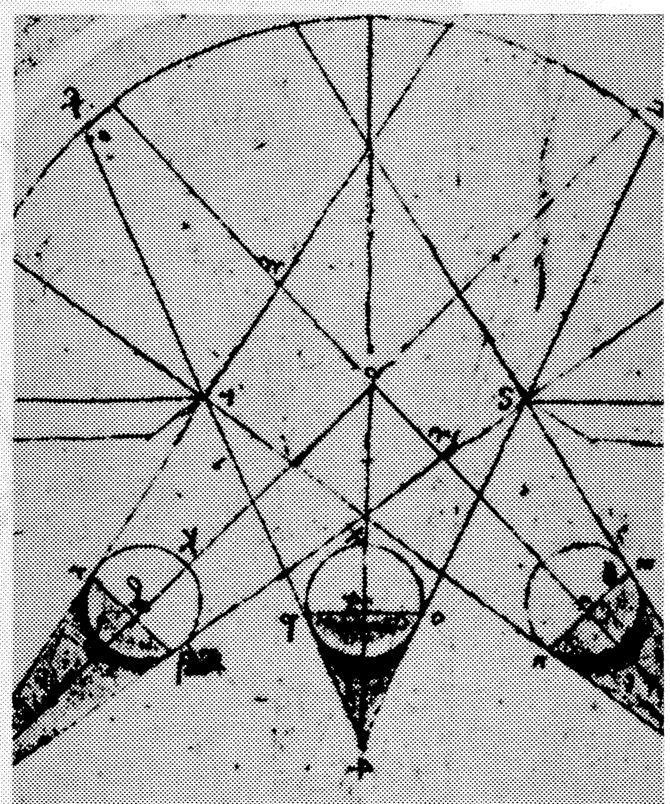
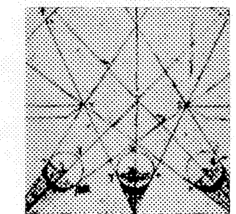
Part Two

BASIC GRAPHICAL MATERIALS AND PROCEDURES



Chapter 6



EQUIPMENT, MATERIALS, AND TECHNIQUES FOR ENGINEERING GRAPHICS

LEARNING OBJECTIVES

Upon completion of this chapter you will be able to:

1. Identify equipment and general drafting tools used in technical drawing.
2. Produce drawings with a variety of drafting instruments.
3. Exhibit knowledge of engineering drawing media and standard drawing formats.
4. Develop the ability to produce ANSI standard line types while recognizing preferred line precedence.
5. Master techniques for drawing construction and printable lines and curves.
6. Use triangles to draw a number of standard angles.
7. Understand the types of scales used on engineering drawings.

6.1 INTRODUCTION

Engineering drawing tools (Fig. 6.1) are used in all fields of engineering and design. Although CAD systems are found increasingly in industry, traditional (manual) drawing techniques and tools are still employed and will continue to be so for the foreseeable future. Therefore, as an aspiring designer or engineer, you must understand these procedures thoroughly and be familiar with drawing tools and techniques. Every engineering office uses—with varying degrees of sophistication—the equipment described in this chapter. The simple lead holder and the complex electronic pen are both important in the design process and share the same purpose.

This chapter covers equipment, instruments, materials, and drawing techniques used in the engineering office. **Equipment** includes drawing boards, drafting machines, print machines, T-squares, triangles, templates, and computer-aided design hardware. **Instruments** are precision-manufactured drawing tools, such as the compass and dividers, in all their variations. **Materials** comprise drawing media (vellum and drafting film) and related support items, such as grid underlays, preprinted title blocks, transfer drafting aids, and print paper.

Techniques are the methods used by the drafter to complete a drawing; they are covered at the end of this chapter. This chapter's primary focus is on equipment and tools and on the methods and techniques of creating a drawing manually. Engineers and designers must know how to use their equipment, instruments, and materials to communicate effectively. The originator and the reader of an

FIGURE 6.1 Drafting Tools

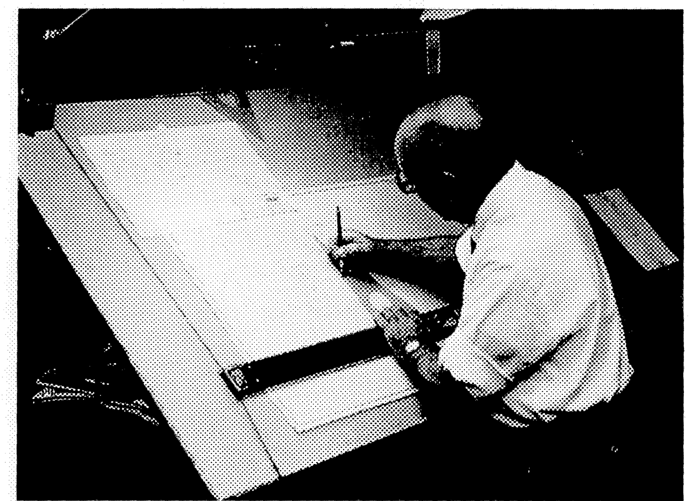


FIGURE 6.2 Drafting Table with Parallel Bar

engineering drawing must understand the procedures, conventions, and concepts used in the drawing. In all fields of engineering drawing and design, symbols, linework, projection procedures, and notation must be in accordance with standard conventions.

6.2 EQUIPMENT

The most important and conspicuous piece of equipment in any engineering office is the **drafting table.** Originally, all engineering drawing was done on flat-surfaced wood drawing boards. Normally, one or more edges were cut as straight and square as possible, creating a "straightedge" that the drafter could use to guide a T-square. Today, board sizes range from hand-carried versions to large-format standalone tables. The table in Figure 6.2 is vertically adjustable and can be tilted to any comfortable angle. Modern tables may be power operated. Whatever the drafting table's size or material, the table surface must have a pliable cover. This can be Borco vinyl (or linoleum) or some other plastic or vinyl covering that permits drafting without destroying the table surface or marring the drawing medium.

Light tables are also used throughout industry to prepare printed circuit artwork, draw pictorial illustrations, and do tracing. Normally, the drawing surface is an opaque glass or plastic sheet that scatters the rays from the light source. Figure 6.3 shows a modern light table and reference desk. Here the tabletop and the light mechanism are an integral part of the drawing surface.

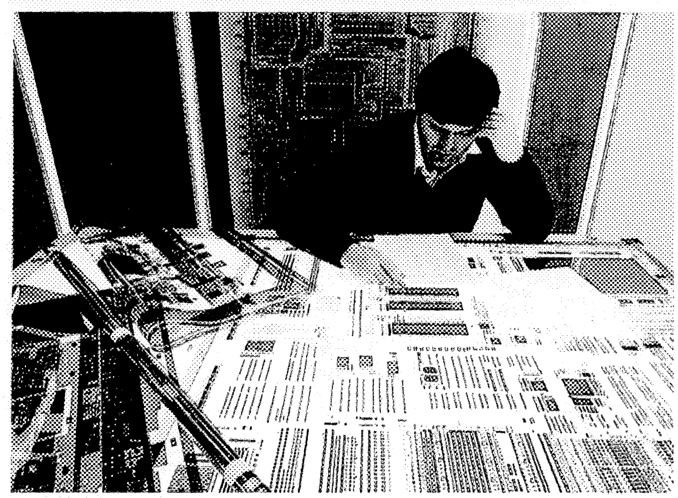


FIGURE 6.3 Light Table Used for Electronic Circuit Layout

6.2.1 Storage and Reproduction Equipment

After a project is drawn, regardless of the method, it must be stored and reproduced. Frequently, drawings are stored as paper originals and prints in multiple-drawer cabinets and in tube storage systems. Because drawings must be cataloged and available for several departments, this method of storage is time-consuming and requires considerable office space, but it is still widely used.

Drawings can also be stored on **microfilm** and **microfiche.** Computer graphics systems enable the user to reproduce, almost instantaneously, design data stored on disk or tape. Another form of reprographics uses 35-mm micrographic **aperture cards** or **design data cards** (Fig. 6.4). Design data systems are used with manually produced drawings or with CAD drawings. When a new or revised drawing is checked and ready for release, it is taken to a processor camera (Fig. 6.5). In seconds, a master data card (an accurately reduced version of the original drawing) is produced. Multiple copies of the data card are then made from the original, for distribution. You can review the drawing with a display device.

Aperture data cards enable the user to make prints quickly, with several reductions and enlargement options. The copier shown in Figure 6.4 can copy a drawing on various kinds of paper and instantly switch enlargement sizes. The copy paper is manually fed into the front of the copier, and the viewing screen allows easy monitoring.

FIGURE 6.4 Aperture Card Drawing Reproduction System

Traditionally, the **blueprint machine** was used to make multiple prints of drawings. The term "blueprint" is no longer accurate, since the prints are actually white, or what are sometimes called blueline prints. **Whiteprint machine** (Fig. 6.6) is a more accurate term, because reproduction with this method involves developing a print with blue lines and white background. These machine are sometimes referred to as **blueline machines.**

When a drawing is completed on a CAD system, it is reproduced with a hard-copy device such as a photocopier or a plotter. The pen plotting method allows the reproduction of an accurate original every time the drawing is plotted. Multiple copies can then be made from a whiteprinter or from input to a data card system.

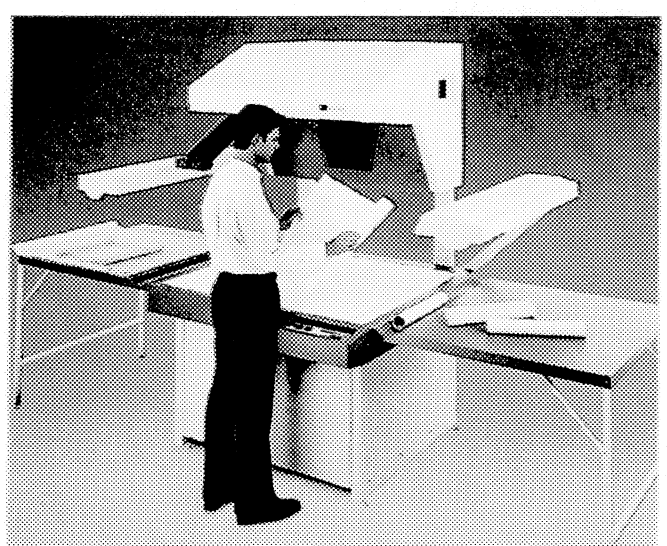


FIGURE 6.5 Microfilm Processor Camera

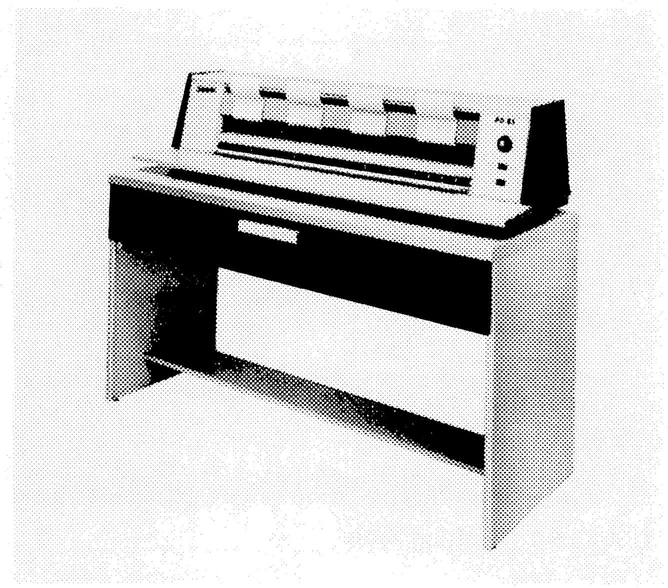


FIGURE 6.6 Whiteprinter

6.2.2 Straightedges

Originally, the primary horizontal straightedge device used in engineering drawing was the **T-square** (Fig. 6.7). This piece of equipment is still found in a few classrooms and for personal drafting. Because the T-square is the most difficult to manage of all straightedge drawing devices, it is said that "if you can draw with a T-square you can draw with anything." If you must learn by using a T-square, you will be glad to know that once you master it, other straightedges will be easier. Wielding a T-square is difficult because it is the easiest to misalign of all straightedge devices. The bar portion of the T is placed along the edge of a drawing board or table. Parallel horizontal lines are drawn with the length

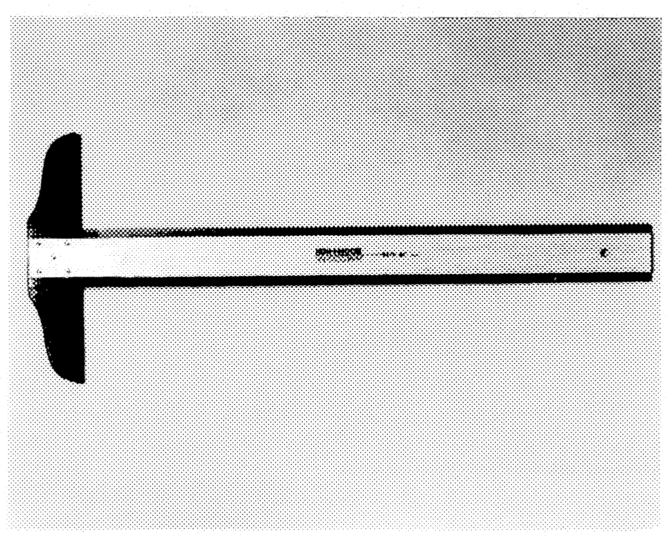


FIGURE 6.7 T-square

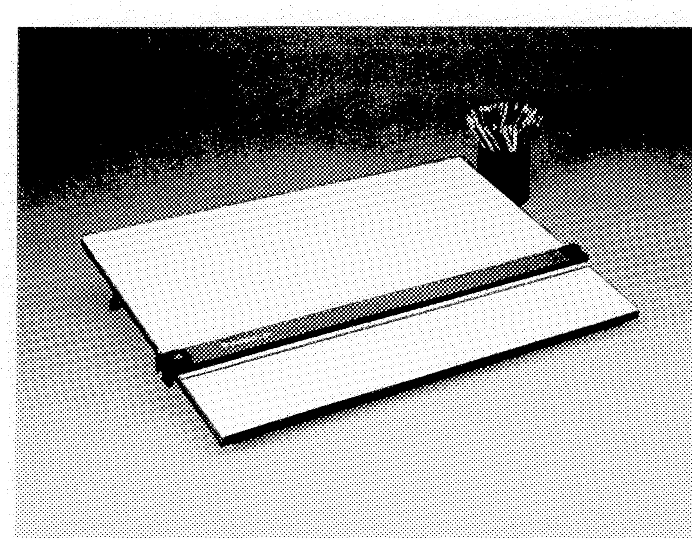


FIGURE 6.8 A Parallel Straightedge

of the T-square, and parallel vertical lines are drawn with a triangle placed against the top edge of the horizontal bar. Obviously, if the T-square and the table edge are not aligned properly, your linework will be inconsistent.

The **parallel straightedge** (Fig. 6.8) is found throughout industry, especially for large drawings such as those required in architecture, piping design, and civil-mapping engineering. The parallel straightedge is attached to the drawing table by a series of cables and pulleys. It remains parallel or at a preset angle to the drawing table as it is moved up or down on the table surface. Parallel straightedges are excellent tools

FIGURE 6.9 Arm Drafting Machine

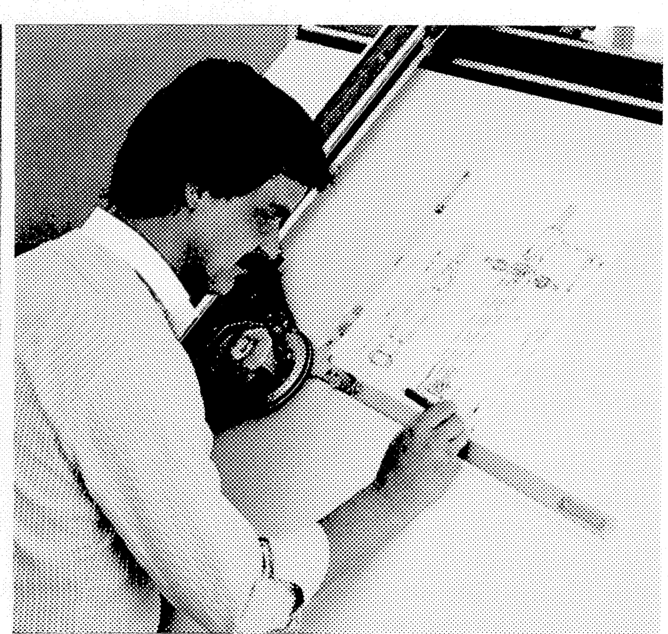


FIGURE 6.10 A Drafter Using a Track Drafting Machine

when the drawing consists of long, straight, parallel horizontal lines.

The **drafting machine** comes in two standard versions: the drafting arm type (Fig. 6.9) and the track type (Fig. 6.10). The track type is the more accurate. Drafting machines are mounted on drawing tables, as shown in these figures. The control head on the drafting machine can be rotated to any angle and set by pushing a button to lock at increments of 15°. It must be hand-locked for intermediate angles. When using a drafting machine, or any straightedge, avoid dragging the equipment across the drawing.

Drafting machines (Fig. 6.11) take the place of triangles, protractors, and scales, but you must still know how to use all types of equipment and instruments.

Regardless of the type of drawing table and straightedge,

FIGURE 6.11 Drafting or Drawing with an Arm Drafting Machine

proper lighting is also essential for relaxed, unstrained work with manual drawing techniques. Since the CRT screen is easier to read if it is shaded from external light sources, lighting requirements are different when using a CAD system.

6.3 GENERAL ENGINEERING DRAWING TOOLS

Traditional manual engineering drawing requires a variety of small tools, instruments, and equipment (Fig. 6.1), for example, special templates, triangles, pencils, lead holders, and technical inking pens. The quality of your engineering drawing is directly influenced by the range and quality of your tools and equipment. This is not to say that expensive, high-quality tools, by themselves, will draw the project. But good-quality tools are beneficial for fast, efficient, and precise linework and projection.

Engineering drawing kits are available from a variety of reputable companies that are sufficient for most classes in engineering drawing. However, precision, high-quality tools and instruments can be purchased individually. Table 6.1 lists standard engineering drawing tools you can buy. Essential items are distinguished from optional items, which can be added as needed.

TABLE 6.1 **Equipment**

Essential Items	Optional Items
Pencils (grades 4H, 3H, 2H, H, HB)	Lead holders
Sandpaper block	Thin-line pencil
Erasers	Electric eraser
Dusting pad or powder	Adjustable triangle
Erasing shield	Symbol templates
Drafting tape	Lettering guide
Drafting brush	Lettering template
Scales (metric, architect, mechanical, civil)	Drop compass
Protractor	Beam compass
30°/60° triangle	Compass inking attachment
45° triangle	Technical inking pens
Irregular curves	Ink
Templates (circle and ellipse)	Ink eraser
Bow compass	Lettering set
Dividers	Grid paper
Drafting board	Drafting table
Straightedge (T-square, parallel straightedge)	Flexible curve
Calculator	Drafting machine
Paper (vellum, drawing film)	

6.3.1 Pencil Leads and Pencils

Drawing **pencils** are graded by the hardness of their lead. The hardness of the lead determines the kind of line that can be drawn. A hard lead can make a very sharp, thin line, but it will lack the darkness and density necessary to make a good print. A soft lead will make dark lines, but it is very difficult to keep sharp. "H" lead grades are used for engineering drawing on vellum. The "H" grades are, from hardest to softest: 9H, 8H, 7H, 6H, 5H, 4H, 3H, 2H, H, F, and HB (Fig. 6.12). The recommended hardness for lead used on vinyl-topped engineering drawing boards with a good grade of paper are:

- 6H–3H for layout and construction lines
- H–HB for reproducible (printable) lines
- H–HB for lettering

The appropriate hardness of lead, combined with proper drawing techniques, will help produce good, reproducible drawings with sharp, dense lines that make good prints. The skills required to use engineering drawing tools and equipment comes only through practice. Engineering drawing is a skill that must be cultivated throughout your career, not just in school.

Engineering drawing pencils are made in three types: the

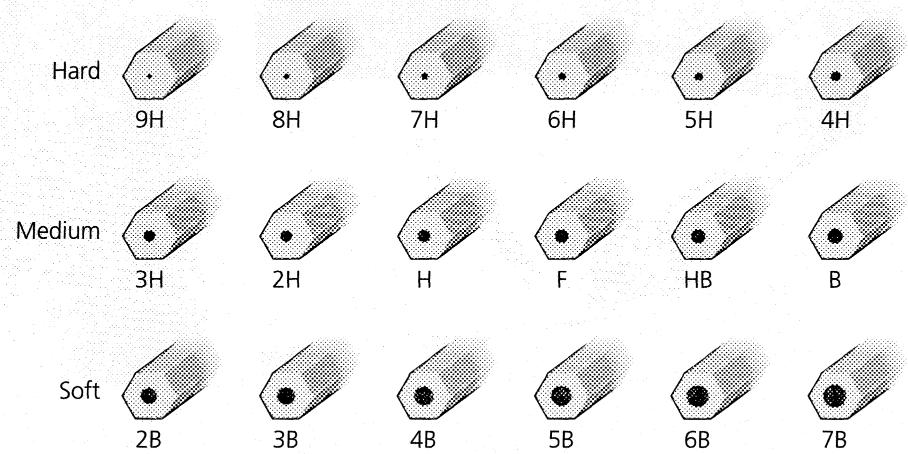


FIGURE 6.12 **Pencil Lead Types**

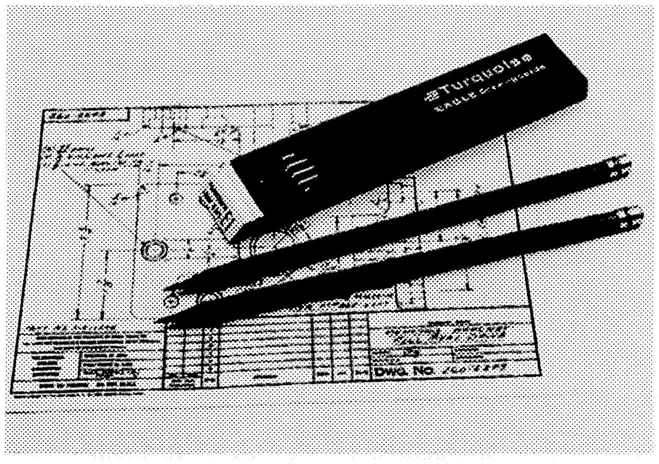


FIGURE 6.13 Drawing Pencils and Leads

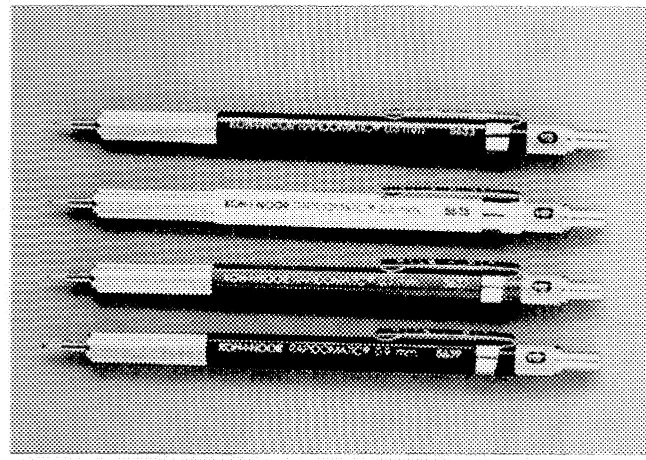


FIGURE 6.15 Fine-Line Mechanical Pencils

familiar **wood pencil** (Fig. 6.13), the **mechanical lead holder,** which uses engineering drawing leads, and the **fine-line mechanical pencil.**

The mechanical lead holder holds a single piece of lead (Fig. 6.14). Having more than one lead holder available with a variety of leads makes it easy to change line weights and types. This drawing tool is easily sharpened, and increases the speed, consistency, and ease of engineering drawing. The mechanical pencil allows the length of exposed lead to be adjusted, both for sharpening and for drawing, without decreasing the length of the holder, which is what happens when sharpening a wood pencil.

The automatic drawing pencil (fine-line pencil) is excellent for drawing lines and letters of consistent width. It never requires sharpening. Automatic drawing pencils come in metric sizes: 0.3, 0.5, 0.7, and 0.9 mm (Fig. 6.15). These sizes are used to draw the typical line weights, 0.25–0.35 mm (centerlines, dimension lines, construction lines), 0.5–0.7 mm (object lines, diagram lines, hidden lines), and 0.7–0.9 mm (cutting plane lines, border lines). Unlike the mechanical engineering drawing pencil, the fine-line pencil holds only one thickness of lead, so you must purchase a number of them. Of course, if you are using a small-width fine-line pencil, you can make the line any width desired by

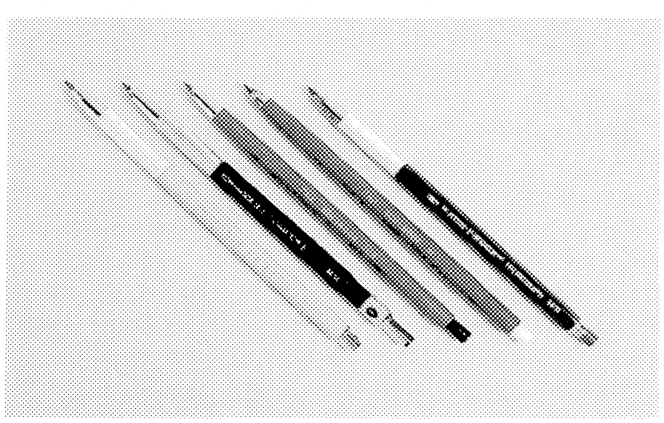


FIGURE 6.14 Mechanical Lead Holders

thickening the line. The thinner the lead, however, the more frequently it breaks. Fine-line pencils are sometimes difficult to use with lettering guides and templates.

