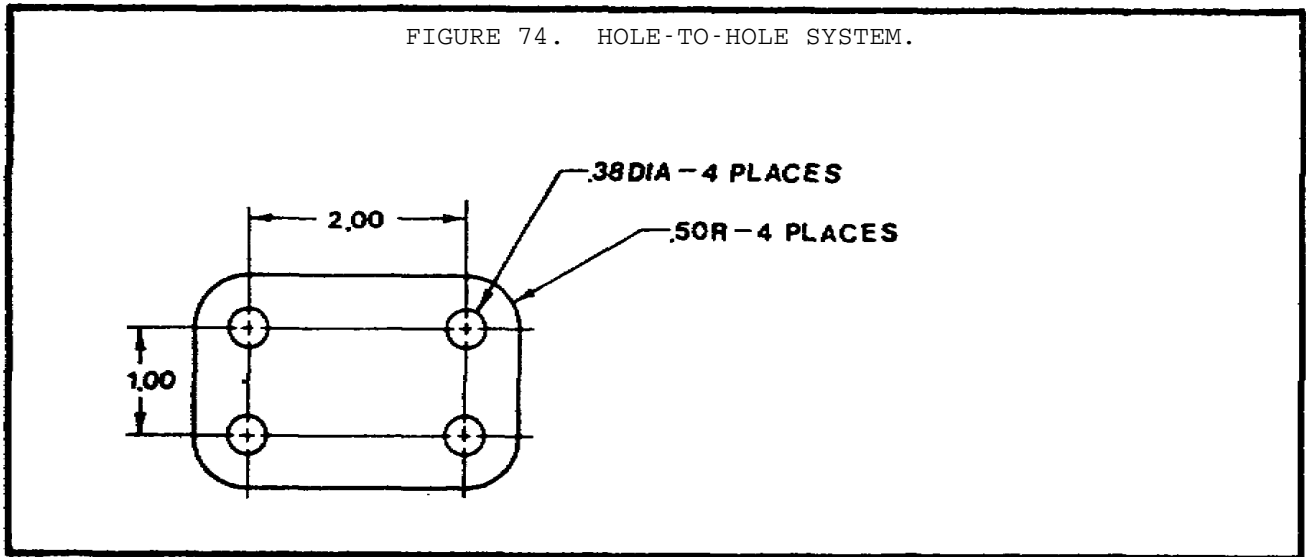
FIGURE 73. BASELINE SYSTEM.



(6) *Baseline System.* The baseline system of dimensioning is illustrated in figure 73 (on the previous page). All dimensions in the same plane are located from the same line which is called a *baseline*. It is sometimes called a *reference line* or *datum line*. This system is particularly useful because it eliminates tolerance buildup, it is easy for manufacturers and inspectors to follow, and it is easily adaptable to the requirements of numerical tape machines. Its chief disadvantage is that the amount of space used on the drawing paper is larger-- usually at least twice the area of the surface being defined. Also, once it is setup, it is difficult to alter.

When you use the baseline system, be careful to include all needed dimensions and be sure to use a large enough piece of paper.

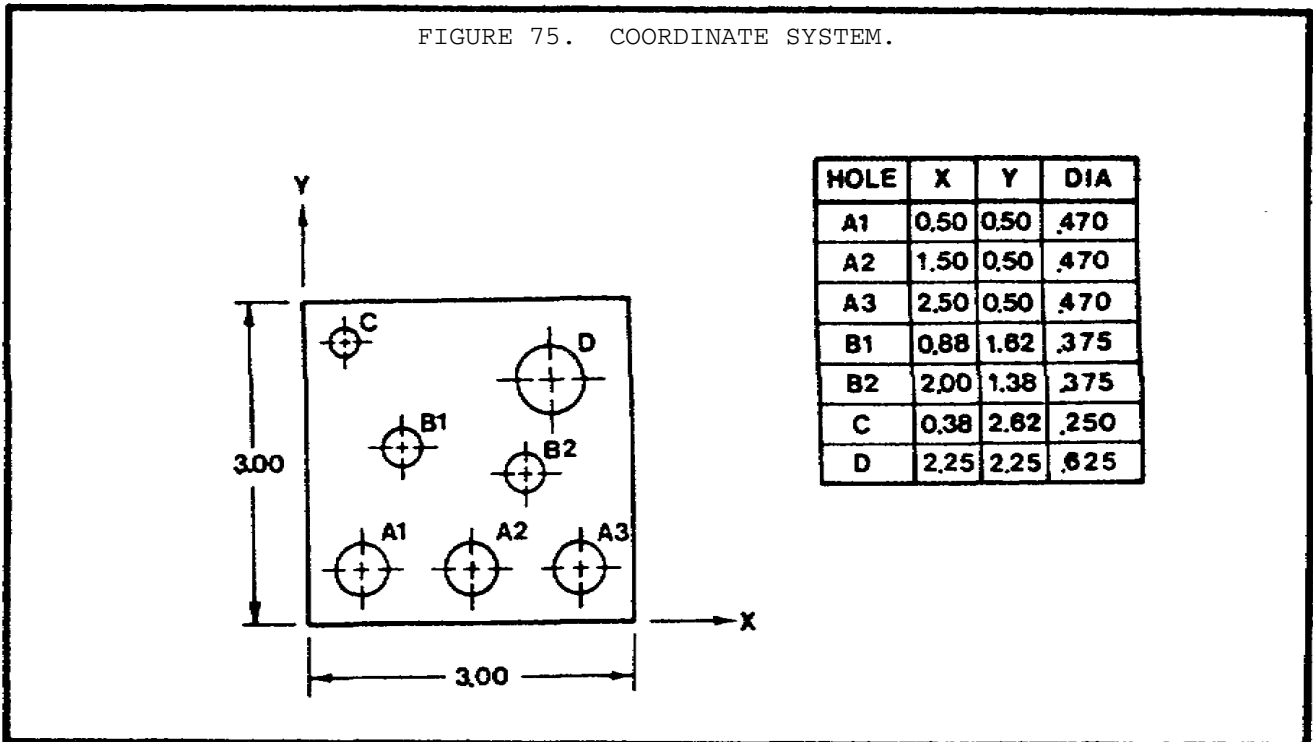
(7) *Hole-to-Hole System.* The hole-to-hole system is illustrated in figure 74. It is a modification of the baseline system used to dimension parts whose hole-to-hole distances are critical; for example, a part that must be aligned with the shafts or dowels of another part for proper assembly.



In the hole-to-hole system, all dimensions in the same plane are measured for the lines that define the critical holes. The baseline is not, in this case, a physical line, but is the center line between the critical holes.

(8) *Coordinate System.* The coordinate system is a dimensioning system based on the mathematical x-y coordinate system. It is usually only used to dimension an object that contains a great many holes, for example, an electrical chassis. It is particularly well-suited to computer use and to numerically controlled tape machines.

Each hole on the given surface is located relative to an x-y coordinate system, then all values are listed in a chart. The overall dimensions are not included in the chart but are located on the picture part of the drawing. Figure 75 is an example of an object dimensioned by using the coordinate system.



(9) *Tabular Dimensions.* Often manufacturers will produce a part in several different sizes. Each part will have the same basic shape, but the part will vary in overall size. To save having to dimension each part individually, a system called *tabular dimensioning* is used. Figure 76 (on the following page) illustrates an example of tabular dimensioning.

To read tabular dimensions, look up the part number in the table and substitute the given numerical values for the appropriate letters in the figure. For example, part number 1003 (according to the

table) has an A value of 2.25, a B value of 1.50, and so on. Part number 1005 has an A value of 2.50, a B value of 1.75, and so on. The numerical dimensions of .50, located on the picture part of the drawing, mean that these dimensions do not vary, that they remain the same for all parts.

FIGURE 76. TABULAR DIMENSIONS.

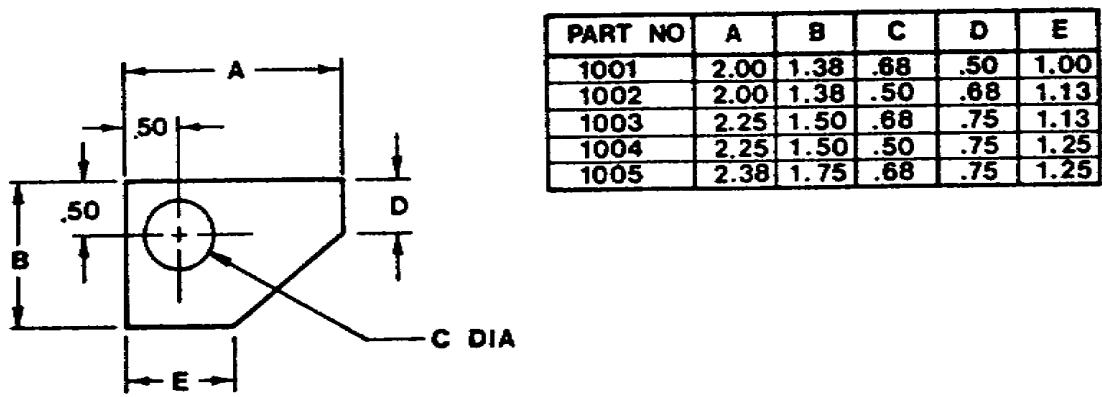
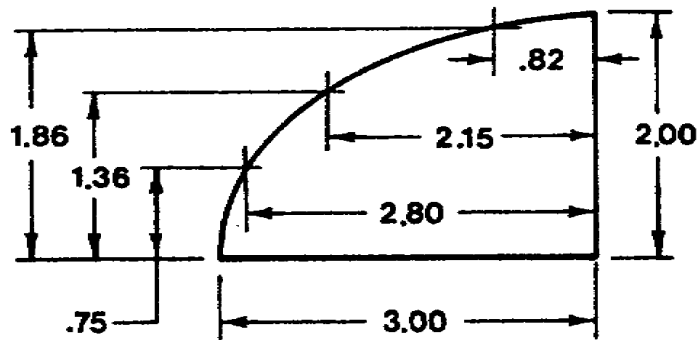


FIGURE 77. DIMENSIONING AN IRREGULAR CURVE.



The table may also be used in reverse. If you know what your given design requirements are, look up these values in the table to find which part number you should call out on the drawing.

