ENGINEERING DRAWING

Compiled BY

Iqbal Matin
Professor
Department of Cibil Engineering
Rajshahi University of Engineering & Technology
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Figure 1-3 Rendering

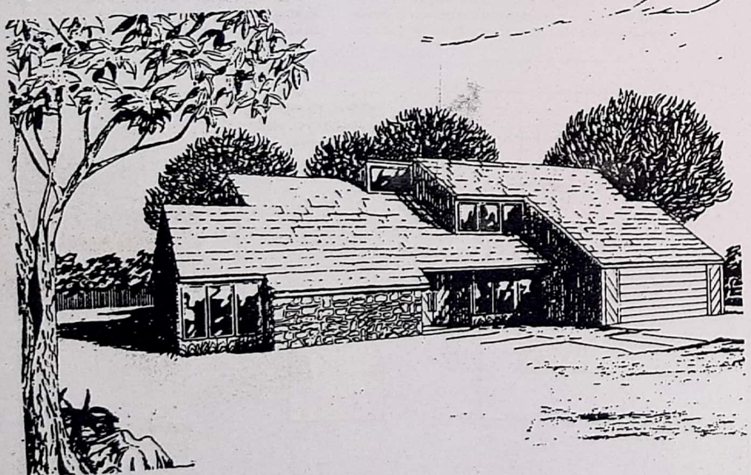


Figure 1-4 Rendering

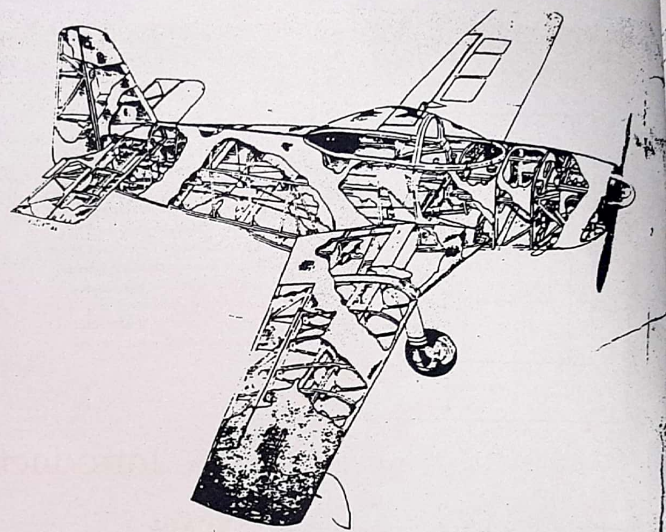


Figure 1-5 Mechanical illustration (*Courtesy Ken Elliott*)

ing the represented parts. Notice that the drawings contain a graphic representation of the part, dimensions, material specifications, and notes.

Illustrations or Renderings

Illustrations or renderings are sometimes referred to as a third type of drawing because they are not completely technical, neither are they completely artistic; they combine elements of both, as shown in Figures 1-3, 1-4, 1-5, and 1-6. They are technical in that they are drawn with mechanical instruments or on a computer-aided drafting system, and they contain some degree of technical information. However, they are also artistic in that they attempt to convey a mood, an attitude, a status or other abstract, nontechnical feelings.

Types of Technical Drawings

Technical drawings are based on the fundamental principles of projection. A *projection* is a drawing or representation of an entity on an imaginary plane or planes. This projection plane serves the same purpose in technical drawing as is served by the movie screen in a theater.

As can be seen in Figure 1-7, a projection involves four components: 1) the actual object that the drawing or projection represents, 2) the eye of the viewer looking at the object, 3) the imaginary projection plane (the viewer's drawing paper or the graphics display in a computer-aided drafting system), and 4) imaginary lines of sight called *projectors*.

Two broad types of projection, both with several subclassifications, are parallel projection and perspective (converging) projection.

Parallel Projection

Parallel projection is subdivided into the following three categories: orthographic, oblique, and axonometric projections.

Orthographic projections are drawn as multiview drawings which show flat representations of principal views

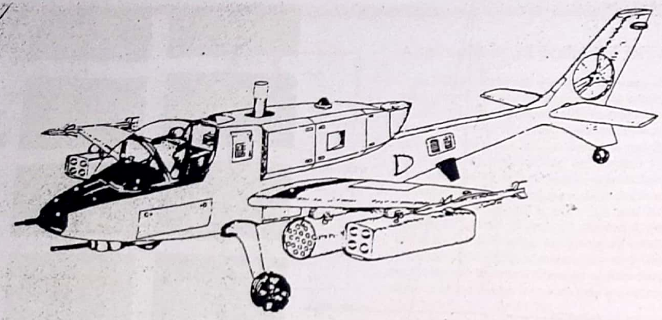


Figure 1-6 Mechanical illustration (*Courtesy Ken Elliott*)

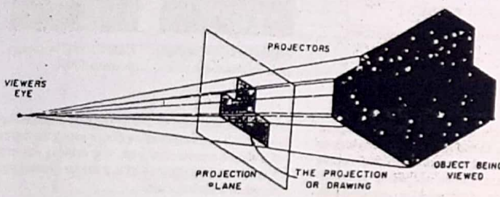


Figure 1-7 The projection plane

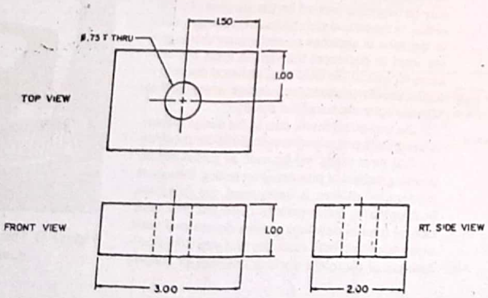


Figure 1-8 Orthographic multiview drawing

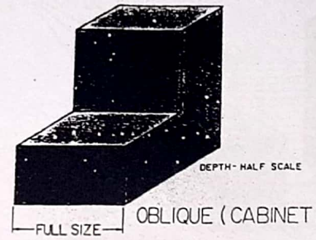


Figure 1-9 Oblique projection (cabinet)

of the subject. Figure 1-8. *Oblique projections* actually show the depth of the subject. and are of two varieties: *cabinet* (half scale) or *cavalier* (full scale) projections. Figures 1-9 and 1-10. *Axonometric projections* are three-dimensional drawings. and are of three different varieties: isometric. dimetric. and trimetric. Figures 1-11. 1-12. and 1-13.

Perspective Projection

Perspective projections are drawings which attempt to replicate what the human eye actually sees when it views an object. That is why the projectors in a perspective drawing converge. There are three types of

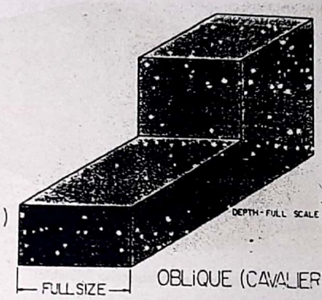


Figure 1-10 Oblique projection (cavalier)

perspective projections: one-point. two-point. and three-point projections. Figures 1-14. 1-15. and 1-16.

Purpose of Technical Drawings

To appreciate the need for technical drawings, one must understand the design process. The design process is an orderly, systematic procedure used in accomplishing a needed design.

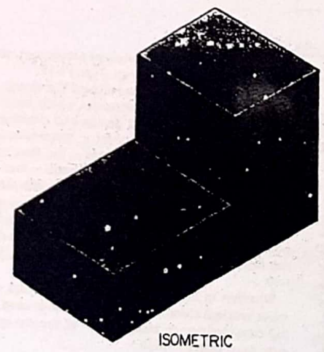


Figure 1-11 Axonometric projection (isometric)

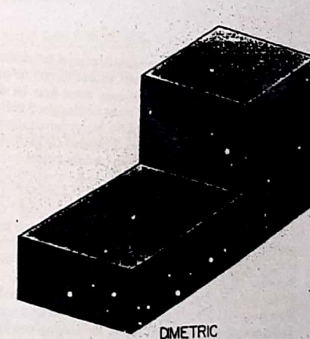


Figure 1-12 Axonometric projection (dimetric)

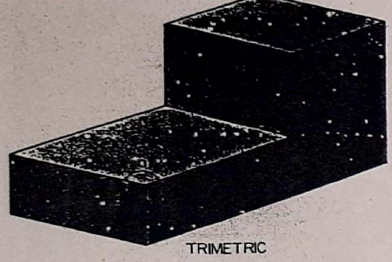


Figure 1-13 Axonometric projection (trimetric)

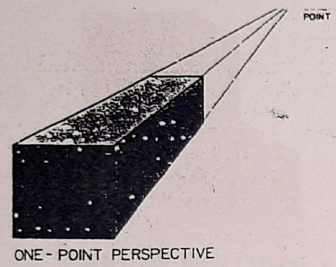


Figure 1-14 One-point perspective projection

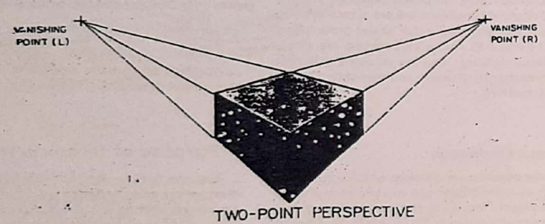


Figure 1-15 Two-point perspective projection

Any product that is to be manufactured, fabricated, assembled, constructed, built or subjected to any other type of conversion process must first be designed. For example, a house must be designed before it can be built. An automobile must be designed before it can be manufactured. A printed circuit board must be designed before it can be fabricated.

The Design Process

The *design process* is an organized, step-by-step procedure in which mathematical and scientific principles, coupled with experience, are brought to bear in order to solve a problem or meet a need. The design process has five steps. Traditionally, these steps have been 1) identification of the problem or a need, 2) development of initial ideas for solving the problem, 3) selection of a proposed solution, 4) development and testing of models or prototypes, and 5) developing working drawings, Figure 1-17.

The age of computers has altered the design process slightly for those companies which have converted to computer-aided design and drafting. For these companies, the expensive, time-consuming fourth step in the design process — the making and testing of actual models or prototypes — has been substantially altered, Figure 1-18. This fourth step has been replaced with three-dimensional computer models which can be quickly and easily produced on a CAD system using the data base built-up during the first three phases of the design process, Figure 1-19.

Whether in the traditional design process or the more modern computer version, in either case, working drawings are an integral part of the design process from start to finish.

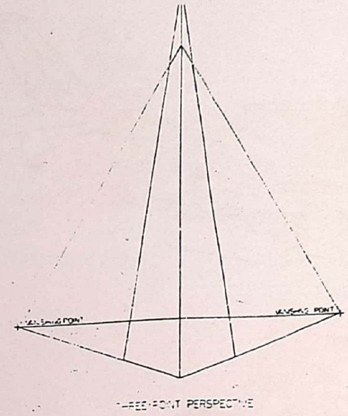


Figure 1-16 Three-point perspective projection

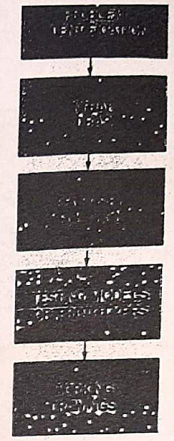


Figure 1-17 The design process (manual)

Figure 1-18 The design process (CAD)

The purpose of technical drawings is to document the design process. Creating technical drawings to support the design process is called *drafting*. People who do drafting are known as *drafters* or *drafting technicians*. The words "draftsman" or "draughtsman" are no longer used.

In the first step of the design process, technical drawings are used to help clarify the problem or the need. The drawings may be old ones on file or they may be new ones created for the purpose of clarification. In the second step, technical drawings — often in the form of sketches or preliminary drawings — are used to document the various ideas and concepts formed. In the third step, technical drawings — again, usually preliminary drawings — are used to communicate the purposed solution.

If the traditional fourth step in the design process is being used, preliminary drawings and sketches from the first three steps will be used as guides in constructing models or prototypes for testing. If the more modern fourth step is being used, the data base built-up during documentation of the first three steps can be used in developing three-dimensional computer models. In both cases, the final step is the development of complete working drawings for guiding individuals involved in the conversion process. Figure 1-20 is a working drawing documenting the design of a simple mechanical part. The drawing was produced manually. Figure 1-21 is a similar drawing produced on a CAD system.

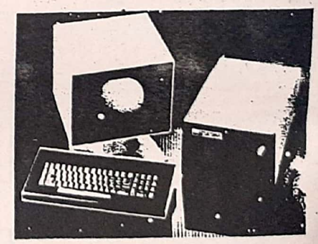


Figure 1-19 Three-dimensional computer model (*Courtesy Terak Corporation*)

Applications of Technical Drawings

Technical drawings are used in many different applications. They are needed in any setting which involves design, and in any subsequent form of conversion process. The most common applications of technical drawings can be found in the fields of manufacturing, engineering, architecture and construction, and all of their various related fields.

Architects use technical drawings to document their designs of residential, commercial, and industrial buildings. Figures 1-22 and 1-23. Structural, electrical, and mechanical (heating, ventilating, air conditioning (HVAC) and plumbing) engineers who work with architects also use technical drawings to document those aspects of the design for which they are responsible. Figures 1-24, 1-25, and 1-26.

Surveyors and civil engineers use technical drawings to document such work as the layout of a new

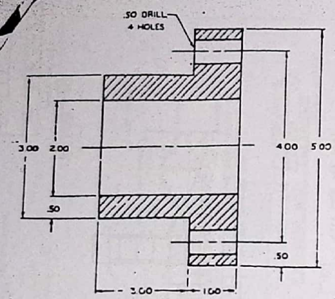


Figure 1-20 Simple mechanical drawing (manual)

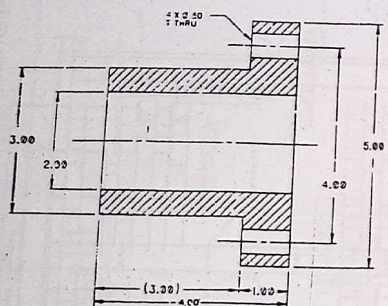


Figure 1-21 Simple mechanical drawing (CAD)

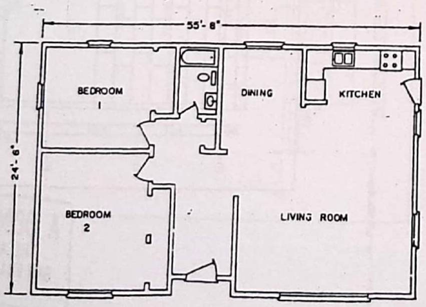


Figure 1-22 Technical drawing (architectural)

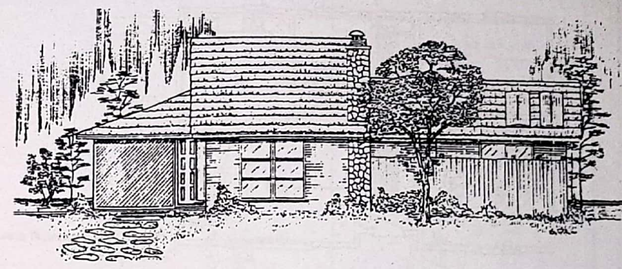


Figure 1-23 Technical drawing (architectural)

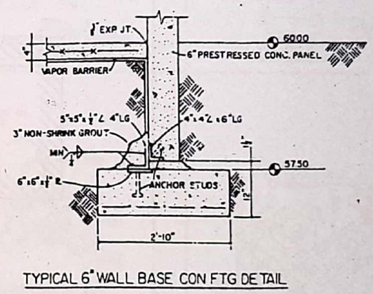


Figure 1-24 Technical drawing (structural)

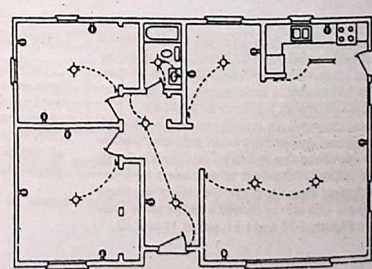


Figure 1-25 Technical drawing (electrical)

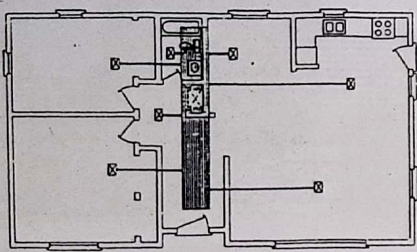


Figure 1-26 Technical drawing (HVAC)

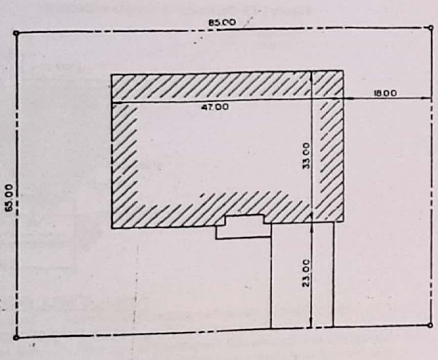


Figure 1-27 Technical drawing (civil)

subdivision, or the marking-off of the boundaries for a piece of property. Figure 1-27. Contractors and construction personnel use technical drawings as their blueprints in converting architectural and engineering designs into reality. Figures 1-28 and 1-29.

Technical drawings are equally important to engineers, designers, and various other individuals working in the manufacturing industry. Manufacturing engineers use technical drawings to document their designs. Technical drawings guide the collective efforts of individuals who are concerned with the same common goal. Figures 1-30 and 1-31, pages 15 and 16.

Regulation of Technical Drawings

Technical drawing practices must be regulated because of the diversity of their applications. Just as the English language must have certain standard rules of grammar, the graphic language must have certain rules of practice. This is the only way to ensure that all people attempting to communicate using the graphic language are speaking the same language.

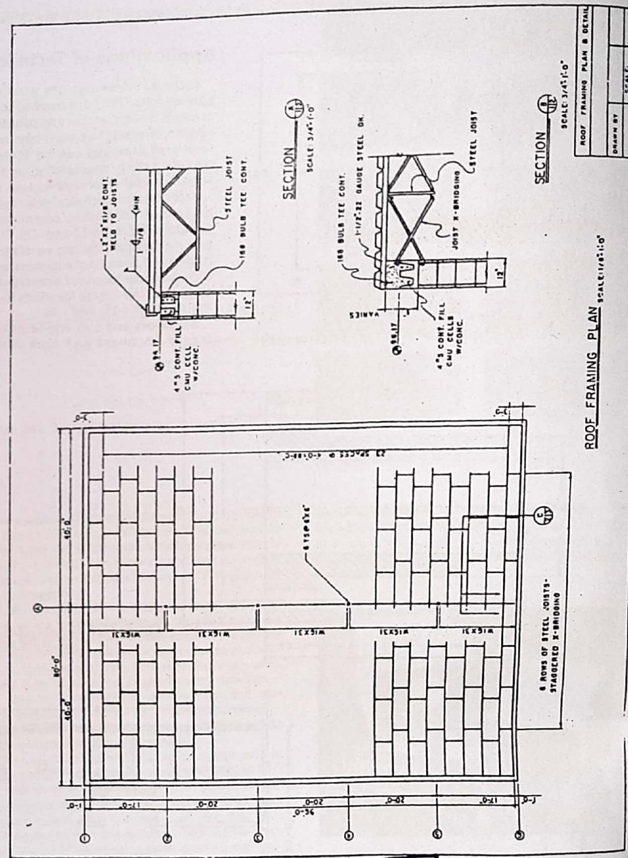


Figure 1-28 Architectural/Engineering drawing

Figure I-28 Archi... ural/Engineering drawing

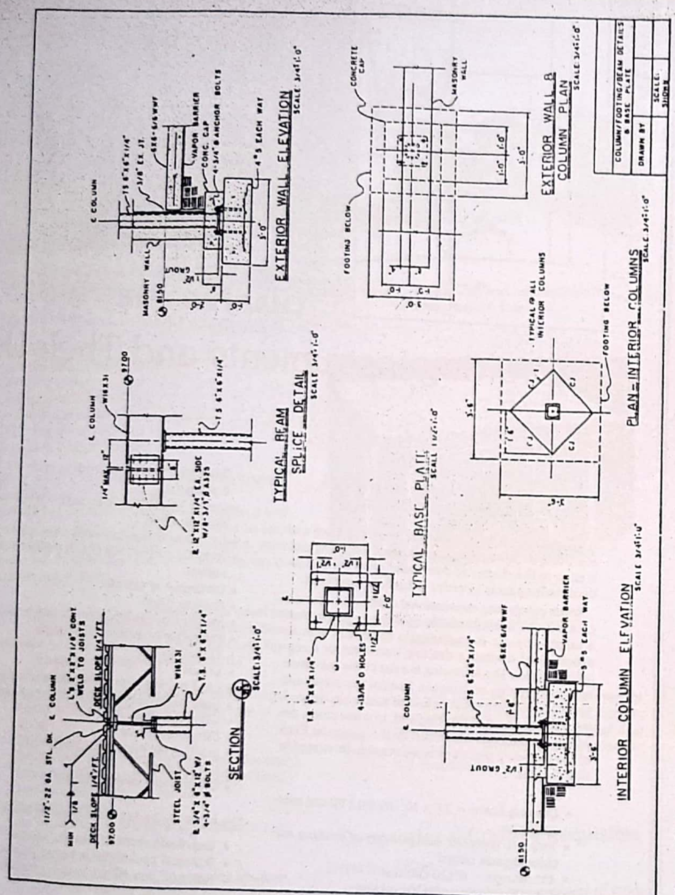
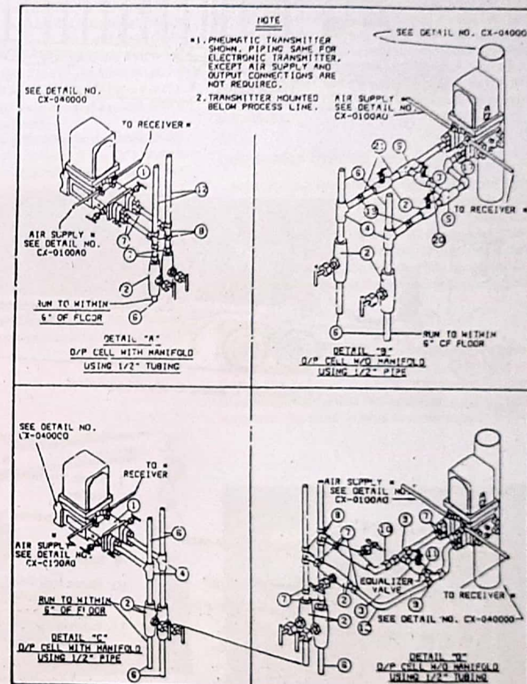


Figure I-29 Architectural/Engineering drawing



ITEM	DESCRIPTION	SPEC	ITEM	DESCRIPTION	SPEC	ITEM	DESCRIPTION	SPEC
1	3-VALVE MANIFOLD		8	1/2"T. TEE		20	1/4" UNION	
2	1/2" VALVE		9	1/2"T. X 1/4"P. TEE		21	1/2" NIPPLE	
3	1/4" VALVE		10	1/2"T. X 1/2"P. ELBOW				
4	1/2" TEE		11	1/4" PIPE				
5	1/2" X 1/4" TEE		12	1/2" TUBING				
6	1/2" PIPE		13	1/2" UNION				
7	1/2"T. X 1/2"P. CONN.		17	1/2" 90° ELBOW				

THE RUST ENGINEERING COMPANY — INSTRUMENTATION INSTALLATION DETAIL — D/P CELL TRANSMITTERS FOR LIQUID AND STEAM SERVICE — CF-040001

Figure I-30 Isometric mechanical drawing (*Courtesy The Rust Engineering Company*)

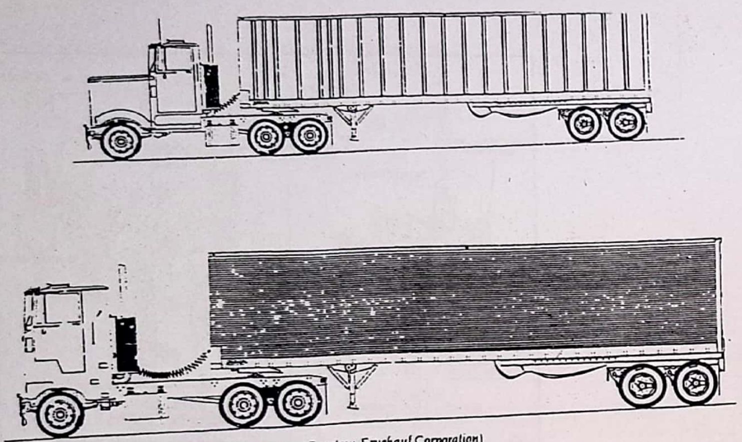
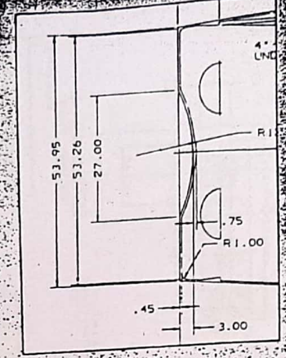


Figure 1-40 Mechanical pictorial drawing (*Courtesy Fruehauf Corporation*)

Review

1. What is a drawing?
2. What old adage explains the basis of the need for technical drawings?
3. What are the two basic types of drawings?
4. Explain the major difference between the two basic types of drawings.
5. What are the four components of a projection?
6. Name the three subdivisions of parallel projection.
7. Name the three types of axonometric projection.
8. Name the three types of perspective projection.
9. What are the five steps in the design process?
10. Name four fields in which technical drawings are used extensively.
11. Explain how technical drawings differ from artistic drawings.
12. Name three organizations that regulate technical drawing practices.



This chapter discusses in detail the use of conventional drafting instruments and equipment, including their proper care; touches on CAD/CAM equipment, which is described more fully in Section 3; line-making methods; drafting media; copying equipment; measuring devices; scales; and many other basic drafting requirements and techniques.

CHAPTER ONE

Drafting Instruments and Their Use

Conventional and CAD/CAM Drafting Equipment

In drafting, no lines are made freehand. Each and every line is drawn using some kind of a drafting tool. It is up to the drafter to own a complete set of standard drafting tools in order to be fully functional.

When purchasing conventional drafting equipment, care must be taken to obtain quality equipment from a reliable dealer. It is advisable to consult with an experienced drafter, a drafting instructor, or a reputable dealer. The following is a list of the minimum required drafting equipment. Special templates and special equipment must be added to this list, depending upon the field of drafting and, in some cases, the actual product manufactured by the company. Each of the following pieces of equipment is illustrated in this chapter.

