Multiview Drawings

Learning Objectives

After studying this chapter, you will be able to:

- Explain the principles of orthographic projection.
- Identify the number and types of views needed to make a multiview drawing.
- Use orthographic projection to create multiview drawings.
- Explain the differences between third-angle projection and first-angle projection.

Technical Terms

Coordinate planes
Curved line
Curved surfaces
End elevation
End view
Fillet
First-angle projection
Foreshortened
Frontal plane
Front elevation
Front view
Glass box
Hidden lines
Horizontal lines
Horizontal plane
Horizontal surfaces
Inclined lines
Inclined surfaces
Lines of sight
Multiview drawing
Oblique lines
Oblique surfaces
Orthographic projection
Point
Plan view
Principal planes
Profile plane
Projectors
Round
Runout
Side elevation
Side view
Straight line
Third-angle projection
Top view
True length
Vertical lines
Vertical surfaces
Visualizing

The ***multiview drawing*** is the major type of drawing used in drafting. It is a projection drawing that incorporates several views of a part or assembly on one drawing, **Figure 8-1**. A multiview drawing describes a three-dimensional object in two dimensions.

The various views of an object are carefully selected to show every detail of size and shape. Additional information and details about the processes to be performed on the part are also included. Usually, three views are drawn. However, drawings may vary from one or two views for a simple part to four or more views for a complicated part or assembly.

In addition, the views are arranged in a manner that is standard drafting practice. The top view always appears above the front view. The right-side view normally appears to the right of the front view. When used, the left-side view is usually placed directly to the left of the front view.

This system of drawing is known as ***orthographic projection***. The terms *multiview drawing* and *orthographic projection drawing* are used to describe an orthographic projection.

In creating a multiview drawing, you must be able to visualize an object in three dimensions, select the appropriate views for representing the object, and use proper drafting conventions for projecting and drawing the views. The same drafting skills are required whether you are drawing manually or using a CAD system. Manual drawing instruments and methods are used in manual drafting, while drawing commands and tools are used in CAD drafting.

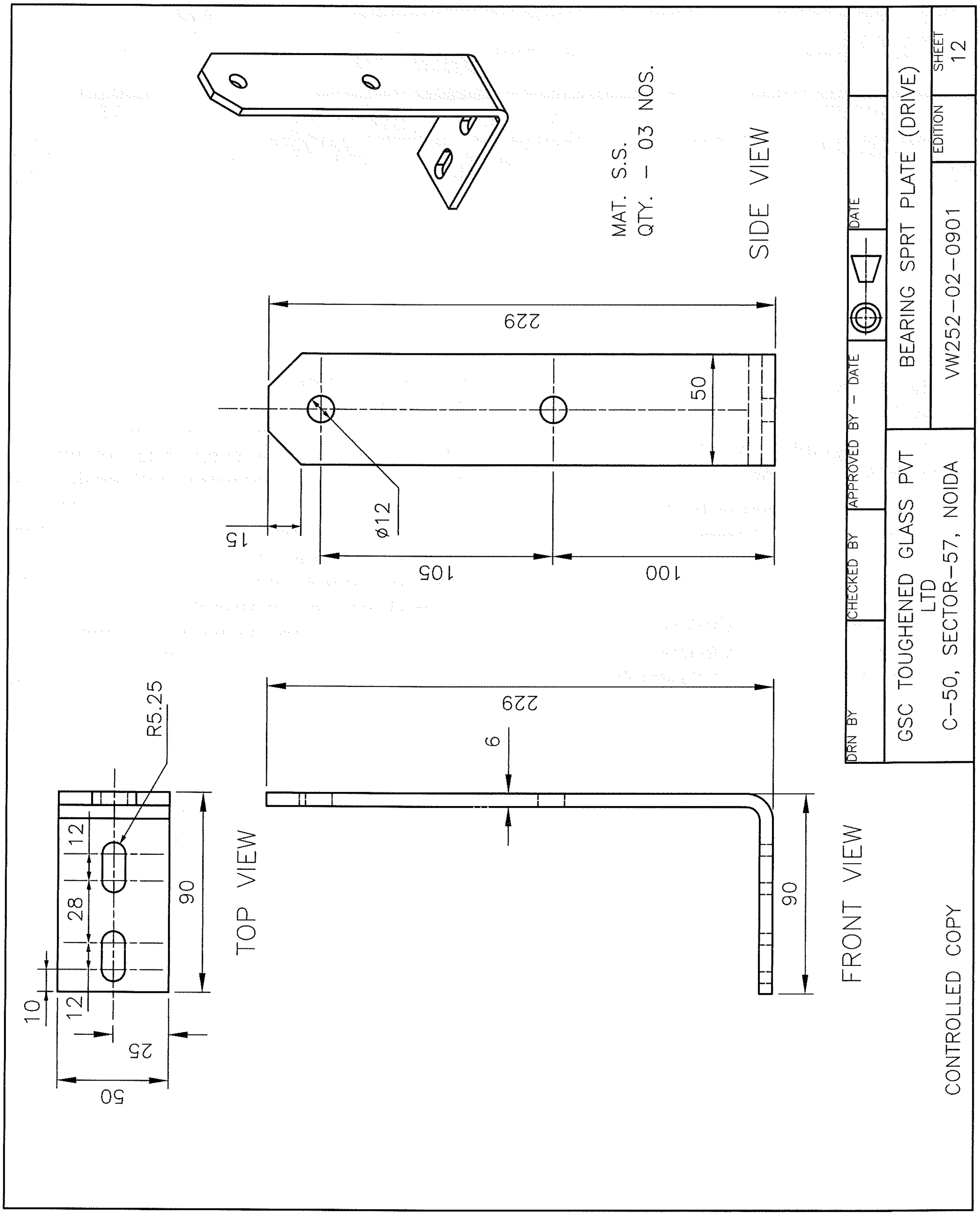


Figure 8-1. Multiview drawings explain three-dimensional objects in two dimensions. (Autodesk, Inc.)

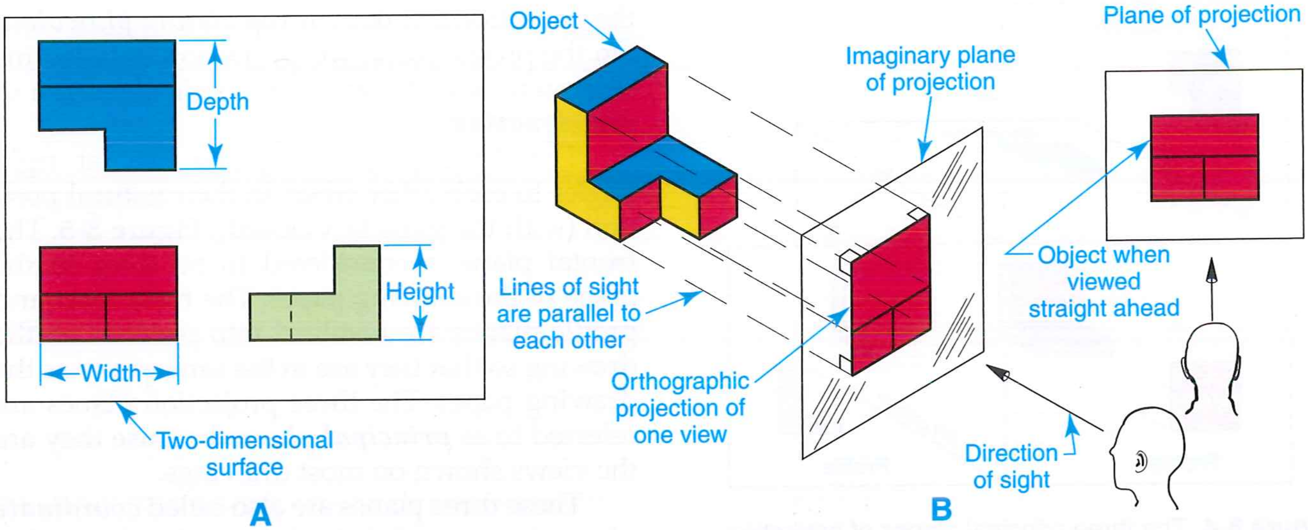


Figure 8-2. In orthographic projection, all the features of an object are projected onto a perpendicular viewing plane. The viewing point is assumed to be at a distance of infinity from the object.

Orthographic Projection

An orthographic projection drawing is a representation of the separate views of an object on a two-dimensional surface. It shows the width, depth, and height of the object, **Figure 8-2A**.

The projection is achieved by viewing the object from a point assumed to be at infinity (an indefinitely great distance away). The ***lines of sight***, or ***projectors***, are parallel to each other and perpendicular to the plane of projection, **Figure 8-2B**.

The Projection Technique

Skilled drafters are readily able to "picture" different views of an object in their minds. This mental process is known as ***visualizing*** the views. Visualizing is done by looking at the actual object or a three-dimensional picture of the object. This is one of the most important drafting skills that you can learn.

The ***glass box*** is a drafting aid that is helpful in developing skill in visualizing a view, **Figure 8-3**. Each face of an object is viewed from a position that is 90°, or perpendicular, to the projection plane for that view. The object views are obtained by projecting the lines of sight to each plane of the glass box.

The three principal projection planes are the ***frontal plane, horizontal plane,*** and ***profile plane***, **Figure 8-4**. The projection shown in the frontal plane is called the ***front view*** or ***front elevation***, **Figure 8-4**. On the horizontal plane,

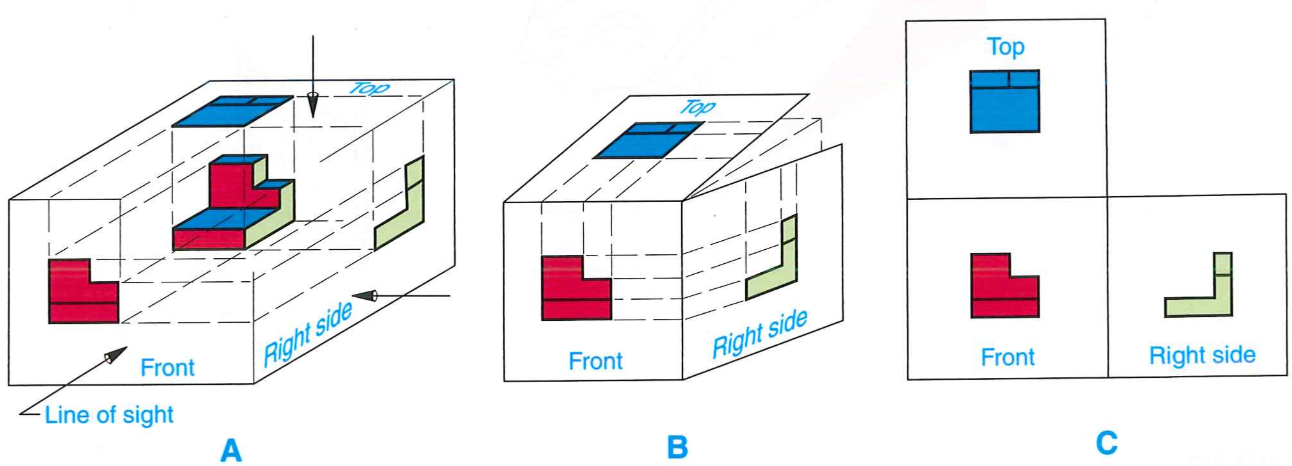


Figure 8-3. The glass box is a helpful drafting aid. It illustrates the visualization system of orthographic projection.

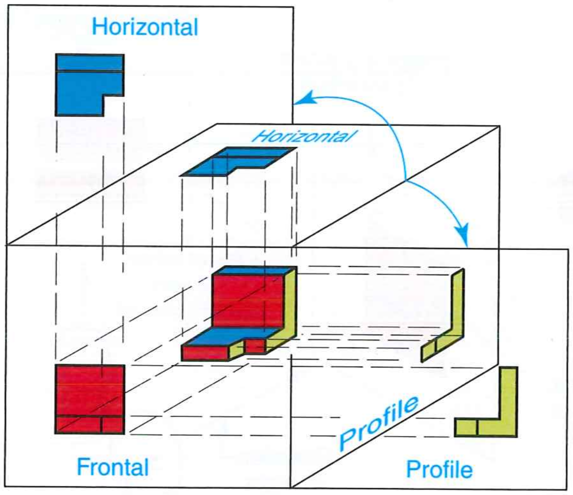


Figure 8-4. The three principal planes of projection used in orthographic projection are the frontal plane, horizontal plane, and profile plane.

the projection is called the ***top view*** or ***plan view***. On the profile plane, the projection is called the ***side view*** or ***end view***, or the ***side elevation*** or ***end elevation***.

The three projection planes are at right angles to each other when in their natural position (with the glass box closed), **Figure 8-5**. The frontal plane is considered to be lying in the plane of the drawing paper. The horizontal and profile planes are revolved into position on the drawing so that they are in the same plane as the drawing paper. The three projection planes are referred to as ***principal planes*** because they are the views shown on most drawings.

These three planes are also called ***coordinate planes*** because of their right-angle relationship in the folded box. When they are unfolded,

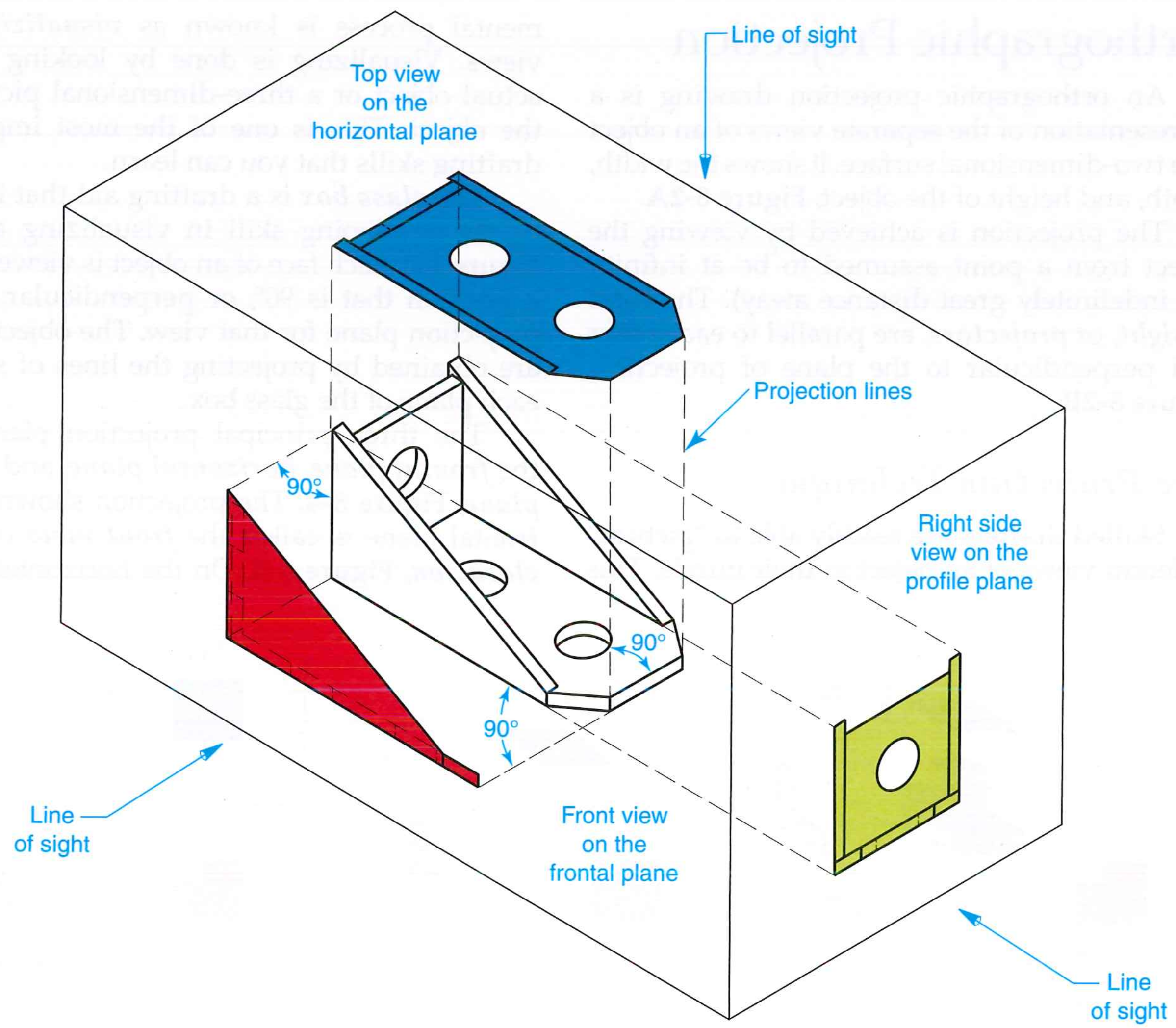


Figure 8-5. The three principal projection planes are at right angles to each other when the "glass box" is closed. These planes are used to project the features of an object onto a two-dimensional surface.

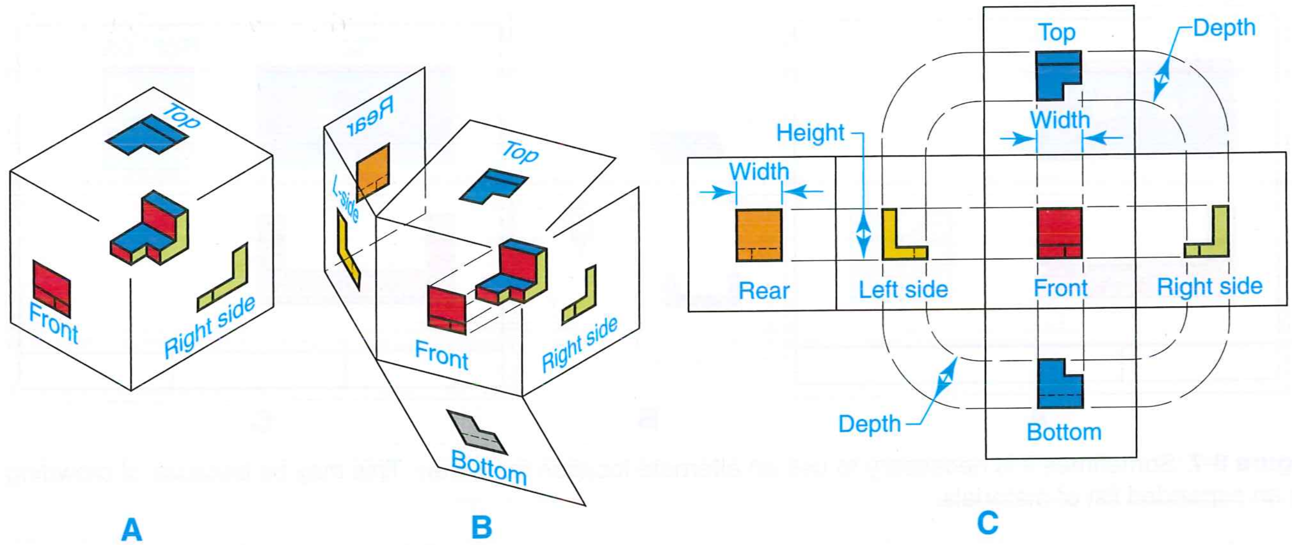


Figure 8-6. When the "glass box" is unfolded, there are six projection planes that may be used for views in orthographic projection.

they establish a definite coordinate relationship between all views of an orthographic projection.

While the three views established by the principal projection planes are the most common on drawings, six object views are possible from the six sides (planes) of the glass box, **Figure 8-6**. Note the manner in which the box is unfolded. This establishes the coordinate relationship of the three additional views. Also note the lines of projection from one view to the next. This ensures that the height dimension will be the same for the rear, left side, front, and right side views, and that they are all aligned. The top, front, and bottom views are all aligned and have the common dimension of width, as does the rear view. The top, right side, bottom, and left side views have the common dimension of depth.

Alternate Location of Views

There are occasions when the preferred location of views shown in **Figure 8-7A** is not feasible due to space limitations. For example, an expanded list of materials on a drawing, which usually appears above the title block, may crowd the usual location of the right side view.

To compensate for this lack of space, the right side view is projected directly across from the top view. This view is located as if the profile plane were hinged to the horizontal plane, **Figure 8-7B**. The projection would then appear on the drawing as shown in **Figure 8-7C**.