(10) *Irregularly Shaped Curves.* To dimension an irregularly shaped curve, dimension the points that define the line. The more points you dimension, the more accurate will be your definition. Figure 77 (on the previous page) illustrates a dimensioned irregularly shaped curve.

b. *Tolerances.* No dimension can be made perfectly. Unless you are very lucky, there will always be some variance. If, for example, you call for a dimension to be made 5 inches long, you will not get exactly 5 inches on the finished part. It may measure 5.0001 or 4.99999, etc., but it will not be exactly 5 inches.

It is not only impossible to manufacture perfect dimensions, it is also unnecessary. It is possible for a carpenter to build a house within the nearest 0.01 inches, but it isn't necessary for the structural soundness of the house. Think of how much time such a constraint would add to the normal time required to build a house, and then think of how this extra time would needlessly affect the building cost of the house.

Because it is impossible to manufacture perfect dimensions, all dimensions must be toleranced. Each dimension must be considered separately in regard to how much variance is acceptable to ensure a satisfactory finished product. The final judgment must be made by considering among other things manufacturing capabilities, customer requirements, usage requirements, material properties, and cost constraints. It takes experience and practice to make such a judgment correctly.

Many companies have "standard" tolerances. That is, their shops will always work to a given standard tolerance unless they are specifically told to do otherwise. The standard tolerance is usually printed on the drawings as part of the company's title block.

c. *Allowances.* This is an intentional difference in the dimensions of mating parts; i.e., the minimum clearance (positive allowance) or maximum

interference (negative allowance) that is intended between mating parts. It represents the tightest possible fit, or the largest internal member mated with the smallest external member.

d. *Basic Hole Allowance System.* This is the standard method of determining the size of a hole into which a shaft is to be fitted.

(1) *Plus Tolerance.* The hole limits are plus only. The hole can be larger than the basic dimension, but not smaller.

(2) *Minus Tolerance.* The shaft has a minus tolerance only. It can be smaller than the basic dimension.

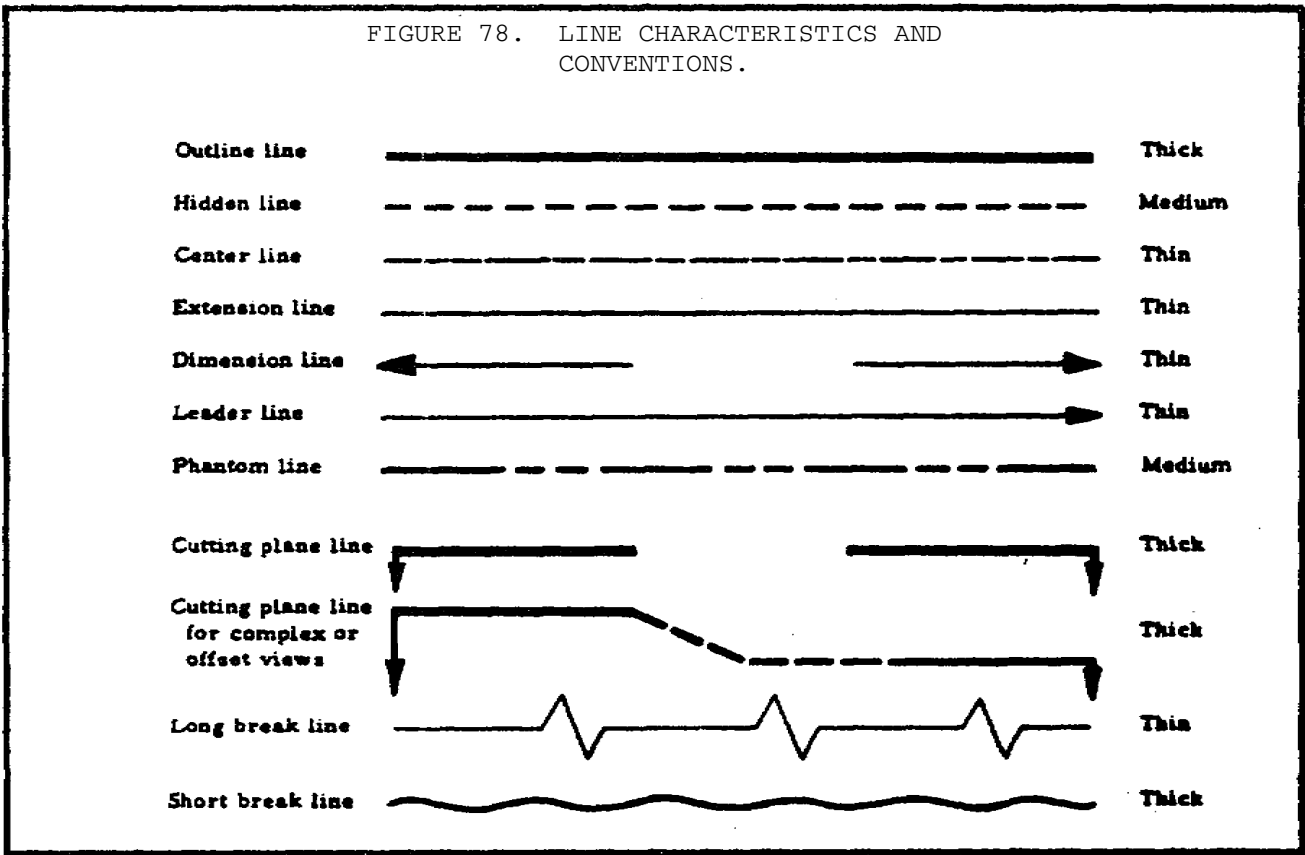
3. Lines and Sections

a. *Lines.* Lines are the language of the draftsman. He must place a lot of information in a small space so he uses as few words as possible. The draftsman's drawings are composed of lines of different construction, each line with a special meaning. To learn the appearance and use of these lines is essential to the understanding of shop drawings. Figure 78 on the following page illustrates each type of line.

(1) *Outline Line.* On a shop drawing, the draftsman uses outline lines. These thick, solid lines represent the edges and surfaces that are visible from the angle at which the view is drawn and make it possible to identify the object.

(2) *Hidden Line.* These lines are used to represent lines known to be on the inside or back surfaces of objects but not visible. To represent these invisible lines, draftsmen use a medium-weight broken line--made by a series of short dashes (all the same length) with uniform spacing.

(3) *Center Line.* Center lines are used to locate the center of a circle or arc, and also to divide drawings into equal or symmetrical parts. They are lightweight, broken lines of alternate long and short dashes. Center lines are aligned to indicate the travel of a center. Center line is abbreviated CL.



(4) *Extension Line.* Extension lines, very light in weight, are extended from lines of the outline. They are started about one-sixteenth of an inch away from the view outline.

(5) *Dimension Line.* Size is indicated on drawings by dimensions. Size dimensions are placed in a break in the dimension line. Some dimensions are placed between arrowhead tipped lines. In either case, the dimension distance is from the point of one arrowhead to the point of the other arrowhead. Normally, to keep dimensions clear, they are placed outside the view; sometimes, out of necessity, they are placed inside.

(6) *Leader Line.* Leaders are used as connectors between names and the proper lines they represent, to avoid confusion. The pointing end of the leader is usually tipped by an arrow. The note or name used with the leader is located in a clear space that is not covered by the views or dimension lines of the drawing.

(7) *Phantom Line.* These lines show possible alternate positions of moving parts. They are composed of alternating one long and two short dashes evenly spaced with a long dash at each end.

They are the same weight as hidden lines but are about twice as long.

(8) *Cutting Plane Line*. These lines indicate an imaginary cut, and arrows are used to show the direction the workman is to look at the sectional view.

(9) *Long Break Line*. These are space savers for the draftsman. They do not change the actual length indicated by the dimension, but make it possible for the draftsman to show an object for which he would not otherwise have room.

(10) *Short Break Line*. These are used to indicate that the draftsman has removed part of an outer surface to reveal the inside structure. They usually come in pairs.

b. *Sections*. A sectional view allows you to look inside an object shown on a shop drawing. Sectional views are necessary for a clear understanding of complicated parts. On simple drawings, a section may serve the purpose of an additional view.

(1) *Full Section*, (figure 79 on the following page). The object is cut completely through, showing the whole view in section.

(2) *Offset Section*, (figure 80 on the following page). A joggle or offset is in the cutting plane.

(3) *Half Section*, (figure 81 on page 91). Two cutting planes meet at right angles at the center line.

(4) *Revolved Section*, (figure 82 on page 91). This is a drawing within a drawing, which eliminates extra views of rolled shapes, ribs, etc.

(5) *Removed Section*, (figure 83 on page 92). This serves the same purpose as the revolved section, but instead of being drawn on the view, it is set off or shifted to some adjacent place on the paper. It may be enlarged to facilitate detailing and dimensioning.

(6) *Broken-out Section*, (figure 84 on page 92). This is done by removing a part of the outside surface when only a small area of the inside need be shown.

FIGURE 79. FULL SECTION.

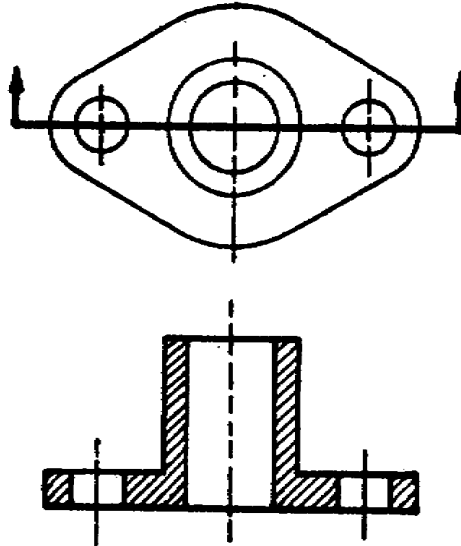
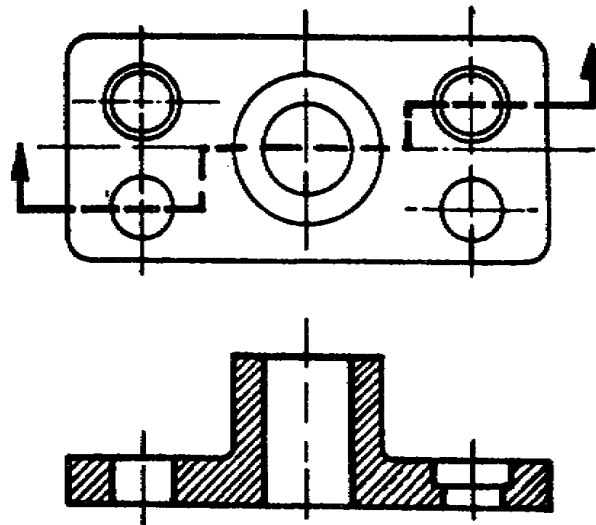


FIGURE 80. OFFSET SECTION.