Regardless of which type of drawing pencil you choose, purchase a variety of leads (Fig. 6.12). Standard leads for vellum range from soft and dark (6B, 5B, 4B, 2B, B, HB, and F) to the medium hard and dark (H, 2H, 3H). The hardest and lightest types are 4H, 5H, 6H, 7H, 8H, and 9H. In general, only the medium leads are used: 2H and 3H for construction lines and blocking in a drawing, H for darkened finished lines. Some drafters prefer HB for finished lines (printable), but great care must be taken to ensure that the drawing is kept clean and unsmudged. To attain a good-quality reproduction, all lines must block light if a whiteprint machine is used, and they must be dark, crisp, and thick enough to be recorded by a camera if a photocopier or an aperture card machine is used. Plastic leads are employed on drawing film. Plastic leads come in three grades: E1, K, and CF.

6.3.2 Pencil Sharpeners/Pointers

Mechanical lead holders and wood pencils require frequent sharpening or pointing. A sharp conical point is needed to make the thin erasable lines required for construction lines. With the lead holder, the lead is sharpened with a pencil pointer that sharpens only the lead; the wood pencil must have the wood cut away before it is sharpened with a engineering drawing pencil sharpener or a knife (Fig. 6.16).

For darkened finished linework, the pencil point is dulled slightly on scrap paper to avoid frequent breaking and for drawing wide lines. *To maintain the line thickness, the pencil or lead holder should be rotated as the line is drawn.* A sharpened, then slightly dulled lead point is required for lettering. The advantage of a fine-line pencil is that the lead never needs sharpening.

The **pencil pointer** sharpens by cutting away only the lead, and produces a uniform conical shape with a rather long taper. The taper should be three to four times the

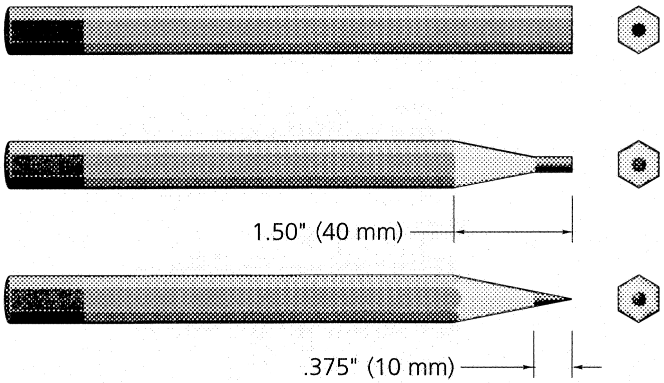


FIGURE 6.16 Sharpening Wood Pencils

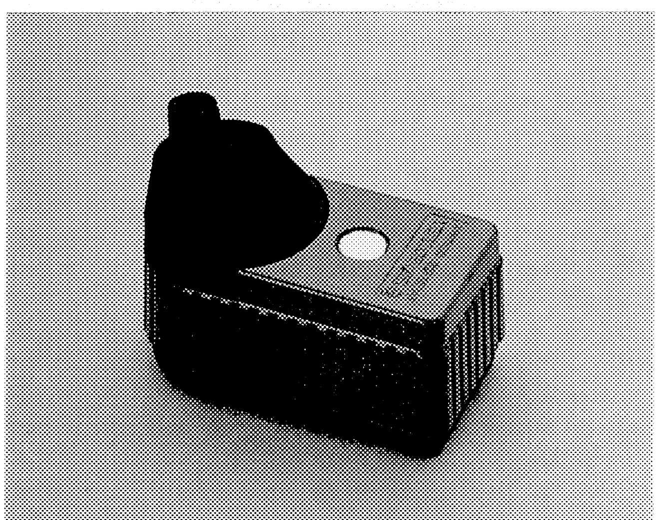


FIGURE 6.17 Mechanical Pencil Sharpener

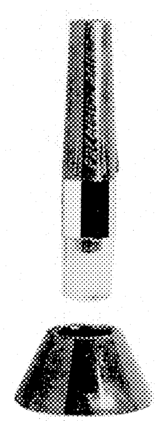


FIGURE 6.18 Sharpener

diameter of the lead. Several good pointers are available that use a ribbed cylindrical metal cutter. Depending on the type of pointer, the pencil or lead holder is put into a hole in the cover and rotated around the cutter (Fig. 6.17). Figure 6.18 shows an inexpensive hand-held pointer for mechanical lead holders.

Another sharpening device for wood pencils and lead

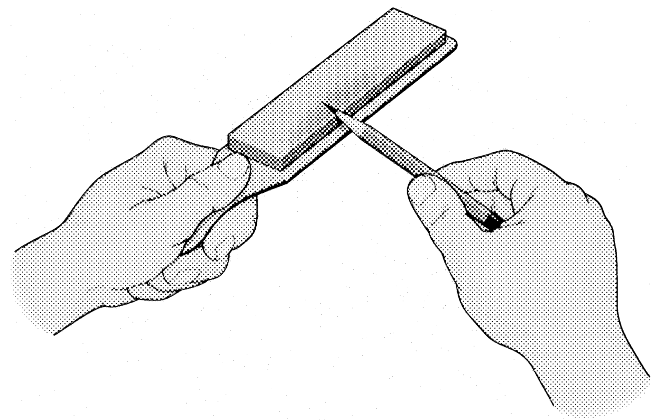


FIGURE 6.19 Sharpening a Pencil with a Sandpaper Block

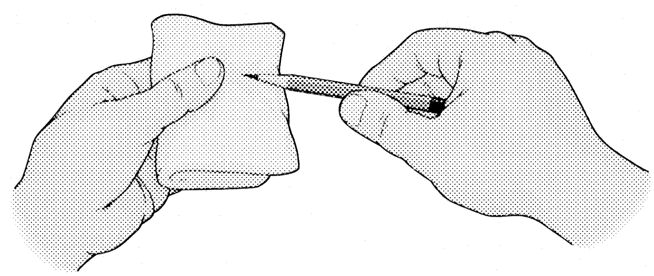


FIGURE 6.20 Cleaning a Pencil Tip

holders is the **sandpaper pad/block.** The pencil or lead holder is rotated as the point is sanded (Fig. 6.19). A sandpaper pad can also sharpen lead points on compasses. Compass leads are sharpened as wedge shapes instead of conical points in order to keep the edge sharper longer. After sanding the lead, wipe it clean with a soft cloth or tissue (Fig. 6.20).

6.3.3 Erasers and Erasing Shields

Erasing is a necessary part of engineering drawing and, when done properly, enables you to improve and correct drawings easily (Fig. 6.21). The **eraser** should have good "pick-up" power without smudging. Eraser selection is based primarily on the engineering drawing medium you are using (vellum, film, etc.).

Erasers come in many shapes and sizes, from hand-held to electric, and in many grades. Pink Pearl, white composite, and Art Gum erasers are used for both paper (vellum) and engineering drawing film. Special vinyl erasers are available for erasing inked drawings on engineering drawing film. Note that ink is extremely hard to erase on paper. An **electric eraser** (Fig. 6.22) is essential in this situation, but great care is required to avoid rubbing holes in the paper. Care should also be taken when using an electric eraser on engineering drawing film since it tends to destroy the tooth, or surface, of the engineering drawing film. To erase ink drawings completed on film, apply a small amount of

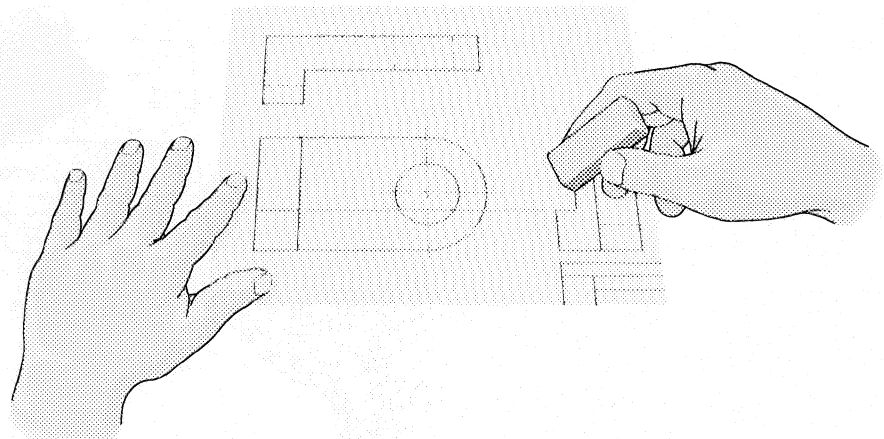


FIGURE 6.21 Erasing

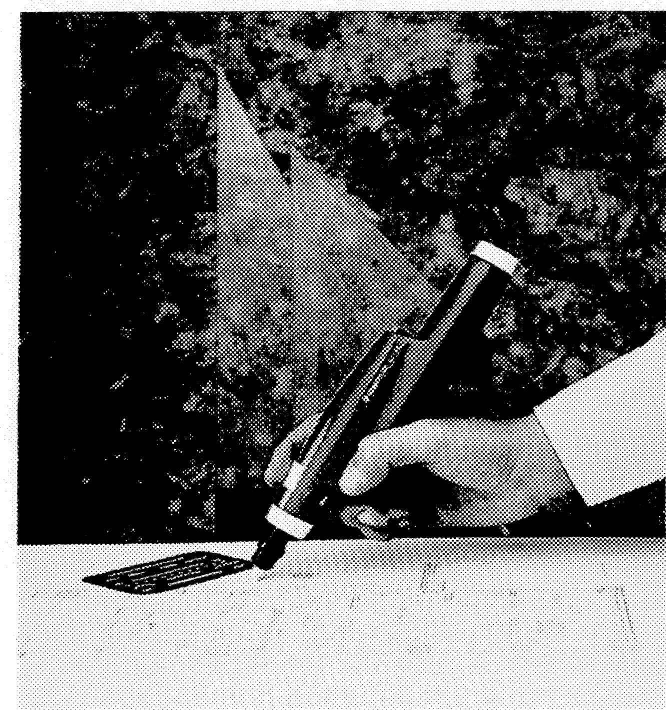


FIGURE 6.22 Electric Eraser

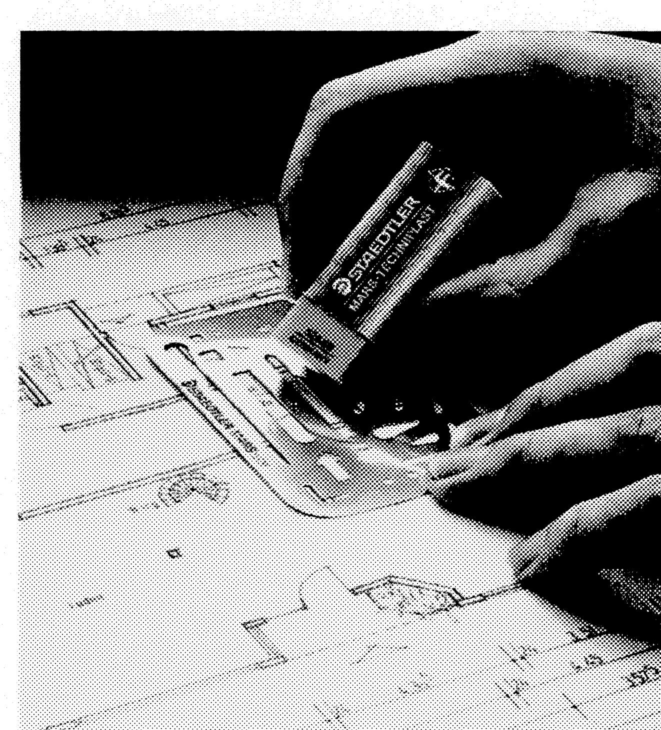


FIGURE 6.23 Erasing Shield

moisture to a vinyl eraser and carefully rub the area to be erased.

To protect adjacent areas of the drawing that are to remain, most erasing is done through the perforations of a stainless steel erasing shield (Fig. 6.23). The **erasing shield** is held firmly in place on the drawing with one hand while the other hand erases through a selected opening (Fig. 6.24). Care must be taken not to erase other areas through adjacent openings.

Eraser crumbs should immediately be swept from the drawing with the engineering **drawing brush** (Fig. 6.25). The crumbs should not be rubbed with the hand—each graphite-laden crumb will act as a dull pencil and make smudges. Figure 6.26 shows an engineering drawing and a brush.

A dry cleaning pad (an erasing dust pad) is another way to keep drawings clean and unsmudged. **Dry cleaning**

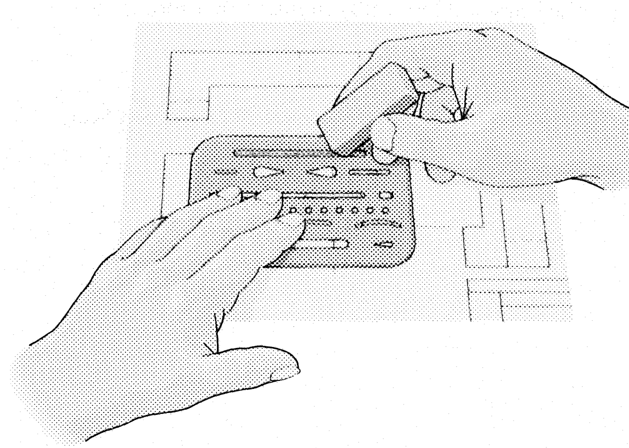


FIGURE 6.24 Using an Erasing Shield

FIGURE 6.25 Brushing the Drawing

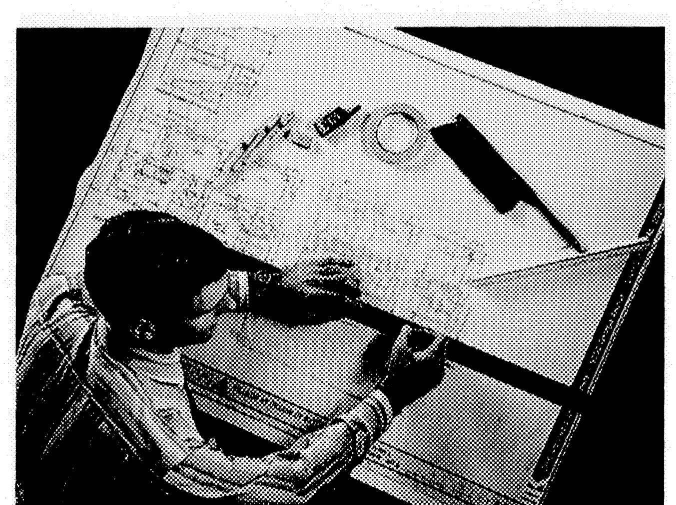


FIGURE 6.26 Drafting Brush

pads, which contain finely ground eraser pieces and powder, can remove dirt and leftover crumbled graphite deposited during drawing and lettering. Do not drag a dry cleaning pad across the drawing. Instead, after a small portion of the drawing is complete, lightly pat the linework and lettering. Then, with a brush, sweep the drawing clean of powder and dirt. Although you must be careful not to lighten the lines and lettering too much by rubbing, frequent patting and dusting ensure a higher-quality drawing. Never use a dry cleaning pad when inking with technical pens. Some designers cover the entire drawing with a very light layer of erasing powder; others find this method messy and uncomfortable. Try different methods in order to discover which works best for you.

6.4 DRAWING SCALES

All instrument drawings are drawn accurately at one size, which may be a reduced or an enlarged size, so that all features of the part are in proportion. Such a drawing is said to be drawn *"to scale."* Some mechanical drawings are drawn to a reduced size, and some are drawn to an enlarged size. CAD drawings are drawn 1:1 (full size) and plotted at any convenient size or scale. Table 6.2 compares the four basic scales.

Since construction projects—piping, structural, architecture, and civil—are large and the paper size is small, all of these drawings are done at a reduced scale. Some mechanical drawings are also drawn to a reduced size. The instrument used to measure and layout these drawings is called a **scale** (not a ruler—a ruler makes only full-size measurements).

Certain scales are used in construction work: the civil engineer's scale, the architect's scale, and the metric scale for

TABLE 6.2 Scales

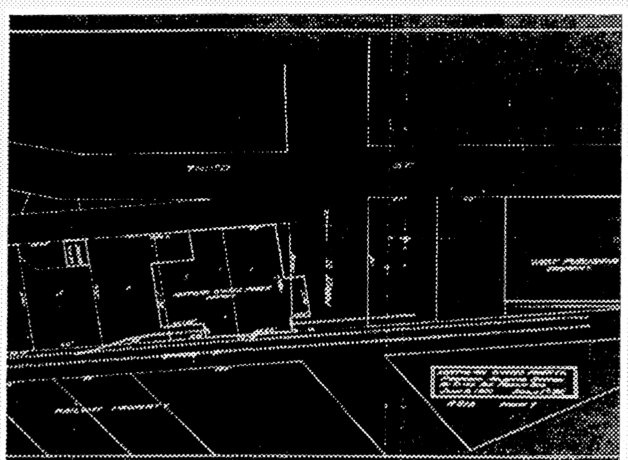
Architect's Scale	Mechanical Engineer's Scale	Civil Engineer's Scale	Metric Scale
$\frac{3}{32}$	1 in. = 1 in. (full size)	10 divisions/unit	1:10
$\frac{1}{8}$	$\frac{1}{2}$ in. = 1 in. ($\frac{1}{2}$ size)	20 divisions/unit	1:20
$\frac{3}{16}$	$\frac{1}{4}$ in. = 1 in. ($\frac{1}{4}$ size)	30 divisions/unit	1:25
$\frac{1}{4}$	$\frac{1}{8}$ in. = 1 in. ($\frac{1}{8}$ size)	40 divisions/unit	1:33.3
$\frac{1}{2}$		50 divisions/unit	1:50
1		60 divisions/unit	1:75
$1\frac{1}{2}$		80 divisions/unit	1:100
3			1:150

Focus On . . .

REPRODUCTION EQUIPMENT

You have probably heard the term *blueprint* to describe an engineering drawing. Blueprinting is a reproduction technique that was, for many years, the only way to duplicate engineering drawings. It is a photographic process in which the original drawing is the negative. The paper for the duplicate print is treated with chemicals that are sensitive to light. After the paper is exposed, it passes through a developing or fixing bath and is then rinsed and dried. The end product is a print (the same size) with blue background paper and white lines.

As more and more engineering drawings were created, it became evident that a new reproduction process that was fast, exact, cost effective, and simple was needed. Considering the number of hours invested in engineering drawings, it seems reasonable that people would also invest many hours trying to create the best reproduction process for those valuable drawings.



Early reproduction process (blueprint).

The *diazo process* was the answer. This process produces a positive print with dark lines on a white background. Light is transmitted through the original onto chemically treated paper. Developing is completed by one of three processes: dry (utilizing an ammonia vapor), moist (transferring an ammonia solution to the print), or pressure (a thin film of activator is deposited on the exposed paper). You can easily read marks and notations made directly on the print with this method. Unfortunately, the prints soil easily and the life of a print is relatively short.

The next evolution in reproduction equipment was developed from an idea that originated in 1937. In that year, a young law student named Chester Carlson developed a method called *xerography* to make copies. (The word *xerography* comes from the Greek words for "dry" and "writing.") A copy made by this method became known as a Xerox. No doubt you have also heard of Xerox, the company that developed and marketed this process throughout the world. Of course, it was only a matter of time until reproduction equipment was made large enough for copying drawings. This process can produce a copy not only from an original, but also from a copy. Enlarged or reduced-size copies are also possible.

Today, a copy of a computer-generated drawing can be produced with a laser printer/plotter. A laser plotter uses a laser to form areas of static charge to attract metallic powder to the paper. The process produces sharp, clear prints, is extremely fast, and is inexpensive enough to be used in small engineering offices. Laser printers have become an integral part of the engineering workplace.

When you walk into an engineering firm today, you could see a diazo print, a Xerox print, or a print produced with a laser plotter. Regardless of the method used to produce the print, many engineers, designers, and drafters ask for a "blueprint" of the latest product or assembly even though blue paper with white lines hasn't been around for many years.

Whatever the next evolution is in reproduction equipment, it will probably be faster, more accurate, easier to use, and more economical—just like all the other versions. Yet whatever process we use, we will probably call the print a "blueprint."

SI projects. The engineer's scale is for drawing very large objects, for example, earthworks, roads, and surveys of property. The architect's scale is for drawing buildings and structures. Generally, the basic shape of each of these scales is either two-sided and flat or triangular (Fig. 6.27), and each is about twelve inches long. The triangular shape makes six surfaces available for the different-sized scales. Figure 6.28 shows the five most common types of scales.

The markings on scales are arranged in two ways: *fully divided* and *open divided.* Fully divided scales, throughout their length, have each main unit of measurement completely divided, like the familiar foot ruler, on which each inch is divided into sixteenths. The engineer's and the metric scale are normally fully divided. Open divided scales have

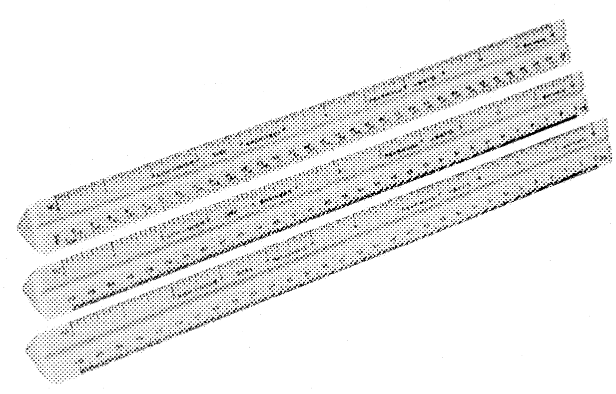


FIGURE 6.27 Triangular and Flat Scales

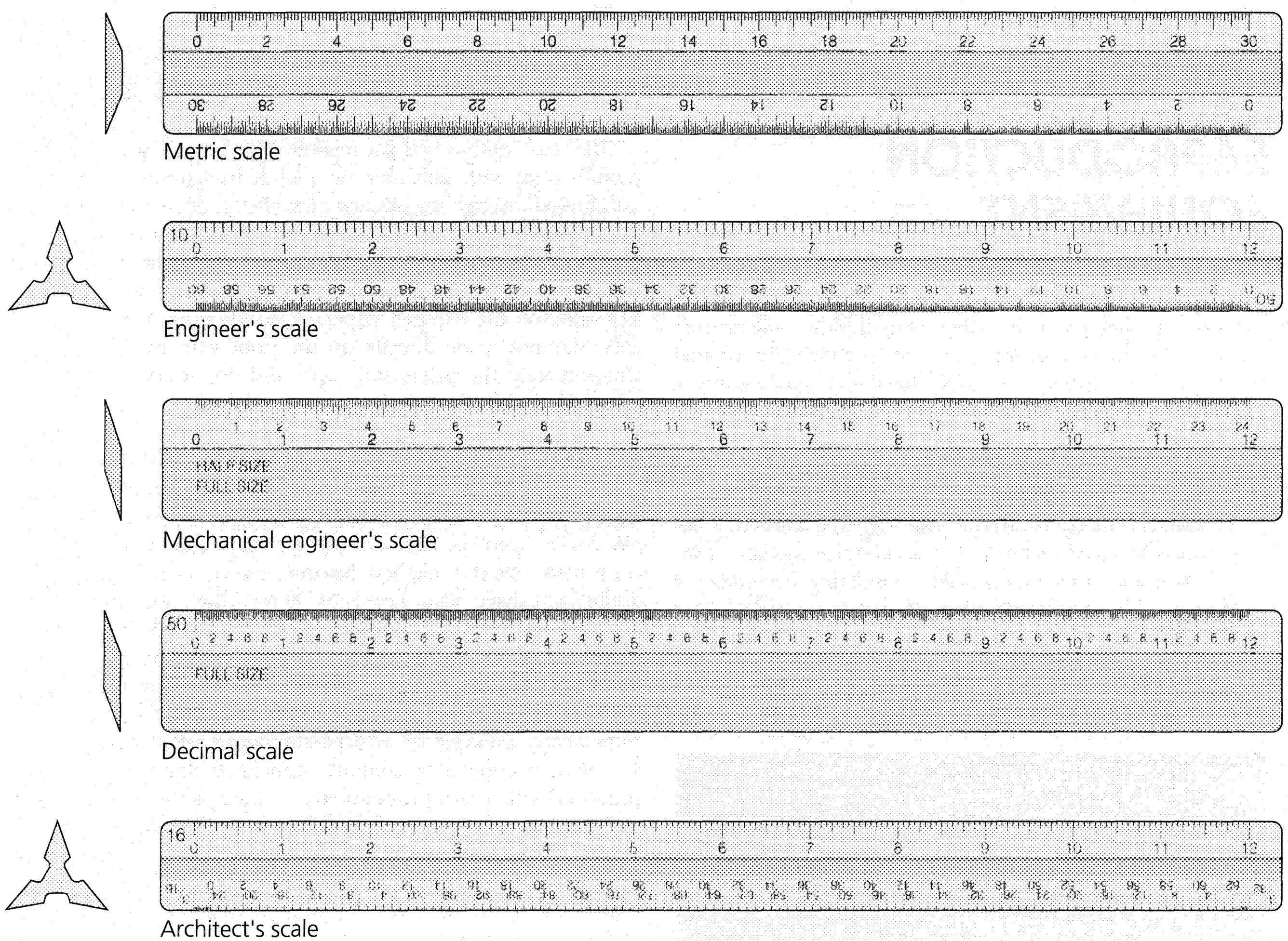


FIGURE 6.28 Five Types of Drawing Scales

each main unit of the scale undivided, except for a fully divided extra main unit at the zero end of the scale. The architect's scale is open divided.

