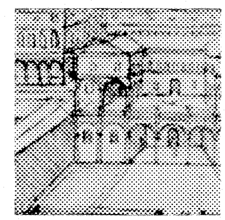
SECTIONS

Chapter 11



LEARNING OBJECTIVES

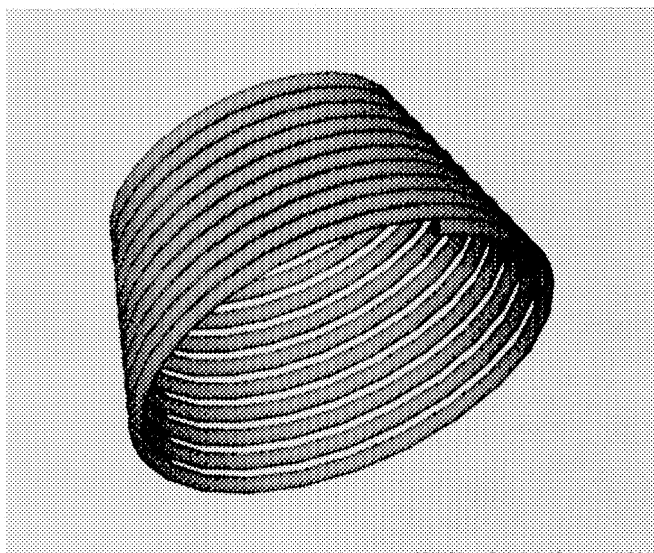
Upon completion of this chapter you will be able to:

1. Identify the need for sectional views in order to clarify interior features of a part.
2. Apply standard drafting conventions and line types to illustrate interior features.
3. Identify cutting planes and resulting views.
4. Differentiate between and produce full, half, offset, aligned, removed, revolved, broken-out, and assembly sections.
5. Integrate standard sectioning methods into the CAD environment.

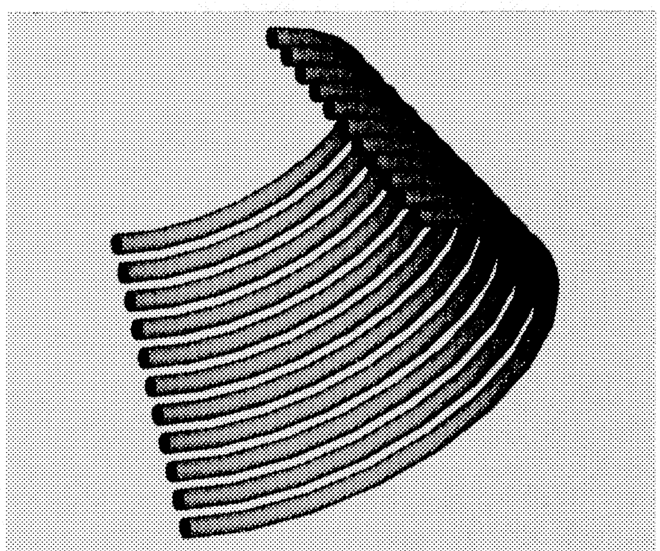
11.1 INTRODUCTION

Designers and drafters use **sectional views,** also called **sections,** to clarify and dimension the internal construction of a part. The spring in Figure 11.1(a) is shown as a removed pictorial section in Figure 11.1(b). Sections are needed for interior features that cannot be described clearly by hidden lines in conventional views. For example, the valve in Figure 11.2(a) has a portion of its exterior body removed to allow a view of the disk, seating, and stem. Figure 11.2(b) shows the same valve with its front removed (full section), allowing a view of all the interior parts. Without removing portions of the valve body it is impossible to describe accurately the internal features of the valve.

This chapter presents different types of sections, and discusses their variations when applied to mechanical parts and assemblies. Sections make use of a number of **drafting conventions**—standard, accepted ways of showing part features on a drawing.

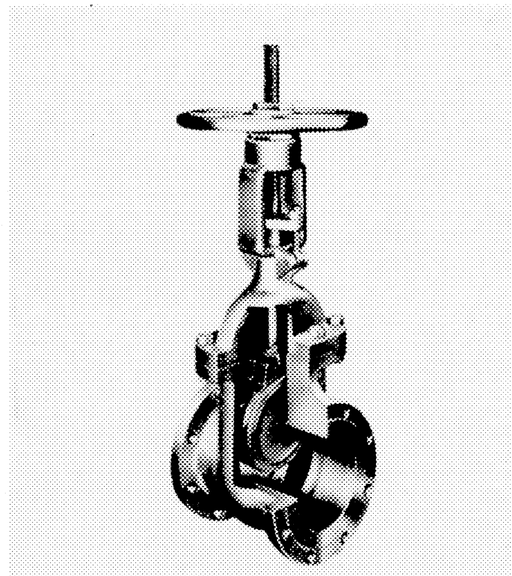


(a) Parametric model of a spring

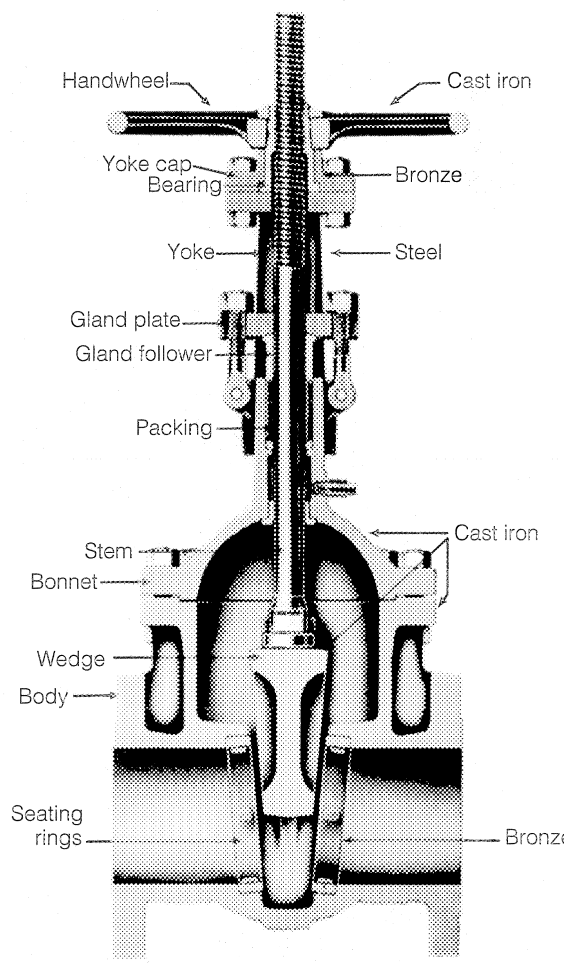


(b) Removed pictorial section of a spring

FIGURE 11.1 **Spring**



(a) Sectioned gate valve

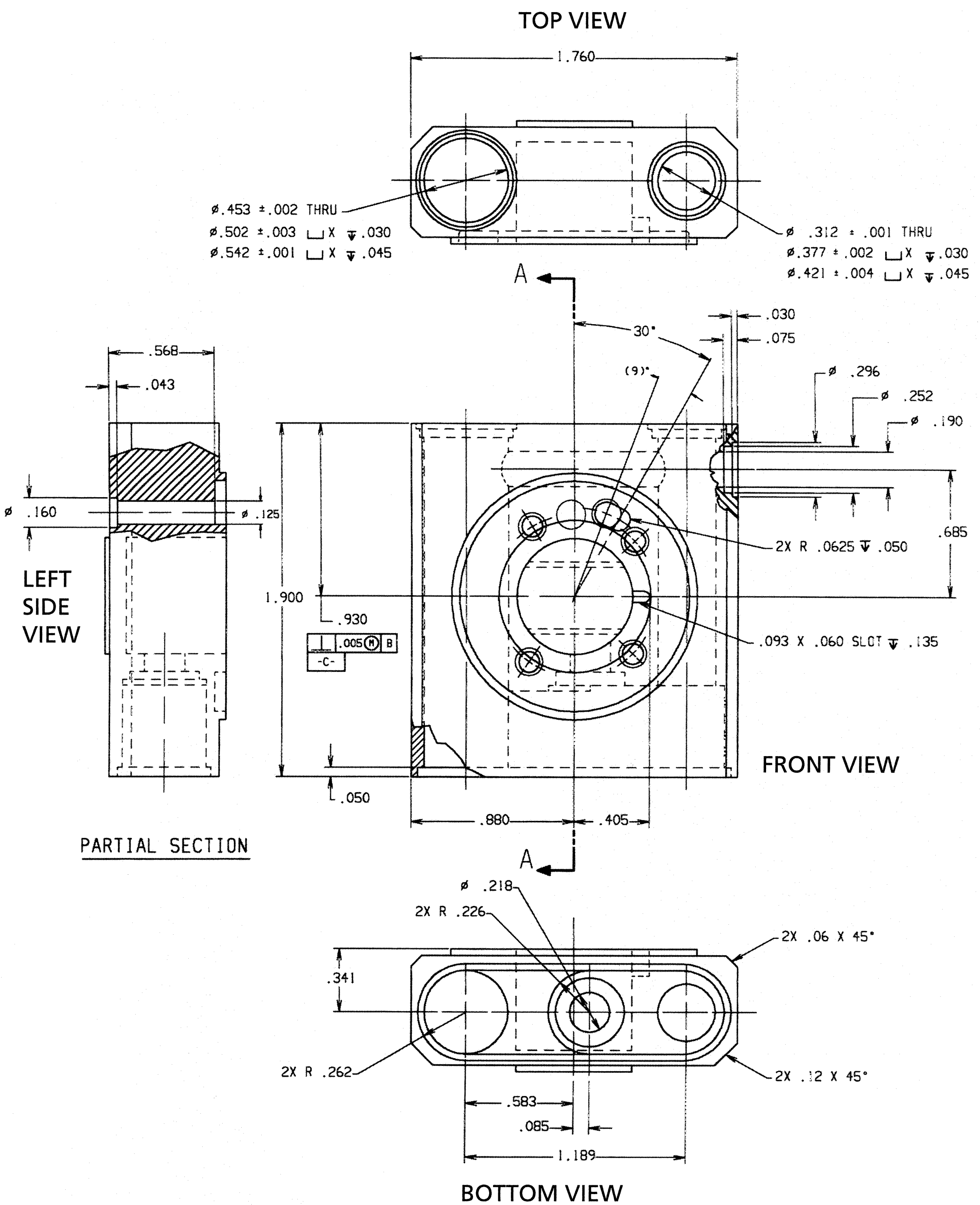


(b) Front section of gate valve showing the stem and disk

FIGURE 11.2 **Valve**

11.2 SECTIONS

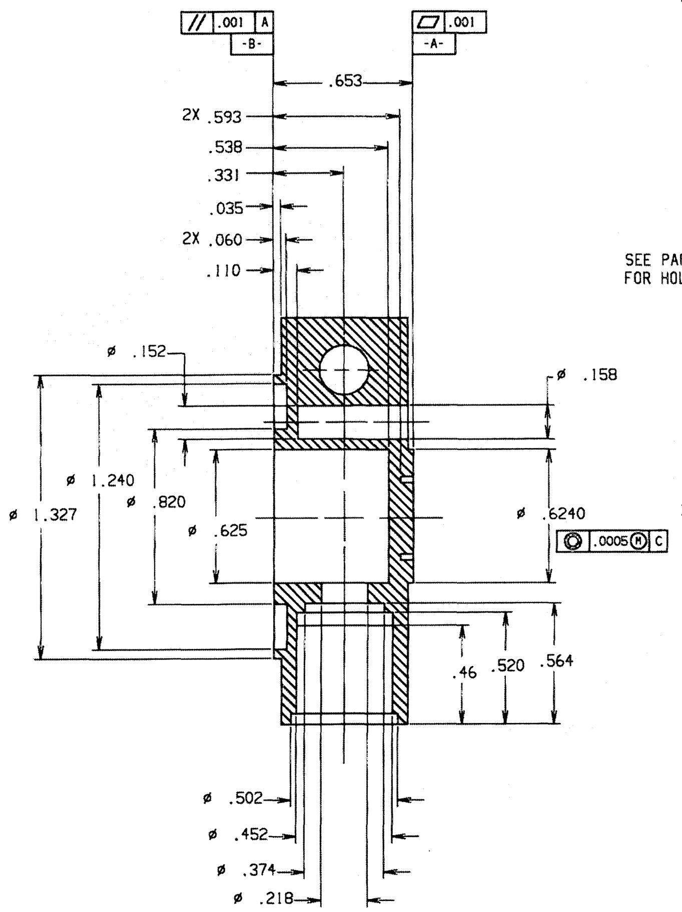
A sectional view is obtained by passing an imaginary **cutting plane** through the part, perpendicular to the **line of sight,** as in Figure 11.3 (**SECTION A–A**). The line of sight is the direction in which the part is viewed (Fig. 11.4). The portion of the part between the cutting plane and the observer is "removed." The part's exposed solid surfaces are indicated by **section lines,** which are uniformly spaced angular lines drawn in proportion to the size of the drawing.



IGURE 11.3 **Detail of a Mechanical Part with Three Sections**

In all section views on a drawing, section lines for the ame part are identical in angle, spacing, and uniformity Fig. 11.4). Spacing of section lines should be as generous as ossible and yet preserve the unity of the sectioned area. In ther words, section lines should be constructed so they are spaced clearly, are pleasing to look at, and will reduce and enlarge without distorting.

There are many different types of section views. Figure 11.3 shows a drawing of a complex part containing a full section (**SECTION A–A**), a partial section (left side), and a

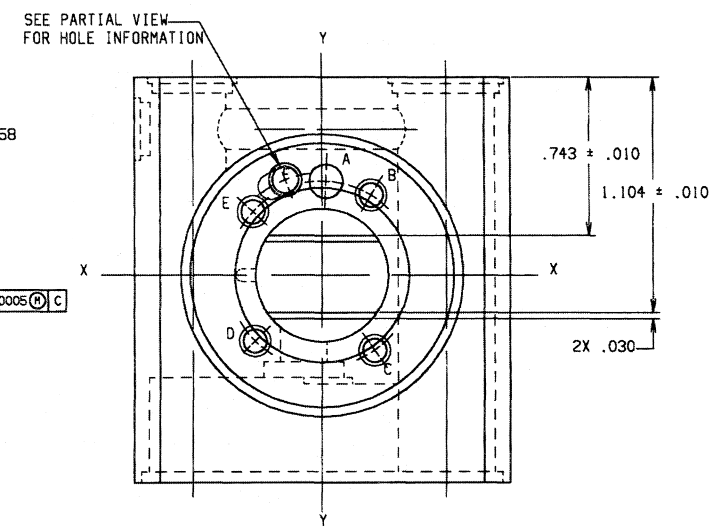


RIGHT SIDE VIEW

SECTION A-A

NOTES UNLESS OTHERWISE SPECIFIED.

1. MATERIAL: CARBON STEEL, AISI 1010-1020 COLD ROLLED
2. FINISH: 100 32√ ALL AROUND.
3. ALL INSIDE RADII ARE TO BE .015 MAXIMUM.
4. TOLERANCE: XX .02
   XXX .013
   ANG. 2°



BACK VIEW

HOLE CHART			
LTR	HOLE SIZE	"X" DIM	"Y" DIM
A	SEE SECTION A-A	.0192"	.4396"
B	NO. 4-40 UNC-2B	.2299"	.3752"
C	NO. 4-40 UNC-2B	.2466"	-.3522"
D	NO. 4-40 UNC-2B	-.3138"	-.3084"
E	NO. 4-40 UNC-2B	-.3244"	.2973"
F	SEE PARTIAL SECTION	-.1713"	.4463"

FIGURE 11.3 Detail of a Mechanical Part with Three Sections—*Continued*

broken-out section (left corner of front view). These types of sections are covered in detail later in the chapter.

Sections are rotated 90° out of the plane of principal or auxiliary views from which they are taken, following the customary rules of projection rotation. A heavy line across or near the principal view indicates the plane of projection, with arrows to indicate the viewing direction, or line of sight (Fig. 11.4). This line, called a *cutting plane line,* represents the edge of the imaginary cutting plane. The sections in Figure 11.4 are also views (front and right side). When the plane of projection passes through the view, it is called the cutting plane, and the resulting adjacent view is called a section. Each cutting plane, and corresponding view, has view identification letters assigned to it, such as **SECTION A–A** in Figure 11.4.

When cutting planes pass through solid portions of the part, these areas are shown by section lines in the adjacent section view. When the cutting plane passes through void areas (open spaces), such as a slot, a hole, or other cutouts, the area is left blank (without section lines) in the adjacent section view (Fig. 11.4).

Since cutting planes are positioned to reveal interior details most effectively, selecting the proper location for the cutting plane is important. In Figure 11.5, the pictorial illustration of the section shows the cutting plane passing through the middle of the part in order to reveal its interior. This is typically the location for the cutting plane.

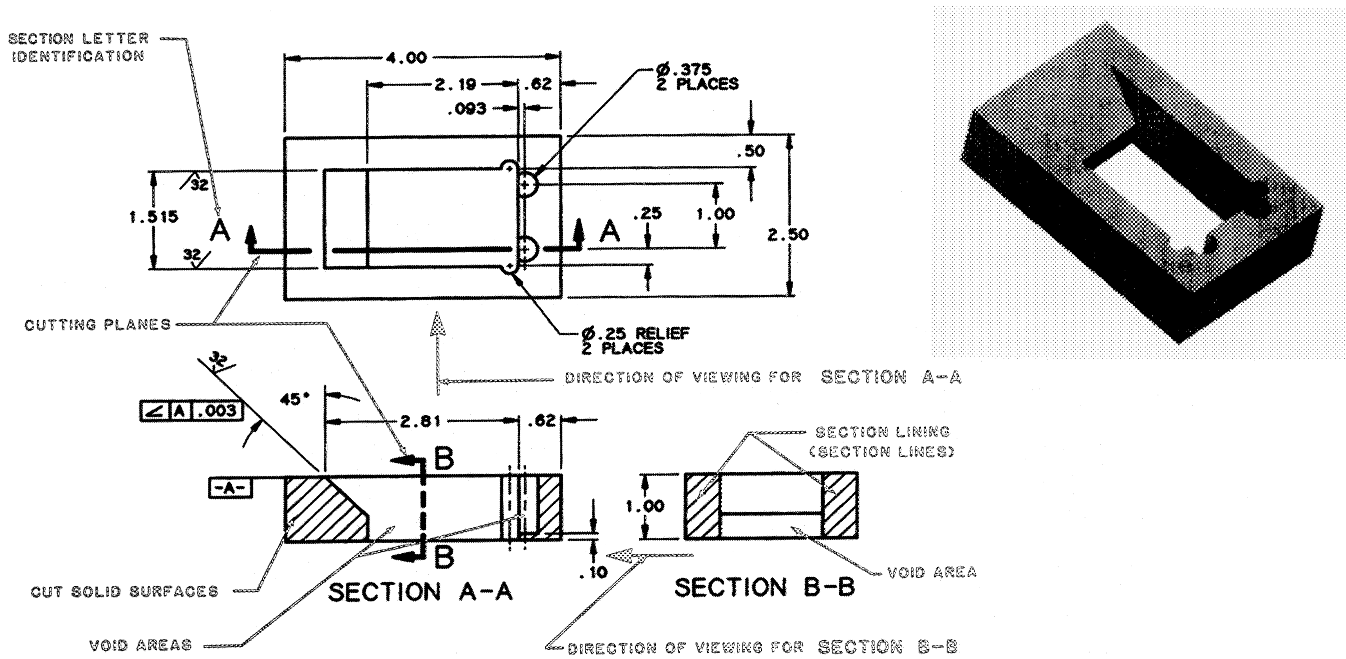


FIGURE 11.4 Three-View Drawing Using Sections as the Front and Side Views

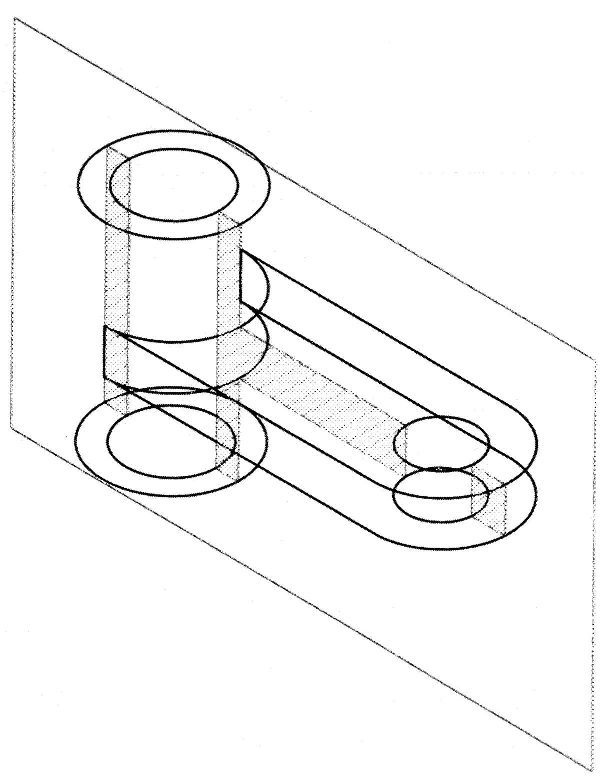


FIGURE 11.5 Sectioned 3D Part

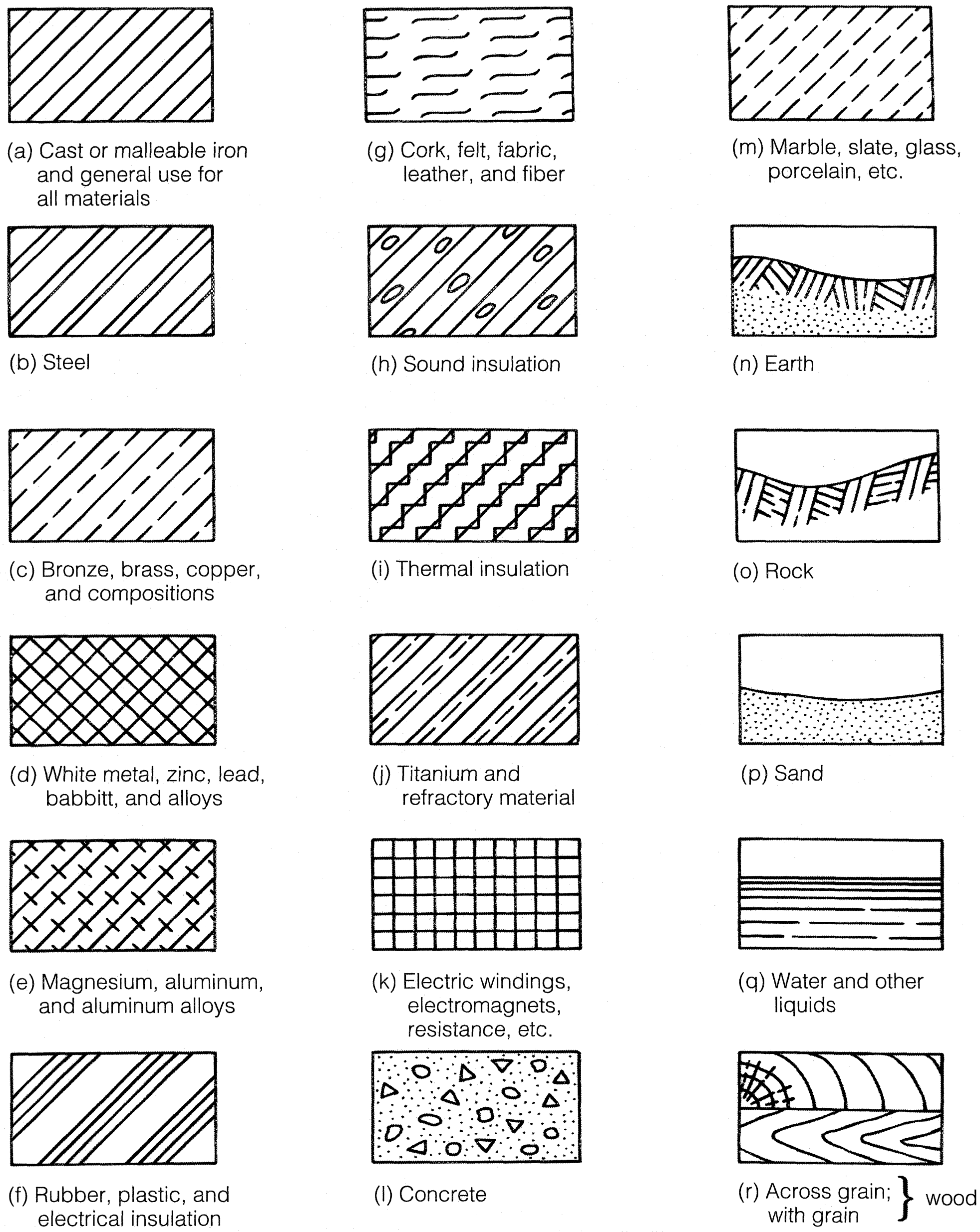


FIGURE 11.6 Section Symbols for Material Specification

11.2.1 Section Material Specification

Sometimes you must distinguish between materials of a part through the use of symbolic section lining. **Symbolic section lining** is sometimes found on assembly drawings, such as illustrations for parts catalogs, display assemblies, promotional illustrations, and when it is desirable to distinguish between different materials.