- Drawing board — 24" x 36" (60 cm x 90 cm) minimum size
- T-square (parallel straightedge or drafting machine) to suit board
- 45° triangle — 8" (20 cm) size
- 30°-60° triangle — 8" (20 cm) size
- Triangular scale (depending upon the field of drafting)
- Center wheel bow compass — 6" (15 cm) with extension bar)
- Drop bow compass (recommended)
- Irregular curves (two or three different configurations)
- Dividers — 6" (15 cm)
- Drafting brush
- Mechanical drafting pencils with lead
- Protractor or adjustable triangle
- Erasing shield
- Eraser
- Lead pointer with steel cutting wheel (pencil)
- Lead sandpaper or flat file (for compass lead)
- Circle template
- Ellipse template
- Drafting tape or drafting dots
- Calculator
- Dry cleaning pad (optional)

The following is a list of the required inking supplies.

- Technical pen #2 1/2 (for lettering scriber)
- Technical pen #1 (for lettering scriber)
- Technical pen #0 (for lettering scriber)

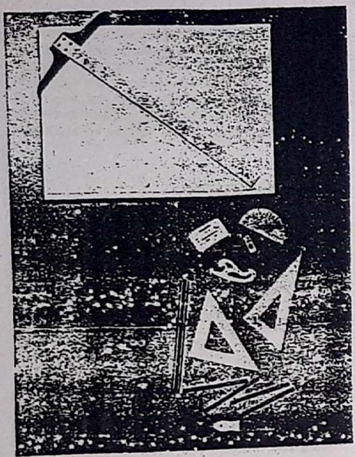


Figure 1-7 T-square in use (*Courtesy Teledyne Post*)

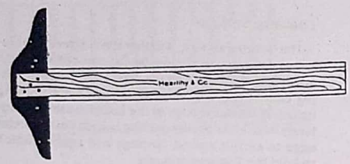


Figure 1-8 Parts of the T-square (*Courtesy Hearlihy and Co.*)

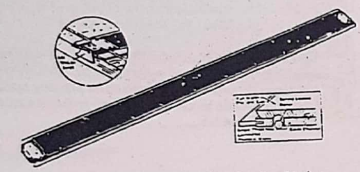


Figure 1-9 Parallel straightedge (*Courtesy Modern School Supplies, Inc.*)

edge of the drawing board to guarantee parallel lines. Figure 1-7.

The T-square is composed of two parts: the head and the blade. Figure 1-8. The two parts are fastened together at an exact right angle. The blade must be straight and free of any nicks or imperfections. A transparent acrylic edge is recommended since this allows the drafter to see the drawing underneath the edge. T-squares can be purchased with adjustable heads for drawing specific angles.

Parallel Straightedge

The parallel straightedge is always parallel, regardless of where it is placed upon the drawing surface. Parallel control is accomplished by a system of cords and pulleys. Figure 1-9. The parallel straightedge replaced the T-square in industry, and is still used somewhat today. Most straightedges come with a transparent acrylic edge, and some have rollers for a smooth gliding action. Some have a locking brake that permits the straightedge to be locked in any position.

Drafting Machines

A drafting machine is a device that attaches to the drafting table and replaces both the T-square and the parallel straightedge. There are two basic kinds of drafting machines. One is the arm type. Figure 1-10, and the other, the newer, is the track type. Figure 1-11. On both types, a round head holds two straightedges at right angles to each other. The head can be rotated to set the straightedges at any angle. Most machines are available with interchangeable straightedges marked with different scales along their edges.

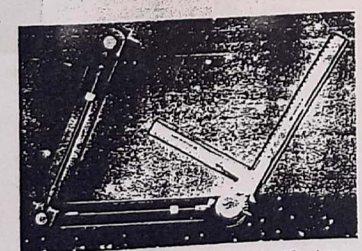


Figure 1-10 Arm-type drafting machine (*Courtesy Teledyne Post*)

Figure 1-11 Track-type drafting machine (*Courtesy Vemco, Inc.*)

Drafting machines replace straightedges, scales, triangles, and protractors. They increase accuracy and greatly reduce drafting time. A drafting machine is one of the few tools that can be purchased either as a right-handed or a left-handed instrument.

vernier which permit readings to 5 minutes of an arc. Figure 1-12. Notice that zero on the protractor is in line with the zero on the vernier. The venier is graduated in 5-minute increments from zero to 60 minutes. To read the vernier, first read the protractor. Figure 1-13. In this example, the zero on the vernier points between 18° and 19°. On the vernier, notice that the only line that lines up with a line on the protractor is the 45; thus this is read as 18°-45'. Some drafting machine heads simplify this process by adding a digital readout, see Figure 1-14.

Drafting machine straightedges come in sizes of 9" (23 cm), 12" (30 cm) and 18" (45 cm), graduated or ungraduated, in both transparent plastic and aluminum scale. Figure 1-15.

A drafting machine, although a precision instrument, should be checked for accuracy at least once a week. The instructions for checking and adjusting a drafting machine are included with the manufacturer's information.

Drawing Sets

Typical drawing sets include compasses, dividers, and a ruling pen. Figure 1-16. Many sets include a variety of tools not normally used by the drafter. It is recommended that only those tools actually needed be purchased.

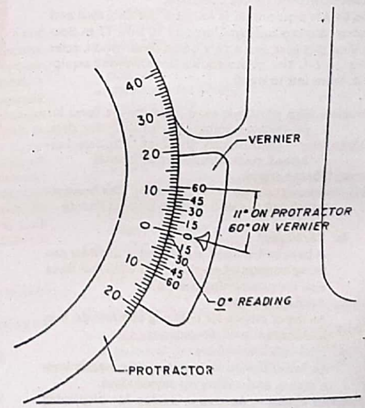


Figure 1-12 Protractor with vernier

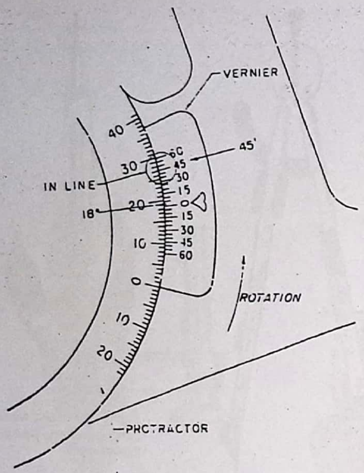


Figure 1-13 Reading the vernier

Compasses

There are two main types of compasses: the friction-joint type, and the spring-bow type. The friction-joint type is still widely used for lightly laying out pencil drawings which will be inked. The disadvantage of this type of compass is that the setting may slip when strong pressure is applied to the lead.

The spring-bow type of compass, Figure 1-17, is best for pencil drawings and tracings as it retains its

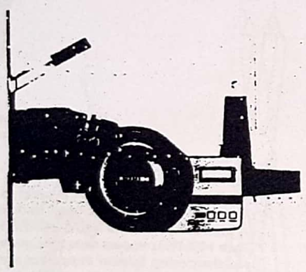


Figure 1-14 Drafting machine head with digital readout (*Courtesy Consul & Mutoh, Ltd.*)

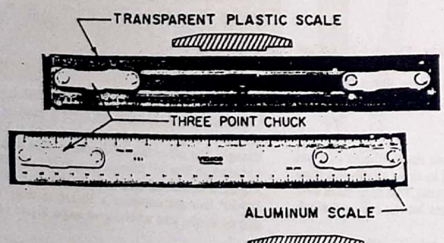


Figure 1-15 Transparent and metal drafting machine straightedges with scale (*Courtesy Vemco, Inc.*)

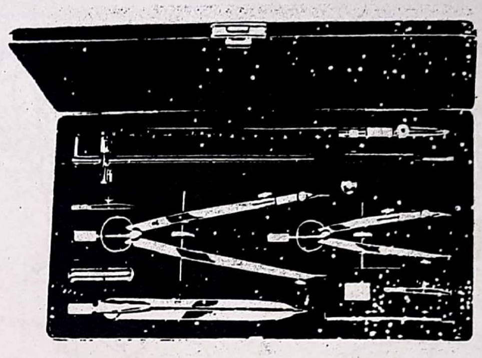


Figure 1-16 Complete drafting set (*Courtesy Keuffel & Esser Co.*)

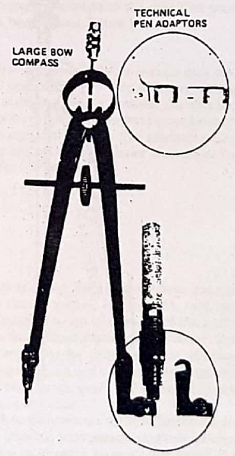


Figure 1-17 Spring bow compass with pen adaptor (*Courtesy Vemco, Inc.*)

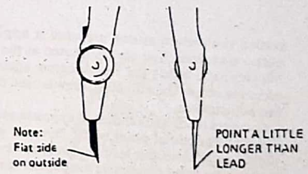


Figure 1-18 Bow compass lead and metal points

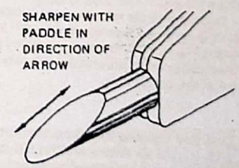


Figure 1-19 Bow compass lead point shape (*Courtesy Drafting for Trades and Industry, Basic Skills, Nelson, Delmar Publishers Inc.*)

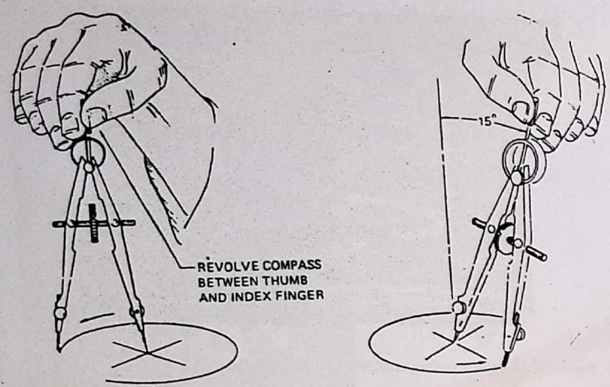


Figure 1-20 Drawing a circle with a bow compass

setting even when strong pressure is applied to obtain dark lines. The spring, located at the top of the compass, holds the legs securely against the adjusting screw. The adjusting screw is used to make fine adjustments.

Compass leads should extend approximately 3/8" (0.9 cm). The metal point of the compass extends slightly more than the lead to compensate for the distance the point penetrates the paper, Figure 1-18. The lead is sharpened with a sandpaper paddle to produce clean, sharp lines. The flat side of the lead faces *outward* in order to produce circles of very small diameter, Figure 1-19. Sharpen with paddle in direction of arrow, as shown, in order to keep the lead sharp longer.

To draw a circle with the bow compass, the compass is revolved between the thumb and the index finger, Figure 1-20. Pressure is applied downward on the metal point to prevent the compass from jumping out of the center hole.

Drop Bow Compass The drop bow compass, Figure 1-21, is used for circles of .03" (0.08 cm) to .50" (1.3 cm) diameter. The compass is adjusted to the required radius. The center point is located on the circle or arc swing point and held in place with the index finger. Rotate the knurled head of the compass between the thumb and second finger.

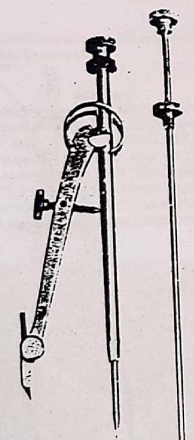


Figure 1-21 Drop bow compass (*Courtesy Vemco, Inc.*)

Figure 1-22 Bow compass with special lead clutch (*Courtesy B. Carter Lykins*)

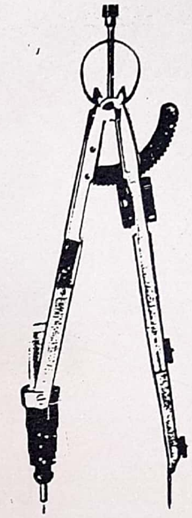


Figure 1-23 Inking bow compass (*Courtesy Koh-I-Noor Rapidograph*)

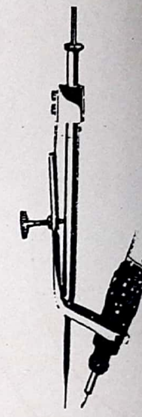


Figure 1-24 Inking drop bow compass (*Courtesy Koh-I-Noor Rapidograph*)

Bow Compass with Lead Clutch In order to eliminate the process of sharpening compass leads, some drafters use a compass with a lead clutch of 0.5-mm lead, Figure 1-22. This compass saves time, and ends messy lead sharpening. Special compasses are designed only for inking. Figures 1-23 and 1-24. An adaptor to attach to a standard compass to draw ink lines is illustrated in Figure 1-25.

Beam Compass A beam compass, Figure 1-26, is used to draw large circles or arcs. Fine line adjustments can be obtained and locked in place. Beam compasses come in sizes from 13" (33 cm) bars and upwards.

Adjustable Curve An adjustable curve, Figure 1-27, has a locking knob, and is used to draw any radius from 6.75" to 200" (17 cm to 500 cm). This tool takes over where the ordinary compass leaves off, and eliminates the beam compass.

Divider

A divider is similar to a compass except that it has a metal point on each leg. It is used to lay off distances and to transfer measurements, Figure 1-28.

Proportional Dividers Proportional dividers are used to enlarge or reduce an object in scale. This too a sliding, adjustable pivot which varies the pr tions of the tips of each leg, Figure 1-29.

Triangle

Two standard triangles are used by drafters. One is a 30-60-degree triangle, usually written as 30°-60° triangle. The other is a 45-degree triangle, written as 45° triangle. The 45° triangle consists of two 45-degree angles, and one 90-degree angle, Figure 1-30A. The 30°-60° triangle contains a 30-degree angle, a 60-degree angle, and a 90-degree angle, Figure 1-30B.

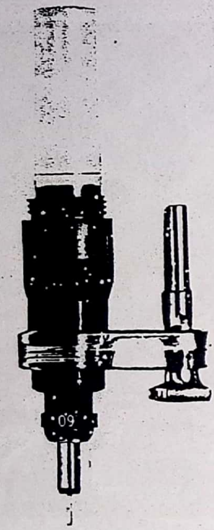


Figure 1-25 Standard compass ink adaptor (*Courtesy Koh-I-Noor Rapidograph*)

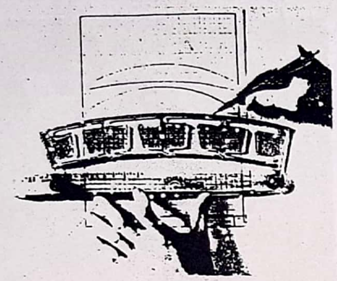


Figure 1-27 Adjustable curve (*Courtesy Hoyle Products, Inc.*)

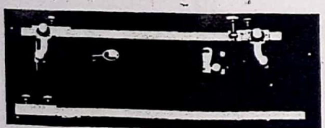


Figure 1-26 Beam compass (*Courtesy Vemco, Inc.*)

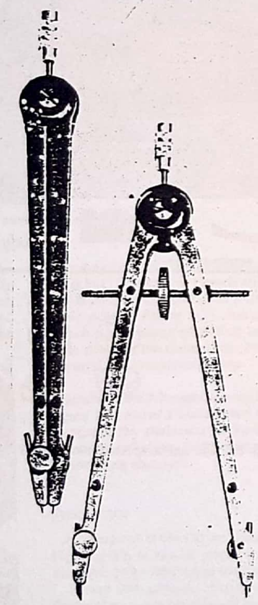


Figure 1-28 Divider (*Courtesy Vemco, Inc.*)

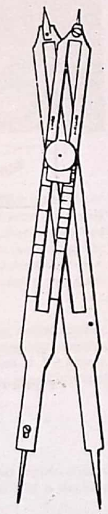


Figure 1-29 Proportional dividers (*Courtesy Modern School Supplies, Inc.*)

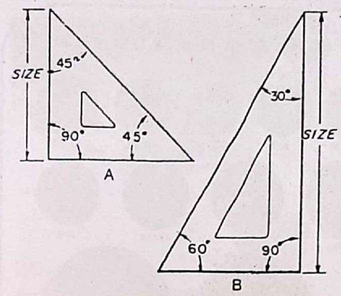


Figure 1-30 (A) 45° triangle, and (B) 30°-60° triangle

Triangles are made of plastic and come in a variety of sizes other than those mentioned. When laying out lines, triangles are placed firmly against the upper edge of the straightedge. Pencils are placed against the left edge of the triangle and lines drawn upwards, away from the straightedge. Parallel angular lines are made by moving the triangle to the right after each new line has been drawn, Figure 1-31.

Adjustable Triangle An adjustable triangle may take the place of both the 30°-60° and 45° triangles, Figure 1-32. It is recommended, however, that this tool be used only for drawing angles that cannot be made with the two standard triangles. The adjustable triangle is set by eye and thus is not as accurate as the solid triangle.

Template

A template is a thin, flat piece of plastic containing various cutout shapes, Figures 1-33, 1-34, and 1-35. It is designed to speed the work of the drafter and to make the finished drawing more accurate. Templates are available for drawing circles, ellipses, plumbing fixtures, bolts and nuts, screw threads, electronic symbols, springs, gears, and structural metals, to name just a few uses.

Templates come in many sizes to fit the scale being used on the drawing. A template should be used wherever possible to increase accuracy and speed. It is preferable to purchase templates that are stamped and not molded, as molded templates become brittle in time and break.

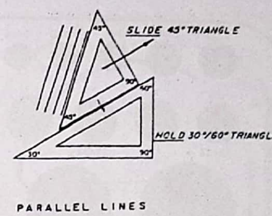


Figure 1-31 Drawing parallel angular lines

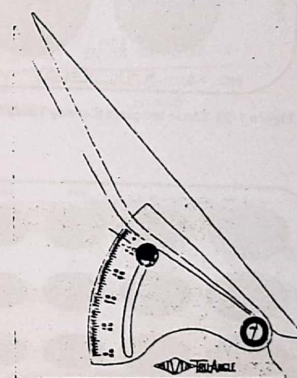


Figure 1-32 Adjustable triangle (*Courtesy Modern School Supplies, Inc.*)

French Curves

French curves are thin, plastic tools that come in an assortment of curved surfaces, Figure 1-36. They are used to produce curved lines that cannot be made with a compass. Such lines are referred to as *irregular curves*. Most good French curves are actually segments of such geometric curves as ellipses, parabolas, hyperbolas, and the like.

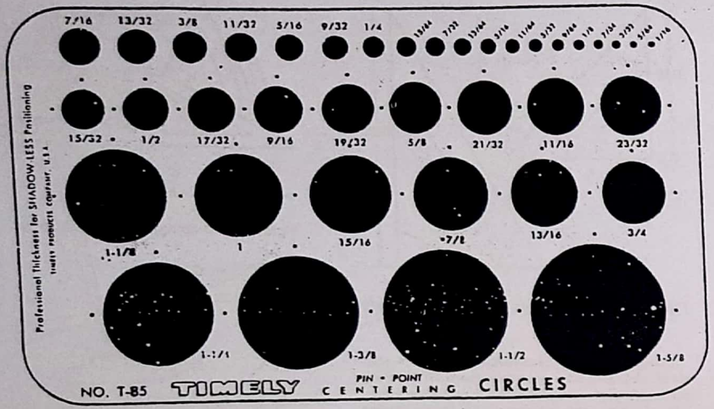


Figure 1-33 Circle template (Courtesy Timely Products Co.)

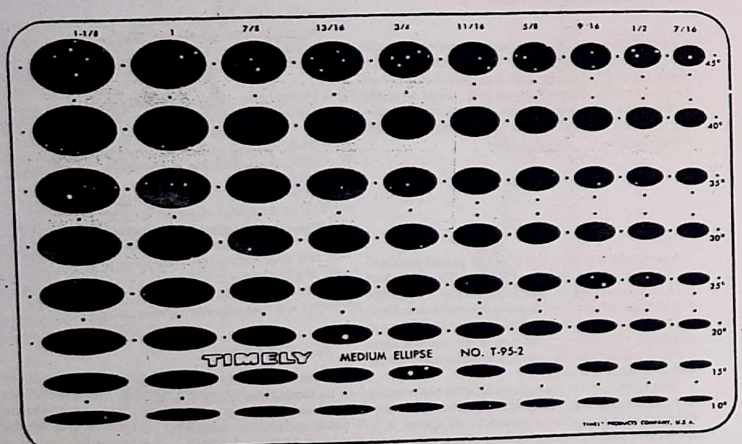


Figure 1-34 Ellipse template (Courtesy Timely Products Co.)

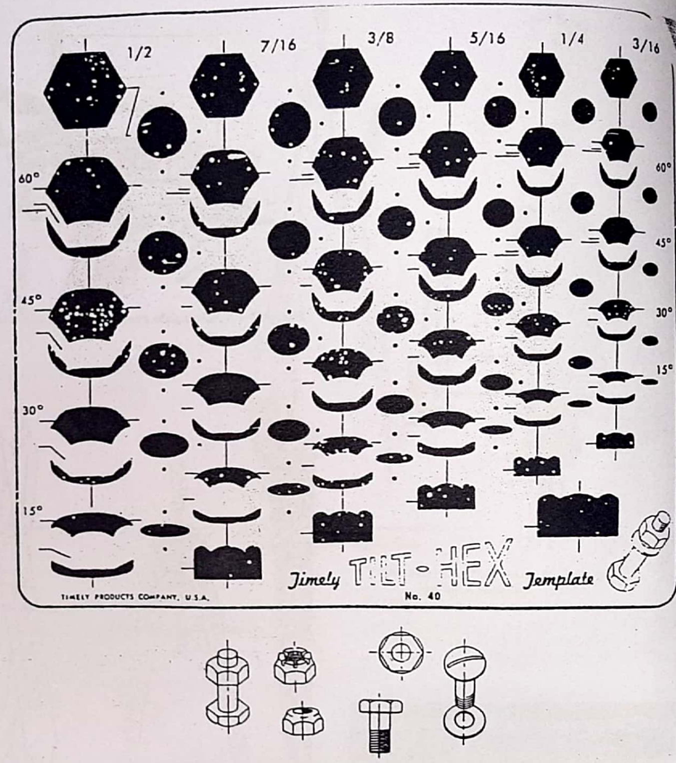


Figure 1-35 Bolt and nut template (Courtesy Timely Products Co.)

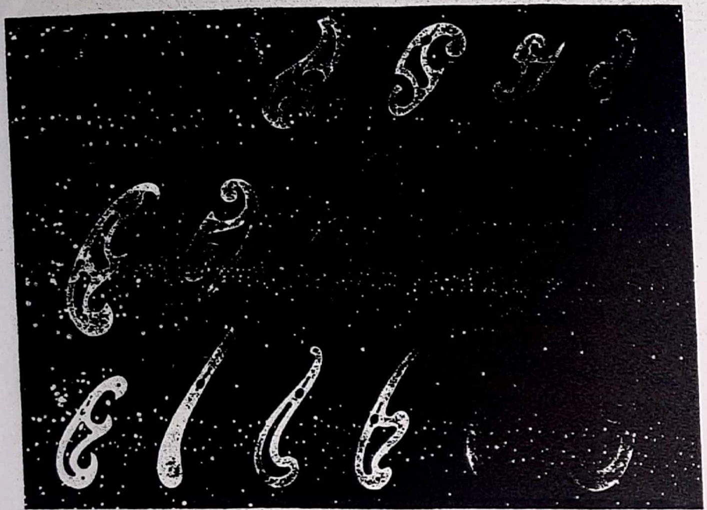


Figure 1-36 Assortment of French curves (*Courtesy Modern School Supplies, Inc.*)

Using a French Curve To use a French curve, the irregular curve must be defined by a series of dots. *Lightly* connect straight lines to get a general idea of where the curved line is going. If the line makes an abrupt turn, a line *lightly* sketched in place of the straight lines may be more useful. Starting from one side or the other, line up the French curve along as many points as possible and draw a dark line connecting these points, Figure 1-37. Readjust and align the French curve along all additional points, and continue drawing the curved line. Proceed in this manner until the line is completed.

Figure 1-37 Drawing an irregular curve (*Courtesy Koh-I-Noor Rapidograph*)

Adjustable Curve Adjustable curves form smooth curves. Figure 1-38 shows a flexible steel measuring tape that measures the perimeter of the curve to be drawn. The curve is held by friction between many layers of interlocking channels.

Protractor

A protractor is used to measure and lay out angles, Figure 1-39. It can be used in place of a drafting machine or an adjustable triangle.

To use the protractor, place the center point (located at the lower edge of the protractor) on the corner point of the angle. Align the base of the protractor along one side of the angle. The degrees are read along the semicircular edge.

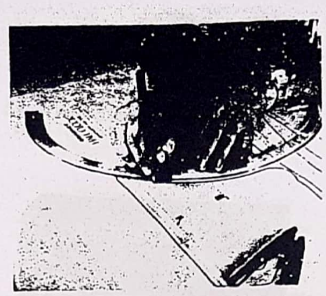


Figure 1-38 Using an adjustable curve (*Courtesy Hoyle Products, Inc.*)

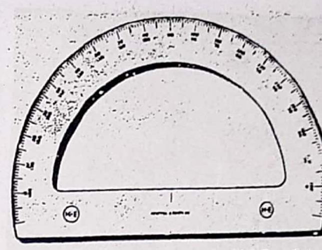


Figure 1-39 Protractor (*Courtesy Keuffel & Esser Co.*)

9H 8H 7H 6H 5H 4H	3H 2H H F HB B	2B 3B 4B 5B 6B 7B
Hard accuracy	Medium general purpose	Soft art work

Figure 1-40 Grades of lead

Pencils and Leads

Lead for a mechanical drafting pencil comes in 18 degrees of hardness, ranging from 9H, which is very hard, to 7B, which is very soft, Figure 1-40. For drafting purposes, the scale of hardness is as follows: 4H lead is recommended for layout work, and 2H lead is recommended for all other lines. Experiment with various leads to determine which ones give the best line thickness. This varies depending upon the pressure applied to the point while drawing lines. Figure 1-41 shows leads for a mechanical drafting pencil.

Regular pencils are sharpened with a pencil sharpener. It is important that enough wood is removed to ensure that the lead, not the wood, of the pencil comes in contact with the straightedge or triangle edges.

Figure 1-41 Drafting lead (*Courtesy Staedtler Mars*)

Figure 1-42 Lead holder (*Courtesy Teledyne Post*)

Lead Holders and Leads

Lead holders hold sticks of lead, Figure 1-42. The leads designed for lead holders come in the same range of hardness as those for regular mechanical pencils, and are used for the same purposes. The main advantage is that they are more convenient to use. Leads are usually sharpened in a lead pointer. Electric lead pointers are fully automatic. A slight downward pressure of the lead starts the motor

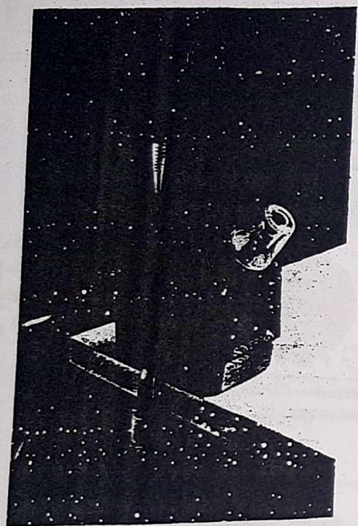


Figure 1-43 Lead pointer (*Courtesy Rotex Co.*)

action, Figure 1-43. This machine produces a perfectly tapered point and eliminates all loose clinging graphite.