The scale is a precision instrument and, with proper use, will produce consistent drawings. Remember, the scale is a measuring instrument, not a drawing instrument; do not draw on the edge of the scale (unless it is one of the two scales of the engineering drawing machine). Scales edges are not designed for drawing.

6.4.1 The Civil Engineer's Scale

The **engineer's scale** (triangular) normally has six scales that are fully divided. Three-sided civil engineering scales are divided into 10, 20, 30, 40, 50, and 60 divisions per inch and are numbered at each tenth division along the length of each scale. The number of divisions per inch is marked at the zero end of each scale. Although in normal usage each division equals 1 foot, you can assign any unit to the scale divisions. This is designated on a drawing as, for instance, 1″ = 20′, where 1 inch on the scale represents 20 feet of real size. This scale can also be used as a decimal scale, where, for example, 1″ = 2′ and each division represents one-tenth of a foot on the 20 scale, or 1″ = 200′ and each division represents 10 feet on the 20 scale. The other scales can be used similarly. Figure 6.29 shows measurements taken along the civil engineer's scale. Here, .50, 3.60, and 4.90 in. are shown measured on the full-size inch scale, which has increments of 10. These measurements could be in feet if the desired scale were 1″ = 1′.

6.4.2 The Architect's Scale

The **architect's scale** (Fig. 6.30) has a "foot ruler" full-size scale on one surface and ten different reduced-size open divided scales. The open divided scale uses only 1-foot units reading in one direction from the zero end, with a fully divided 1-foot unit reading in the opposite direction. Therefore, the number of feet is read along the length of the scale and the number of inches is read in the fully divided unit at the zero end of that same scale. Both numbers become larger with increasing distance from the zero end.

Each scale is identified by a number or a fraction at its zero end. This number does not represent a proportion of

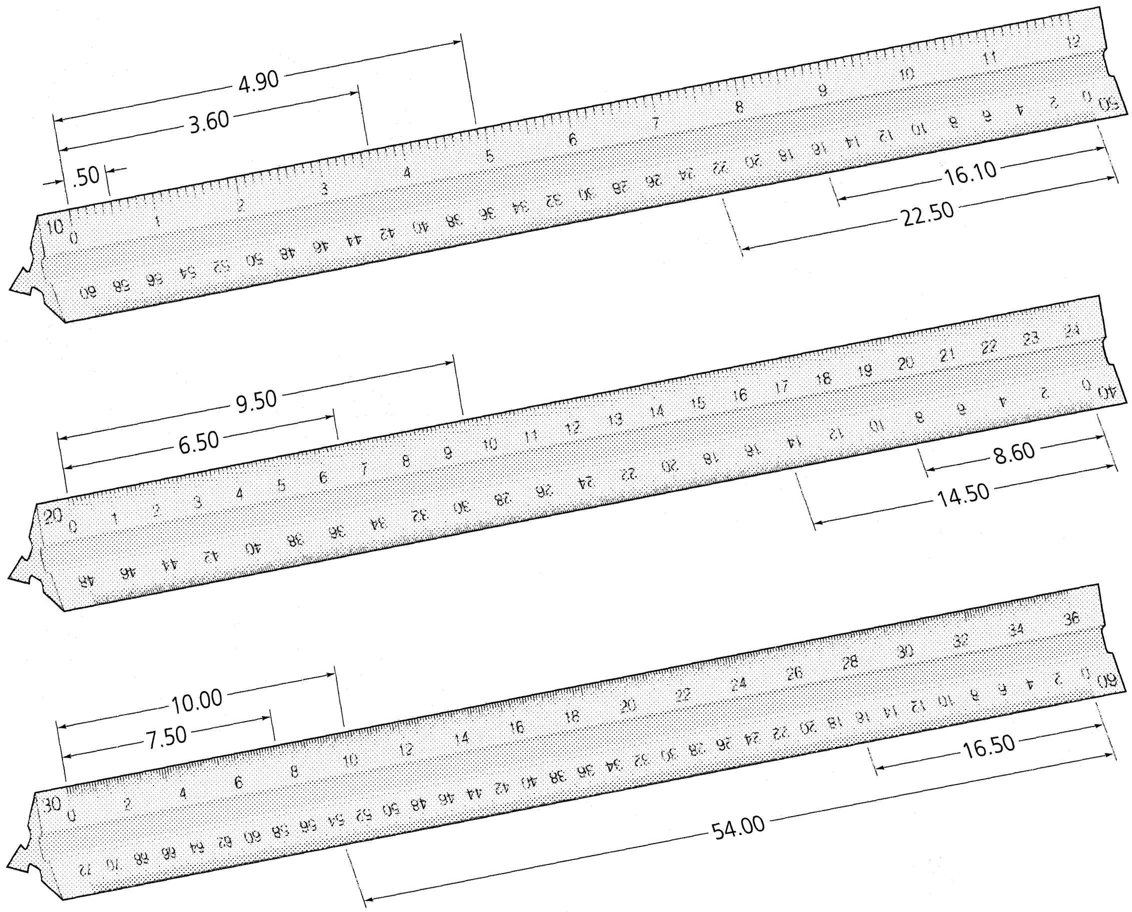


FIGURE 6.29 Civil Engineer's Scale

size but is an abbreviation for the unit of length in inches that represents 1 foot of real size. Figure 6.30 shows measurements taken along the architect's scale.

Some Architect's Scale Abbreviations

Abbreviation	Meaning	Proportion
3	3″ = 1′0″	$\frac{1}{4}$ size
$1\frac{1}{2}$	$1\frac{1}{2}$″ = 1′0″	$\frac{1}{8}$ size
1	1″ = 1′0″	$\frac{1}{12}$ size
$\frac{3}{4}$	$\frac{3}{4}$″ = 1′0″	$\frac{1}{16}$ size
$\frac{1}{2}$	$\frac{1}{2}$″ = 1′0″	$\frac{1}{24}$ size
$\frac{3}{8}$	$\frac{3}{8}$″ = 1′0″	$\frac{1}{32}$ size
$\frac{1}{4}$	$\frac{1}{4}$″ = 1′0″	$\frac{1}{48}$ size

Each of the ten open divided scale surfaces has two scales printed on it, reading in different directions from each end. Each pair of scales has a 1:2 size ratio and is $3-1\frac{1}{2}$, $1-\frac{1}{2}$, $\frac{3}{4}-\frac{3}{8}$, $\frac{1}{4}-\frac{1}{8}$, and $\frac{1}{36}-\frac{3}{32}$. In the smaller of the two scales, the "foot" numbers are nearer the working edge of the scale. Also, both scales have alternate foot markers (numbered on the larger scale), whereas the other foot markers are for only the smaller scale.

On the $\frac{1}{4}$ and the $\frac{3}{16}$ scales, only the even-numbered are numbered; on the $\frac{1}{8}$ and $\frac{3}{32}$ scales, only the markers divisible by 4 are numbered. Care must be used in making correct readings from all of these foot markers.

The fully divided 1-foot unit at the zero end of each scale is divided into inches and fractions of an inch and is read from the zero. The number of divisions varies with the unit of length that represents 1 foot. The value of the smallest unit varies from $\frac{1}{8}$ in. for the 3 scale to 2 in. for the $\frac{1}{8}$ and $\frac{3}{32}$ scales. Study the various scales to become familiar with the smallest units on each. The lengths of the dividing lines vary to make reading the scales easier. The 3, 6, and 9 in. marks are numbered on the 1 and $\frac{1}{2}$ scales, and each inch is marked on the 3 scale.

In Figure 6.30, $3\frac{9}{16}$ in. and $4\frac{1}{2}$ in. have been set off on the full-size inch scale (16), which is divided into increments of $\frac{1}{16}$ in. A variety of other measurements is provided on each of the other scale edges.

6.4.3 The Mechanical Engineer's Scale

The **mechanical engineer's scale** (Fig. 6.31) is normally two-sided and flat. One side, the full inch scale, is divided into either decimal units of .10 in. or as many as fifty divisions (every .02 in.). The opposite side is half scale (1:2). This scale also comes in a triangular version.

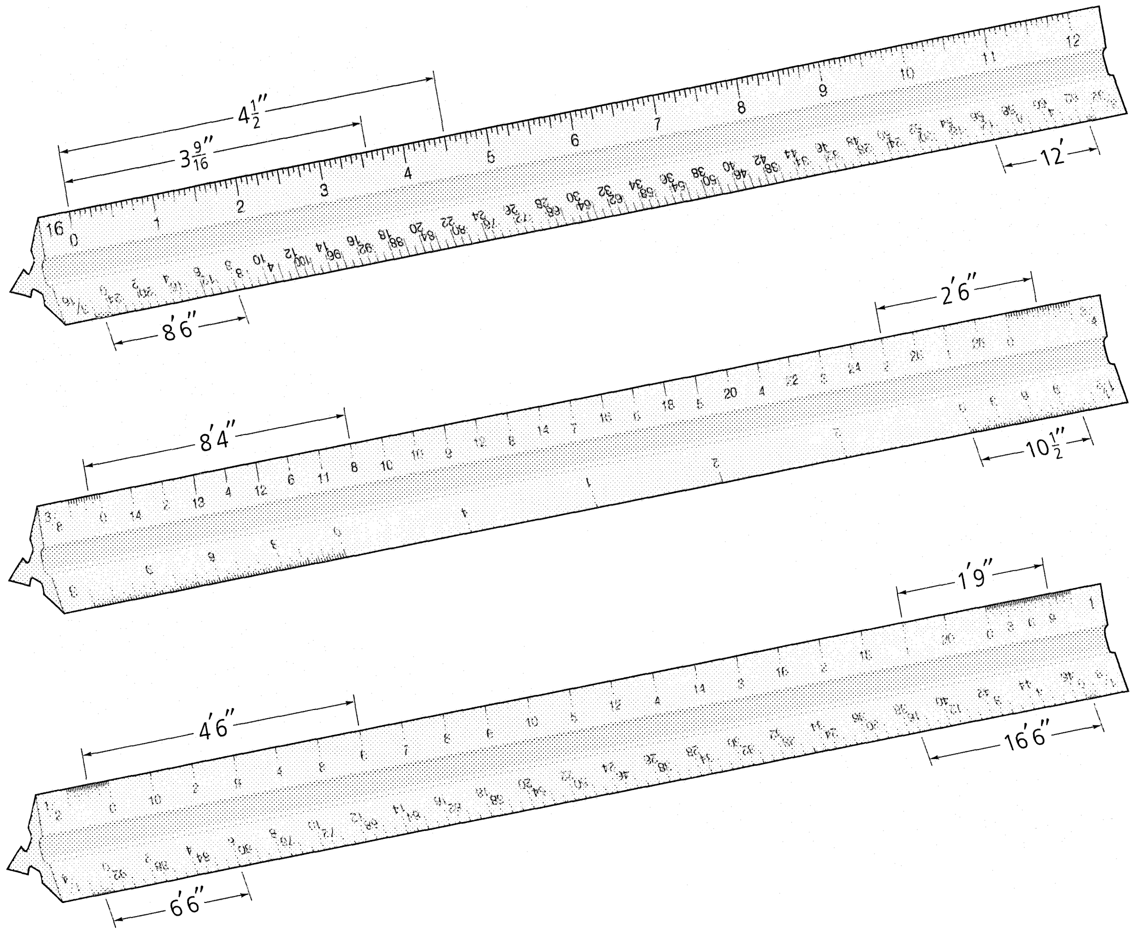
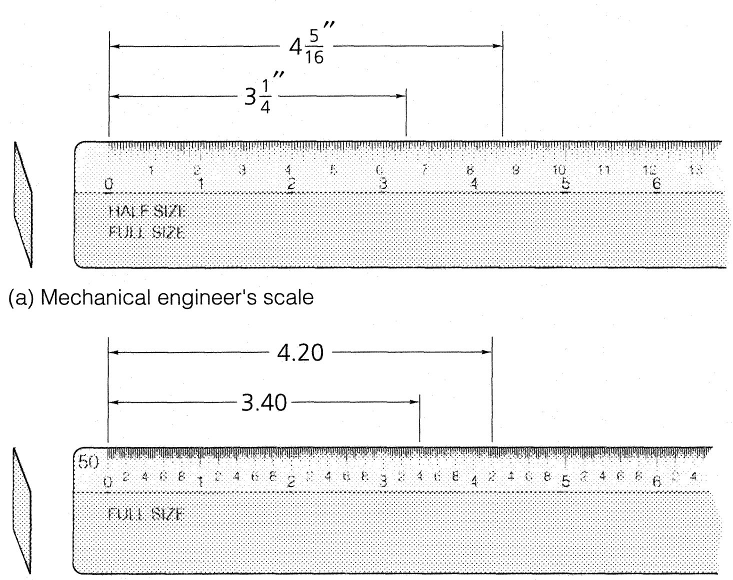


FIGURE 6.30 **Architect's Scale**



(a) Mechanical engineer's scale

(b) Decimal scale

FIGURE 6.31 **Mechanical Engineer's Scale**

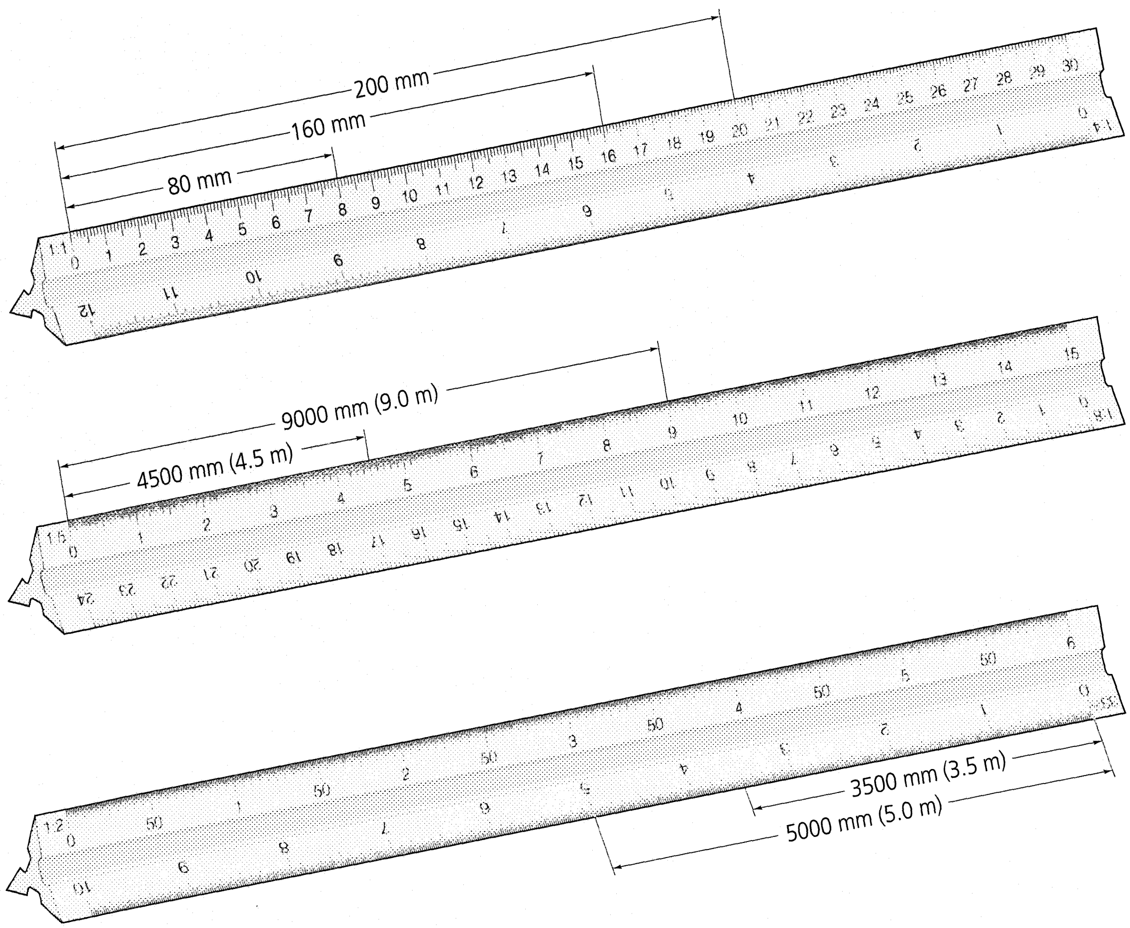


FIGURE 6.32 Triangular Metric Scale

Figure 6.31 also shows a sixteenth scale used by mechanical engineers. This scale is flat and has a full-scale fractionally divided scale on one side and a half-size fractionally divided scale on the other side. Figure 6.31(a) demonstrates full-size inch measurements $4\frac{5}{16}$ and $3\frac{1}{4}$ in.; Figure 6.31(b) shows 4.20 and 3.40 full-size decimal-inch measurements.

6.4.4 The Metric Scale

Metric units, also called **Sl units (Système Intemationale d'Unites),** are measured with a metric scale (Fig. 6.32). Many different versions of metric scales are available. To convert customary-unit (inch decimal and inch fraction) drawings, multiply the inch value by 25.4 to get the metric equivalent (1 in. = 25.4 mm) (or use tables provided on the inside front left cover of the text). As an example, 6.50 in. × 25.4 mm/in. = 63.5 mm. To change a metric value into decimal inches, divide by 25.4. As an example, 50 mm ÷ 25.4 mm/in. = 1.96 in.

The full-size metric scale is divided into major units of centimeters and smaller units of millimeters. There are 10 millimeters in each centimeter. Metric units, in full size as well as in reductions and enlargements, are being used more and more in all forms of design work. To many, the metric scale is much easier to master and use than decimal-inch or fraction-inch scales. Figure 6.32 shows a triangular metric scale with measurements. To set off 80 mm full size (1:1), start at the zero end of the 1:1 scale (Fig. 6.32) and count to the right until you get to the 8 (8 cm = 80 mm). On the 1:5 scale ratio, the 4.5 mark on the scale gives you 4500 mm, or 4.5 m.

This text has been designed for use with all types of scales. Many of the problems, and all of the exercises, in the text are not dimensioned, allowing your instructor to choose the unit of measurement. Use of different scales is highly recommended.

6.5 DRAWING TOOLS

Drawing tools include a variety of items to create geometric figures, measure and layout constructions, and establish features as a drawing of a part. These include protractors, triangles, and templates.

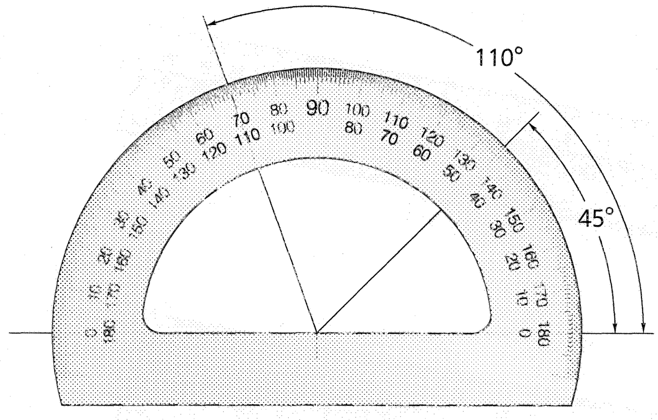


FIGURE 6.33 180° Protractor

6.5.1 Protractors

The **protractor** measures angles instead of lines. A 360° protractor (circular) is the easiest to use. Figure 6.33 shows a 180° protractor. Protractors can measure existing angles and can lay out lines at an angle. The center of the protractor is aligned with the intersecting point of the lines to be drawn or measured.

Note that the drafting machine can replace not only the straightedge, the triangle, and the scale, but also the protractor. However, a circular protractor is still an excellent investment, whether you have access to a drafting machine or not. Since it is easy to misread angle measurements when drawing with a drafting machine or an adjustable triangle, use of a protractor is recommended. Features of a part drawn at angles, regardless of the method of construction, should always be checked with a protractor.

6.5.2 Triangles

The standard **triangles** (Fig. 6.34) are the 45° triangle, the 30°/60° triangle, and the adjustable triangle. Triangles are positioned with a straightedge as a horizontal baseline and then used to draw a vertical line. When a drafting machine is available, triangles are unnecessary. But for productivity, triangles are extremely useful in conjunction with a drafting machine. The vertical scale of a drafting machine is difficult to keep 90° (perpendicular) to the horizontal scale; triangles used with drafting machines eliminate this problem.

The **45° triangle** is used to draw lines at an angle of 45° with the baseline. The **30°/60° triangle** is used to create lines at 30° or 60° with the baseline. Together the two triangles create angles of 15° and 75°. Combinations of the 45° and the 30°/60° triangle divide the 360° of a full circle into twenty-four 15° segments. Other angles are drawn with an adjustable triangle or with the aid of a protractor.

The **adjustable triangle** (Fig. 6.35) is the same as a 45° triangle when closed, but can be opened to form two parallel edges. The amount of opening of the triangle is measured by a protractor scale that reads from 0° to 45° and then doubles back from 45° to 90°. Zero-degree to 45° angles are formed by the two edges at the "open" corner of the triangle. Forty-five degree to 90° angles are formed by the sides at the "hinge" corner. By rotating the adjustable triangle into position, you can draw all angles. Check with a protractor all the measurements and constructions made with an adjustable triangle, because it is very easy to make a mistake with an adjustable triangle. For example, 40° and 50° have the

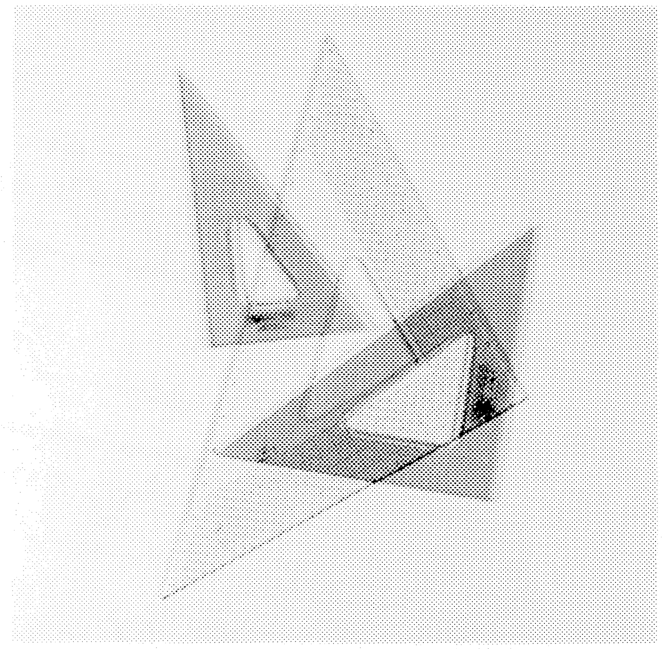


FIGURE 6.34 Triangles

FIGURE 6.35 Using an Adjustable Triangle

same setting, so the angle you establish depends on which side of the triangle is touching the straightedge. The New Draft™ shown in Figure 6.36 is a combination of a 45° triangle, a 30°/60° triangle, and a template.

6.5.3 Templates

A **template** is a tool for drawing shapes of varying sizes. Standard templates (Fig. 6.37) are essential for the quick,

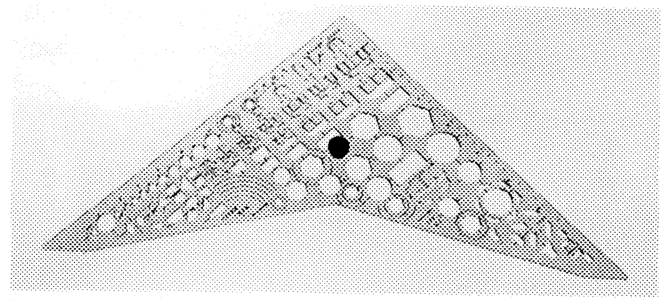


FIGURE 6.36 New Draft™ Template Triangle

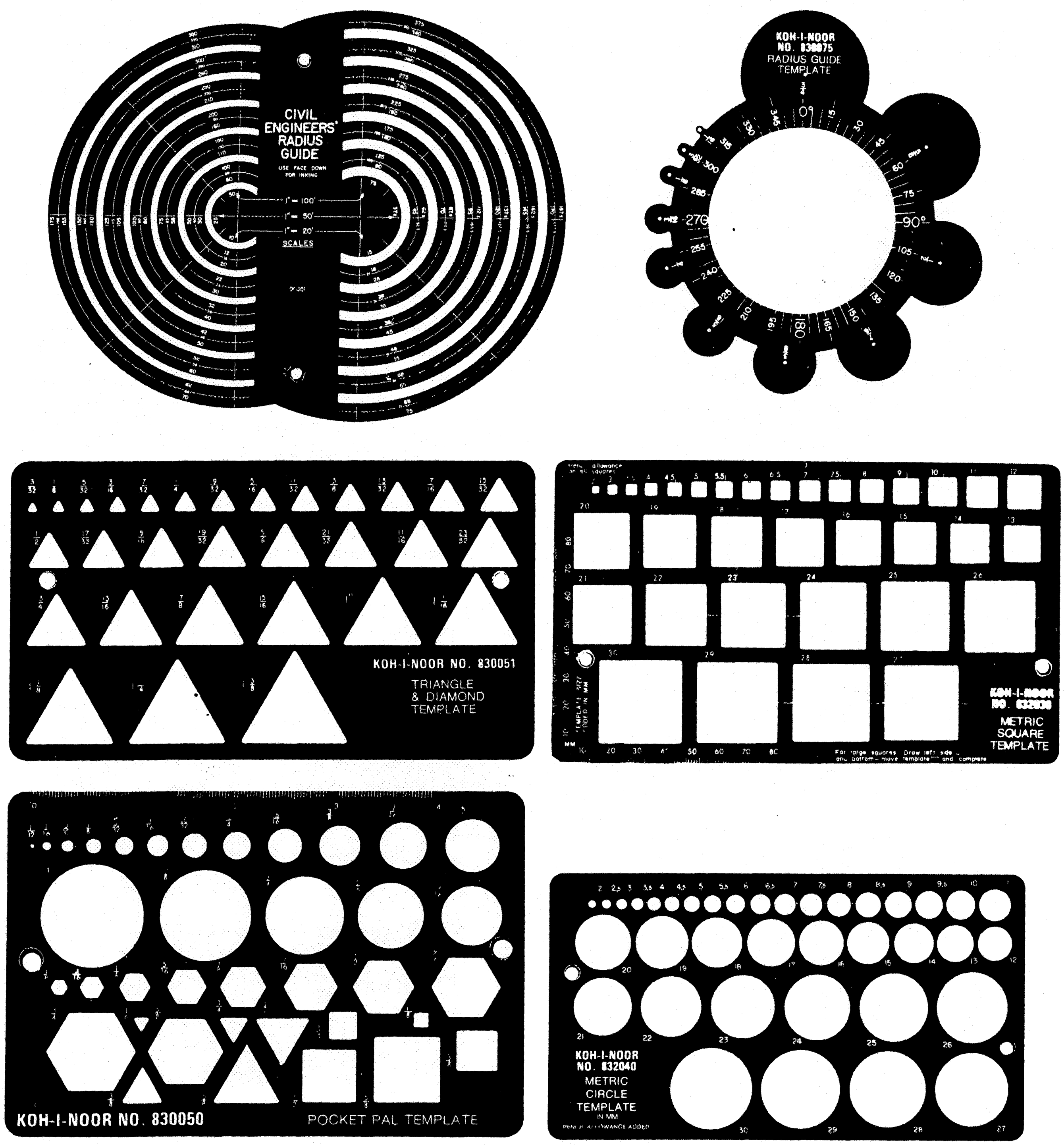


FIGURE 6.37 Templates

easy construction of circular, square, rectangular, triangular, elliptical, and symbolic shapes. Templates are better than a compass for small-diameter circles.