(7) *Aligned Section* (figure 85 on page 93). When an object is symmetrical in shape but has an odd number of divisions, it is not considered good practice to make a true sectional view. It is,

therefore, necessary to depict two of the divisions, one of them being revolved into the plane of the other so as to result in a sectional view on both sides of the center line.

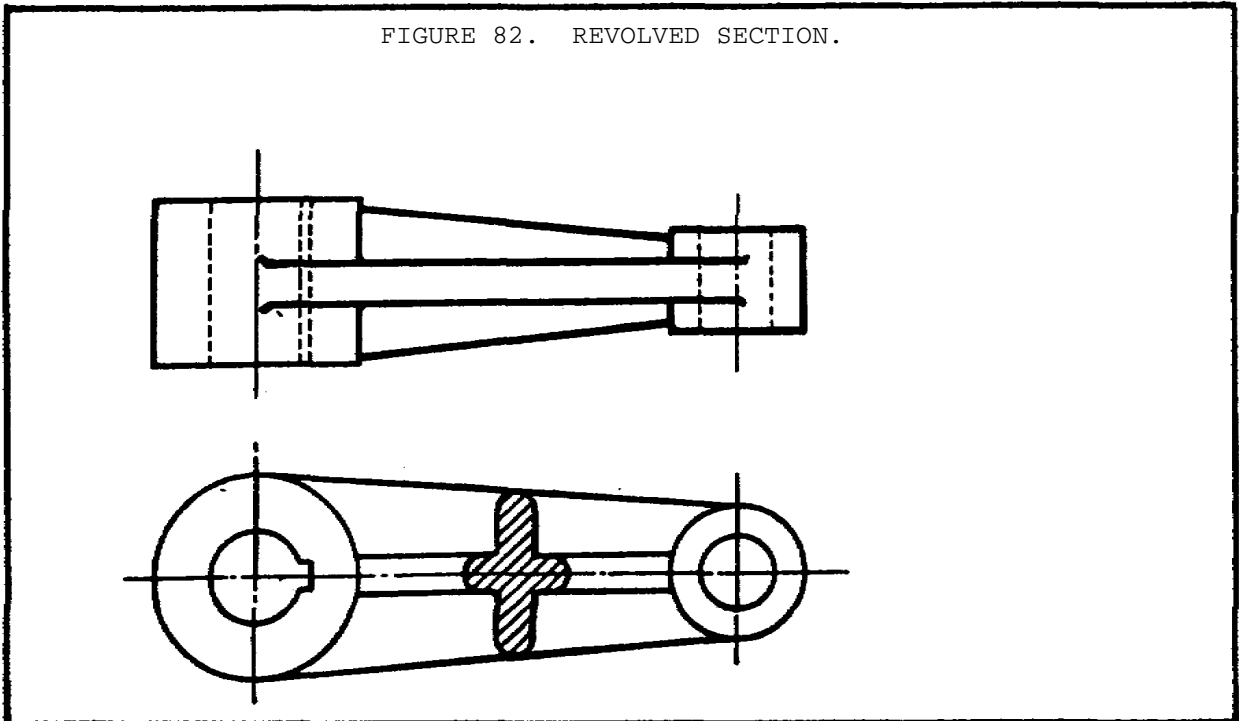
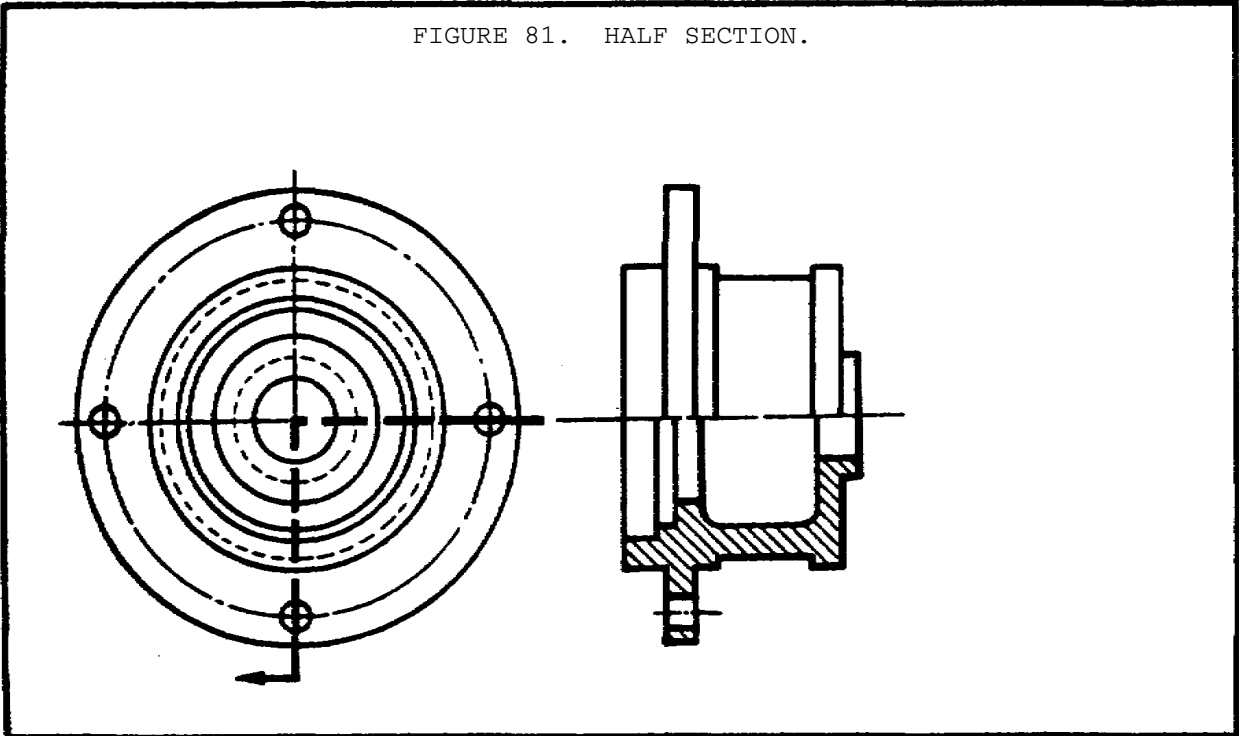


FIGURE 83. REMOVED SECTION.

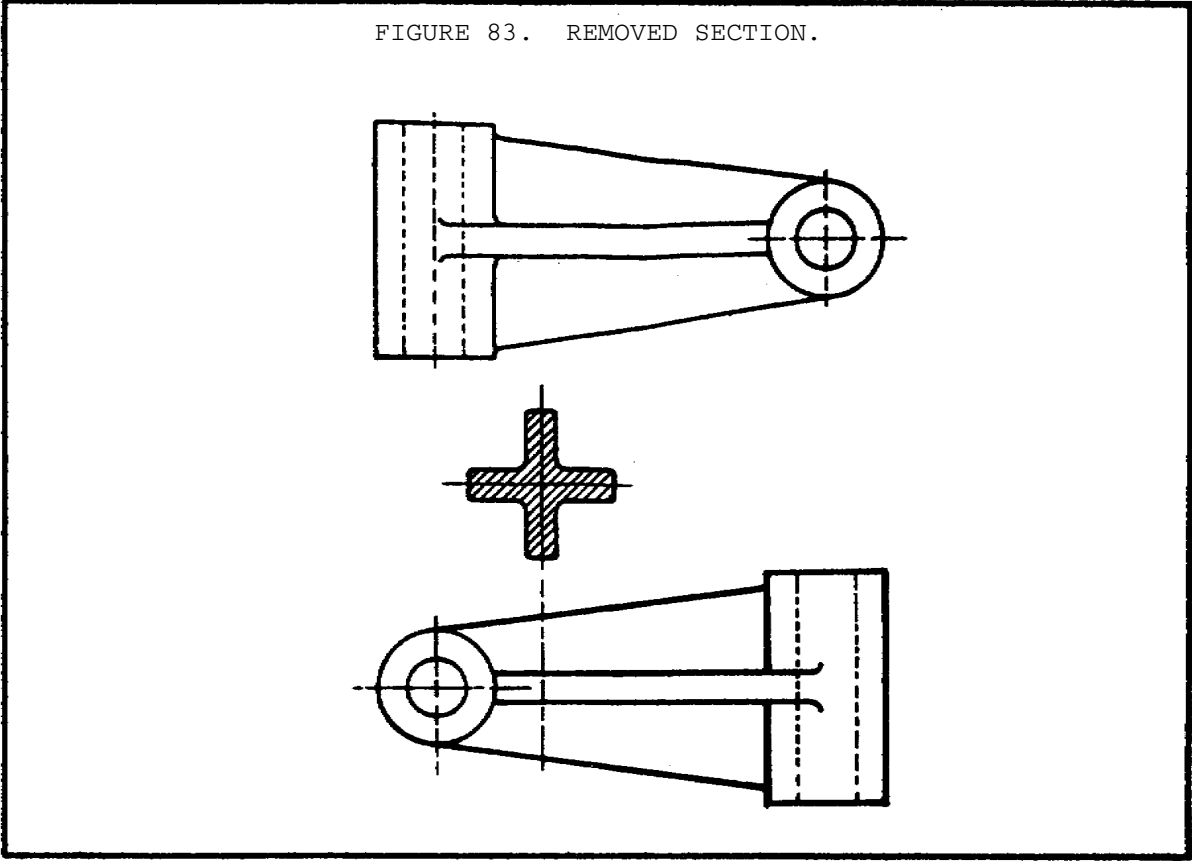


FIGURE 84. BROKEN-OUT SECTION.