Sandpaper Paddle A sandpaper paddle consists of several layers of sandpaper attached to a small wooden holder, Figure 1-44. The sandpaper is used to sharpen compass leads only. Do not sharpen leads over a drawing as the graphite will smear the drawing surface.

Erasers

Various kinds of erasers are available to a drafter. One of the most commonly used is a soft, white block-type eraser, Figure 1-45. Figure 1-46 shows a pencil-type eraser with an adjustable clutch. By developing good drawing habits, erasing can be kept to a minimum.

Electric Eraser An electric eraser speeds up corrections. Some models take a 7" (17.5 cm) long eraser strip.

Figure 1-44 Sandpaper paddle (*Courtesy Keuffel & Esser Co.*)

Figure 1-45 Block-type eraser (*Courtesy Staedtler Mars*)

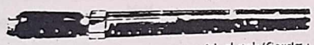


Figure 1-46 Pencil-type eraser with clutch (*Courtesy Staedtler Mars*)

The model illustrated in Figure 1-47 has a slip clutch to hold the eraser strip in place.

A cordless erasing machine can be used with or without the standard electric cord, and uses rechargeable NiCad batteries, Figure 1-48. As the eraser is placed in the stand, the batteries are recharged.

Electric erasers do save time, but care must be taken not to burn through the drawing paper. This can be avoided by using an erasing shield and placing a thick sheet of paper beneath the drawing to cushion it.

Erasing Shield An erasing shield restricts the erasing area so that correctly drawn lines will not be disturbed during the erasing procedure. It is made from a thin, flat piece of metal with variously sized cutouts, Figure 1-49. The shield is used by placing it over the line to be erased and erasing through the cutout.

Drafting Brush

The drafting brush is used to remove loose graphite and eraser crumbs from the drawing surface, Figure 1-50. Do not brush off a drawing surface by hand as this tends to smudge the drawing. Drafting brushes

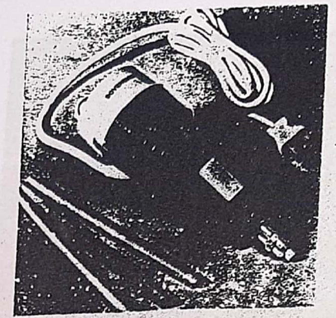


Figure 1-47 Electric eraser with slip clutch (*Courtesy Rotex Co.*)

come in various sizes from 10½" to 14" (26 cm to 35 cm). The bristles can be either horsehair or nylon, and they can be cleaned with warm, soapy water.

Dry Cleaning Powder

Cleaning powder is used to help keep drawings clean, to avoid smearing, and to speed up the drafting process. Cleaning powder comes in a can or as pads, Figure 1-51, and is sprinkled over the drawing before starting. It is imperative that all cleaning powder is removed before placing the original drawing into a whiteprinter as the powder tends to stick to the roller. If good drafting habits are followed, the dry cleaning powder is not necessary.

Scales

Various kinds of scales are used by drafters, Figure 1-52. A number of different scales are included on each instrument. Scales save the drafter the work of computing new measurements every time a drawing is made larger or smaller than the original.

Scales come open divided and full divided. A *full-divided scale* is one in which the units of measurement are subdivided throughout the length of the scale. An *open-divided scale* has its first unit of measurement subdivided, but the remaining units are open or free from subdivision.

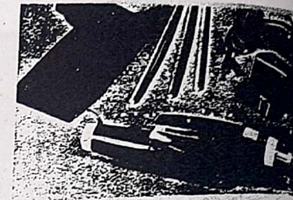


Figure 1-48 Rechargeable electric eraser (*Courtesy Rotex Co.*)

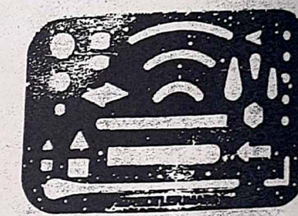


Figure 1-49 Erasing shield (*Courtesy Staedtler Mars*)

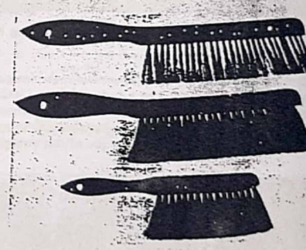


Figure 1-50 Drafting brush (*Courtesy Hearlihy & Co.*)

Mechanical Engineer's Scale

Mechanical engineer's scales are divided into inches and parts to the inch. To lay out a full-size measurement, use the scale marked 16. This scale has each inch divided into 16 equal parts or divisions of 1/16 inch. It is used by placing the 0 on the

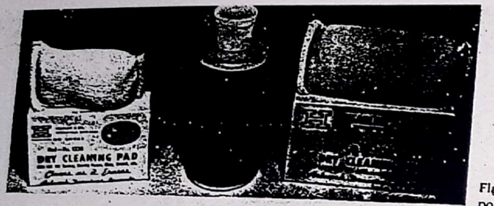


Figure 1-51 Dry cleaning powder (*Courtesy Hearlihy & Co.*)

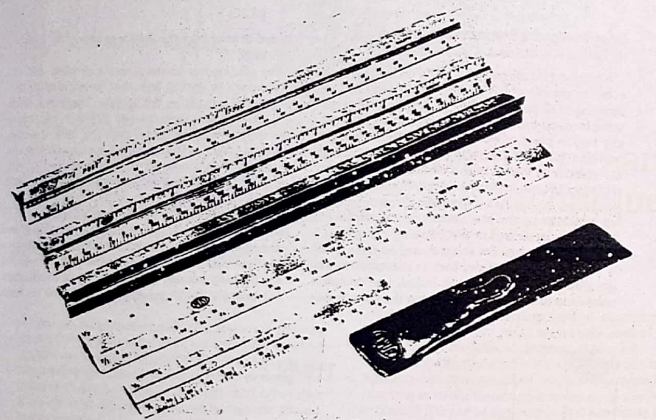


Figure 1-52 A variety of drafting scales (*Courtesy Teledyne Post*)

Figure 1-53 Regular full-size scale

point where measurement begins, and stepping off the desired length, Figure 1-53.

To reduce a drawing 50 percent, use the scale marked 1/2. The large 0 at the end of the first subdivided measurement lines up with the other unit measurements that are part of the same scale. The large numbers crossed out in Figure 1-54 go with the 1/4 scale starting at the other end. These numbers are ignored while using the 1/2 scale. To lay out

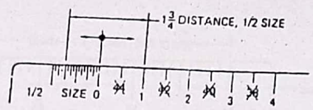


Figure 1-54 Half-size scale

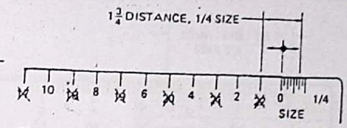


Figure 1-55 Quarter-size scale

1 3/4 inches at the 1/2 scale, read full inches to the right of 0 and fractions to the left of 0.

The 1/4 scale is used in the same manner as the 1/2 scale. However, measurements of full inches are made to the left of 0 and fractions to the right, because the 1/4 scale is located at the opposite end of the 1/2 scale, Figure 1-55.

Architect's Scale

The architect's scale is used primarily for drawing large buildings and structures. The full-size scale is used frequently for drawing smaller objects. Because of this, the architect's scale is generally used for all types of measurements. It is designed to measure in feet, inches, and fractions of an inch. Measure full feet to the right of 0; inches and fractions of an inch to the left of 0. The numbers crossed out in Figure 1-56 correspond to the 1/2 scale. They can be used, however, as 6 inches as each falls halfway between full-foot divisions. Measurements from 0 are made in the opposite direction of the full scale, because the 1/2 scale is located at the opposite end of the scale, Figure 1-57.

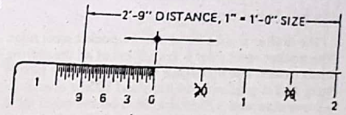


Figure 1-56 Architectural scale (full size)

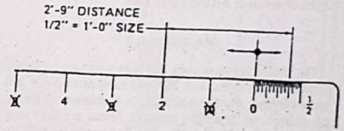


Figure 1-57 Architectural scale (half size)

Civil Engineer's Scale

A civil engineer's scale is also called a ***decimal-inch scale***. The number 10, located in the corner of the scale in Figure 1-58, indicates that each graduation is equal to 1/10 of an inch or .1". Measurements are read directly from the scale. The number 20, located in the corner of the scale shown in Figure 1-59, indicates that it is 1/20 of an inch.

Using the same scale for civil drafting, one inch equals two hundred feet, Figure 1-60, and one inch equals one hundred feet, Figure 1-61.

A metric scale is used if the millimetre is the unit of linear measurement. It is read the same as the decimal-inch scale except that it is in millimetres, Figure 1-62.

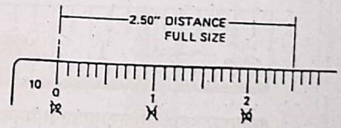


Figure 1-58 Civil engineer's scale

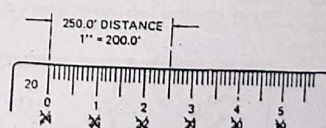


Figure 1-59 Civil engineer's scale (half scale)

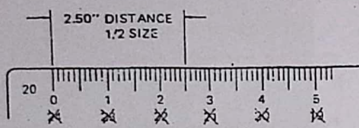


Figure 1-60 Mechanical scale (half size)

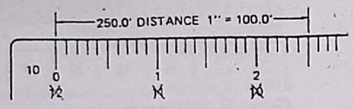


Figure 1-61 Civil scale

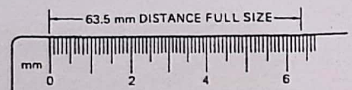


Figure 1-62 Metric scale

Pocket Steel Ruler

The drafter should make use of a pocket steel ruler. The pocket steel ruler is the easiest of all measuring tools to use. The inch scale, Figure 1-63, is six inches long and is graduated in 10ths and 100ths of an inch on one side and 32nds and 64ths on the other side.

The metric scale is 150 millimetres long (approximately six inches) and is graduated in millimetres and half millimetres on one side. Figure 1-64. Sometimes metric pocket steel rulers are graduated in 64ths of an inch on the other side.

Measuring

The metric system uses the metre (m) as its basic dimension. A metre is 3.281 feet long or about 3 3/8 inches longer than a yardstick. Its multiples, or parts, are expressed by adding prefixes. These prefixes represent equal steps of 1000 parts. The prefix for a thousand (1000) is *kilo*; the prefix for a thousandth (1/1000) is *milli*. One thousand metres (1000 m), therefore, equals one kilometre (1.0 km). One thousandth of a metre (1/1000 m) equals one millimetre (1.0 mm). Comparing metric to English then:

One millimetre (1.0 mm) = 0.001 metre (0.01 m) = .03937 inch

One thousand millimetres (1000 mm) = 1.0 metre (1.0 m) = 3.281 feet

One thousand metres (1000 m) = 1.0 kilometre (1.0 km) = 3281.0 feet

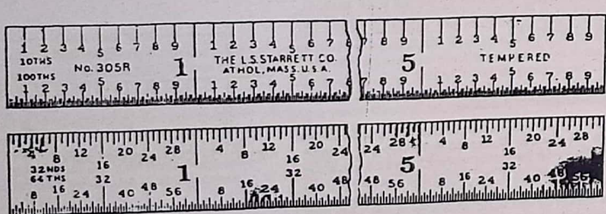
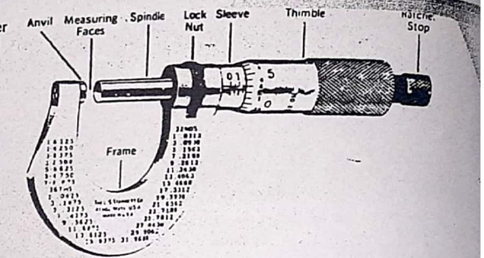


Figure 1-63 Steel scale (inch) (Courtesy L. S. Starrett Co.)

Figure 1-64 Steel scale (metric) (Courtesy L. S. Starrett Co.)

Figure 1-65 Micrometer (Courtesy L. S. Starrett Co.)



How To Read a Micrometer Graduated in Thousandths of an Inch (.001")

A micrometer consists of a highly accurate ground screw or spindle which is rotated in a fixed nut, thus opening or closing the distance between two measuring faces on the ends of the anvil and spindle, Figure 1-65. A piece of work is measured by placing it between the anvil and spindle faces, and rotating the spindle by means of the thimble until the anvil and spindle both contact the work. The desired work dimension is then found from the micrometer reading indicated by the graduations on the sleeve and thimble, as described in the following paragraphs.

Since the pitch of the screw thread on the spindle is 1/40" or 40 threads per inch in micrometers that are graduated to measure in inches, one complete revolution of the thimble advances the spindle face toward or away from the anvil face precisely 1/40 or .025 inch.

The reading line on the sleeve is divided into 40 equal parts by vertical lines that correspond to the number of threads on the spindle. Therefore, each vertical line designates 1/40 or .025 inch and every fourth line, which is longer than the others, designates hundreds of thousandths. For example: the line marked "1" represents .100", the line marked "2" represents .200", and the line marked "3" represents .300", and so forth.

The beveled edge of the thimble is divided into 25 equal parts, with each line representing .001" and every line numbered consecutively. Rotating the thimble from one of these lines to the next moves the spindle longitudinally 1/25 of .025" or .001 inch; rotating two divisions represents .002", and so forth.

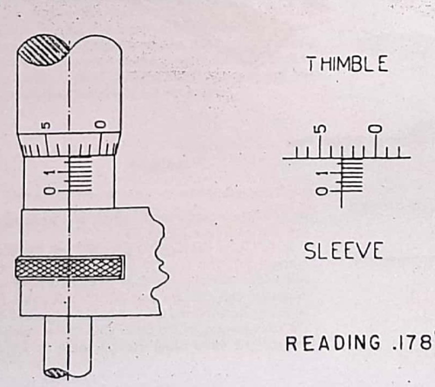
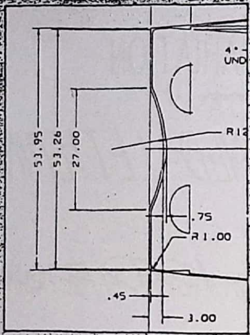


Figure 1-66 Reading a micrometer (Courtesy L. S. Starrett Co.)



This chapter covers three of the basics that are needed in preparing all types of technical drawings. All three concepts represent manual drafting techniques. Computer-aided drafting (CAD) techniques are covered in later chapters. The major topics covered in this chapter are freehand lettering, freehand lettering techniques, line work, and sketching.

CHAPTER TWO

Lettering, Sketching, and Line Techniques

Freehand Lettering

Text is an important part of a technical drawing. Not all information required on technical drawings can be communicated graphically; the most obvious data being dimensions. *Text* on technical drawings consists of dimensions, notes, legends, and other data that are best conveyed using alphanumeric characters, Figure 2-1.

Several different ways are used to create text on technical drawings. The traditional method is by freehand lettering. Other methods include such mechanical lettering techniques as scriber templates, typewritten notation, and typed lettering generated by computer-aided drafting systems. This chapter focuses on freehand lettering. Other methods are described elsewhere in this text.

Lettering Styles

There are numerous different lettering styles or fonts, Figure 2-2. The standard style for freehand lettering on technical drawings, as established in American National Standards document Y14.2-1973, is single-stroke Gothic lettering. Vertical, single-stroke Gothic letters are the most universally used of the various styles available to drafters, Figure 2-3.

Some modifications of the standard Gothic configuration of letters are often made, without actually changing from the Gothic style of lettering. One way is through the use of uppercase and lowercase letters, Figure 2-4, but this is seldom acceptable on technical drawings. Another method is to condense or extend the letters, Figure 2-5.

The most common way of modifying Gothic letters is by inclining them slightly to the right, Figure 2-6. Inclined lettering is easier to make as it lends itself to a natural direction of wrist action. The correct angle of the inclined elements is a two-unit incline to the right for each five units of letter height. Errors are not as detectable with inclined letters as they are with vertical elements. As the inclined elements are longer, they are easier to read. However, inclined lettering is not universally accepted, and caution must be exercised to not conflict with customary drafting styles. A backhanded or left-leaning inclination is never an acceptable modification.

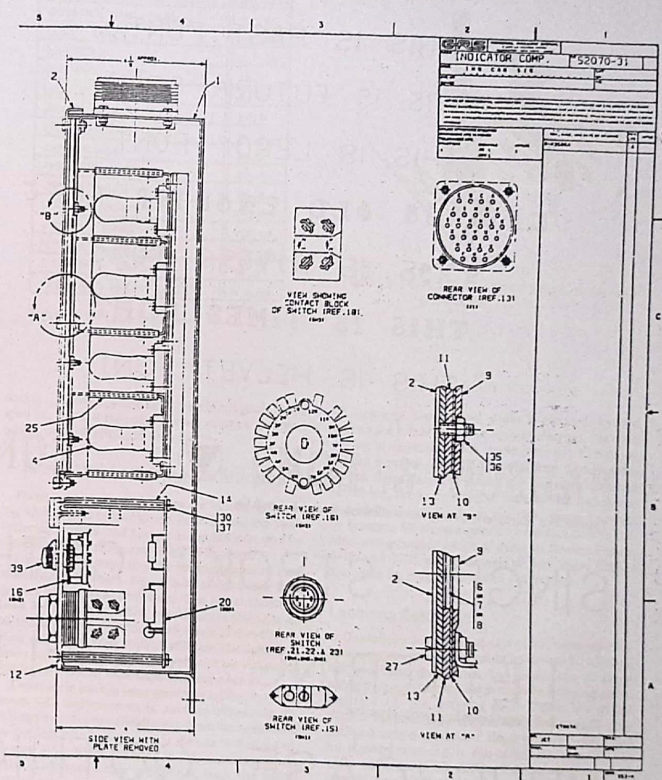


Figure 2-1 Examples of text on a technical drawing (*Courtesy General Railway Signal*)

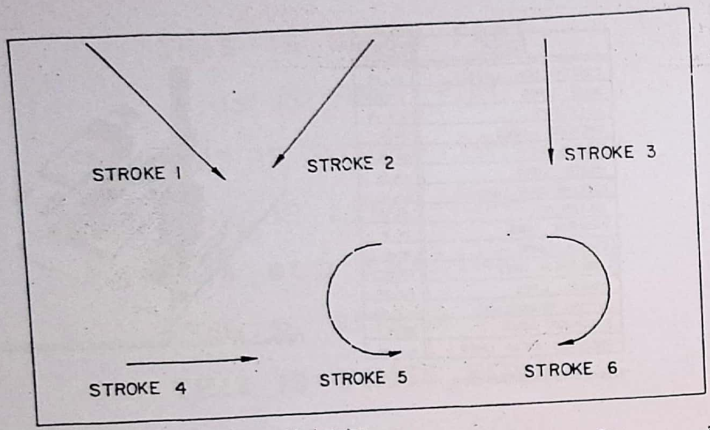


Figure 2-15 Six basic strokes are used for lettering

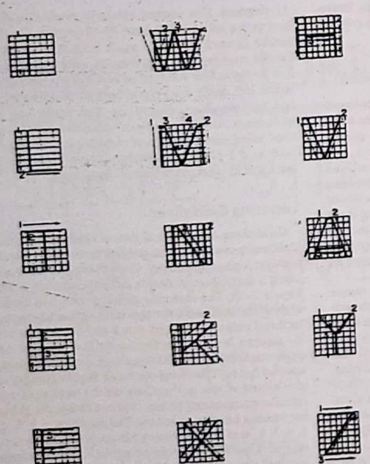


Figure 2-16 Forming straight letters

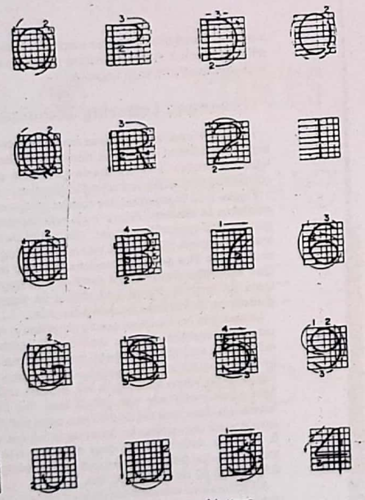


Figure 2-17 Forming curved letters

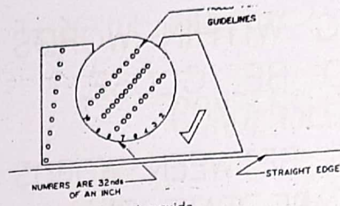


Figure 2-18 Lettering guide

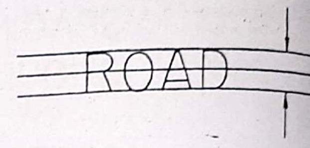


Figure 2-19 A complete set of guidelines

2-19. The middle guideline helps drafters space middle elements of such letters as A. B. E. F. G. H. P. R. S. and Y.

The center row of holes on the lettering guide. being equally spaced. is the one used most frequently for freehand Gothic lettering. The two outer rows of holes are used when lowercase letters are desired. The outer row of holes on the left produces guidelines for lowercase letters. the bottom portions of which are 3/5ths of the letter's total height. The outer row of holes on the right produces guidelines for lowercase letters. the bottom portions of which are 2/3rds of the total height of the letters.

Horizontal guidelines are made by placing the pencil point in the appropriate holes and sliding the guide across the top of the parallel bar. Figure 2-20. Guidelines for vertical lettering are produced by using the guide together with a triangle or vertical straightedge. Figure 2-21.

Guidelines for letters. numbers. and fractions are created in the same way. However. when lettering fractions. drafters should be careful to leave a visible distance between the numerator. denominator. and the fraction crossbar. which should be parallel. Figure 2-22.

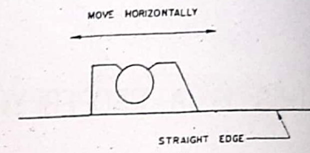


Figure 2-20 Making horizontal guidelines

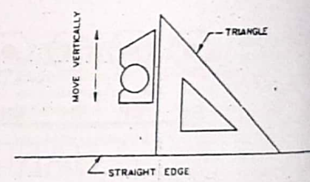


Figure 2-21 Making vertical guidelines

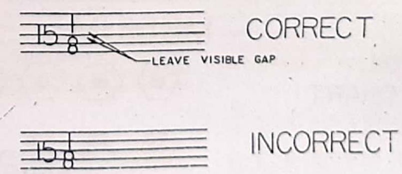


Figure 2-22 Correct method for lettering fractions

Line Work

Line work is the generic term given to all of the various techniques used in creating the graphic data on technical drawings. Mechanical line work is made using either mechanical pencils or technical pens. Such devices as parallel bars, drafting machines, triangles, scales, and numerous other tools are used to guide the line-making. Since inking is dealt with in the first chapter, this chapter focuses on pencil line work.

Characteristics of Lines

Twelve basic types of lines are used in manual drafting. Each has its own individual characteristics. The *visible* line is thick and dark. The *hidden* line is a series of short dashes separated by even shorter breaks. The hidden line is thinner than the visible line. *Dimension* lines and *extension* lines are solid, thin lines of approximately the same width as hidden lines. *Dimension* lines should be broken for dimensions, and have arrowheads for terminations.

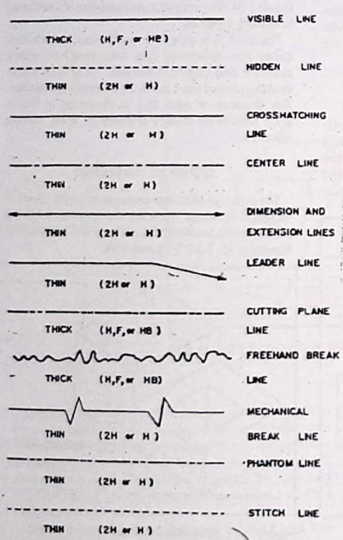


Figure 2-23 Line types used on technical drawings

The *center* line is broken with one short dash in its center. It is the same width as the hidden, dimension, and extension lines. The *phantom* line is just like the center line except that it has two dashes. The dashes are repeated approximately every two inches. The *cutting plane* line is thick like the visible line and consists of a series of long, equally spaced dashes. All lines used on technical drawings should closely match those in Figure 2-23.

Horizontal and Vertical Lines

Horizontal lines are formed by pressing the straightedge (T-square, parallel bar, drafting machine scale, and so forth) against the worksheet with one hand and moving the pencil with the other. Uniformity of line widths and weights can be achieved by holding the pencil at approximately 60 degrees from the drawing surface, maintaining an even pressure downward, and slowly revolving the pencil axially as it moves across the drawing surface, Figure 2-24. This keeps the lead tip symmetrical.

Vertical lines are created according to the same principles, except that the drafter's hand moves upward rather than from left to right. The angle of inclination, the amount of pressure, and the rotating motion are the same as they are for horizontal lines.

Angular Lines

Many modern devices are available to assist drafters in making angular lines. These include protractors, adjustable triangles, and adjustable arms on drafting machines. However, most angular lines can be created simply by using the standard 30°-60° and 45° triangles alone, and in various combinations, Figures 2-25, 2-26, 2-27, and 2-28. These standard tools create angles of 15°, 30°, 45°, 60°, and 75°.

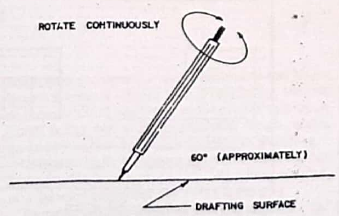


Figure 2-24 Maintaining uniformity of lines

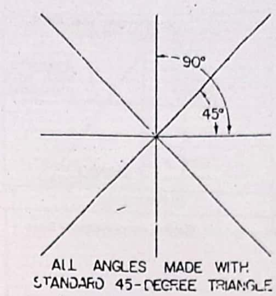


Figure 2-25 Making angular lines with the 45° triangle

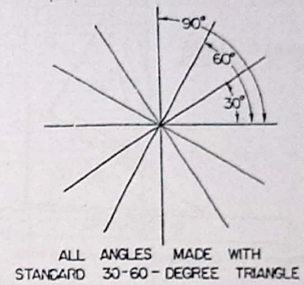


Figure 2-26 Making angular lines with the 30°-60° triangle

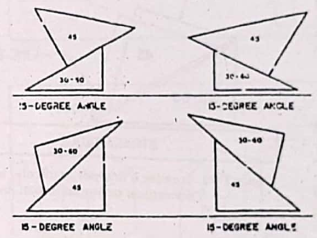


Figure 2-27 Making 15° angles

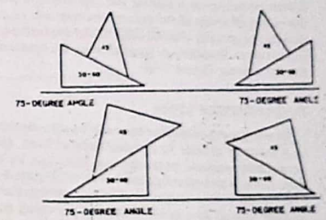


Figure 2-28 Making 75° angles

Parallel Lines

Parallel lines can be created in a number of different ways. Vertical (and horizontal) parallel lines are made by simply moving the straightedge the required distance and making each successive line, Figure 2-29.