Although the usual practice is to locate required views in normal projected positions, the side view or profile planes may be projected off the top or bottom views. Likewise, the rear view may be projected upward from the top view, or downward from the bottom view. Each is revolved into position in the same plane as the front view when the alternate location is necessary.

Projecting Elements

To draw the views of an object, measurements of elements (including points, lines, and surfaces) are made in one view and projected to the other views. Features such as circular holes or arcs should be located initially in the view where they appear as circles or arcs, then projected to the remaining views, **Figure 8-8**.

Projection of the elements provides for greater accuracy in the alignment of views. Projection is also faster than measuring each view separately. A single, 45° miter line is drawn to project point, line, and surface measurements from one view to another. In **Figure 8-8**, this line is Line PC. The miter line meets the projection planes (Lines AP and PB) at Point P equidistant between the views.

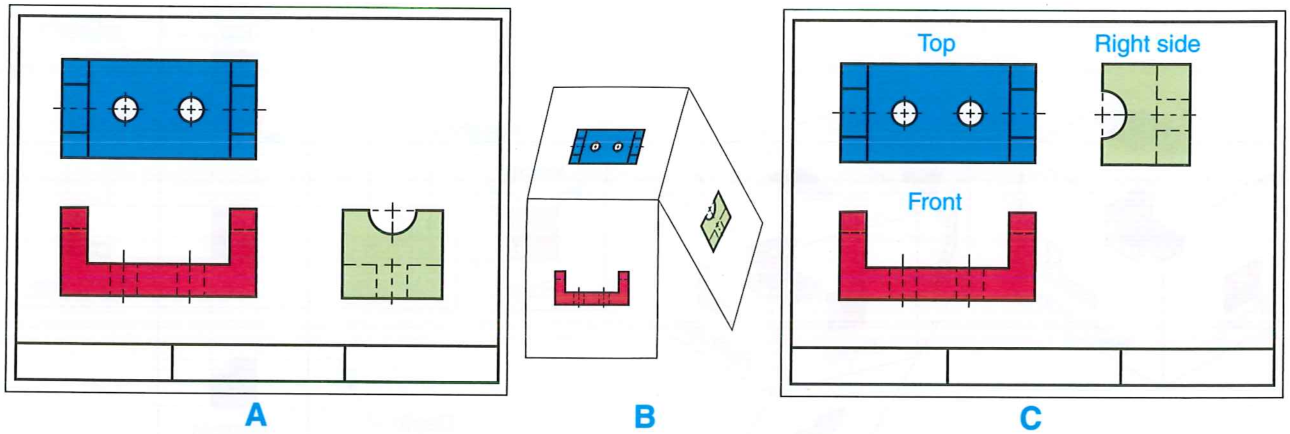


Figure 8-7. Sometimes it is necessary to use an alternate location for a view. This may be because of crowding by an expanded list of materials.

Projecting points

A ***point*** is defined as something having position, but not extension. It has location in space, but no length, depth, or height. A point on a manual drawing is indicated by a small cross (+) mark. It may be the intersection of two lines, the end of a line, or the corner of an object, **Figure 8-9**.

Referring to **Figure 8-9A**, Point P in space is located by measuring in three directions (the length, depth, and height) from the planes of projection. These measurements are made from the frontal, horizontal, and profile planes. In **Figure 8-9A**, these measurements are represented by Point P_F, Point P_H, and Point P_P. On manual drawings, points in the orthographic projection

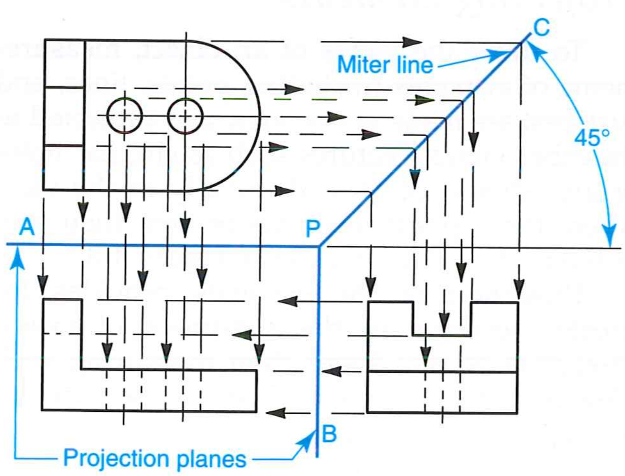


Figure 8-8. Projecting elements between views. A 45° miter line is used to help project the elements and draw the views.

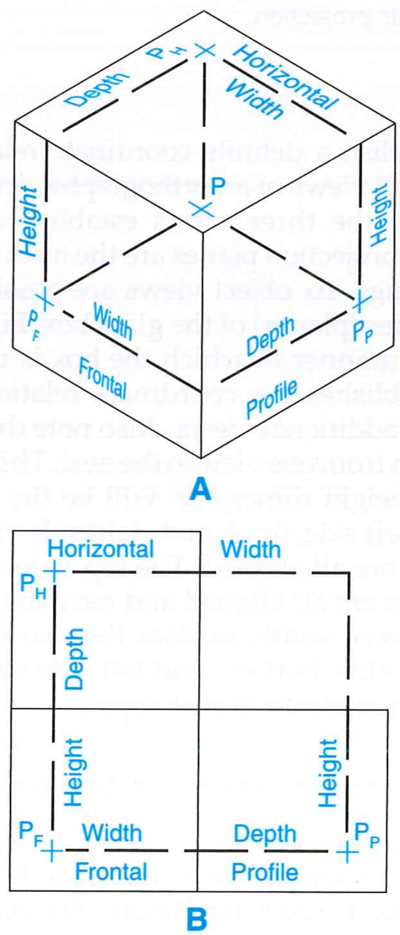


Figure 8-9. A point in space is located by measuring in three directions (the length, depth, and height). A—Point P is located by measuring from the projection planes. B—Points P_F, P_H, and P_P are located in the orthographic projection by making each measurement once in the appropriate view and projecting the measurements to the other views.

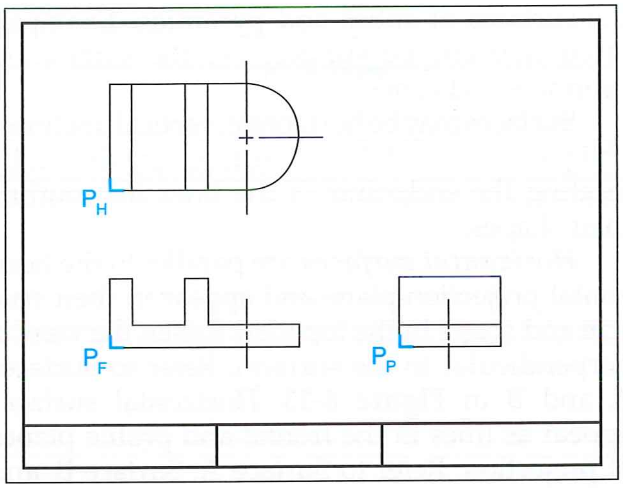


Figure 8-10. Typically, a point representing a corner or other convenient feature of an object is first located on a drawing. All other points, lines, and surfaces are then located from this first point.

are located by making each measurement once in the appropriate view and projecting measurements with a triangle and straightedge to the other views, **Figure 8-9B**. On CAD drawings, points are located by using drawing commands and coordinate entry, or drawing aids such as object snaps.

Measurements need not be made from planes of projection on a drawing. Usually, the first point representing a corner, centerline, or other feature of the object is properly located. Then space between views is allotted to produce a balanced drawing. Other points, lines, or surfaces are located from this first point, **Figure 8-10**.

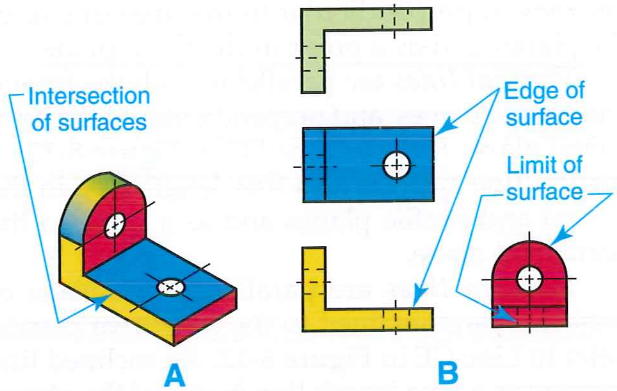


Figure 8-11. Lines can represent the intersections of surfaces, the edges of surfaces, or the limits of surfaces.

Projecting lines

A ***straight line*** is defined as the shortest distance between two points. A ***curved line*** is a line following any of a variety of arcs or curved forms.

In a drawing, lines may represent the intersection of two surfaces, **Figure 8-11A**. Lines may also represent the edge view of a surface or the limits of a surface, **Figure 8-11B**.

There are four basic types of straight lines found on objects in drawings. These are horizontal, vertical, inclined, and oblique. Each line is projected by first locating its endpoint.

Horizontal lines are parallel to the horizontal plane of projection and one of the other planes, while being perpendicular to the third plane. Refer to Line AB in **Figure 8-12**. A horizontal line appears as a ***true length*** line

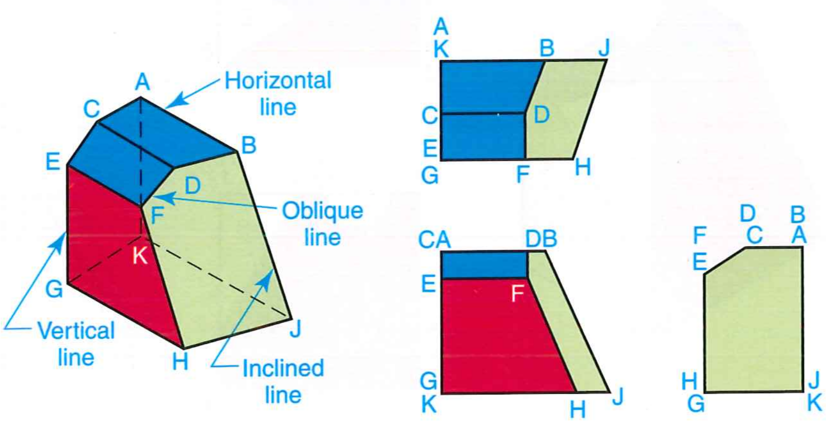


Figure 8-12. The four basic types of straight lines used on drawings are horizontal, vertical, inclined, and oblique.

(as viewed perpendicular to the line) in two of the planes and as a point in the third plane.

Vertical lines are parallel to both the frontal and profile planes, and perpendicular to the horizontal plane. Refer to Line EG in **Figure 8-12**. A vertical line appears as a true length line in the frontal and profile planes and as a point in the horizontal plane.

Inclined lines are parallel to one plane of projection and inclined in the other two planes. Refer to Line CE in **Figure 8-12**. An inclined line appears as a true length line in one of the planes and ***foreshortened*** (not as long) in the other two.

Oblique lines are neither parallel nor perpendicular to any of the planes of projection. Refer to Line DF in **Figure 8-12**. An oblique line appears foreshortened in all three planes of projection.

Curved lines may appear as a circle, an ellipse, a parabola, a hyperbola, or some other geometric curve form. They may also represent irregular curves. For curves other than circles and circular arcs, a number of points must be located on the curve and projected to the appropriate view.

Projecting surfaces

Plane surfaces and curved surfaces represent most of the surface features found on machine parts. Examples of plane surfaces are the surfaces of cubes and pyramids. Examples of circular curved surfaces are the surfaces of cylinders and cones.

Surfaces may be horizontal, vertical, inclined, oblique, or curved. These surfaces are drawn by locating the endpoints of the lines that outline their shapes.

Horizontal surfaces are parallel to the horizontal projection plane and appear in their true size and shape in the top view (when the view is perpendicular to the surface). Refer to Surfaces A and B in **Figure 8-13**. Horizontal surfaces appear as lines in the frontal and profile planes of projection. Refer to Surface A, Surface B, and Lines 4–13 in **Figure 8-13**.

Vertical surfaces are parallel to one or the other of the frontal or profile plane. They appear in their true size and shape in this plane. Refer to Surfaces G and F in **Figure 8-13**. They are perpendicular to the other two planes and appear as lines in these planes. Refer to Lines 6–8 in the frontal and profile planes in **Figure 8-13**.

Inclined surfaces are neither horizontal nor vertical. Refer to Surface D in **Figure 8-13**. They are perpendicular to one of the projection planes and appear as a true length line in this view. Refer to Line 1–5 in the side view in **Figure 8-13**. In the other two planes or views, inclined surfaces appear foreshortened. Refer to the top and front views in **Figure 8-13**.

Oblique surfaces are neither parallel nor perpendicular to any of the planes of projection.

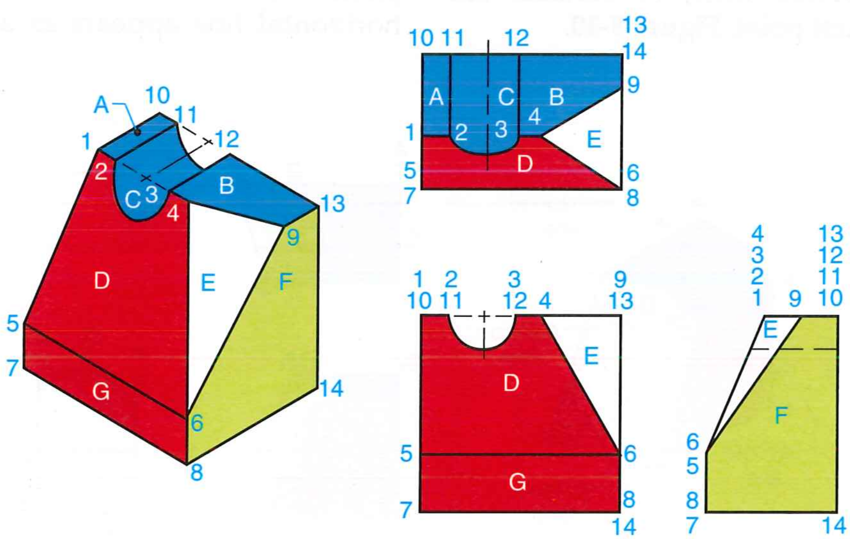


Figure 8-13. Plane surfaces appear differently in each projection of a drawing.

Refer to Surface E in **Figure 8-13**. They appear as a surface in all views but not in their true size and shape.

Curved surfaces may represent a single-curve surface (a cone or cylinder), a double-curve surface (a sphere, spheroid, or torus) or a warped surface (a helix), **Figure 8-14**.

Curved surfaces of the circular curve forms (cylinders) appear as circles in one view and as rectangles in the other views. Three views for the cylinder are shown in **Figure 8-14**, but two are usually sufficient.

When necessary, auxiliary views are used in drawings to show the true size and shape of lines and surfaces. Methods for drawing auxiliary views are covered in detail in Chapter 12.

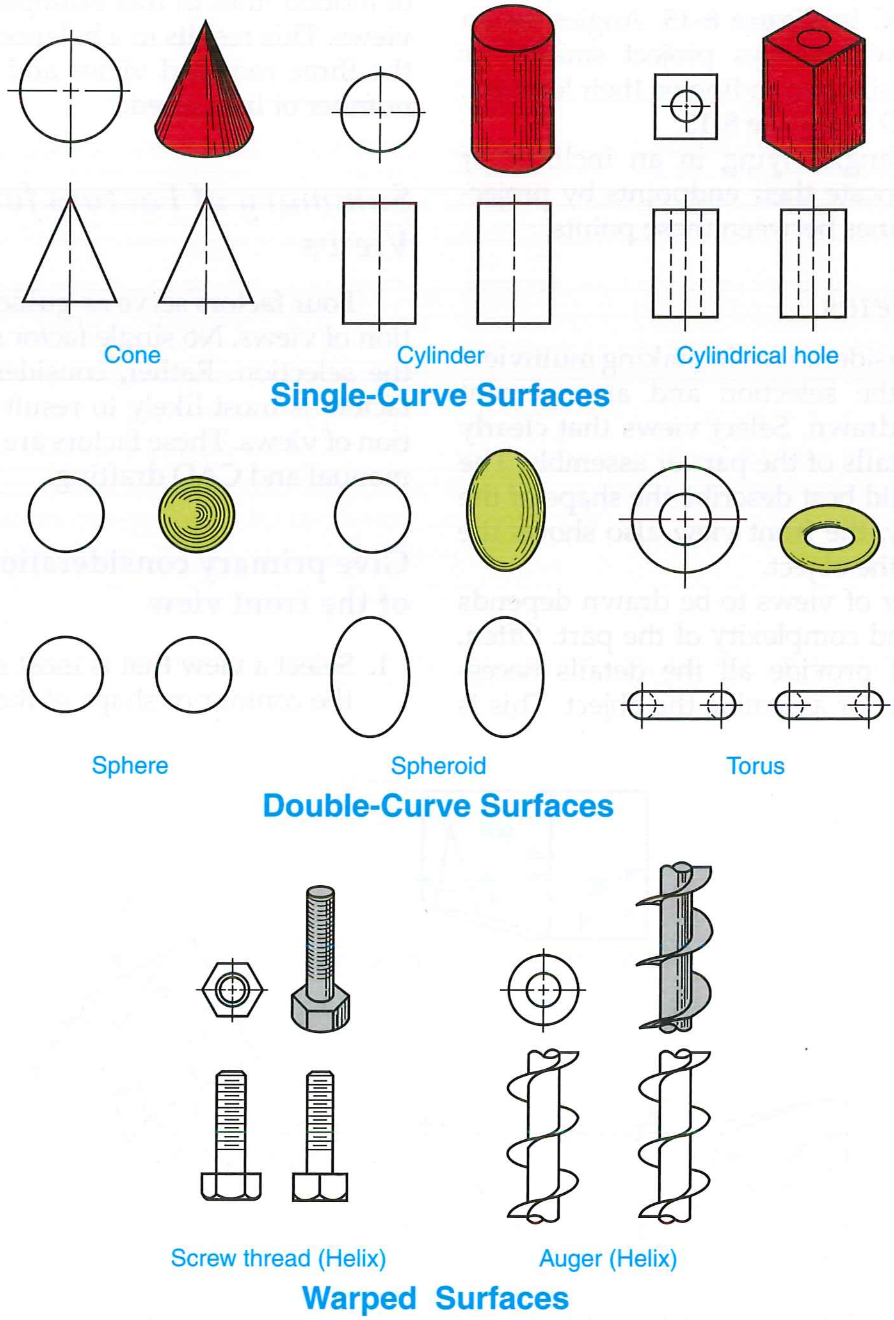


Figure 8-14. Common objects with curved surfaces and the views used to represent them.

Projecting angles

Angles that lie in a plane parallel to one of the projection planes will project their true size on that plane. Refer to Angle A in **Figure 8-15**. Angles that lie in a plane inclined to the projection plane will project smaller or larger than true size, depending on their location. Refer to Angle B in **Figure 8-15**.

Also, when a 90° angle on an inclined plane has one of its legs parallel to two projection planes, it will project true size on two planes. Refer to Angle C in **Figure 8-15**. Angles on an oblique plane will always project smaller or larger than true size depending on their location. Refer to Angle D in **Figure 8-15**.

To project angles lying in an inclined or oblique plane, locate their endpoints by projection and draw lines between these points.

Selecting Views

The first considerations in making multiview drawings are the selection and arrangement of views to be drawn. Select views that clearly describe the details of the part or assembly. The front view should best describe the shape of the object. Typically, the front view also shows the most details of the object.

The number of views to be drawn depends on the shape and complexity of the part. Often, two views will provide all the details necessary to construct or assemble the object. This is particularly true of cylindrical or round objects, **Figure 8-16A**.

Flat objects made from relatively thin sheet stock may be adequately represented with only one view by noting the stock thickness on the drawing, **Figure 8-16B**.

The views for the object in **Figure 8-16C** were not well chosen. This results in a poor arrangement of the views. However, the views in **Figure 8-16D** have been well selected to best describe the part. Also, notice that the number of hidden lines in this example is reduced in all views. This results in a balanced arrangement of the three required views and helps reduce the number of lines used.

Summary of Factors for Selecting Views

Four factors serve as guidelines in the selection of views. No single factor should determine the selection. Rather, consideration of all four factors is most likely to result in the best selection of views. These factors are the same for both manual and CAD drafting.