Since it may not reduce and enlarge well, symbolic section lining is not recommended for drawings that will be microfilmed or put onto microfiche. Thus, the most common practice is to use the general-purpose symbol for all materials

11.2.2 General-Purpose Section Lines

Figure 11.6(a) shows the lining symbol for cast iron, which is also considered the general-purpose symbol. **General-**

purpose section lines do not distinguish between different materials; they identify the cut solid surfaces of the section view. Most drawings use general-purpose section lines. General-purpose section lines are single lines drawn at 45°, slanting from the lower left toward the upper right, and spaced evenly at about .10 in. (2.5 mm). Some drawings use $\frac{1}{8}$ in. (.125 in.) spacing with decimal-inch measurements and 2.5 to 3 mm spacing on drawings with SI units.

Since they are easy to draw, general-purpose section lines are constructed quickly. The exact material specification is given elsewhere on the drawing in note form or in the title block. An exception is made for parts made of wood, for which it is necessary to show the direction of the grain [Fig. 11.6(r)].

Figure 11.7 shows measurements for the construction of general-purpose section lines. This figure includes examples of incorrect construction. Section lines should be thin (0.25 to 0.30 mm), sharp, and black. And they should not be too close [Fig. 11.7(d)], or they may merge and blotch during reduction and reproduction. Section lines must be spaced consistently and be of consistent weight [Fig. 11.7(b) and (e)], and they must end at visible object lines [Fig. 11.7(f)]. When the shape or position of a section area is such that the section lines would be parallel or perpendicular to a prominent visible line bounding the sectioned area [Fig. 11.7(g)], a different angle should be chosen.

To avoid drawing section lines perpendicular or parallel to object lines, the angle of the section lines can be changed (Fig. 11.8). Remember, a 45° angle is preferred, but is not mandatory.

11.2.3 Lines Behind the Cutting Plane

Sections describe the interior space of a part. *Hidden features that are behind the cutting planes are almost always omitted.* In half sections, however, hidden lines are occasionally shown on the unsectioned half when needed for dimensioning or for clarity (see Section 11.3.2). The following rules apply when determining the precedence of lines on a section.

Line Precedence on a Section

1. **Visible object lines** take precedence over hidden lines and centerlines.
2. **Hidden lines** take precedence over centerlines.
3. **Cutting-plane lines** take precedence over centerlines when locating a cutting plane. However, the cutting-plane line can be omitted entirely if it falls along a centerline of symmetry for the part. This will be discussed in Section 11.2.5.

Figure 11.9 illustrates a few examples of line representation in sections. The correct procedure shows all visible lines as solid [Fig. 11.9(a)]. Remember, even though the section "removes" a portion of the part in front of the cutting plane, the object lines on and behind the plane are still visible.

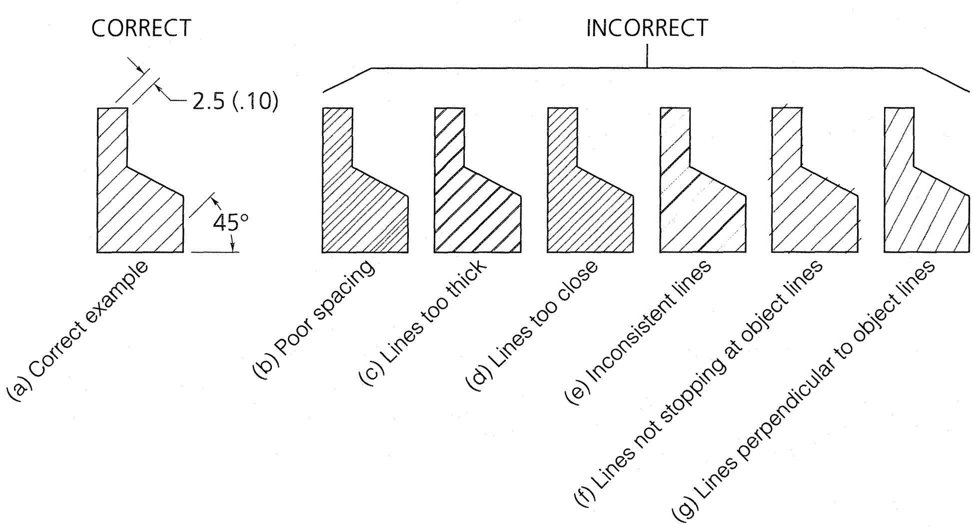


FIGURE 11.7 Section Lining

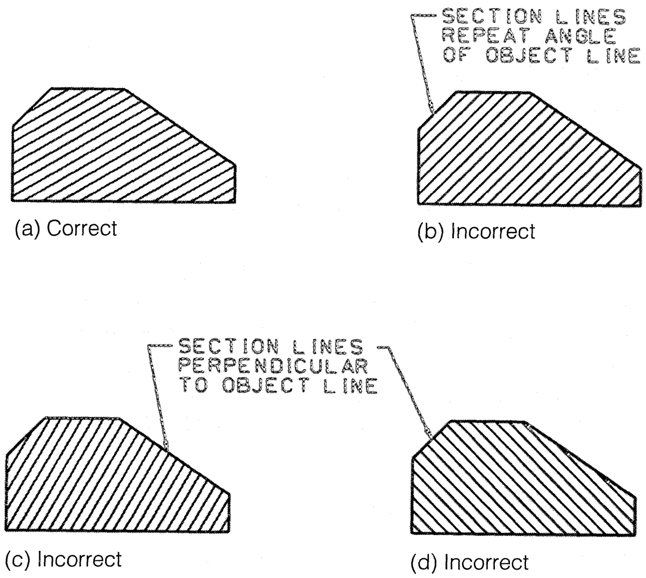


FIGURE 11.8 Section Line Direction

Figure 11.9(b) neglects to show the back portion of the hole's edges (void area), which should be shown with solid lines. Figure 11.9(c) shows a hidden line running through the section, a practice that should be avoided because it complicates the drawing and does not add any clarity to the part definition. Visible lines behind the cutting plane are always shown in the sectional view, whereas hidden lines are not. In some cases, it is acceptable to show hidden lines in sections, but only if the part could not be properly defined otherwise.

Figure 11.9(d) shows incorrectly dashed interior lines representing the outline of the hole and the slot (void areas). The outline of a part should never be described with dashed lines. This type of line symbol is reserved for hidden lines, not visible lines.

Section lines on the same part must run in the same direction, not opposing directions (on assemblies, mating parts that are sectioned have section lines with differing angles). Figure 11.9(e) shows the incorrect procedure for section lines on the same part that are separated by a void area.

Dimensions or other labeling should not be placed within sectioned areas of the drawing. When this is unavoidable, the section lines are omitted behind the label (see Chapter 15).

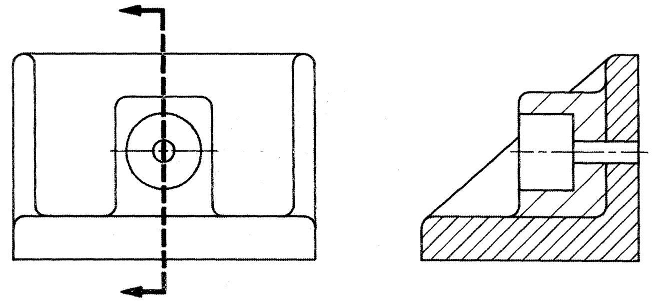


FIGURE 11.10 Double-Spaced Section Lines

Some features on a part are shown with **double-spaced section lines,** as in Figure 11.10. Here, the cutting plane passes through distinct features of the part. To show the part's features clearly, the section lining is drawn at the same angle, but the spacing is doubled.

11.2.4 Sections as Views

The section view should appear on the same drawing sheet with the cutting-plane view. Section views are projected directly from, and perpendicular to, the cutting plane, in conformity with the standard arrangement of views. If, because of space limitations, this arrangement of views is impractical, the views should be clearly labeled as to type.

The section view is placed in direct projection with the principal view from which it is taken, behind and normal to the cutting plane. The view should not be rotated or shown on a different sheet than the cutting plane unless necessary due to the size of the view or the drawing space available. If rotation is necessary, specify the angle and the direction of rotation below the section label, as in Figure 11.11, where only the section view is shown. Here, **SECTION A–A** has been rotated counterclockwise (**CCW**) out of its normal position **13°**. In some cases, the section will be enlarged, as in this figure (**SCALE: 2/1**). In Figure 11.11 the section identification label is center-justified and displayed as follows:

SECTION A–A
ROTATED 13° CCW
SCALE: 2/1

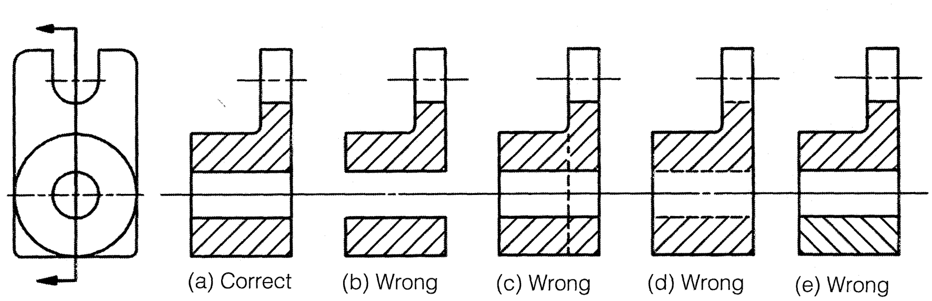


FIGURE 11.9 Hidden Lines in Sections

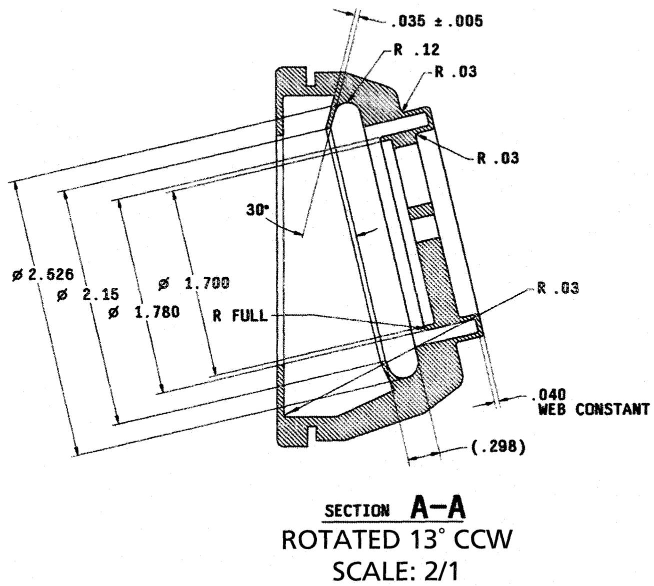


FIGURE 11.11 Rotated Sections

Figure 11.4 illustrated the practice of making a section the principal view. **SECTION A–A** is the front view of the part and **SECTION B–B** the right side view. The cutting plane is passed through the front view—which is also a section. In general, *avoid constructing a section through a section view.* This can lead to confusion and misinterpretation because it sometimes involves multiple plane rotations. (As a rule, you should draw a section through a section view only when necessary to clarify the intent of the drawing or to make an assembly sequence understandable.) The preferred practice is to pass the cutting plane through an exterior view and not through a section view. In Figure 11.4, the cutting plane for **SECTION B–B** could have been drawn in the top view instead of through the front view (**SECTION A–A**).

11.2.5 Cutting Planes

The cutting-plane line is shown on the view where the **cutting plane** appears as an edge (Figs. 11.4 and 11.12). The ends of the cutting-plane line are turned 90° and terminated with large arrowheads to show the direction of sight, as was shown in Figure 11.4. The cutting-plane arrows point away from the viewer and away from the section view. Figure 11.12 shows the proper direction of the cutting-plane arrows. Figure 11.13(a) shows the incorrect direction for arrows and in (b) the correct direction.

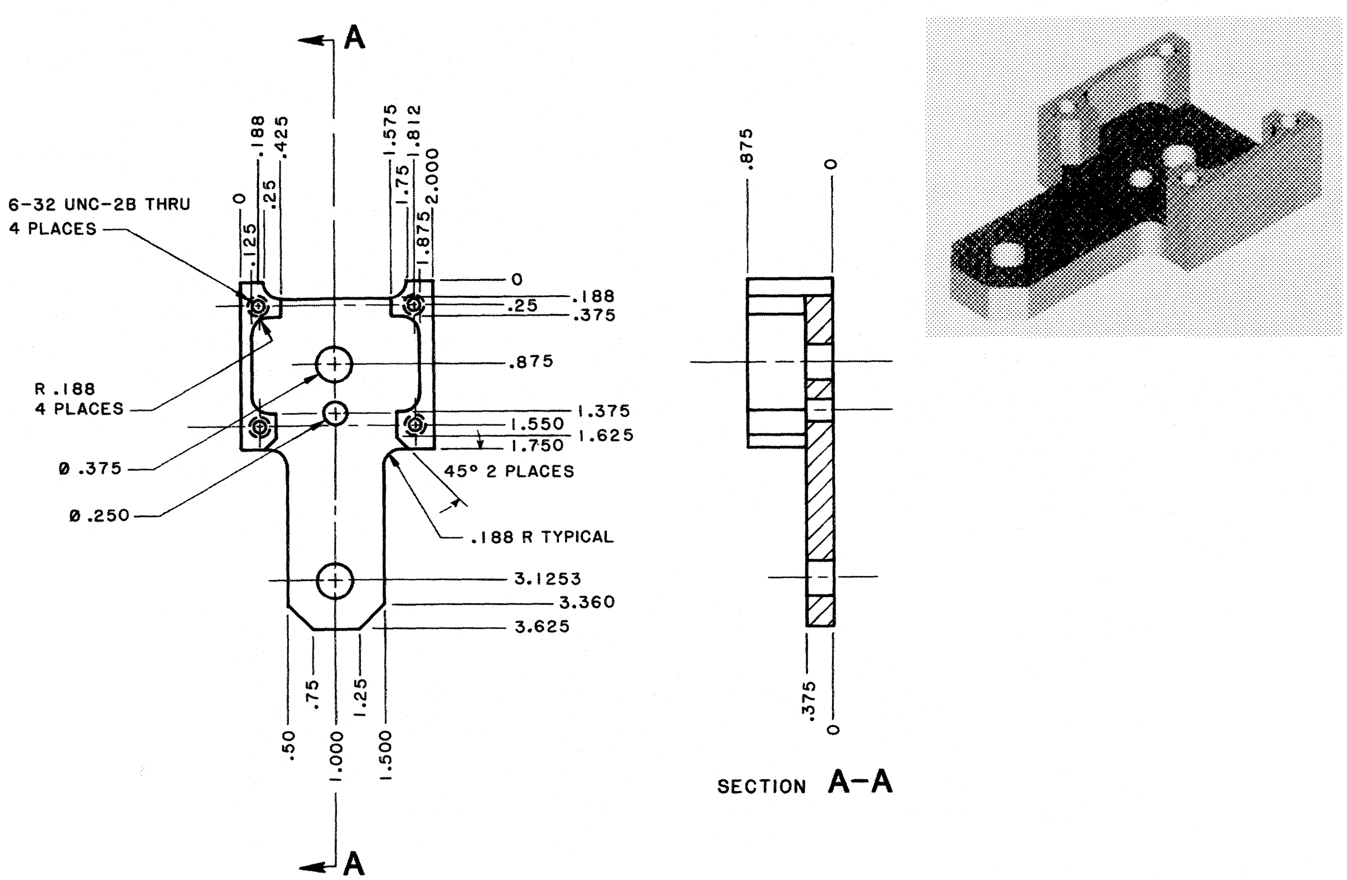


FIGURE 11.12 Section with Correct Direction of the Cutting-Plane Arrows

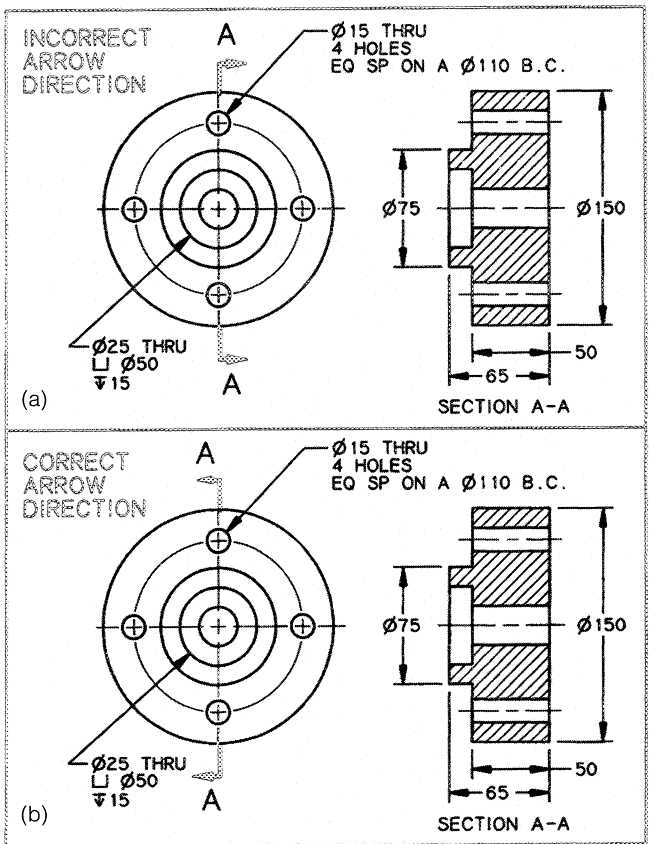


FIGURE 11.13 Arrow Direction on Sections

In simple sections, or when the location of the section is obvious, the cutting-plane line is omitted. The cutting-plane line and all identifying letters may be omitted only when the location of the cutting plane coincides with a centerline of symmetry (Fig. 11.14) or, as mentioned, when the location is obvious. Figure 11.14 is an industry example of a welded pipe fabrication. The pipe and flange are separate pieces that are to be joined by welding. The front view is a full section assembly. The pieces have section lines drawn at different angles so as to differentiate between the pipe and the flange.

Figure 11.15 shows the accepted sizes and line types for constructing cutting-plane lines. The first two examples in this figure follow the accepted ANSI standard. However, some companies use a solid line (third example) or just a portion of the cutting-plane line—the bent ends and the arrows (Fig. 11.12). The cutting-plane line is always shown when the cutting plane is bent or offset or when the resulting section is not symmetrical. Cutting-plane lines are drawn 0.7 to 0.9 mm thick. Border lines and cutting-plane lines will be the thickest lines on your drawing.