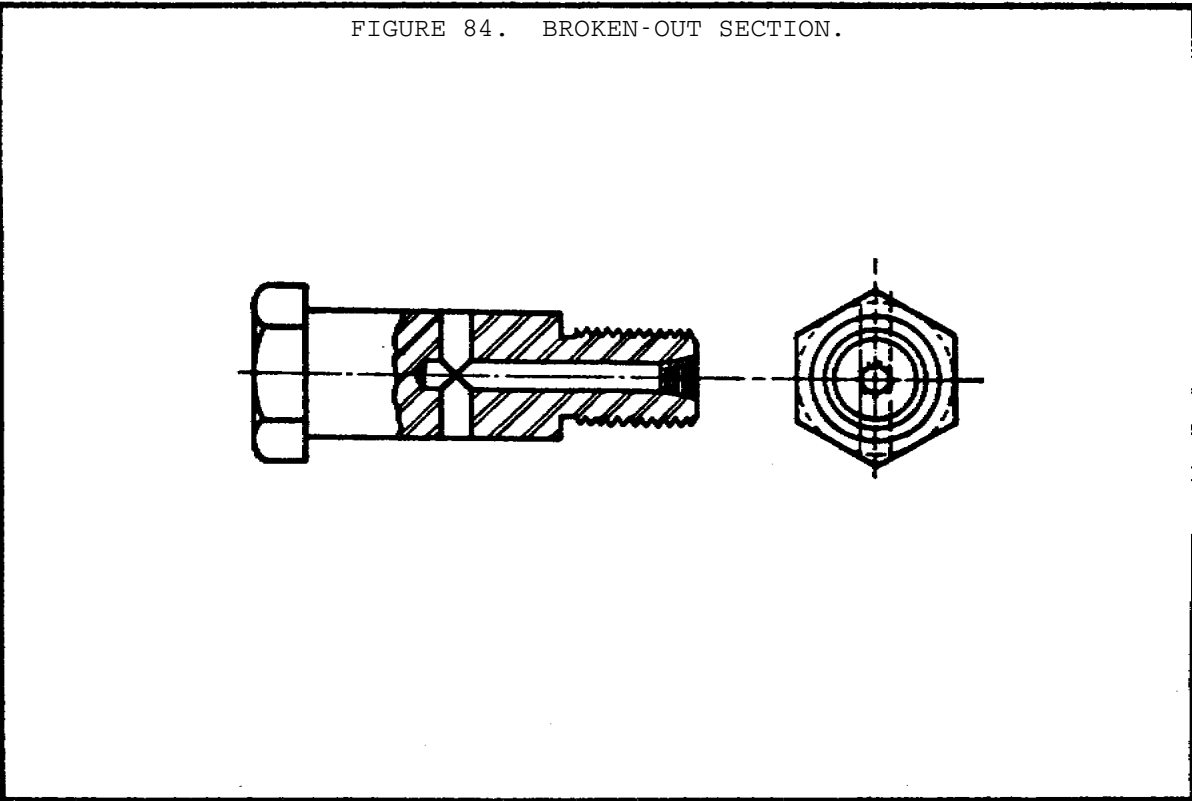
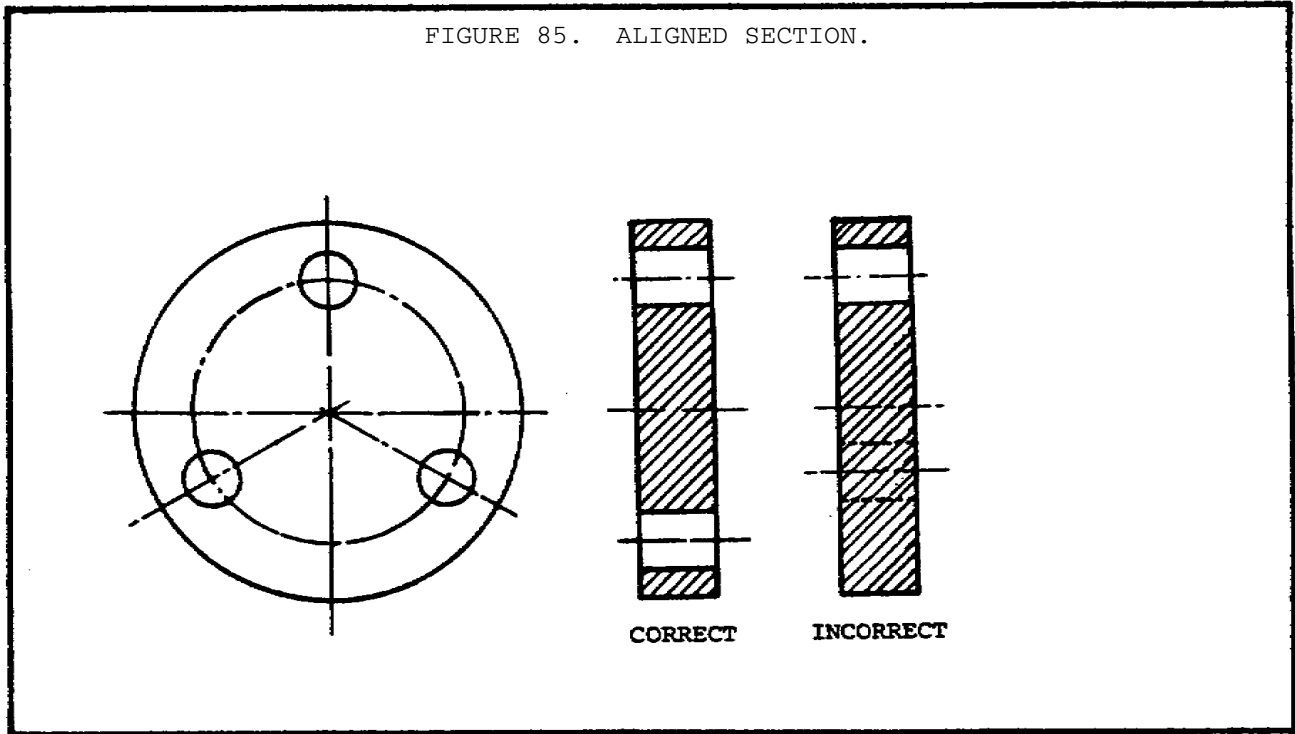


FIGURE 85. ALIGNED SECTION.



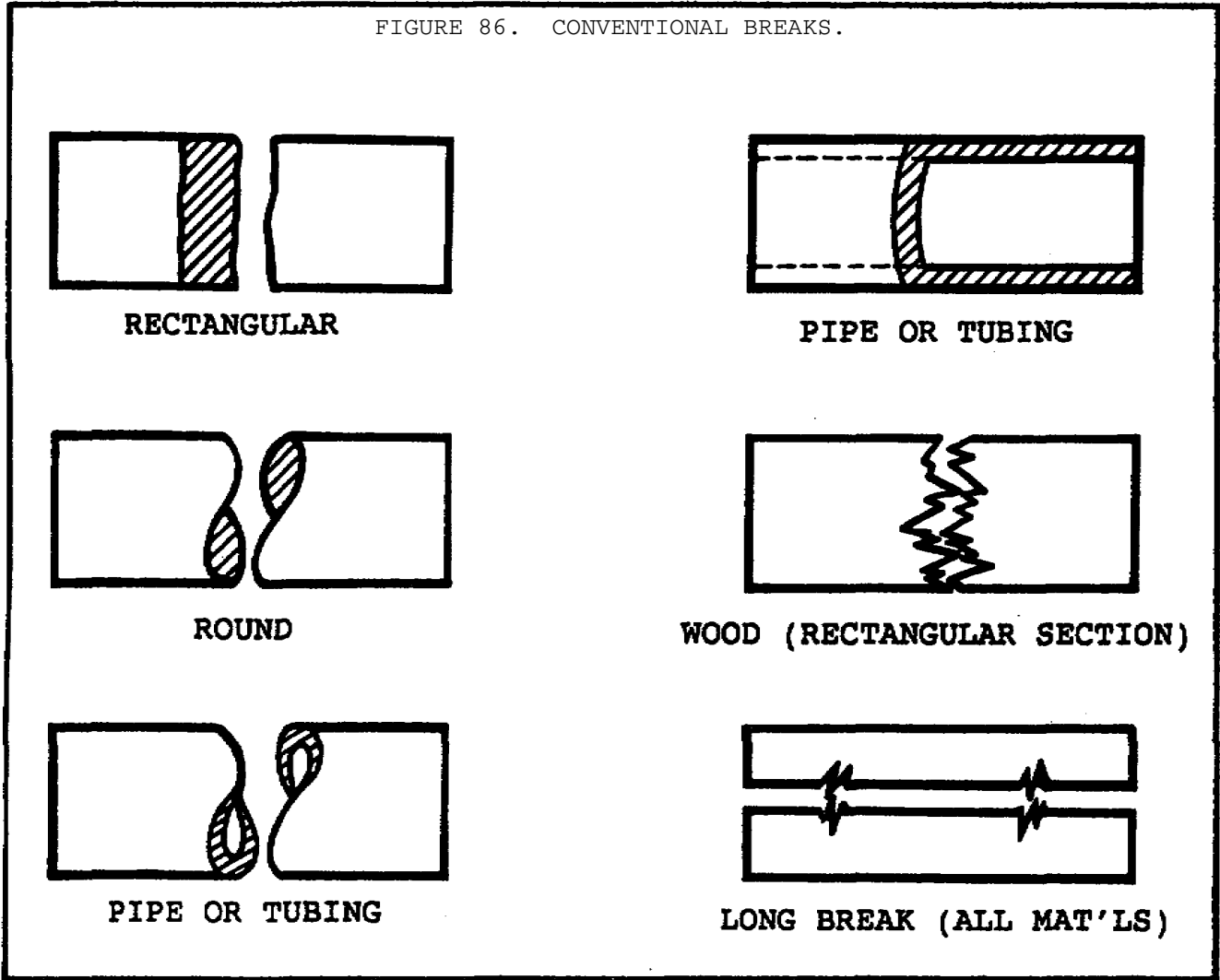
NOTE

When sectional views are made, the part that is cut by the cutting plane is marked with diagonal parallel section lines. The process of making these lines is termed "cross hatching." Shafts, bolts, nuts, screws, keys, pins, rivets, balls, etc., the axes of which lie in the cutting plane, have no interior parts to be shown and consequently are left in full on assembly sections, as if they had been removed when the section was cut off and afterward laid back in place.

4. Conventional Breaks

In describing the shape of an object, such as a long bar or similar object that is small in cross section but of considerable length, the draftsman is faced with two problems: first, if drawn to full size, it would require a large sheet of paper with considerable space wasted; second, if drawn to a small scale, it would be too small for dimensioning clearly. If the object is uniform in shape, there is no necessity for drawing its entire

length. A piece is "broken cut," therefore, and the object is drawn full size. The methods used to indicate this are termed "conventional breaks." Figure 86 shows some of the most common of these.