Give primary consideration to selection of the front view

1. Select a view that is most representative of the contour or shape of the object.

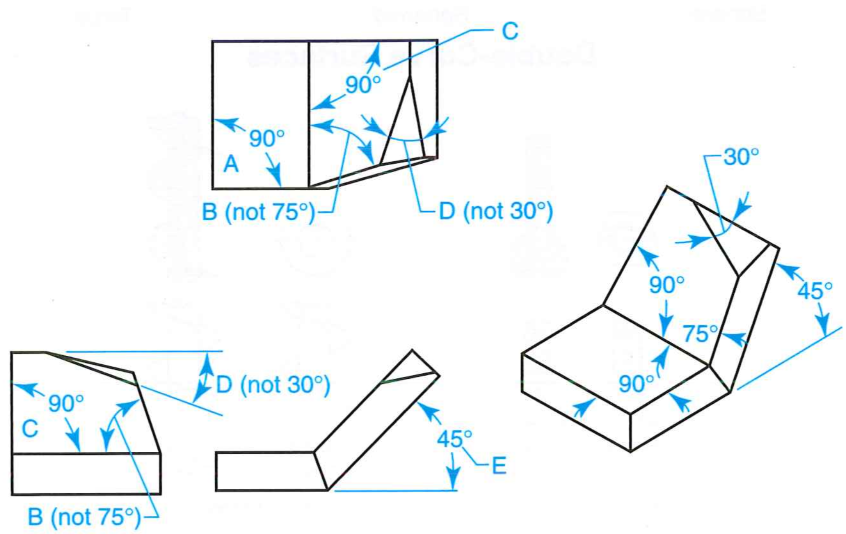


Figure 8-15. Angles that lie in a plane parallel to one of the projection planes project their true size on that plane. Angles that lie in a plane inclined to the projection plane do not project true size.

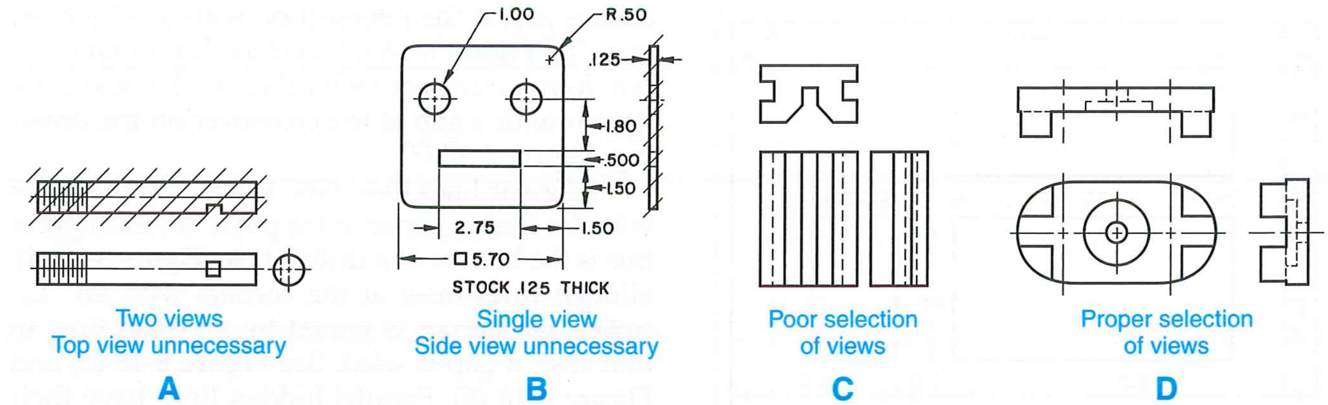


Figure 8-16. When selecting views, select the views that best describe the object. Eliminate views that are redundant or unneeded. A—Some objects require only two views. B—A single view can be used for some objects, such as flat parts made from thin stock. The stock thickness is given on the drawing. C—This arrangement of views results in a poor description of the object. D—This selection of views describes the object well by showing the necessary details and minimizing hidden lines.

2. Consider the natural or functioning position of the object.
3. Place the principal surface area parallel or perpendicular to one or more planes of projection.
4. Consider an orientation of the view that produces the least hidden lines in all views.

Consider space requirements of the entire drawing

1. Long and narrow objects may be best described with a top and front view.
2. Short and broad objects may be best described with a front and side view.
3. When the title block or list of materials tends to crowd one of the views, consider an alternate position of the view or select another view.

Choose between two equally important views unless space or other factors prohibit

1. The right-side view is preferred over the left-side view when a choice is available.
2. The top view is preferred over the bottom view when a choice is available.

Consider the number of views to be drawn

1. Use only the number of views necessary to present a clear understanding of the object.
2. One or two views may be sufficient for a relatively simple object. Three or more views may be required for more complex objects.

Space Allotment for Multiview Drawings

It is important to allocate the correct amount of space for views on a multiview drawing. Crowding the views detracts from the appearance of the drawing. Crowding makes reading and understanding the drawing more difficult.

The standard drafting practice is to provide ample space between the views of a drawing for dimensions, callouts (specific notes), and general notes. This serves to make the views more distinct and provides a neat appearance. Anticipate the number of dimensions or notes to be used and allow sufficient space.

Once the scale of the drawing has been determined, calculating the allotment of space is rather easy. Add the combined width and depth of the front and side views, **Figure 8-17**. Lay off this total (6.5″, for example) to scale along the lower border. Allow approximately 1″ spacing between views and lay off this distance beyond the first measurement. Divide the amount remaining between the two ends of the drawing area. As shown in **Figure 8-17**, for an A-size sheet, this allows for about 1.5″ for each end. Vertical spacing is determined similarly by laying off the distances along a vertical border line. Refer to **Figure 8-17**.

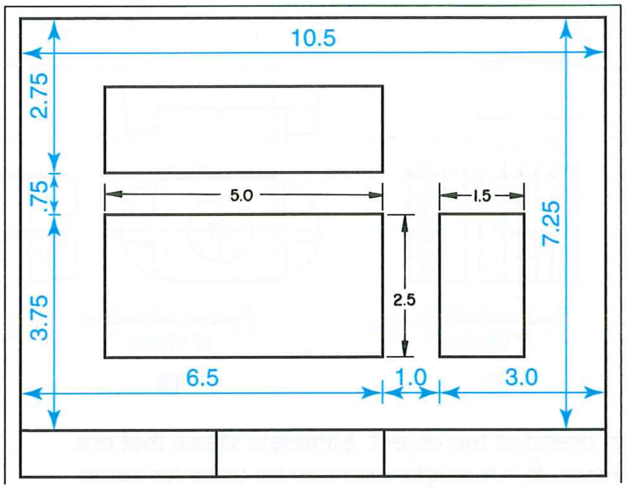


Figure 8-17. Once the overall dimensions of all of the views are known, the spacing of the views on a drawing sheet is a simple procedure.

Projecting Hidden Lines and Surfaces

Surfaces and intersections that are hidden behind a portion of the object in a particular view are usually represented by ***hidden lines***, also called *invisible lines*. Obviously, these terms are used to refer to the surface or intersection that the line represents, rather than the line itself being invisible.

Hidden lines and arcs begin with a dash. Conventions for drawing hidden lines are shown in **Figure 8-18**. Each convention is designated by a number (the conventions are numbered 1–8). If the hidden line is a continuation of a line or arc, a space is left to show exactly where the hidden line or arc begins, **Figure 8-18** (1). When hidden surfaces actually intersect on the object itself, the dashes join at the intersection with a "+" (cross) or a "T," **Figure 8-18** (2). Hidden lines that cross but do not intersect each other on the object are drawn with a gap at the crossover on the drawing, **Figure 8-18** (3).

Angular lines that come to a point are shown with the dashes joined at the point. An example of this is the bottom of a drilled hole, **Figure 8-18** (4). Hidden lines meet at the corners with an "L," unless the corner is joined by a visible line. In that case, a gap is used. See **Figure 8-18** (5) and **Figure 8-18** (6). Parallel hidden lines have their dashes staggered, **Figure 8-18** (7).

Hidden lines are usually omitted in section views unless absolutely necessary for clarity, **Figure 8-18** (8). Drafters frequently omit some hidden lines from views when the drawing is clear without them. This avoids a cluttered appearance. However, it is good practice for the beginning drafter to include all hidden lines in regular views until a better understanding of the problem of clarity in a drawing is gained.

Determining Precedence of Lines

Occasionally, you will find that certain lines coincide in the projection of views in multiview drawings. Should this occur, visible lines take precedence over all others. The following convention of line importance governs precedence of lines.

1. Visible lines.
2. Hidden lines.
3. Cutting-plane lines.
4. Centerlines.

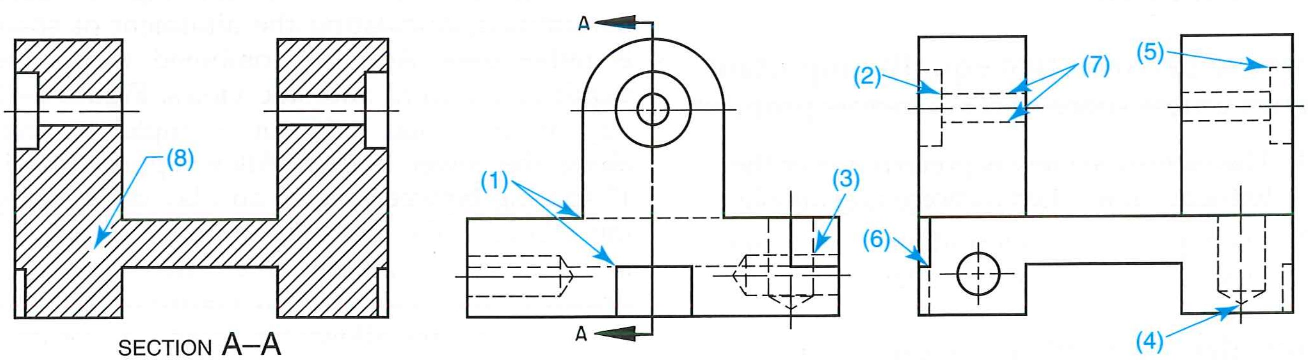


Figure 8-18. Hidden lines and surfaces appear as dashed lines on a drawing. Shown are drafting conventions used for drawing these lines.

5. Break lines.
6. Dimension and extension lines.
7. Section lines (crosshatching).

All lines have precedence over any line numbered below it. For example, a centerline (Number 4) will have precedence over a break line (Number 5), a dimension or extension line (Number 6), and a section line (Number 7).

Removed Views

Sometimes it is desirable to show a complete or partial view on an enlarged scale to clarify the detail of the part, **Figure 8-19**. This particular view is removed to a nearby area of the drawing. However, the same orientation of the view is maintained. The removed view is appropriately identified and referred to on the regular view.

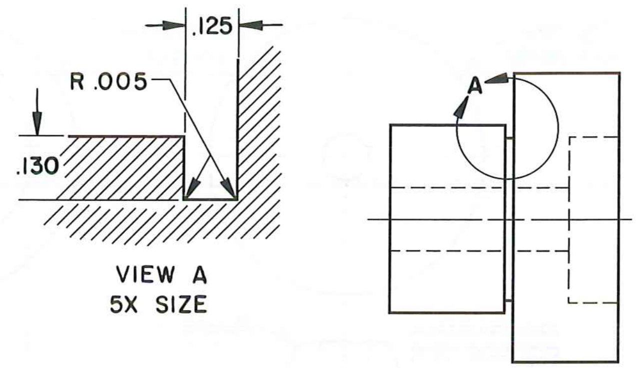


Figure 8-19. Sometimes it is necessary to provide a removed partial view that is enlarged to clarify information, such as a machining detail.

Partial Views

Because of their shape, some objects may not require all views to be full views. Objects that are symmetrical in one view may require only a half view in that view, **Figure 8-20A**. A partial view may be broken on the centerline or at another place with a broken line, **Figure 8-20B**.

Objects with different side views should have two partial side views drawn. Each of these views should include lines for that view only, thus avoiding a confusion of lines from the other view, **Figure 8-20C**.

Conventional Drafting Practices

A number of conventional drafting practices are used in industry to reduce costs, speed the drafting process, and clarify drawings. Some of these practices are presented here. Other conventions appear in chapters related to the specific practice being described.

Drawing Fillets and Rounds

When making metal castings, it is necessary to avoid sharp interior corners. This prevents fractures of the metal. Also, sharp exterior corners are difficult to form in the mold. To eliminate these problems, patterns for the castings are made with rounded corners.

A small, rounded, internal corner is known as a ***fillet***. A small, rounded, external corner is known as a ***round***. See **Figure 8-21**.

Since there is no sharp line intersecting the two surfaces in a rounded feature, an

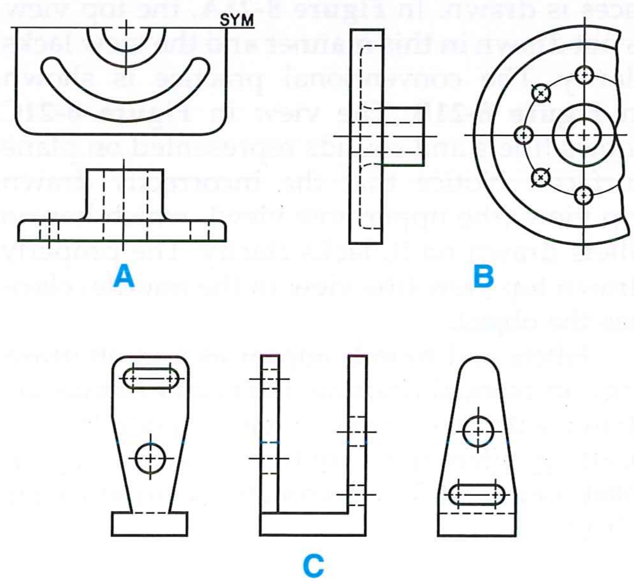


Figure 8-20. If an object is symmetrical, it is not always necessary to draw the complete object. Shown are conventions for drawing partial views. A—Using a line of symmetry. B—Using a break line. C—Sometimes it is necessary to show two side views if the object is different on both sides. In this case, show only the features that can be seen on that side. This improves the clarity of the drawing.

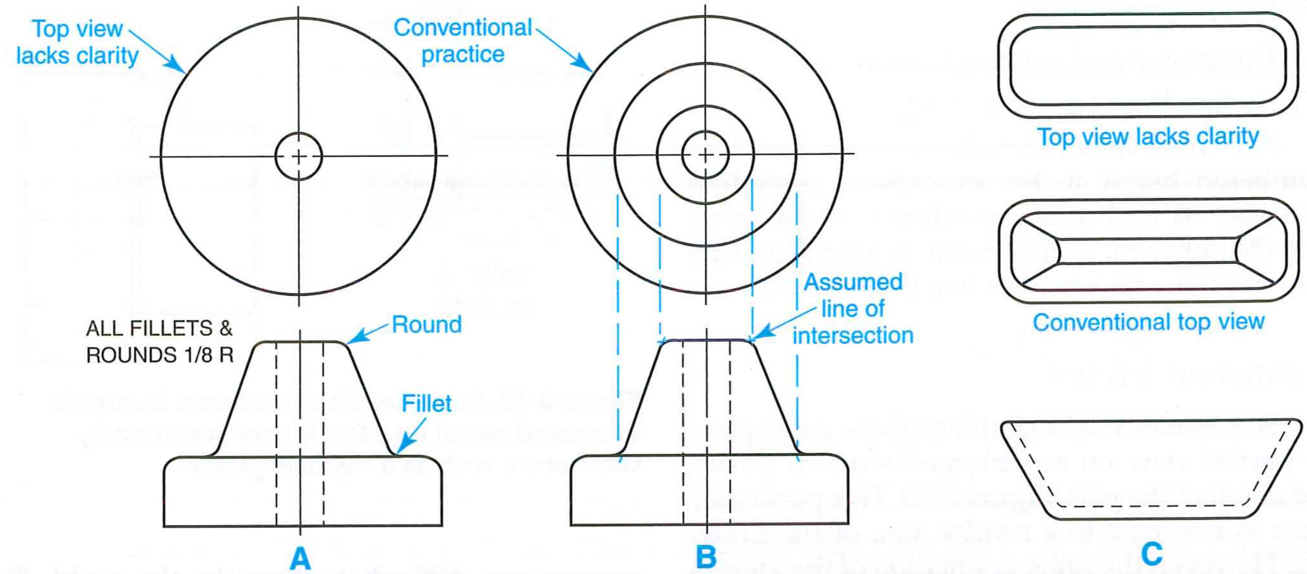


Figure 8-21. Fillets and rounds are used to eliminate sharp corners between surfaces. Fillets and rounds are typically shown as lines in a drawing. A—The top view does not show the lines of intersection between surfaces. B—The conventional practice. C—The conventional top view (the view in the middle) shows the rounded features as lines and provides much more clarity than if the drawing is shown as it truly appears.

assumed line of intersection of the two surfaces is drawn. In **Figure 8-21A**, the top view is not drawn in this manner and the view lacks clarity. The conventional practice is shown in **Figure 8-21B**. The view in **Figure 8-21C** shows fillets and rounds represented on plane surfaces. Notice that the incorrectly drawn top view (the uppermost view), which has no fillets drawn on it, lacks clarity. The properly drawn top view (the view in the middle) clarifies the object.

Fillets and rounds appear as arcs on drawings. In manual drafting, fillets and rounds are drawn with a compass or circle template. In CAD drafting, fillets and rounds are drawn using the **Fillet** command. This command is introduced in Chapter 4.

Drawing Runouts

A ***runout*** is the intersection of a fillet or round with another surface. The shape of an arm, spoke, or web also affects the shape of the runout, **Figure 8-22**. The arc of the runout should be the same radius as the fillet or round. In manual drafting, a runout may be drawn freehand, with an irregular curve, or with a compass. In CAD drafting, the **Fillet**, **Arc**, or **Circle** command can be used.

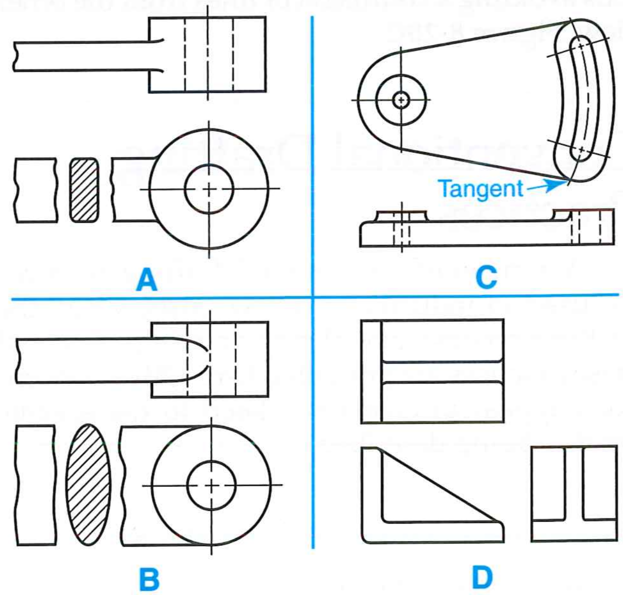


Figure 8-22. Common conventions for representing runouts on drawings.

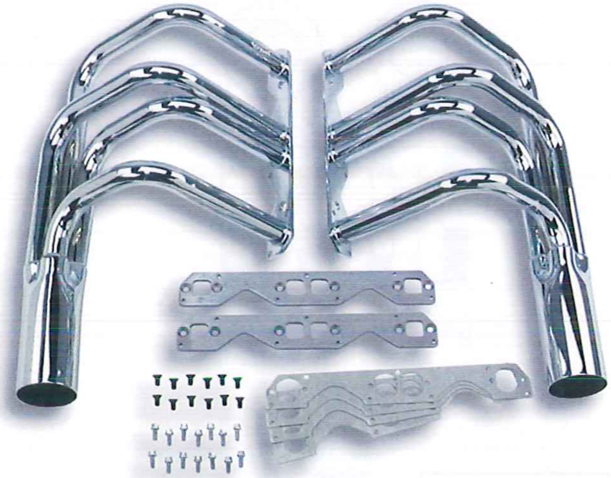


Figure 8-23. Automobile exhaust headers are examples of opposite parts that are not always identical. (Holley Performance Products)

Drawing Right-Hand and Left-Hand Parts

Whenever possible, opposite parts are made identical to reduce the number of different parts required for an assembly. Examples include automobile wheels, tires, and some doors for kitchen cabinets. In some cases, opposite parts are not identical. Examples include automotive parts, cabinet drawer slides, and cabinet doors that can only be hung one way. See **Figure 8-23**.