Circle templates, one of the most common types of templates in engineering drawing, come in all standard sizes for U.S. and metric units. After you master the essentials of linework and compass work, you will use templates for all standard-shape construction.

6.5.4 Irregular Curves

Noncircular curves are drawn with a French curve or **irregular curve** (Fig. 6.38) or a flexible curve as a guide, but the guide fits the curve only for a short distance. Noncircular curves are difficult to draw since they must be equal in width to the straight lines with which they blend to produce a uniform drawing.

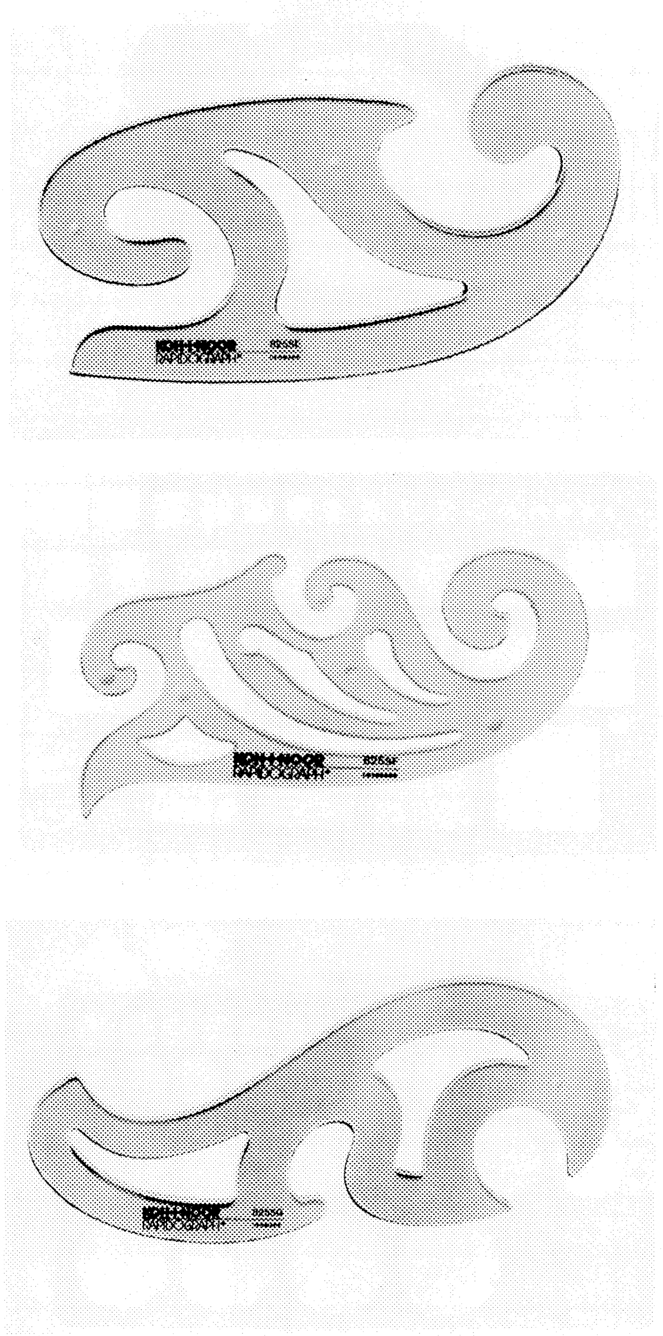


FIGURE 6.38 Irregular Curves

6.6 INSTRUMENTS

Instruments include all forms of *compasses, dividers,* and *inking tools.* The drafting instrument set (Fig. 6.39) consists of one or two sizes of compass, a divider, and accessories. The compass is used to draw circles and circular arcs. Although many types of drafting sets are available, they normally contain such obsolete items as the ruling pen, which has been replaced by the technical pen. You need only purchase a medium-sized, high-quality bow compass and medium-sized dividers in most cases.

6.6.1 Bow Compass and Dividers

A good bow compass and dividers are essential to the accurate construction of all forms of engineering drawings. A **bow compass** (Fig. 6.40) has a center thumbwheel to set and hold the spacing between the center point and the lead. Compasses without such a center thumbwheel and compasses that do not rigidly hold the spacing between point and lead are not recommended for engineering drawing. **Dividers** (Fig. 6.41) lack a center wheel and are used to set off measurements from one view to another quickly. This is extremely valuable in the construction of mechanical drawings and for descriptive geometry.

The centering point for the compass is either a tapered point or a short needle point projecting from a wider shaft that creates a "shoulder." The shoulder acts as a limit to the point's penetration into the paper and board. To restrict the compass point from penetrating the drawing medium and to provide a stable, secure centering point from which to swing an arc or a circle, you can place a small piece of drafting tape

FIGURE 6.39 Drafting Instruments

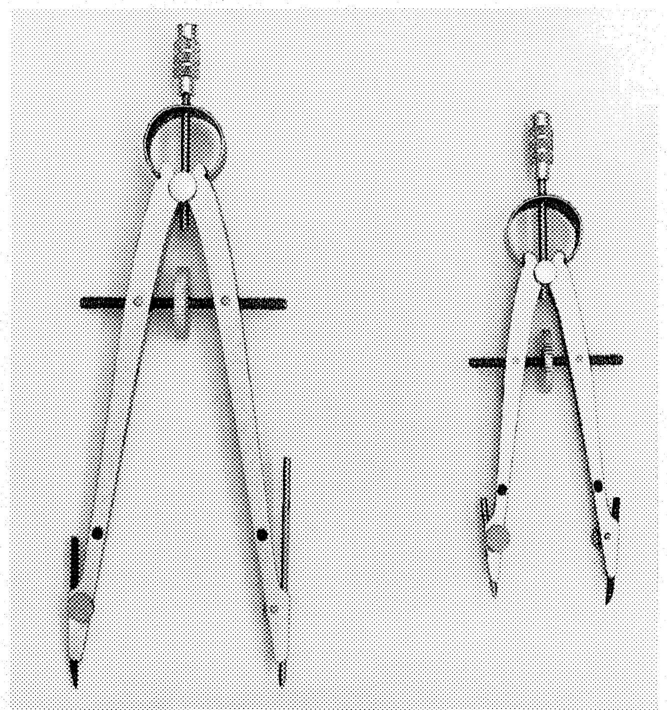


FIGURE 6.40 Bow Compasses

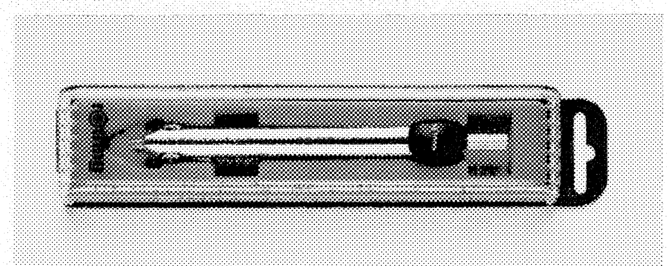


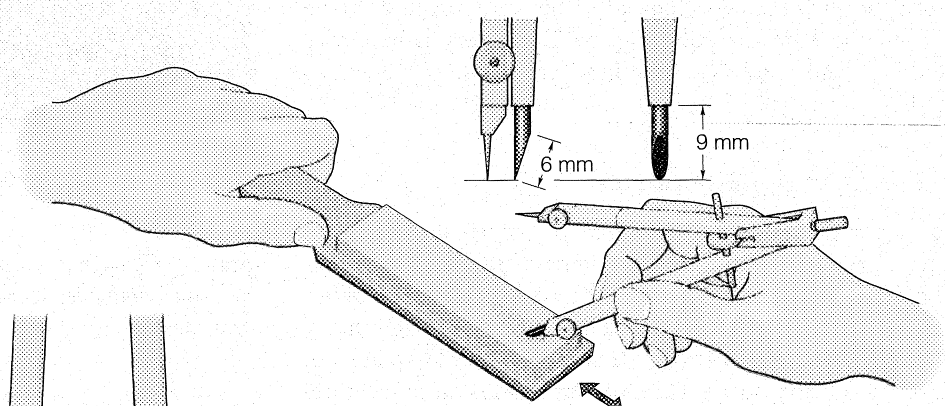
FIGURE 6.41 Dividers

(or dot) on the drawing at the center of the arc or circle to be drawn and then draw construction centerlines over the tape. Circles smaller than .50 in. (12 mm) are much easier to draw with a template or a drop bow compass than with a large- or medium-sized compass. *Use templates whenever possible.* A compass is best for odd-sized and large circles and for construction techniques.

The compass lead should be a piece of the drafting pencil lead (same grade lead or softer). Then both straight and curved lines will be drawn with the same lead and it will be easier to maintain uniformity. The lead is secured in the compass with about $\frac{1}{8}$ in. (9 mm) exposed and is sharpened with a sandpaper block (Fig. 6.42). Use care when sharpening the lead to keep the line through the point and the lead perpendicular to the sandpaper. Make a flat cut that leaves an oval surface, called a *bevel*. The bevel should be about three times as long as the diameter of the lead. The resulting point is chisel-shaped and should have about the same taper, when viewed from the side, as the drafting pencil. Do not try to adjust the lead in the compass after it is sharpened because it is almost impossible to reposition the chisel shape properly. The centering point is adjusted so that the midpoint of the needle point is even with the end of the lead. The beveled end can be on either side of the lead (Fig. 6.43), though usually it is put on the outside. To create a thin, dark curve, both sides of the lead may be beveled, which also creates a longer-lasting point/edge but is harder to maintain.

Dividers come with two identical tapered metal points. Some drafters prefer to replace one metal point with a piece of 4H lead. The lead point can be used to set off dimensions (especially for descriptive geometry), instead of using the two metal points, which tend to mar the drafting medium.

FIGURE 6.42 Sharpening the Lead of a Compass



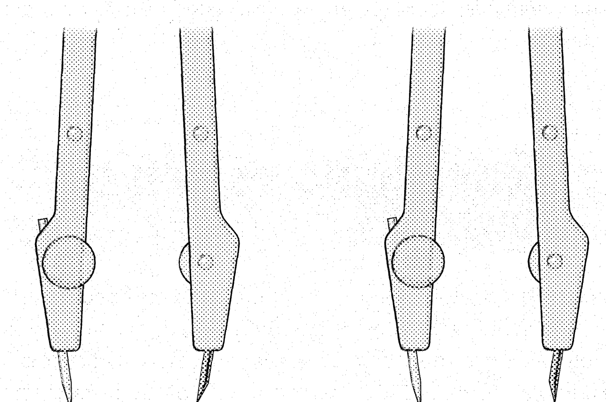


FIGURE 6.43 Positioning the Compass Lead

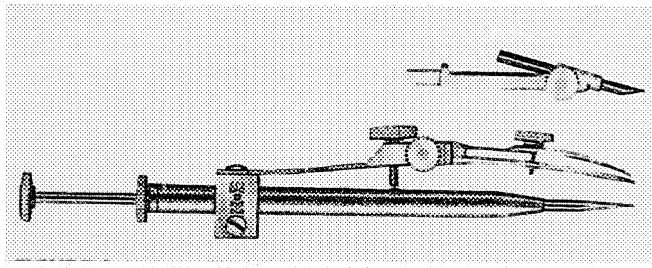


FIGURE 6.44 Drop Compass

FIGURE 6.45 Beam Compass

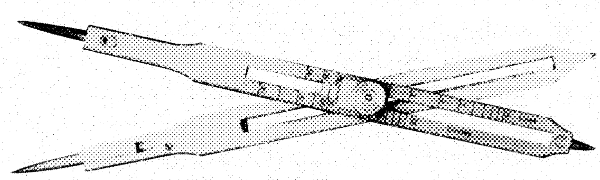


FIGURE 6.46 Proportional Dividers

For special drawing needs, three useful tools are available: the *drop compass* (Fig. 6.44) for very small, accurate circles; the *beam compass* (Fig. 6.45) for very large circles and arcs; and *proportional dividers* (Fig. 6.46) for reductions and enlargements.

6.6.2 Inking Instruments

Most compasses have inking-pen or technical-pen attachments. When you purchase a compass set, attempt to find one equipped with an attachment for holding a *technical pen* (Fig. 6.47), not a nib-type ruling pen. Although many drafting sets contain ruling pens (Fig. 6.39), they are not used in industry, so we will limit our discussion to technical pens.

Technical pens, like the sets shown in Figure 6.48, although expensive, have replaced all other forms of inking tools. Technical pens come in a wide range of pen widths (diameters) (Fig. 6.49), and each pen width corresponds to a metric thickness. Inked projects may include diagrams and pictorials for technical manuals, sales brochures, and graph and chart presentations. In general, technical pens in 0.25, 0.35, 0.45, 0.50, and 0.70 mm widths are used for such

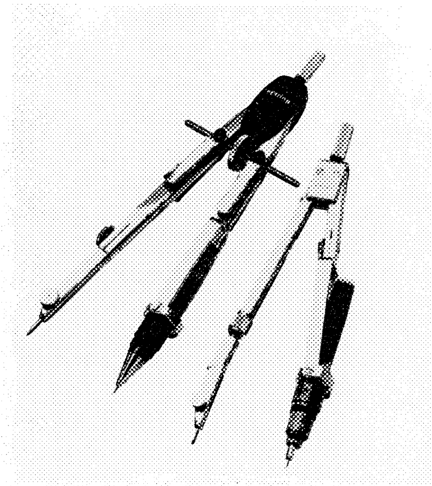


FIGURE 6.47 Bow Compass with Technical Pen Attachment

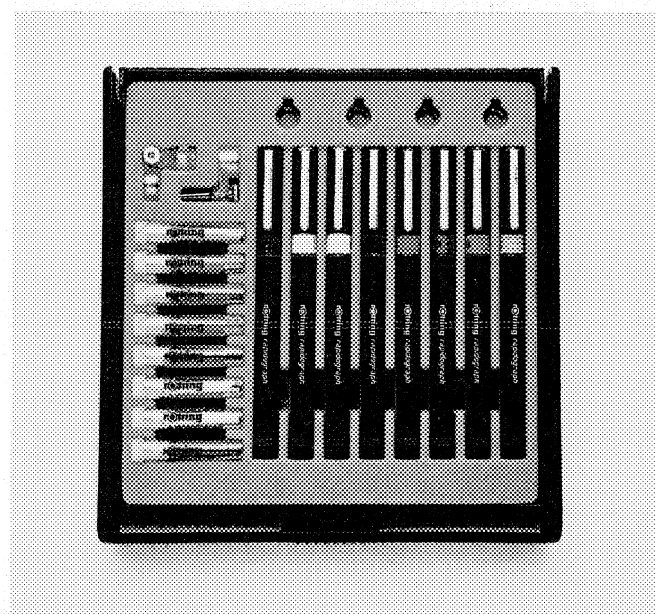


FIGURE 6.48 Technical Pens

drawing. *Though it is a poor practice, manual inking is also used by some companies to make minor corrections on CAD-plotted drawings.*

6.7 ENGINEERING DRAWING MATERIALS

Engineering drawing materials include drawing media (vellum, film, sepia, grid sheets) and preprinted transfer items (title blocks, lettering, symbols). A wide variety of materials are available for manually drawn and CAD-plotted drawings.

6x0	4x0	3x0	00	0	1	2	2½	3	3½	4	6	7
.13	.18	.25	.30	.35	.50	.60	.70	.80	1.00	1.20	1.40	2.00
.005 in.	.007 in.	.010 in.	.012 in.	.014 in.	.020 in.	.024 in.	.028 in.	.031 in.	.039 in.	.047 in.	.055 in.	.079 in.
.13 mm	.18 mm	.25 mm	.30 mm	.35 mm	.50 mm	.60 mm	.70 mm	.80 mm	1.00 mm	1.20 mm	1.40 mm	2.00 mm

FIGURE 6.49 Technical Pen Sizes

6.7.1 Engineering Drawing Media

Traditional engineering drawing media that are transparent enough to be whiteprinted include vellum and drafting film. Drawing **vellum** is a high-quality, translucent paper. Paper used for the diazo reproduction process must allow light to shine through (i.e., be translucent). In addition, pencil on vellum is easily erased, and vellum also takes ink well.

Drafting film is made of durable, high-quality polyester sheets. This medium is excellent for ink and also for plastic lead and combination leads. Special leads and erasers are available for use on drafting film. Although film is expensive compared to vellum, you should have some experience drawing on it with graphite lead, plastic lead, and ink. Vellum and drafting film are available in a plain version or a version with fine, nonreproducible-blue grids.

Vellum and film are secured to the drawing table with drafting tape. **Drafting tape** (or drafting dots) is a high-quality version of masking tape that is designed not to pull the finish off the paper surface.

6.7.2 Drawing Sheet Size and Format

Vellum and film come in standard sheet sizes and rolls. Table 6.3 compares International and ANSI drawing sizes. Rolls of paper and film are available in widths of 30, 36, 42, and 54 inches and in lengths of 25 feet or more. International standards establish a series of paper sizes based on width-to-length proportions. Figure 6.50 illustrates the various ANSI sheet sizes. (This same figure appears on the inside back right cover.) The margins shown in Figure 6.50 produce net drawing areas that are well within the sheet sizes of both standards. Drawing formats made to this standard can be reproduced on either U.S. or international sheet sizes by contact printing and microfilm projection methods. Most U.S. companies purchase preprinted standard sheets in ISO or ANSI specifications. Figure 6.51 compares the ISO and ANSI drawing formats.

Standardization of drawing size and location of format features on drawing forms provides definite advantages for the design office in the areas of readability, handling, filing, and reproduction. If companies are to share drawings successfully, similar items of information must be in the same location on all drawings and the information must be recorded in the same manner. Sheet size and format are covered in ANSI Standard Y14.1.

TABLE 6.3 Drawing Sheet Sizes

American National Standard Y14.1, in.	International Standard, mm
A 8½ × 11	A4 210 × 297
B 11 × 17	A3 297 × 420
C 17 × 22	A2 420 × 594
D 22 × 34	A1 594 × 841
E 34 × 44	A0 841 × 1189
F 28 × 40	

6.7.3 Drawing Formats

The size and style of lettering on **drawing formats** (within title blocks) is to be in accordance with ANSI Y14.2M. To provide contrasting divisions between major elements of the format, the following guide should be used on all projects taken from this text.

Thick lines: 0.7 to 0.9 mm (approximately .03 in.)

- Borderline
- Outline of principal blocks
- Main division of blocks

Medium lines: 0.45 to 0.5 mm (approximately .02 in.)

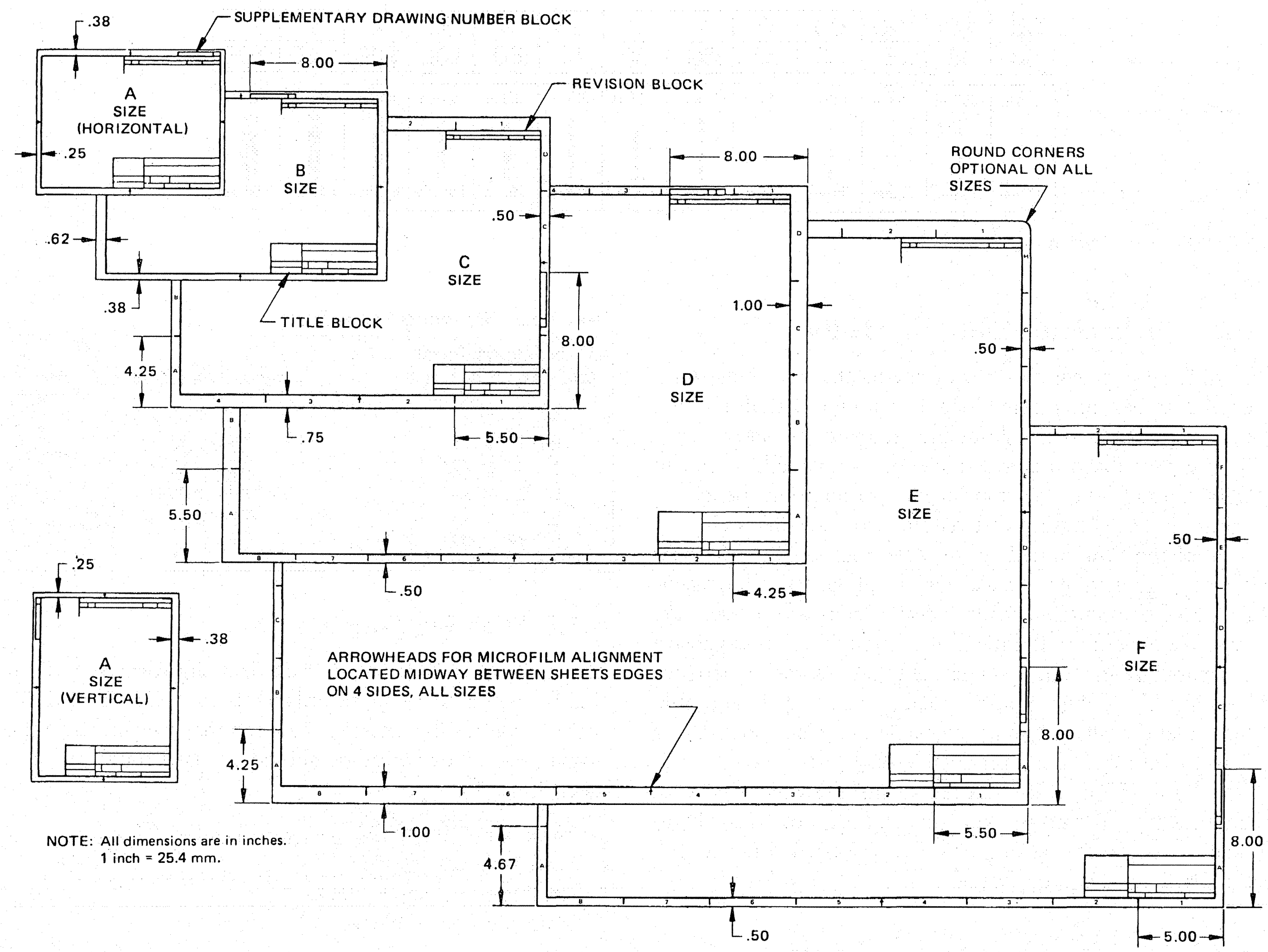
- Minor divisions of the title block

6.7.4 Title Blocks

The **title block** is one of the most important parts of the drawing. The title block is usually located in the lower right corner of the format. Normally, it includes spaces for the following information:

- Company/school name
- Project title/part name/job number
- Scale
- Drawn by
- Material specification
- Date
- Checked by
- Sheet number
- Drawing number
- Standard company tolerances (sheet tolerance)
- Revision box

Figure 6.52 shows the ANSI standard title block layouts for A–K sheet sizes. Title blocks are discussed in detail in Chapter 23.



Size Designation	Width (Vertical)	Length (Horizontal)	Margin		International Designation	Width		Length	
			Vertical	Horizontal		mm	in.	mm	in.
A (Horiz)	8.5	11.0	0.38	0.25	A0	841	33.11	1189	46.11
A (Vert)	11.0	8.5	0.25	0.38	—	—	—	—	—
B	11.0	17.0	0.38	0.62	A1	594	23.39	841	33.11
C	17.0	22.0	0.75	0.50	A2	420	16.54	594	23.39
D	22.0	34.0	0.50	1.00	A3	297	11.69	420	16.54
E	34.0	44.0	1.00	0.50	A4	210	8.27	297	11.69

FIGURE 6.50 Flat Size Formats

6.8 BASIC ENGINEERING DRAWING TECHNIQUES

When graphics are used to communicate engineering, design, production, and manufacturing data, high-quality drawing skills are essential. Drawings must be neat and accurate. Lettering and linework must be precise, dark, and of high quality. This section covers the basics of *linework*. It presents procedures and techniques to help you develop high-quality drawing skills.