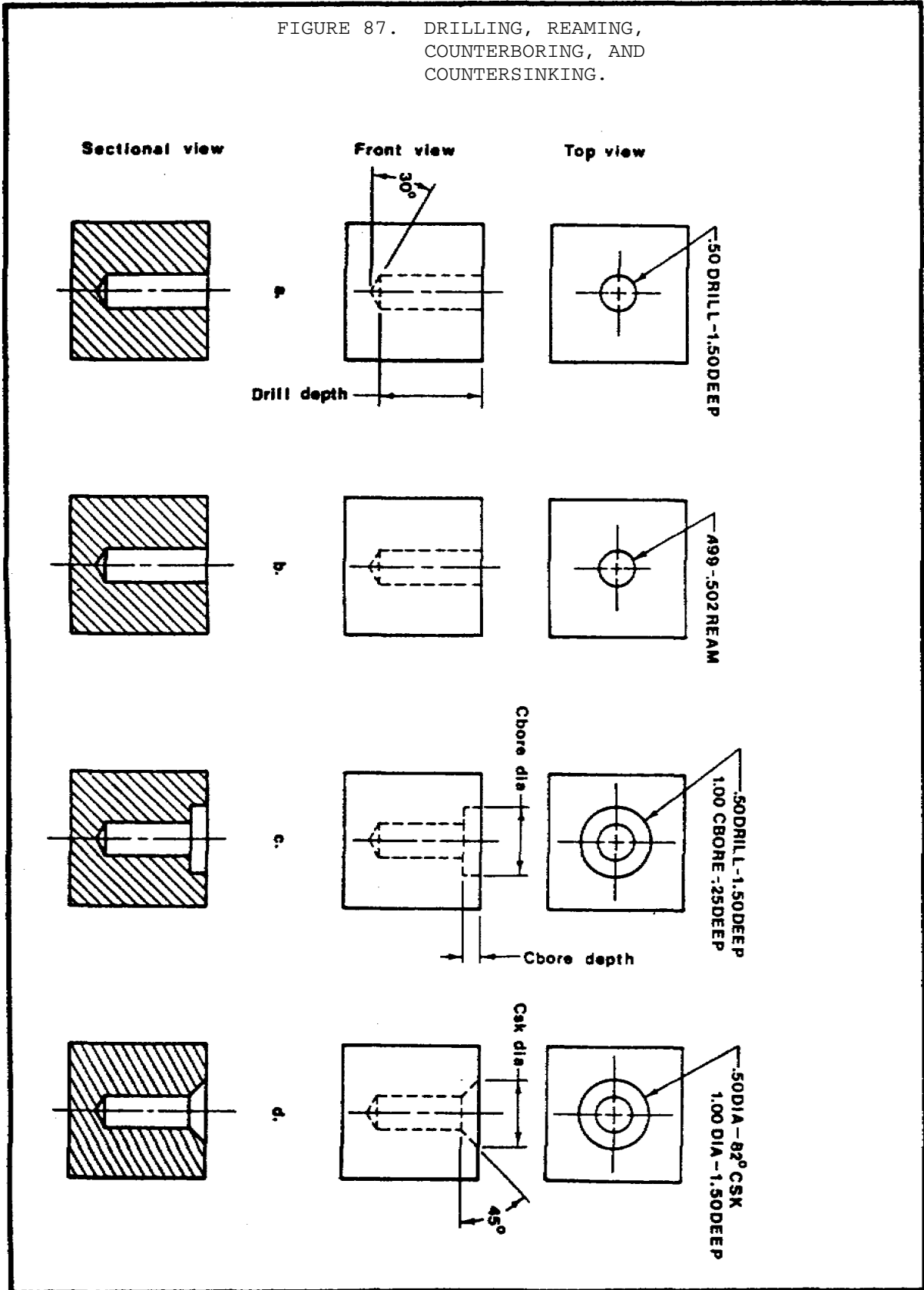


5. Shop Terms--Drilling, Reaming, Counterboring, and Countersinking

Drilling, reaming, counterboring, and countersinking are very common machining operations that are called for on a drawing by a drawing note. Each operation is defined in the following subparagraphs and illustrated in figure 87 (on the following page).

a. *Drilling.* Drilling is a machine operation that produces holes. The bottom of drilled holes are drawn to a 30°-tapered point as shown in figure 87, view A.

FIGURE 87. DRILLING, REAMING, COUNTERBORING, AND COUNTERSINKING.



b. *Reaming.* Reaming is a machine operation that smoothes out the surface of a drilled hole. From a drawing standpoint, reamings are drawn the same way that drilled holes are drawn. The call out notes, however, are different as shown in figure 87, view B (on the previous page).

c. *Counterboring.* Counterboring is a machine operation in which part of a drilled hole is redrilled to a larger diameter (figure 87, view C).

d. *Countersinking.* Countersinking is a machine operation in which a drilled hole is redrilled to produce the tapered shape shown in figure 87, view D. Countersinks are usually made at 82°, but they may be drawn at 90° (45° on each side).

TABLE 1. ABBREVIATIONS.

Addendum.....	ADD.	Chamfer.....	CHAM
Alteration.....	ALTN	Chord.....	CHD
Aluminum.....	AL	Circle.....	CIR
American Standard.....	AMER STD	Circular pitch.....	CP
American Standards Association.	ASA	Cold-rolled steel.....	CRS
American wire gage.....	AWG	Company.....	CO
Appendix.....	APPX	Concentric.....	CONC
Approved.....	APPD	Copper.....	Cu, CO
Approximate.....	APPROX	Correct.....	CORR
Arc weld.....	ARC/W	Counterbore.....	CBORE
Area.....	A	Counterdrill.....	CDRILL
Assemble.....	ASSEM	Countersink.....	CSK
Assembly.....	ASSY	Cross section.....	X-SECT
Attach.....	ATT	Decimal.....	DEC
Auxiliary.....	AUX	Degree.....	(°), D
Average.....	AVG	Department.....	DEPT
Babbitt.....	BAB	Design.....	DSGN
Ball bearing.....	BB	Detail.....	DET
Bearing.....	BRG	Diagonal.....	DIAG
Between centers.....	BC	Diameter.....	DIA
Bill of material.....	B/M	Diametral pitch.....	DP
Blueprint.....	BP	Distance.....	DIST
Bolt circle.....	BC	Draftsman.....	DFTSMN
Bottom.....	BOT	Drawing.....	DWG
Bracket.....	BRKT	Drill.....	DR
Brass.....	BRS	Drive fit.....	DF
Break.....	BRK	Drop forge.....	DF
Brinell hardness.....	BH	Each.....	EA
Broach.....	BRO	Electric.....	ELEC
Bronze.....	BRZ	Engineer.....	ENGR
Bushing.....	BUSH.	Equal.....	EQ
Cap screw.....	CAP SCR	External.....	EXT
Carburize.....	CARB	Extra heavy.....	X HVY
Case-harden.....	CH	Fabricate.....	FAB
Casting.....	CSTG	Far side.....	FS
Cast iron.....	CI	Feet.....	('), F
Castle nut.....	CAS NUT	Fillet.....	FIL
Cast steel.....	CS	Fillister.....	FIL
Center.....	CTR	Finish.....	FIN
Center line.....	CL	Finish all over.....	FAO
Center to center.....	C to C	Fitting.....	FTG

TABLE 1. ABBREVIATIONS (CONTINUED).

Flange.....	FLG	On center.....	OC
Flat head.....	FH	Original.....	ORIG
Foot.....	('), FT	Outside diameter.....	OD
Forged steel.....	FST	Outside radius.....	OR
Forging.....	FORG	Over-all.....	OA
Foundry.....	FDRY	Parallel.....	PAR.
Gage.....	GA	Part.....	PT
Galvanize.....	GALV	Pattern.....	PATT
Girder.....	G	Perpendicular.....	PERP
Grade.....	GR	Piece.....	PC
Grind.....	GRD	Pitch.....	P
Half round.....	H RD	Pitch diameter.....	PD
Hard drawn.....	HD	Plastic.....	PLSTC
Harden.....	HDN	Point.....	PT
Head.....	HD	Quadrant.....	QUAD
Headless.....	HDLS	Quantity.....	QTY
Heat-treat.....	HT TR	Radial.....	RAD
Heavy.....	HVY	Radius.....	R
Height.....	HGT	Ream.....	RM
Hexagon.....	HEX	Recommend.....	RECM
High-speed steel..	HSS	Rectangle.....	RECT
Horizontal.....	HOR	Reference.....	REF
Hot-rolled steel..	HRS	Required.....	RQD
Inch.....	("), IN.	Revise.....	REV
Inside diameter... ID		Revolutions per minute.....	RPM
Internal.....	INT	Right.....	RT
Intersect.....	INT	Right hand.....	RH
Iron.....	I	Riser.....	R
Key.....	K	Rivet.....	RIV
Keyseat.....	KST	Rockwell hardness.....	RH
Keyway.....	KWY	Rough.....	RGH
Left hand.....	LH	Round.....	RD
Length.....	LG	Sand blast.....	SD BL
Length over all... LOA		Schematic.....	SCHEM
Light.....	LT	Screw.....	SCR
Line.....	L	Section.....	SECT
Long.....	LG	Semifinished.....	SF
Longitudinal.....	LONG	Series.....	SER
Machine.....	MACH	Setscrew.....	SS
Machine steel.....	MS	Shaft.....	SFT
Male and female... M & F		Sheet.....	SH
Malleable iron... MI		Shop order.....	SO
Manual.....	MAN.	Society of Automotive Engineers.....	SAE
Material.....	MATL	Specification.....	SPEC
Maximum.....	MAX	Spherical.....	SPHER
Mechanical.....	MECH	Spot faced.....	SF
Metal.....	MET.	Spring.....	SPG
Minimum.....	MIN	Square.....	SQ
Minute.....	('), MIN	Stainless steel.....	SST
Miscellaneous.....	MISC	Stamp.....	STP
Model.....	MOD	Standard.....	STD
National.....	NATL	Steel.....	STL
Near side.....	NS	Steel casting.....	STL CS
Nominal.....	NOM	Stock.....	STK
Not to scale.....	NTS	Straight.....	STR
Number.....	NO.	Structural.....	STR
Obsolete.....	OBS	Substitute.....	SUB
Octagon.....	OCT	Surface.....	SUR

TABLE 1. ABBREVIATIONS (CONTINUED).