When opposite parts cannot be made interchangeable, the conventional practice is to draw one part and to note "RH PART SHOWN, LH PART OPPOSITE," **Figure 8-24**. This works quite well for most simple parts and saves considerable drafting time. Where there is a chance for confusion in the details of the opposite part, both parts should be drawn.

Drawing Cylinder Intersections

Small cylinder intersections on surfaces are not typically shown as the true projection. The conventional representation for small cylinder intersections with plane or cylindrical surfaces is shown in **Figure 8-25A**. The same practice is used for cuts in small cylinders, **Figure 8-25B**. For keyseats and small drilled holes, the intersection is typically unimportant. Clarity on the drawing is accomplished by treating these intersections conventionally, **Figure 8-25C**. Drawing methods for showing intersections of larger cylinders are discussed in Chapter 14.

Revolving Radial Features

Some objects that have features arranged radially appear confusing when true orthographic projection techniques are followed. For example, the lugs on a flange appear awkward and out of position with the flange in true projection, **Figure 8-26A**. When revolved to a position on a common centerline, the ribs appear to be symmetrical, **Figure 8-26B**. This drawing has more clarity, even though the projection is not a true projection.

On other parts, such as a plate with a number of small holes arranged radially, the side view is confusing when true projection techniques are followed, **Figures 8-26C** and **8-26D**. Conventional practices call for the holes to be revolved to symmetrical positions, **Figure 8-26E**. Ribs on a hub are another example of radial features that appear more clearly when revolved to a position of symmetry, **Figure 8-26F**. Study and compare **Figures 8-26G** and **8-26H**.

Drawing Parts in Alternate Positions

At times, it is necessary to draw an alternate position of a part to show the limits and necessary clearance during operation. The part is

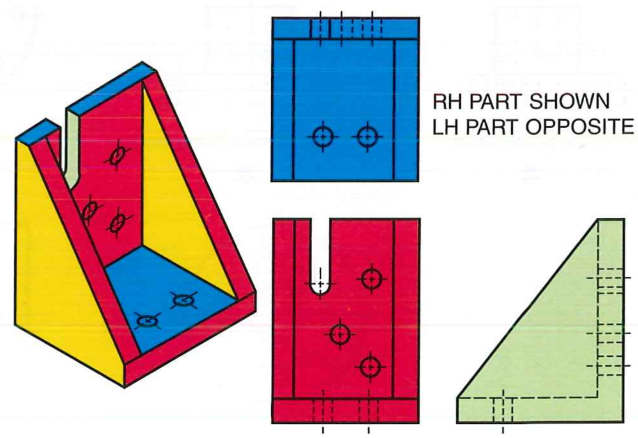


Figure 8-24. When right-hand and left-hand parts cannot be made interchangeable, a note on the drawing is a way for the drafter to save time.

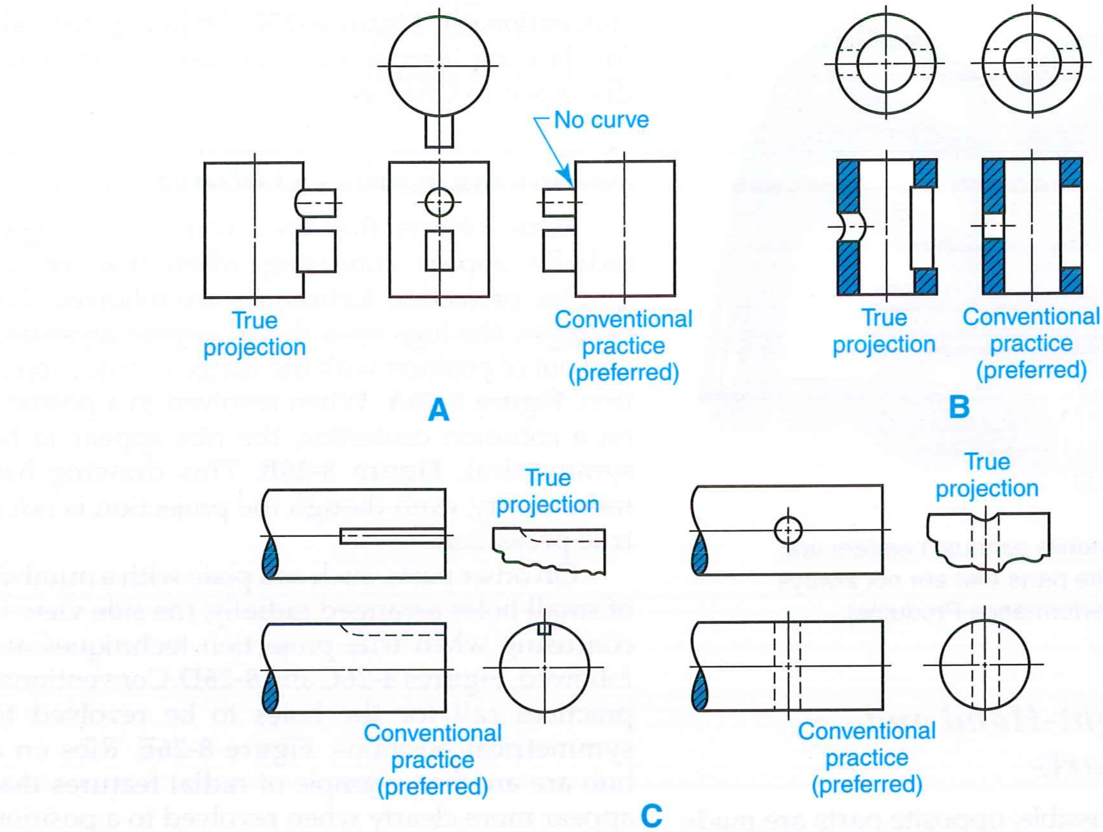


Figure 8-25. Conventions for representing intersections of small cylindrical surfaces, cuts in surfaces, keyseats, and small, drilled holes. True projections are shown for reference. A—When small cylinders intersect, no curve is drawn to show the intersection. B—Curves are not used to show cuts on small cylindrical surfaces. C—The same practice is used for keyseats and small, drilled holes.

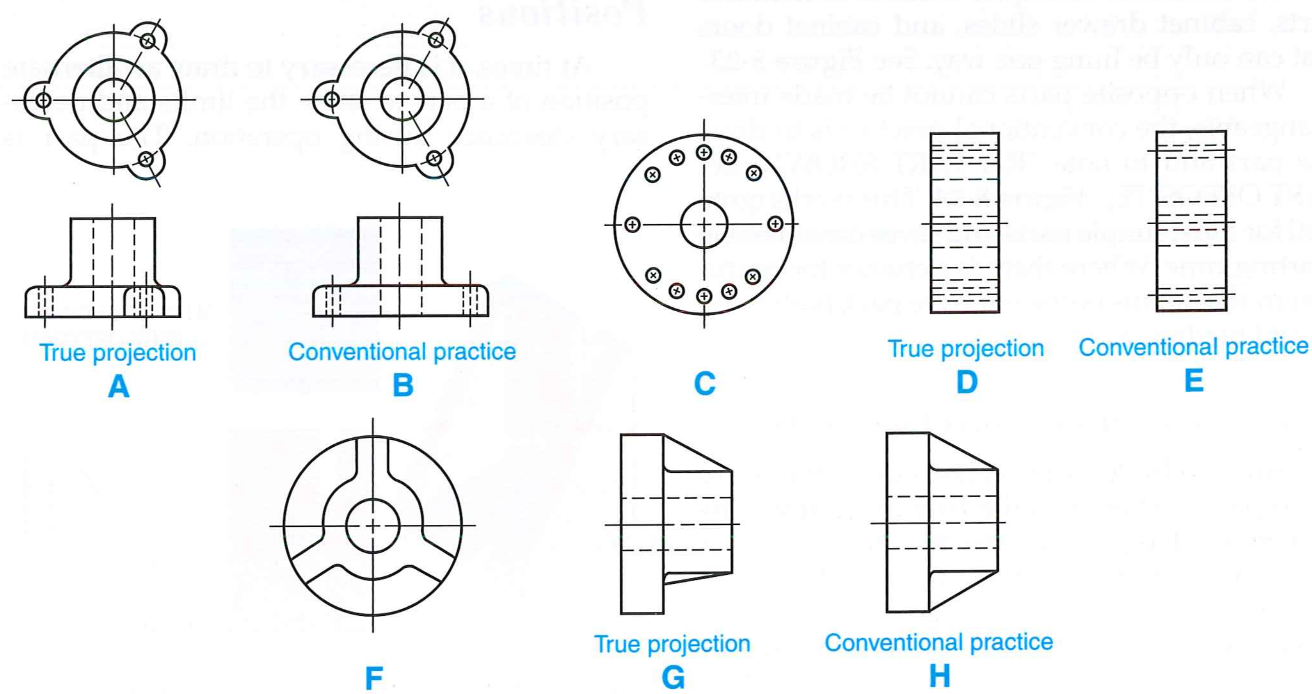


Figure 8-26. Radial features on certain parts are typically revolved to achieve symmetry and clarity. Although this is not the true projection, it makes the drawing more understandable.

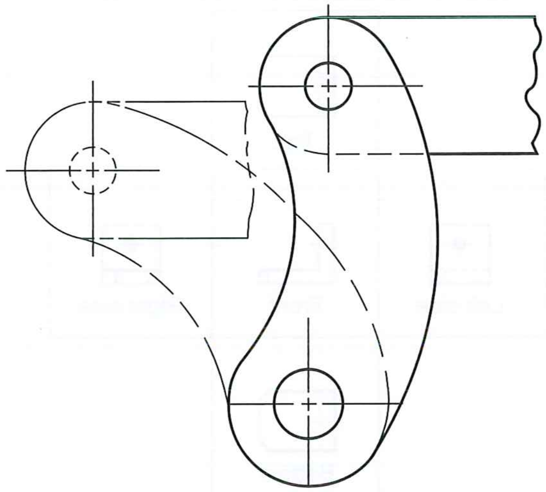


Figure 8-27. Phantom lines are used to show alternate positions of parts. This practice is used in many cases where a part has specific movement limits or clearance requirements.

drawn in its alternate position by using phantom lines, **Figure 8-27**.

Drawing Repeated Details

Drawings of coil springs, radial flutes, and other repeated details would require considerable drafting time if they were drawn in full views. Conventional drafting practices require the drawing of one or two of the individual details, with the remainder represented by phantom lines, **Figure 8-28**.

First-Angle and Third-Angle Projections

In orthographic projection, there are two common methods used for making drawings. These methods are referred to as ***first-angle projection*** and ***third-angle projection***. These two projection methods are derived from a theoretical division of all space into four quadrants by a vertical plane and a horizontal plane, **Figure 8-29**. The quadrants are numbered 1 through 4, starting in the upper-left quadrant and continuing clockwise, when viewed from the right side. The viewer of the four quadrants is considered to be in front of the vertical (or frontal) plane, and above the horizontal plane. The position of the profile plane is not affected by the quadrants. It is considered to be either to the right or left of the object, as desired. In orthographic projection, an object is placed in an imaginary "glass box" in the first or third quadrant and the views are projected to the sides of the box. The box is "unfolded" and the views are revolved onto the vertical (or frontal) plane.

Third-angle projection is used in the United States and Canada. Most European countries use first-angle projection. The main difference between the two is how the object is projected and the positions of the views on the drawing.

In third-angle projection, the frontal projection plane is considered to be between the

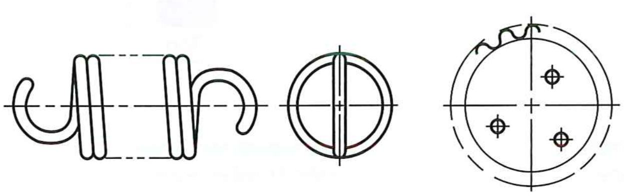


Figure 8-28. Phantom lines are used to represent repeated details.

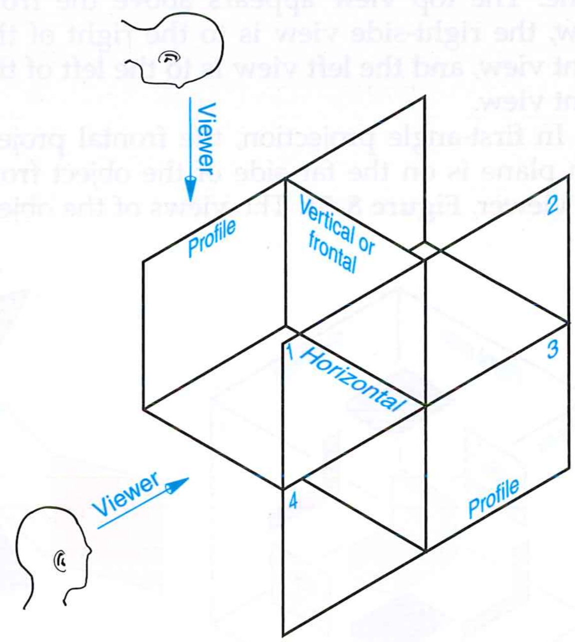


Figure 8-29. The four quadrants used in orthographic projection are created by the intersection of a horizontal plane and a vertical, or frontal, plane. The quadrants are numbered clockwise from the upper-left quadrant (when viewed from the right side). The first quadrant is used for first-angle projection. The third quadrant is used for third-angle projection.

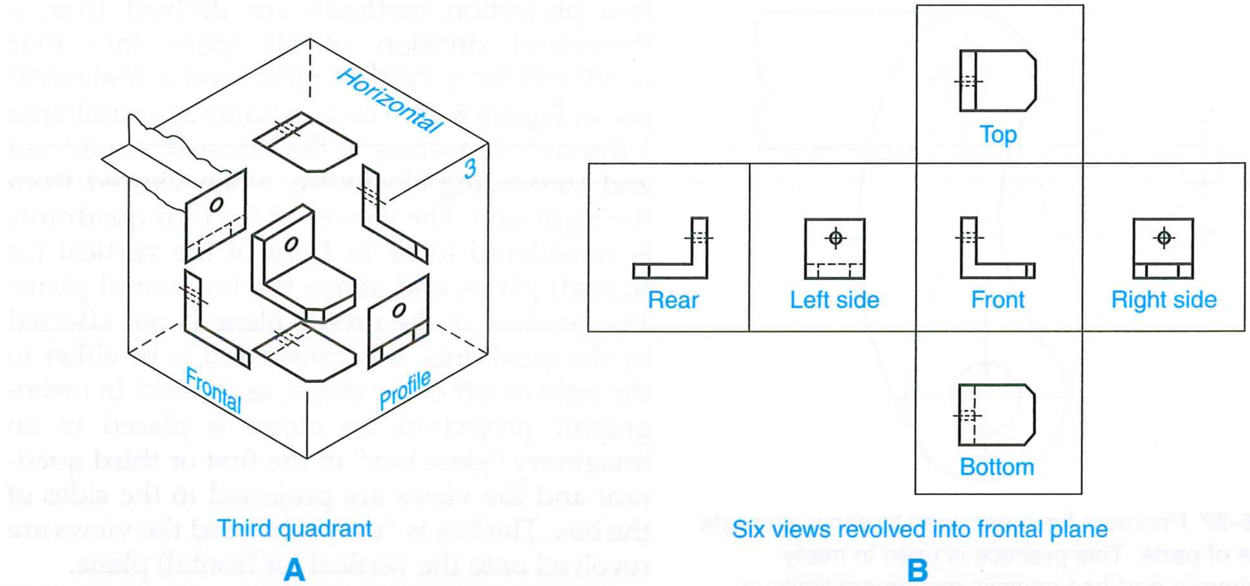


Figure 8-30. Views are projected forward to the frontal plane in third-angle projection.

viewer and the object. The views are projected forward to the frontal projection plane from the third quadrant, **Figure 8-30**. The views appear in their natural positions when the views are revolved into the same plane as the frontal plane. The top view appears above the front view, the right-side view is to the right of the front view, and the left view is to the left of the front view.

In first-angle projection, the frontal projection plane is on the far side of the object from the viewer, **Figure 8-31**. The views of the object are projected to the rear from the first quadrant instead of being projected forward.

The individual views in first-angle projection are the same as those obtained in third-angle projection, but their arrangement on the drawing is different when revolved into the frontal plane, **Figure 8-32**. The "glass box" is still hinged to the frontal plane, but the frontal plane is behind the object. The top view appears below the front view, the right-side view appears to the left of the front view, and the left-side view appears to the right of the front view.

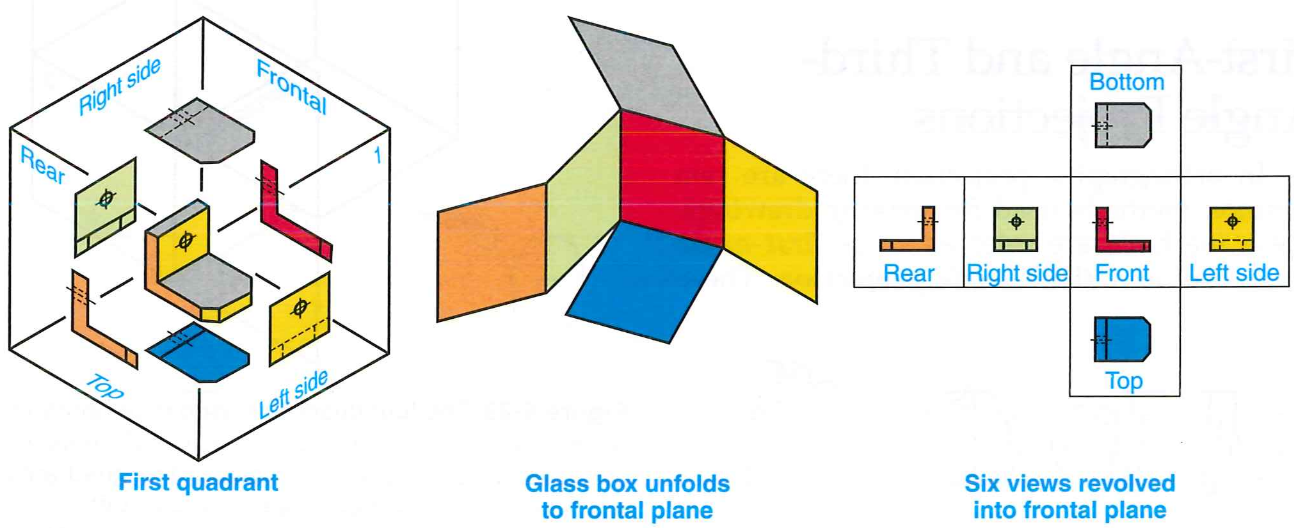


Figure 8-31. In first-angle projection, the frontal projection plane is on the far side of the object from the viewer and the views are projected toward the rear.

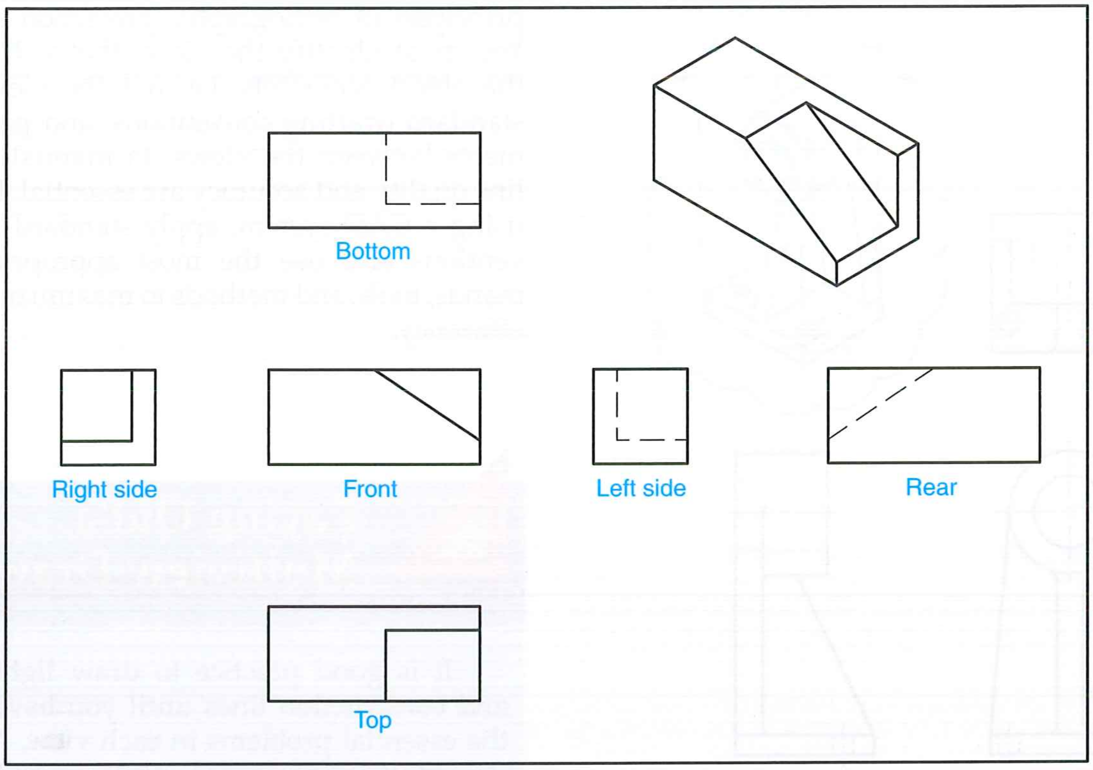


Figure 8-32. The arrangement of views in first-angle projection. The top view is below the front view. The right-side view is to the left of the front view.