Parallel lines at angles can be created by using the 30°-60° and 45° triangles in combination much the same as they are used for making angular lines. When using triangles to create angular lines, the first line is created at the desired angle. Aligning one edge of a

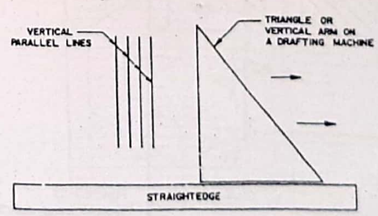


Figure 2-29 Making vertical parallel lines

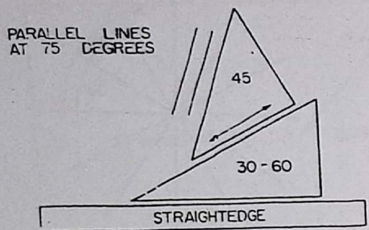


Figure 2-30 Creating successive parallel lines

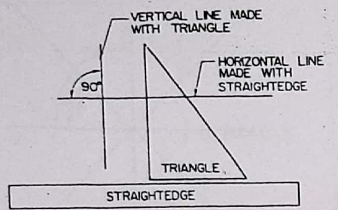


Figure 2-31 Making perpendicular lines

triangle to the line, register any side of the second triangle against one of the nonaligned edges of the first triangle. Holding the second triangle to prevent it from moving, and sliding the first triangle along the engaged edge of the second triangle, will reposition the originally aligned edge to any desired parallel position. Successive parallel lines are created in the same way. Figure 2-30.

Perpendicular Lines

Drawing perpendicular lines can be accomplished in a manner similar to drawing parallel lines. Horizontal and vertical perpendicular lines can be created using a straightedge and a triangle. Figure 2-31.

Creating a line perpendicular to a nonhorizontal or nonvertical line is accomplished by using triangles in conjunction with a straightedge. Figure 2-32.

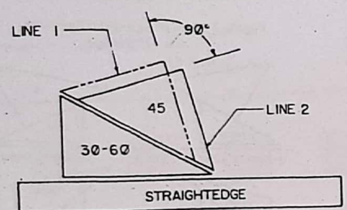


Figure 2-32 Creating a line perpendicular to a nonvertical or nonhorizontal line

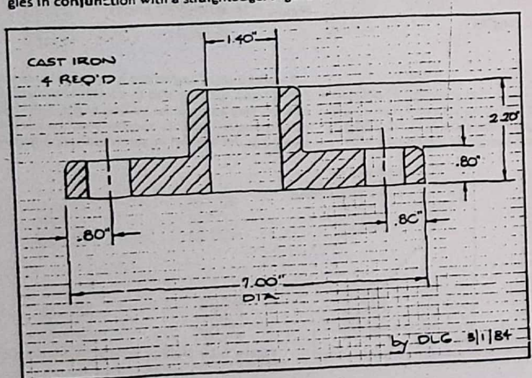


Figure 2-33 Typical design sketch

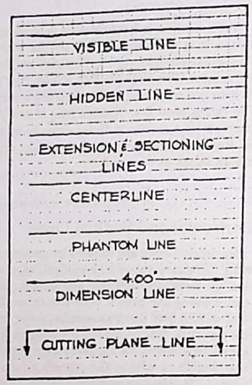


Figure 2-34 Lines used in sketching

Line 1 in this figure is drawn first. Then the 45° triangle is slid along the 30°-60° triangle and the perpendicular line is created with the opposite side of the 45° triangle.

Sketching

Even in the world of high technology and computers, sketching is still one of the most important skills for drafters and designers. Sketching is one of the first steps in communicating ideas for a design, and it is used in every step thereafter. It is common practice for designers to prepare sketches that are turned over to drafters for conversion to finished working drawings. Figure 2-33 is an example of a typical design sketch.

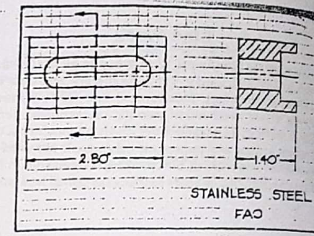


Figure 2-35 Sample design sketch

Sketching Lines

The lines used in creating sketches closely correspond to those used in creating technical drawings except, of course, that they are not as sharp and crisp. Figure 2-34 illustrates the various types of lines used in making sketches.

The basic line types are: visible line, hidden line, center line, dimension line, sectioning line, extension line, and cutting plane line. These lines represent the various lines available for creating sketches. The character of each line, as illustrated in Figure 2-35, should be closely adhered to when making sketches.

Types of Sketches

The types of sketches correspond to the types of technical drawings. There are four types of sketching: orthographic, axonometric, oblique, and perspective. Figures 2-36, 2-37, 2-38 and 2-39.

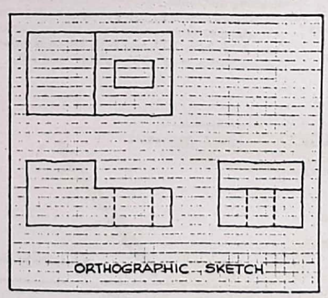


Figure 2-36 Orthographic sketch

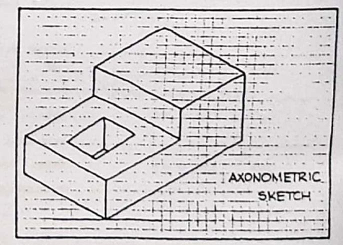


Figure 2-37 Axonometric sketch

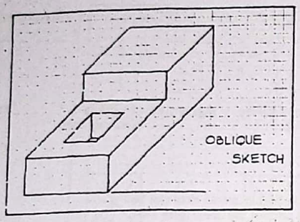


Figure 2-38 Oblique sketch

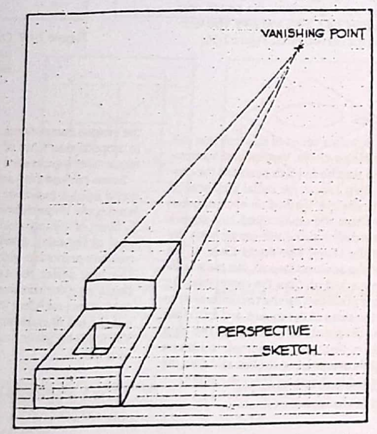


Figure 2-39 Perspective sketch

Orthographic sketching relates to flat, graphic facsimiles of a subject showing no depth. Six principal views of a subject may be incorporated in an orthographic sketch: top, front, bottom, back, right side, and left side, Figure 2-40. The views selected for use in a sketch depend on the nature of the subject and the judgment of the sketcher.

Axonometric sketching may be one of three types, isometric, dimetric, or trimetric, Figure 2-41. The type most frequently used is *isometric*, in which length and width lines recede at 30° to the horizontal and height lines are vertical, Figure 2-42. In sketching, the use of these terms is academic as they relate to proportional scales and angle positions of length, width, and depth, which are only estimated in sketching.

Oblique sketching involves a combination of a flat orthographic front surface with depth lines receding at a selected angle (usually 45°), Figure 2-43.

Perspective sketching involves creating a graphic facsimile of the subject. Consequently, depth lines must

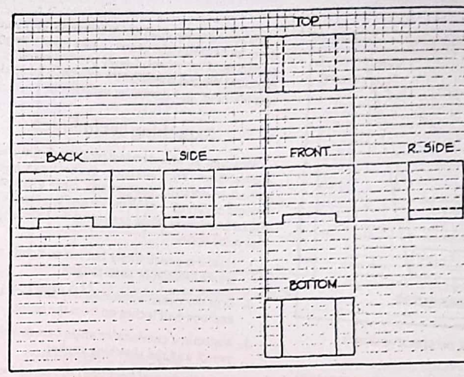


Figure 2-40 Six principal views in orthographic sketching

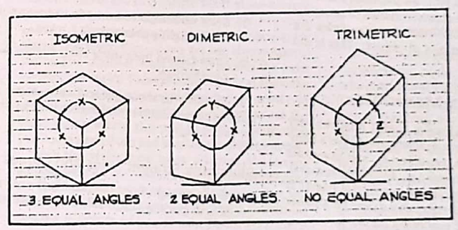


Figure 2-41 Three types of axonometric sketches

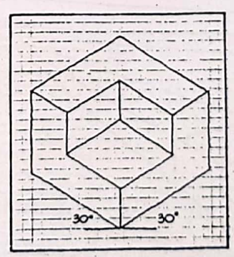


Figure 2-42 Isometric sketch

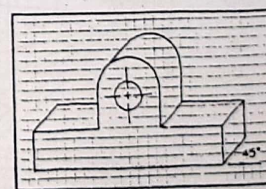


Figure 2-43 Oblique sketch

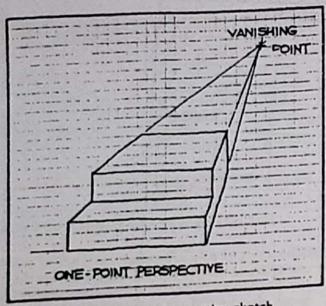


Figure 2-44 One-point perspective sketch

recede to a hypothetical vanishing point (or points), Figures 2-44 and 2-45. In fact, all pictorial sketches naturally tend to assume characteristics of perspective sketches as a result of how the eye views the apparent relative proportions of objects. This is not necessarily undesirable.

Sketching Materials

An advantage of sketching is that it requires very few material aids. Whereas drafters must have a complete collection of tools, equipment, and materials in order to do working drawings, sketching requires nothing more than a pencil and a piece of paper. It is not uncommon for a sketch to be drawn on a paper napkin during a hurried luncheon meeting.

Sketching done in an office environment requires three basic materials: pencil, media (paper or graph paper), and an eraser. Graph paper simplifies the sketching process considerably, especially for students just learning, and should be used freely.

Sketching Techniques

Sketches, as with drawings, consist of straight and curved lines. With practice, drafters can become skilled in creating neat, sharp, clear examples — straight or curved — of all the various lines types introduced previously. When sketching, the following general rules apply.

1. Hold the pencil firmly, but not so tightly as to create tension or hand fatigue.
2. Grip the pencil approximately one inch to one and one-half inches up from the point.
3. Maintain a comfortable angle between the pencil and the sketching strokes.
4. Draw horizontal lines from left to right using short, slightly overlapping strokes.
5. Draw vertical lines from top to bottom using short, slightly overlapping strokes.
6. Draw curved lines using short slightly overlapping strokes.

In addition to these general rules, some specific techniques are used in making the various line types for sketching.

Sketching Straight Lines and Curves

Making straight lines on graph paper is a simple process of guiding the pencil using the existing lines.

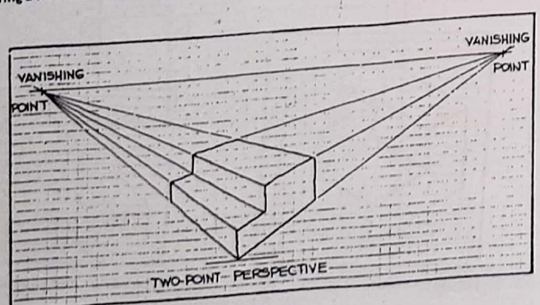


Figure 2-45 Two-point perspective sketch

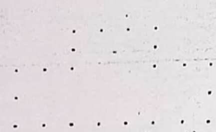


Figure 2-46 Dots used as guides in sketching

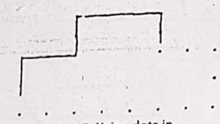


Figure 2-47 Using dots in sketching lines

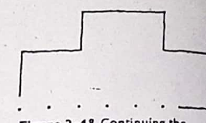


Figure 2-48 Continuing the sketch by connecting the dots

If graph paper is not available, pencil dots can be positioned to plot the path of the line, Figure 2-46. In this figure, the sketcher enters a series of pencil dots on the paper which provide a basic outline as to the shape of the object. Then, using a series of short, slightly overlapping strokes, the pencil dots are connected, Figures 2-47, 2-48, and 2-49. This technique is also used for curved lines, Figure 2-50.

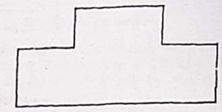


Figure 2-49 Completing the sketch made by using dots as guides

Sketching Circles

Figure 2-51 illustrates a series of six steps that can be used for sketching a circle. Vertical and horizontal center lines are sketched, which positions the center of the circle (Step 1) and the radial distances of the desired circle size are marked on each of these lines, equidistant from the center (Step 2). A square is drawn symmetrically around the center, with the sides located at the radial line marks (Step 3). On the diagonals of the square (Step 4), the radial distances are again marked off from the center (Step 5). This provides four positions for the circumference to pass through at the sides of the square, and four more positions on the diagonals of the square. The right half of the circle is sketched in from top to bottom using short, slightly overlapping strokes, and then the left half is sketched in the same manner (Step 6).

Sketching Ellipses

A similar technique is used for sketching ellipses, except that the square becomes a rectangle, Figure 2-52. Ellipses are oriented on the object being sketched as shown in the diagram in Figure 2-53.

Proportion in Sketching

Sketches are not done to scale, but it is important that they are made proportionately accurate. All of the various components of a sketch should be kept in proportion to those of the actual object. This technique takes a great deal of practice to master.

Some methods for achieving proportion recommend using a pencil or a strip of paper as a simulated scale. These techniques are not only unrealistic in terms of the real world, they defeat the very purpose of sketching. A skilled sketcher must learn to maintain proportion without the use of tools and aids. The best device for accomplishing proportion in sketching is the human eye. With practice, the drafter can become proficient in maintaining proportion without the use of extraneous, time-consuming devices. The following general rules relating to proportion w also help.

Step 1. In sketching, use graph paper whenever possible.

Step 2. Examine the object to be sketched and mentally break it into its component parts.

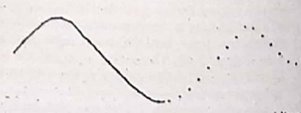
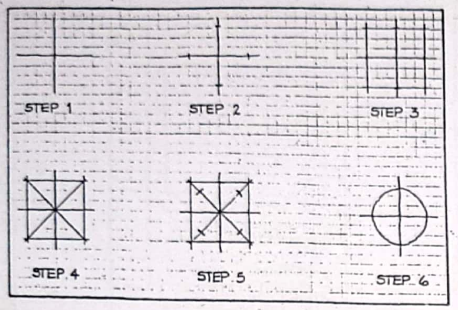


Figure 2-50 Using dots in sketching curved lines

Figure 2-51 Sketching a circle



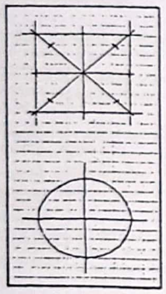


Figure 2-52
Sketching an ellipse

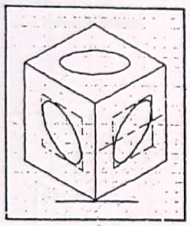


Figure 2-53 Orienting an ellipse on an object

Step 3. Beginning with the largest components (length and width), estimate the proportion, such as the length is 4/3 times the width or 5/2 times the width, and so on.

Step 4. Lay out the largest component according to the proportions decided upon in Step 3. Use construction line squares and rectangles to block in irregularly shaped components, Figure 2-54.

Repeat Steps 3 and 4 until the entire object is finished.

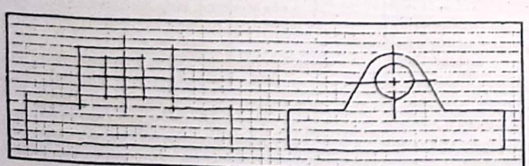


Figure 2-54 Blocking in components

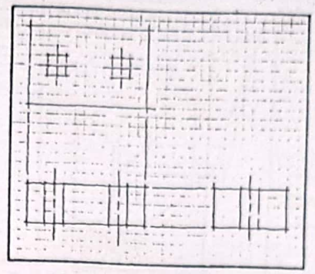


Figure 2-55 Blocking in an orthographic sketch

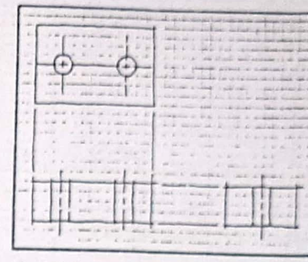


Figure 2-56 Completing the top view

Ortnographic Sketching

Orthographic sketching may involve sketching any combination of the six principal views of the subject. The top, front, and right-side views are normally selected for representing an object in an orthographic sketch. However, these views are not always appropriate. The sketcher must learn to choose the most appropriate views. These are the views that show the most detail and the fewest hidden lines. A good rule of thumb to use in selecting views is to select the views which would give you all of the information you would need if you had to make the object yourself.

Once the views have been selected, the orthographic sketch may be laid out using the techniques set forth earlier in this chapter. To ensure that the sketched views align, the entire sketch should be blocked in before adding details, Figure 2-55. Once the layout is blocked in, the details can be added one view at a time, Figures 2-56, 2-57, and 2-58.

Axonometric Sketching

As was mentioned earlier, there are three types of axonometric projection: isometric, dimetric, and trimetric. Isometric projection is used in sketching. Dimetric and trimetric projection have little application in sketching, due to the difficulty in proportioning scale values of length, width, and height. Isometric views have the same scaling value in all three directions, eliminating the need to vary proportions among the three directions. In an isometric sketch, height lines are vertical, and width and length lines recede at approximately 30° and 150° (180°−30°) from the horizontal.

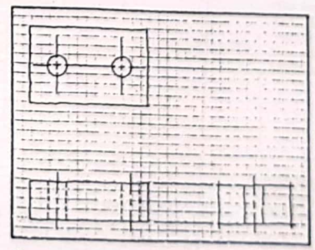


Figure 2-57 Completing the front view

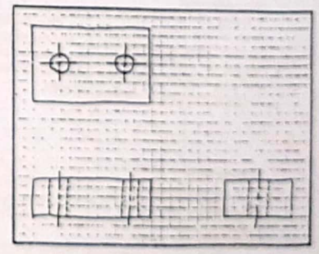


Figure 2-58 Completing the sketch

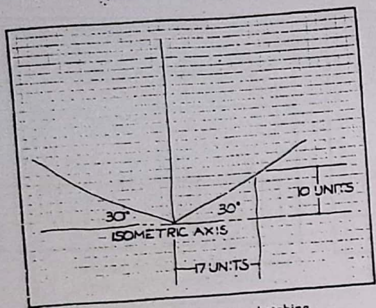


Figure 2-59 The isometric axis in sketching

The first step in creating an isometric sketch is to lay out the isometric axis. Figure 2-59. All normal lines will be parallel to one of the axis lines. The next step is to block in the object using construction lines. Figure 2-60. Five steps in the development of an isometric sketch are shown in Figures 2-61, 2-62, 2-63, 2-64 and 2-65.

Oblique Sketching

Oblique sketching involves laying out the front view of an object, and showing the depth lines receding at an angle (usually 45°) from the horizontal. Oblique sketching is particularly useful for dealing with an object having round components. Oblique sketching allows round components to be drawn round, rather than elliptical.

Using the blocking in method, the flat front surface of the object is laid out. The depth is then blocked in using parallel lines, and the sketch is completed by outlining the exposed profile of the rear surface. Figures 2-66, 2-67, and 2-68 illustrate three steps in creating an oblique sketch.

Perspective Sketching

Perspective sketching closely approximates how the human eye actually sees an object. Two common types of perspective sketches are one-point and two-point perspectives.

A one-point perspective sketch is similar to an oblique sketch, except that depth lines recede to a

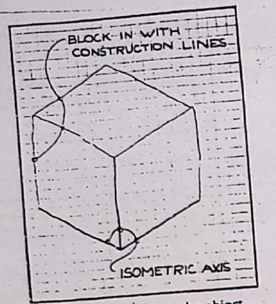


Figure 2-60 Blocking in the object

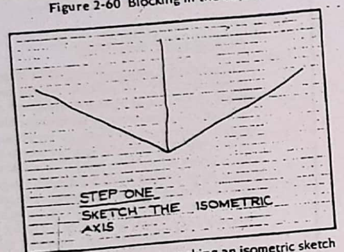


Figure 2-61 Step one in making an isometric sketch

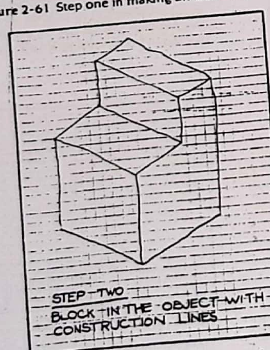


Figure 2-62 Step two in making an isometric sketch

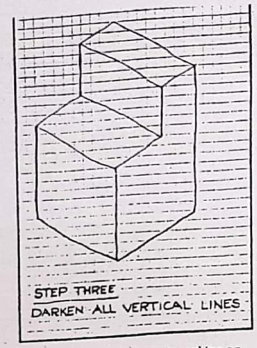


Figure 2-63 Step three in making an isometric sketch

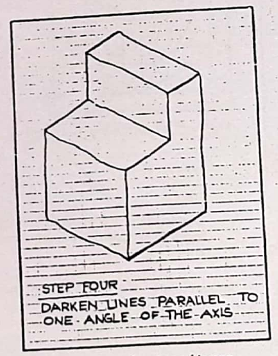


Figure 2-64 Step four in making an isometric sketch

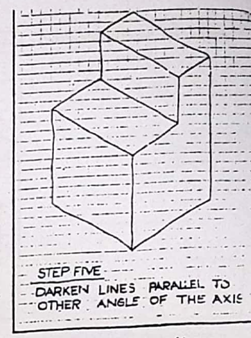


Figure 2-65 Step five in making an isometric sketch

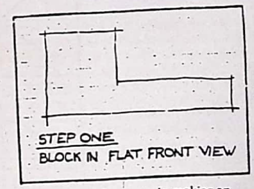


Figure 2-66 Step one in making an oblique sketch

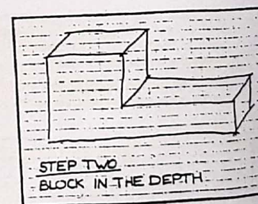


Figure 2-67 Step two in making an oblique sketch

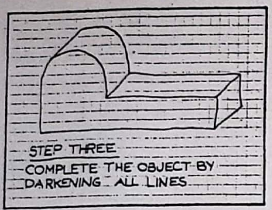


Figure 2-68 Step three in making an oblique sketch

vanishing point instead of receding parallel to one another, Figure 2-69. In constructing a one-point perspective, the following procedures apply.

Step 1. Lay out the flat front surface of the object using the blocking in method, Figure 2-70.

Step 2. Select and mark a single vanishing point. Project all points on the front surface back to the vanishing point, Figure 2-71.

Step 3. Estimate the depth of the object and mark it off on all line projectors, Figure 2-72.

Step 4. Complete the sketch by outlining the exposed profile of the rear surface, Figure 2-73.

A two-point perspective resembles an isometric sketch, except that width and depth lines recede to the left and right vanishing points rather than receding in parallel, Figure 2-74.

In constructing a two-point perspective, the following procedures apply.

Step 1. Lay out the two-point perspective frame which consists of the vertical height line, the vanishing point left, the vanishing point right, and the receding lines (all estimated locations), Figure 2-75. The horizon line when positioned below the view provides a view of the bottom of the object, and when positioned above shows the top. The vanishing points must be on the horizon.

Step 2. Block in the object, estimating the length and width for proportion, Figure 2-76.

Step 3. Lay out the details, lightly giving special attention to proportion, Figure 2-77.

Step 4. Complete the two-point perspective sketch, Figure 2-78.

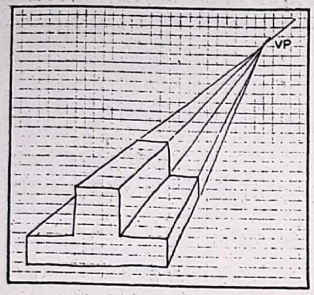


Figure 2-69 One-point perspective sketch

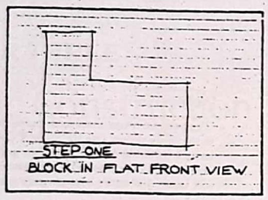


Figure 2-70 Step one in making a one-point perspective sketch

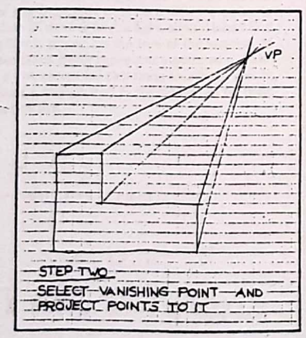


Figure 2-71 Step two in making a one-point perspective sketch

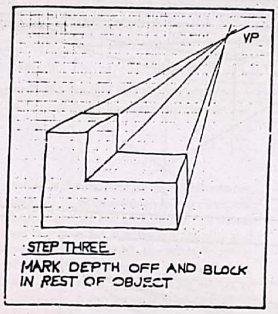


Figure 2-72 Step three in making a one-point perspective sketch

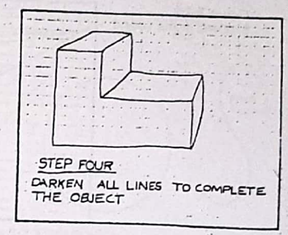


Figure 2-73 Step four in making a one-point perspective sketch

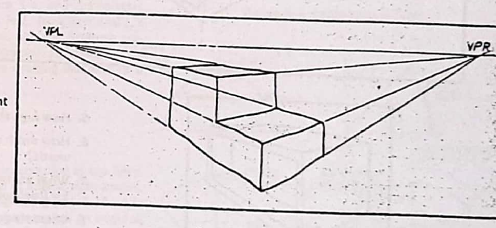


Figure 2-74 Two-point perspective sketch

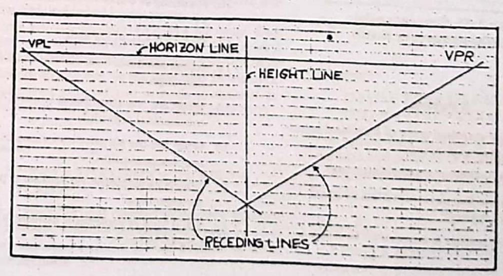
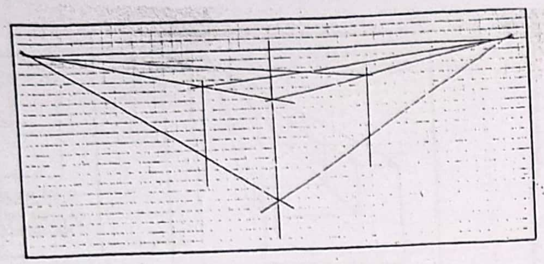


Figure 2-75 Laying out the two-point perspective frame

Figure 2-76
Blocking in the object



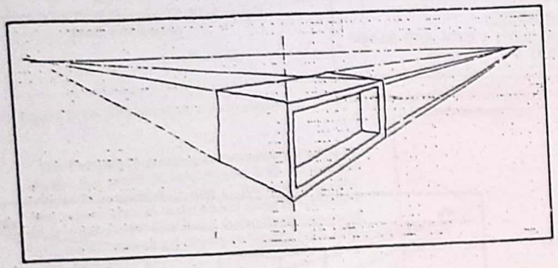


Figure 2-77
Laying out the details

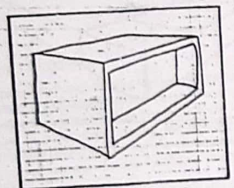


Figure 2-78 Completing the two-point perspective sketch

Review

1. What is the standard style of freehand lettering on technical drawings?
2. What is the slope of slanted lettering?
3. What are the five characteristics of good freehand lettering?
4. How many strokes are required to make a letter B?
5. How high should fractions be?
6. How much space should be left between words?
7. What are two grades of lead commonly used for freehand lettering?
8. What are guidelines?
9. Why are guidelines important?
10. A setting of 8 on a lettering guide will produce letters of what height?
11. Define the term *line work*.
12. Name ten basic lines types used on technical drawings.
13. What are two advantages of sketching over mechanical drawing?
14. What are the six principal views of orthographic projection?
15. Which axonometric projection is preferred for sketching?
16. What kind of projection exhibits a circle as an elliptic shape?