Symbol.....	SYM	Typical.....	TYP
Symmetrical.....	SYM	United States Standard.....	USS
Tangent.....	TAN.	Vertical.....	VERT
Taper.....	TPR	Volume.....	VOL
Tee.....	T	Washer.....	WASH.
That is.....	IE	Weight.....	WT
Thick.....	THK	Width.....	W
Thread.....	THD	Wire.....	W
Threads per inch..	TPI	Wood.....	WD
Tolerance.....	TOL	Woodruff.....	WDF
Tool steel.....	TS	Wrought iron.....	WI
Tooth.....	T		

6. Abbreviations

When working in shops and with blueprints and shop drawings, you will be exposed to a great number of abbreviations. It is important that you understand what each of these abbreviations represents. The abbreviations are contained in table 1 (on the previous 3 pages).

7. Conclusion

This concludes our discussion of shop terms, abbreviations, and dimensioning elements. In the next task, we will interpret a shop drawing.

LESSON 1

DRAFTING AND SHOP DRAWING FUNDAMENTALS

TASK 5. Interpret a shop drawing.

CONDITIONS

Within a self-study environment and given the subcourse text, without assistance.

STANDARDS

Within one hour

REFERENCES

No supplementary references are needed for this task.

1. Introduction

In the previous four tasks, we covered a great deal of information concerning drafting, shop drawings and blueprints.

As a repair shop technician, you will be required, from time to time, to interpret shop drawings and blueprints, not only to enable you to explain and teach lower ranking personnel, but also to enable you to brief higher authority on the status of work within the shop. In this task, we are going to cover production drawings and interpret a shop drawing.

2. Production Drawings

Production drawings are used to aid a craftsman in the manufacturing of an object. They are generally either detail drawings or assembly drawings. A detail drawing usually presents only one object. An assembly drawing presents several objects together.

It is sometimes difficult to realize that the picture portion of a drawing is only one part of the total finished drawing. The title block, revision block, and drawing notes are just as important as the picture portion, and often they are just as time-consuming to prepare.

a. *Assembly Drawings.* Assembly drawings show several objects joined together. An assembly drawing must include all information needed by the craftsman to correctly assemble the parts. They do not usually include specific object dimensions which are necessary for assembly.

Figure 88 (on the following page) illustrates an assembly drawing. Each object is identified by part number, but it is not dimensioned. Hidden lines have been omitted to make the drawing easier to read. This is not always possible, especially for assemblies that contain internal parts.

If any specific operation is to be performed by the assembler, it must be noted on the assembly drawing. For example, if several parts are to be joined together by a bolt, the bolt hole should, if possible, be drilled during the parts assembly to ensure that all the parts align properly.

Assembly drawings sometimes reassign new part numbers to the various component pieces that make up the assembly. Assembly numbers are usually one or two digit numbers (1, 2, 3, 14, 22, etc.) and are added to save printing the larger, more complicated part numbers on the assembly drawing. If assembly numbers are used, include them in a column in the parts list next to and to the left of the part numbers.

b. *Detail Drawings.* Detail drawings are used by the craftsman to produce a finished object. They are a set of instructions that should include all information necessary for the complete and accurate manufacture of the object. They should include, among other things, a complete size and shape definition of the object; the material from which the object is to be made; all necessary information on the treatment of the materials; surface finish requirements; references to applicable specifications; any necessary inspection information; and, if necessary, instructions for handling the finished object. Figure 89 (on page 102) illustrates a detail drawing.

FIGURE 88. AN ASSEMBLY DRAWING.

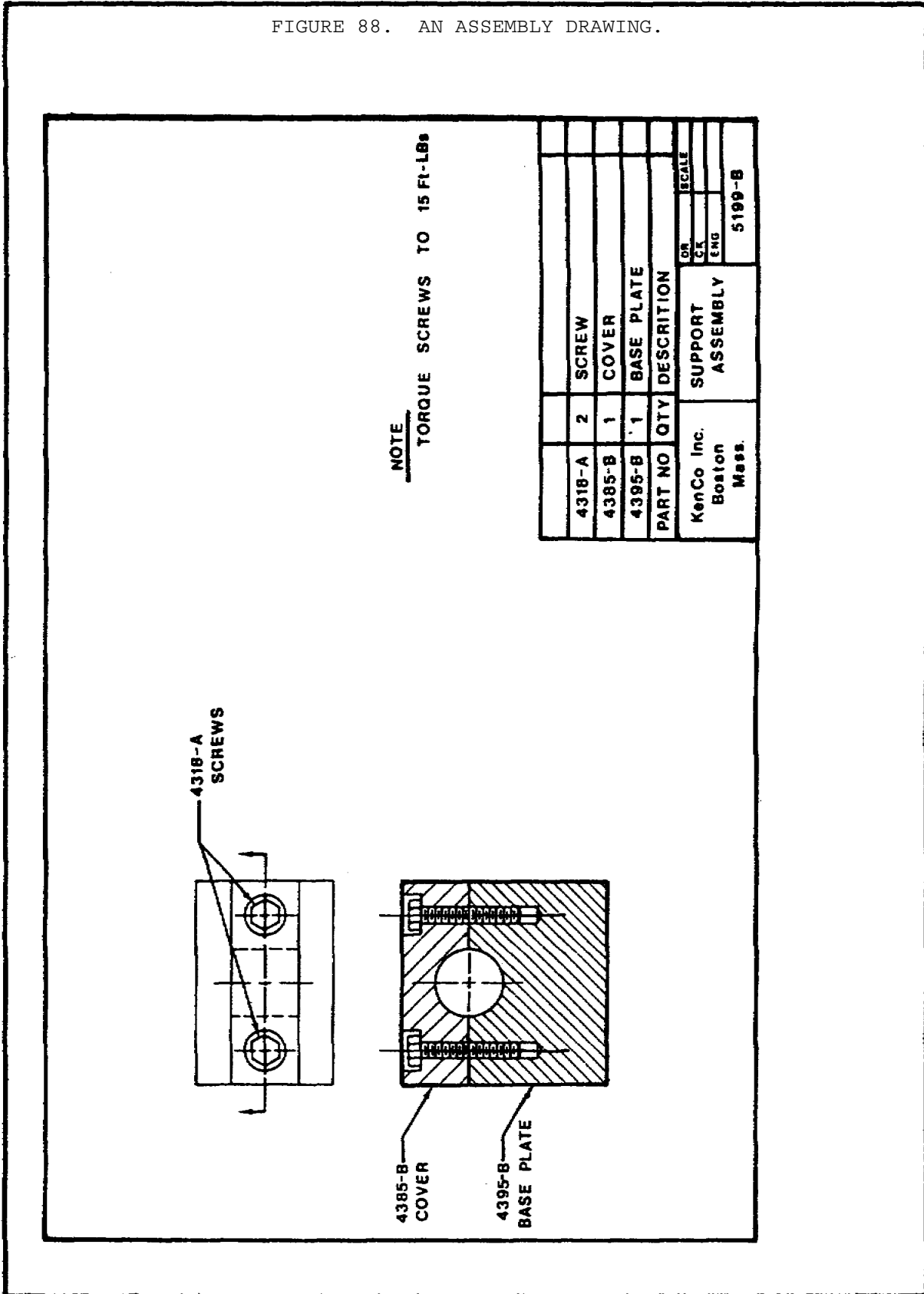
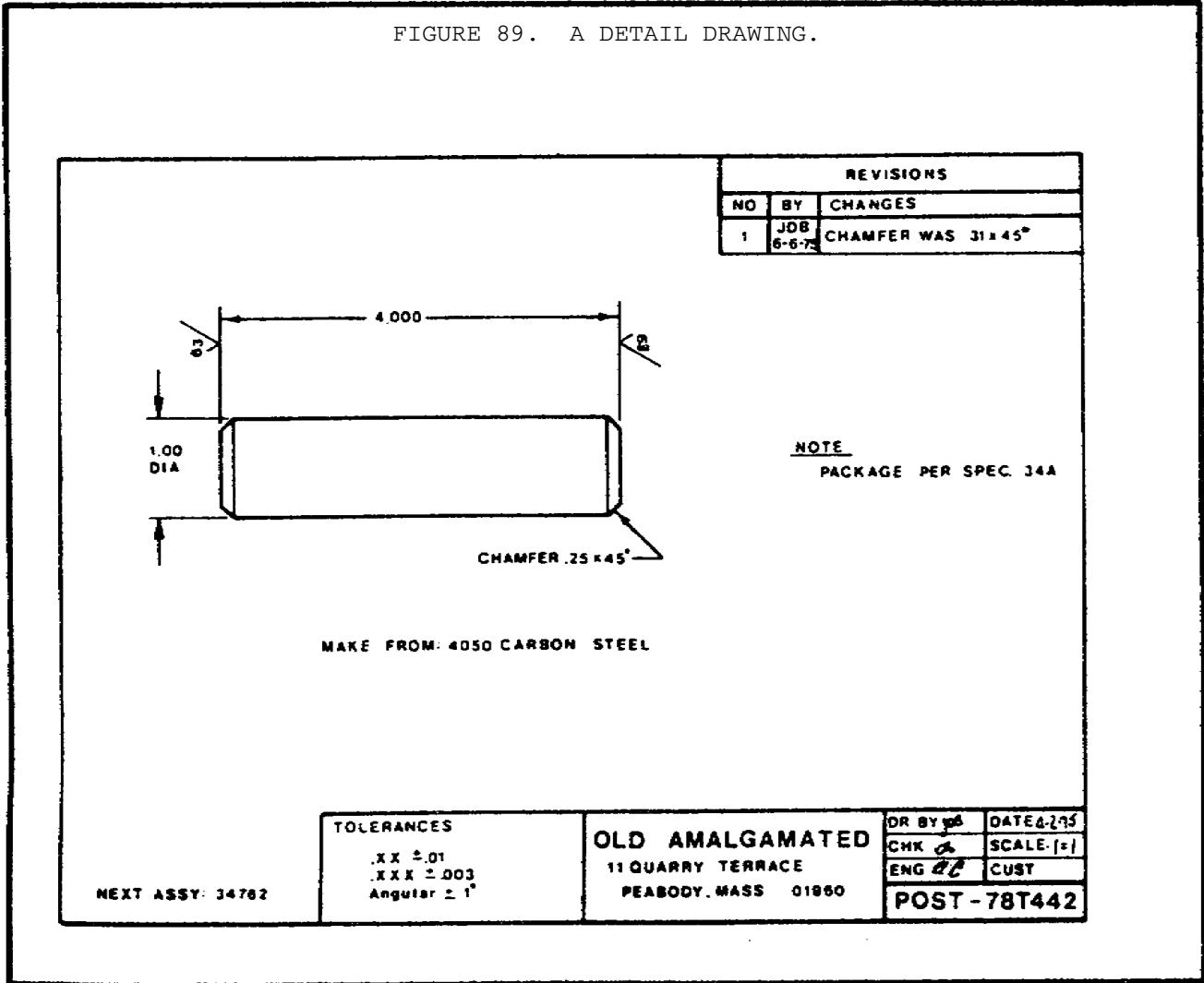


FIGURE 89. A DETAIL DRAWING.



c. *Composition of a Drawing.* Shop drawings are divided into several areas and blocks. In the following subparagraphs, we will discuss these blocks and areas.