It is possible to place an object in any of the four quadrants. However, the second and fourth quadrants are not practical. Third-angle projection is followed entirely in this text. However, it is good for you to understand first-angle projection as well. This will allow you to interpret a drawing prepared in another country.

Industries that serve customers in the international market sometimes mark their drawings with symbols to indicate third-angle or first-angle projection, **Figure 8-33**.

Visualizing an Object From a Multiview Drawing

Most students in beginning drafting have difficulty visualizing a machine part or assembly from a multiview drawing. Mastery of a few simple techniques will enable you to solve the "mystery" and interpret the information. The following steps are listed to help you visualize an object, **Figure 8-34**.

1. Break each view down to a basic geometric shape (a rectangle, circle, cone, or triangle).
2. Consider possibilities for each shape. Is a circle a hole or a protruding shaft? Is a rectangle a base plate or web? Is a triangle a brace or support?

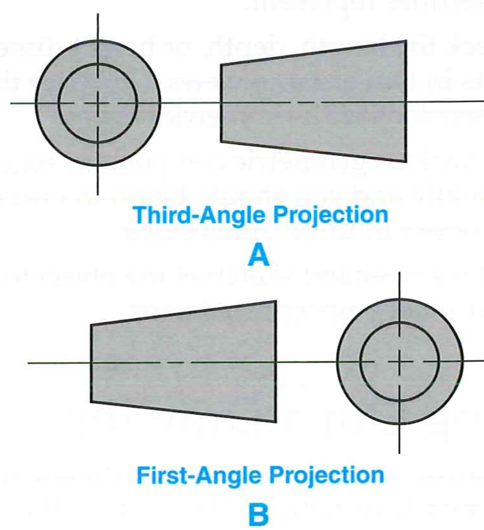


Figure 8-33. Symbols are used to indicate whether a drawing is a third-angle or a first-angle projection.

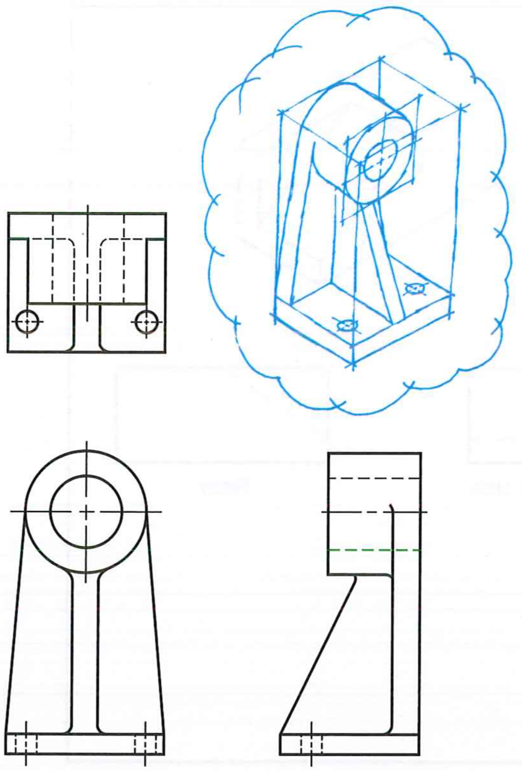


Figure 8-34. An object in a multiview drawing should be visualized in three dimensions. If the drawing is broken down into basic geometric shapes, it is much easier to visualize the three-dimensional representation of the object.

3. Check the basic geometric shape in one view against its shape in another view. Identify the features that hidden lines and centerlines represent.
4. Check the length, depth, or height dimensions in two or more views. Compare these dimensions with geometric shapes.
5. Put various geometric components together mentally and you should begin to visualize the object in three dimensions.
6. Make a freehand sketch of the object to clear up any uncertain details.

Laying Out a Drawing

Whether you are creating multiview drawings manually or with a CAD system, the same principles of orthographic projection are used. You must identify the views that will describe the object accurately, lay out the views using standard drafting conventions, and project elements between the views. In manual drafting, line quality and accuracy are essential. If you are using a CAD system, apply standard line conventions and use the most appropriate commands, tools, and methods to maximize drawing efficiency.

Laying Out a Multiview Drawing

It is good practice to draw light layout and construction lines until you have solved the essential problems in each view. All lines should then be darkened to complete the drawing. If changes are necessary, they are relatively simple to make when lines are lightly drawn. Observe the following steps until they become an unconscious part of your drafting.

1. Select a sheet size and drawing scale that will avoid crowding the views, dimensions, and notes.
2. Draw light lines at first (heavy lines tend to "ghost" and are difficult to erase).
3. Check your measurements carefully in "blocking in" the required views.
4. Locate and lay out arcs and circles first, then straight lines.
5. During layout, do not include hidden lines, centerlines, or dimension lines. A short mark, or a dimension figure lightly noted near its location, will serve as a reminder that it is to be included.
6. Check your layout carefully for missing lines, dimensions, notes, or special features required in the problem.
7. Remove unnecessary construction lines. Give the drawing a general cleaning.

8. Darken the lines. Start with arcs and circles, then darken the lines from the top down. Next, darken the rest of the lines from your non-drawing hand to your drawing hand.
9. Letter the notes and title block.
10. Check the finished drawing carefully for spelling, proper line weights, and general appearance.

CAD Creating a Multiview Drawing

After determining the views that will be drawn, start a new drawing and configure drawing settings such as the title block format, sheet size, and drawing unit format. As an alternative, you may want to start the drawing using a predrawn template. Set up the layers, linetypes, and text styles that you will need to make the drawing. Also, set up drawing aids such as object snaps and grid spacing. Save the file to a hard drive location or to portable media and save your work frequently once you start drawing.

1. Enter the **Xline** command and draw construction lines to "block in" the required views. Draw the construction lines on a construction layer so that you can freeze it when the drawing is completed. Locate the views using the space allotment methods discussed in this chapter. You can use the **Offset** command to offset the construction lines at the required distances, or you can use the **Copy** command and direct distance entry. Block in the front, top, and side views. Use Ortho mode to your advantage. As an alternative, you can draw each view separately and use the **Move** command later to arrange the views in their proper locations.
2. Enter the **Line** command and draw the object lines that outline each view. Use object snaps to snap to intersections established by the construction lines.
3. Enter the **Line** command and draw the remaining object lines in each view. Offset the lines outlining the views as needed to establish point locations.
4. To create round features, such as holes, use the **Offset** command to offset object lines to locate the center points. Place the offset lines on the construction layer. Enter the **Circle** command and draw the circular features. If necessary, use the **Trim** command to create circle arcs by trimming to cutting edges.
5. Create hidden features by offsetting or copying lines in the appropriate views. Use the **Trim** command to trim the lines to the required cutting edges. Place the hidden lines on a layer that uses a hidden linetype.
6. Create centerlines for round features in a similar manner. Use the **Offset** or **Copy** command. Place the centerlines on a layer that uses a centerline linetype.
7. For drawings requiring filleted lines or chamfered corners, use the **Fillet** or **Chamfer** commands to draw the features.
8. Add drawing notes and title block information using the **Text** command.
9. Freeze the construction layer and any other layers that you do not wish to display.
10. Check your drawing carefully for missing lines or special features. Add any final features using the appropriate drawing commands. Check the finished drawing carefully for spelling, proper linetypes and weights, and general appearance.

Chapter Summary

The multiview drawing is the major type of drawing used in industry. The various views of an object are carefully selected to show every detail of size and shape. Usually three views are drawn. This system of drawing is known as orthographic projection.

An orthographic projection drawing is a representation of the separate views of an object on a two-dimensional surface. It shows the width, depth, and height of the object. The projection is achieved by viewing the object from a point assumed to be at infinity with lines of sight parallel to each other and perpendicular to the plane of projection.

The projection shown in the frontal plane is the front view. The projection shown on the horizontal plane is the top view. The projection shown on the profile plane is the side view. The frontal, horizontal, and profile planes are called the principal planes and are at right angles to each other in their natural position.

To draw the views of an object, measurements of points, lines, and surfaces are made in one view and projected to the other views. A point is defined as something having position, but not extension—no length, depth, or height. A straight line is defined as the shortest distance between two points. Surfaces may be planar or curved.

The first considerations in making multiview drawings are the selection and arrangement of views to be drawn. Select the views that best describe the details of the part or object. The front view should best describe the shape of the object. The number of views to be drawn depends on the complexity of the part. Also, consider the natural or functioning position of the object, place the principal surface parallel or perpendicular to one or more planes, and orient the object to produce the least hidden lines.

Precedence of lines often is a concern of the drafter. The order of precedence is as follows: Visible lines, hidden lines, cutting-plane lines, centerlines, break lines, dimension and extension lines, and section lines.

A number of conventional drafting practices are used to reduce costs, speed the drafting process, and clarify drawings. Conventional practices are used for drawing fillets and rounds, runouts, right- and left-hand parts, cylinder intersections, revolving radial features, parts in alternate positions, and repeated details.

Drawings made in orthographic projection are referred to as first-angle or third-angle projections. Third-angle projection is used in the United States and Canada. Most European countries use first-angle projection. The main difference is the arrangement of the views.

Study and learn to visualize objects from multiview drawings. This will take some practice.

Review Questions

1. What is a multiview drawing?
2. In multiview drawing, the top view always appears above which view?
3. Another name for the multiview drawing process is _____.
4. What are the three principal projection planes?
5. The _____ plane is considered to be lying in the plane of the drawing paper.
6. A _____ is defined as something having position, but not extension.
7. A _____ is defined as the shortest distance between two points.
8. Name the four basic types of straight lines found on objects in drawings.
9. _____ lines are parallel to both the frontal and profile planes.
10. _____ lines are parallel to one plane of projection and inclined in the other two planes.
11. _____ lines are neither parallel nor perpendicular to any of the planes of projection.
12. Horizontal surfaces are parallel to the horizontal projection plane and appear in their true size and shape in the _____ view.

13. Oblique surfaces are neither parallel nor _____ to any of the planes of projection.
14. A regular cylinder will appear as a circle in one view and as a _____ in the other views.
15. When making a multiview drawing, which view should best describe the shape of the object?
16. Flat objects made from relatively thin sheet stock may be adequately represented with only one view by indicating what information on the drawing?
17. Name four factors that serve as guidelines in the selection of views when making multiview drawings.
18. Surfaces and intersections that are hidden behind a portion of the object in a particular view are usually represented by _____.
19. _____ lines take precedence over all others.
20. A small, rounded, internal corner is known as a _____, while a small, rounded, exterior corner is known as a _____.
21. A(n) _____ is the intersection of a fillet or round with another surface.
22. In orthographic projection, there are two common methods used for making drawings. These methods are referred to as first-angle projection and _____ projection.
23. _____ projection is the orthographic projection method used in the United States and Canada.

Problems and Activities

Multiview problems are given in the following sections to provide you with experience in multiview projection techniques. These problems can be completed manually or using a CAD system.

Multiview Drawings with Missing Lines

Study the multiview drawings in **Figure 8-35.** Draw the views of the problems and add the missing lines. Use approximate dimensions and keep the objects in proportion. Center the views as shown. If you are drawing the problems manually, make a sketch of each problem first. Use the Layout II sheet format given in the Reference Section. Have your problem sketches approved by your instructor before proceeding.

Multiview Drawings with Missing Views

Study the multiview drawings in **Figure 8-36.** Draw the given views of the problems and add the missing views. Use approximate dimensions and keep the objects in proportion. Center the views as shown. If you are drawing the problems manually, make a sketch of each problem first. Use the Layout II sheet format given in the Reference Section. Have your problem sketches approved by your instructor before proceeding.

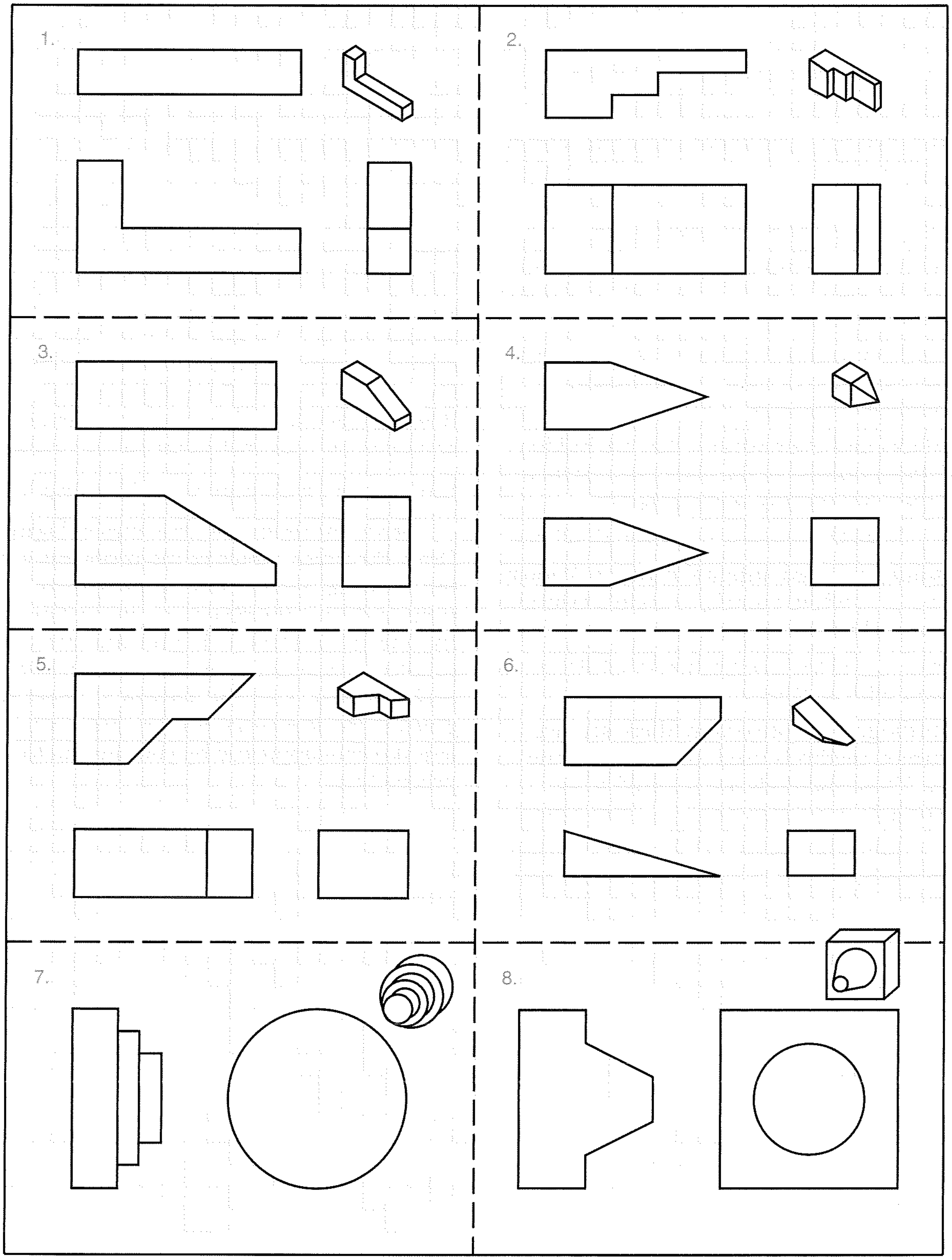


Figure 8-35. Shown are multiview drawings with missing lines in the views. Draw these problems and complete the views.

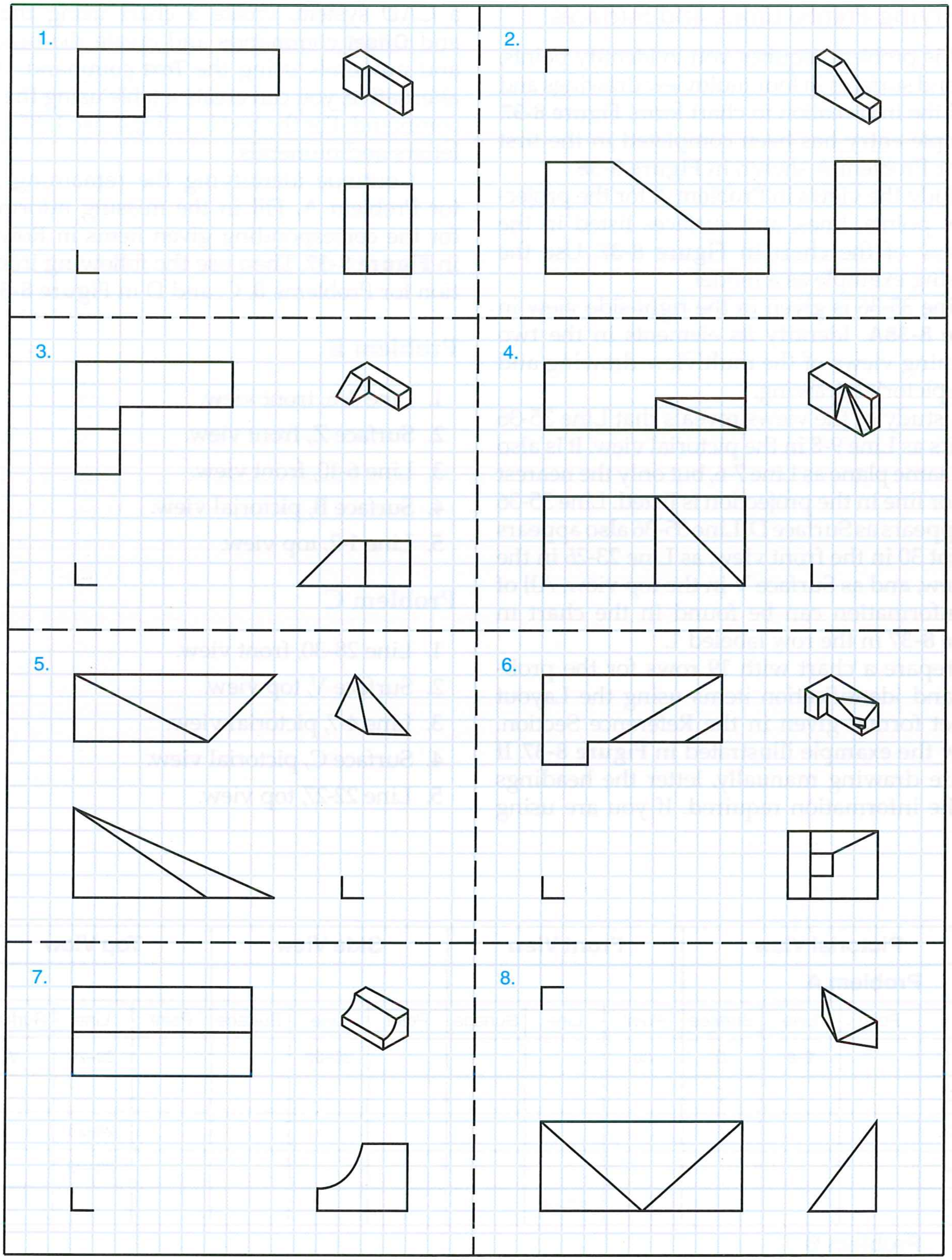


Figure 8-36. Shown are multiview drawings with missing views. Draw each problem and complete the missing view.