Chapter Two Problems

The following problems are intended to give the beginning drafter practice in using the various lettering, line work, and sketching techniques that are fundamental to drafting. Each problem should be studied carefully, while following the individual instructions.

Problem 2-1

Lay out an A-size sheet for lettering practice, according to the figure shown. Use 1/2" borders. Use 5/16" guidelines, using a lettering guide if available, and letter 3 rows of characters in the manner shown, under each respective row. Leave 1/8" space between each row.

Problem 2-2

Repeat Problem 2-1, but use 1/4" guidelines.

Problem 2-3

Repeat Problem 2-1, but use 3/16" guidelines

Problem 2-4

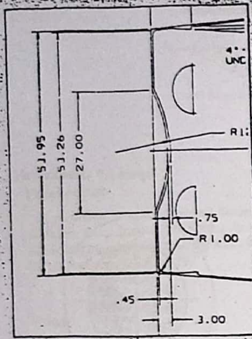
Repeat Problem 2-1, but use 1/8" guidelines.

A B C D E F G H I

J K L M N O P Q R S T

U V W X Y Z 0 1 2 3 4 5 6 7 8 9

Problems 2-1 through 2-4



The basic techniques associated with geometric construction must be thoroughly mastered. The various procedures discussed in this chapter will be used in solving all drawing problems throughout this book, as well as later on the job. By using these geometric construction techniques, drawings will be of professional quality and accomplished in the least amount of time. It is important for the beginning drafter to thoroughly know and understand these techniques and, more importantly, to know when and where to apply them.

CHAPTER THREE

Geometric Construction

To be truly proficient in the layout of both simple and complex drawings, the drafter must know and fully understand the many geometric construction methods used. These methods are illustrated in this chapter, and are basically simple principles of pure geometry. These simple principles are used to actually develop a drawing with complete accuracy, and in the fastest time possible, without wasted motion or any guesswork. Applying these geometric construction principles give drawings a finished, professional appearance.

In laying out the various geometric constructions, it is important to use a very sharp, 4-H lead and to be extremely accurate at all times. Always draw light construction lines that can hardly be seen when held at arm's length. These light construction lines should not be erased as this takes up valuable drawing time and they can also be reused to check layout work if necessary.

Geometric Nomenclature

Points in Space

A *point* is an exact location in space or on a drawing surface. Figure 3-1. A point is actually represented on the drawing by a crisscross at its exact location. The exact point in (drawing) space is where the two lines of the crisscross intersect. When a point is located on an existing line, a light, short dashed line or crossbar is placed on the line at the location of the exact point. Never represent a point on a drawing by a dot, except for sketching locations. This is not accurate enough, and is considered to be poor drafting practice.

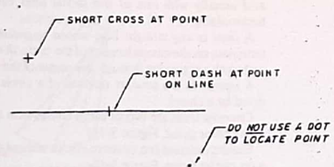


Figure 3-1 Points in space or on a surface

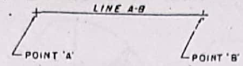


Figure 3-2 A straight line is the shortest distance between two points

Line

A straight line is the shortest distance between two points. Figure 3-2. It can be drawn in any direction. A *line* can be straight, an arc, a circle or a free curve, as illustrated in Figure 3-3. If a line is indefinite, and the ends are not fixed in length, the actual length is a matter of convenience. If the end points of a line are important, they must be marked by means of small, mechanically drawn crossbars, as described by a point in space.

Straight lines and curved lines are considered to be parallel if the shortest distance between them remains constant. The symbol used for parallel lines is //. Lines that are tangent and at 90° are considered perpendicular. The symbol for perpendicular lines is ⊥ (singular), Figure 3-4, and ⊥s (plural). The symbol for an angle is ∠ (singular) and ∠'s (plural). To draw an angle, use the drafting machine, a triangle, or a protractor. For extra accuracy, use the vernier on the drafting machine or a vernier protractor.

Angle

An *angle* is formed by the intersection of two lines. There are three major kinds of angles: right angles, acute angles, and obtuse angles, Figure 3-5. The *right angle* is an angle of 90°. An *acute angle* is an angle at less than 90°, and an obtuse angle is an angle at more than 90°. Note that a straight line is 180°. Figure 3-5 also illustrates the complementary and supplementary angles of a given angle.

There are 360 degrees (360°) in a full circle. Each degree is divided into 60 minutes (60'). Each minute is divided into 60 seconds (60"). Example: 48°28'38" is read as 48 degrees, 28 minutes, and 38 seconds.

To convert minutes and seconds to decimal degrees, divide minutes by 60 and seconds by 3600.

Example:

21°18'27" = 21° + (18/60)° + (27/3600)° = 21.3075°

To convert decimal degrees to degrees, minutes, and seconds, multiply the degree decimal by 60 to obtain minutes, and the minute decimal by 60 to obtain seconds.

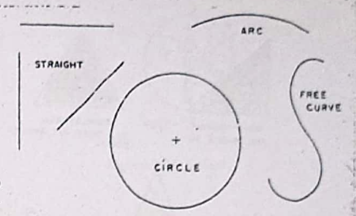


Figure 3-3 Kinds of lines

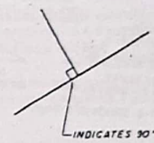


Figure 3-4 Perpendicular lines

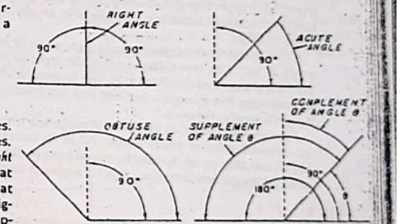


Figure 3-5 Kinds of angles

Example:

77.365° = 77° + (.365 X 60)' = 77°21.9'
77°21.9' = 77°21' + (.9 X 60)" = 77°21'54"

A vernier may be used to measure and read off minutes and seconds of a degree. The vernier scale is discussed in Chapter 1.

Triangle

A *triangle* is a closed plane figure with three straight sides and three interior angles. The sum of the three

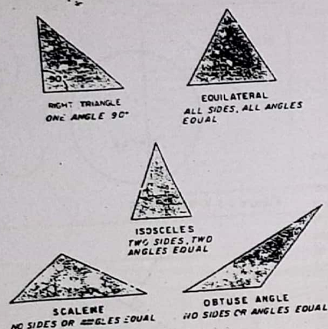


Figure 3-6 Kinds of triangles

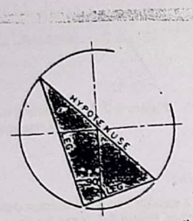


Figure 3-7 Any triangle inscribed within a semicircle is a right triangle

internal angles is always exactly 180°, half of the 360° in a full circle. Figure 3-6 shows the various kinds of triangles: a right triangle, an equilateral triangle, an isosceles triangle, a scalene triangle, and an obtuse angle triangle.

A *right triangle* is a triangle having a right angle or an angle of 90°. The two sides forming the right angle are called **legs**, and the third side (the longest) is the hypotenuse. Any triangle inscribed in a semicircle is a right triangle. Figure 3-7.

An *equilateral triangle*, as its name implies, is a triangle with all sides of equal length. All of its interior angles are also equal. An *isosceles triangle* has two sides of equal length and two equal interior angles. A *scalene triangle* has no equal sides or angles. An *obtuse angle triangle* is a triangle having an obtuse angle greater than 90°, with no equal sides.

Polygon

A *polygon* is a closed plane figure with three or more straight sides. Figure 3-8. More specifically, shown in the figure are regular polygons, meaning that all sides are equal in each of these examples. The most important of these polygons as they relate to drafting are probably the triangle with three sides, the square with four sides, the hexagon with six sides, and the octagon with eight sides.

Quadrilateral

A *quadrilateral* is a plane figure bounded by four straight sides. When opposite sides are parallel, the quadrilateral is also considered to be a *parallelogram*. Figure 3-9.

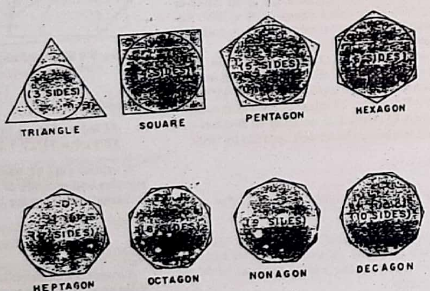


Figure 3-8 Examples of polygons

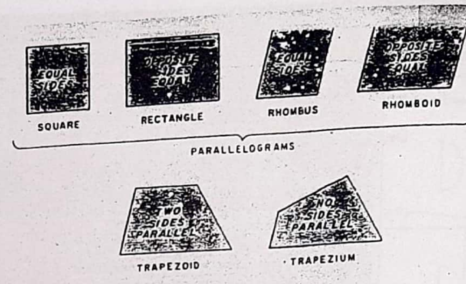


Figure 3-9 Quadrilaterals

Circle

A *circle* is a closed curve with all points on the circle at the same distance from the center point. The major components of a circle are the diameter, the radius, and the circumference, Figure 3-10.

The *diameter* of a circle is the straight distance from one outside curved surface through the center point to the opposite outside curved surface. The diameter of a circle is twice the size of the radius.

The *radius* of a circle is the distance from the center point to the outside curved surface. The radius is half the diameter, and is used to set the compass when drawing a diameter.

The *circumference* of a circle is the distance around the outer surface of the circle. To calculate the circumference of a circle, multiply the value of π (use the approximation 3.1416) by the diameter. A chart similar to the one found in the appendix of this text may be used.

Other important parts of a circle are the central angle, the sector, the quadrant, the chord, and the segment. Figure 3-11.

A *central angle* is an angle formed by two radial lines from the center of the circle.

A *sector* is the area of a circle lying between two radial lines and the circumference.

A *quadrant* is a sector with a central angle of 90°, and usually with one of the radial lines oriented horizontally.

A *chord* is any straight line whose opposite ends terminate on the circumference of the circle. (A diameter is a chord passing through the center of the circle.)

A *segment* is the smaller portion of a circle separated by a chord.

Concentric circles are two or more circles with a common center point. Figure 3-12.

Eccentric circles are two or more circles without a common center point. Figure 3-12.

A *semicircle* is half of a circle.

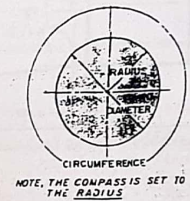


Figure 3-10 The major components of a circle

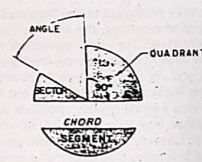


Figure 3-11 Other parts of a circle

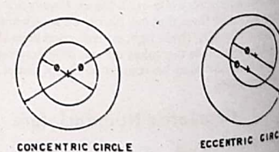


Figure 3-12 Concentric and eccentric circles

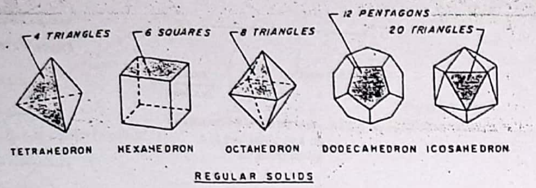


Figure 3-13 Polyhedrons (solids)

Polyhedron

A *polyhedron* is a solid object bounded by plane surfaces. Each surface is called a face. If the faces are equal, regular polygons, the solid figure is a regular polyhedron. Figure 3-13.

Prism

A *prism* is a solid having ends that are parallel matched polygons, and sides that are parallelograms. Figure 3-14. This definition also applies to round or circular objects, such as a cylinder. When the polygon on one end of a prism is not parallel to the other end, it is said to be *truncated*. The *altitude* of a prism is the perpendicular distance between its end polygons (or bases).

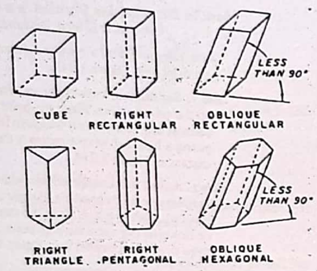


Figure 3-14 Prism

Pyramid and Cone

A *pyramid* is a polyhedron having a polygon as its base. Three or more triangles form its lateral sides which meet at a common vertex. Figure 3-15. A *cone* is a pyramid with a central axis, and an infinite number of sides which form a continuous curved lateral surface. When the vertex of a pyramid or cone has been removed by a plane that intersects all the lateral sides (which forms a new polygon), the pyramid or cone is said to be *truncated*. Figure 3-16.

Sphere

A *sphere* is a closed surface, every point on which is equal distant from a common point or center. Figure 3-17. If a sphere is cut into two equal parts, the parts are called *hemispheres*. *Poles* are two reference measuring positions on the surface of the sphere on opposite sides of its center.

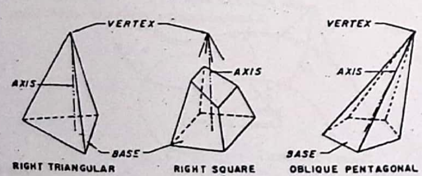


Figure 3-15 Pyramid

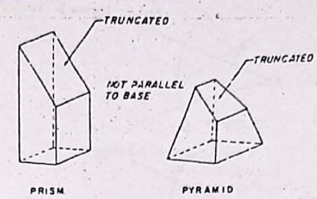


Figure 3-16 Truncated pyramid

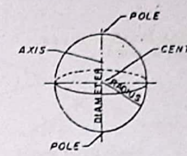


Figure 3-17 Sphere

Elemental Construction Principles

The remaining portion of this chapter is devoted to illustrating step-by-step the many geometric construction principles used by the drafter to develop various geometric forms. It is important that each step be fully understood and followed. As the beginning drafter uses these geometric construction principles, various shortcuts will become evident, thus reducing the drawing time and increasing accuracy even more. At the end of the chapter, each of these techniques is incorporated or used in some way to complete the various given problems.

How To Bisect a Line

To *bisect* a line means to divide it in half or to find its center point. In the given process, a line will also be constructed at the exact center point at exactly 90°.

Figure 3-18A How to bisect a line

Given: Line A-B, Figure 3-18A.

Step 1. Set the compass approximately two-thirds of the length of line A-B and swing an arc from point A. Figure 3-18B.

Step 2. Using the exact same compass setting, swing an arc from point B. Figure 3-18C.

Step 3. At the two intersections of these arcs, locate points X and Y. Figure 3-18D.

Step 4. Draw a straight line connecting point X with point Y. Where this line intersects line A-B is the bisect of line A-B. Figure 3-18E. Line X-Y is also perpendicular to line A-B at the exact center point.

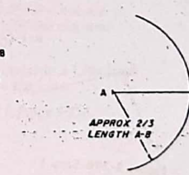


Figure 3-18B Step 1

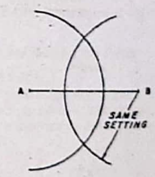


Figure 3-18C Step 2

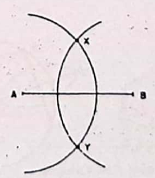


Figure 3-18D Step 3

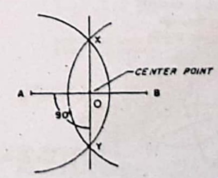


Figure 3-18E Step 4

by underlining NTS dimensions with a thick straight line. The older version, a wavy line, is no longer used.

Although a scale may have been indicated in the title block, it is frequently necessary to add an enlarged view of a characteristic. The scale for such enlarged views should be shown adjacent to it, even though a different overall scale applies to the entire drawing.

Dimensioning Systems

Three dimensioning systems are used on technical drawings in the United States: metric dimensioning, decimal-inch dimensioning, and fractional dimensioning. Certain rules of practice pertain to each of these dimensioning systems with which drafters should be familiar.

Metric Dimensioning

The standard metric unit of measurement for use on technical drawings is the millimetre (0.001 metre) or .039 inch. Figure 9-1 is a chart of the various metric units of measurement less than a metre showing where the millimetre fits in.

When using metric dimensioning, several general rules should be observed. When a dimension is less than one millimetre, a zero must be placed to the left of the decimal point. Figure 9-2, Part A. When a metric dimension is a whole number, neither the zero nor the decimal is required. Figure 9-2, Part B. When a metric dimension consists of a whole number and a decimal portion of another millimetre, it is written as follows: whole number first, decimal point next, and, finally, the decimal part of the number. The decimal part of the number is *not* followed by a zero in metric dimensioning. Figure 9-2, Part C. Individual digits in metric dimensions are not separated by commas or spaces. Figure 9-3. Drawings prepared with metric dimensions are identified with the word METRIC contained in a small rectangle below the part.

UNIT	MULTIPLE OF A METRE
METRE	[illegible]
DECIMETRE	0.1
CENTIMETRE	0.01
MILLIMETRE	0.001

Figure 9-1 Metric linear measurements

Decimal-inch Dimensioning

Decimal-inch dimensioning is frequently used in the dimensioning of technical drawings. It is a much less cumbersome system for mechanical drawings than is the fractional system, and it is still used more than the metric system.

When using the decimal-inch dimensioning system, several rules should be observed. If a dimension is less than one inch, only a decimal point and the numbers are required. A zero is not required to precede the decimal point. Figure 9-4, Part A. The number of places beyond the decimal that a decimal-inch dimension is carried is determined by the specified tolerance for the part in question. Figure 9-4, Part B. In this figure, a tolerance of .001 (three places to the right of the decimal) is specified. Consequently, the dimension 1.637 is carried out three places to the right of the decimal.

There are no specified sizes for decimal points, but they should be made dark enough and large enough to be seen, and to reproduce through any normal reproduction process (diazo, photocopy or microfilm).

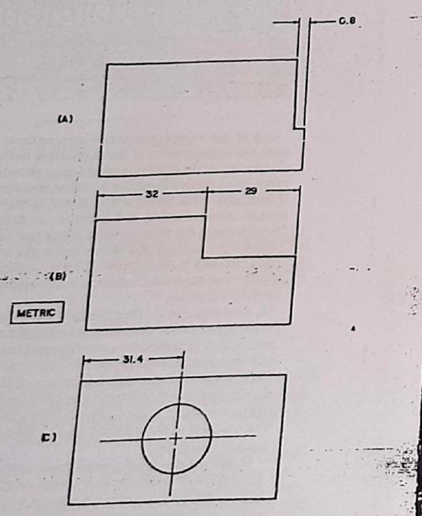


Figure 9-2 Metric dimensioning

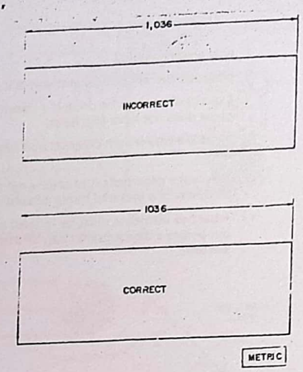


Figure 9-3 No commas in metric dimensions

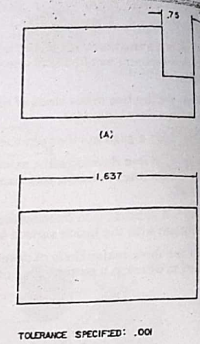


Figure 9-4 Decimal-inch dimensioning

Fractional Dimensioning

Fractional dimensioning is not frequently used on mechanical technical drawings. Its primary use is on architectural and structural engineering drawings. However, since it is occasionally still used on mechanical drawings, drafters should be familiar with this system.

When using fractional dimensions on mechanical drawings, several rules should be observed. The line separating the numerator and denominator of a fraction should be a horizontal line, not an inclined line. Figure 9-5. Full-inch dimensions should be a minimum of one-eighth inch in height. The combined height of the numerator, denominator, and horizontal line of a fraction should be one-quarter inch. Figure 9-6 for A-, B-, and C-size drawings, and a minimum of five-sixteenths inch for D, E, and F sizes.

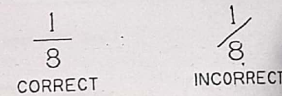


Figure 9-5 Horizontal line is the correct metho

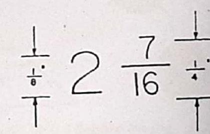


Figure 9-6 Proportions for fractions

Dimension Components

Several components are common to all dimensioning systems. These include extension lines, dimension lines, leader lines, arrowheads, and the actual numbers or dimensions. Drafters and engineers should be knowledgeable in the proper use of these components.

Extension Lines

An *extension line* is a thin, solid line that extends fro the object in question or some feature of the obje Several rules should be observed when placing ex sion lines on technical drawings.

There should be a small but visible gap betwe the object or object feature and the beginning of

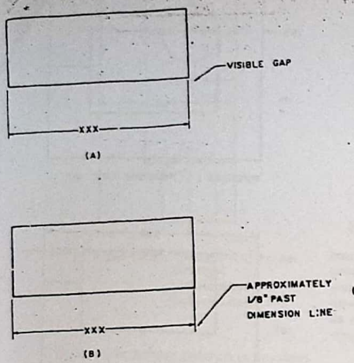


Figure 9-7 Drawing extension lines

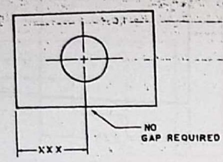


Figure 9-8 Center lines as extension lines

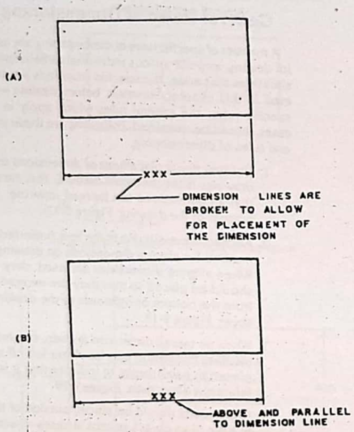


Figure 9-9 Placement of dimensions

extension line. Figure 9-7, Part A. Extension lines should extend uniformly beyond dimension lines a distance of approximately one-eighth inch. Figure 9-7, Part B. Extension lines that originate on the object, such as center lines, may cross visible lines with no gap required. Figure 9-8.

Dimension Lines

A *dimension line* is a thin, solid line used to indicate graphically the linear distance being dimensioned. Dimension lines are normally broken for placement of the dimension. Figure 9-9, Part A. If a horizontal dimension line is not broken, the dimension is placed above the dimension line with guidelines parallel to it. Figure 9-9, Part B.

When dimensioning multiple features of an object, dimensions should be aligned uniformly rather than staggered or randomly scattered about the object. Figure 9-10.

Dimension lines are drawn parallel to the direction of measurement. Sufficient distance between the object and the dimension lines and between successive dimension lines is important so that cramped and crowded dimensions do not result. The first dimension line should be at least three-eighths inch away from the object. Figure 9-11, Part A. Successive dimension lines should be at least one-quarter inch apart. If using metric dimensions, the first dimension line should be at least 10 millimetres away from the object. Successive lines should have at least 6 millimetres between them. Figure 9-11, Part B.

When the shape of an object requires a series of parallel dimension lines, the breaks and the dimensions should be staggered to make it easier to read the dimensions. Figure 9-12.

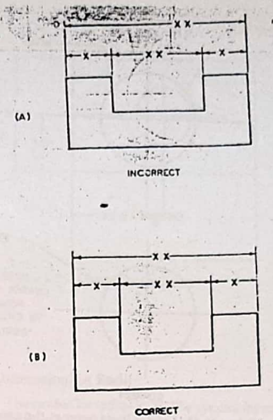


Figure 9-10 Proper placement of dimensions

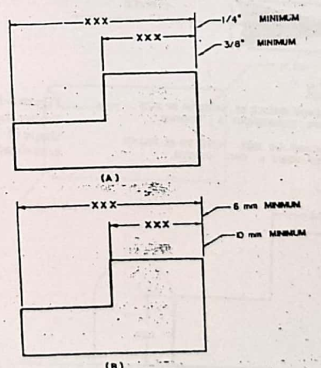


Figure 9-11 Successive dimension lines

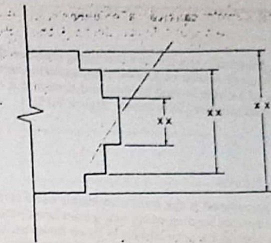


Figure 9-12 Staggering dimensions

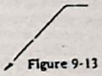


Figure 9-13 Leader line

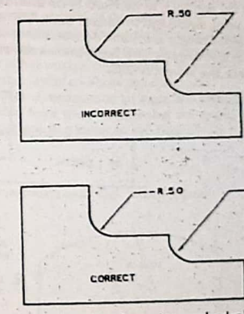


Figure 9-14 One dimension per leader line is preferred

Leader Lines

A *leader line* is a thin line that begins horizontally, breaks at an angle, and terminates in an arrowhead or, on occasion, a dot. Figure 9-13. Leader lines are used for tying dimensions, notes, symbols or other data to a specific point on a drawing.

When using a leader line to direct a dimension to its appropriate feature on a drawing, a dimension for each leader line is the preferred method. Figure 9-14. More than one leader line extending from the

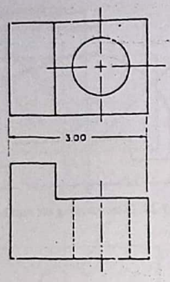


Figure 9-21 Placement of common dimensions between views

9. Dimensions that are common to two views should be placed between the views, as long as they can be clearly read. Figure 9-21.
10. In a series of dimensions, begin with the shortest and work out and away from the object so that the last dimension is the longest. Figure 9-22.
11. No other type of line should cross a dimension line unless it is absolutely unavoidable. Figure 9-23.

Specific Dimensioning Techniques

All of the information on dimensioning so far has been of a general nature. The following sections deal with the techniques used for applying dimensions to specific situations that are recurrent in drafting. With a thorough knowledge of the general information presented earlier, and the specific information presented in these sections, drafters will be able to dimension any situation confronted on technical drawings.