11.2.6 Section Identification and Multiple Sections

To identify the cutting plane with its sectioned view, capital letters (**A**, **B**, **C**, etc.) are placed adjacent to or behind the

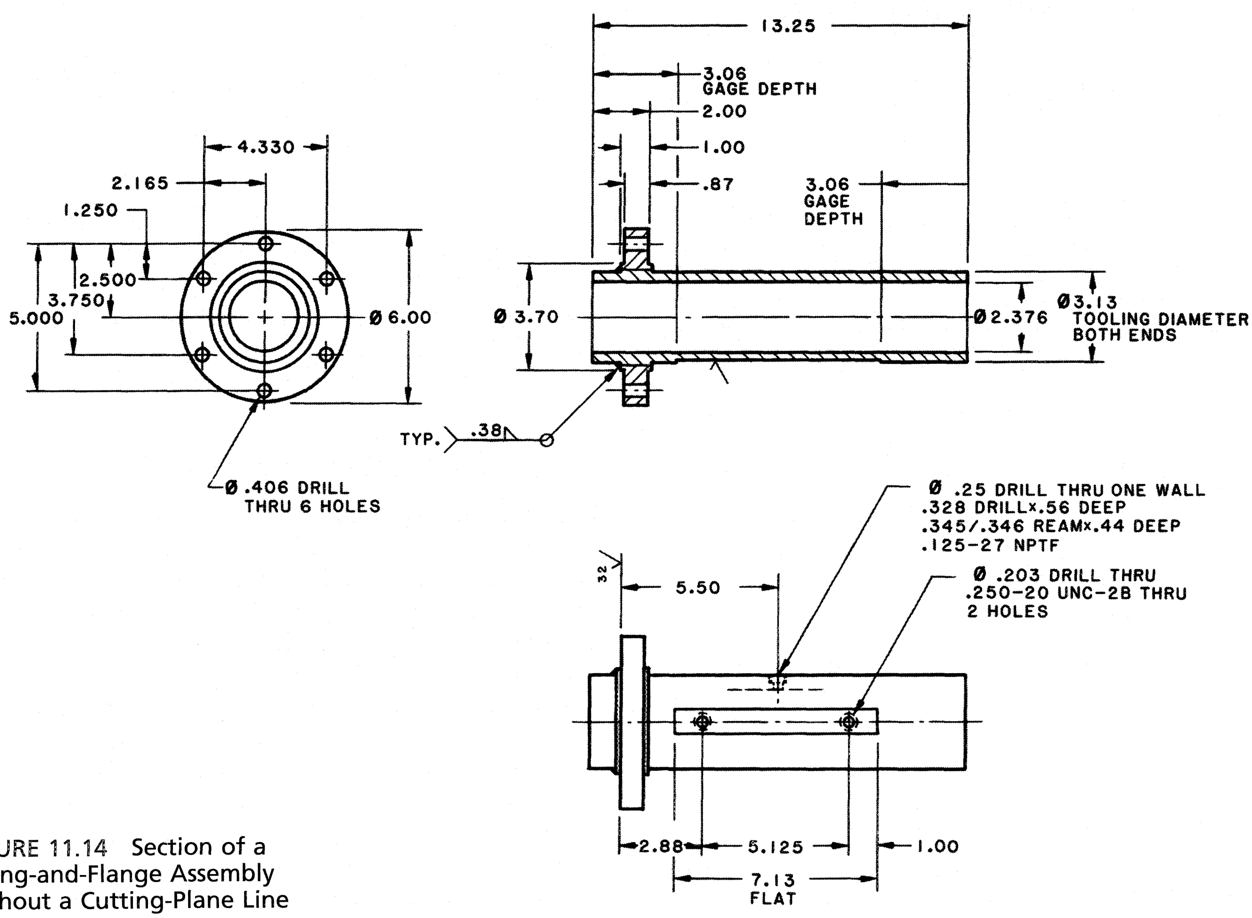


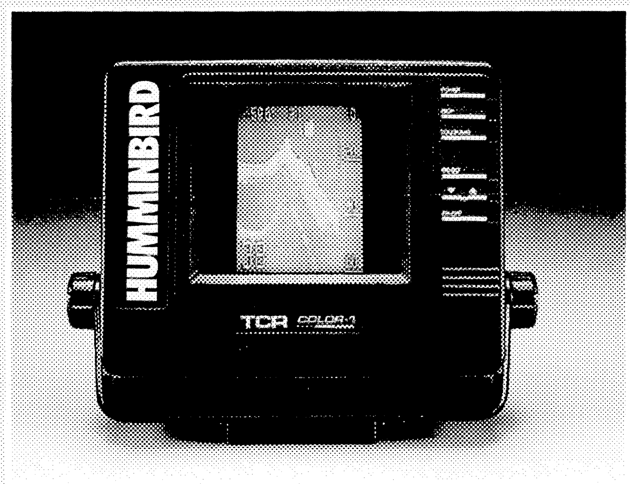
FIGURE 11.14 Section of a Piping-and-Flange Assembly Without a Cutting-Plane Line

Focus On . . .

ULTRASOUND

What do submarines, bats, whales, fish finders, and modern hospital technology have in common? They all depend on information gained via ultrasonic waves.

Ultrasonic waves are vibrations similar to the sound waves that are audible to humans. They are measured by intensity, length, velocity, wave period, and frequency. The number of vibrations per unit time is the frequency of that wave. Waves with a frequency greater than 20,000 Hz are ultrasonic waves.



A fish finder.

Ultrasonic waves are generated by passing an electric current through quartz or certain other materials. As an echo strikes the quartz, an electric current is produced, which in turn is used to produce a picture. This property of quartz is called *piezoelectricity.* The generating and receiving device is a *transducer.* In medical equipment, the transducer passes over the part of the body that is being examined. Since each tissue varies in density, these waves are reflected differently, producing different images. These images are displayed on a screen or recorded. Internal organs such as the heart and heart valves can be viewed in a static image or, by moving the transducer to different views, can be viewed in sequences in real time.

Recently, tiny ultrasonic transducers have been developed that can produce images from inside blood vessels and ducts. The transducer is rotated 360° to create a series of 2D cross sections. Computers are used to combine these 2D section images into a 3D image.

The sections produced with ultrasound equipment for medical applications are not unlike the sectional drawings in mechanical drawing. Both types of sections show internal details. It doesn't really matter whether they are the internal features of a part or of an organ. The concepts are the same. Mechanical engineers also use ultrasound waves to check for internal defects, such as cracks and small holes (voids). Sectional views in medicine and in graphics are intended to show internal features that would not otherwise be visible. Sectional views are valuable for visualization regardless of the application.

arrowheads. These letters are called **section identification letters.** The corresponding section views are identified by the same letters, for example, **SECTION A–A**, **SECTION B–B**, and **SECTION C-C**. If two or more sections appear on the same sheet, they are arranged in alphabetical order from left to right and/or top to bottom (Fig. 11.4). This applies to the cutting plane as well as the sectional view.

Section letters are applied in alphabetical order, excluding I, O, and Q. Once all alphabet letters have been exhausted, use double letters for additional sections, for example, **AA–AA**, **AB–AB**, **AC–AC**, etc., in alphabetical order.

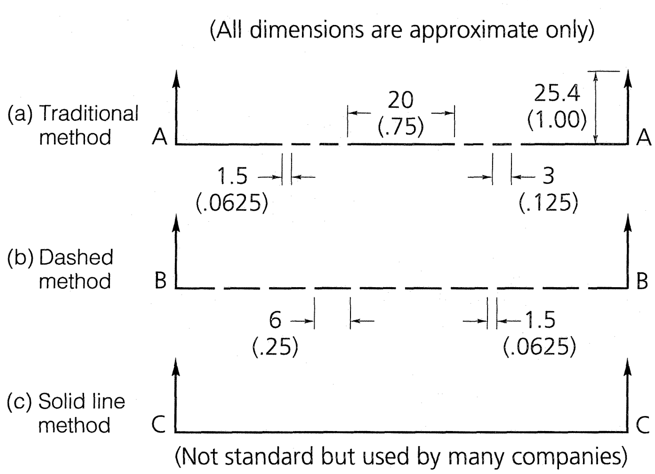


FIGURE 11.15 Dimensions for Drawing Cutting-Plane Lines and Arrows

11.2.7 Conventional Representation

Conventional representation, or accepted practice, is any recognized practice of description or representation of a part that has been established in industry over time. Ordinarily, conventional representations involve simplifications that speed the drawing task. This is done in the interest of drawing economy and clarity.

For **outline sections,** limited section lines drawn adjacent only to the boundaries of the sectioned area are the preferred conventional representation for large sectioned areas. Outline section lining is used only where clarity will not be sacrificed (Fig. 11.16). This eliminates the need to cover large areas with section lines.

Thin sections, such as for sheet metal, packing, and

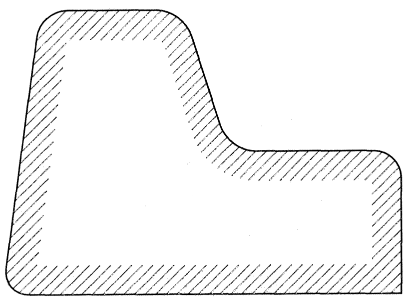


FIGURE 11.16 Outline Section Lining

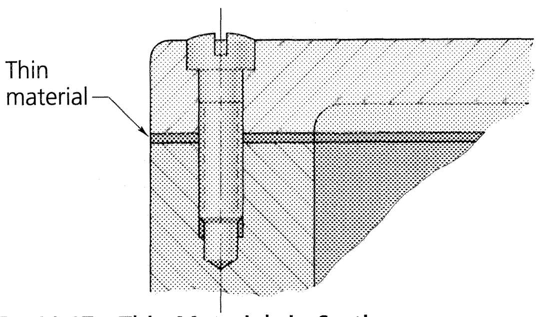


FIGURE 11.17 Thin Materials in Sections

gaskets, are drawn solid (filled). When drawing two or more thicknesses or layers, leave a narrow space between them to maintain their separate identities. Figure 11.17 illustrates the use of the solid sectioning symbol on thin materials such as gaskets. This figure shows three parts and a gasket. The screw is not sectioned because solid standard parts are not sectioned. The top cover has section lining at 45° angling in one direction, and the lower part has section lining in the opposite direction, per section standard conventions.

11.3 TYPES OF SECTIONS

Many types of sections are used on technical drawings, including the following.

- Full sections
- Half sections
- Offset sections
- Aligned sections
- Removed sections
- Revolved sections
- Broken-out sections
- Assembly sections
- Auxiliary sections (covered in Chapter 12)

A drawing may contain one or more of these types of sections, as in Figure 11.3. Each of these section types is covered in the following discussion, except auxiliary views, which, as noted, are covered in Chapter 12.

11.3.1 Full Sections

When the cutting plane extends through the entire part, in a straight line, usually on the centerline of symmetry, a full section results (Fig. 11.18). **Full sections,** because the entire orthographic view is sectioned, are the most common type of section view. The part in Figure 11.18 shows four different aspects of the sectioning process. Figure 11.18(a) gives a pictorial view of the part. In Figure 11.18(b), a cutting plane is passed through the part and the sectioned area is shown. In Figure 11.18(c), the line of sight is displayed and the part split along the cutting plane. Figure 11.18(d) presents three views of the part: a front view, a left side view, and a full right side section view.

The part in Figure 11.19 has a right side view along with a full right side section view. The portion of the part between the observer and the cutting plane is assumed to be removed, exposing the cut surface and the visible background lines of the remaining portion. (This is an actual industry drawing.)

Figure 11.20 contrasts a full section view and a half section view. The front view is a normal external view. Note that the outline of each is the same.

11.3.2 Half Sections

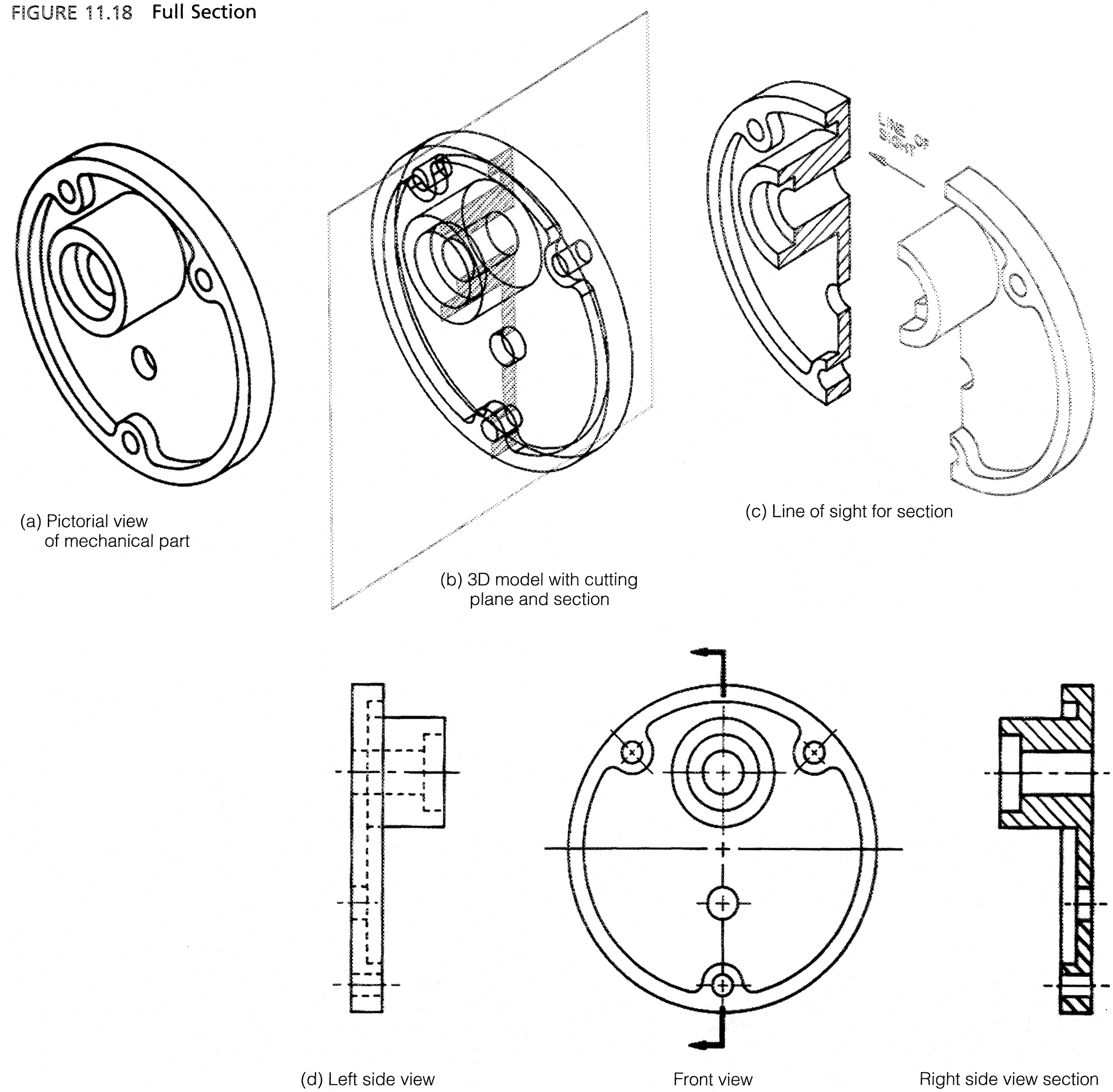
The view of a symmetrical or cylindrical part that represents both the interior and the exterior features by showing one-fourth in section and the other three-fourths as an external view is known as a **half section,** because the half of the orthographic view is sectioned (Fig. 11.21). Figure 11.22 is a half section obtained by passing two cutting planes at right angles to each other. The intersection line of the two cutting planes is coincident with each axis of symmetry of the part. One-fourth of the part is "removed," and the interior is exposed. Figure 11.22(b) shows the part placed in the front and the top views, with the front view showing the half section. When the cutting planes are coincident with the centerline, the cutting-plane line, arrows, and section letters may be omitted. The line that separates the sectioned half from the nonsectioned half is a centerline and not a visible solid line.

You May Complete Exercises 11.1 Through 11.4 at This Time

11.3.3 Offset Sections

To include features of a part not located in a straight line, the cutting plane may be stepped, or offset, at right angles to pass through these features. **Offset sections** reduce the number of required sections for a complicated part. An offset section (Fig. 11.23) is drawn as if the offsets were in one plane, and *the offsets are not indicated in the sectioned view.* In Figure 11.23 the front view shows the section as if it had a straight cutting plane. No extra lines are introduced into the view to show where the section changes direction.

FIGURE 11.18 **Full Section**



The part in Figure 11.24 has important features at three separate positions in the top view. The cutting plane is offset twice, once to pass through the hole and again to pass through the counterbored hole near the back of the part. Observe that no line is shown at the offset in the cutting-plane line in the section view [Fig. 11.24(d)]. When changes in viewing direction are not obvious, you can place reference letters at each turning point of the cutting plane.

11.3.4 Aligned Sections

If the true projection of a part results in foreshortening or requires unnecessary drawing time, inclined elements such as lugs, ribs, spokes, and arms are rotated into a plane perpendicular to the line of sight of the section. Cutting-plane lines are normally omitted for rotated features. This type of section is called an **aligned section** (Fig. 11.25).

Aligned sections are the recommended conventional practice in industry. This convention speeds the construction of the view, even though it is not a true projection. The true projection is completed only if it is important to establish clearance between features of a part or in an assembly of parts. Holes, slots, and similar features spaced around a bolt circle or a cylindrical flange may also be rotated to their true distance from the center axis and then projected to the adjacent section view.

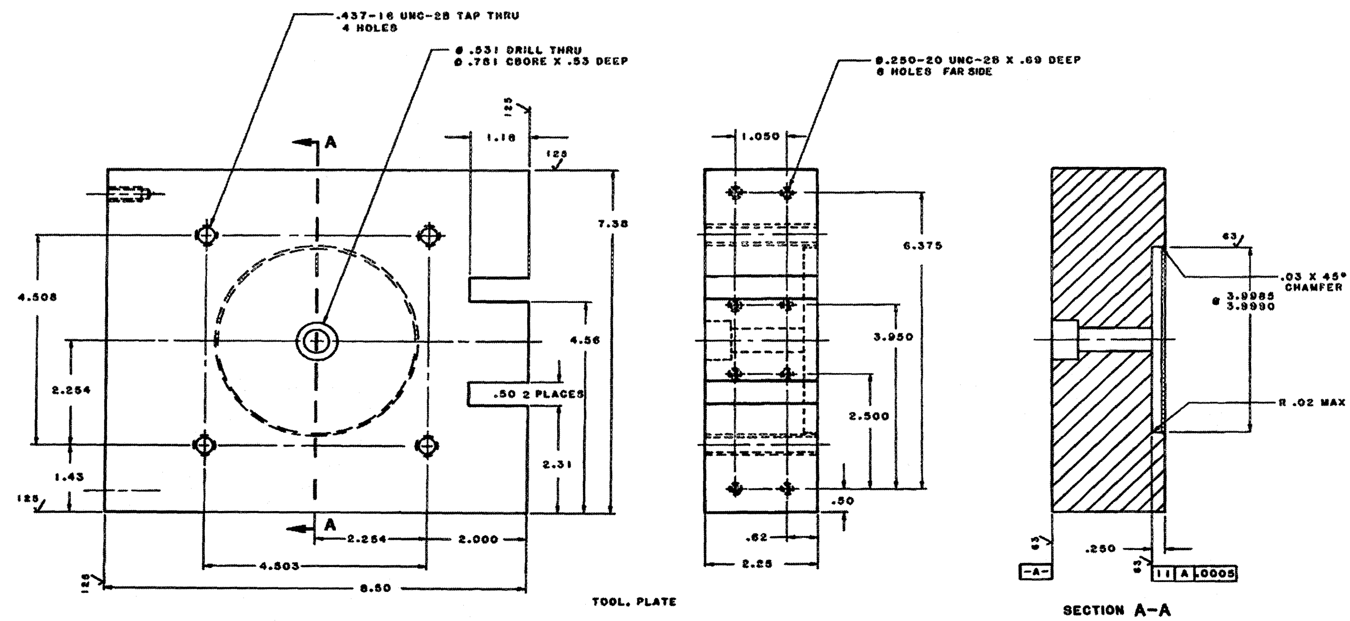


FIGURE 11.19 Detail with Both an External Right Side View and a Full Right Side Section

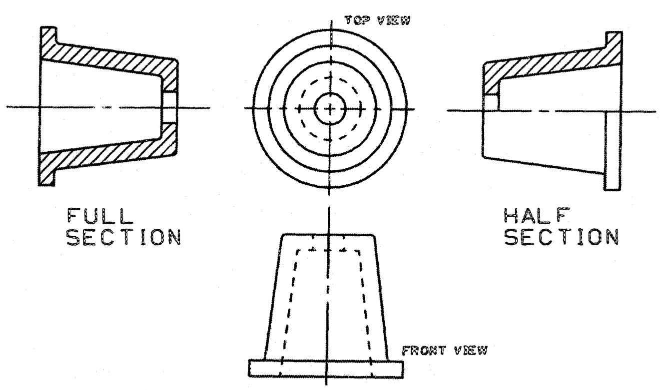
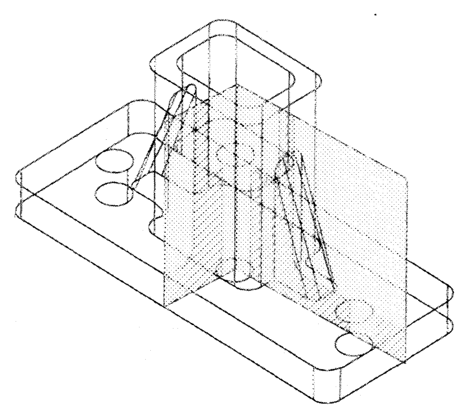
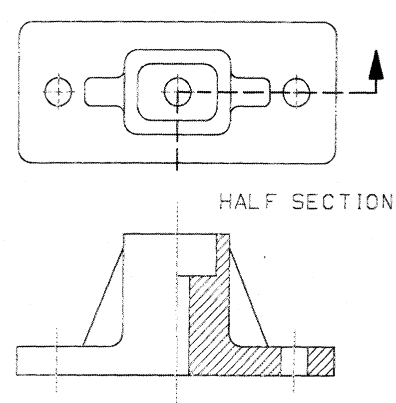


FIGURE 11.20 Full Section, Half Section, and External Views



(a) Pictorial illustration of a half section



(b) Top view and front half section of a part

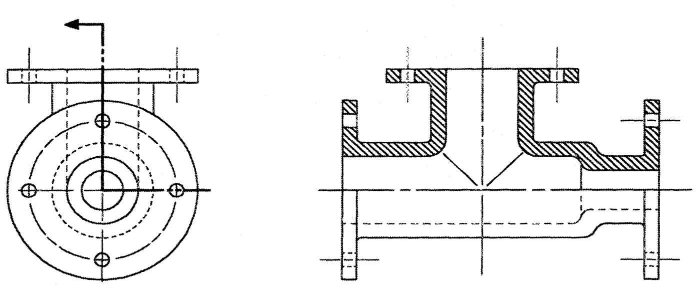


FIGURE 11.21 Half Section

FIGURE 11.22 Half Sections

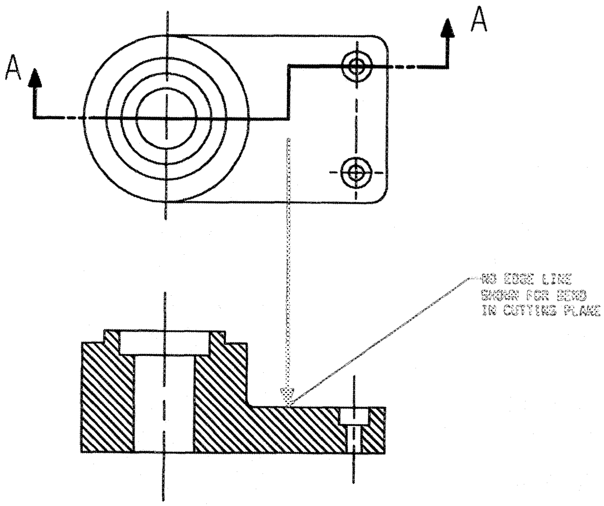


FIGURE 11.23 Offset Section

In aligned sections, features of a symmetrical part that would be foreshortened in a strict interpretation are rotated into the plane of the paper. This preserves the feeling of symmetry, is easier to draw, and is more easily interpreted by the machinist. In Figure 11.25, the unrecommended, foreshortened, true projected view of the part is provided to contrast the two methods. The true projected view of the spokes is hard to construct and does not add to the drawing's clarity. In this figure, the spokes of the wheel have been rotated to project as true shape in the right side view. In Figure 11.26, the right side view is an aligned section. Both spokes and the keyseat are drawn as if they were cut by the cutting plane.