Identifying Points, Lines, and Surfaces

This problem requires you to identify points, lines, and surfaces in four multiview drawings and record the information in chart form, **Figure 8-37**. A sample entry has been completed in the first row for Problem A shown in **Figure 8-38**.

Study the views in Problem A for the projection of points, lines, and surfaces listed in the first row of the chart in **Figure 8-37**. Use the following example as a model.

Line 35-36 is given in the right-side view in **Figure 8-38A**. Identify its elements in the two remaining views of the multiview drawing and in the pictorial drawing.

A study of the views reveals that Line 35-36 appears as Line 9-8 in the pictorial view. It is also in the same plane as Line 7-6, but only the nearest point or line in the projection is listed. Line 35-36 also appears as Surface D. Line 35-36 also appears as Point 30 in the front view, as Line 23-26 in the top view, and as Surface V in the top view. All of this information can be found in the chart in **Figure 8-37** in the row labeled 1.

Prepare a chart with 19 rows for the problems and identification items using the Layout II sheet format given in the Reference Section. Follow the example illustrated in **Figure 8-37**. If you are drawing manually, letter the headings and the information required. If you are using a CAD system, create a chart using the **Line** and **Offset** commands and create the headings and numerals using the **Text** command. As an alternative, you can create a table using the **Table** command. For the text headings, use 1/8″ capital letters and numerals.

Continue identifying the remaining items for Problem A. Fill in the missing information for the corresponding given items in Rows 2–5 in **Figure 8-37**. Then use the following information for Problems B, C, and D in **Figure 8-38**.

Problem B

1. Line 3-6, front view.
2. Surface Z, front view.
3. Line 6-10, front view.
4. Surface B, pictorial view.
5. Line 1-2, top view.

Problem C

1. Line 28-30, front view.
2. Surface V, top view.
3. Line 4-7, pictorial view.
4. Surface C, pictorial view.
5. Line 22-27, top view.

	Pictorial View			Front View			Side View			Top View		
Problem A												
	Point	Line	Surface	Point	Line	Surface	Point	Line	Surface	Point	Line	Surface
1.		9–8	D	30				35–36			23–26	V
2.			C									
3.											24–26	
4.											23–26	
5.					27–28							
Problem B												
1.												

Figure 8-37. Draw a chart similar to this one and use it to record information about the multiview drawings in **Figure 8-38**. Follow the directions given in the Problems and Activities section.

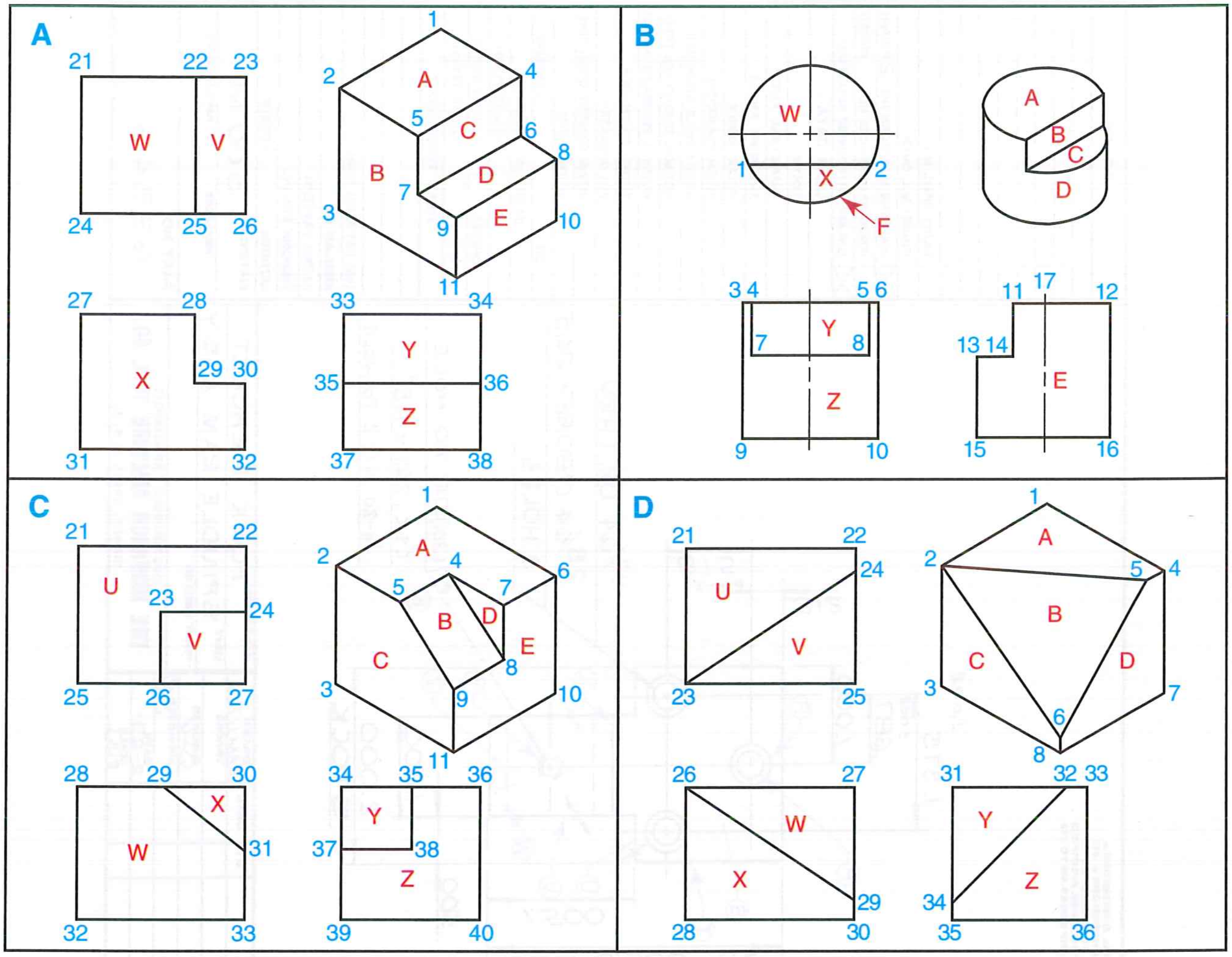


Figure 8-38. Use these drawings and identify the points, lines, and surfaces indicated. Follow the directions given in the Problems and Activities section.

Problem D

1. Line 26-27, front view.
2. Surface Z, right-side view.
3. Line 23-25, top view.
4. Surface B, pictorial view.

Reading a Drawing

This problem requires you to read information from a given mechanical drawing. Reading drawings will give you practice in visualizing the views. Answer the following questions in relation to the drawing in **Figure 8-39**. Answer the questions on a separate sheet of paper.

1. What views are shown?
2. What is the name of the part?
3. What is the number of the part?
4. From what size stock is the part to be made?
5. Starting with the circled letters, match the lines and surfaces in the two views. Note there are two extra numbers for which no letter matches.
6. Why were the two views chosen by the drafter? Would a top view make the drawing any clearer?
7. Is the circle at Number 7 a recessed or protruding cylinder? What confirms this?
8. What size hole is drilled through at Number 1?
9. Give the pilot drill size for the threaded hole at Number 8.
10. How thick is the piece at S?

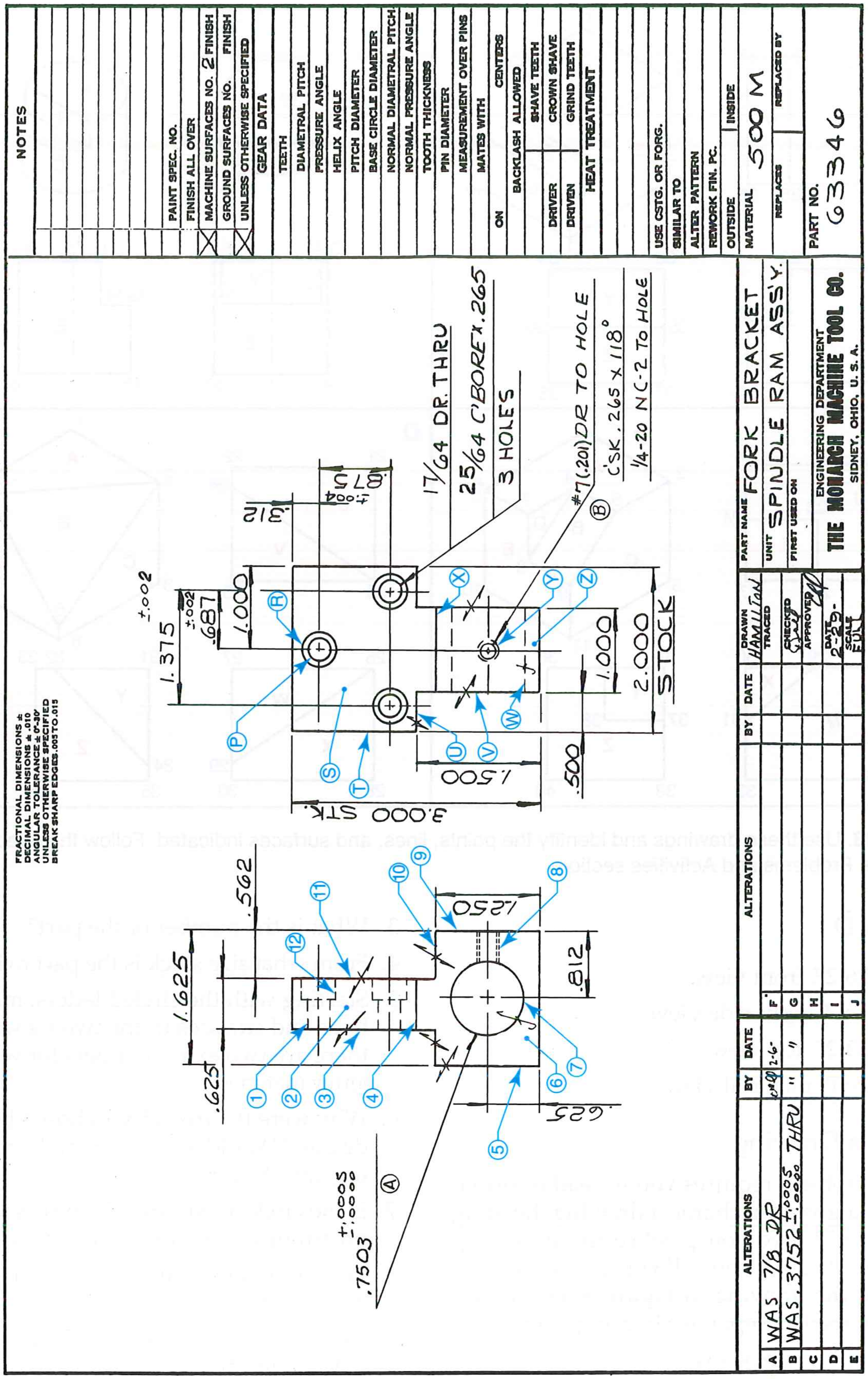


Figure 8-39. Use this mechanical drawing to answer the questions in the Problems and Activities section.

Drawing Problems

The following problems are designed to give you practice in making multiview drawings. Draw the problems as assigned by your instructor. The problems are classified as introductory, intermediate, and advanced. A drawing icon identifies the classification.

The given problems include customary inch and metric drawings. Use one sheet for each problem and do not dimension. Center the views and make the best use of space available.

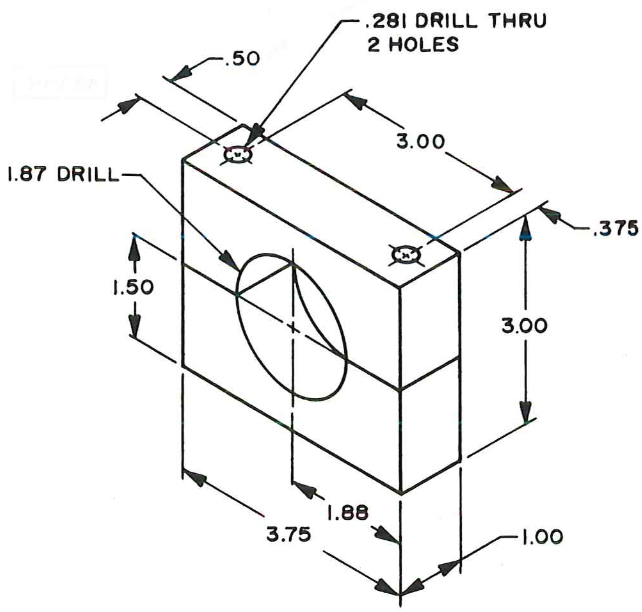
If you are drawing the problems manually, use the Layout I sheet format given in the Reference Section. If you are using a CAD system, create layers and set up drawing aids as needed. Use an A-size sheet and draw a title block or use a template. Save each problem as a drawing file and save your work frequently.

Multiview Drawings

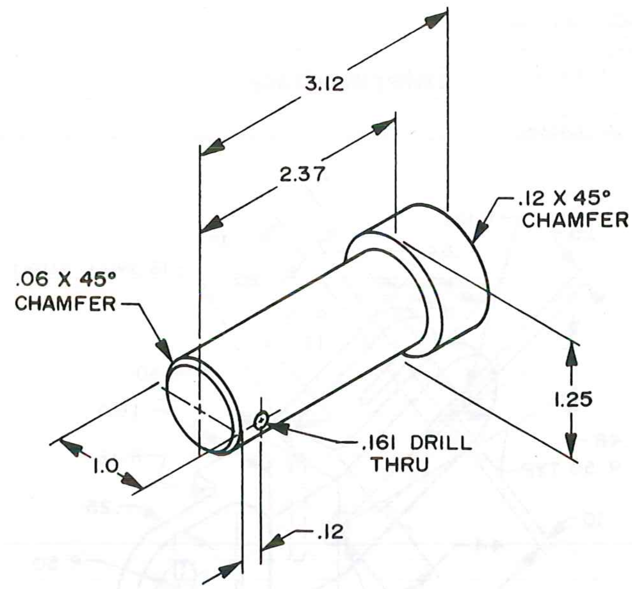
Study the drawings shown in Problems 1–13. Select and draw the necessary views for each problem. If you are drawing the problems manually, sketch each problem first and have it checked by your instructor.