Dimensioning Diameters

Diameters may be dimensioned using extension and dimension lines or using leader lines. In either case, the diameter dimension is preceded by a diameter symbol ø. If the diameter is a spherical diameter, the diameter symbol is preceded by a capital "S." Figure 9-24 illustrates how diameters may be dimensioned in longitudinal views. Figure 9-25 illustrates how diameters are dimensioned in views where they appear as circles. Figure 9-26 illustrates the dimensioning of a spherical diameter.

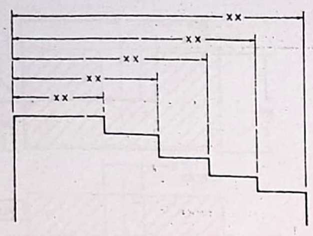


Figure 9-22 The topmost dimension in a series should be the longest

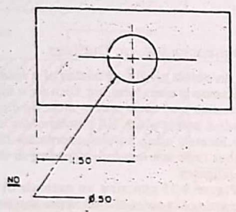


Figure 9-23 Avoid crossing dimension lines

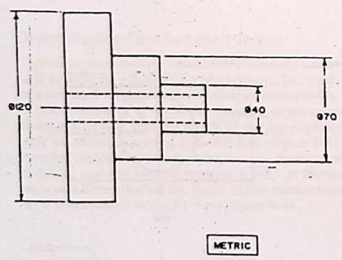


Figure 9-24 Dimensioning diameters in longitudinal views

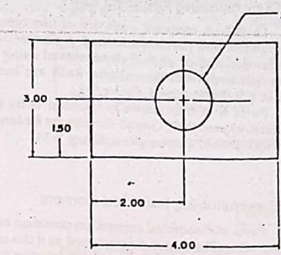


Figure 9-25 Dimensioning holes

Dimensioning Radii

The symbol for radius is "R." The symbol for spherical radius is "SR." Each time a radius is called out, it must be preceded by either the R or SR symbol. Radii are dimensioned using leader lines which terminate in arrowheads. Figures 9-27 and 9-28 illustrate various ways in which radii are dimensioned.

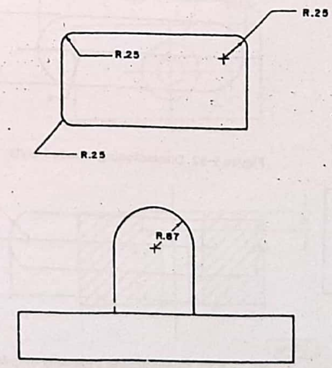


Figure 9-27 Dimensioning radii

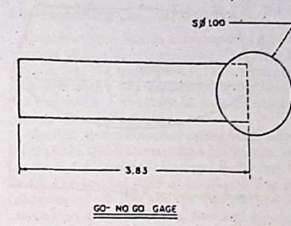


Figure 9-26 Dimensioning a spherical diameter

Dimensioning Chords, Arcs, and Angles

Chords, arcs, and angles are dimensioned in a similar manner. When dimensioning a chord, the dimension line should be perpendicular to the extension lines and parallel to the chord. Figure 9-29.

When dimensioning an arc, the dimension line runs concurrent with the arc curve, but the extension lines are either vertical or horizontal. Figure 9-30. An arc symbol is placed above the dimension.

When dimensioning an angle, the extension lines extend from the sides forming the angle, and the dimension line forms an arc. Figure 9-31.

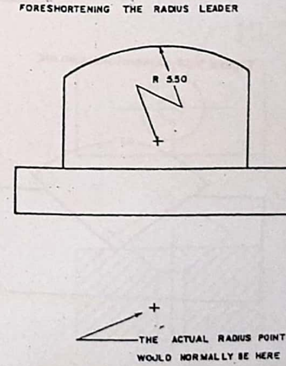


Figure 9-28 Dimensioning the radius

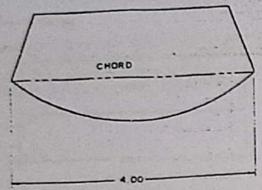


Figure 9-29 Dimensioning a chord

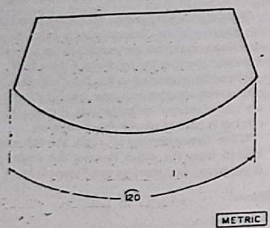


Figure 9-30 Dimensioning an arc

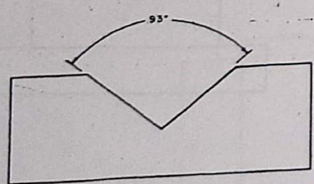


Figure 9-31 Dimensioning an angle

Dimensioning Rounded Ends

Parts with rounded ends are of two types: fully rounded and partially rounded. A part with a fully rounded end or ends is dimensioned using overall length and width dimensions. Radii are indicated, but not dimensioned. Figure 9-32.

Parts with only partially rounded ends require dimensioned radii. Overall dimensions for length and width should also be given. Figure 9-33.

Dimensioning Rounded Corners

Parts with rounded corners are common in manufacturing. The part is dimensioned as if the rounded corner is square. Then, a radius dimension is added for the rounded corner. Figure 9-34.

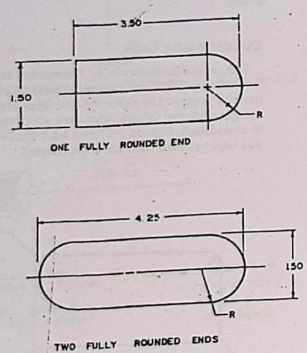


Figure 9-32 Dimensioning rounded ends

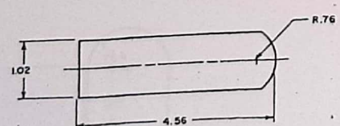


Figure 9-33 Dimensioning a partially rounded part

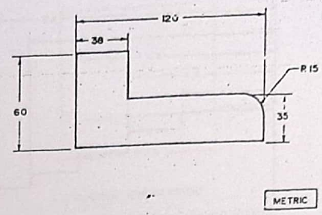


Figure 9-34 Dimensioning a rounded corner

Dimensioning Arc Outlines

An object profile consisting of a series of arcs is common in manufacturing. Each arc in the series has a radius and each radius must be dimensioned. Radius points which fall outside of the object must be located using normal coordinate dimensions. Other radii are located according to their points of tangency.

Figure 9-35 contains an example of an object consisting of a series of arcs. Notice how the unusually long radii are dimensioned.

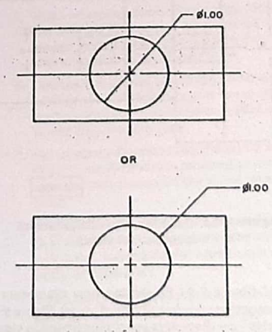


Figure 9-36 Dimensioning round holes

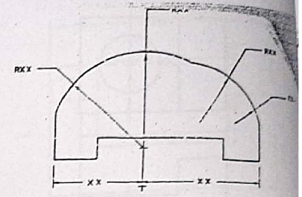


Figure 9-35 Dimensioning arc outlines

Dimensioning Round Holes

One of the most common dimensioning situatio[n] is the round hole. Holes drilled in objects may eith[er] pass through the object or penetrate it to a spec[i]fied depth. Depending on the nature of the drawing, [it] may or may not be clear graphically which is the cas[e].

When it is not clear as to whether a hole passe[s] through an object or only penetrates it partially, th[e] condition must be clarified by the dimension. Fi[g]ures 9-36 through 9-39 illustrate the various meth[o]ds used for dimensioning round holes.

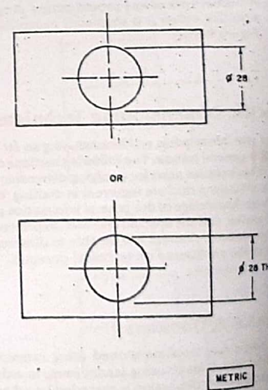


Figure 9-37 Dimensioning round holes

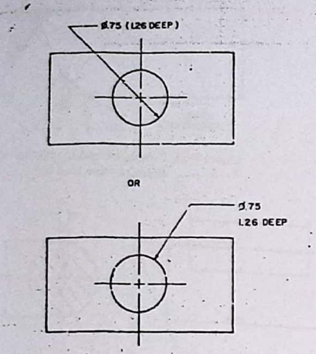


Figure 9-38 Dimensioning round holes

Dimensioning Slotted Holes

Slotted holes are a common dimensioning situation. Several different methods are used in dimensioning slotted holes. The most commonly used method involves dimensioning the overall length and width of the slot and calling out but not dimensioning the radii, Figure 9-40.

Another method involves dimensioning the overall width of the slot, the distance between the radii centers, and calling out, but not dimensioning, the radii, Figure 9-41.

Still another method involves using leader lines to call out the overall length and width of the slot and calling out, but not dimensioning, the radii, Figure 9-42.

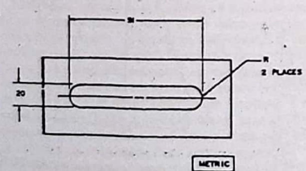


Figure 9-40 Dimensioning a slotted hole

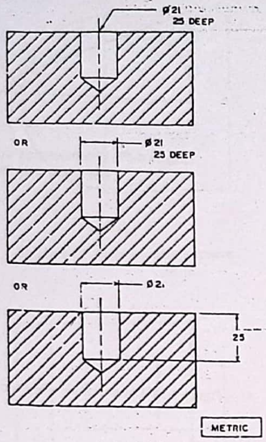


Figure 9-39 Dimensioning round holes

Dimensioning Counterbored Holes

Holes in manufactured parts are frequently *counterbored* to allow for a flush fitting of a fastener. Two methods are used for dimensioning counterbored holes. The diameter of the hole, the diameter of the counterbore (CBORE), and the depth of the counterbore may be called out using a leader line, Figure 9-43. Another method involves calling out the diameter of the hole and the counterbore on a plan or frontal view and dimensioning the depth of the counterbore on a longitudinal or depth view, Figure 9-44.

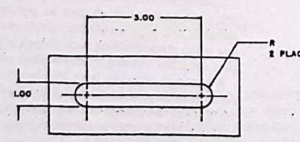


Figure 9-41 Dimensioning a slotted hole

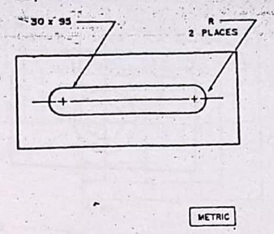


Figure 9-42 Dimensioning a slotted hole

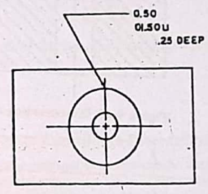


Figure 9-43 Dimensioning a counterbored hole

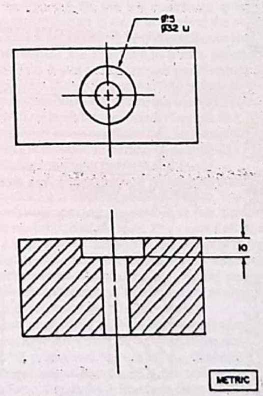


Figure 9-44 Dimensioning a counterbored hole

Dimensioning Countersunk Holes

Countersinking a hole in manufacturing a part is a process similar to counterboring. The major difference is that the countersink (CSK) is at an angle to accommodate a different head style on a fastener or for clearance. A countersunk hole may be dimensioned in one of two ways.

The first method involves calling out the diameter of the hole, the diameter of the countersink, and the angle of the countersink using a leader line, Figure 9-45. The second method involves calling out the diameter of the hole and the diameter of the countersink on a plan or frontal view and dimensioning the countersink angle on a longitudinal or depth view, Figure 9-46.

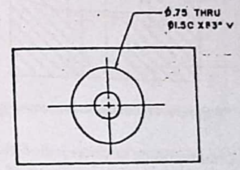


Figure 9-45 Dimensioning a countersunk hole

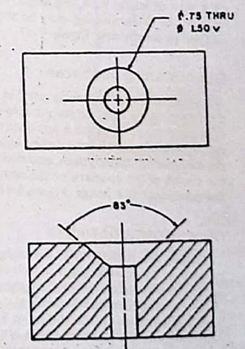


Figure 9-46 Dimensioning a countersunk hole

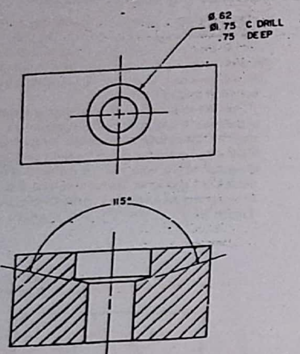


Figure 9-47 Dimensioning a counterdrilled hole

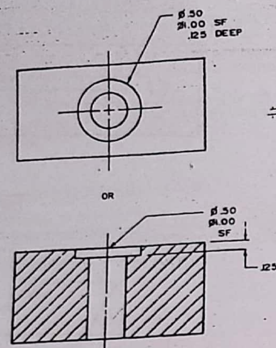


Figure 9-48 Dimensioning a spotface

Dimensioning Counterdrilled Holes

Dimensioning a *counterdrilled* hole involves specifying the diameter of the hole, the diameter of the counterdrill (CDRILL), the depth of the counterdrill, and the angle of the included angle of the counterdrill. The first three items of information can be placed on a plan or frontal view. The angle, which is optional in terms of dimensioning, may be shown on a longitudinal or depth view, Figure 9-47.

Dimensioning Spotfaces

A *spotface* (SF) is frequently used in manufacturing parts to provide an accurately machined surface seat for a fastener or a washer. A spotface involves dimensioning the diameter of the drilled hole, dimensioning the diameter of the spotface, and dimensioning either the depth of the spotface or the remaining depth of the part: usually a flange, Figure 9-48.

Dimensioning Chamfers

Chamfers are used to avoid sharp edges on machined parts and to provide essential clearances so as to avoid interferences. Several methods are used for dimensioning chamfers. In the first method, an angle and a dimension are used, Figure 9-49. In the second method, the chamfer angle and linear dimension are called out using a leader line, Figure 9-50.

Internal chamfers require a chamfer angle and a diameter dimension, as shown in Figure 9-51. Chamfers applied to edges of less than 90° require an angle

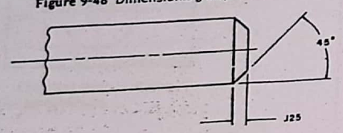


Figure 9-49 Dimensioning a chamfer

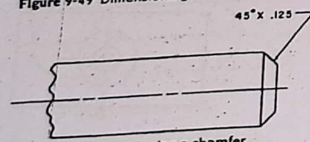


Figure 9-50 Dimensioning a chamfer

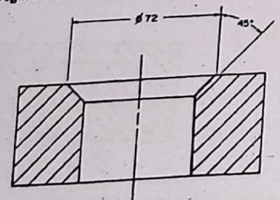


Figure 9-51 Dimensioning an internal chamfer

METRIC

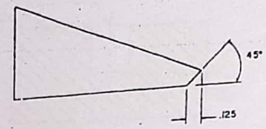


Figure 9-52 Dimensioning a chamfer on edges less than 90°

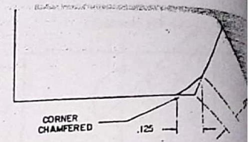


Figure 9-53 Dimensioning a chamfer on edges of more than 90°

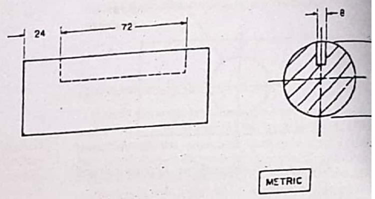


Figure 9-54 Dimensioning a keyseat

and a linear dimension, as shown in Figure 9-52. Chamfers applied to edges of more than 90° require linear dimensions with extension lines that are perpendicular to the subject edges, Figure 9-53.

Dimensioning Keyseats

A *keyseat* is a slot in a shaft to hold a key. Keyseats represent a fairly common dimensioning situation on manufactured parts. Dimensioning a keyseat involves dimensioning the width, depth, and length, as shown in Figure 9-54. Notice that the keyseat must be located if it does not extend the entire length of the part. It must also be located if it is allowed to run out at the shaft.

Dimensioning Geometric Shapes

Special techniques are called for when dimensioning such geometric shapes as pyramids, cones, spheres, and tapered objects. A rule of thumb to follow when dimensioning such shapes is to *provide only those dimensions necessary to define the shape and nothing more.*

A pyramid requires base and height dimensions. An intermediate dimension showing the distance from the apex of the pyramid to any corner in a top orthographic view can also be provided, but is not required, Figure 9-55.

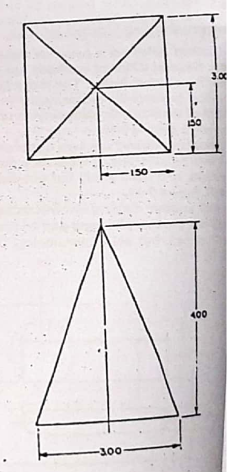


Figure 9-55 Dimensioning a pyrami

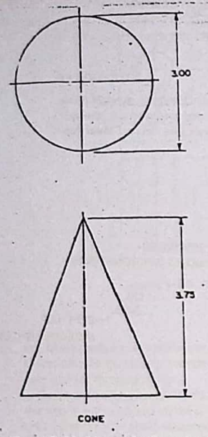


Figure 9-56 Dimensioning a cone

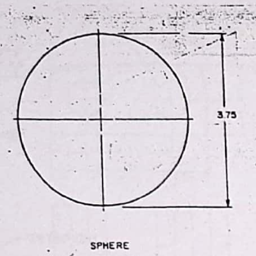


Figure 9-57 Dimensioning a sphere

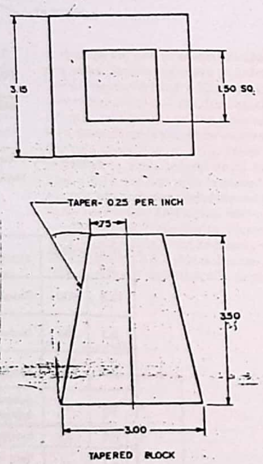


Figure 9-58 Dimensioning a tapered object

A cone requires only two dimensions: a height dimension and a base diameter dimension, Figure 9-56. Dimensioning a sphere is even simpler. A sphere requires only a diameter dimension, Figure 9-57.

Tapered objects may be cones or pyramids in their overall shape. Tapered objects are dimensioned according to the rules of their basic shapes and, then, a note specifying the degree of taper is added using a leader line, Figure 9-58.

Locational Dimensioning Systems

Individual and multiple features on manufactured parts must be located from some *datum* (reference point or plane) and, on occasion, with respect to one another. Holes are the most frequently dimensioned features located with respect to some datum. Their location with regard to a specified datum is critical in some cases. In other cases, hole locations with regard to other holes is critical. Which case applies depends on the function and nature of the part and its related features in the final assembly process.

Two basic dimensioning systems are used for locating features on manufactured parts: rectangular coordinate dimensioning and polar coordinate dimensioning. *Rectangular coordinate dimensioning* involves locating features using linear dimensions from specified X-Y or X-Y-Z axes. *Polar coordinate dimensioning* involves the use of both linear dimensions and angular dimensions for locating features.

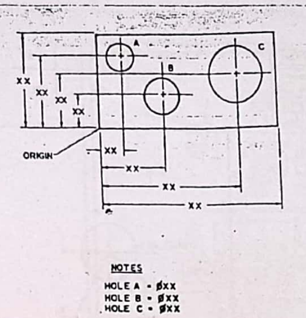


Figure 9-59 Rectangular coordinate dimensions

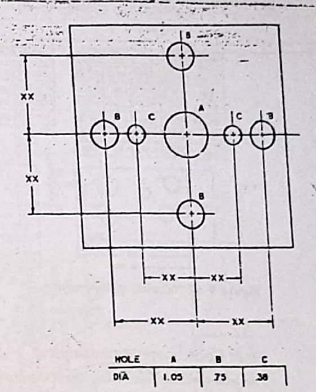


Figure 9-60 Rectangular coordinate dimensions

Rectangular Coordinate Dimensions

Rectangular coordinate dimensions can be applied to a part in several different ways: with linear dimensions, in table form, and in a modified dimensioning format in which dimension lines are left off.

The first method is illustrated in Figures 9-59 and 9-60. In Figure 9-59, the X-Y coordinate system of the rectangular part is used in locating the various holes from a hypothetical zero origin. Notice that the hole diameters are specified in a note rather than with leaders. A more complex part would require that the holes be shown in a table. This is done to avoid overcrowding the drawing, and is a method frequently used with rectangular coordinate dimensioning. Moreover, it lends itself to production by numerical control (NC), computer numerical control (CNC), or computer-aided manufacturing (CAM).

Figure 9-60 illustrates how rectangular coordinate dimensioning is applied to circular parts. The datum plane for referencing dimensions in this illustration is the center line of the part. The various other centers are located in relation to the center of the part. Notice that the hole diameters have been specified in tabular form. This is another method frequently used with rectangular coordinate dimensioning to avoid overly complicating the drawing.

Another method used in rectangular coordinate dimensioning involves giving dimensions from an X-Y or X-Y-Z origin, but leaving off the dimension lines. The dimensions are placed at the ends of the extension lines, Figure 9-61. The hole sizes are tabulated. Notice that each dimension refers to the distance from the origin to the hole center.

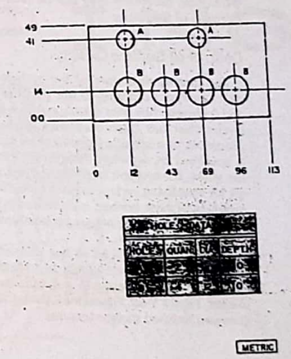


Figure 9-61 Rectangular coordinate dimensions

A final method used in rectangular coordinate dimensioning takes the method illustrated in Figure 9-61 one step farther. In this method, dimensions and hole sizes are tabulated, Figure 9-62. Dimensions are referenced to a three-dimensional X-Y-Z axis. The only dimensions placed on the part are overall length, width, and depth.

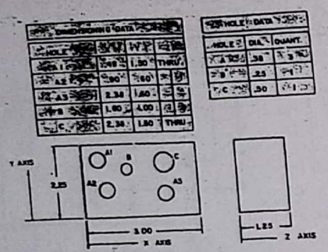


Figure 9-62 Tabulating dimensions

Polar Coordinate Dimensioning

In *polar coordinate dimensioning*, linear dimensions and angular dimensions are used to locate features from a fixed point. This concept is illustrated in Figure 9-63. Hole diameters may still be tabulated for the purpose of simplicity.

Control of Surface Quality

The quality or texture of the surface of a metal part can vary according to the purpose of the part and its interaction with mating parts. A *finished surface* is one that has been machined through various processes to a specified texture. The actual texture is specified on drawings using finish symbols. Over the years, the symbols used by drafters and designers for specifying surface texture have changed. The evolution of these symbols is illustrated in Figure 9-64. Figure 9-65 shows the proper proportions for the finish symbol used today.

Surface texture is defined as the distance between the lowest and highest points of irregularity. Such measurements are made in microinches or micrometres. Figure 9-66. Figure 9-67 contains a chart of common finished surface textures.

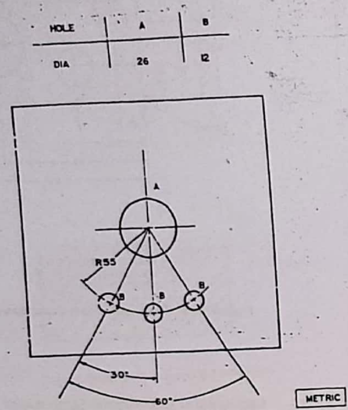


Figure 9-63 Polar coordinate dimensions

Notation

A good drawing may be defined as one that contains all of the information required by the various design and manufacturing people who will use it in producing the subject part. Most of this information can be conveyed graphically, using standard dimensioning practices. However, it is not uncommon to encounter a situation in which all of the needed information cannot be communicated graphically. In these cases, notes are used to communicate or clarify the designer's intent.

Notes are brief, carefully worded statements placed on drawings to convey information not covered or

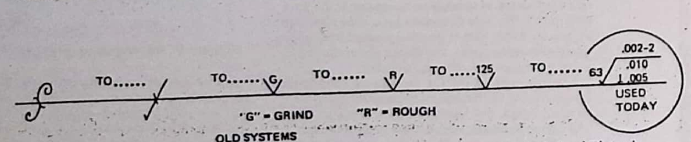


Figure 9-64 Evolution of the finish symbol (*From Drafting for Trades and Industry – Mechanical and Electronic*, John Nelson. Delmar Publishers Inc.)

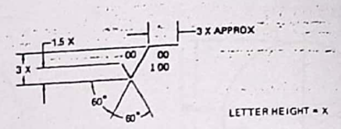


Figure 9-65 Proportions of the finish symbol (*From Drafting for Trades and Industry – Mechanical and Electronic*, John Nelson. Delmar Publishers Inc.)

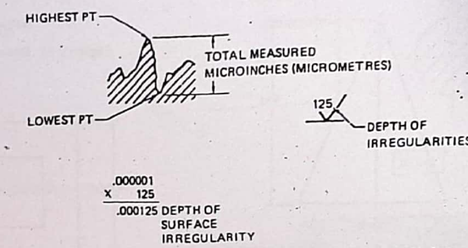


Figure 9-66 Measuring surface texture (*From Drafting for Trades and Industry – Mechanical and Electronic*, John Nelson. Delmar Publishers Inc.)

ROUGHNESS μm	ROUGHNESS μin.	KIND OF SURFACE	USAGE
12.5	500	Rough	Used where vibration or stress concentration are not critical and close tolersnces are not required.
6.3	250	Medium	For general use where stress requirements and appearance are of minimal importance.
3.2	125	Average smooth	For mating surfaces of parts held together by bolts and rivets with no motion between them.
1.6	63	Smoother than average finish	For close fits or stressed parts except rotating shafts, axles, and parts subject to vibrations.
0.8	32	Fine finish	Used for such applications as bearings.
0.4	16	Very fine finish	Used where smoothness is of primary importance such as high-speed shaft bearings.
0.2	8	Extremely fine finish	Use for such parts as surfaces of cylinders (engines).
0.1	4	Super fine finish	Used on areas where surfaces slide and lubrication is not dependable.

Figure 9-67 Surface texture chart (*From Drafting for Trades and Industry – Mechanical and Electronic*, John Nelson. Delmar Publishers Inc.)

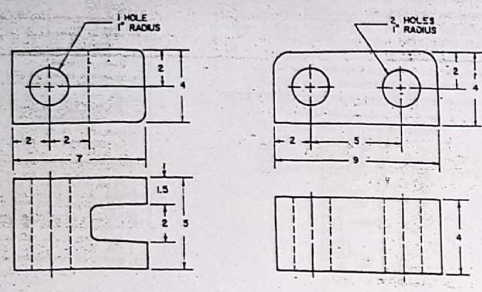


Figure 9-68 Notes on drawings improve communication

not adequately explained using graphics. Figure 9-68. Notes should be clearly worded so as to allow only one correct interpretation.