Another example of an aligned section is provided in Figure 11.27. Figure 11.27(a) shows the true front view projection of a part; Figure 11.27(b) shows the rib as rotated. It is now easier to complete a full section of the part. Compare the two views for clarity and simplicity: Figure 11.27(a) is a less clear and more complex projection than Figure 11.27(b).

When the features of a part lend themselves to an angular change of less than 90° in the direction of the cutting plane, the section view is drawn as if the cutting plane and feature were rotated into the plane of the paper. In some cases, the cutting plane is bent to pass through a desired feature, as in the industry drawing in Figure 11.28. In Figure 11.29, the cutting plane is drawn through the portion to be rotated.

Figure 11.29 also shows an alternative way of sectioning a rib (also see Section 11.3.5). Here, the cutting plane passes through the rib. Instead of leaving the rib area without section lines, as is common practice, the area was **double sectioned** by extending every other section line from the surrounding area. This method was also used in Figure 11.10.

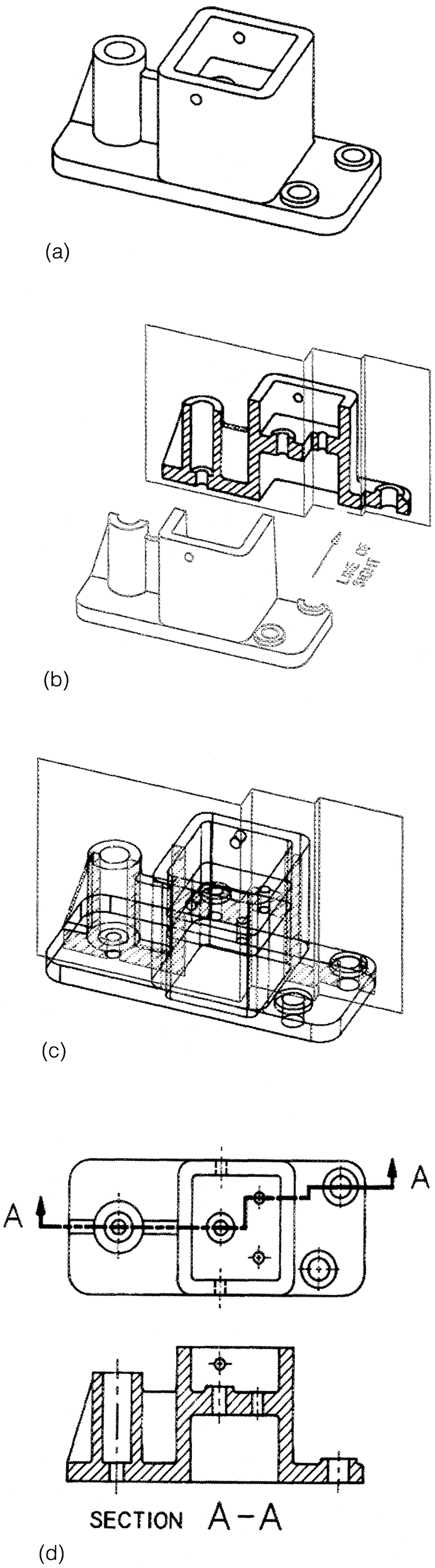


FIGURE 11.24 Multiple Bends in an Offset Section

11.3.5 Nonsectioned Items in a Section View

When the cutting plane lies along the longitudinal axis of shafts, bolts, nuts, rods, rivets, keys, pins, screws, ball or roller bearings, gear teeth, ribs, or spokes, sectioning is not required except where internal construction must be shown. This convention is needed mainly on assembly sections

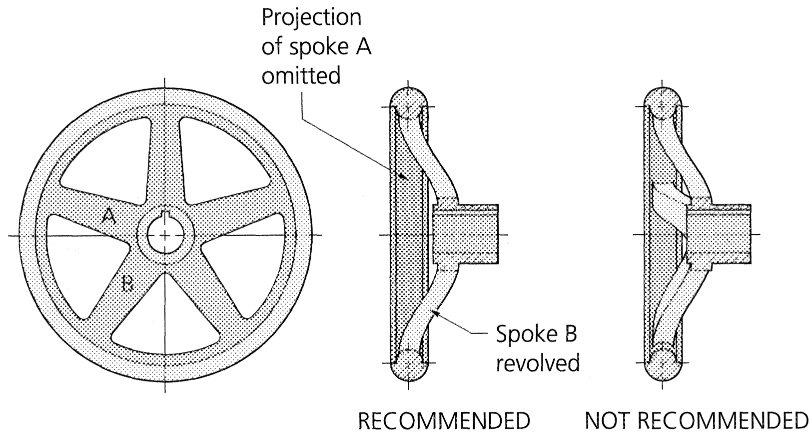


FIGURE 11.25 Spokes in Section

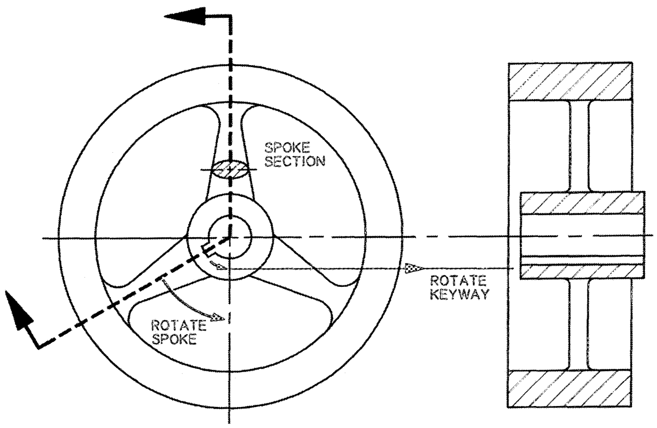


FIGURE 11.26 Conventional Layout for Aligned and Rotated Sections

where more than one part is sectioned and a number of standard hardware items, such as bolts, screws, and dowels, are found.

For shafts and other machine parts detailed as separate parts, it is normal practice to use **broken-out sections** for any internal construction that needs to be displayed. Sections through nuts, bolts, shafts, pins, and other solid machine elements that have no internal construction are not shown sectioned, even though the cutting plane passes through these features. These items are more easily recognized by their exterior (Fig. 11.30). Figure 11.31 shows an example of a sectioned assembly. The shaft in this figure is also unsectioned.

When a cutting plane passes through a rib (Fig. 11.32), leave the rib portion of the section without section lining. Because ribs fall into the category of a thin solid shape, they are usually represented without section lining or are sometimes double sectioned.

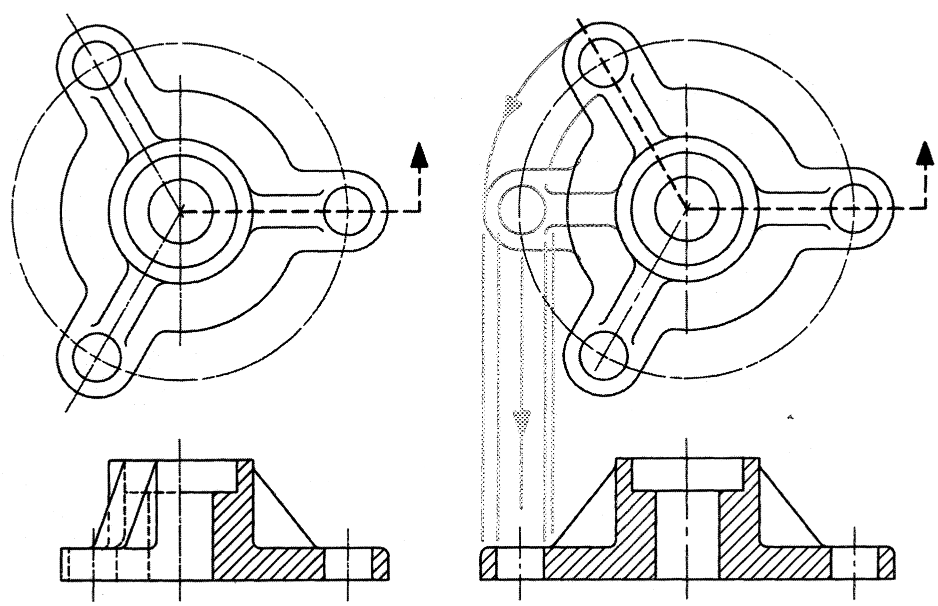
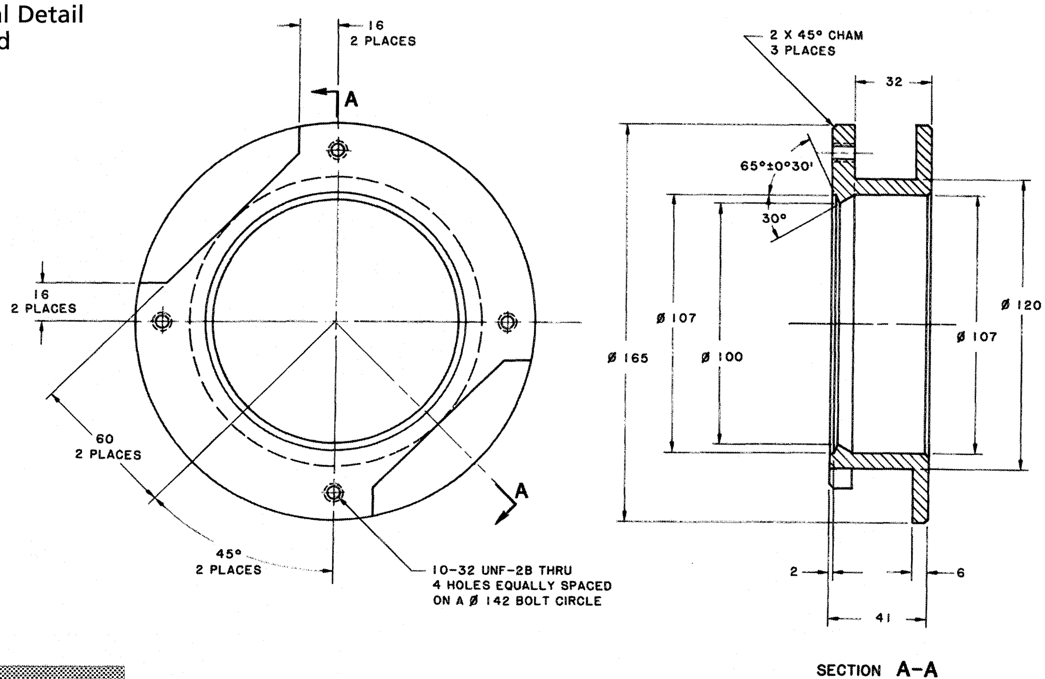
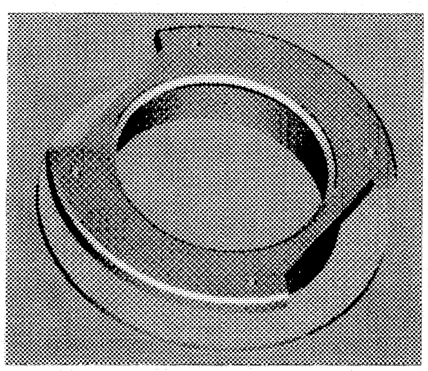


FIGURE 11.27 Full and Half Sections

FIGURE 11.28 Mechanical Detail of a Part Using an Aligned Section





detailed mechanical part from industry. **SECTION A–A** is a removed section drawn at **2:1** scale.

If it is impractical to place a removed section on the same sheet with the regular views, you must clearly identify the sheet number and the drawing zone location of the cutting-plane line. Where the cutting plane is shown, place a note that refers to the sheet and the zone where the removed section or section title is, along with a leader pointing to the

Sectioning ribs gives the appearance of more mass than actually exists, as in the incorrect example of Figure 11.32. Ribs are not sectioned when the cutting plane passes through them "flatwise," but are shown as visible edges. However, ribs are sectioned when the cutting plane passes perpendicular to them.

11.3.6 Removed Sections

Removed sections show the special or transitional details of a part. They are like revolved sections, except that they are placed outside the principal view. In some cases, removed sections are drawn to a larger scale.

Removed sections that are symmetrical may be placed on centerlines extended from the imaginary cutting planes (Fig. 11.33). A removed section is usually not a direct projection from the view containing the cutting-plane line; it is displaced from its normal projection position. In this case, formal identification is necessary. Figure 11.34 shows a

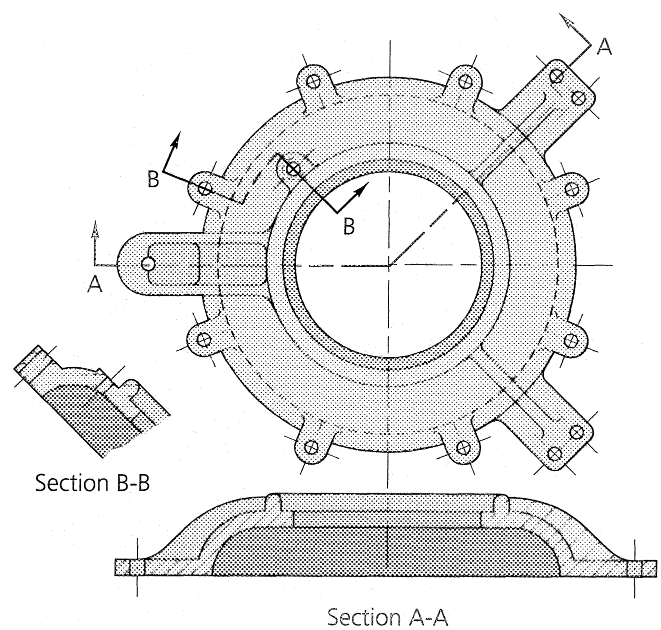


FIGURE 11.29 Aligned Section Through a Rib. An alternative method of sectioning a rib with double-spaced section lines is also shown.

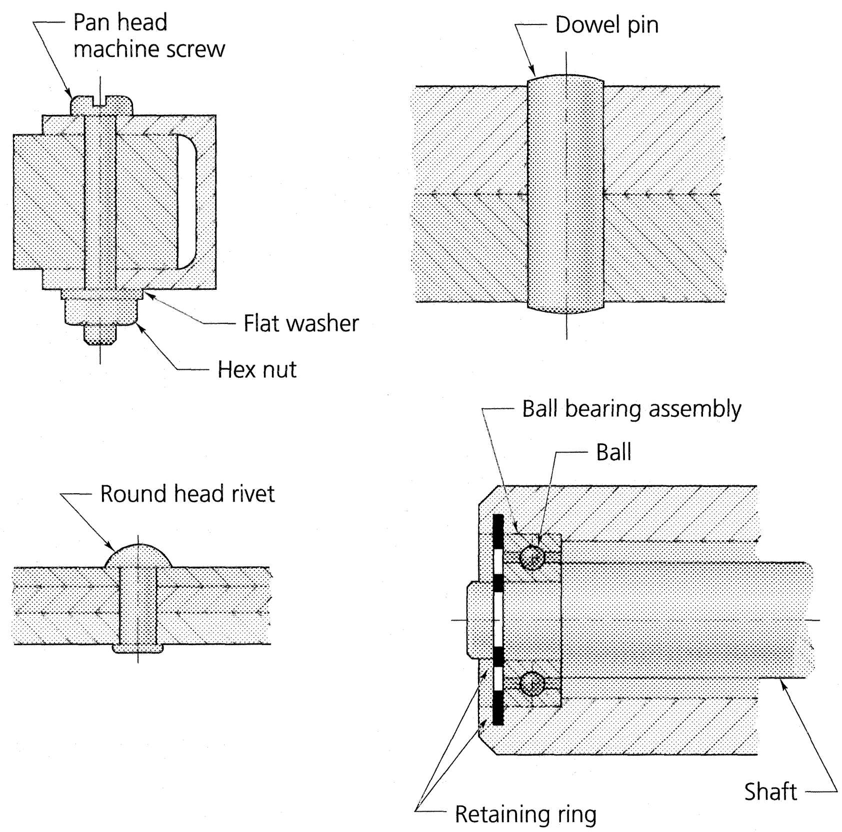


FIGURE 11.30 Solids in Section

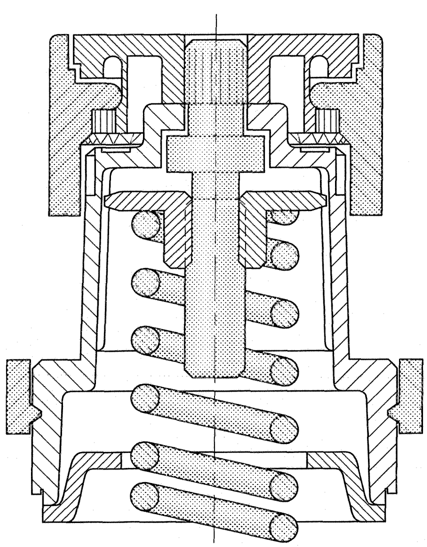


FIGURE 11.31 Assembly and Solid Threaded Part in Section

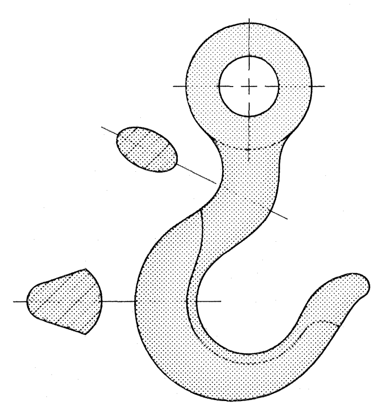


FIGURE 11.33 Removed Sections

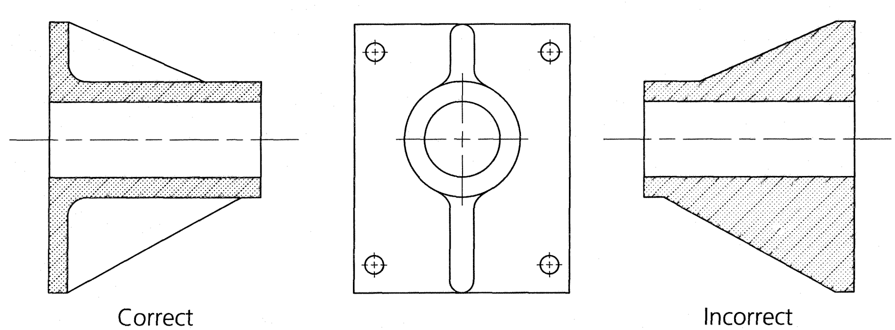


FIGURE 11.32 Ribs in Sectional Views

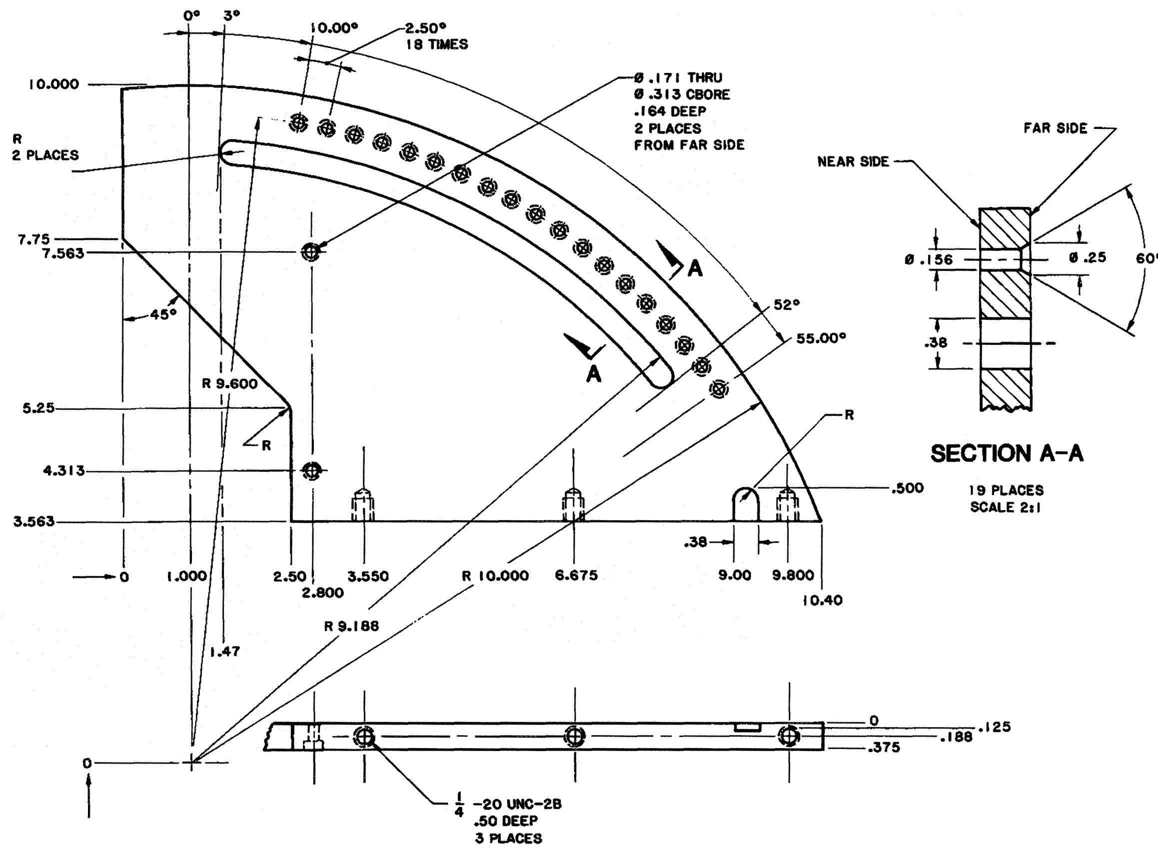


FIGURE 11.34 **Detail of a Mechanical Part with a Removed Section**

cutting plane. Figure 11.35 is an example of a part detail that employs a removed section (**SECTION B–B**) to display interior features that would be difficult to dimension with only an exterior view.

11.3.7 Revolved Sections

A **revolved section** is constructed by passing a cutting plane perpendicular to the axis of an elongated symmetrical feature such as a spoke, a beam, or an arm, and then revolving it in place through 90° into the plane of the drawing (Fig. 11.36). Visible lines extending on each side of the revolved section may be left in, or they may be removed and break lines used. Figure 11.37 involves both methods. The spoke sections do not have the visible lines removed and broken, as does the wheel section. Cutting planes are not indicated on this type of section.

11.3.8 Broken-Out Sections

When it is necessary to show only a portion of the part in section, the sectioned area is limited by a freehand **break line,** and the section is called a **broken-out section** (Fig. 11.38). A cutting-plane line is not indicated for this type of section. Broken-out sections are sometimes referred to as **partial sections** (see Fig. 11.3).

One of the most important reasons for showing sections on a drawing is to display complicated interior features that require dimensioning. Figures 11.39 and 11.40 show industry drawings that make use of broken-out sections to display and dimension normally hidden features.