(1) *Title Blocks.* The title block of a drawing contains the title of the object, the part number, the company name and address, and signatures of the engineers and draftsmen who prepared the drawing. It may also include customer order numbers, tolerance specifications, signature blocks (for various approval signatures), and the drawing scale. Figure 90 (on the following page) illustrates the title block. Title blocks are located in the lower right-hand corner of the drawing.

FIGURE 90. AN EXAMPLE OF A TITLE BLOCK.

TOLERANCES ON MACHINE DIMENSIONS UNLESS OTHERWISE SPECIFIED FRACTIONAL DIMENSIONS ± 1/32 ANGULAR DIMENSIONS ± 1/2° SURFACE FINISHES 125v ALL CORNERS 1/32 R OR CHAM UNLESS OTHERWISE SPECIFIED		TITLE INSERTED HERE		DRAWN	SCALE
				APP'VD	B/M
		DATE	PATT.	ATWOOD & MORRILL CO. SALEM, MASS	

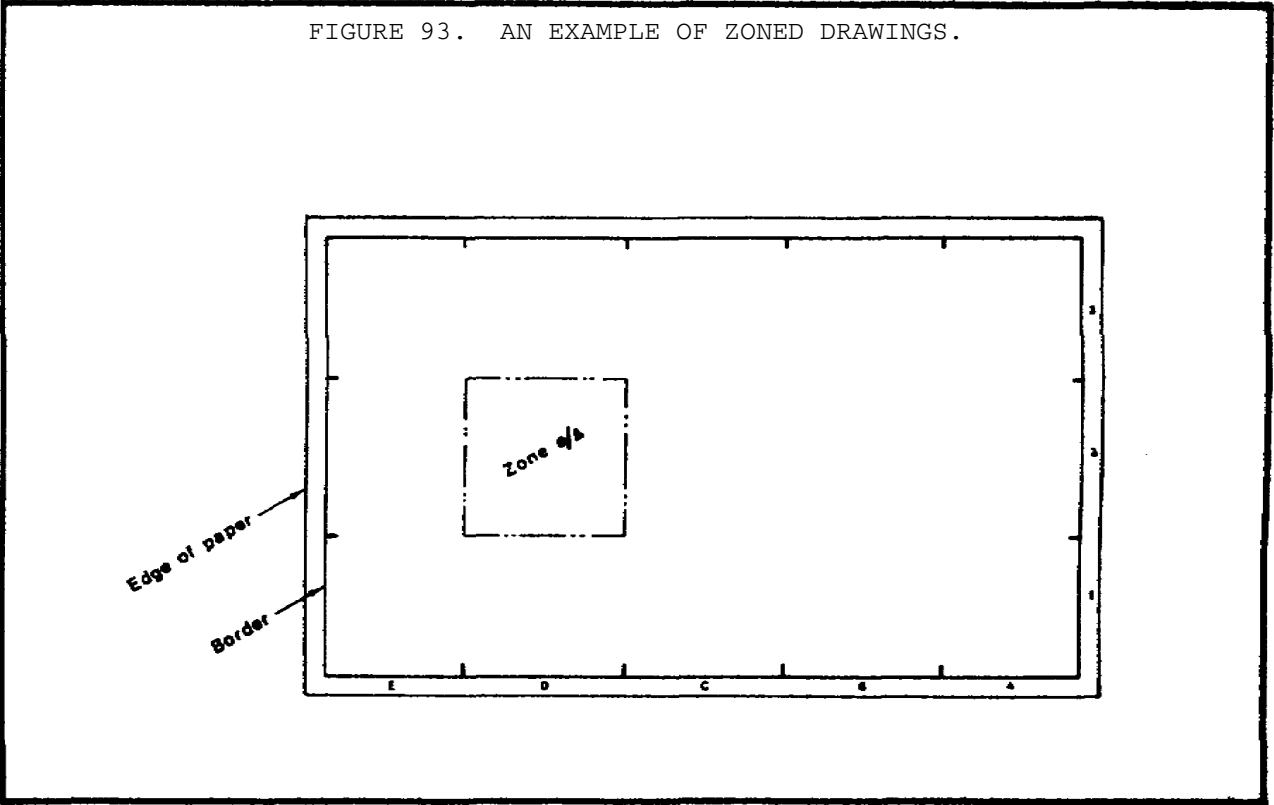
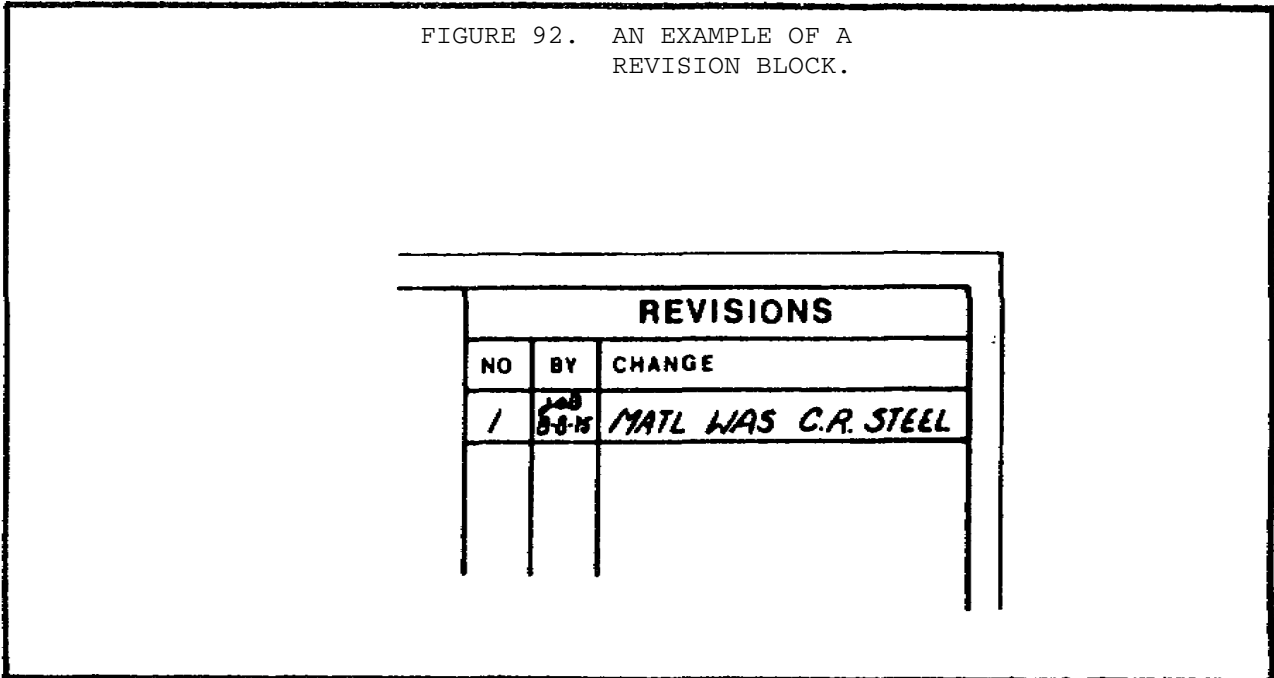
(2) *Parts List*. A parts list is a listing of the names and numbers of parts called for in the drawing. It may also include material information, stock size, manufacturing quantity, finishing specifications, weight calculations, and so on. Figure 91 illustrates a parts list.

FIGURE 91. AN EXAMPLE OF A PARTS LIST.

PART NO	QTY	DESCRIPTION	STOCK SIZE	MATL
5025-02	3	CLIP	.06 x 1.5 x 6.0	7075-T6
5025-01	1	BRACKET	2 x 6 x 20	STL

(3) *Revision Blocks*. A revision block is a listing of all changes that have been made in the drawing. It should include a description of the change, the date the change was made, where the change is located on the drawing, the draftsman's

initials, and any necessary approval signatures. Revision blocks are usually located in the upper right-hand corner of the drawing. Figure 92 illustrates a revision block.