There are no ANSI standards specifically governing the use of notes on technical drawings. However, several rules of a general nature should be observed. These rules apply to both general notes and the more specific detail notes.

Rules for Applying Notes on Drawings

Notes may be lettered freehand, entered using a keyboard in a computer-aided drafting (CAD) system, or through any one of several mechanical lettering processes. Sample notes are included on the drawings in Figures 9-69 and 9-70. In any case, regardless of how they are put on the drawing, notes should be oriented horizontally on the drafting sheet. Figure 9-71. General notes should be located directly above the title block. Figure 9-72. When using manual processes to apply general notes such as those in Figure 9-72, the first note is placed directly above the title block, the second is placed on top of it and so on up the line. This allows notes to be added as needed without renumbering. However, when using a CAD system, this is not necessary since one of the advantages of CAD is that notes can be renumbered and rearranged automatically. Detail notes should

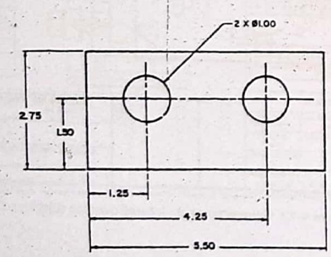


Figure 9-69 Sample note lettered mechanically

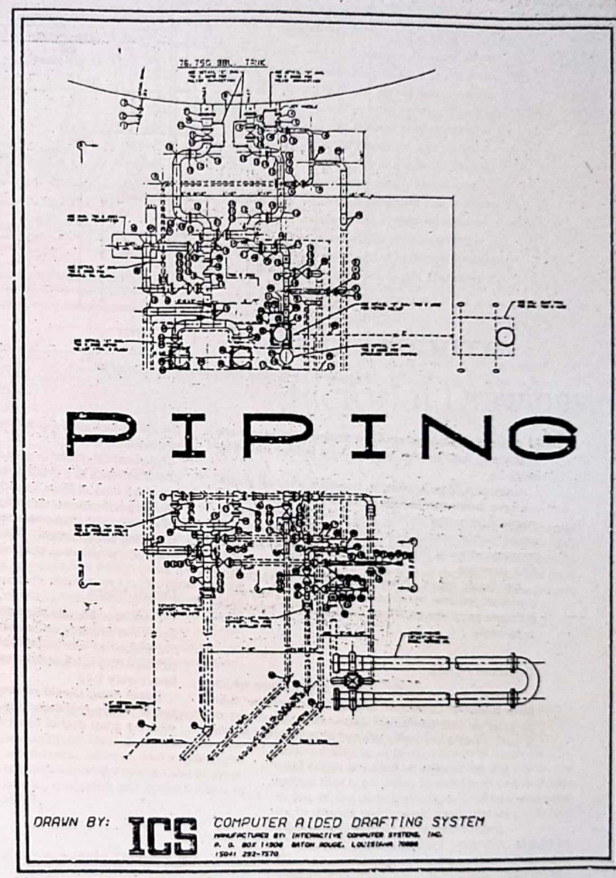


Figure 9-70 Notes lettered on a CAD system (*Courtesy Interactive Computer Systems, Inc.*)

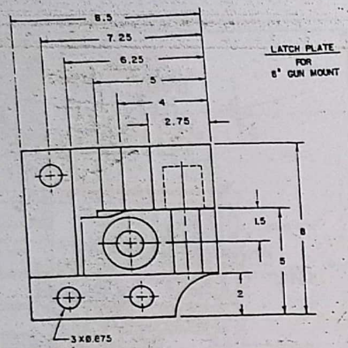


Figure 9-71 Notes are placed horizontally

be located as close as possible to the detail they are describing and connected to it by a leader line. Figure 9-73.

Notes should be applied to drawings after all graphics have been completed. This prevents notes and graphics from overlapping and minimizes other technique problems such as smudging the worksheet and frequent erasing of notes as changes are required on a drawing.

Two basic types of notes are used on technical drawings: general notes and detail notes. They serve different purposes and, therefore, must be examined separately.

General Notes

General notes are broad items of information which have a job- or project-wide application rather than relating to just one single element of a project or a part. They are usually placed immediately above the title block on the drawing sheet and numbered sequentially.

Information placed in general notes includes such characteristics of a product as finish specifications; standard sizes of fillets, rounds, and radii; heat treatment specifications; cleaning instructions; general tolerancing data; hardness testing instructions; and stamping specifications. Figures 9-74 and 9-75 are examples of drawings containing general notes.

Detail Notes

Detail notes are specific notes that pertain to one particular element or characteristic of a part. They are placed as near as possible to the characteristic to which they apply and are connected using a leader line, Figure 9-76.

Detail notes should not be placed on views. Figure 9-77. The only exception to this rule is in cases where a great deal of open space exists on a view.

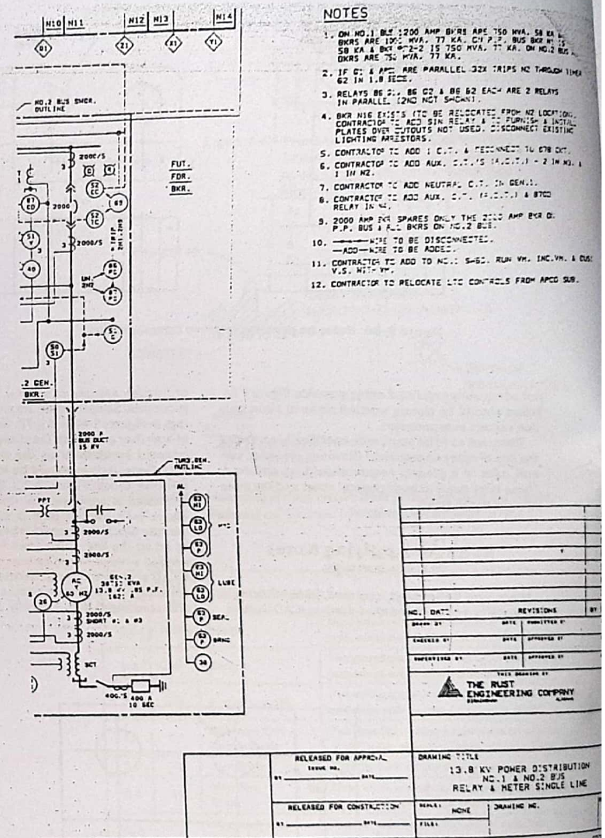
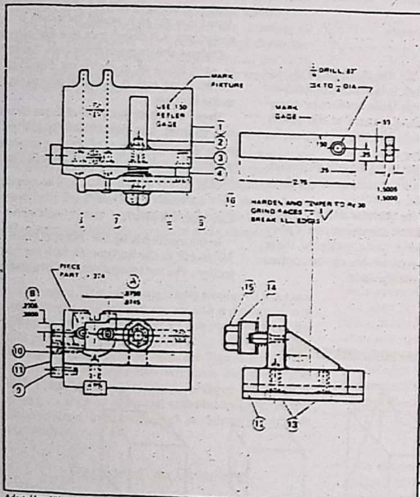


Figure 9-72 General notes are located over the titleblock (*Courtesy The Rust Engineering Co.*)

Chapter Seventeen Industry Print

1. How many parts make up the assembly?
2. How many screws are used in the assembly?
3. What are the part numbers of the screws used in the assembly?
4. Of what material is the base of the assembly made?
5. How many springs does the assembly contain?
6. How many revisions have been made to the assembly drawing?
7. When were the revisions made?
8. Who made the revisions?
9. What is the upper-limit thickness of the feeler gage?
10. Describe the dowel pins used in the assembly.



PARTS LIST				
DET #	PART IDENTITY	QTY	SIZES	MAT'L
1	BASE	1	3/8 × 3 × 4	AISI 1020
2	SUPPORT	1	3/8 × 2 × 1 1/4	AISI 1020
3	VERTICAL PLATE	1	3/8 × 1 1/2 × 4	AISI 1020
4	GUIDE PIN	1	3/8 DIA × 1	DRILL ROD
5	CLAMP PLATE	1	1/2 × 1 × 3 1/4	AISI 1020
6	SPRING	1	.025 DIA	SPG WIRE
7	CLAMP SCREW	1	1/4 DIA × 1 5/8 LG	AISI 1020
8	LOCATOR PINS	2	1/2 × 1	DRILL ROD
9	DOWEL PINS	2	3/32 DIA × 1/2 LG	STD
10	SCREW	1	5/16-18NC × 7/8 SOC HD CAP SCR	STD
11	SETUP PLATE	1	11/16 × 3/8 × 1 1/2	AISI 1090
12	TONGUE	1	5/8 × 3/8 × 4	AISI 1020
13	SCREWS	2	5/16-18NC × 7/8 SOC HD CAP SCR	STD
14	WASHERS	2	3/8 ID-1GD × 7/8 OD	AISI 1020
15	CLAMP NUT	1	3/8-16NC HEX FIN.	STD
16	FEELER GAGE	1	11/64 × 1/2 × 3 GROUND STOCK	01S

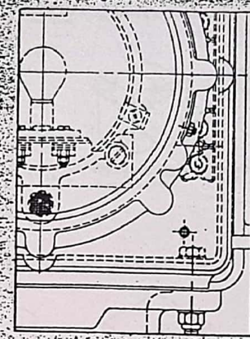
DET. #	CHANGE	DATE	APPVD.
B	WAS .1875/.1870	[illegible]	JMR
A	WAS .860/.861	[illegible]	JMR

CHANGE NOTES

FIXTURE ASSEMBLY

MACHINE TOOL IDENT.	MILLING MACHINE MM 22	DRAWN BY	CF
TOOLING IDENT.	FIXTURE X274	CHECKED BY	HJP
WORK STATION	3.4M	APPVD BY	FT
PART NAME SPACER PLATE	SHEET 1 OF 3	DATE	10-22-83

Adapted from "Blueprint Reading and Technical Sketching for Industry" and used by permission of Thomas P. Olivo and C. Thomas Olivo. Published by Delmar Publishers Inc.



Although pictorial drawings are not used extensively in drafting and designing, the drafter should have the ability to create a pictorial drawing if necessary. A pictorial drawing is often needed in industry to convey an idea, present a new product, or to aid in the assembly of a completed object. This chapter describes and illustrates how to develop the major kinds of pictorial drawings, and discusses the techniques used to draw such features as threads, chamfers, and knurls. How to add dimensions is fully illustrated.

CHAPTER EIGHTEEN
Pictorial Drawings

Pictorial drawings are, as their name implies, pictorial views of an object. They are used in industry for sales presentations, to aid workers on complicated assemblies, to record new design ideas, for owner's manuals and parts catalogs, and for technical printed articles. In industry, a technical illustrator usually does most of this type of drawing, but all drafters should have a basic working knowledge in this area of drawing. This chapter touches on the various kinds of illustrations used, and basically how they are developed.

Types of Pictorial Drawings

Three types of pictorial drawings are used in industry today: axonometric, oblique, and perspective. Each type is illustrated using a simple cube in order that they may be compared and studied. Each is explained in full.

Axonometric Drawings

In *axonometric drawing*, an object is represented by its perpendicular projection on a surface so that it appears as inclined and shows three faces. Axonometric projection includes isometric, dimetric and trimetric projections, Figure 18-1. It is customary to consider the three edges of the basic shape that meet at the corner *nearest* the viewer as the *axonometric axes*, Figure 18-2.

Isometric Projection

Isometric means "equal measure": all three principal edges or axes are projected with equal 120° angles, Figure 18-3. Any line on any surface that is either parallel to or perpendicular to one of the principal edges is called an *isometric line*. Any line on any surface that is *not* either parallel to or perpendicular to one of the principal edges is called a *nonisometric line*. In drawing an isometric projection, use the 30°-60° triangle to construct all isometric lines.

Technically, an isometric projection should be drawn approximately 80% of its true size, but, in actual practice, it is drawn full size. Isometric templates and grid paper are available to aid and speed up the drawing process.

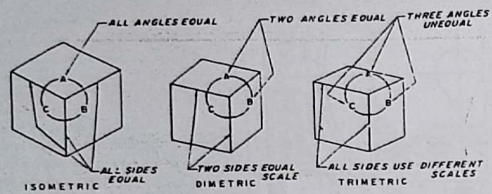


Figure 18-1 Axonometric projections

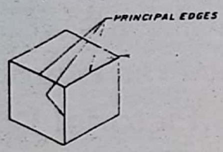


Figure 18-2 Axonometric axes

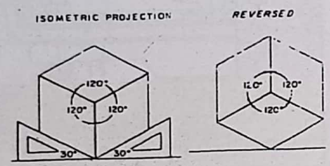


Figure 18-3 Isometric projection

Dimetric Projection

Dimetric projection differs from isometric projection in that only *two* angles are equal. Figure 18-4 illustrates some of the many combinations used to draw a dimetric projection.

In drawing a dimetric drawing, the object is turned so that two of the axes make the *same* angle with the plane of projection while the third is at a different angle. Edges that are parallel to the first two axes are drawn full size. The edge parallel to the third axis is drawn to a different scale. Because two different scales are used, less distortion is apparent and the object looks more natural.

A dimetric drawing is laid out in exactly the same way as an isometric drawing. All layout procedures to locate and draw nondimetric lines, circles, and arcs are exactly the same as those used in isometric projections.

Isometric and dimetric grid paper are available to aid and speed up the drawing process, Figure 18-5. Dimetric templates are also available.

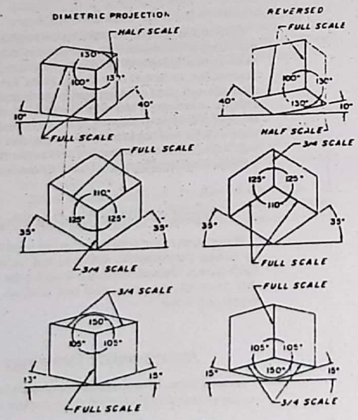


Figure 18-4 Dimetric projection

Trimetric Projection

In *trimetric projection* the axes are rotated so that each of the three axes are drawn at different angles to the plane of projection. Each axis uses a different scale

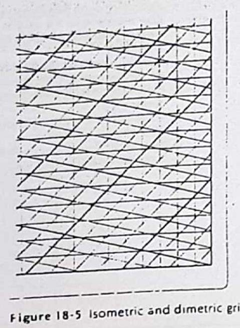


Figure 18-5 Isometric and dimetric grid

of reduction, Figure 18-6. Of the three kinds of axonometric projection, trimetric is the most complicated to draw, but it has by far the least amount of distortion, and truly appears as a picture of the object. Trimetric projections are rarely used in industry as they take too much drafting time.

All basic procedures used in laying out an isometric or dimetric projection are incorporated into drawing the trimetric projection.

As this text is primarily for drafters and not particularly for technical illustrators, concentration is given only to isometric projections. Once mastered, these same methods and basic procedures can be applied to dimetric and trimetric projections.

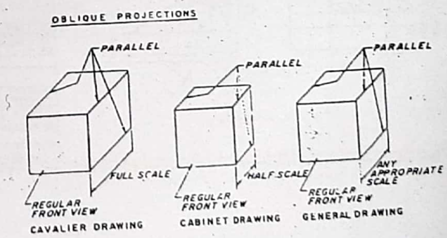


Figure 18-7 Oblique drawings

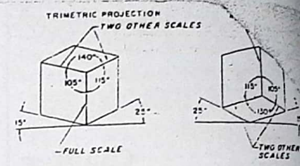


Figure 18-6 Trimetric projection

Oblique Drawings

The easiest type of pictorial drawing to develop the oblique projection. In *oblique drawing*, one surfa of the object, usually the most important view, drawn exactly as it would be drawn in a multivi projection. It is drawn true size and shape.

Oblique drawings use three axes. Two at right ang to each other, as in multiview drawings; the oth the receding axis, is drawn at any convenient an to the horizon.

There are three kinds of oblique drawings: ca lier, cabinet, and general oblique, Figure 18-7. each of the three kinds of oblique drawings, its m important surface is drawn parallel to the pl of projection.

Cavalier Drawing

In the *cavalier drawing*, the receding axis is drawn f 30° to 60° to the horizon. As with the isometric p jection, the receding distances are drawn full s

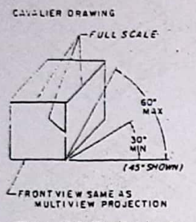


Figure 18-8 Cavalier drawing

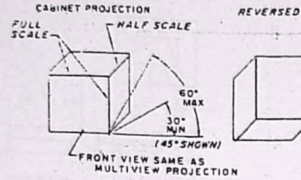


Figure 18-9 Cabinet drawing

Figure 18-8. Notice how this creates much distortion; therefore, this type of drawing is seldom used.

The term *cavalier* originated from the drawing of medieval fortifications. The center area of these fortifications was much higher than the rest of the fortification, and was referred to as the *cavalier* because of its command position.

Cabinet Drawing

In the *cabinet drawing*, the receding axis is drawn from 30° to 60° to the horizon. The receding distances are drawn half size, Figure 18-9. This helps somewhat to eliminate the distortion associated with the oblique projection system. In past years, cabinet drawings were used to illustrate furniture and cabinets.

General Oblique

The *general oblique* drawing is very similar to the cabinet drawing, except that the receding distances are drawn to *any* scale that seems the most natural for that particular object. This could be from one-third full size to three-quarters full size, Figure 18-10.

The receding angle can vary from 30° to 60°, as with all oblique projections. In oblique drawings, it is best to choose the most complete shape as the front surface, and project all receding lines from that surface.

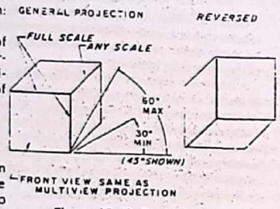


Figure 18-10 General oblique

Perspective Drawing

Perspective drawings illustrate the object better than any other method. In a *perspective drawing*, there is little or no distortion, and it approximates the object as it would be seen by the human eye or as projected upon the film inside a camera, Figure 18-11.

A perspective drawing is used by architects, designers, and technical illustrators in order to convey their ideas. Architects often use perspectives to illustrate how a proposed building will look when completed. As a general rule, however, perspective drawings are *not* used in the mechanical drafting field. Although they illustrate the object exactly as it will appear, they are too time-consuming and costly for drafters to construct. Therefore, drafters need only a working knowledge of perspective layout procedure.

Perspective drawings are discussed more fully later in this chapter.

Isometric Principles

An isometric drawing is drawn around three equally spaced principal edges or axes, Figure 18-12. The top illustration is the most commonly used. The object should be placed either in the position it is usually seen or in the position that best illustrates all the most important features.

How To Draw an Isometric Drawing

Given: A multiview drawing of an object, Figure 18-13A.

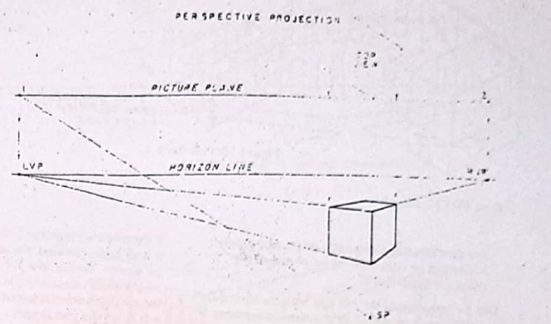


Figure 18-11 Perspective drawing

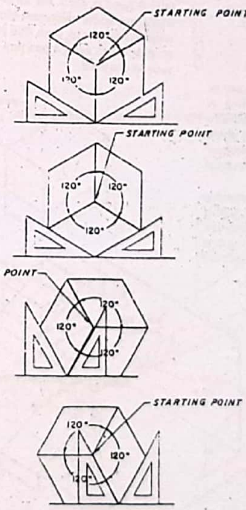


Figure 18-12 Isometric principles

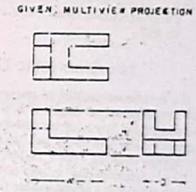


Figure 18-13A How to draw an isometric drawing

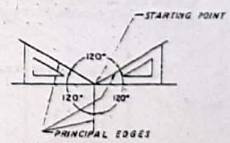


Figure 18-13B Step 1

Step 1. Locate the starting point and lightly draw the three principal edges 120°, as illustrated in Figure 18-13B. Use the 30°-60° triangle.

Step 2. Transfer the depth, height, and width directly from the multiview drawing, Figure 18-13A, to the three principal edges. Measure

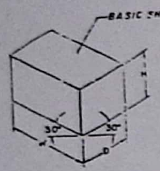


Figure 18-13C Step 2

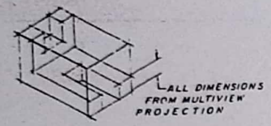


Figure 18-13D Step 3

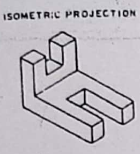


Figure 18-13E Completed isometric view

full size directly along each edge, and lightly construct an isometric, basic shape of the object. Figure 18-13C.

Step 3. Transferring the full size lengths from the multiview drawing, fill in the various features of the object. Again, all full size measurements must be constructed along or parallel with one of the principal edges. Figure 18-13D.

Step 4. Check all work and, if correct, darken in the object using correct line thickness. Figure 18-13E.

Nonisometric Lines

If a line is *not* parallel or perpendicular to any of the three principal edges, it is a *nonisometric* line. A nonisometric line must be reduced to two points: a point at each end of the line, as shown in the given multiview drawing, Figure 18-14A. Line a-b is *not* parallel or perpendicular to any of the three principal edges, thus it is a nonisometric line.

Referring to Figure 18-14B, the isometric drawing is developed exactly as described, except that points a and b must be located before the nonisometric line a-b can be drawn. Point a is located along one axis distance X from the back end; point b is located Y distance up from the bottom surface. When points a and b are located, the nonisometric line a-b can be drawn. Notice, the 30° angular dimension given on the multiview drawing in Figure 18-14B has *no* bearing on the isometric layout and is *not* used. Also, line a-b is *not* the true length.

Hidden Lines

Hidden lines in pictorial drawings, regardless of which kind is used, are *not* drawn, unless needed to illustrate some important hidden feature that otherwise would not be seen. The object should be rotated or placed in such a position that no important feature is omitted.

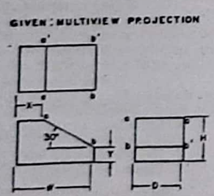


Figure 18-14A Nonisometric lines

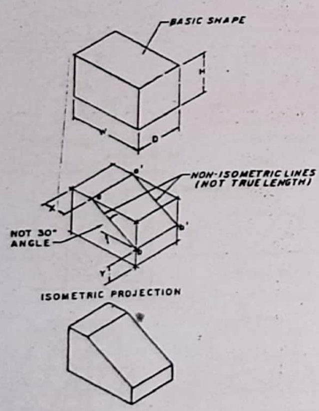


Figure 18-14B Locating points

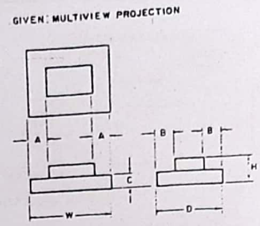


Figure 18-15A Multiview projection

Offset Measurements

Offset measurements are used to locate one feature in relationship to another. All offset measurements must be made either parallel to or perpendicular to any of the three principal surfaces.

A multiview drawing is given in Figure 18-15A. The isometric drawing is developed as outlined before, except that the offset measurements A, B, and C are measured parallel to and perpendicular to the three principal edges. Figure 18-15B. If a line or surface is *parallel* to another line or surface in the multiview drawing, the line or surface must be parallel, respectively, in the isometric drawing also.

Center Lines

Center lines are used to indicate symmetry and to aid in dimensioning. Center lines in an isometric drawing are drawn following the same drafting standards as in a multiview drawing. All holes must include the coordinates to indicate the exact center point. Figure 18-16. Center lines must extend outside the circle.

Box Construction

Some objects do not conform to any of the three principal edges. If an object does not conform, a *box* or rectangle must be constructed around the object parallel to and perpendicular to the principal edges. This then becomes the basic shape of the object. Refer to the multiview in Figure 18-17A. A basic shape is constructed around the object so various points of the object touch. Figure 18-17B.

An isometric basic shape of the object is drawn as shown in Figure 18-17C, and the various points, A, B, C and 0, are located on or within the basic shape. Figure 18-17D. Points A, B, and C are located on the base of the basic shape, and point 0 is located, by offset measurements, on the top surface.

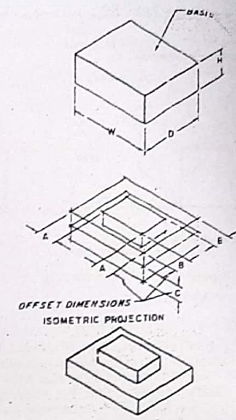


Figure 18-15B Offset measurements

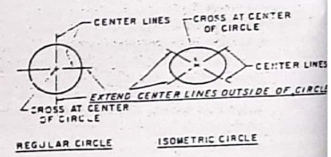


Figure 18-16 Center lines

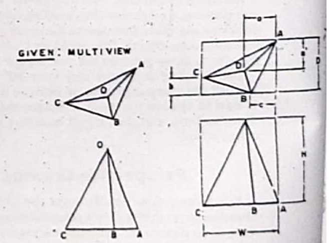


Figure 18-17A Box construction

Figure 18-17B Basic shape

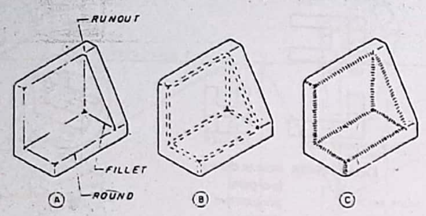


Figure 18-41 Isometric rounds and fillets

Extension lines are projected from the various surface features and at the same angle as the feature. All dimension lines are drawn parallel to the angle of the corresponding surface. Figure 18-42.

Isometric Templates

Various isometric templates are available to the drafter to speed up the drawing process. A unique template to help simplify isometric drawing is the Iso-Drafter. Figure 18-43. This template combines optical reference lines, 16 different isometric ellipses, and two scales. It also offers a right angle (90°) reference line, and isometric reference lines offset 30° on either side of it. These isometric reference lines are at precisely 120° angles to the main straight edges. Complete color instructions that clearly explain its many functions, operation, and uses are included with the template.

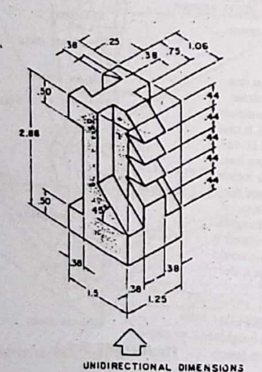


Figure 18-42 Isometric dimensioning

Perspective Drawing Procedures

A *perspective drawing* is a three-dimensional drawing of an object that shows it exactly as the eye views it from one particular viewing location. The perspective drawing is actually like a photograph of an object, see Figure 18-44. At the top of the figure is an outside view of a building; below it is an inside view of a room. Notice how all lines project to two points in space.