11.3.9 Intersections in Section

If the exact shape of the curve of an intersection is slight or of no consequence, you may simplify sections through **intersections** by ignoring the true projection. Conventional practice does not require the true projection when the true lines of intersection are time-consuming to draw or are of no value in reading the drawing.

When a difference in proportions exists, the true projection should be shown. When the cutting plane is perpen-

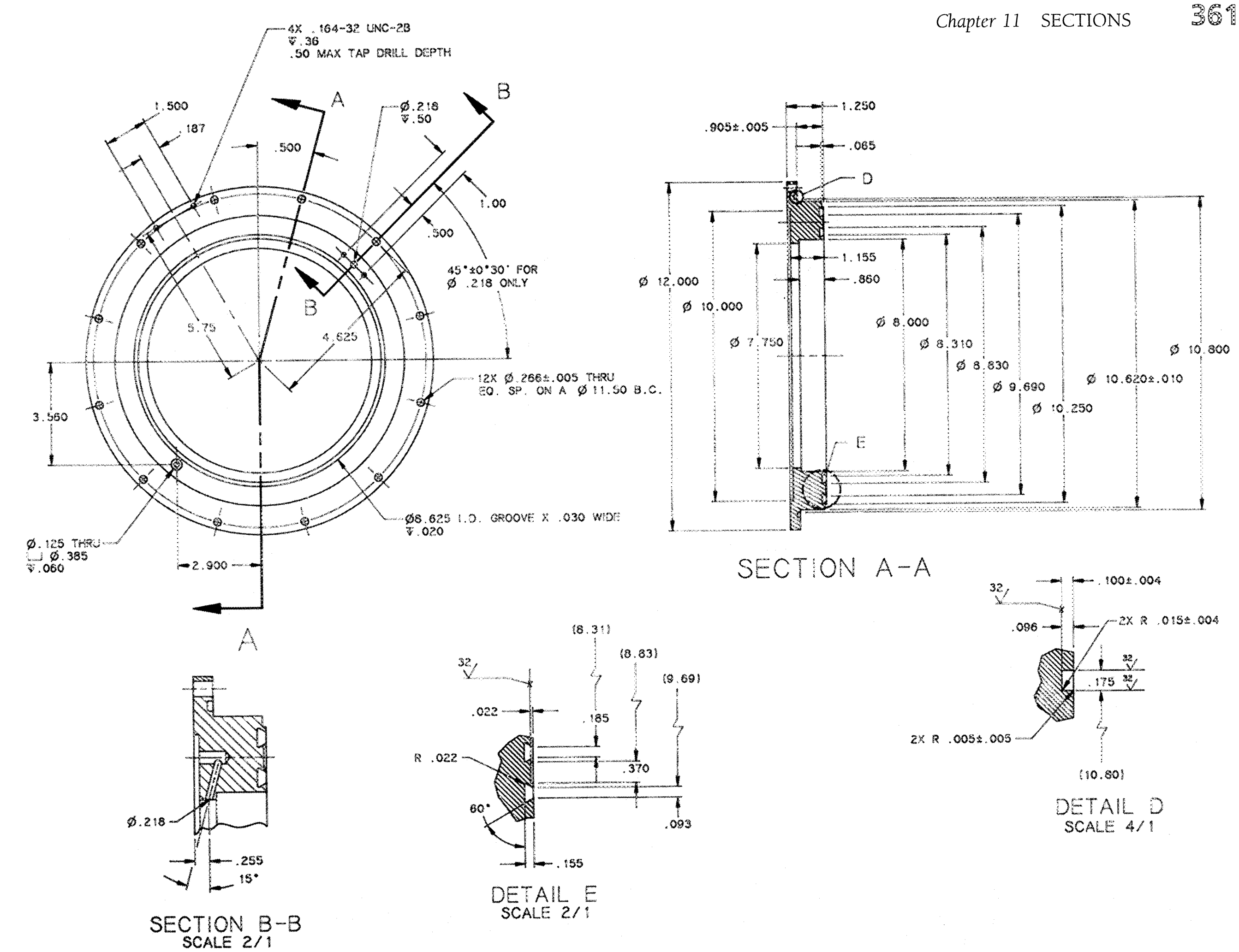


FIGURE 11.35 Removed Sections on Detail Drawing

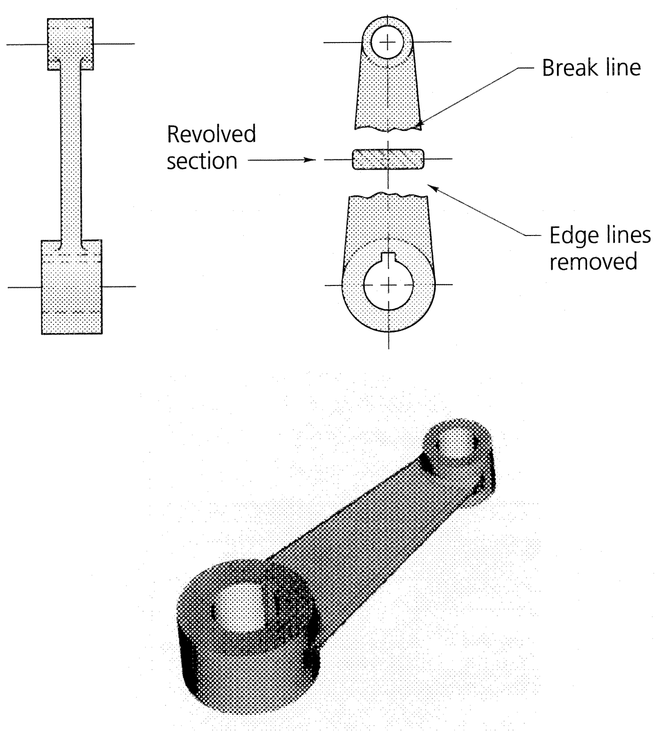


FIGURE 11.36 Revolved Section of an Arm

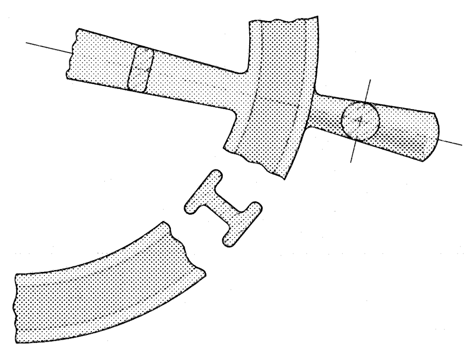


FIGURE 11.37 Revolved Sections on a Handwheel

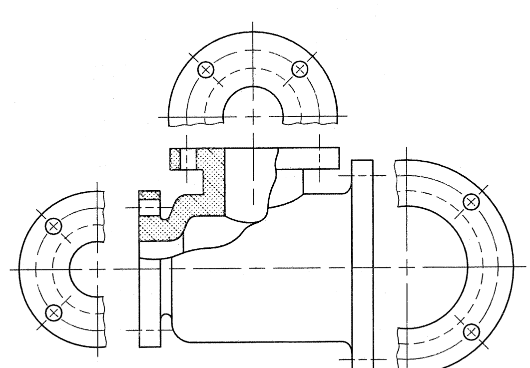


FIGURE 11.38 Broken-Out Section of a Pipe Fitting

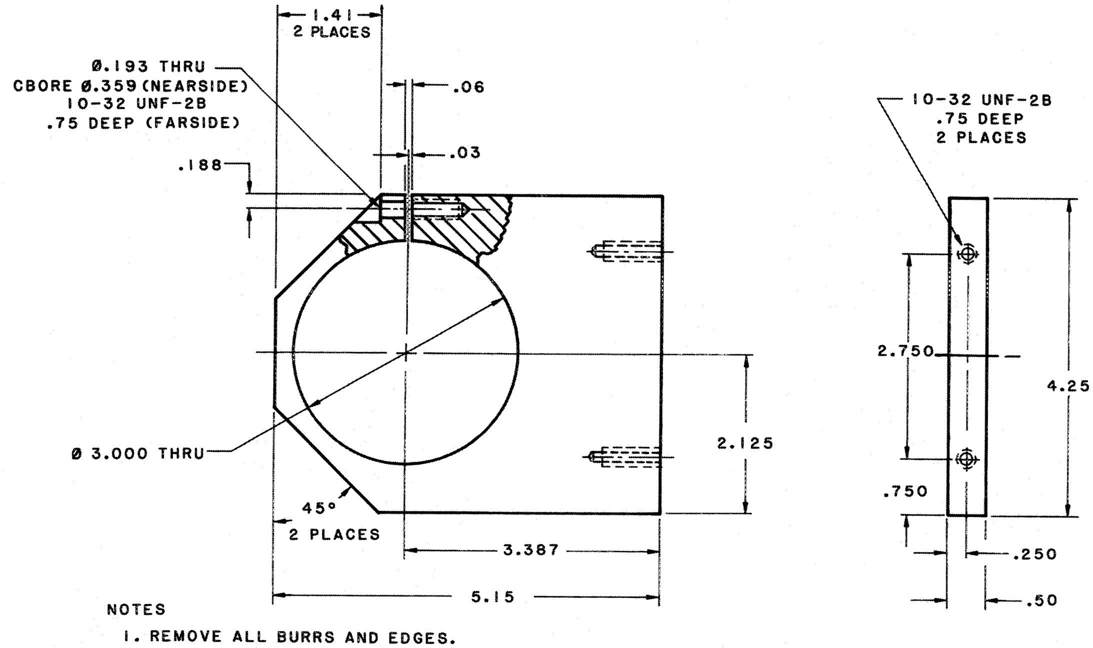


FIGURE 11.39 Broken-Out Section

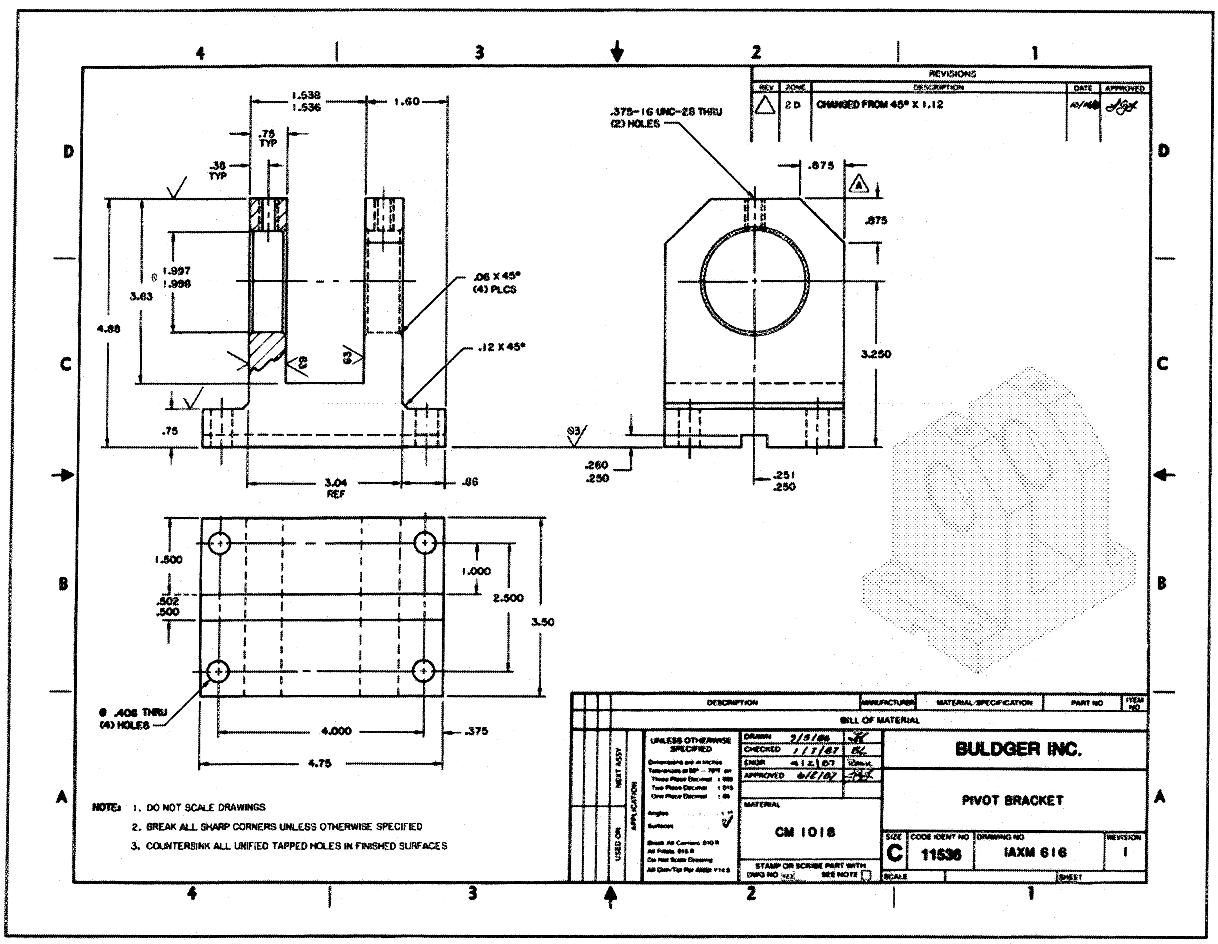


FIGURE 11.40 Mechanical Part with a Broken-Out Section

Applying Parametric Design . . .

SECTIONING PARAMETRIC MODELS

Cross-sectional views are slices through a part or an assembly and are valuable for opening up the part or assembly to display features and detailing in draw mode. Part cross sections may also be used to calculate cross-sectional mass properties. Each cross section has its own unique name within the part or assembly, allowing any number of cross sections to be created and then retrieved for use in drawing. A variety of ANSI-standard section lining materials can be generated automatically (see Fig. A). You have can create a variety of cross-section types:

- Standard planar cross sections of models (part or assemblies)
- Offset cross sections of models (part or assemblies)

Planar cross sections are created along a datum plane (Fig. B). The datum may be created during the creation of the cross section using the **Make Datum** options, or an existing plane may be selected. DTM5 (Fig. C) was used to create the removed section in the next example (Fig. D). The socket-head cap shoulder screw (Fig. E) is sectioned along DTM3 (Fig. F) and shown as shaded. The section can also be created for use in a drawing, in Draw Mode (Fig. G).

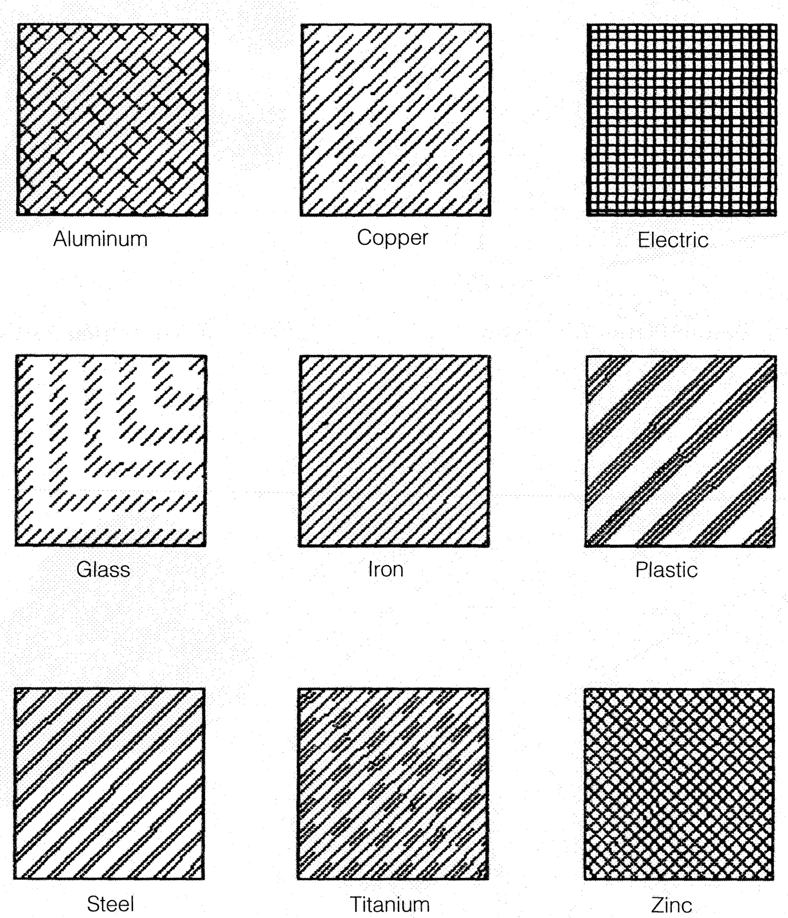
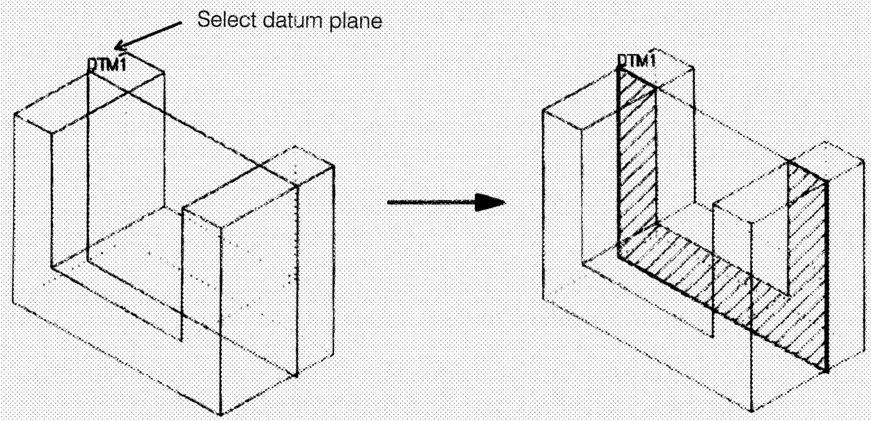
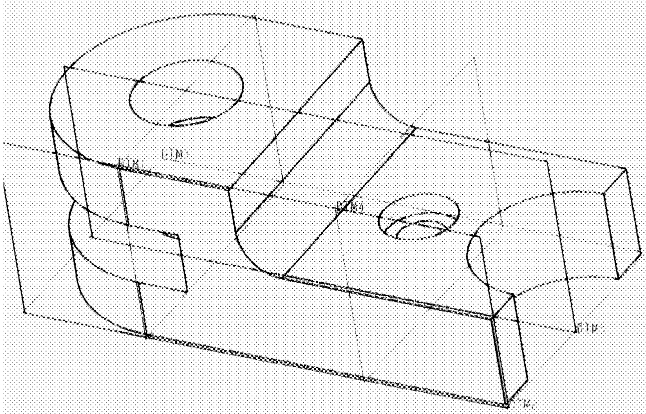


FIGURE A Material Lining Symbols

(Continued)



IGURE B Selecting a Datum Plane for Cross Section



GURE C Part with Datum Planes Displayed

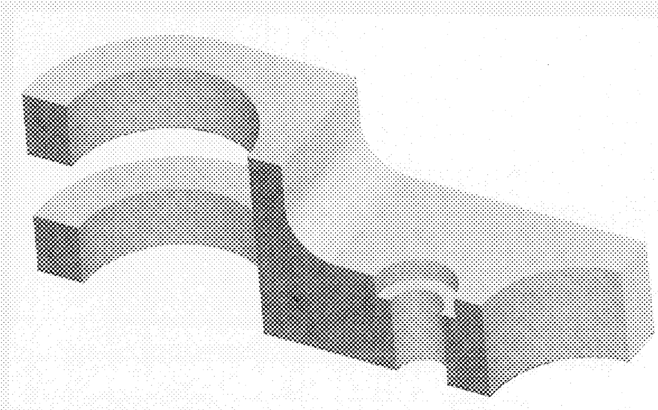
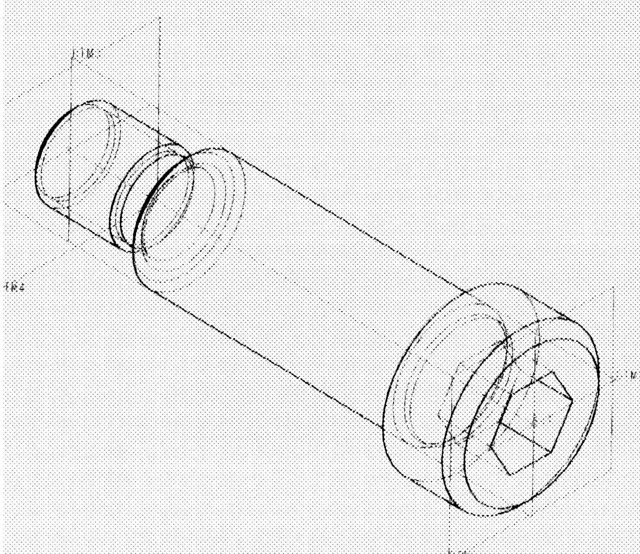


FIGURE D Sectioned Part with Front Removed



URE E Socket-Head Cap Shoulder Screw

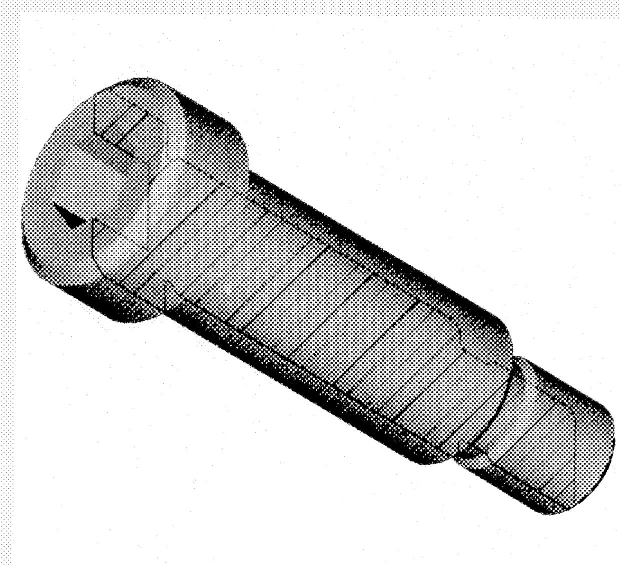


FIGURE F Sectioned and Shaded Model of Screw

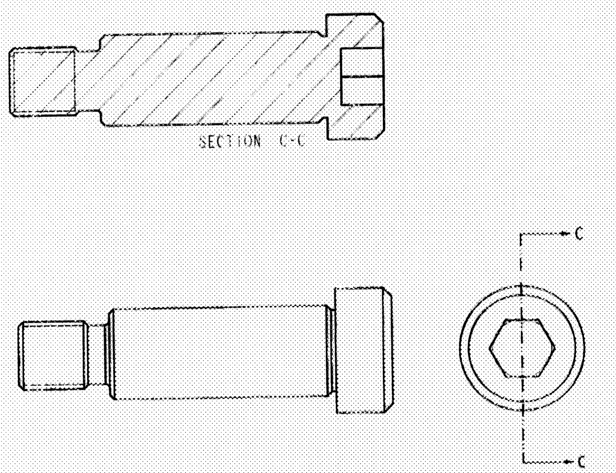


FIGURE G Drawing of Screw with a Sectioned View

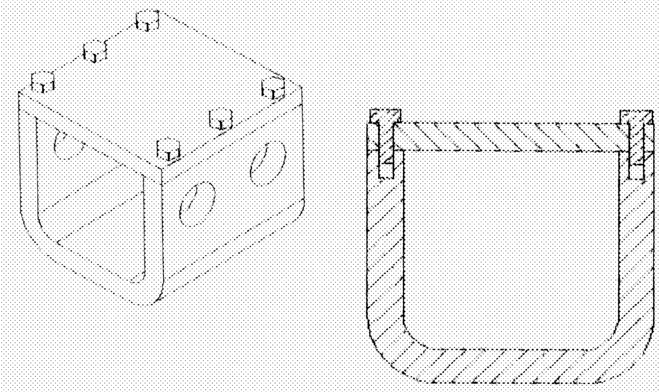


FIGURE H Assembly and Section

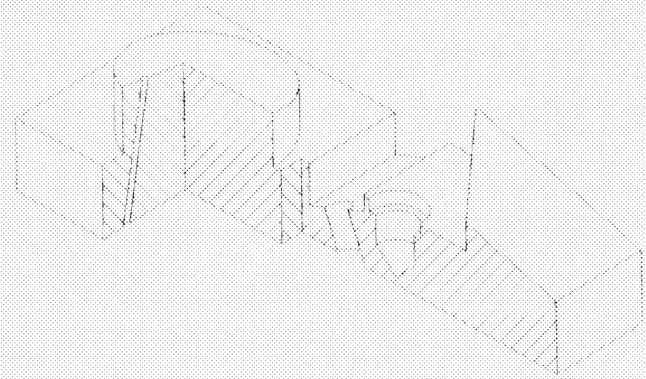


FIGURE I Offset Section

To Create a Planar Cross Section of a Part:

1. Choose **X-section** from the PART menu and **Create** from the XSEC ENTER menu.
2. Choose **Planar** from the XSEC CREATE menu, then **Done**.
3. Enter a name for the cross section, and then select (or make) the datum along which the section is to be generated.