6.8.1 Lines

All drawings are made of **lines**. The control you have over the pencil or pen and the techniques you use determine the quality of the drawing and the accuracy of the graphic communication. The conscientious designer or engineer

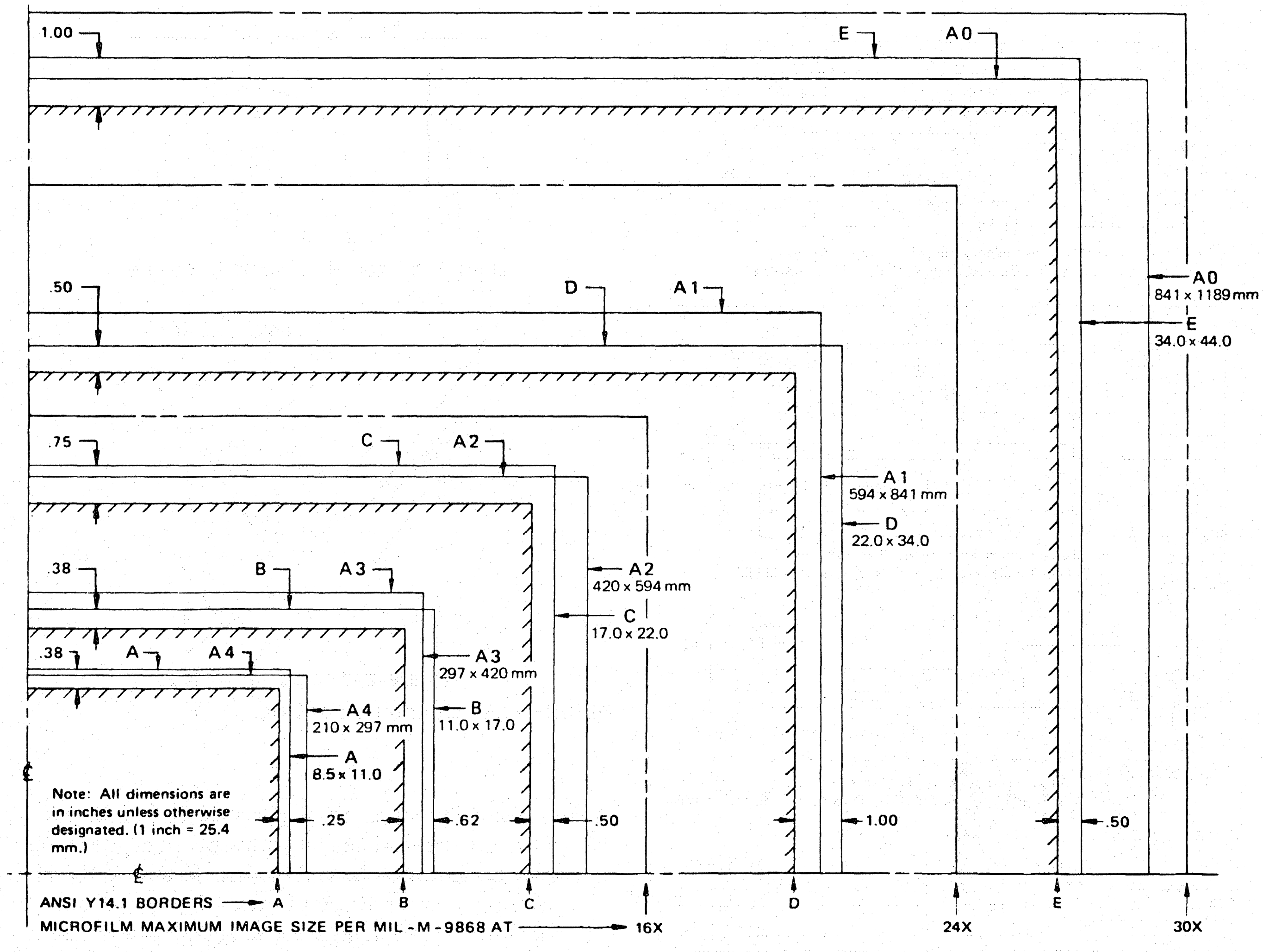


FIGURE 6.51 Comparison of ANSI Y14.1 Drawing Format Sizes with ISO Paper Sizes

constantly strives to improve his or her technique through practice and attention to detail. The characteristics of all lines on a drawing are that they be black, clean-cut, precise, and opaque, with sufficient contrast in thickness between line types. The most important aspect is to convey the precise understanding of the process, the intent, and the content of a drawing. Understanding how lines function and what they mean is particularly important.

Lines (Fig. 6.53) and their relationships are important concerns of engineering graphics. A *line* is considered to have length but no width. A straight line is the shortest distance between two points and is the type of line implied by the word "line." A line that bends is called a *curve.*

Parallel lines are equally spaced along their entire length, becoming neither closer together nor farther apart. The symbol for parallel lines is // (Fig. 6.53). *Perpendicular lines* are at an angle of 90° to each other and can be intersecting or nonintersecting (Fig. 6.53). The symbol for perpendicular lines is ⊥.

The lines in engineering drawings are drawn with different widths to provide specific information. Each line type is actually a symbol that represents a function or idea or communicates a special situation. What thickness to draw any line is determined by what it represents and the smallest size to which it will be reduced. To avoid confusion, lines representing the same function must be the same thickness throughout a single drawing. The minimum spacing between parallel lines is determined by how much the drawing will be reduced. Two parallel lines that are placed too close will merge when the drawing is reduced—this is called *fill-in,* a situation that must be avoided. Normally, .06 in. (1.5 mm) minimum parallel spacing meets reduction requirements for most drawings.

The following list describes traditional line thickness used on engineering drawings.

1. **Fine lines.** Thin, black lines used to provide information about the drawing or to construct the drawing. These include dimension lines, leader lines, extension lines, centerlines, and construction lines.
2. **Medium lines.** Medium-width, solid, black lines used to outline planes, lines, surfaces, and solid shapes Medium lines are also used for hidden (dashed) lines.

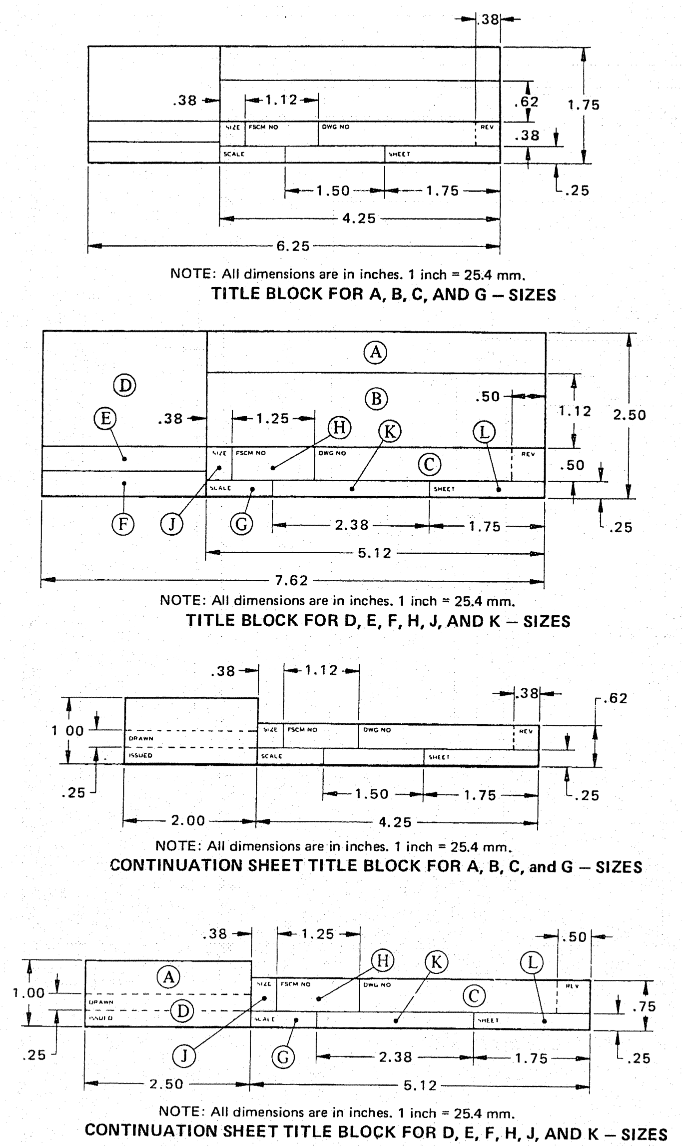


FIGURE 6.52 ANSI Title Block Dimensions

3. **Heavy lines.** Solid, thick, black lines used for the border, cutting plane lines, and break lines.

The newest ANSI standard suggests only two line-thickness choices—thin and thick. All lines listed under 1 and 2 from the preceding list are now drawn with thin lines, and all lines listed under 3 are drawn with thick lines. Many companies still use the three line thicknesses shown in the list.

6.8.2 Line Types

Line types and conventions for mechanical drawings are covered in ANSI Standard Y14.2M (Fig. 6.54). Figure 6.55 provides examples of each type of line. Every line on your drawing has a meaning. In other words, lines are *symbols* that mean specific things. The line type determines if the line is part of the part or conveys information about the part.

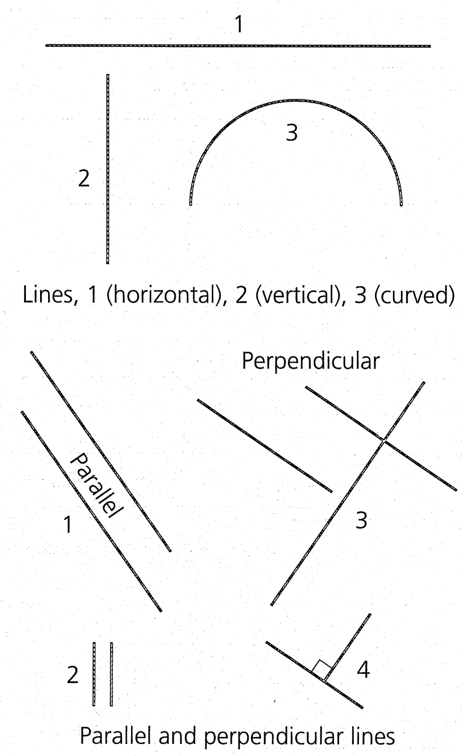


FIGURE 6.53 Orientation of Lines

A *visible object line* represents the visible edges of the part. A *hidden line* is a dashed line that represents an edge that does not show because it is behind another feature of the part. Part description is composed of these two types of lines.

Other lines convey information about the part but are not lines of the part itself. In this category are *section lines, cutting-plane lines, centerlines, dimension lines, extension lines,* and *phantom lines.*

Besides having different configurations, such as dashes and spaces, each line type has a weight (thickness). The following list gives the suggested weight (thickness) of lines on your drawing.

THICK	
Visible object line	0.60 to 0.70 mm
Cutting-plane line	0 70 to 0.90 mm
Border line	0.70 to 0.90 mm
Break line	0.45 to 0.70 mm
THIN	
Hidden line	0.45 to 0.50 mm
Section line	0.25 to 0.30 mm
Centerline	0.30 to 0.35 mm
Dimension line	0.30 to 0.35 mm
Phantom line	0.45 to 0.50 mm
Break line	0.45 to 0.70 mm

Visible Object Lines. Visible object lines are thick lines that represent the visible edges and contours of a part. Since visible lines are the most important lines, they must stand

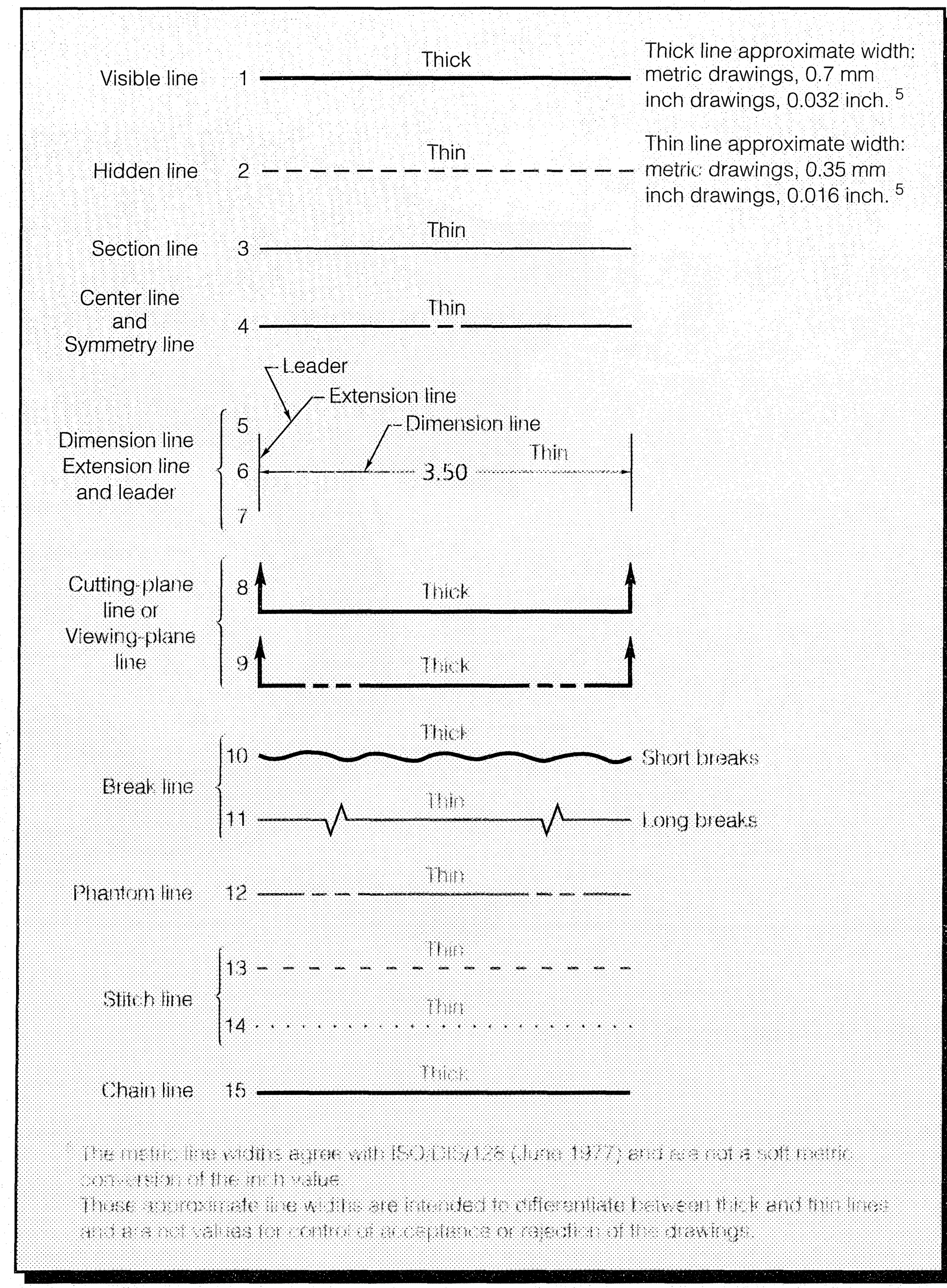


FIGURE 6.54 Standard Line Types and Thicknesses

out from all other secondary lines on the drawing. In mechanical drawing, visible lines are normally drawn about .032 in. thick (between 0.6 and 0.7 mm).

Hidden Lines. Hidden lines are short, thin dashes, approximately .12 in. (3.0 mm) long, spaced about .03 to .06 in. (0.7 to 1.5 mm) apart. They show the hidden features of a part. Hidden lines should always begin and end with a dash, except when a dash would form a continuation of a visible line.

Dashes always meet at corners, and a hidden arc should start with dashes at the tangent points. When the arc is small, the length of the dash may be modified to maintain a uniform and neat appearance. Excessive hidden lines are difficult to follow. Therefore, only lines or features that add to the clearness and the conciseness of the drawing are shown; confusing and conflicting hidden lines should be eliminated. If hidden lines do not adequately define a part's configuration, a section should be taken (see Chapter 11). Whenever possible, hidden lines are eliminated from the sectioned portion of a drawing. Hidden lines are drawn approximately .017 in. (0.45 to 0.50 mm) thick (see Chapter 10).

Centerlines. Centerlines are thin, long and short dashes, alternately and evenly spaced, with long dashes placed at

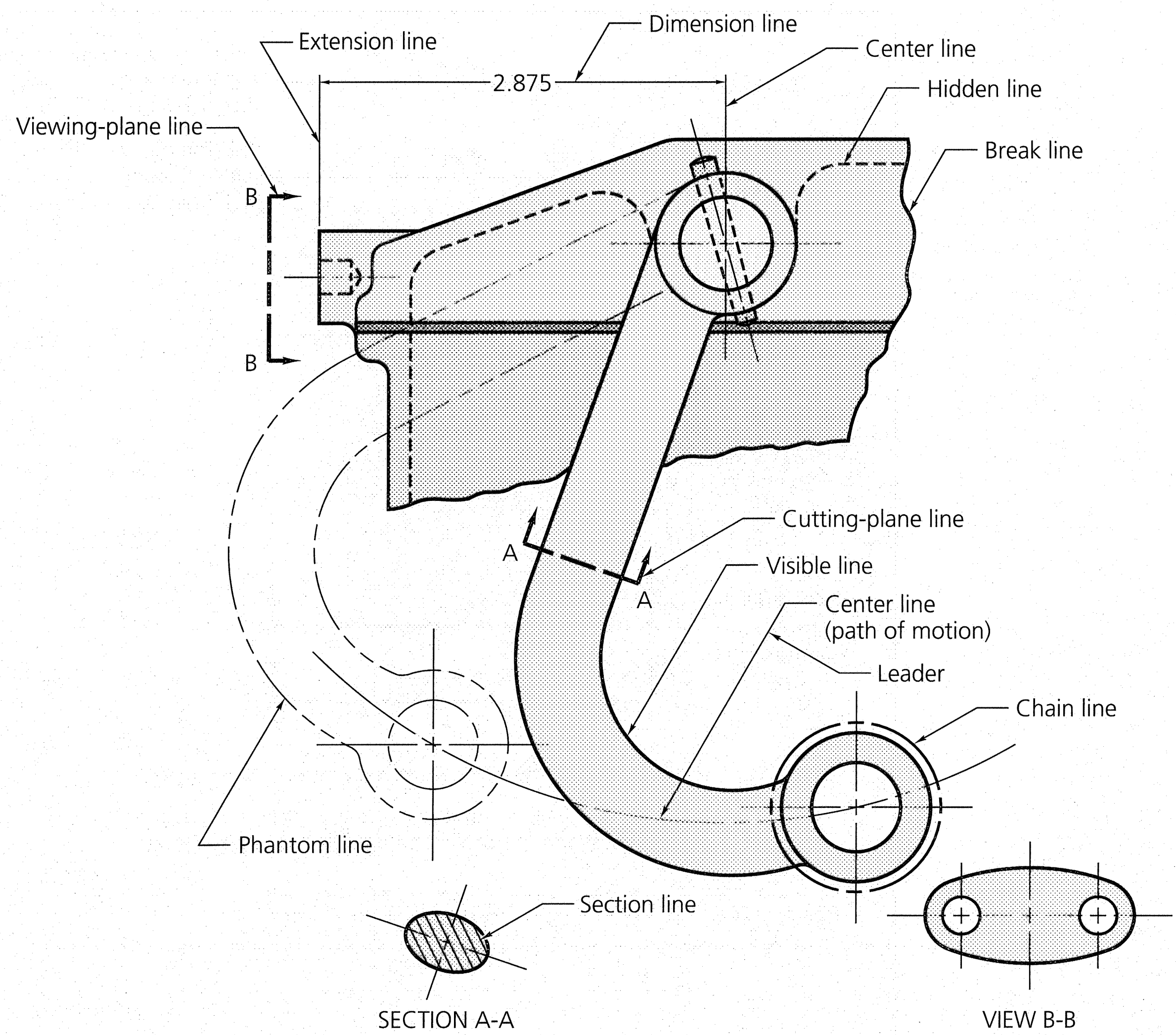


FIGURE 6.55 Application of Line Types

each end of the line. The long dash is dependent on the size of the drawing and normally varies in length from .75 to 2 in. (20 to 50 mm). Short dashes, depending on the length of the required centerline, should be approximately .06 to .12 in. (1.5 to 3.0 mm). Very short centerlines may be unbroken, with dashes at both ends.

Centerlines indicate the axes of symmetrical parts of features, bolt circles, paths of motion, and pitch circles. They should extend about .12 in. (3 mm) beyond the outline of symmetry, unless they are used as extension lines for dimensioning. Every circle, and some arcs, should have two centerlines that intersect at the center of their short dashes. Centerlines are usually drawn about .012 in. (0.3 mm) thick.

Dimension Lines. Dimension lines are thin lines that show the extent and the direction of dimensions. Space for a single line of numerals is provided by a break in the dimension line. However, on horizontal line dimensions, when two lines of numerals are used in the form of limits, one may be placed above and the other below an unbroken dimension line.

If possible, dimension lines are aligned and grouped for uniform appearance and ease of reading. For example, parallel dimension lines should be spaced no less than .25 in. (6 mm) apart, and no dimension line should be closer than .38 in. (10 mm) to the outline of a part feature [.50 in. (12 mm) is the preferred distance].

All dimension lines terminate with an arrowhead on mechanical engineering drawings, with a slash or a dot in architecture. The preferred ending is the arrowhead. Arrowheads are drawn with a 1:3 ratio (width is $\frac{1}{3}$ the length). The actual size is determined by the drawing scale, the total drawing size and area used, and the reduction requirements. Avoid large, elaborate arrowheads. Dimension lines are drawn the same thickness as centerlines, .012 in. (0.3 mm). See Chapter 15 for complete information on dimensions.

Extension Lines. Extension lines indicate the termination of a dimension. An extension line must not touch the feature from which it extends, but should start approximately .04 to .06 in. (2 mm) from the feature being dimensioned and extend the same amount beyond the arrow side of the last dimension line. When extension lines cross other extension lines, dimension lines, leader lines, or object lines, they are usually not broken. When extension lines cross dimension lines close to an arrowhead, breaking the extension line is recommended, for clarity. Extension lines are drawn at the same thickness as dimension lines and centerlines, .012 in. (0.3 mm).

Leader Lines. A leader line is a continuous straight line that extends at an angle from a note, a dimension, or other reference to a feature. An arrowhead touches the feature at that end of the leader. At the note end, a horizontal bar .25 in. (6 mm) long terminates the leader approximately .12 in. (3 mm) away from midheight of the note's lettering, at either the beginning or the end of the first line. Leaders should not be bent to underline the note or dimension. Unless unavoidable, leaders should not be bent in any way except to form the horizontal terminating bar at the note end of the leader.

Leaders usually do not cross. Leaders or extension lines may cross an outline of a part or extension lines if necessary, but they usually remain continuous and unbroken at the point of intersection. When a leader is directed to a circle or a circular arc, its direction should be *radial*. Leader lines are drawn the same thickness as centerlines, dimension lines, and extension lines, .12 in. (0.3 mm).

Section Lines. Section lines are thin, uniformly spaced lines that indicate the exposed cut surfaces of a part in a sectional view. Spacing should be approximately .10 in. (3 mm) and at an angle of 45°. The spacing is dependent on the reduction percentage of the drawing. Section lines are drawn slightly thinner than centerlines and dimension lines, .01 in. (0.25 mm) (see Chapter 11).

Phantom Lines. Phantom lines consist of medium-thin, long and short dashes. They indicate alternate positions of moving parts, adjacent positions of related parts, and repeated details. They can also show the cast, or the rough shape, of a part before machining. The line starts and ends with the long dash of .60 in. (15 mm), with about .06 in. (1.5 mm) space between the long and short dashes. A phantom line is drawn approximately as thick as a hidden line, .016 in. (0.45 mm). Phantom lines are drawn similar to centerlines, except they have two short dashes between each long dash. The short dashes are drawn approximately .12 in. (0.3 mm) or longer, depending on the size of the drawing and the reduction requirements. In some cases, as when showing alternate or related positions of parts, or when a part is the workpiece on a jig and fixture assembly, the phantom line is drawn in red.

Cutting-Plane Lines and Viewing-Plane Lines. Cutting-plane lines and viewing-plane lines consist of thick, long and short dashes. These lines indicate the location of cutting planes for sectional views and the viewing positions for removed partial views. Cutting-plane lines start and stop with long dashes—.60 in. (15 mm) or longer. The short dashes are approximately .25 in. (6 mm) long, with about .12 in. (3 mm) of space between them. An alternative method uses medium-length [.38 in. (9 mm)] dashed lines for the total cutting plane. Both methods are acceptable. Cutting plane lines are normally drawn with a thickness of about .032 in. (0.70 mm) and are the thickest lines on a drawing (see Chapter 11 on sectioning).

Break Lines. Break lines are thick, freehand, continuous, ragged lines used to limit a broken view, a partial view, or a broken section. For long breaks, where space is limited, a neat break may be made with long, medium-thickness, ruled dashes joined by freehand zigzags. For short breaks, the lines are drawn thicker, the same as cutting plane lines, .03 in (0.7 mm). Long break lines are about as thick as thin lines, .017 in. (0.45 to 0.50 mm) (see Chapter 11).