Introductory

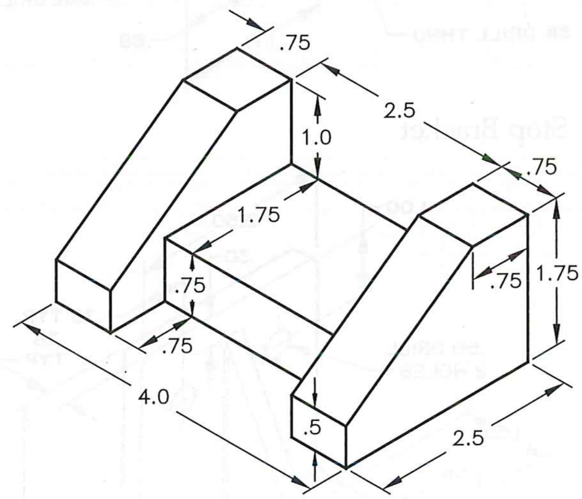
1. End Clamp



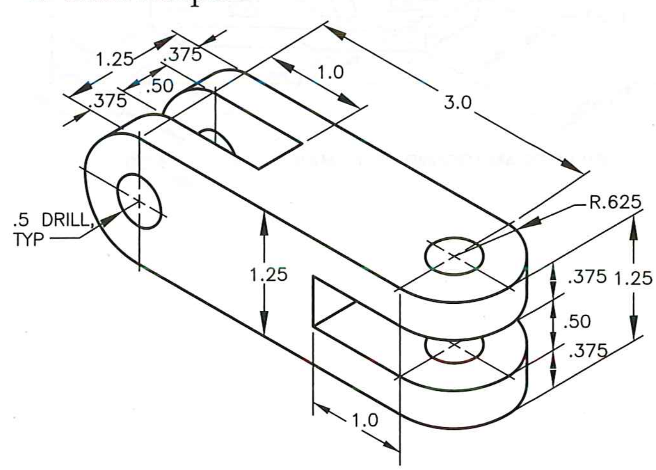
2. Shoulder Pin



3. Stop Block

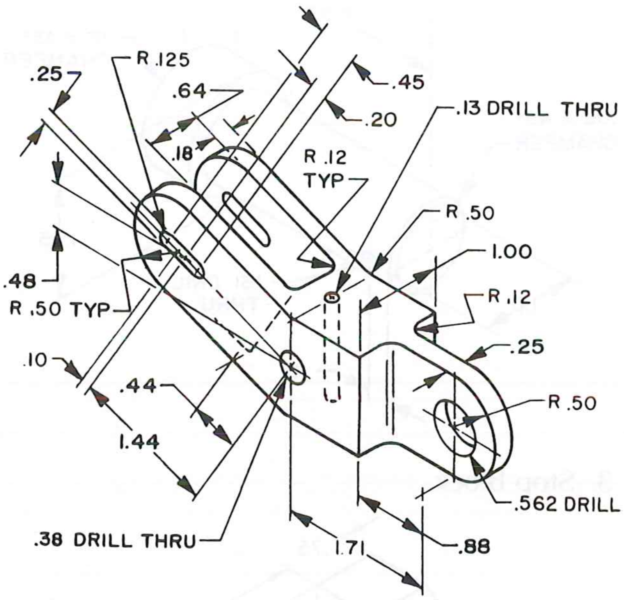


4. Link Coupler

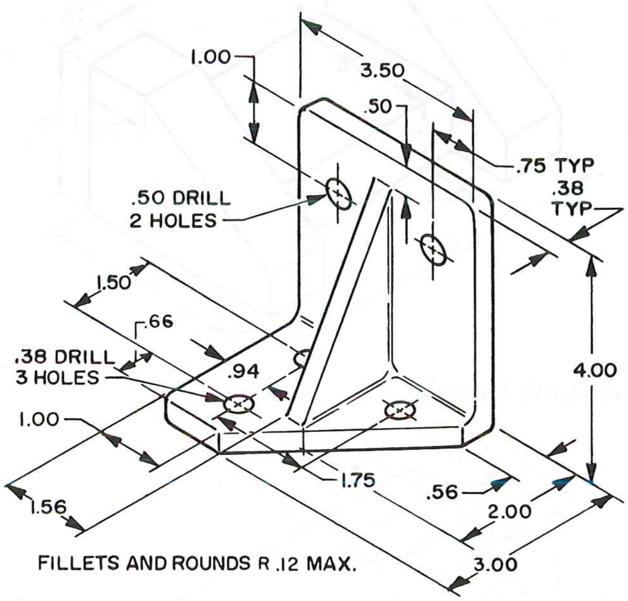


Intermediate

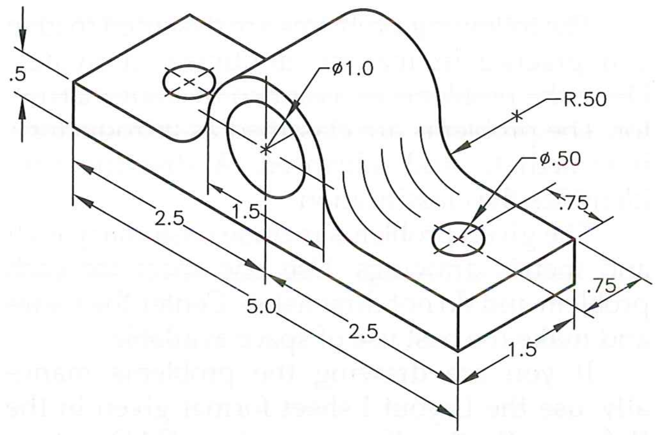
5. Link



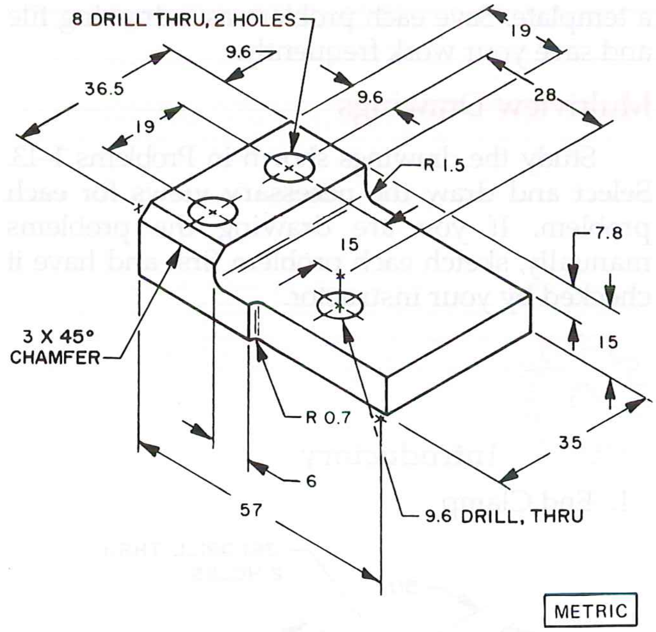
6. Stop Bracket



7. Pillow Block

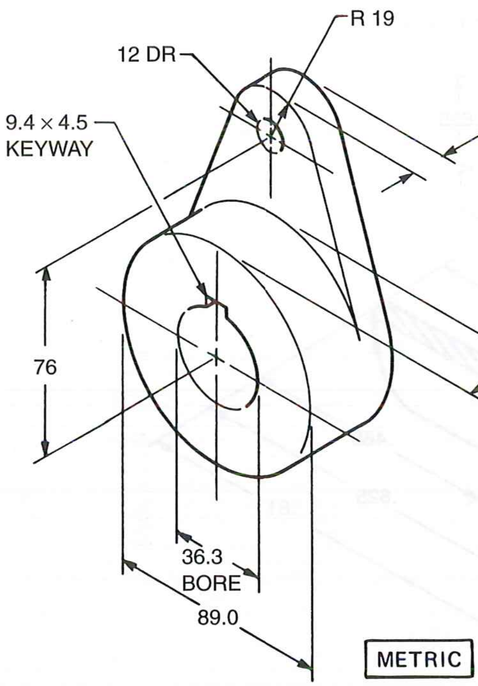


8. Sheet Stop Pivot Bracket

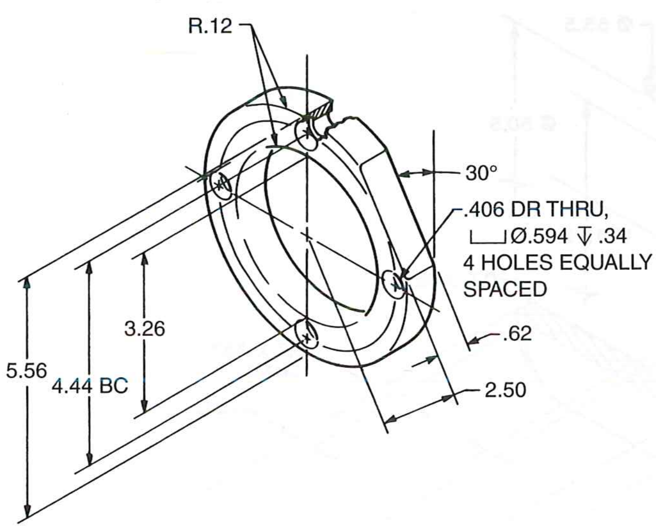


Intermediate

9. Crank Arm

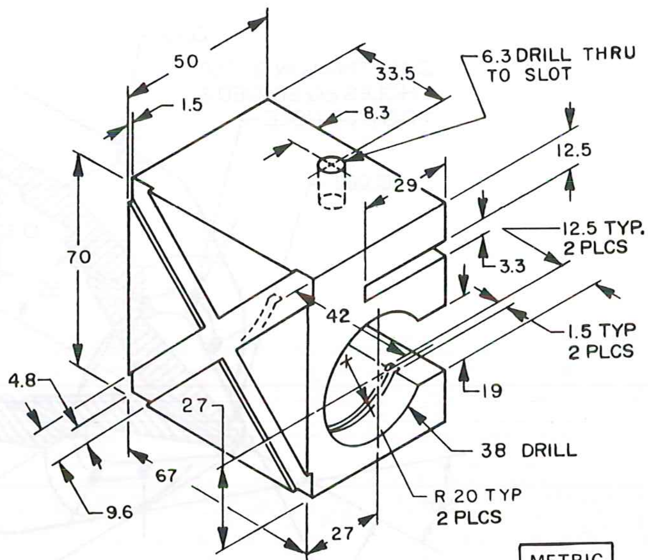


10. Bearing Cap



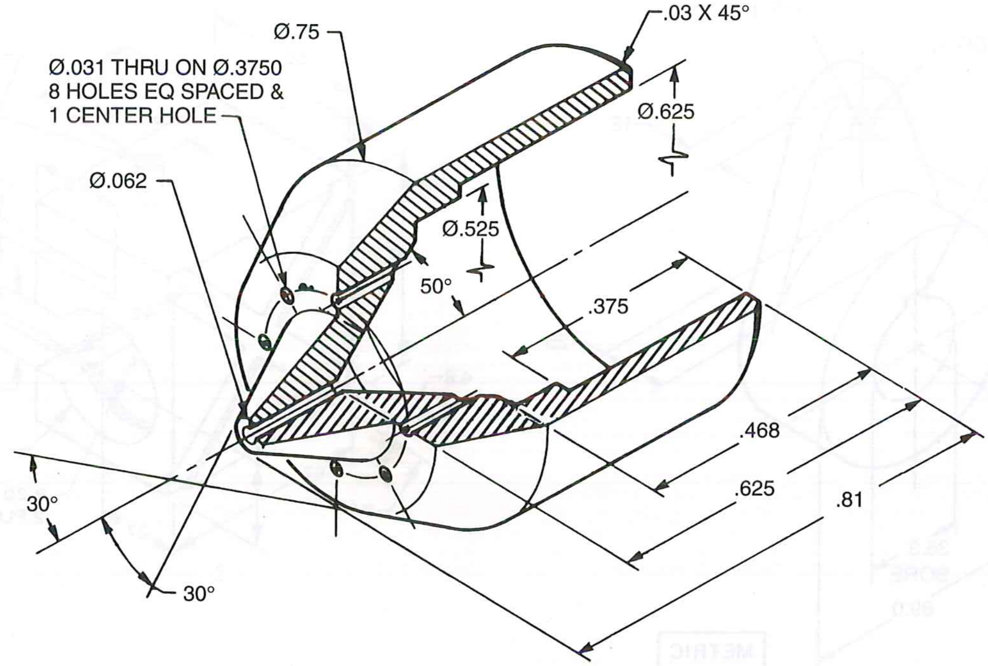
Advanced

11. Bearing Support

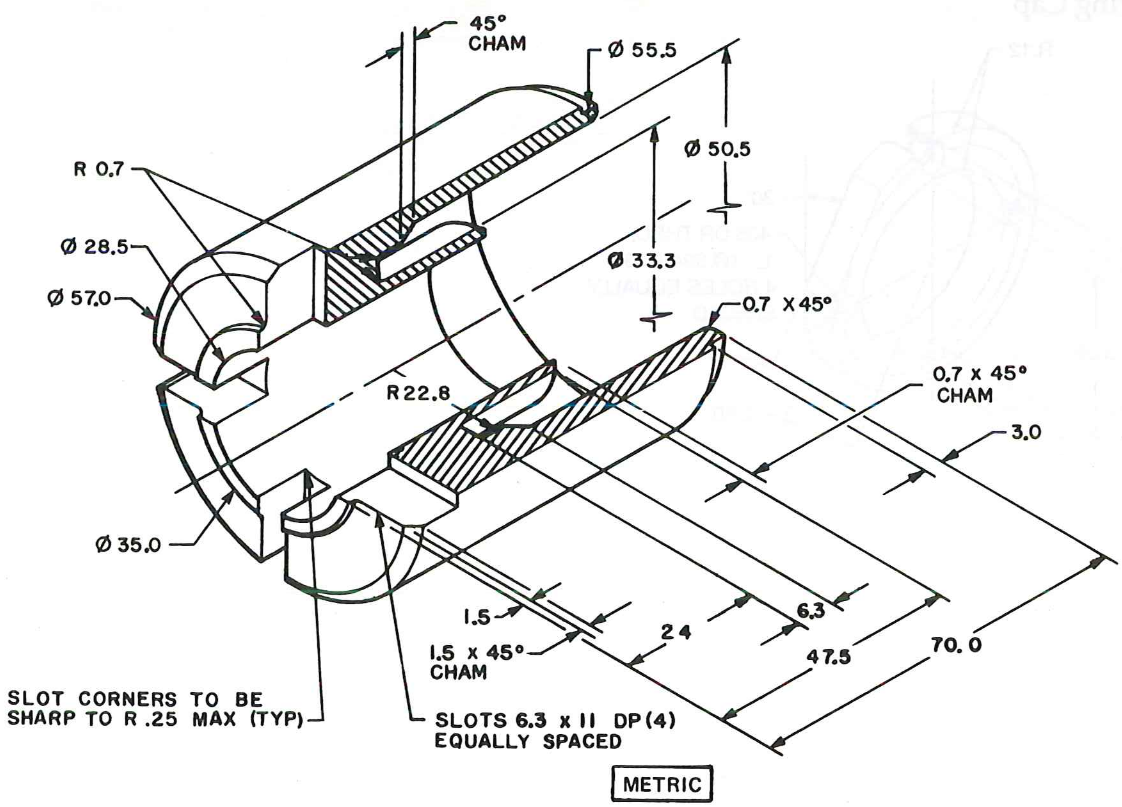


Advanced

12. Multiple Nozzle

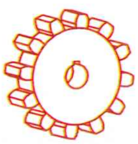


13. Sliding Pulley Hub



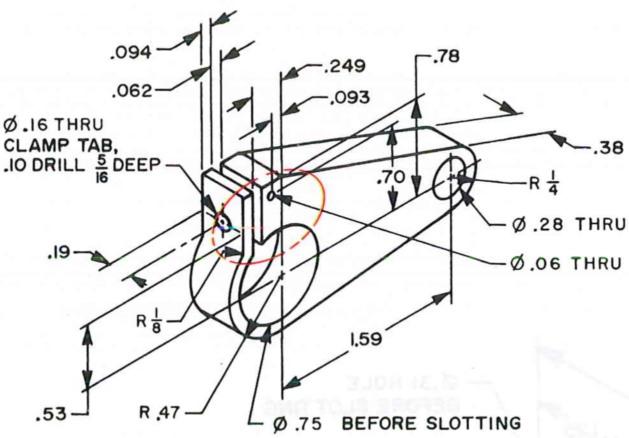
Multiview Drawings with Removed Views

Study the drawings shown in Problems 14–19. Then select and draw the necessary views for each problem, including a removed view of the feature circled in red. Unless otherwise indicated, the removed view is to be drawn at twice size. If you are drawing the problems manually, a free-hand sketch is not required. However, it is good practice to first sketch all drawn views until you have become proficient in visualizing multiview drawings and spacing views on a sheet.



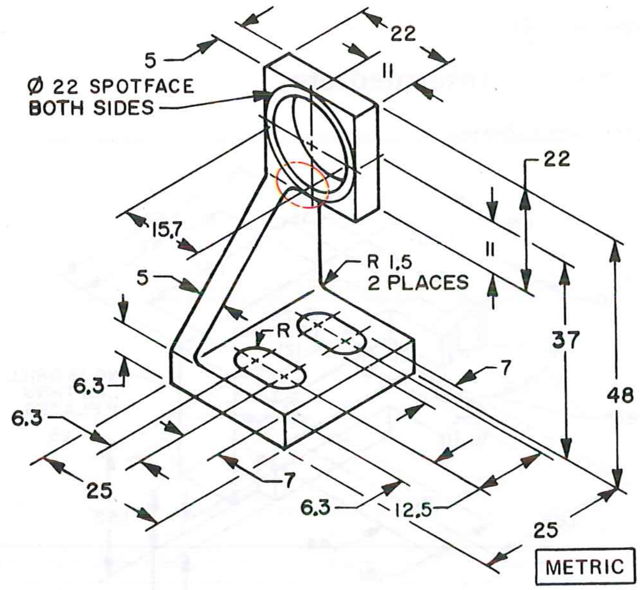
Intermediate

14. Hub Clamp

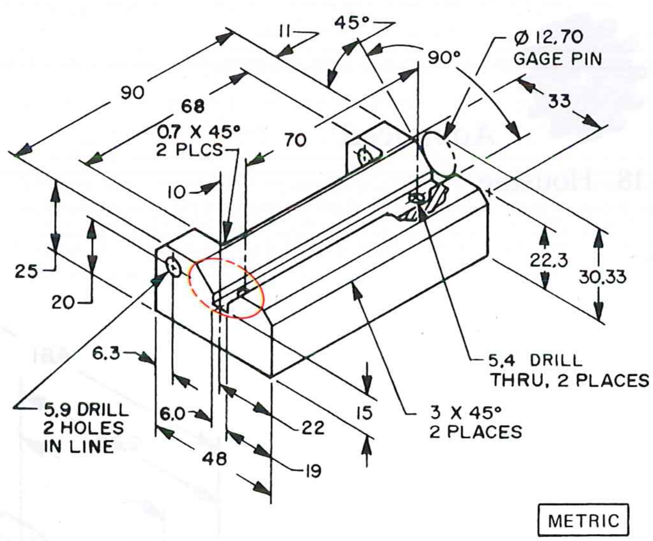


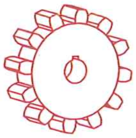
NOTES:
1. REMOVE BURRS AND SHARP EDGES, UNLESS OTHERWISE SPECIFIED
2. FINISH ALL OVER 125
3. .250/PERMITTED ON OUTSIDE CONTOUR

15. Single Bearing Hanger



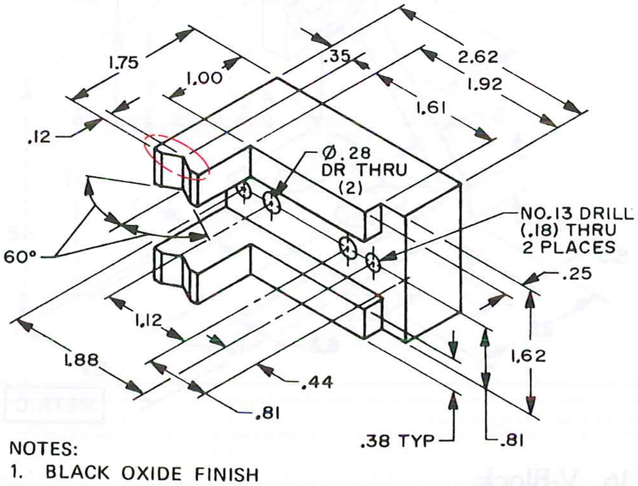
16. V-Block





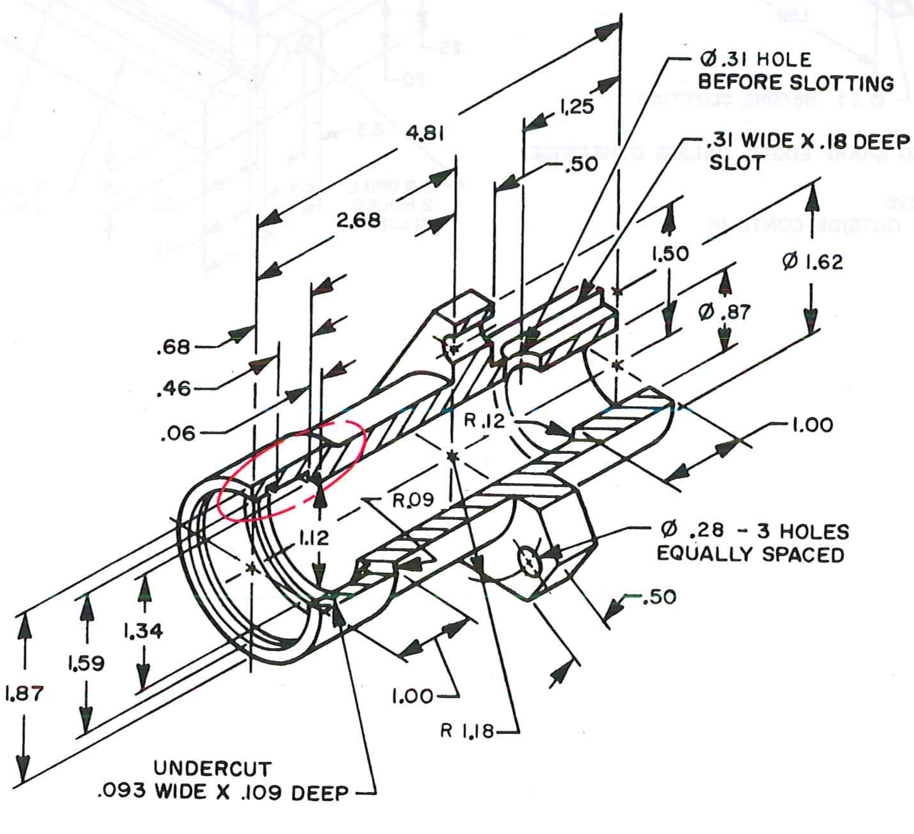
Intermediate

17. Tool Setter



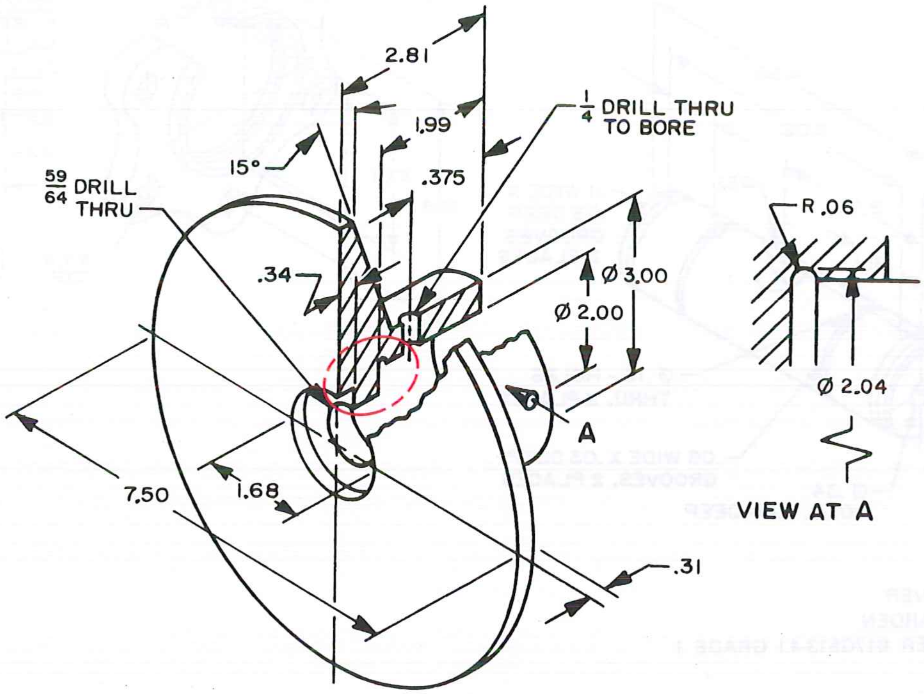
Advanced

18. Housing



Advanced

19. Stock Stop

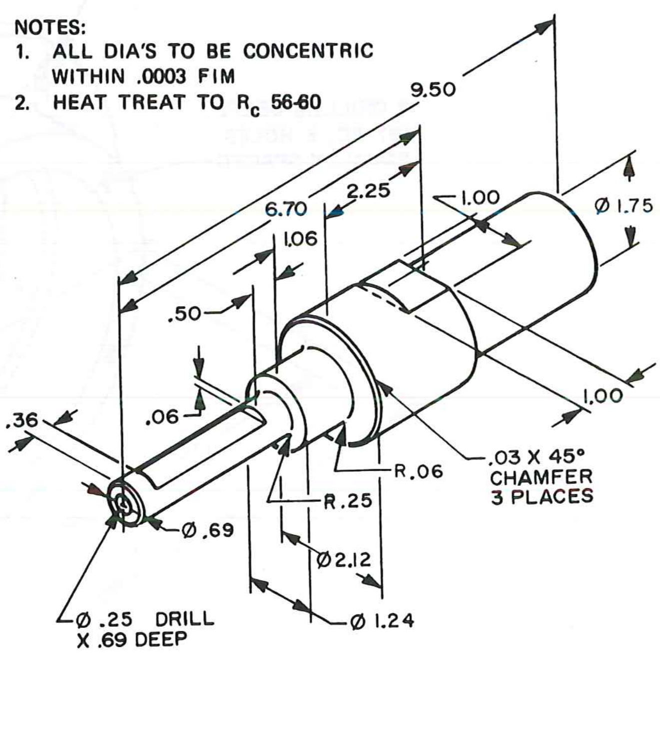


Multiview Drawings with Partial Views

When a part is symmetrical in one view, a single partial view may be drawn. In others, because of differences in side views, two partial-side views should be drawn. Study the drawings shown in Problems 20–25. Then select and draw the necessary views for each object, including a partial view representation.