To Create a Planar Cross Section of an Assembly (Fig. H):

1. Choose **Set Up** from the ASSEMBLY menu and **X-section** from the ASSEM SETUP menu, then Create from the XSEC ENTER menu.
2. Choose **Planar** from the XSEC CREATE menu, then **Done**.
3. Enter a name for the cross section.
4. Select or create the **assembly** datum along which the section is to be generated.

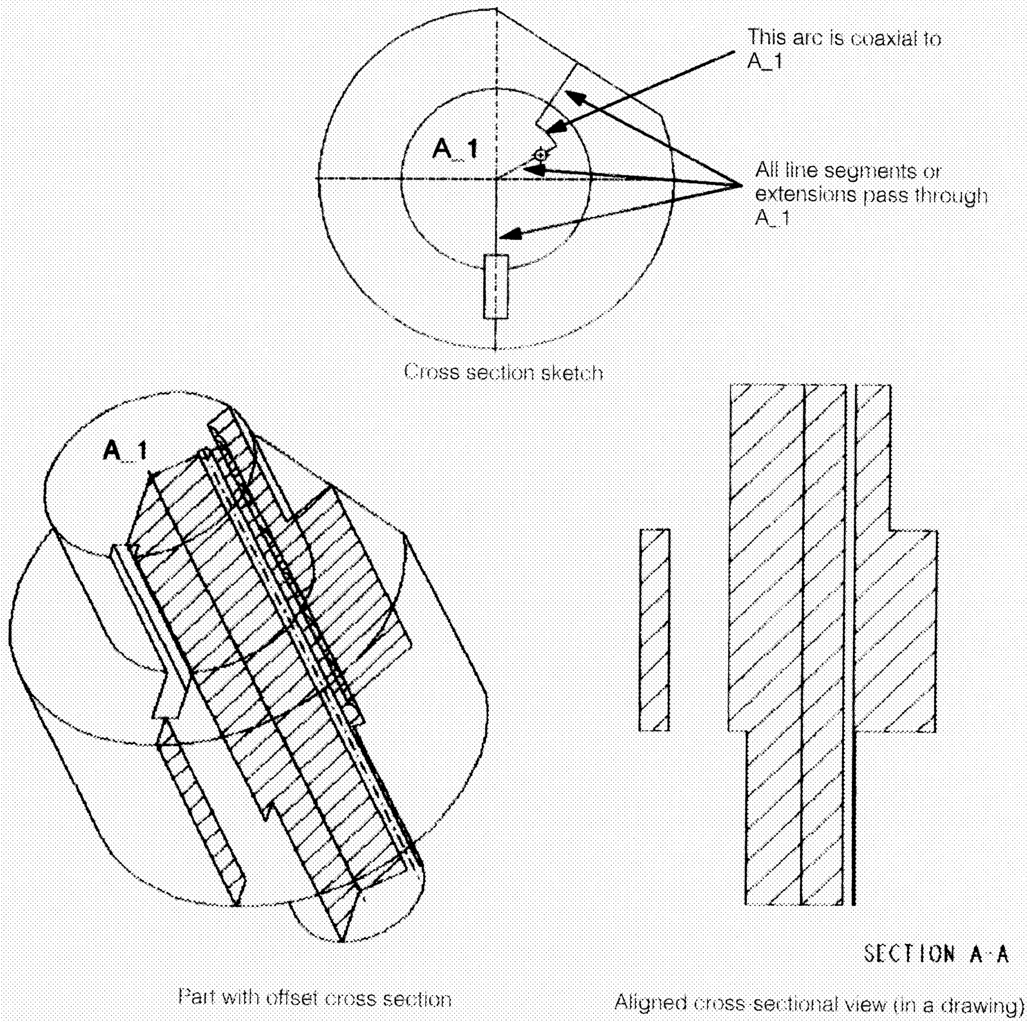
An **offset cross section** (Fig. I) is created by extruding a 2D section perpendicular to the sketching plane, just like creating an extruded cut but without removing any material. This type of cross section is valuable for opening up the part to display several features with a single cross section (Fig. J).

Restrictions on the Offset Cross Section:

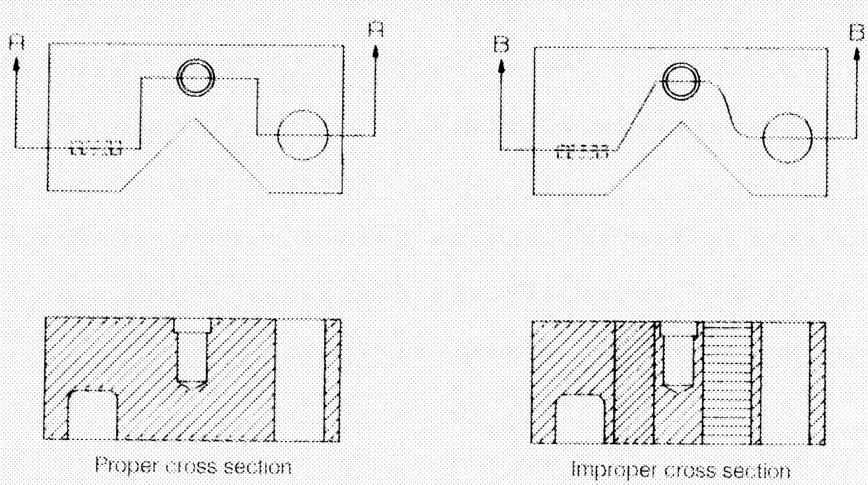
- The sketched section must be an open section.
- The first and last segments of the open section must be straight lines. The cutting-plane arrows displayed in a drawing will be perpendicular to these end segments.
- Circular and spline cross-section geometry will create unmodifiable horizontal crosshatching.
- In drawing, cross-section edges will always appear wherever the plane of the cross section is not parallel or perpendicular to the screen (Fig. K).

To Create an Offset Cross Section:

1. Choose **X-section** from the PART or ASSEM SETUP menu and **Create** from the XSEC ENTER menu.
2. Choose **Offset** and **One Side** or **Both Sides** from the XSEC CREATE menu, and then **Done**.
3. Enter a name for the cross section.
4. Answer the prompts for entering Sketcher. The sketching plane can be created using the **Make Datum** option.
5. Sketch the cross section and dimension it to the model. Choose **Done** when the section has been regenerated successfully.



IGURE J **Aligned Offset Cross Section**



GURE K **Correct and Incorrect Representations of a Cross Section**

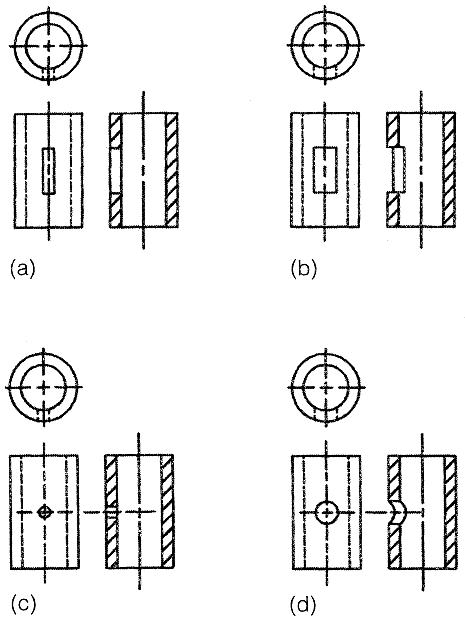


FIGURE 11.41 **Intersections in Section. (a) and (c) show a small intersection; (b) and (d) show more pronounced intersecting features, which are projected true.**

dicular or cuts across these features, the section view is section lined in the usual manner.

When a section is drawn through an intersection in which the true projection of the intersection is small, the true line of intersection is disregarded [Fig. 11.41(a) and (c)]. More pronounced intersecting features are projected true [Fig. 11.41(b)] or approximated by arcs [Fig. 11.41(d)].

11.3.10 Breaks and Sectioning

Conventional breaks shorten a view of an elongated part (Fig. 11.42) and in broken-out sections. The type of break representation is determined by the material and the shape of the part. Solid and tubular rounds are shown in Figure 11.42(a) and (b), respectively. The break can be drawn with the aid of an ellipse template or constructed manually. In industry, because they are time-consuming and therefore costly, such representations are never constructed via precise methods.

Tubular shapes are sectioned as shown in Figure 11.42(c). Break lines for Figure 11.42(c) and (d) are drawn freehand. The break for wood is also drawn freehand, but is jagged, not smooth, as shown in Figure 11.42(e).

You May Complete Exercises 11.5 Through 11.8 at This Time

11.4 ASSEMBLY DRAWINGS AND SECTIONING

Assembly sections show two or more mating parts in section (Figs. 11.43 and 11.44). General-purpose section lines are normally used on assembly drawings. When several adjacent parts are shown in a section view, the parts are sectioned as shown in the industrial example in Figure 11.43. Here the fixture has its two major parts sectioned with the general-purpose sectioning symbol. Because the piece to be machined is not really a portion of this fixture, it is shown in phantom lines and is not sectioned.

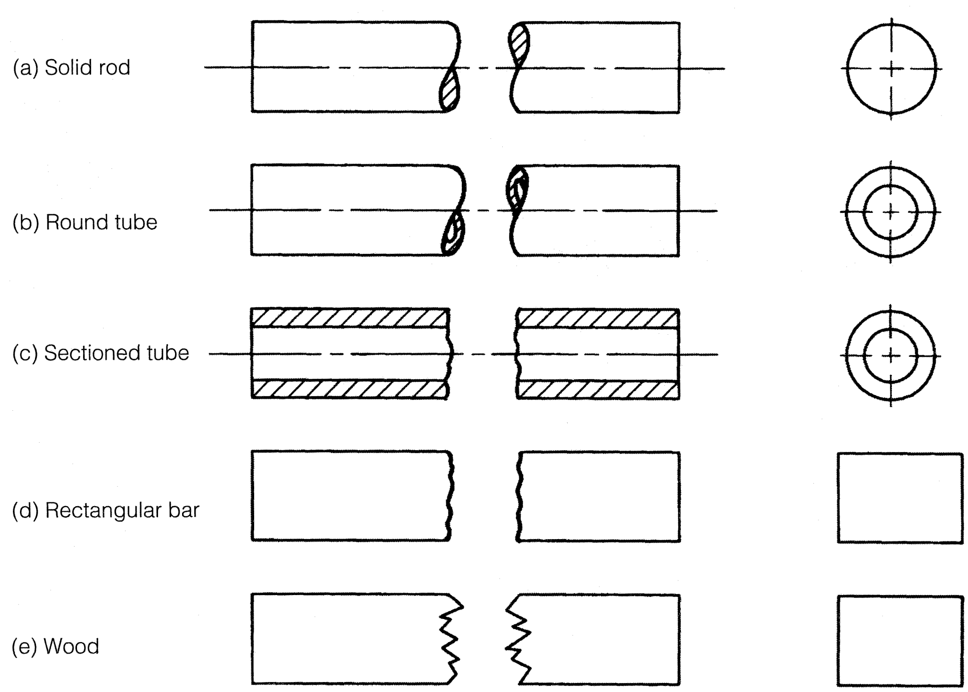


FIGURE 11.42 **Conventional Representation of Breaks in Elongated Parts**

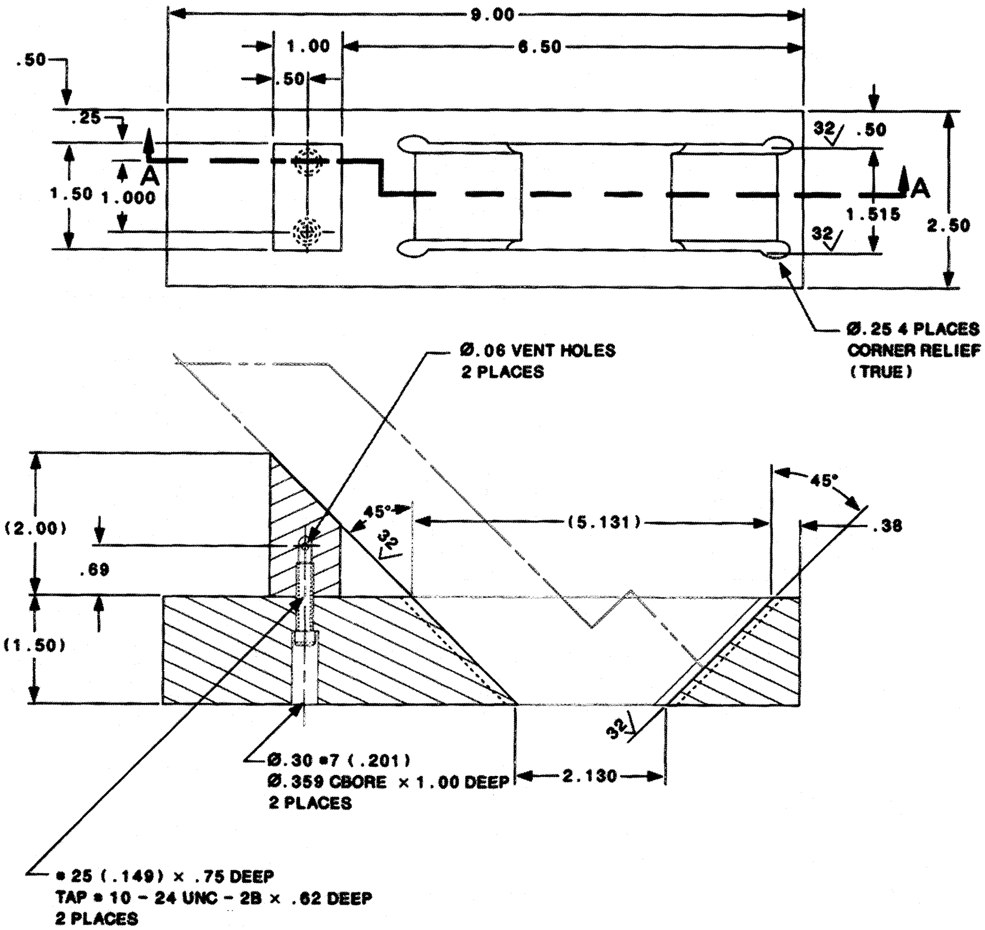


FIGURE 11.43 Assembly of Fixture with a Full Front Section View

Figure 11.44 shows the jack assembly as a front section. Each individual piece of the assembly has section lines running in different directions than in the adjoining piece. The threaded pieces and other solid items are not sectioned per the sectioning conventions explained earlier in the chapter. Symbolic section lines are also used in this example. (Sectioned assemblies are also covered in Chapter 23.)

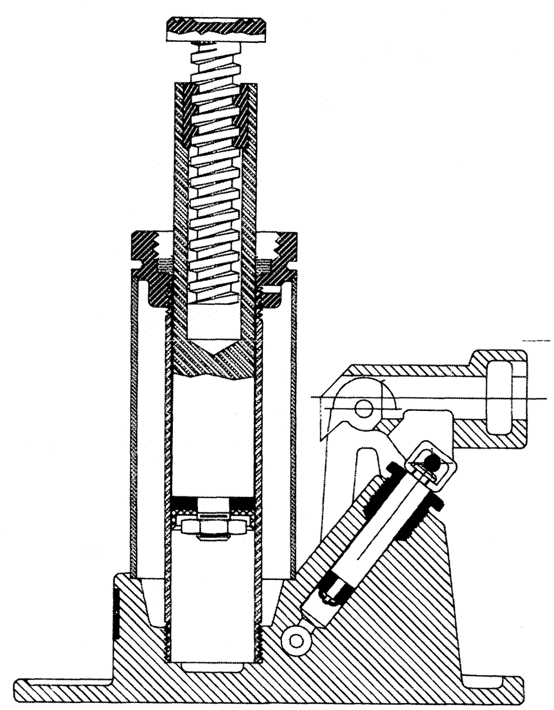


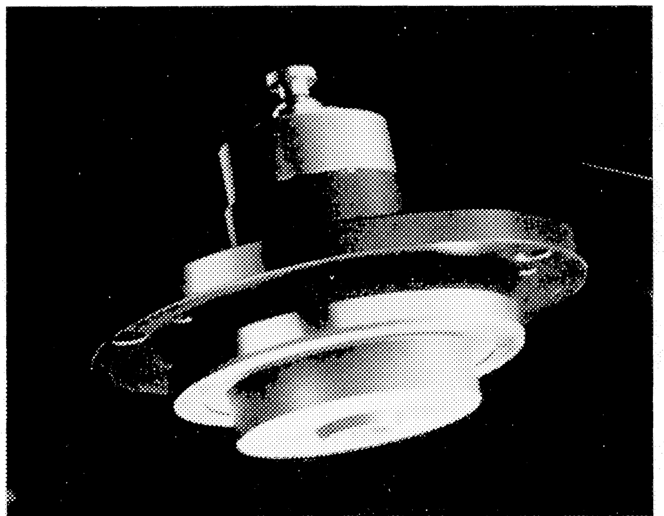
FIGURE 11.44 Assembly Section

11.5 SECTIONING WITH CAD

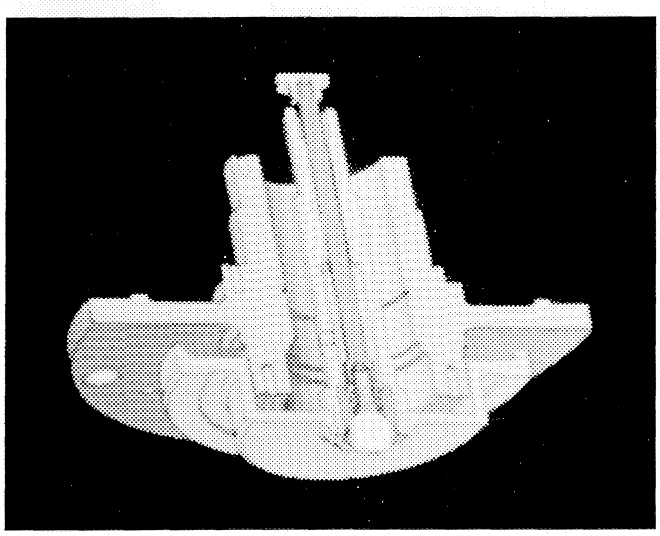
Sectioning can be done on both 3D and 2D CAD systems. In Figure 11.45(a) we see a 3D solid model assembly. In Figure 11.45(b), the assembly is sectioned so that the interior features can be seen. Figure 11.46 is an example of 3D product design using CAD.

The methods used for 2D CAD section drawings are similar to manual drafting techniques, except that the computer does the actual drawing. The views to describe the part are laid out and the required sections, including dimensioning, are completed.

In many drafting applications, it is common practice to



(a) Solid model of an assembly



(b) Sectioned solid model of an assembly

FIGURE 11.45 Solid Modeling and Sections

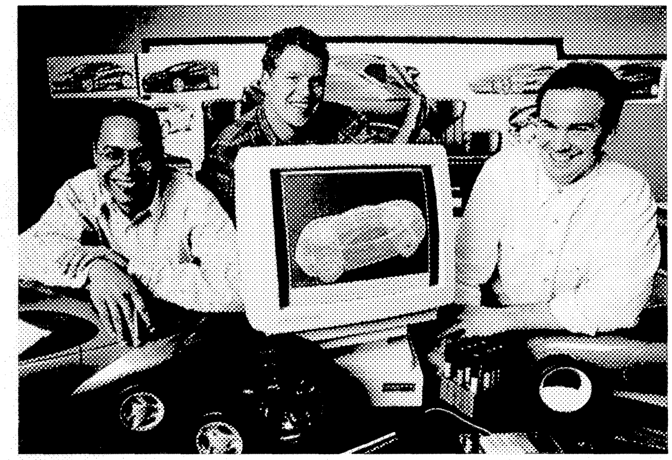


FIGURE 11.46 An Assembly Shown on a CAD System

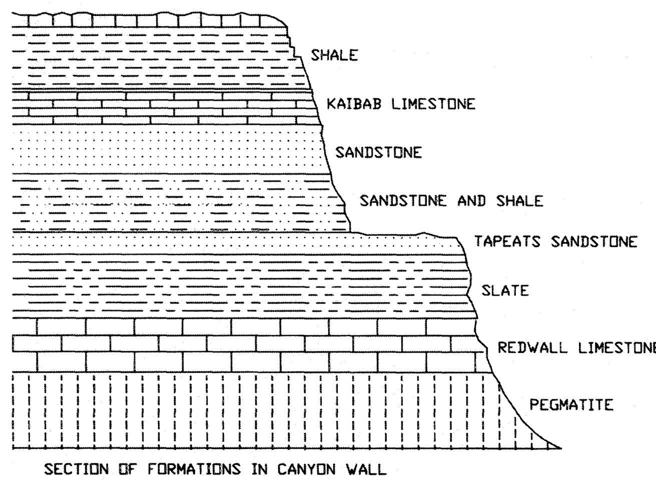


FIGURE 11.47 Section Formations in Canyon Wall Using Hatch Patterns to Represent the Types of Rock and Mineral Layers of Stratification

fill an area with a pattern. The pattern can help differentiate between components of a 3D part, can define an area of a part that has been sectioned, or can identify the material that composes a part (Fig. 11.47). Filling an area with a pattern is called crosshatching, hatching, or pattern filling, and it can be accomplished using a **HATCH** command.