Construction Lines. Construction lines lay out the part's features and locate the dimensions. They are very thin, light gray lines. Normally, 6H–3H lead is used for construction lines. In most cases, excess construction lines are erased before the part is darkened. When construction lines are drawn with nonreproducible-blue lead, they do not require erasing.

6.8.3 Precedence of Lines

Whenever lines coincide in a view, certain ones take precedence. Since the visible features of a part (object lines) are represented by thick solid lines, they take precedence over all other lines. If a centerline and a cutting plane coincide, the more important one should take precedence. Normally the cutting-plane line, drawn with a thicker weight, will take precedence. The following list gives the preferred *precedence of lines* on your drawing:

1. Visible (object) lines
2. Hidden (dashed) lines
3. Cutting-plane lines
4. Centerlines
5. Break lines
6. Dimension and extension lines
7. Section lines

6.8.4 Placing the Paper or Drafting Film on the Board

Drafting paper is placed on the board in a position that will allow you to use the drawing tools properly and to be comfortable while drawing. This position is approximately halfway up on the board and either near the working edge of the board or centered.

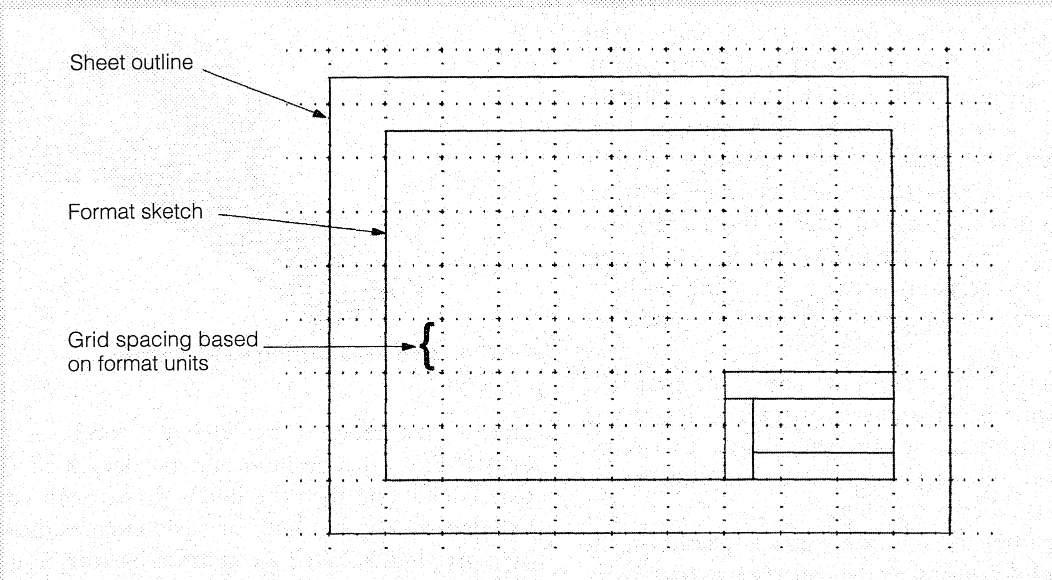


FIGURE C **Sketching a Standard Format**

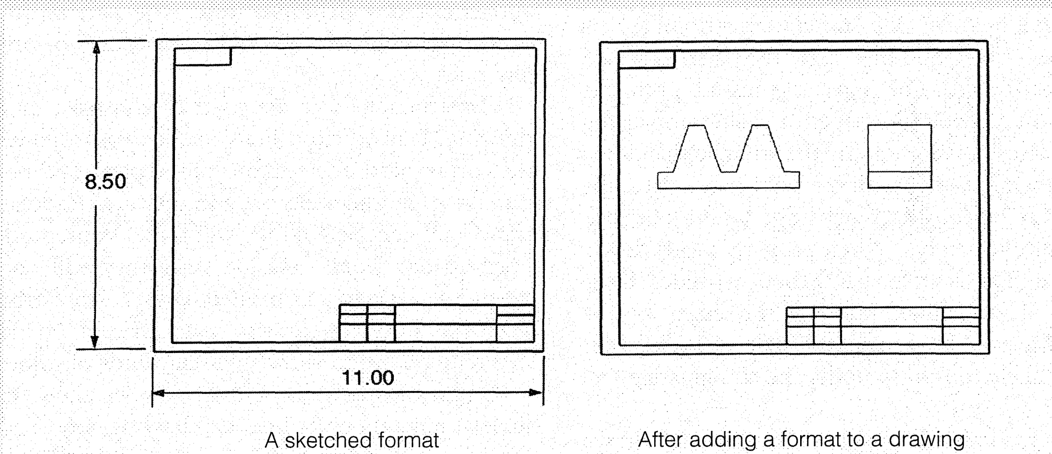


FIGURE D **A Sketched Format**

Sketched formats (see Fig. C), created in sketcher mode, may be parametrically modified, enabling you to create nonstandard-size formats or families of formats. They can consist of note text, symbols, tables, and drafting geometry, including drafting cross sections and filled areas.

With Pro/ENGINEER you are able to do the following:

- Create draft geometry, notes.
- Move, mirror, copy, group, translate, and intersect geometry.
- Use and modify the draft grid.
- Enter user attributes.
- Create drawing tables.
- Use interface tools to create plot, DXF, SET, and IGES files.
- Import IGES, DXF, and SET files into the format.
- Create user-defined line styles.
- Create, use, and modify symbols.
- Include drafting cross sections in a format.

Regardless of whether you use a standard format or a sketched format, the format is added to a drawing created from a specified view of a parametric 3D model. The sketched format shown here (see Fig. D) was added to the drawing of the part. The system automatically fits a sketched format to the proper size piece of paper. Views and draft entities are scaled accordingly.

When using a T-square, the working edge of the board is the side against which the head of the T-square rests (normally the left side). With the paper positioned near it, the head of the T-square will make full contact with the working edge of the board in all necessary drawing positions. In addition, the blade of the T-square is slightly flexible and "gives" as pressure is applied when drawing. Placing the paper near the working edge of the board allows the T-square to be used with minimum bending of the blade.

When using a parallel straightedge or a drafting machine, the bottom of the paper is aligned first and the corners are then taped.

Unless standard-format preprinted sheets are available, the piece of drawing paper is always about 1 inch larger in width and height than the size of the final sheet. This excess paper is trimmed off when the sheet is complete. (A completed sheet is called a drawing.)

After it is cut from the roll, the paper is placed on the board with its curl down (unless the paper has a "tooth" side that cannot be reversed). This keeps the edges of the paper from being accidentally torn—for instance, by a triangle corner. The paper is square with the board and taped down with small strips of drafting tape—.5 × 1.00 in. is sufficient, or you can use drafting dots. One-half of each strip of tape is attached to the paper first, and then, after the paper is pulled snug (but not stretched), the tape is pressed onto the drawing board. You can hold the paper in position by laying the straightedge across it and holding the straightedge down with the left arm while taping with the right hand. After the two top corners are taped, the straightedge can be released. Then tape the bottom corners. When properly taped down, the paper clings tightly to the board without wrinkles, loose edges, or signs of stretching. Rubbing the edges of the masking tape with your fingernail will make it stick better and make it less likely to roll up under the straightedge and triangles.

Once the paper is taped in position, trim lines are drawn using a straightedge and triangles (corresponding to a standard drawing format). Upon completion of the drawing, the excess paper is trimmed. The trim lines will be the edges of the completed drawing. Standard sheet sizes do not need trimming.

6.9 INSTRUMENT DRAWINGS

Drawings with straight lines that have been drawn with the aid of a T-square, a straightedge, or a drafting machine and triangle are known as **instrument drawings.** These are carefully drawn to an accurate size. Lines of each type are uniform in width and density. The lines begin and end so as to form square corners and intersections.

You should first find the exact center of the sheet by drawing diagonals (connecting opposite corners). This will help center the work on a layout drawing.

Drafting a line in an instrument drawing is a two-step process that requires two different kinds of lines to be drawn. First, the position and the length of the line are determined, and then the line is drawn with correct width and density. The first line, for positioning, is drawn thin and light gray and is called a **construction line.** You may prefer to lay out your work with a nonreproducible-blue lead. After the line's position has been verified and its length measured and marked (Fig. 6.56), a second line is drawn exactly over the first line. This second line is drawn dense and uniform and is called a **printable line.** The part or project being drawn is completely blocked in (laid out) before darkening any lines.

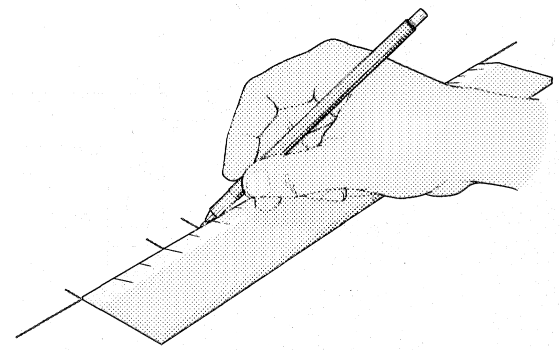


FIGURE 6.56 Measuring with a Scale

Construction lines are used to construct or lay out the drawing. Construction lines may extend somewhat beyond the corners and intersections of the part's outline. Construction lines are thin and gray, and they are cleaned up after the drawing is complete if they will print. Nonreproducible-blue lines do not require erasing since they will not reproduce when the drawing is printed with a whiteprint machine. Printable lines are drawn, with 2H, H, or HB lead, at different widths to show different kinds of information.

Unless company (or school) practice allows construction lines to remain on the finished drawing, any extra lines used for construction purposes are erased before the drawing is darkened. Ask your instructor which method to follow before you complete a project.

6.9.1 Techniques for Drawing Lines

All engineering drawings are created using triangles and/or some form of straightedge. Vertical lines are constructed with a straightedge and triangle or a drafting machine. Horizontal lines are drawn with a straightedge that will give consistently parallel lines. Curved lines are drawn with a compass, a template, or an irregular curve. Lines are not formed freehand; only lettering is drawn freehand.

A properly drawn line is uniform for its entire length. When using a wood pencil or a lead holder, you can make a line consistent in two ways:

1. Incline the pencil or the lead holder so it makes an angle of about 60° with the surface of the paper. Pull the pencil in the direction in which it is leaning (Fig. 6.57). Keep the pencil at a consistent angle as you draw the line.

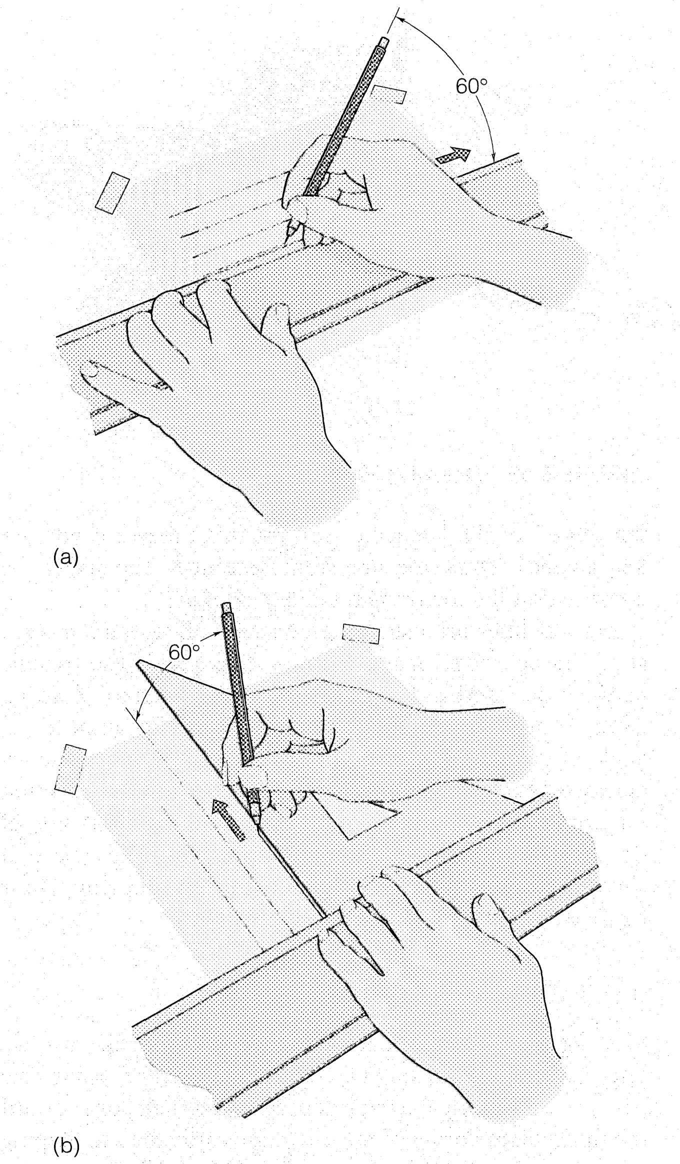


FIGURE 6.57 Angling the Pencil While Drawing

2. Rotate the pencil or the lead holder slowly as the line is drawn, to maintain a semisharp conical point. This will enable you to control the thickness and the quality of the line.

These techniques take practice but will soon become automatic. Your lines will be uniform from end to end and from one line to another. Fine-line pencils are held straight (vertical to the board) instead of at an angle and usually do not need to be rotated.

Since most drawings are reduced or enlarged when reproduced, the correct use of line weights and line techniques is essential. Because even the smallest mistake can be magnified, special care must be taken on drawings that are to be enlarged; otherwise the mistake will also be enlarged. On drawings that are to be reduced—for example, printed circuit artwork drawings that are normally drawn at 2:1 or 4:1 enlargements—reduction will clean up and minimize any small problems. However, accuracy is still important, regardless of the scale. Do not rely on reduction to hide any poorly constructed areas of your drawing.

How well lines print is determined by their density—that is, their ability to block light. Density is controlled by the hardness/softness of the lead and by the pressure applied while the line is being drawn. The width and the sharpness of the line are determined by the size of the point touching the paper. A sharpened pencil point should be smoothed and rounded on scratch paper after being repointed. It can also be resharpened on scratch paper. Uniform lines require uniform point preparation.

Fine-line lead holders are available in a variety of different lead thicknesses. A 0.5 and 0.7 mm lead holder with H or 2H leads is good for lettering and linework. Construction lines can be drawn with 0.3 and 0.4 mm fine-line pencils with 3H or 6H leads or nonreproducible-blue leads. These instruments require no sharpening and help maintain a high-quality, consistently uniform line.

Construction lines are drawn with the greatest accuracy possible. To achieve accuracy, place the pencil point on the paper where the line is to be drawn. Then carefully move the straightedge or triangle up to it so as to just touch the pencil point without moving it. Draw a construction line with the pencil point riding along the top edge of the straightedge. Tilt the pencil slightly away from the straightedge. Pull the pencil; do not push it, except when using a fine-line pencil.

6.9.2 Pencil Position for Printable Lines

Once the lines, corners, and intersections have been positioned and verified using construction lines, the figure must be redrawn with printable lines. These are drawn exactly over the construction lines, even though they will not extend the full length of the construction lines. Printable lines will make sharp corners and intersections.

Drawing one line exactly over another is not difficult with the proper technique. Let the pencil lead ride along the top edge of the straightedge (or triangle) by tilting the pencil slightly toward the straightedge. This will move the point slightly away from the straightedge so that both edges of the line are visible as it is being drawn. Also, the construction line is completely visible ahead of the point, so it is easy to see that it has been completely covered by the printable line. It is usually necessary to go over a printable line a couple of times in order to build up enough density to make sharp, clear prints. Again, the wood pencil and the lead holder are pulled (never pushed—they may tear the paper). A consistent line width is maintained by touching up the lead point as often as necessary.

Drawing a straight line while guiding the lead along the top edge of the straightedge requires practice and technique. First, if the point is to stay the same distance from the straightedge as it is being rotated, the pencil point must be prepared with a smooth cone shape—no flat spots. Second, the angle that the pencil tilts over the straightedge, as seen when viewed parallel to the straightedge, must be kept

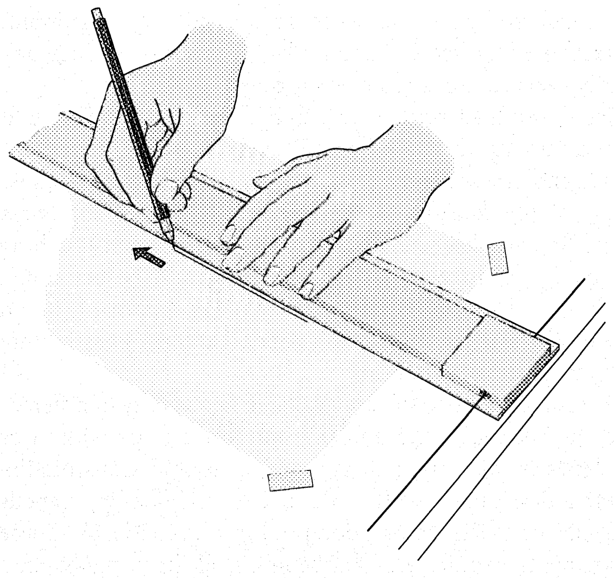


FIGURE 6.58 Drawing Horizontal Lines

uniform by proper wrist and arm action. This technique will become automatic with a little practice.

6.9.3 Drawing Horizontal Lines

Horizontal lines are drawn with the T-square, the parallel bar, or the drafting machine. Place the pencil point at the desired position of the horizontal line and move the straightedge up to the point, just touching it. When the straightedge is positioned, hold it with the free hand and forearm. This will minimize the deflection of the blade (when using the T-square or a drafting machine) as the line is drawn. Employing the previously discussed techniques, draw the line from left to right (Fig. 6.58). Horizontal lines are always drawn along the top edge of the straightedge. This places the straightedge between the hand and the paper and helps keep the drawing clean.

As any line is drawn, some graphite "chalks" off the point and lies as dust on the drawing. To avoid smearing this graphite dust, frequently blow or brush the dust off the drawing. Always use a drafting brush, never your hand (Fig. 6.25.) Graphite dust is the source of almost all "dirt" on drawings. All drawing equipment is lifted from the board before being moved. If you drag the equipment or instruments across the drawing, you will smear the linework and dirty the drawing. Keep the board, your hands, equipment, and instruments clean to minimize smearing your linework.

6.9.4 Drawing Vertical Lines

Vertical lines are drawn with the vertical edge of any triangle (or the vertical scale of the drafting machine). Position the straightedge and the triangle at the desired spot, with the vertical edge of the triangle to the left (Fig. 6.59). Then place the pencil point at the desired position of the vertical line and move the triangle up to the point, just touching it. This is done by holding the straightedge with the left hand and forearm and positioning the triangle with

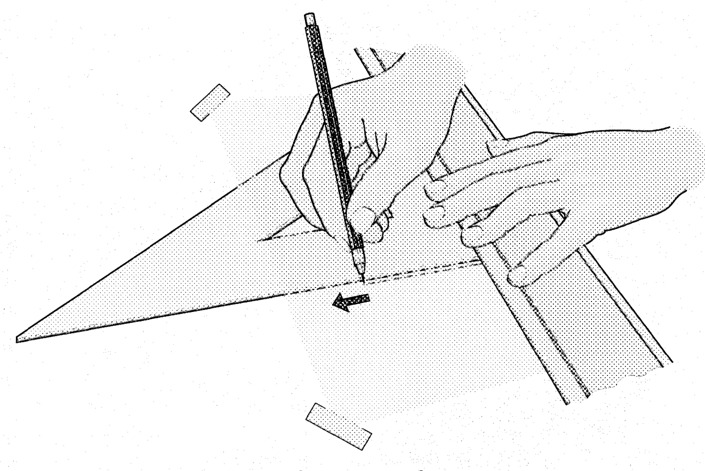


FIGURE 6.59 Drawing Vertical Lines

the fingers of the left hand (reverse this process if you are left-handed). Draw the line from bottom to top using the construction line or printable line technique.

Vertical lines are usually drawn with an upward motion along the left edge of the triangle. This places the triangle between the hand and the paper and helps keep the drawing clean. When drawing a construction line, change only the angle of the pencil. (Twist your body slightly in a counterclockwise direction to achieve a more comfortable position for printable lines.) You can also draw on the right side of the triangle, pulling the pencil toward you. The goal is a clean, accurate, and quickly constructed drawing. Your method of achieving this may differ slightly.

6.9.5 Drawing Lines at an Angle

Sloping lines (angled lines) are drawn much like vertical lines except that the sloping edge of the triangle, adjustable triangle, or drafting machine is used. Lines that slope toward the upper right corner of the board are easily drawn. Sloping lines must first be accurately measured and laid out with construction lines. Check the angle with a protractor before darkening. Figure 6.60 shows how to use a 45° triangle and a 30°/60° triangle to draw a variety of angles when used singly and together. Separately or in combination, the two triangles can achieve any 15° angle increment—15°, 30°, 45°, 60°, 75°, or 90°.

To draw parallel lines (Fig. 6.61), draw the first line as required and then slide the triangle in the direction of the second line. Establish the exact position of the line and complete the construction. Any other parallel lines can be drawn the same way.

Perpendicular lines (Fig. 6.62) are drawn similarly to parallel lines. The exception is that instead of sliding the triangle, you flip the triangle so the edge you were drawing on is now perpendicular to the first line.

6.9.6 Making Accurate Measurements

Accurate drafting is possible only with accurate use of the scale in marking measurements. The thickness of the edge of

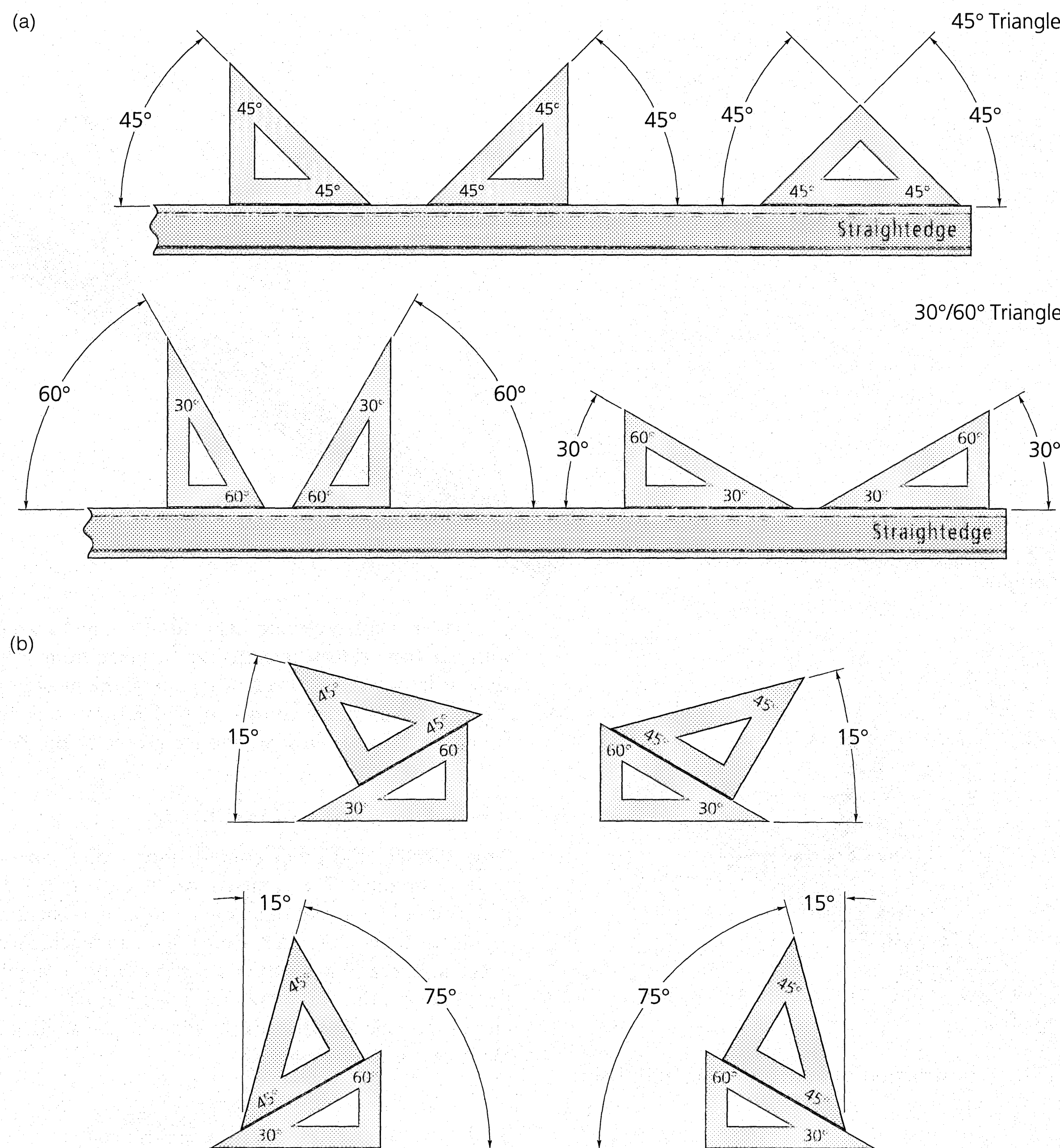


FIGURE 6.60 Drawing Sloping (Angled) Lines with Triangles

the scale and the distance from the mark on the scale to the surface of the paper is a physical limitation of your scale's accuracy. The most accurate measurements are made by sighting along a line that is perpendicular to the paper.

All scale readings should be marked on the paper with a short, thin dash (Fig. 6.63). This dash is easily seen after the scale is removed and the straightedge is positioned to use the measurement. Errors in measurement are seldom discovered until much work has been done, at which point the only way to correct them is to erase and redraw. Measurements put down as dots are too often lost, and many incorrect lines have been drawn from specks of dust.