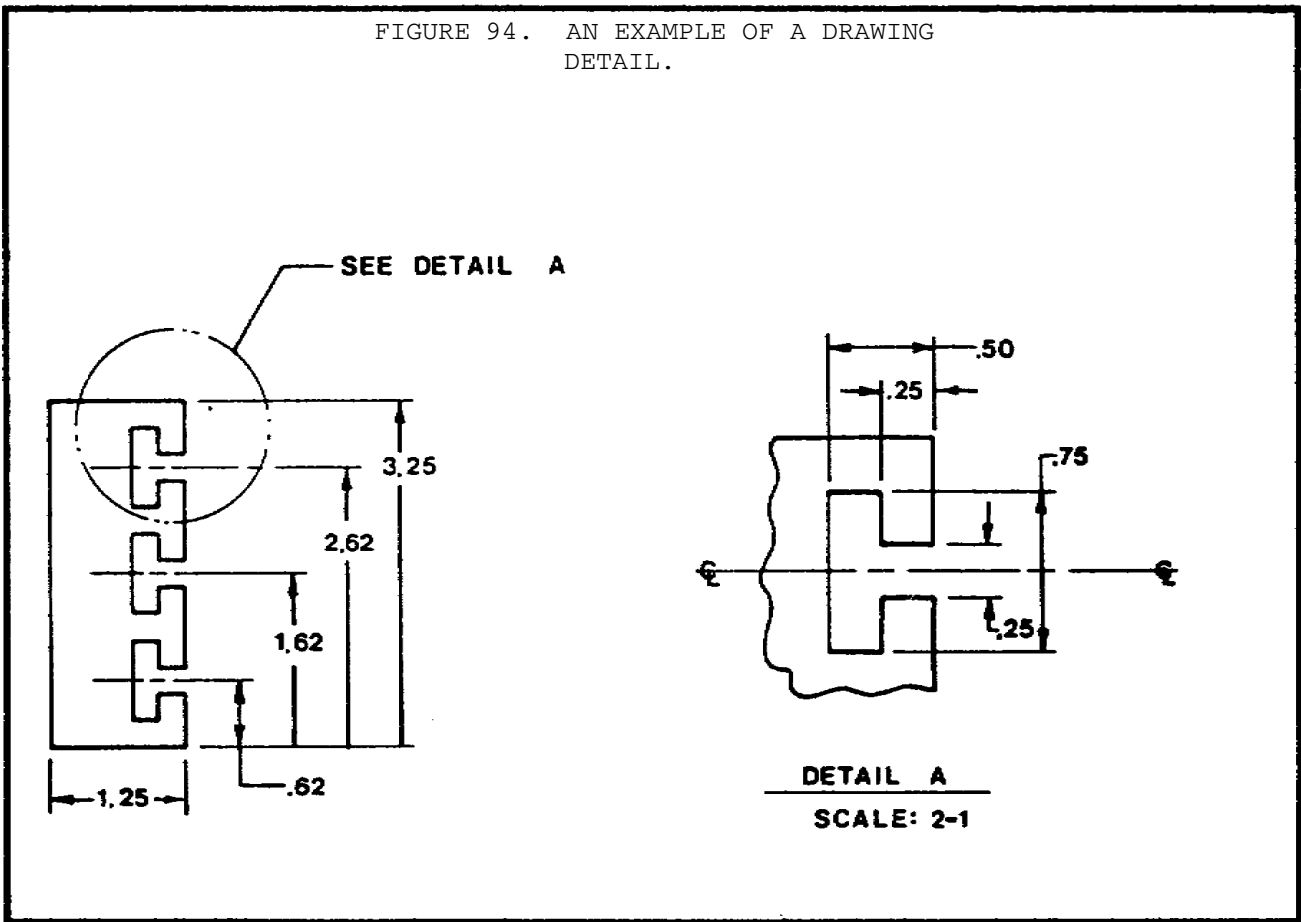


(4) *Drawing Zones.* Large drawings are divided into zones similar to those used on a map. Letters are used to define the horizontal zones and numbers are used to define the vertical zones. Figure 93 (on the previous page) illustrates a zoned drawing. Zone numbers are usually written in boxes with the letter over the number.

(5) *Drawing Notes.* Drawing notes are written instructions that are included as part of a drawing. They are written because they cannot be drawn (for example, heat treating or finishing instructions). Figure 88 (on page 101) includes a note that defines the torquing requirements of the assembly.

d. *A Drawing Detail.* A drawing detail is a special kind of partial drawing. It is used to enlarge a specific part of a drawing that is too small or too complicated to be completely understood if only shown in its actual size. Figure 94 is an example of a drawing that includes a drawing detail.

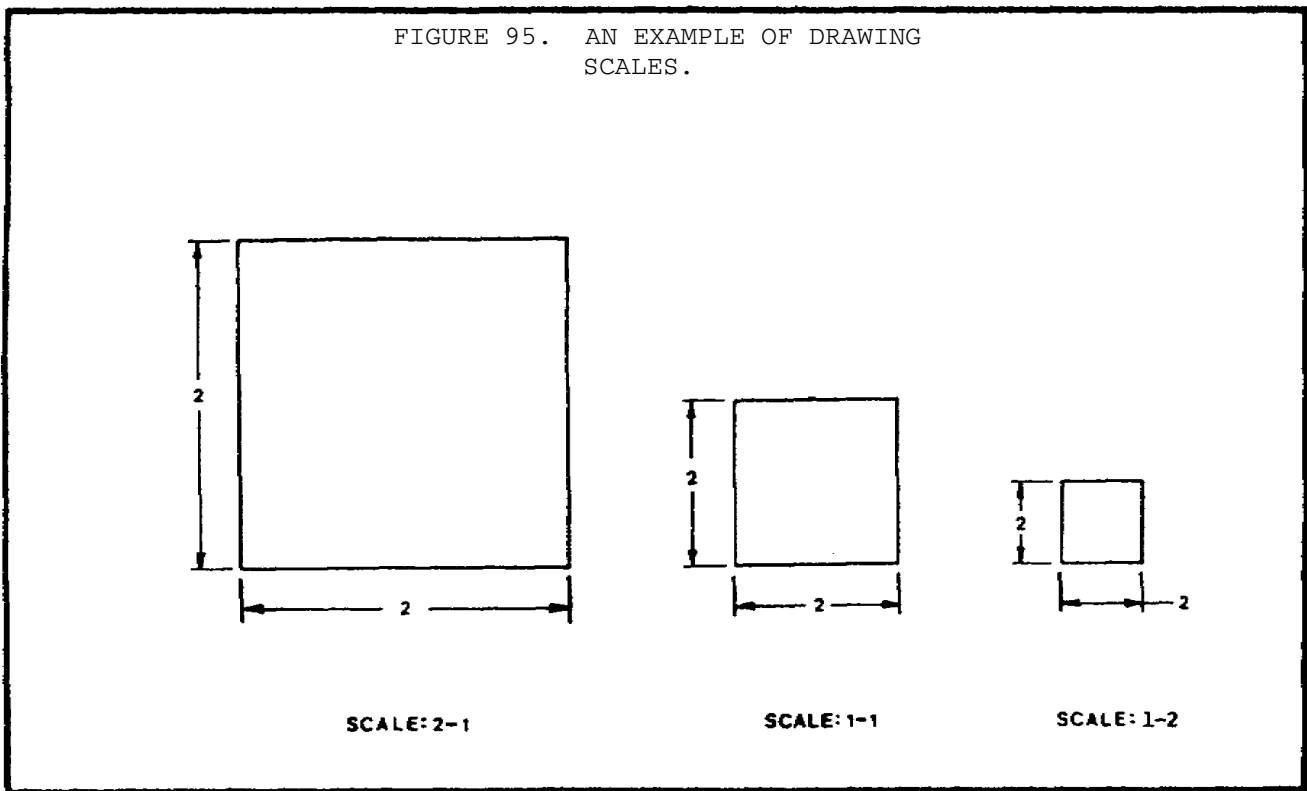
FIGURE 94. AN EXAMPLE OF A DRAWING
DETAIL.



There is no rule for the draftsman to follow concerning the use of a drawing detail. It is up to him to determine whether or not a drawing detail will help clarify any particular area.

e. *Drawing Scales.* Drawing scales are used because some objects are too big to fit on a sheet of drawing paper and others are so small that they could not be seen on a drawing. House drawings, for example, are drawn at a reduced scale. Electronic microcircuits are drawn at an increased scale.

Figure 95 shows one full-sized and two scaled drawings of the same square. Note that the scale used is clearly defined.



The scale note 1 = 2 means that every 1/2 inch on the drawing is actually 1 inch on the object. In other words, the drawing is one-half the size of the true object size. Similarly, the scale note 2 = 1 means that 2 inches equal 1 inch; thus, the drawing is twice as large as the actual object. The note 1 = 1 means that the drawing is the exact same size as the object.

3. Conclusion

This concludes this subcourse dealing with the principles of drafting and shop drawing. In this subcourse, we covered orthographic projection theory, freehand drafting, drafting instruments, the fundamentals of geometric construction, the theory and fundamentals of pictorial drawings: oblique and isometric, shop terms, abbreviations, dimensioning elements, and interpreting a shop drawing.

Immediately following this task is a practice exercise. This practice exercise was designed to test your retention of the material presented in this subcourse. When you feel you have sufficiently mastered the information, turn the page and take the practical exercise.

PRACTICAL EXERCISE 1

1. Instructions

Successful completion of this exercise provides indication of success in this subcourse. On a blank sheet of paper write down the answers to the questions that follow. Then check your answers against those provided on the answer page following the questions.

2. Requirement

- a) Name the six orthographic views.
- b) How many classes of sketches are there?
- c) What is a T-square used for?
- d) A protractor does what?
- e) What is the geometric way of finding the center of any line?
- f) Isometric drawings may be dimensioned by using either the _____ or _____ system.
- g) What makes it very easy to transfer information from the orthographic front view to the oblique front view?
- h) Briefly explain the uses of the three types of lines associated with dimensioning.
- i) Explain the coordinate system of dimensioning.
- j) What do phantom lines show?
- k) A sectional view allows you to look _____ an object shown on a shop drawing.
- l) Briefly describe the two types of production drawings.

LESSON 1. PRACTICAL EXERCISE - ANSWERS

- a) The six orthographic views are:
- (1) top view
 - (2) bottom view
 - (3) right-hand side view
 - (4) left-hand side view
 - (5) front view
 - (6) rear view.
- b) There are two kinds of sketches.
- c) A T-square is used as a guide for drawing horizontal lines and as a support for the triangles.
- d) A protractor measures angles.
- e) The geometric way of finding the center of a line is bisecting.
- f) Isometric drawings may be dimensioned by using either the unidirectional or aligned system.
- g) It is very easy to transfer information from the orthographic front view to the oblique view is because of the 90° relationship between the left-hand axis and the vertical axis.
- h) The three types of lines associated with dimensioning are:
- (1) Extension lines, which are used to indicate the extension of an edge or point to a location outside the part outline.
 - (2) Dimension lines, which show the direction and extent of dimension.
 - (3) Leader lines, which are used to direct an expression in note form, to the intended place on the drawing. The leader line should terminate in an arrowhead or dot.

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- i) The coordinate system is a dimensioning system based on the mathematical x-y coordinate system. It is usually only used to dimension an object that contains a great many holes, for example, an electrical chassis.
- j) Phantom lines show the possible alternate positions of moving parts.
- k) A sectional view allows you to look inside an object shown on a shop drawing.
- l) The two types of production drawings are:
 - (1) Assembly drawings show several objects joined together. An assembly drawing must include all information needed by the craftsman to correctly assemble the parts. They do not usually include specific object dimensions which are necessary for assembly.
 - (2) Detail drawings are used by craftsman to produce a finished object. They are a set of instructions that should include all information necessary for the complete and accurate manufacture of the object.

REFERENCES

PRIN. OF DRAFTING AND SHOP DRAWINGS - 0D1641 - REFERENCES

REFERENCES

The following documents were used as resource materials in developing this subcourse:

FM 5-553
ST 9-166