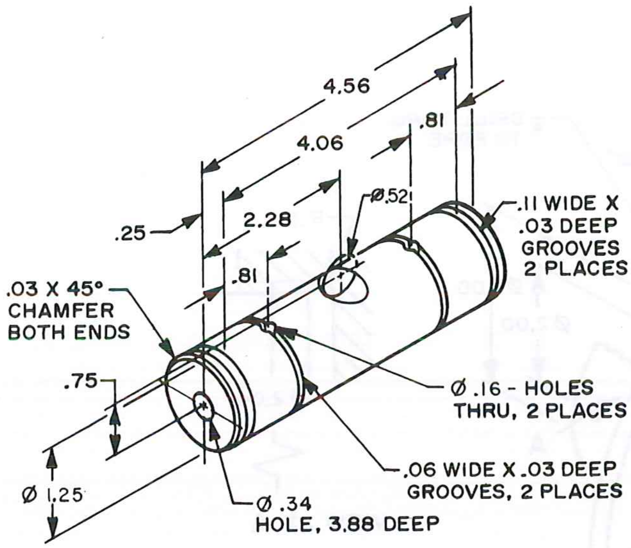
Intermediate

20. Lower Straight Anvil



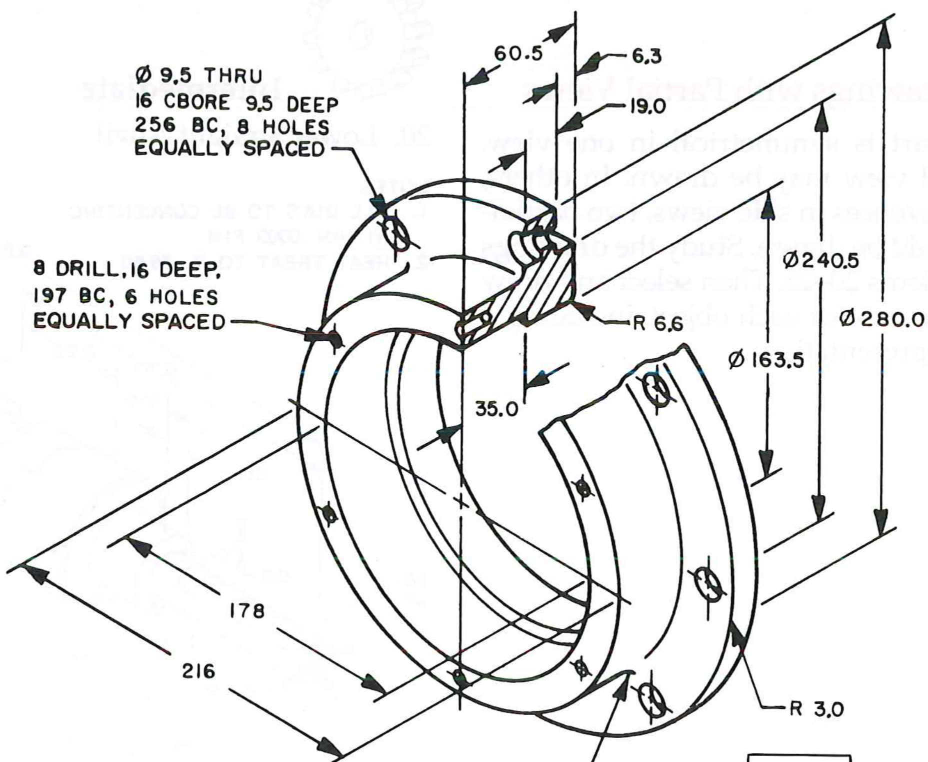
Intermediate

21. Brake Shoe Anchor Pin

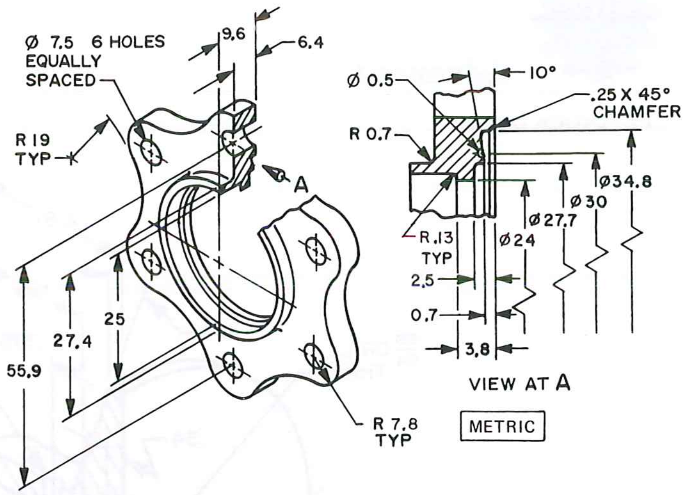


NOTES:
1. FINISH ALL OVER
2. INDUCTION HARDEN
3. ZINC PLATE PER 817G513-4.1 GRADE I

22. Lower Bearing Housing

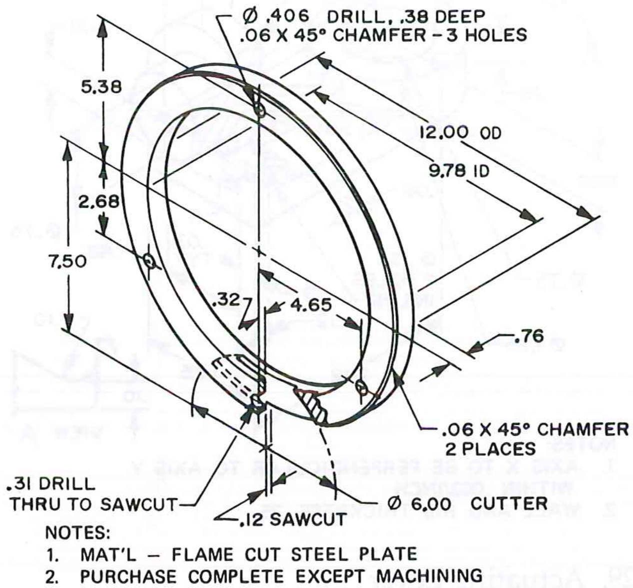


23. Flange

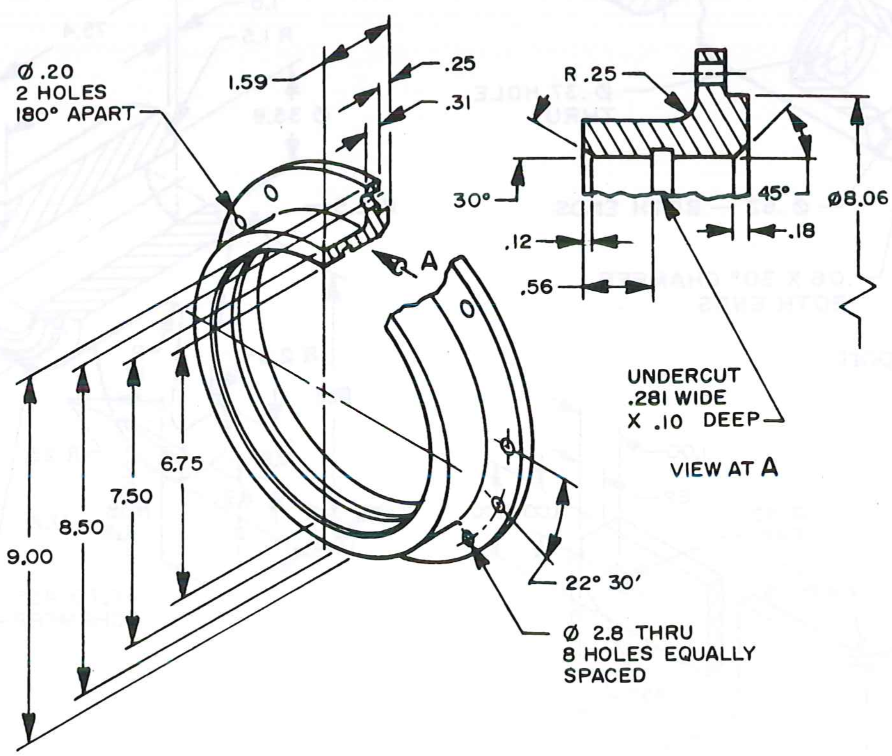


Intermediate

24. Nut



25. Dyno Pilot Cap

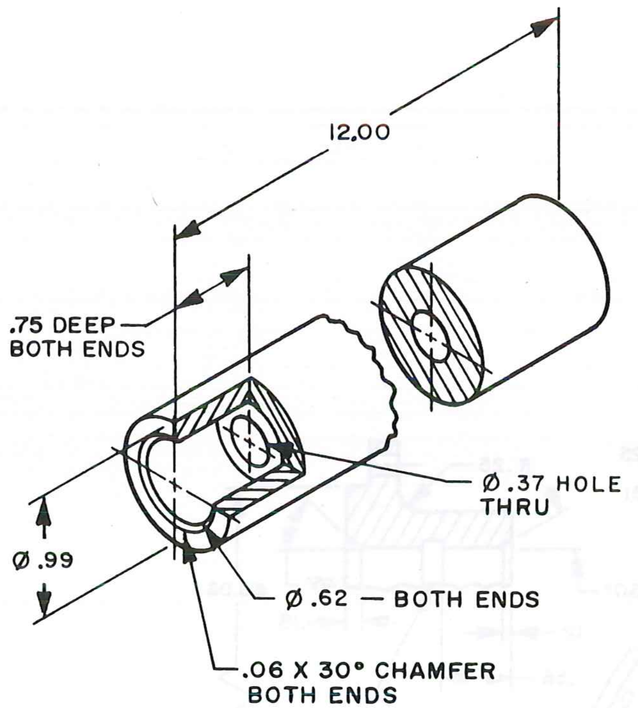


Multiview Problems Involving Conventional Drafting Practices

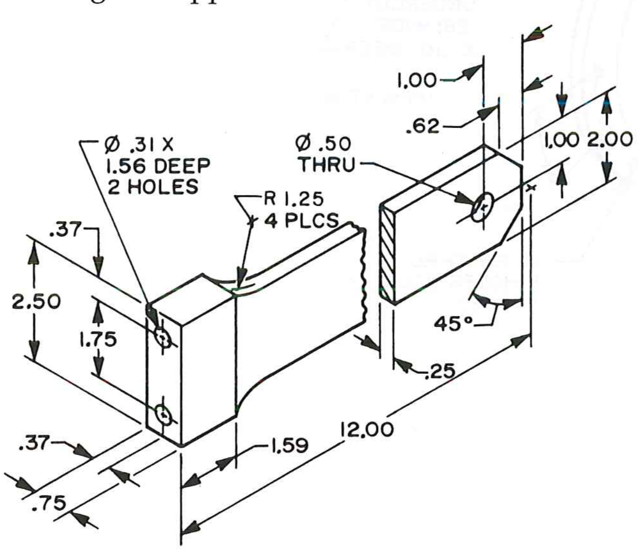
Study the drawings shown in Problems 26–31. Select and draw the necessary views for the parts shown. Use standard conventional drafting practices where applicable as discussed in this chapter.

Intermediate

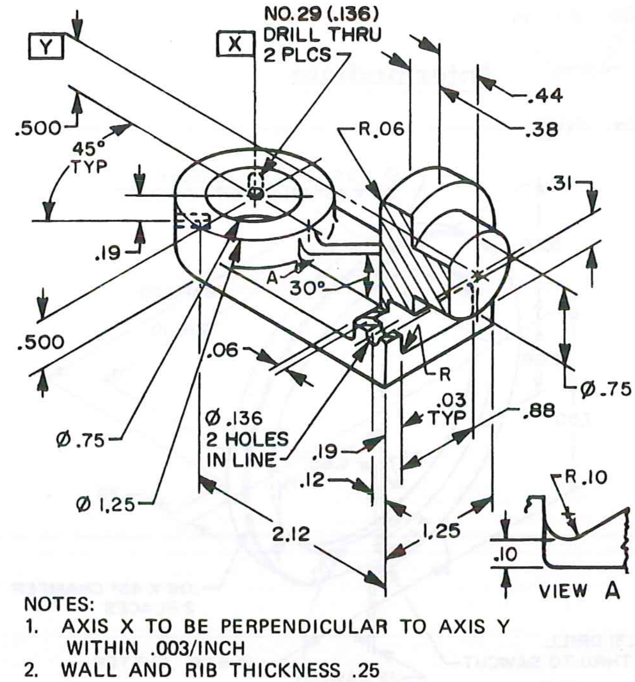
26. Spindle



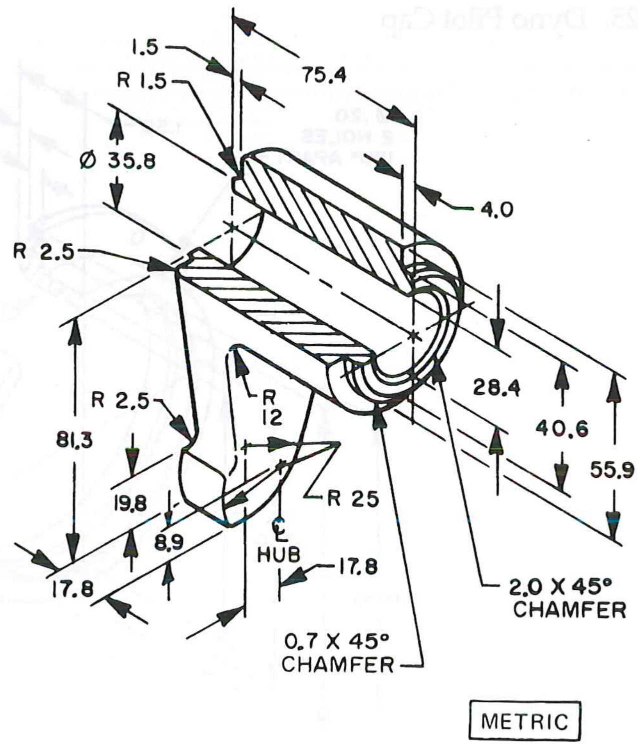
27. Engine Support



28. Ellipse Mirror Mount

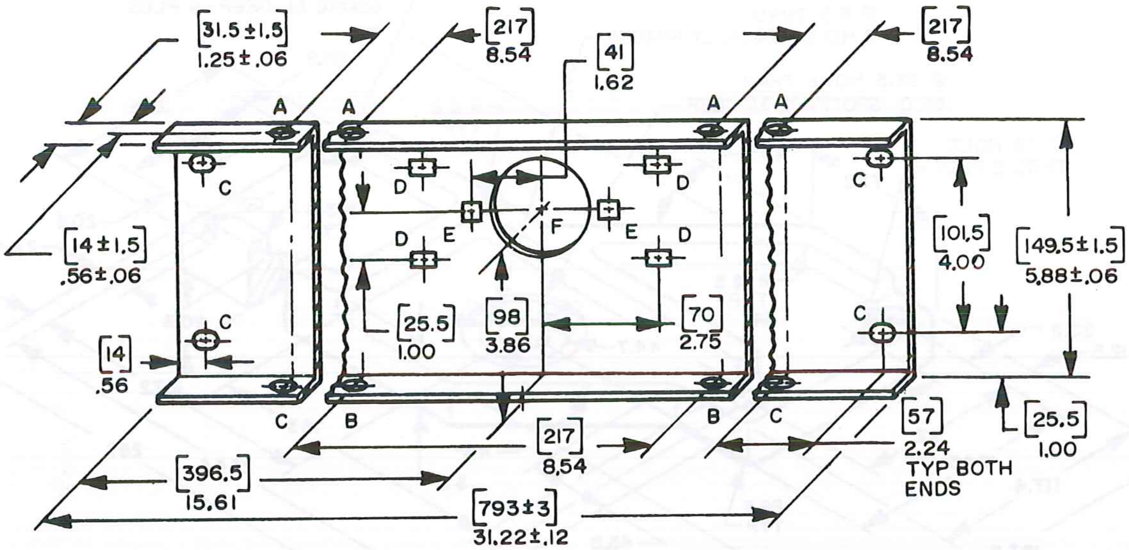


29. Actuating Lever



Advanced

30. Straw Spreader Fan Support



NOTES:
1. BEND RADII -- .12 [3]
2. TRIM RADII -- .12 [3]

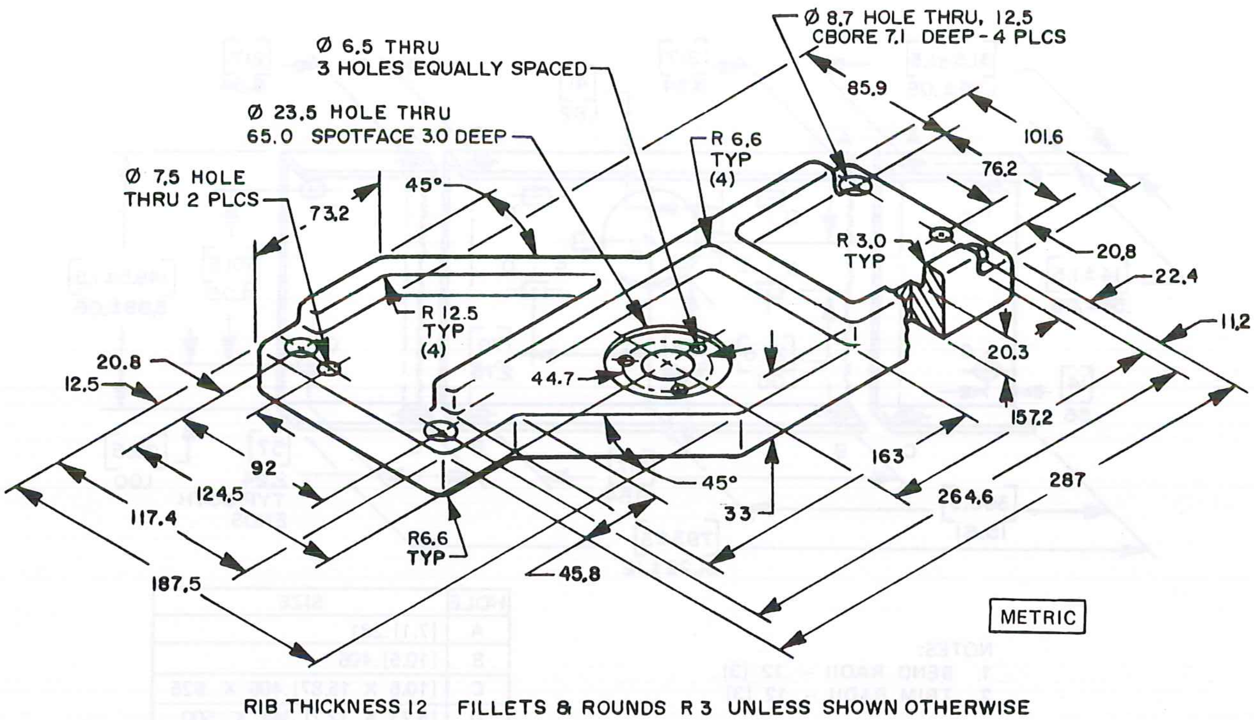
[METRIC]
INCH

MATL THK [3] .12

HOLE	SIZE
A	[7.1] .281
B	[10.5] .406
C	[10.5 X 15.87] .406 X .625
D	[8.73 X 12.7] .344 X .500
E	[8.73] .344
F	[60.32] 2.375

Advanced

31. Variable Gear Cover



First-Angle Projection Problems

Although most of your work in drafting will be done in third-angle projection, making a drawing in first-angle projection is the best way to understand the system. Make the necessary first-angle projection views of the Link Coupler in Problem 4 or the Actuating Lever in Problem 29.