If a number of measurements are to be put down end-to-end, all of them should be measured from the same point. If the measurements are put down by moving the scale for each measurement to the end of the previous one, an accumulation of errors may result in a large error. Remember, a series of successive dimensions is equal to the dimensions' arithmetic total and must be drawn that way.

6.9.7 Using Dividers

Dividers are used to transfer dimensions and measurements. They are *not* for setting off distances when cumulative errors could result; the scale is how to measure divisions in these cases.

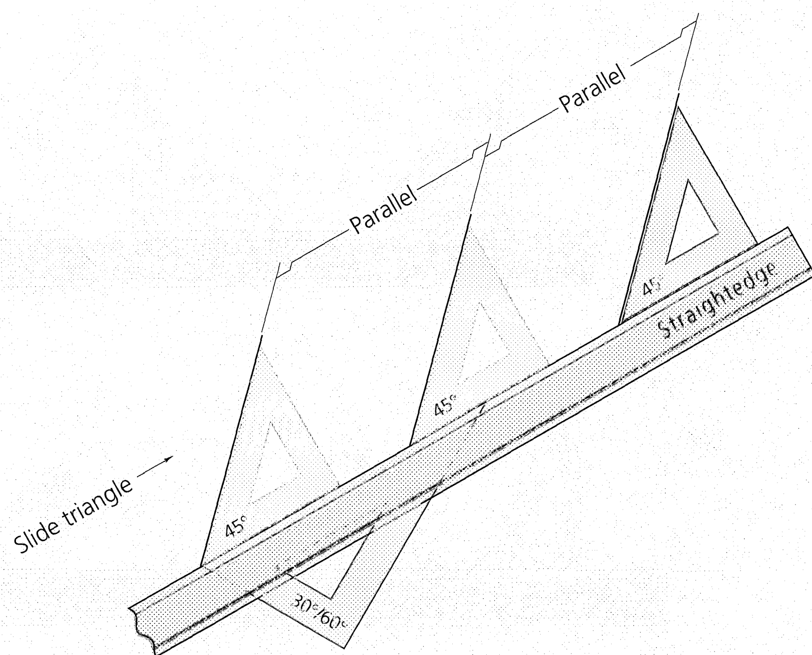


FIGURE 6.61 Construction of Parallel Lines Using Triangles

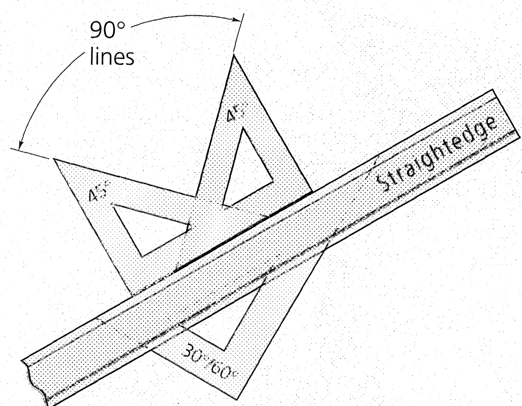


FIGURE 6.62 Construction of Perpendicular Lines Using Triangles

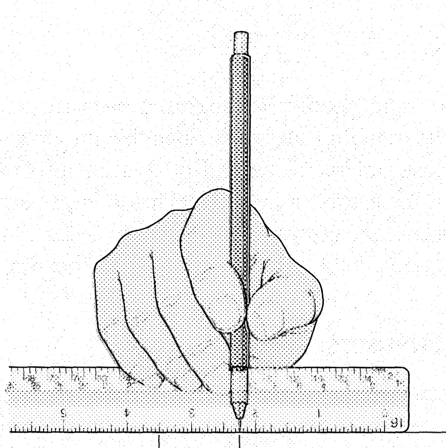


FIGURE 6.63 Measurements with a Scale

Dividers (Fig. 6.64) are held, adjusted, and manipulated with one hand. Measurements can be taken from an existing view or from a scale. Dividers are one of the most important instruments for quick construction of accurate drawings and are essential for solving descriptive geometry problems.

6.9.8 Drawing Curved Lines

Arcs, circles, and other **curved lines** require special linework techniques. The compass lead is fixed in the compass and cannot be rotated, therefore it requires frequent repointing. Noncircular curves are drawn with a French curve or an irregular curve (Fig. 6.38) or a flexible curve as a guide, but the guide fits the curve only for a short distance. Moreover, curves must be drawn equal in width to the straight lines to produce a uniform drawing.

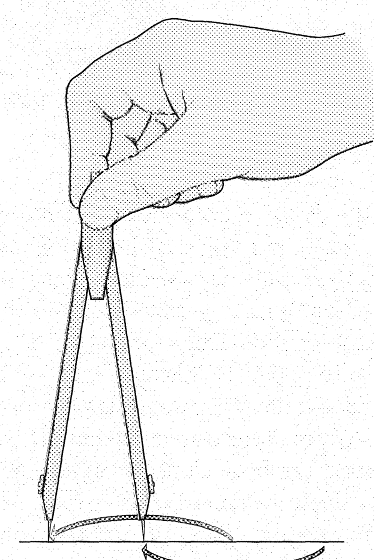


FIGURE 6.64 Using Dividers

The use of the compass and the irregular curve to create dark, consistent linework is typically one of the most frustrating aspects of mastering engineering drawing. Circle, ellipse, and other curved templates are available in standard sizes. These excellent tools can be helpful for many constructions, though they are somewhat limited in sizes and shapes and are relatively expensive if you need to purchase more than a few. Wait to practice curves with templates until you have mastered the compass and the irregular curve.

6.9.9 Using the Bow Compass

As mentioned in the section on instruments, the compass lead in a bow compass should be a short piece of the *same lead* as in the drafting pencil. The lead that comes with the compass is usually unsatisfactory and should be discarded. By using the same lead, both straight and curved lines will be drawn uniformly. Recall that the lead is secured in the compass with about $\frac{1}{8}$ in. (0.9 mm) exposed, and it is sharpened with a sandpaper pad (Fig. 6.42). (Remember, sandpaper pads are very messy and should be kept off of the drawing board and in a plastic bag.) Exercise care in sharpening the lead to keep the line through the point and the lead perpendicular to the sandpaper and to make a flat cut that gives an oval surface. This surface should be about three times as long as the diameter of the lead. The sides of this oval can be lightly sanded. When viewed from the side, the resulting "point" is chisel shaped and should have about the same taper as the cone-shaped taper of the drafting pencil. Because it is almost impossible to reposition the chisel shape properly, the lead in the compass is not adjusted after it has been sharpened. The chisel point should be touched up on scratch paper, and the centering point should be adjusted so that the midpoint of the needle point portion is even with the end of the lead. This adjustment ensures that the point makes proper contact with the paper. The compass can now be adjusted to the required radius and used to draw an arc or a circle.

On a construction line drawn on scratch paper, a distance equal to the radius of the circle or arc to be drawn is measured. The compass is set to this distance and a construction circle is drawn. When the diameter of the circle is measured, the reading should be twice that of the given radius. To get an accurate diameter reading, the measurement must be taken along a line that passes through the center point of the circle (Fig. 6.65). Any difference between the measured diameter and twice the given radius is twice the error of the compass setting. In Figure 6.66, the compass is being set by using the scale. This is not the easiest or most accurate method, but it is faster.

The width of the line drawn is determined by the thickness of the lead at the bevel. As a circle is drawn, the point shortens and the line widens. Therefore, a circle is started with a line somewhat narrower than desired. The line is redrawn until it is the correct width and density. A longer taper will hold a line width longer than a short stubby taper.

Figure 6.67 shows the proper method of constructing a

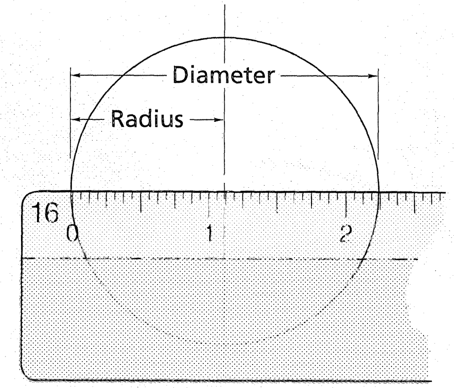


FIGURE 6.65 Measuring a Circle

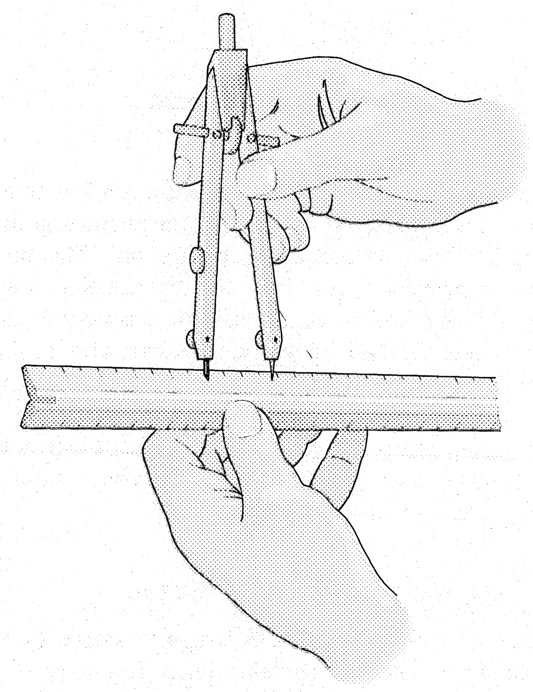


FIGURE 6.66 Setting the Compass Radius

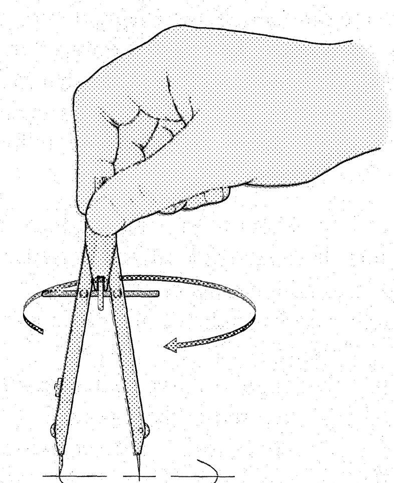


FIGURE 6.67 Using the Bow Compass

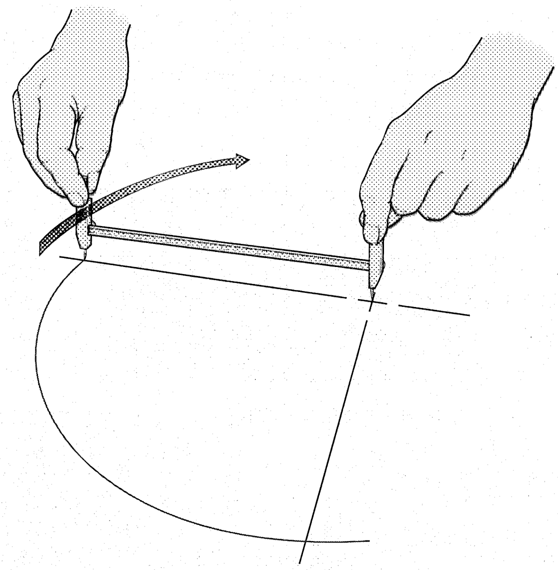


FIGURE 6.68 Using the Beam Compass

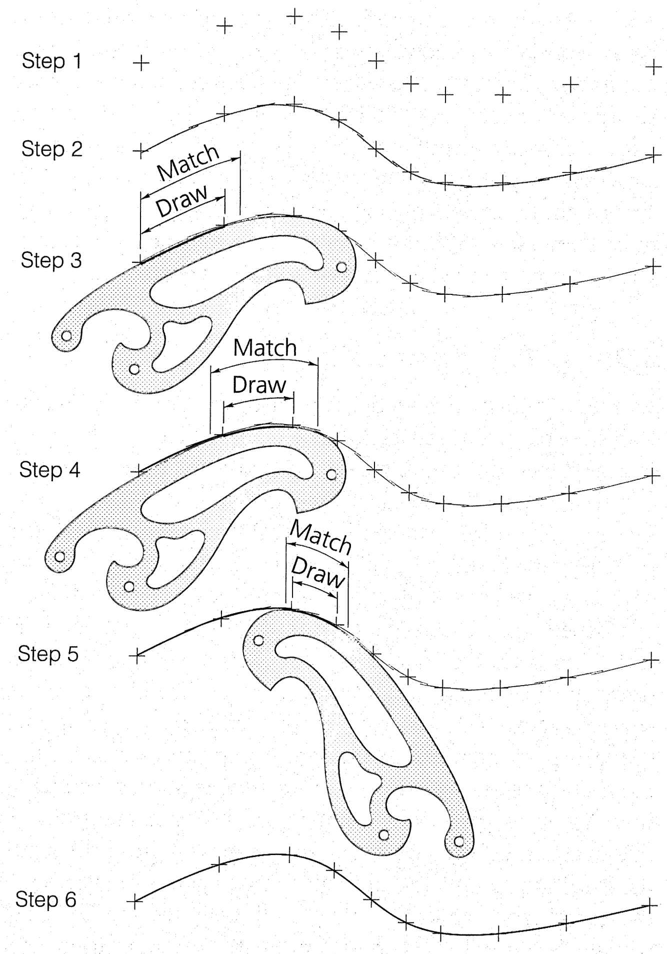


FIGURE 6.69 Using the Irregular Curve

circle with a bow compass. First, draw the circle with a thin dark line. Then thicken it by resetting the radius slightly and drawing another curve touching the first one. This method ensures crisp, black lines of the appropriate thickness. Of course, this method is of no use for drawing a hidden (dashed) line. Dashed curves are drawn with a slightly dulled compass lead point and only one pass to complete the circle.

The beam compass (Fig. 6.68) is used when a large-diameter circle or arc is required. Both hands are required to draw a circle with this instrument.

6.9.10 Using the Irregular Curve

Noncircular curves require the **irregular curve** (see Fig. 6.38) to make smooth, printable lines. Examples of such curves are the ellipse—an angular view of a circle—the helix, and spirals. Irregular curves are manufactured in many shapes and sizes.

Curves that are drawn with the irregular curve are usually determined by first plotting a series of points that are known to lie on the curve. Then a curve is drawn that includes all of these points. Figure 6.69 illustrates the use of the irregular curve. Good results can be obtained by following these steps:

1. Lightly sketch a smooth line freehand to include the plotted points. It is easier to set the irregular curve to a line than it is to match a series of points.
2. Set the irregular curve so that it matches a part of the line (at least three points).
3. Draw the line that fits the curve, but stop a little before the end of the fit (before the third point).
4. Reset the irregular curve to fit the next part of the curve and draw the next portion of the line. Again, the last portion of fit is not drawn.
5. Repeat this process until the curve is complete.

If the sketched curve and the first series of matching the irregular curve to the sketched line are all done on a tracing paper overlay, then the result will be much neater. The ends of each segment of the line are marked as the line matches the irregular curve. Then the same fits can be used in the next step. When all fits are made, the tracing paper overlay is placed under the drawing and carefully aligned with the curve under the plotted points. The curve is traced onto the drawing with the irregular curve marked on the overlay. This technique has two advantages. First, all fits are made on throwaway paper, where erasures can easily be made without erasing the plotted points. Second, before the final drawing of the curve, the accuracy of fit can be seen when the overlay is positioned under the drawing.

The overlay technique is particularly valuable when the curve is symmetrical. For example, an ellipse has four identical curves—two are mirror images of the other two. All are symmetrical about the major and minor axes. It is necessary to fit only one of these curves, then this fit is duplicated on the other three.

If a smooth curve is desired, the plotting of the points of an irregular curve is particularly important. A small error in the position of a point can easily cause irregularities in the curve. The spacing of plotted points should be small where the curve is sharpest and long where the curve is the straightest.

6.9.11 Keeping Your Drawings Clean

All drawings attract dirt. How much dirt is determined by your habits as a drafter. Cleanliness does not just happen; it is the result of developing correct habits. Procedures and techniques that will keep your drawings clean include the following.

Keep your hands clean. Periodically wash your hands to remove accumulations of graphite, perspiration, body oils, and dirt.

Keep your equipment clean. Periodically wash with soap and water all tools that touch the paper. Tools that contain wood or metal should be cleaned with a damp sponge; when they become soiled, they must also be scrubbed. The drawing surface should be cleaned regularly.

Clean up graphite dust. Most dirt on a drawing is actually graphite. Repeated and consistent use of the drafting brush and the dust pad to remove this graphite dust, before other tools smear it around, will contribute significantly to cleaner drawings. Always brush after erasing.

Keep your pencil point clean. The pencil pointer leaves dust clinging to the lead. Some pointers also push shavings up into the pencil's jaws. If the dust and the shavings are not removed before drawing starts, they will drop onto the drawing. Thus, after each sharpening, lightly tap the pencil on the side of the desk to dislodge any shavings and then wipe the lead on a piece of tissue. Poking the lead point into a piece of Styrofoam also works well.

Keep your paper clean. Proper use of the straightedge and triangle always places these instruments between your hands and the paper. Even clean hands will put body oils onto the paper; this has a magnetic effect on dirt. When lettering, place a sheet of clean paper under your hands to keep the drawing cleaner.

6.9.12 Inking Drawings

Ink is frequently used on drafting film or vellum. Drawings used in product literature, technical manuals, and pictorial illustrations are normally inked to get good photographic quality.

Ink drawings must first be laid out with construction lines and then inked. It is very difficult to ink a drawing while laying it out. Light tables are excellent for inking and tracing drawings. Because ink tends to flow between surfaces and to smear lines, triangles and templates must be raised from the drawing when inking a line. Specially designed equipment with a ledge or with inking risers prevents the equipment from being flush with the paper.

Ink drawings are prepared with technical pens (Fig. 6.70). Keeping the technical pen almost vertical helps prevent uneven and ragged linework (Fig. 6.71). If possible, no more than one pass should be made for thin and medium lines. Extremely thick lines are drawn with an appropriate pen size. If a thinner pen is used to thicken the line in stages, better results may be obtained.

The ink should be completely dry before you start another portion of the drawing. Some drafters prefer to ink all horizontal lines from the top of the sheet downward and then from left to right. Ink lines should be erased very

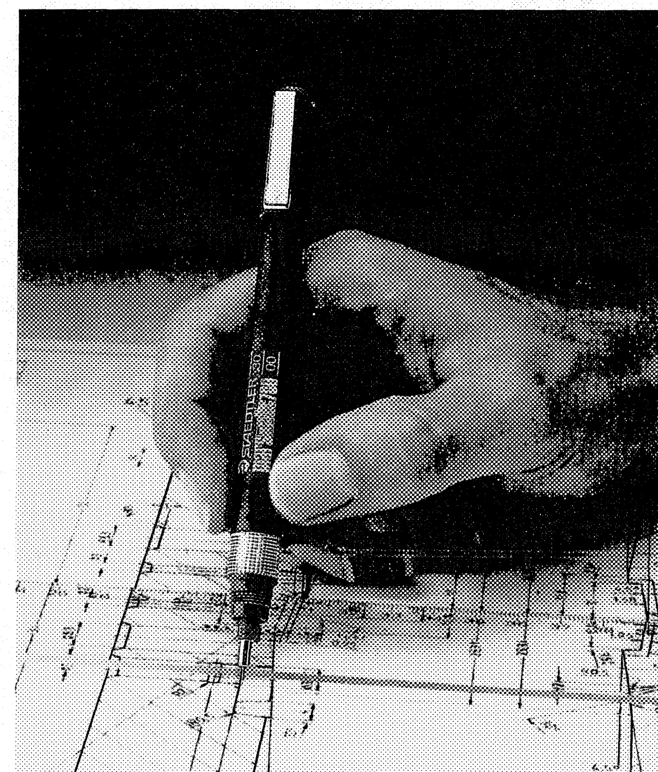


FIGURE 6.70 Inking with a Technical Pen

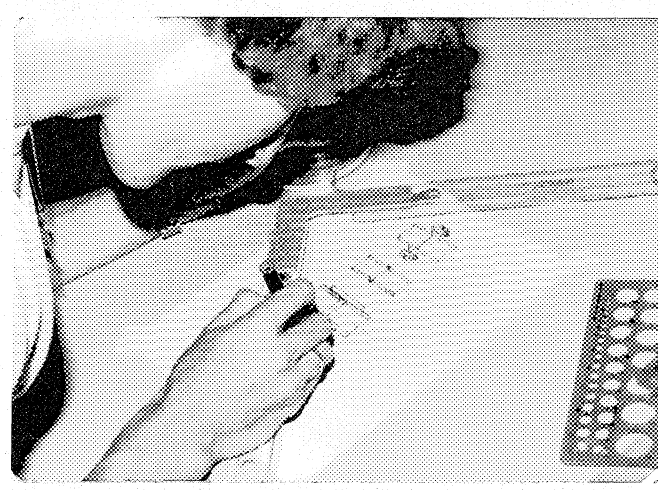


FIGURE 6.71 Inking

carefully, especially on vellum or other types of paper. You can easily erase ink from drafting film with the proper type of eraser and a small amount of moisture. As in pencil drawings, the surrounding lines should be protected while erasing.

You May Complete Exercises 6.1 Through 6.12 at This Time

QUIZ

True or False

1. Plastic leads are used on vellum.
2. 5H and 6H leads are used to darken the final drawing.
3. Construction lines drawn with nonreproducible-blue lead do not require erasing before the drawing is darkened.
4. The title block is always placed in the lower left-hand corner of the sheet.
5. Hidden lines always take precedence over centerlines.
6. Object lines are thin, black, and approximately 0.35 mm.
7. Break lines are normally drawn freehand.
8. A dry cleaning pad is used to remove graphite from a newly sharpened pencil.

Fill in the Blanks

9. A sandpaper pad is used to __________ .
10. Dry cleaning pads are used to __________ and __________ a drawing.
11. An architect's scale is __________ divided.
12. __________ and __________ curves are used to draw odd-sized circular curves and arcs.
13. Technical pens should be held __________.
14. A mechanical engineer's scale is __________ divided.
15. Always draw on the __________ side of the straightedge.
16. Incline lead holders at __________ degrees to the drafting board when drawing.

Answer the Following

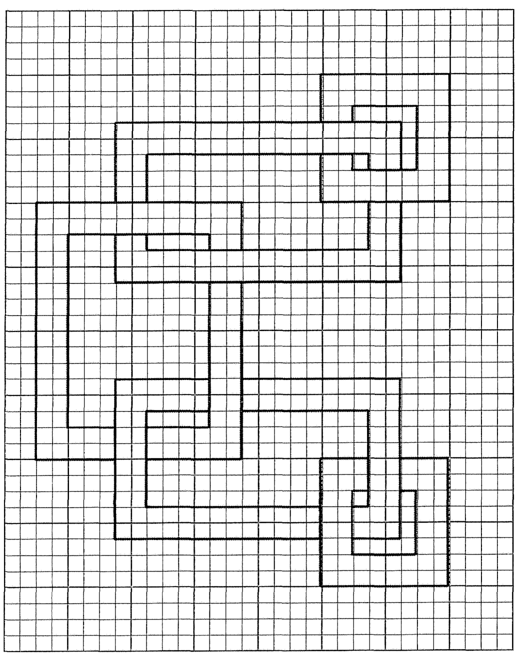
17. Describe the process of drawing a vertical instrument line.
18. Describe three ways to keep your drawing clean.
19. Explain how to sharpen and prepare a wooden pencil for drawing an instrument line.
20. Describe the process of drawing an irregular curve.
21. Describe the two primary types of drawing media used in drafting.
22. What does the term *precedence of lines* mean?
23. What line widths are used on a drafting format and title block?
24. Name five types of information included in a title block.

EXERCISES

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.

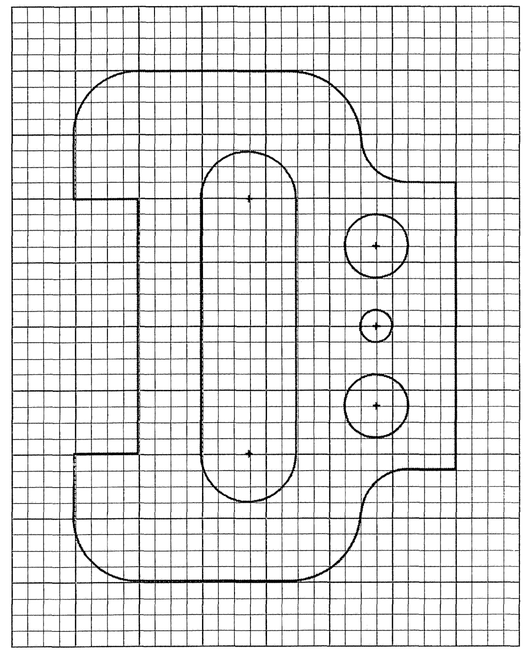
After Completing the Chapter You May Draw the Assigned Exercises

Exercise 6.1 Draw the given design.



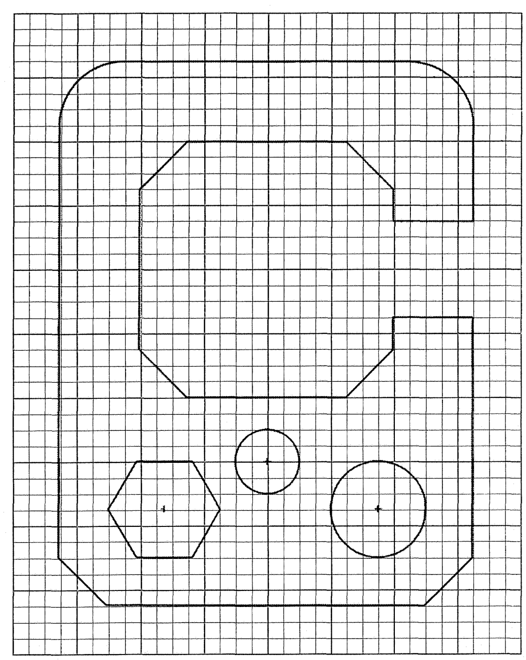
EXERCISE 6.1

Exercise 6.2 Draw the cover plate.