CAD systems provide a library of standard ANSI hatch patterns. You can hatch with one of these standard patterns, with a custom pattern from your own library, or with a simple pattern defined during the command. On most systems the screen or tablet menu normally has a variety of hatch patterns available for immediate insertion (Fig. 11.48). For example, AutoCAD has more than forty predefined patterns that can be identified through the **HATCH** command (Fig. 11.48). AutoCAD's pulldown menus and dialog boxes will graphically display the hatch patterns and allow you to select visually the hatch pattern for your application. Hatch patterns can be modified before insertion.

11.5.1 Hatch Patterns on CAD Systems

Each hatch pattern is composed of one or more hatch lines or figures at specified angles and spacing. The pattern you insert is repeated or clipped, as necessary, to fill exactly the area being hatched.

Hatching generates line entities for the chosen pattern and adds them to the drawing. Hatched areas are blocks or groups. This means that the CAD system treats the group of section lines as a unit. Therefore, if you have hatched an area but then decide you do not like the hatching, you can select any individual line of the pattern with the **ERASE** command and the hatching will be removed.

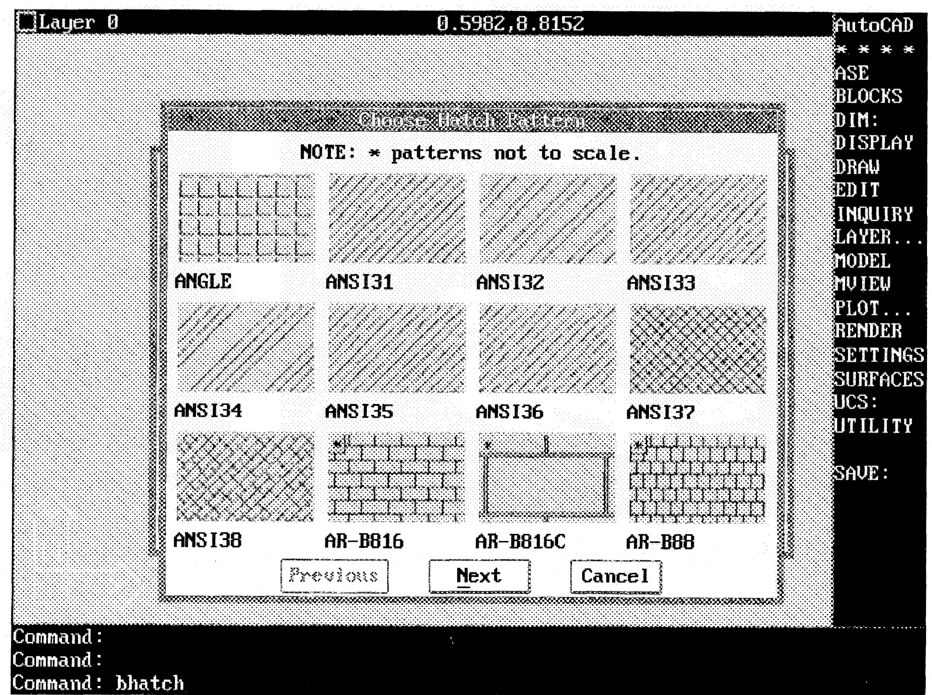


FIGURE 11.48 AutoCAD Hatch Pattern Dialog Box

11.5.2 Defining the Boundary Using CAD

Hatching fills in an area of the drawing enclosed by a boundary made from lines, arcs, circles, splines, polylines, or other geometric entities. When hatching an area, the entities that define the boundary must be selected (normally in sequence). The entities forming the hatching boundary should intersect. If your system requires that the endpoints of the entities meet, overhanging entities will produce incorrect hatching and hatching may spill out of the selected boundary area. Some systems allow for entities to cross, and some even hatch areas not completely enclosed by boundaries, although on most systems you must define a closed nonintersecting envelope of geometry.

Figure 11.49 illustrates the hatching of a section of a part using AutoCAD. After the hatching command is given, the boundaries of the area to be hatched are successively indicated by picking each entity, in this case D1 through D5. The following command illustrates the procedure. Enter the **HATCH** command from the **DRAW** pull-down menu and use the following steps:

`Command:` HATCH

`Pattern (? or name/U, style):` Pick the desired hatch pattern (ANSI31 was used here)

`Scale for Pattern:` Press the *Enter* key to accept full scale

`Angle for Pattern <a>:` Select angle, or use default by pressing the *Enter* key (ANSI31 uses 45°)

`Select Objects:` D1 D2 D3 D4 D5 (select the outline border)

Hatching patterns are varied by specifying the angle of the hatching and the spacing, as in Figure 11.50. Figure 11.51 shows two concentric circles: The outer circle was picked first, and then the inner circle was picked. The resulting hatch filled a doughnut-shaped area on the part. Because default values were used, the pattern was a series of lines with a predetermined angle and spacing. The system inserted hatch-

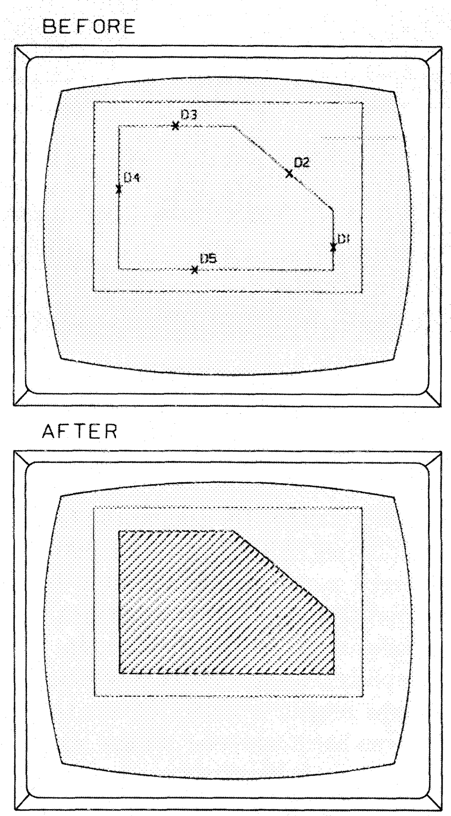


FIGURE 11.49 Defining Hatch Boundary

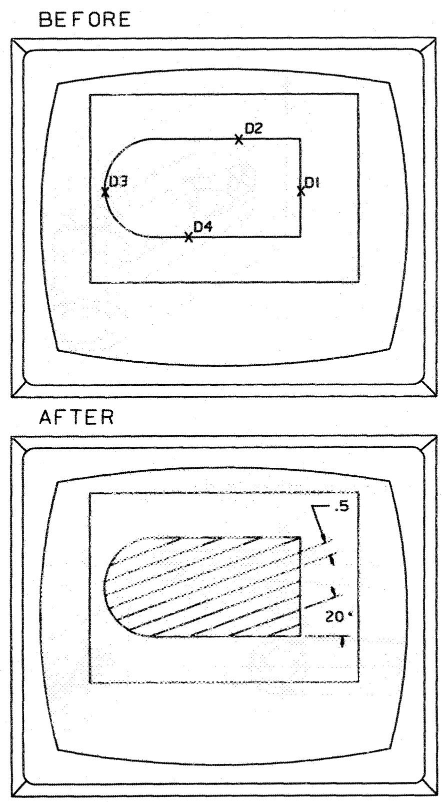


FIGURE 11.50 Altering Hatching Default Settings

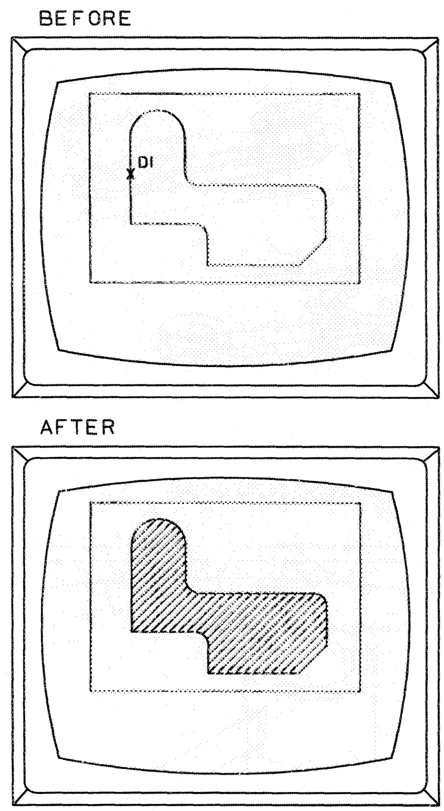


FIGURE 11.52 Using CHAIN Modifier on Personal Designer CAD Software

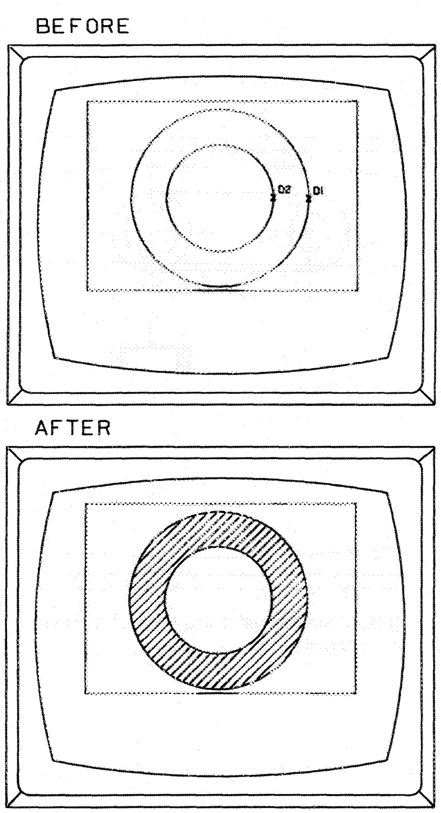


FIGURE 11.51 Hatching Interior and Exterior Areas

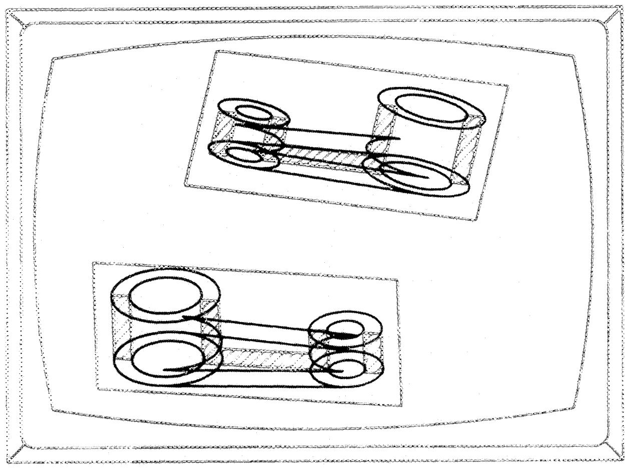
ing inward, starting at the boundary of the first (outer) circle. When an internal entity is encountered, the hatching turns off until another entity is encountered (each item must be picked in the command). AutoCAD has an option called **OUTERMOST,** which hatches from an outside boundary to the first interior boundary it encounters.

Some systems (though not AutoCAD) have a **CHAIN** capability. **CHAIN** is normally used with a command to select a series of connected entities quickly. The **CHAIN** modifier ties all entities that touch into a single, temporary unit. The area to be hatched is identified by entering the **CHAIN** modifier and then simply selecting one entity on the boundary. The area enclosed (linked) by the chain is then quickly hatched (Fig. 11.52).

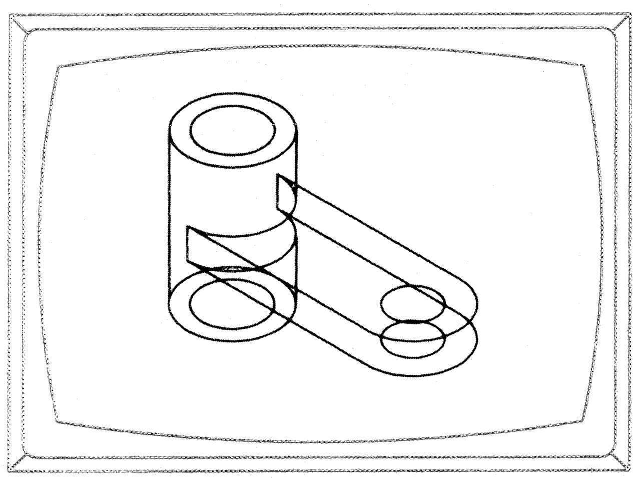
By creating a boundary with a string or a **polyline,** you can hatch an area by simply picking the entity. The system uses the polyline or string as the outer boundary for the hatch pattern.

11.5.3 Sectioning with 3D CAD

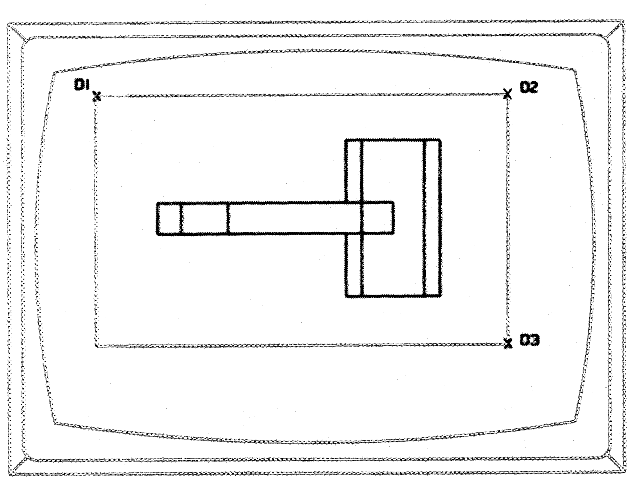
Because the section can be an actual 3D slice through the part at a selected level or along a defined plane, the 3D process is different. In Figure 11.53(a), a 3D model of the part is shown in two orientations. Unlike a 2D section, which is confined to its views on the drawing, the 3D model



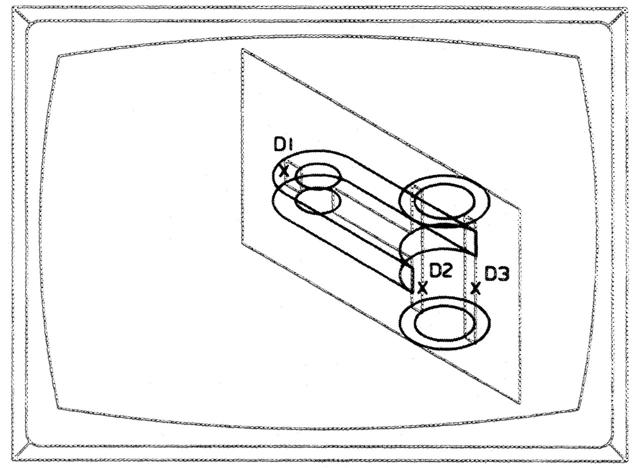
(a) Two-view orientations of 3D model



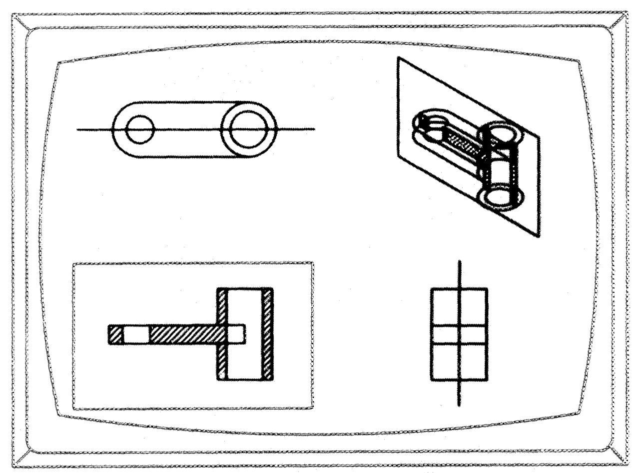
(b) Wireframe model



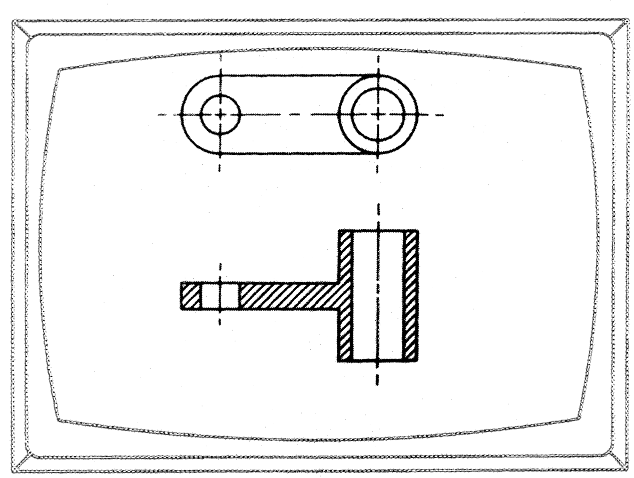
(c) Intersecting the model with a plane



(d) Inserting a hatch pattern in 3D



(e) Cut-plane, orthographic section views



(f) Displaying front section and top view of the part with correct visibility

FIGURE 11.53 Creating Sections with a 3D CAD System

can be displayed in multiple viewports, rotated, and viewed from any angle.

In Figure 11.53(b), a rotated view of the 3D part is shown as a wireframe model. Figure 11.53(c) shows the part in a front view; a plane has been established lengthwise along its center. A **CUT PLANE** (or **INTERSECT SURFACE**) com-

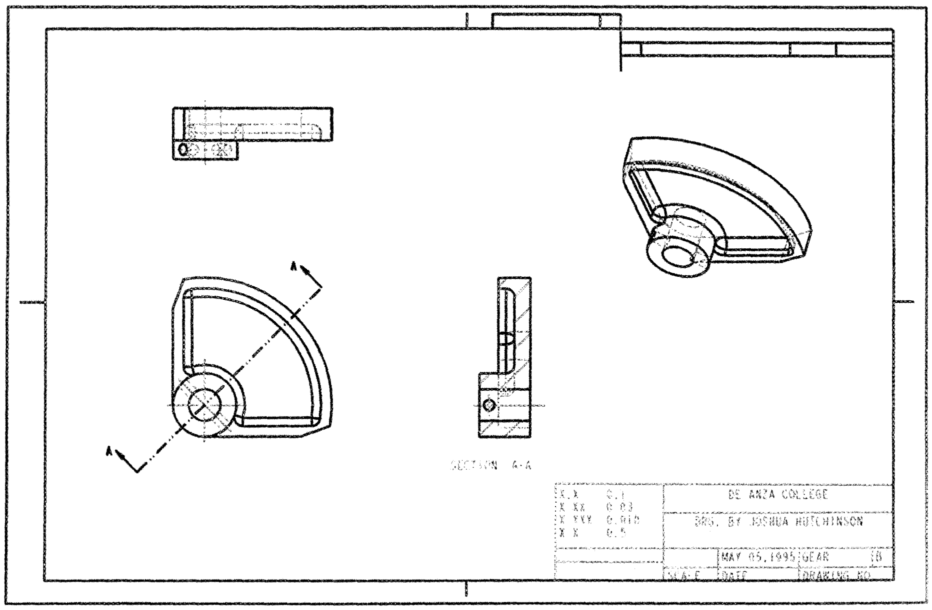


FIGURE 11.54 Part Displayed in Drawing with Section View

mand is used to section the model by selecting the plane (**D1**, **D2**, and **D3**) and then identifying the surfaces to be intersected. The rotated model is shown in Figure 11.53(d). Here, the cut lines are shown along with the plane used in the command. Figure 11.53(e) shows the section and the hatch pattern in the three standard views and in a rotated pictorial view. In Figure 11.53(f), the part is placed in the standard top view and front view orientations, the cutting plane is removed, and the drawing displayed according to ANSI projection standards. Centerlines are also added. The result looks basically the same when using 2D or 3D CAD or when drawn manually. However, with 3D CAD the section and model can be rotated to other positions. (The part in Figure 11.53 was designed and sectioned using Computervision's Personal Designer System.)

Figure 11.54 shows a part created as a parametric model, displayed in appropiate views and sectioned using a system command.

You May Complete Exercises 11.9 Through 11.12 at This Time

QUIZ

True or False

1. Sections describe the exterior of a part so that fewer views are required.
2. Sections and views are always rotated 90° as projections from existing views.
3. It is conventional practice to show all hidden lines that fall behind the cutting plane.
4. The cutting-plane arrows are always pointing in the direction of sight.
5. Section lines should be drawn thick, black, and close together so as to be readily seen and identified.
6. Material-specific hatching symbols are used on all drawings.
7. The placement of dimensions within sectioned areas is a common and accepted practice.
8. Intersections in sections always show the true projection of the elements.

Fill in the Blanks

9. A section is an ________ cut taken through an ________ .
10. Section lining on assembly drawings should be drawn at __________ angles for each __________ .
11. A __________ taken through an existing __________ view should be avoided.
12. Section lettering for identification of sections and views should be used in __________ __________ .
13. Thin sections are always shown __________ .
14. ____________ , ____________ , ____________ , and __________ are usually not shown sectioned.
15. The __________ symbol is used on most sectional drawings.
16. On simple parts or where the section location is obvious, it is common practice to ____________ the ____________ __________ __________ .

Answer the Following

17. What is the difference between a removed section and a revolved section?
18. When is a broken-out section likely to be used?
19. What are hatch patterns, and how are they used with a CAD system?
20. Describe the difference between a full section, a half section, and an external view.
21. What is an offset section, and when is it used?
22. What type of part features are rotated in aligned sections?
23. What is a cutting plane?
24. Name and describe three conventional practices used on sections.

EXERCISES

Exercises may be assigned as sketching, instrument, or CAD projects. Transfer the given information to an "A"-size sheet of .25 in. grid paper. Complete all views, and solve for proper visibility, including centerlines, object lines, and hidden lines. Exercises that are not assigned by the instructor can be sketched in the text to provide practice and to enhance understanding of the preceding instructional material.