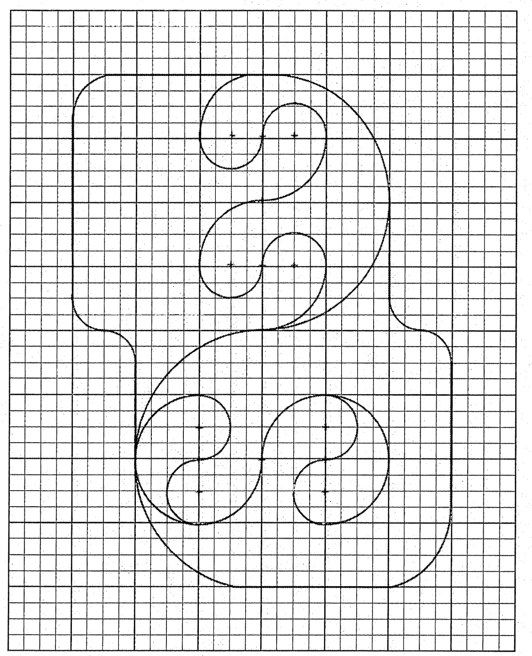
EXERCISE 6.2

Exercise 6.3 Draw the gage plate.



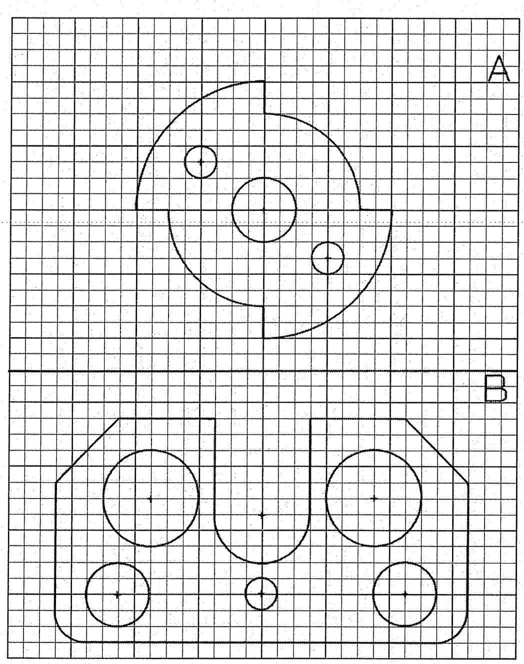
EXERCISE 6.3

Exercise 6.4 Draw the design.



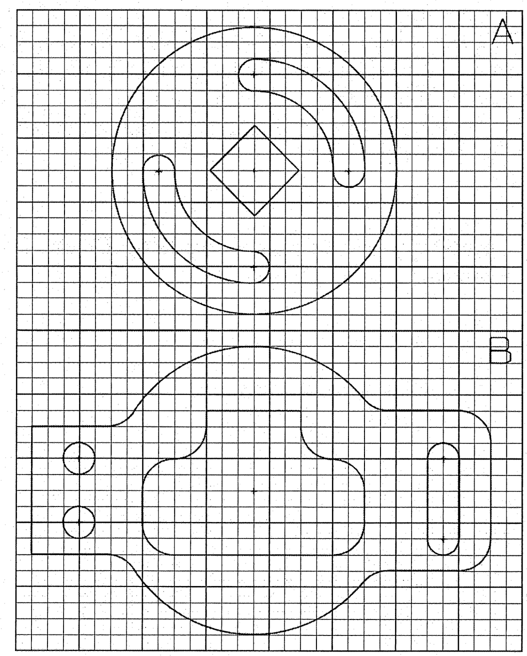
EXERCISE 6.4

Exercise 6.5 Draw the two gaskets.



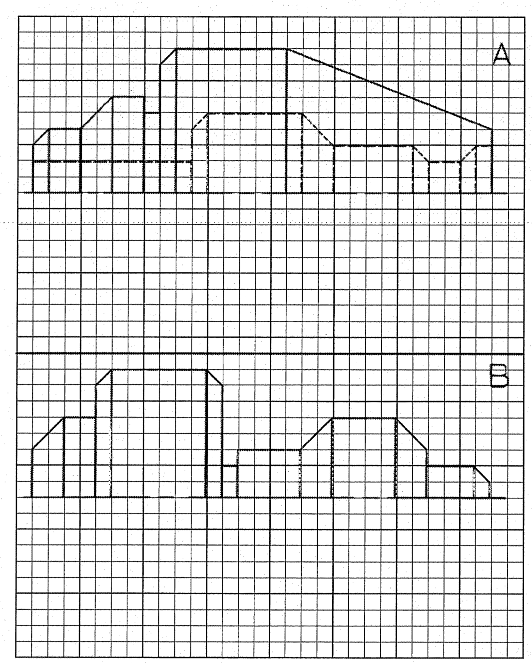
EXERCISE 6.5

Exercise 6.6 Draw the two cover plates.



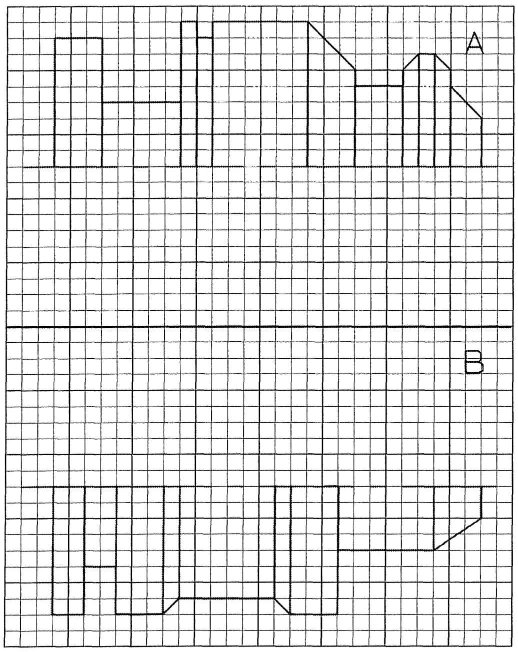
EXERCISE 6.6

Exercise 6.7 Draw the complete cone check and guide.



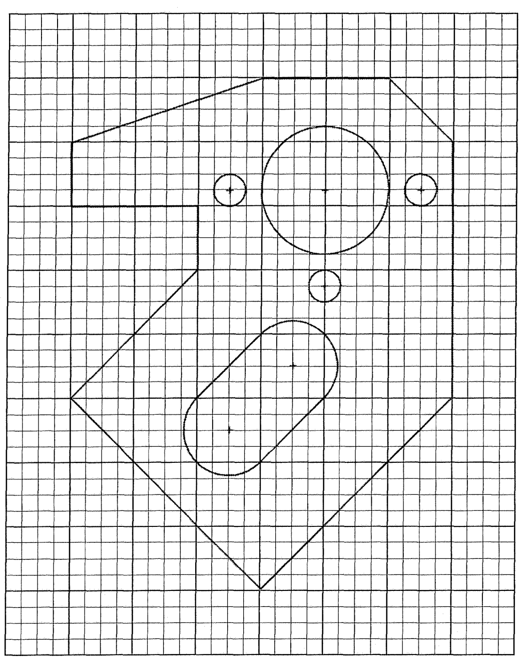
EXERCISE 6.7

Exercise 6.8 Draw the two guides.



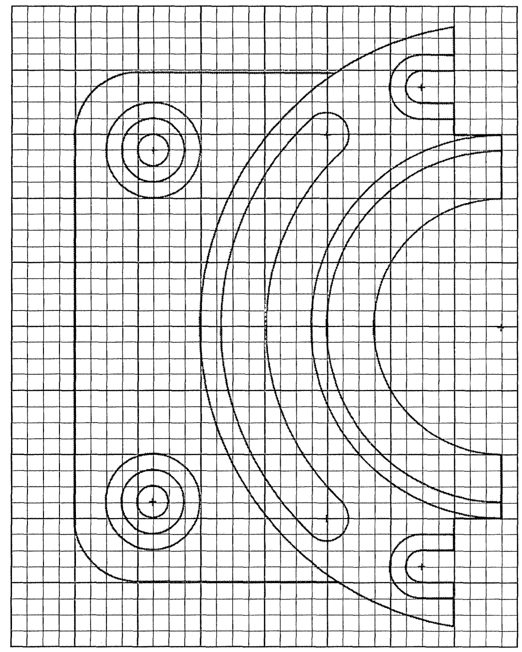
EXERCISE 6.8

Exercise 6.9 Draw the control plate.



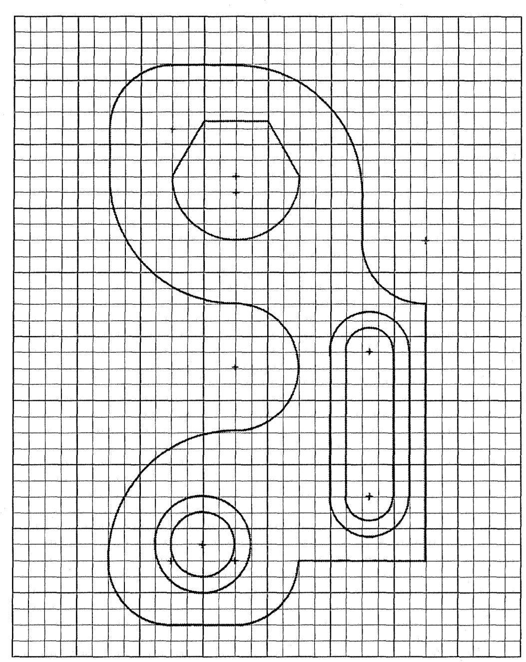
EXERCISE 6.9

Exercise 6.10 Draw the disk guide.



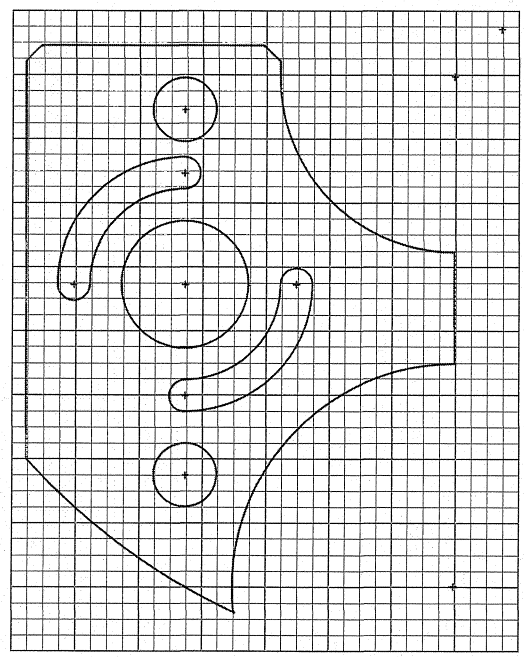
EXERCISE 6.10

Exercise 6.11 Draw the mount surface.



EXERCISE 6.11

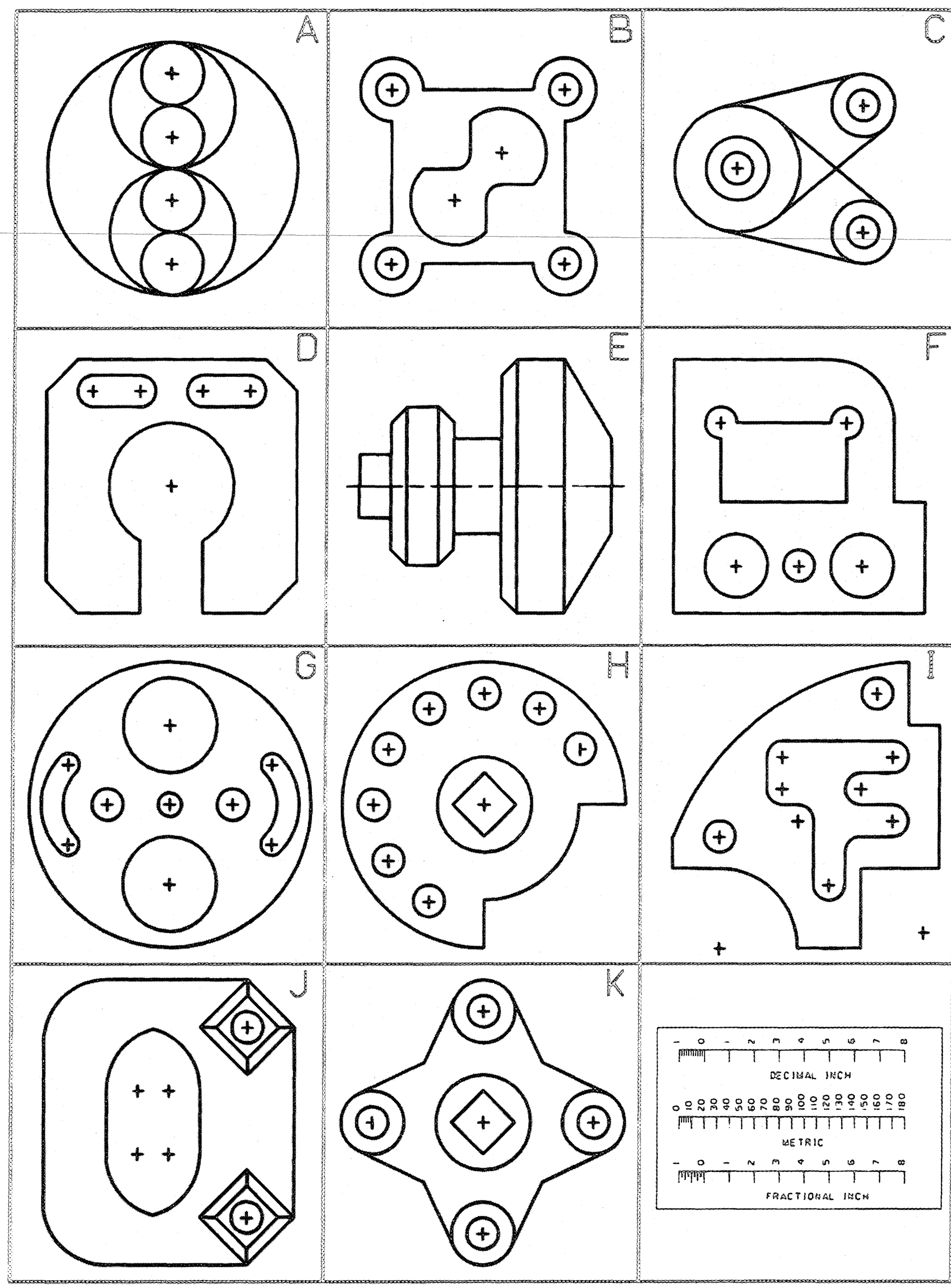
Exercise 6.12 Draw the tube gasket.



EXERCISE 6.12

PROBLEMS

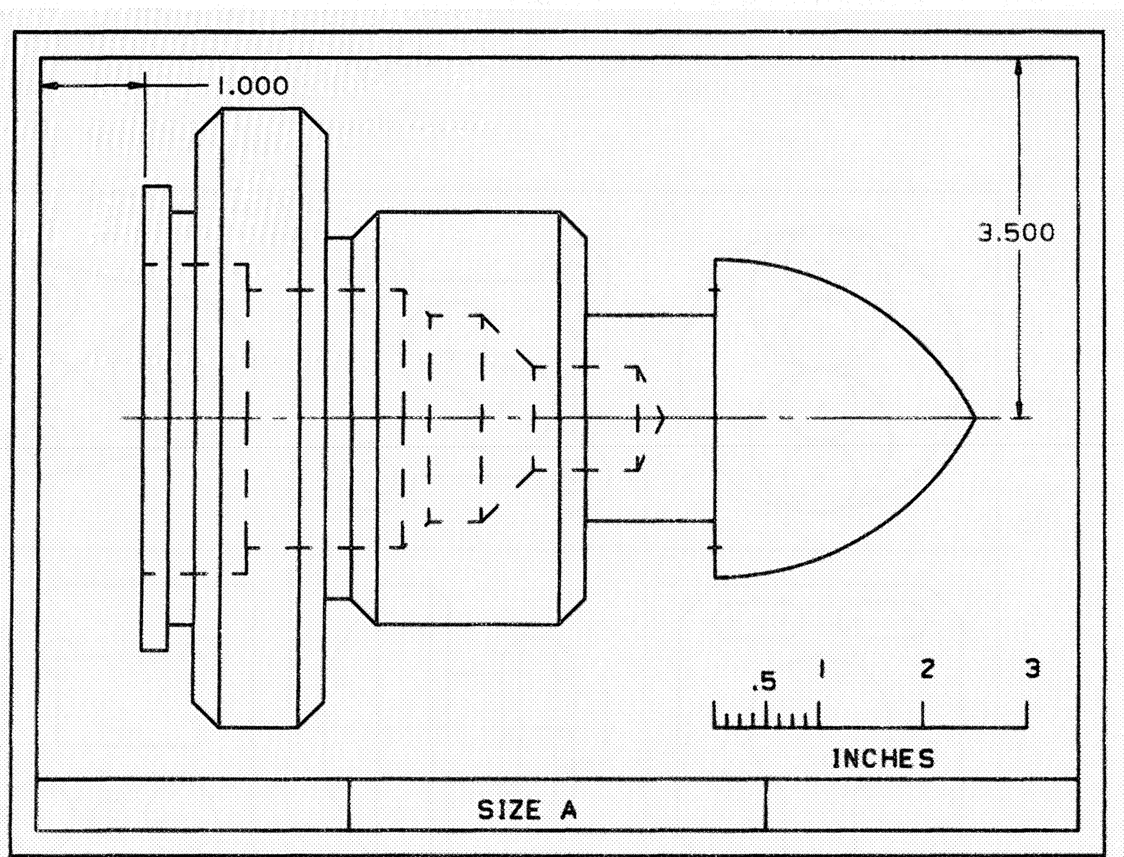
Problems 6.1(A) Through (K) Draw each problem assigned by the instructor on an "A"-size sheet, one drawing per sheet. Establish measurements by using one of the three scales provided. Your instructor may request enlarged or reduced drawings as needed.



PROBLEM 6.1

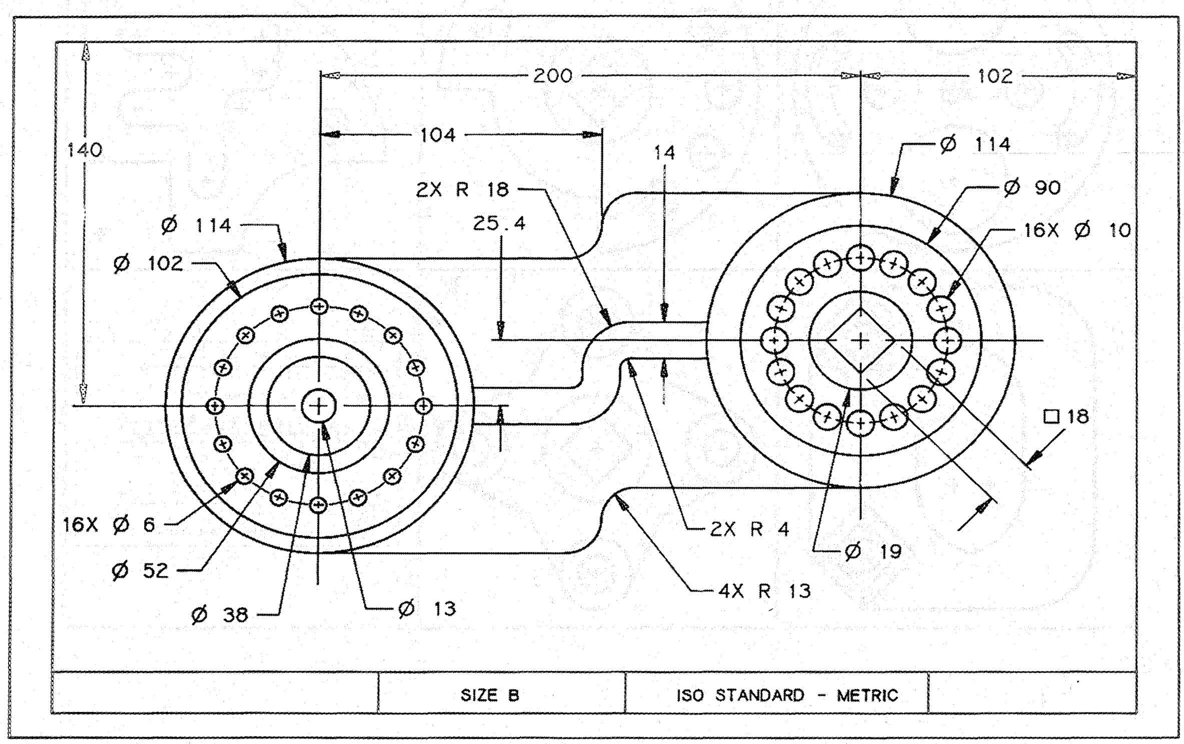
Problem 6.2

An "A"-size drawing format is called for in this project. Redraw the given object. Do not dimension.



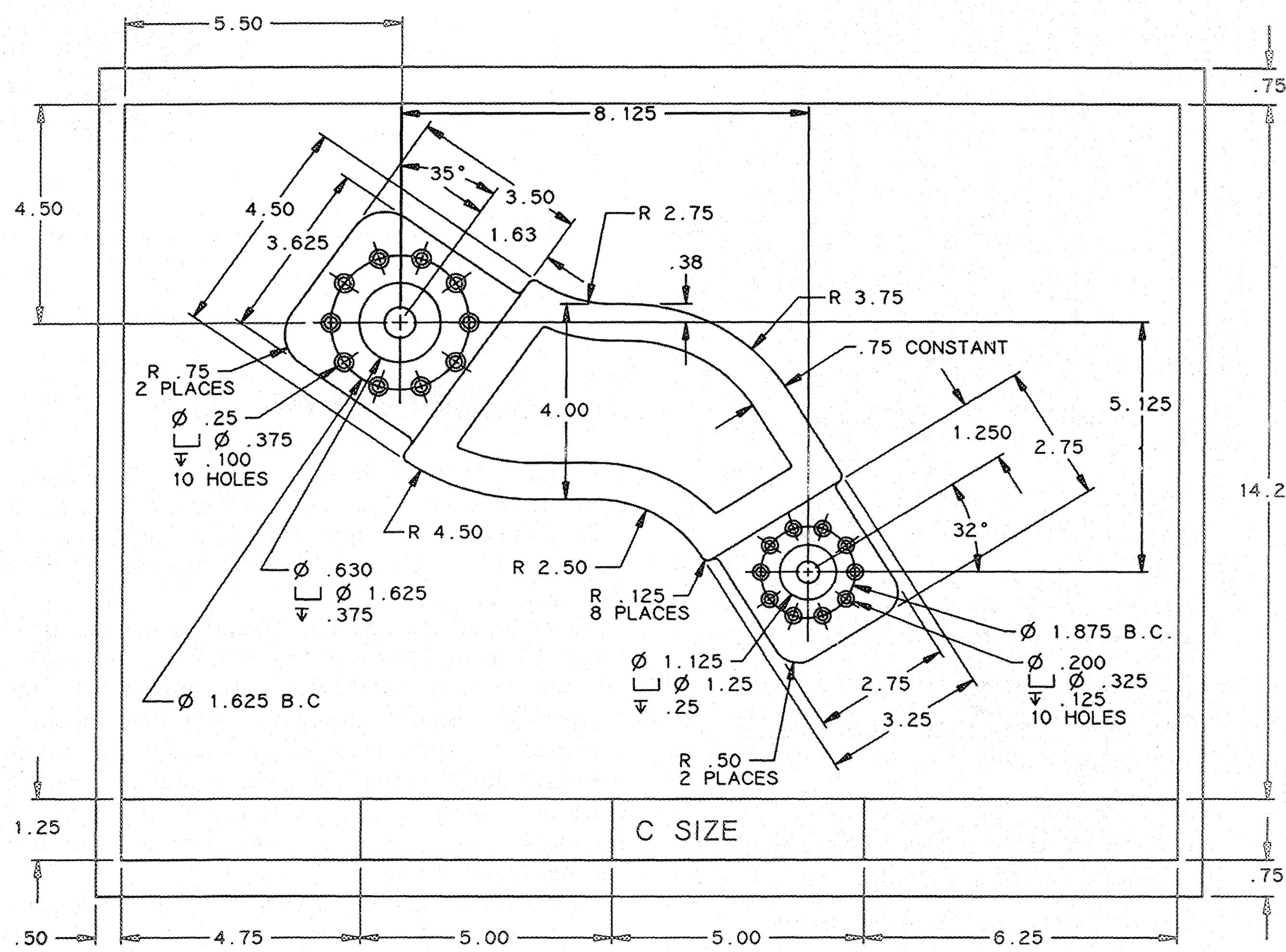
PROBLEM 6.2

Problem 6.3 Using a "B"-size sheet, redraw the part. This is an ISO (International Standards Organization—see Chapter 1) standard drawing using metric dimensions (millimeters). Do not dimension. This drawing includes the diameter symbol ∅ and the square symbol □.



PROBLEM 6.3 Assembly Plate

Problem 6.4 Using a "C"-size sheet, draw the part as shown. Dimension only if assigned by the instructor. (This project is difficult; information contained in Chapter 8 concerning tangent arcs may be helpful.)



PROBLEM 6.4 Arm