After Reading the Chapter Through Section 11.3.2 You May Complete the Following Exercises

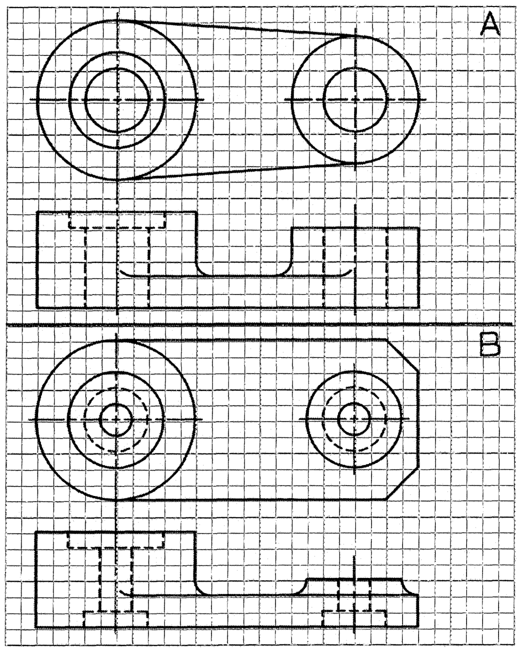
Exercises 11.1(A) and (B) Draw the two views of the part, and do a full section for the front view.

Exercises 11.2(A) and (B) Draw three views of the part. Construct a full front section.

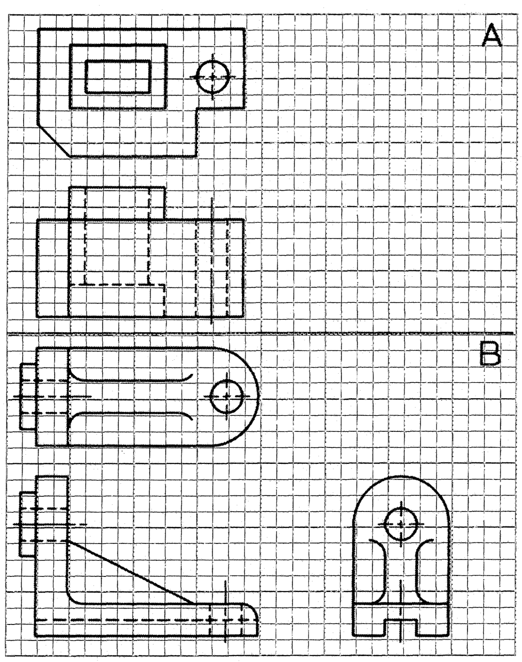
Exercises 11.3(A) and (B) Section the appropriate views for each problem.

Exercise 11.4(A) Draw a full left side section.

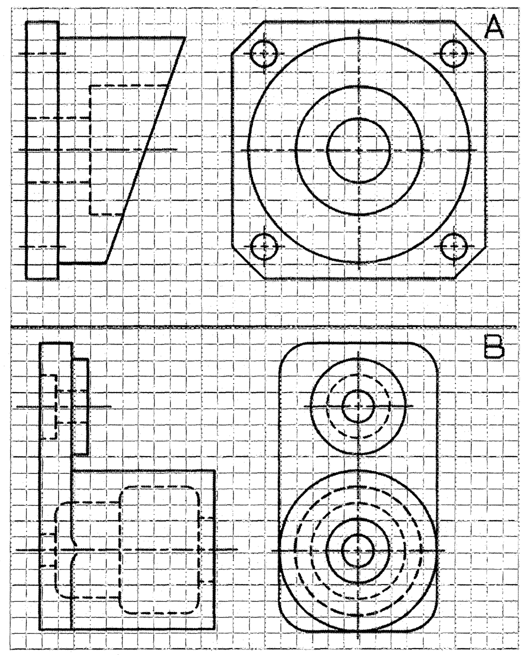
Exercise 11.4(B) Draw the two views. Construct a half section for the left side view.



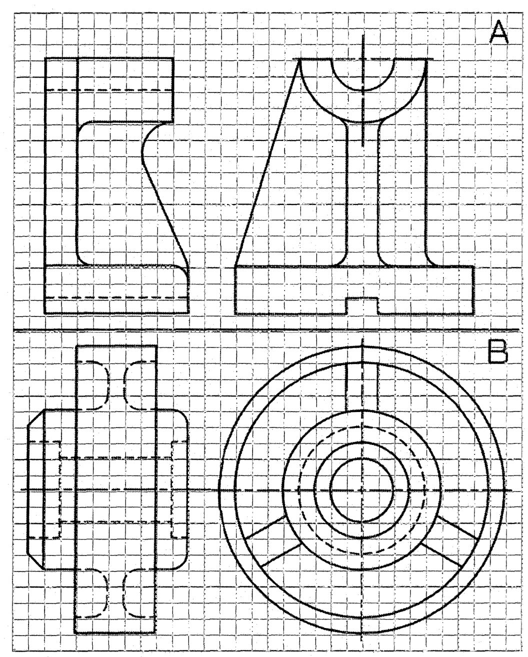
EXERCISE 11.1



EXERCISE 11.2



EXERCISE 11.3



EXERCISE 11.4

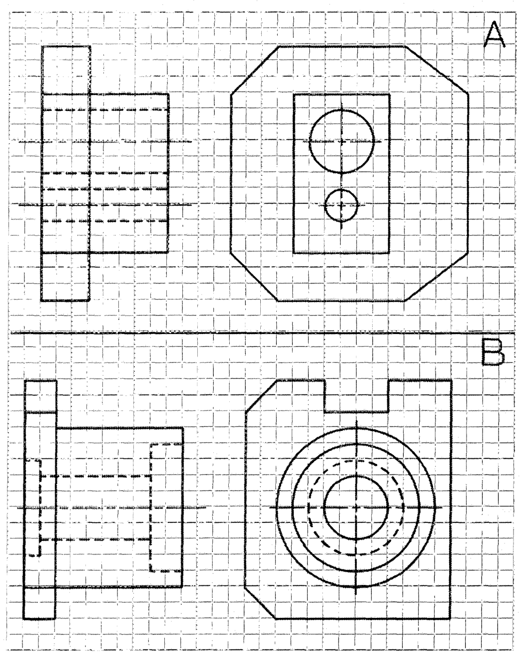
After Reading the Chapter Through Section 11.3.10 You May Complete the Following Exercises

Exercises 11.5(A) and (B) Construct a full left side section view for each part.

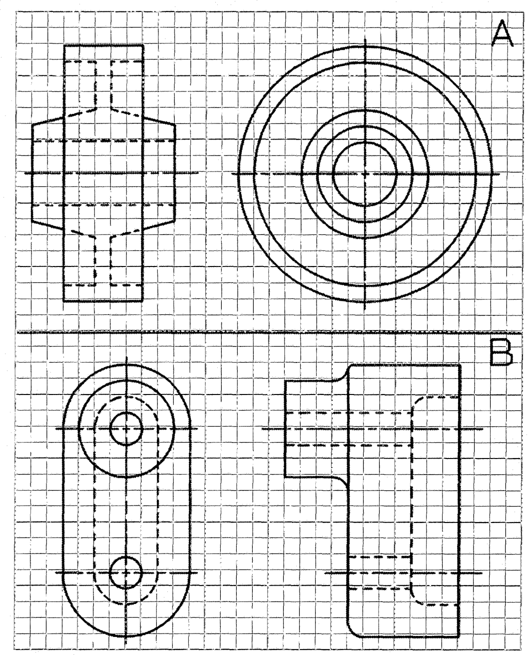
Exercises 11.6(A) and (B) Draw half sections of the parts.

Exercises 11.7(A) and (B) Draw full sections of the parts.

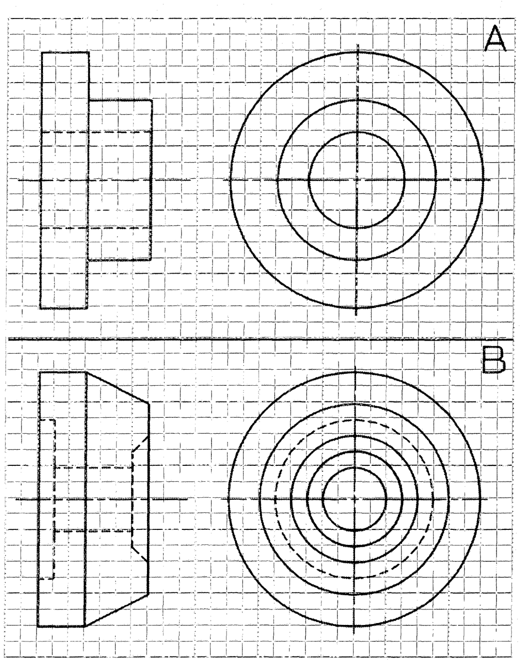
Exercises 11.8(A) and (B) Draw half sections of the parts.



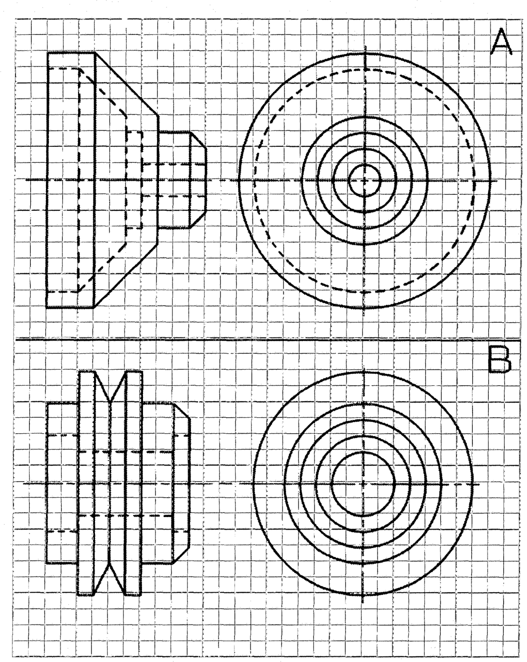
EXERCISE 11.5



EXERCISE 11.7



EXERCISE 11.6



EXERCISE 11.8

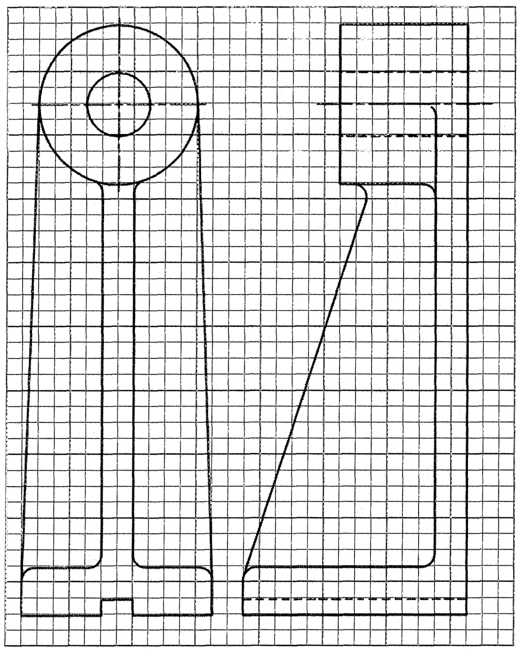
After Reading the Chapter Through Section 11.5.3 You May Complete the Following Exercises

Exercise 11.9 Section the right side view of the part.

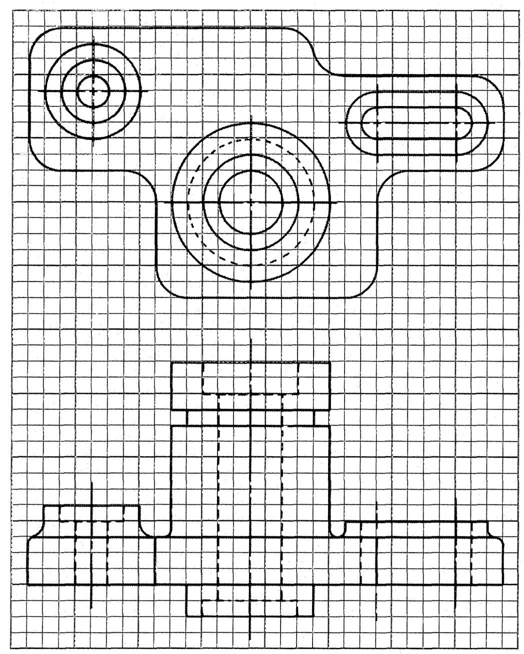
Exercise 11.10 Section the whole part in the right side view, and construct a partial (broken-out) section, as required, for the hub in the front view (left). The right side view is an aligned view.

Exercise 11.11 Draw an offset section of the part. Pass the cutting plane through the two holes and the slot.

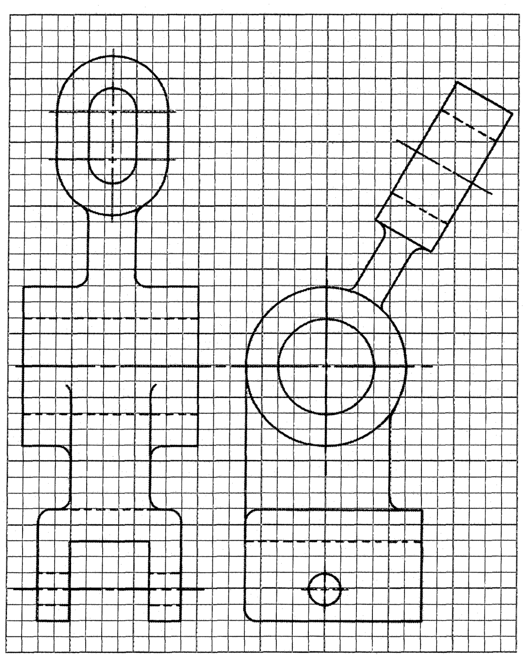
Exercise 11.12 Draw a complete full section of the assembly.



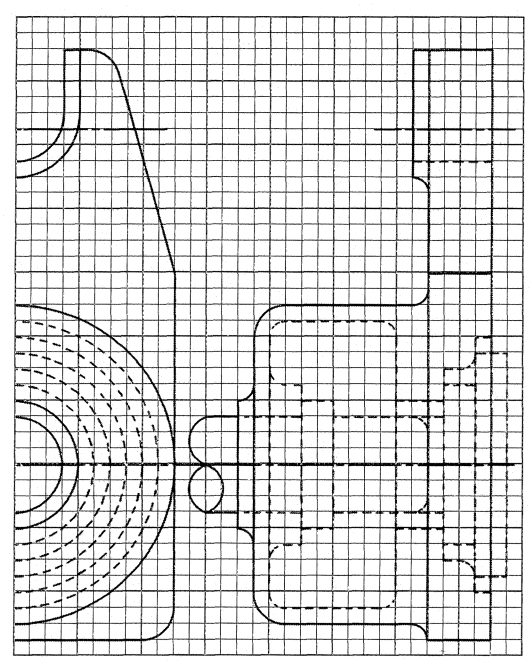
EXERCISE 11.9



EXERCISE 11.11



EXERCISE 11.10

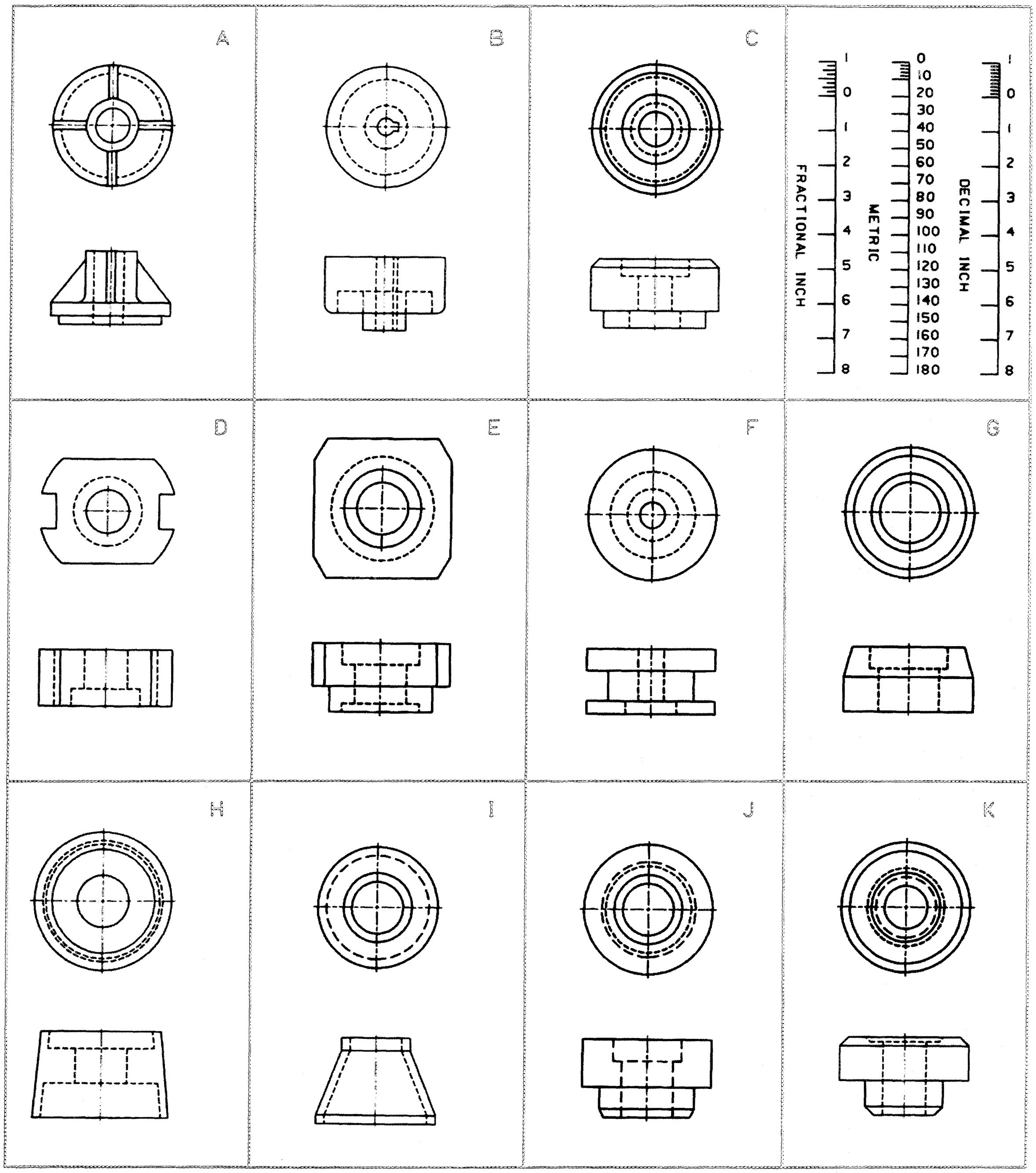


EXERCISE 11.12

PROBLEMS

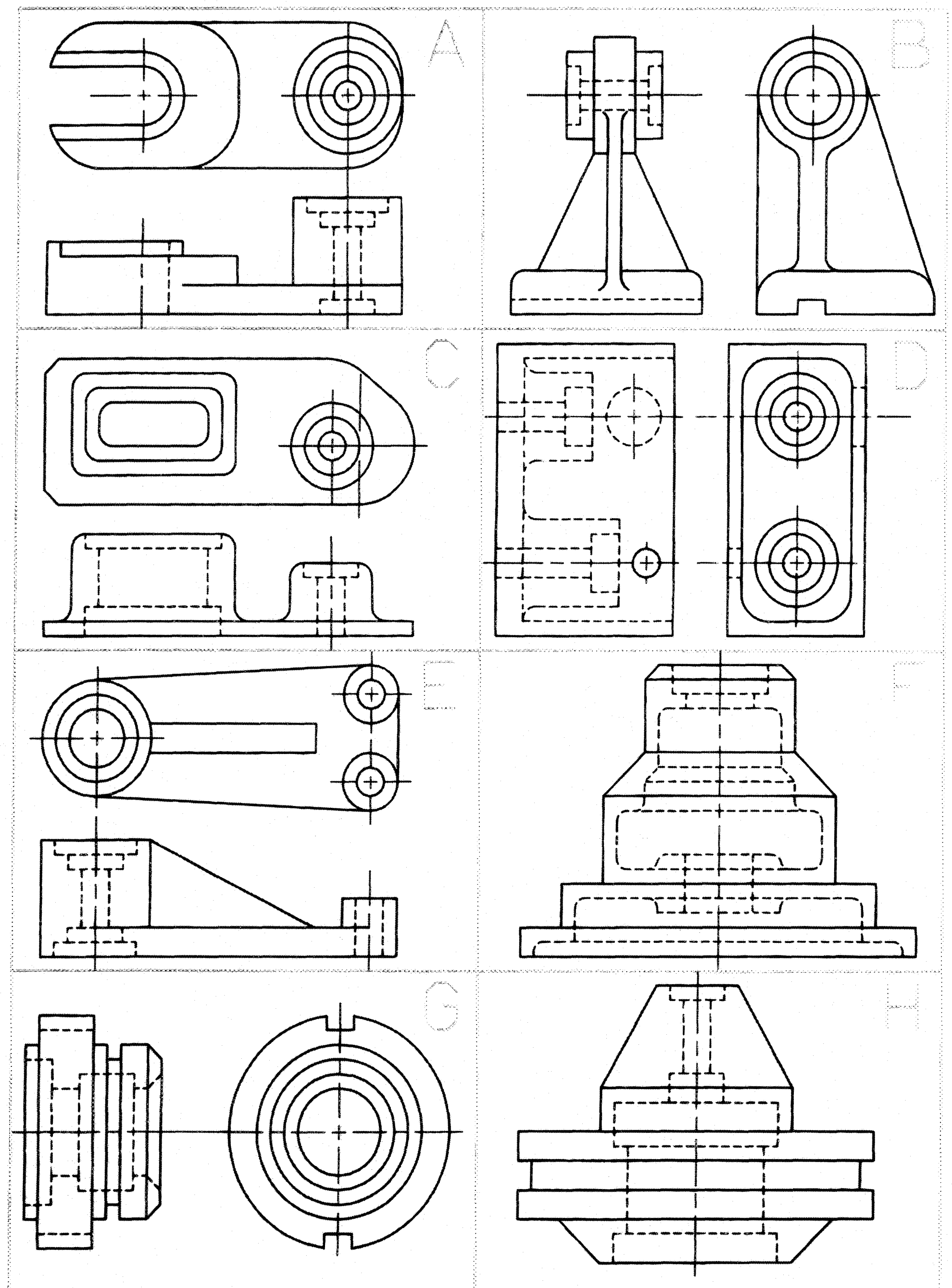
To use these same projects for dimensioning after covering Chapter 15, allow enough space between views and select an appropriate-size sheet of paper when completing these problems. Complete all views, and solve for proper visibility, including centerlines, object lines, and hidden lines. Do *not* dimension any of the following problems until you complete Chapter 15 or are requested to do so by your instructor.

Problems 11.1(A) Through (K) Using the scales provided, draw and section the appropriate views. Problems can be either metric, fraction-inch, or decimal-inch units. One, two, or three views may be required for a particular problem.



PROBLEM 11.1

Problems 11.2(A) Through (H) Same as Problem 11.1.



PROBLEM 11.2

Problems 11.3 Through 11.18 Establish the views and sections required to describe the parts properly. Do not dimension the parts. Use half sections, broken-out sections, aligned sections, and revolved sections where useful to describe the part. Complete all views, and add centerlines, hidden lines, and correct visibility for each problem.