Perspective Terms

A full understanding of all terminology used in perspective drawing is very important in learning the layout procedures that follow. Refer to Figure 18-45.

Station point (SP) is the exact location from which the observer views the object.

Object to be viewed, as implied, is simply the object that is to be drawn.

Ground line (GL) is the edge view of the ground, or base upon which the object to be viewed rests.

Horizon (H) is a line at the level of the viewer; in this example, approximately 5'-0'' above the ground

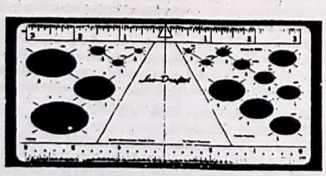


Figure 18-43 Isometric template (*Courtesy International Design Corporation*)

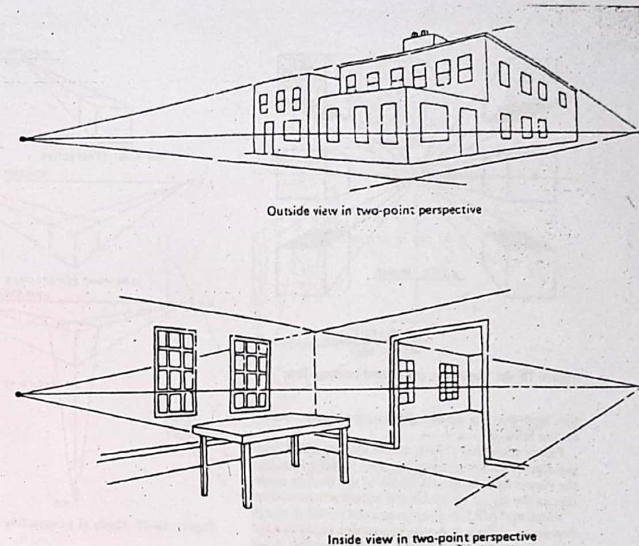


Figure 18-44 Outside and inside perspective view

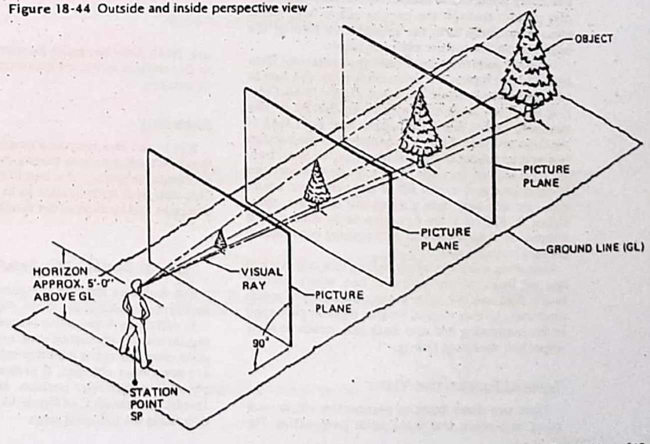


Figure 18-45 Perspective terms

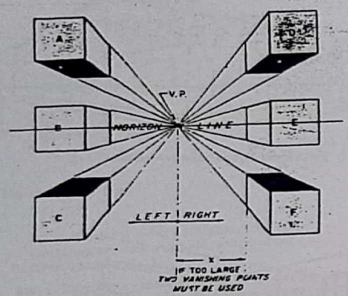


Figure 18-46 Vanishing point and horizon line

line. Note that the vanishing points are always located on the horizon line.

Picture plane line (PP) is an imaginary plane perpendicular to the ground line and located between the viewer and the object. Think of the picture plane line as the paper on which the object will be drawn.

Visual rays (VR) are lines projected from the eye of the viewer while standing at the station point to each and every point of the object. Notice how the visual rays project through the picture plane line. These rays, collectively, form the perspective view of the object upon the picture plane or paper.

Vanishing point (VP) the vanishing point(s) (not illustrated in the figure) is a point on the horizon line to which all other lines are projected. Figure 18-46. Cube A is *above* the horizon line and to the *left* of the vanishing point, thus, the bottom and right side of the cube are seen. Cube B is centered *on* the horizon line and to the *left* of the vanishing point; thus, only the right side of the cube is seen. Cube C is *below* the horizon line and to the *left* of the vanishing point; thus, the top and right side of the cube are seen. Cubes D, E, and F are opposite to A, B, and C. If dimension X is too great, a two-point perspective drawing must be used.

Measuring line (M) the measuring line is a vertical line 90° from the picture plane line, where all true length distances or heights are projected to and measured from. All true vertical heights must be projected to the measuring line and back into space to their respective vanishing points.

Types of Perspective Views

There are three types of perspective views: one-point, two-point, and three-point perspective. Figure 18-47. Only two-point perspective is discussed in this chapter, as it is the type most commonly used in industry.

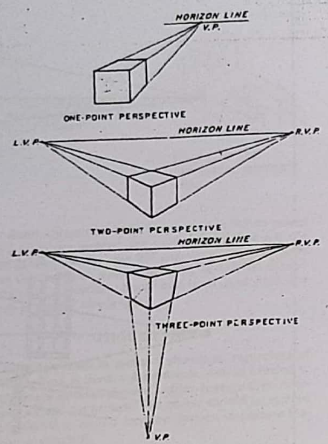


Figure 18-47 Kinds of perspective drawings

Sketching

It is a good idea to make a simple, quick sketch of the object before actually starting the drawing in order to choose the position that best illustrates the object. This also gives an indication as to the approximate direction and location of the vanishing points.

How To Sketch a Two-Point Perspective

The multiview drawing in Figure 18-48A is given, and various sketches are made, Figure 18-48B.

In setting up a two-point perspective, two of the regular multiviews must be used; usually, the top view (plan view) and either a front or side view. The views are sometimes changed, if necessary, to draw the object in a particular position. Multiview drawing 18-48A, and sketch C of Figure 18-48B are used for describing the following steps:

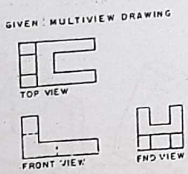


Figure 18-48A How to draw a two-point perspective drawing

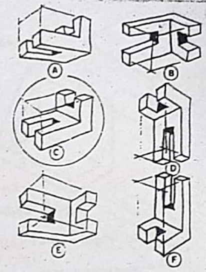


Figure 18-48B Sketch of object in various positions

Step 1. Draw the top view at the top of a sheet of paper at any angle; in this example, 30° in order to come close to the sketch. Draw the picture plane line tangent to the front edge of the object. Figure 18-48C.

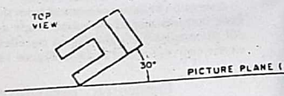


Figure 18-48C Step 1

Step 2. From the front edge of the object, where it is tangent to the picture plane line, project the measuring line 90° to the picture plane line. Figure 18-48D. Locate the station point anywhere on the measuring line so that the maximum inclusive angle is 30° or less.

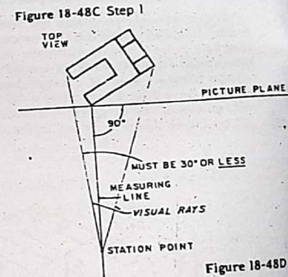


Figure 18-48D St

Step 3. From the station point, construct lines parallel to the two edges of the top view above. Figure 18-48E. Think of these three steps as 1) an overall top view of the object, 2) a picture plane line on edge, and 3) a station point. In a regular two-point perspective there are actually two views superimposed over each other. This is the first of the two views.

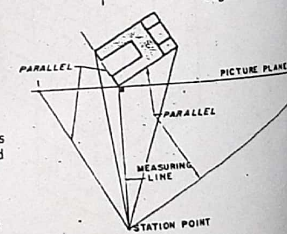


Figure 18-48E Step 3

Step 4. Draw a line to represent the horizon line at any convenient location. It is best to draw this horizon line away from the other construction work, if possible. If space is limited, it can be drawn over the original work. Figure 18-48F. From points 1 and 2 on the picture plane line, project downward to the horizon line to locate the left and right vanishing points. Locate the ground line and draw the side or front view of the object on the ground line. In this example, the object is viewed from above. If the object is to be viewed from below, the ground line would have been located *above* the horizon line (refer back to Figure 18-46).

Step 5. From the right-side view, project the true height to the measuring line. From the height on the measuring line, project back into space

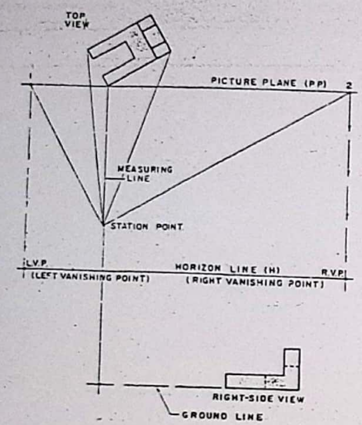


Figure 18-48F Step 4

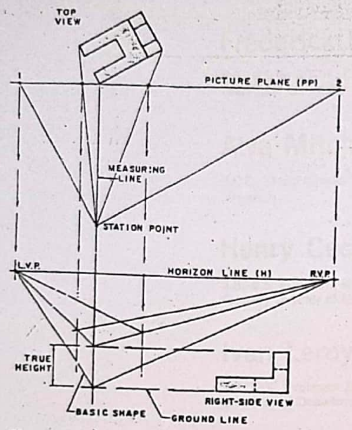


Figure 18-48G Step 5

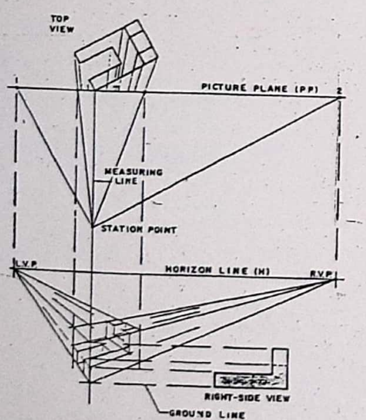


Figure 18-48H Step 6

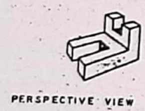


Figure 18-48I
Completed two-point perspective drawing

to the left and right vanishing points. Figure 18-48G. Construct the perspective basic shape of the object. The basic shape projects back into space until it intersects a line projected downward from the picture plane line.

Step 6. Project the true heights of each feature from the right-side view to the measuring line and back toward the appropriate vanishing point to a point where the same feature intersects the picture plane line. Figure 18-48H. Lightly develop the various features of the object as would be done in an isometric view.

Step 7. Check all work and, if correct, darken in the object using correct line thickness. Figure 18-48I. As a general rule, hidden lines are *not* usually drawn except to illustrate an important feature that would otherwise not be seen.

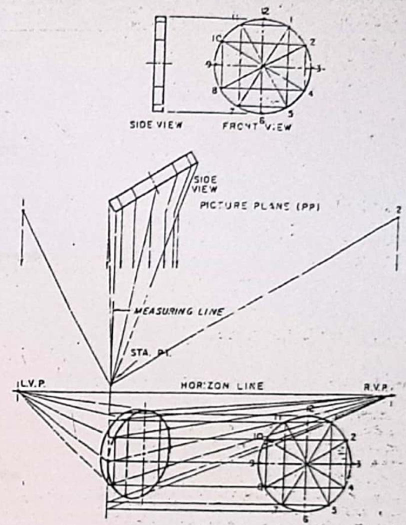


Figure 18-49 Perspective circles or arcs

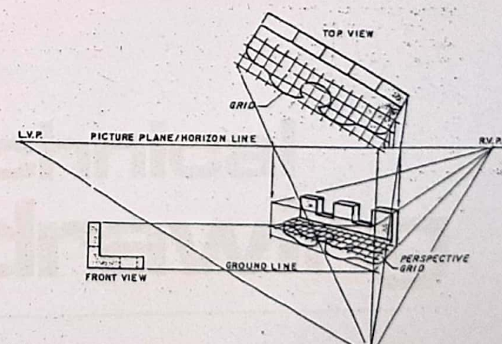


Figure 18-50 Perspective irregular curves

1.9 Definitions. After surveying briefly the historical development of the graphic language and before starting a serious study of theory and applications, the definitions of a few terms should be considered.

Descriptive Geometry is the grammar of the graphic language; it is the three-dimensional geometry forming the background for the practical applications of the language and through which many of its problems may be solved graphically.

Instrumental or *Mechanical Drawing* should be applied only to a drawing made with drawing instruments. Mechanical Drawing has been used to denote all industrial drawings, which is unfortunate not only because such drawings are not always mechanically drawn, but also because it tends to belittle the broad scope of the graphic language by naming it superficially for its principal mode of execution.

Engineering Drawing and *Engineering Drafting* are broad terms widely used to denote the graphic language. However, since the language is not used by engineers only, but also by a much larger group of people in diverse fields who are concerned with technical work or with industrial production, the term is still not broad enough.

Technical Drawing is a broad term that adequately suggests the scope of the graphic language. It is rightly applied to any drawing used to express technical ideas. This term has been used by various writers since Monge's time at least and is still widely used, mostly in Europe.

Engineering Graphics or *Engineering Design Graphics* is generally applied to drawings for technical use and has come to mean that part of technical drawing which is concerned with the graphical representation of designs and specifications for physical objects and data relationships as used in engineering and science.

Technical sketching is the freehand expression of the graphic language, while *mechanical drawing* is the instrumental expression of it. Technical sketching is a most valuable tool for the engineer and others engaged in technical work, because through it most technical ideas can be expressed quickly and effectively without the use of special equipment.

Blueprint reading is the term applied to the "reading" of the language from drawings made by others. Actually, the blueprint process is only one of many forms by which drawings are reproduced today (see Chapter 15), but the term "blueprint reading" has been accepted through usage to mean the interpretation of all ideas expressed on technical drawings, whether the drawings are blueprints or not.

Computer Graphics is the application of conventional computer techniques with the aid of one of many graphic data processing systems available to the analysis, modification, and the finalizing of a graphical solution.

1.10 What Engineering and Science Students Should Know. The development of technical knowledge from the dawn of history has been accompanied, and to a large extent made possible, by a corresponding graphic language. Today the intimate connection between engineering and science and the universal graphic language is more vital than ever before, and the engineer or scientist who is ignorant of or deficient in the principal mode of expression in his technical field is *professionally illiterate.* That this is true is shown by the fact that training in the application of technical drawing is required in virtually every engineering school in the world.

The old days of fine-line drawings and of shading and "washes" are gone forever; no artistic talent is necessary for the modern technical student to learn the fundamentals of the graphic language. For its mastery he needs precisely the aptitudes and abilities he will need to learn the science and engineering courses that he studies concurrently and later. The student who does poorly in the graphic language courses is like to do poorly in his other technical courses.

The well-trained engineer, scientist, or technician must be able to make correct graphical representations of engineering structures, designs, and data relationships.

This means that he must understand the fundamental principles, or the *grammar* of the language, and must be able to execute the work with reasonable skill, which is *penmanship.*

Graphics students often try to excuse themselves for inferior results (usually caused by lack of application) by arguing that after graduation they do not expect to do any drafting at all; they expect to have others make any needed drawings under their direction. Such a student presumptuously pictures himself, immediately after graduation, as the accomplished engineer concerned with bigger things and forgets that in his first assignment he may well be working with drawings and possibly may be called upon to make or revise drawings either on the board or with computerized aids under the direction of a really experienced engineer. Entering the engineering profession via graphics provides an excellent opportunity to learn about the product, the company operations, and the supervision of others.

Even if the young engineer has not been too successful in developing a skillful penmanship in the graphic language, he still will have great use for its grammar, since the ability to *read* a drawing is of utmost importance, and he will need this ability throughout his professional life. See §14.1.

Furthermore, the engineering student is apt to overlook the fact that, in practically all the subsequent courses taken in college, technical drawings will be encountered in most textbooks. The student is often called upon by instructors to supplement calculations with mechanical drawings or sketches. Thus, a mastery of a course in technical drawing will aid materially not only in professional practice after graduation but more immediately in other technical courses, and it will have a definite bearing on scholastic progress.

Besides the direct values to be obtained from a serious study of the graphic language, there are a number of very important training values which, though they may be considered by-products, are fully as essential as the language itself. Many a student learns for the first time in a drawing course the meaning of *neatness, speed,* and *accuracy*—basic habits that every successful engineer and scientist must have or acquire.

All authorities agree that the ability to *think in three dimensions* is one of the most important requisites of the successful scientist and engineer. This training to visualize objects in space, to use the constructive imagination, is one of the principal values to be obtained from a study of the graphic language. The ability to *visualize* is possessed in an outstanding degree by persons of extraordinary creative ability. It is difficult to think of Edison, De Forest, or Einstein as being deficient in constructive imagination.

With the increase in technological development and the consequent crowding of drawing courses by the other engineering and science courses in our colleges, it is doubly necessary for the engineering or science student to make the most of the limited time devoted to the language of the profession, to the end that he will not be professionally illiterate, but will possess an ability to express ideas quickly and accurately through the correct use of the graphic language.

1.11 Projections. Behind every drawing of an object is a space relationship involving four imaginary things: the *observer's eye* or *station point,* the *object,* the *plane* or *planes of projection,* and the *projectors.** For example, in Fig. 1.10 (a) the drawing EFGH is the projection on the plane of projection A of the square ABCD as viewed by an observer whose eye is at the point O. The projection or drawing upon the plane is produced by the piercing points of the projectors in the plane of projection. In this case, where the observer is relatively close to the object and the projectors form a "cone" of projectors, the resulting projection is known as a *perspective.*

If the observer's eye is imagined as infinitely distant from the object and the plane of projection, the projectors will be parallel, as shown in Fig. 1.10 (b); hence, this type of

*Also called *visual rays* and *lines of sight.*

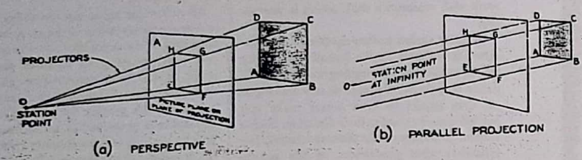
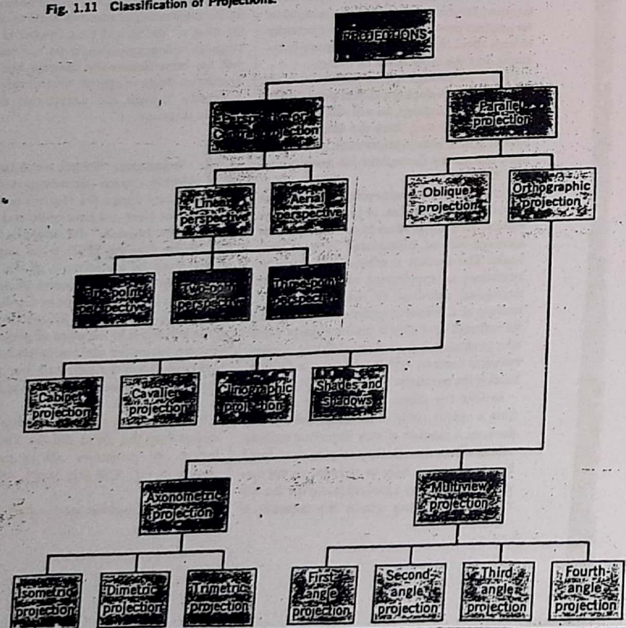


Fig. 1.10 Projections.

Fig. 1.11 Classification of Projections.



Classes of Projection	Distance from Observer to Plane of Projection	Direction of Projectors
Perspective	Finite	Radiating from station point
Parallel	Infinite	Parallel to each other
Oblique	Infinite	Parallel to each other and oblique to plane of projection
Orthographic	Infinite	Perpendicular to plane of projection
Axonometric	Infinite	Perpendicular to plane of projection
Multiview	Infinite	Perpendicular to planes of projection

Fig. 1.12 Classification by Projectors.

projection is known as a *parallel projection.* If the projectors, in addition to being parallel to each other, are perpendicular (normal) to the plane of projection, the result is an *orthographic* projection.* If they are parallel to each other but oblique to the plane of projection, the result is an *oblique projection.*

**Orthographic* means written or drawn at right angles.

These two main types of projection—perspective or central and parallel projection—are further broken down into many subtypes, as shown in Fig. 1.11, and will be treated at length in the various chapters that follow.

A classification of the main types of projection according to their projectors is shown in Fig. 1.12.

2 instrumental drawing

Details are trifles, but trifles make perfection, and perfection is no trifle.

BEN FRANKLIN

2.1 Typical Equipment. The essential items of equipment needed by students in technical schools and by draftsmen and designers in professional practice are shown in Fig. 2.1. To secure the most satisfactory results, the drawing equipment should be of high grade. When drawing instruments (item 3) are to be purchased, the advice of an experienced draftsman or designer, or of a reliable dealer,* should be sought because it is difficult for beginners to distinguish high-grade instruments from those that are inferior.

*Keuffel & Esser Co., New York; Eugene Dietzgen Co., New York; Charles Bruning Co., Mt. Prospect, Ill.; Frederick Post Co., Chicago; V & E Manufacturing Co., Pasadena, Calif.; and the Gramercy Guild Group, Inc., Denver, are some of the larger distributors of this equipment; their products are available through local dealers.

A complete list of equipment, which should provide a satisfactory selection for students of technical drawing, follows. The numbers refer to Fig. 2.1:

1. Drawing board (approx. 20" × 24"), drafting table, or desk.
2. T-square (24", transparent edge), drafting machine, or parallel ruling edge, §§2.5, 2.61, and 2.62.
3. Set of instruments, §§2.34 and 2.35
4. 45° triangle (8" sides).
5. 30° × 60° triangle (10" long side).
6. Ames Lettering Guide or lettering triangle.
7. Triangular architects scale (or flat mechanical engineers scale), see also Fig. 2.35.
8. Triangular scales (two) for engineering,

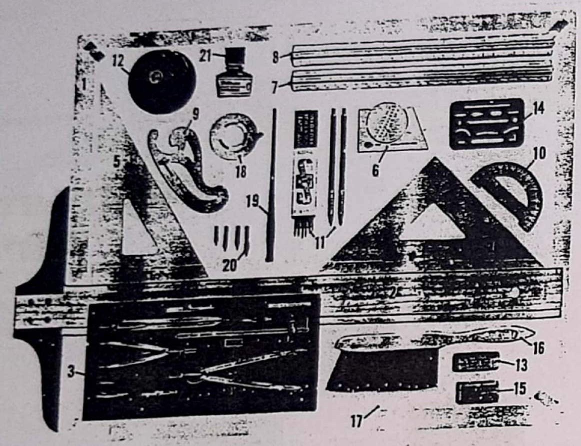


Fig. 2.1 Principal items of Equipment.

decimal and metric (or flat metric scale), see also Fig. 2.35.

9. Irregular curve.
10. Protractor.
11. Mechanical pencils and HB, F, 2H, and 4H to 6H leads or drawing pencils, see also Fig. 2.9.
12. Tru-Point pencil pointer, sandpaper pad, or file.
13. Pencil eraser.
14. Erasing shield.
15. Plastic drafting eraser or Artgum cleaning eraser.
16. Dusting brush.
17. Drawing paper, tracing paper, tracing cloth, or films as required. Backing sheet (drawing paper—preferably white—to be used under drawings and tracings).
18. Drafting tape.

Optional equipment.

19. Pen staff.
20. Pen points (Gillott's 303, 404; Hunt's 512; Leonardt's ball-pointed 516F).
21. Drawing ink (black waterproof) and pen wiper.

The following items (not shown in Fig 2.1) may also be included if necessary:

Technical fountain pens, drop pen, detail pen, proportional dividers, beam compass, and contour pen.
Circle and ellipse templates.
Calculator or slide rule.
Cleansing tissue or dust cloth.

2.2 Objectives in Drafting.

On the following pages the correct methods to be used in instrumental drawing are explained. The student should learn and practice correct manipulation of the drawing instruments so that correct habits may be formed and maintained. Eventually he should draw correctly by habit so that his full attention may be given to the problems at hand. The instructor will insist upon absolutely correct form at all times, making exceptions only in cases of physical disability.

The following are the important objectives the student should strive to attain:

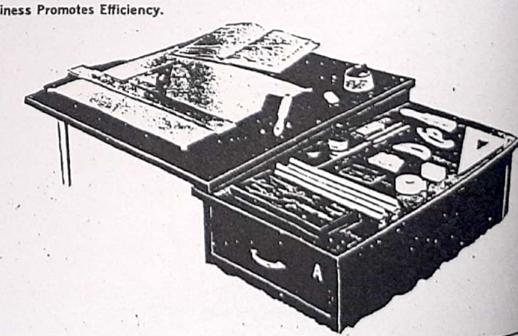
1. Accuracy. No drawing is of maximum usefulness if it is not accurate. The student must learn from the beginning that success in a college career or later in professional employment cannot be had if the habit of accuracy is not acquired.

2. Speed. "Time is money" in industry, and there is no demand for the slow draftsman or engineer. However, speed is not attained by hurrying; it is an unsought by-product of *intelligent and continuous work.* It comes with study and practice, and the fast worker is usually more mentally alert.

3. Legibility. The draftsman or engineer should remember that the drawing is a means of communication to others, and that it must be clear and legible in order to serve its purpose well. Care should be given to details, especially to lettering, Chapter 3.

4. Neatness. If a drawing is to be accurate and legible, it must also be clean; therefore, the student should constantly strive to acquire the habit of neatness. Untidy drawings are the result of sloppy and careless methods, §2.13, and will not be accepted by the instructor.

Fig. 2.2 Orderliness Promotes Efficiency.



2.3 Drafting at Home or School.

In the school drafting room, as in the industrial drafting room, the student is expected to give thoughtful and continuous attention to the problems at hand. If this is done, time will not be available to annoy others. Work must be done in quiet surroundings without distractions. Technical drawing requires headwork. The efficient drafting student sees to it that the correct equipment is available and refrains from borrowing—a nuisance to eveyone. While the student is drawing, the textbook—the chief source of information—should be available and in a convenient position, Fig. 2.2.

When questions arise, first use the index of the text and endeavor to find the answer for yourself. Try to develop self-reliance and initiative. On the other hand, if you really need help, ask your instructor. The student who goes about his work intelligently, with a minimum waste of time, *first* studies the assignment carefully to be sure that he understands the principles involved; *second,* makes sure that the correct equipment is in proper condition (such as sharp pencils); and *third,* makes an effort to dig out answers for himself (the only true education).

One of the principal means of promoting efficiency in drafting is *orderliness.* All needed equipment and materials should be placed in an orderly manner so that everything is in a convenient place and can readily be found when needed, Fig. 2.2. The drawing area should be kept clear of equipment not in direct use. Form the habit of placing each item in a regular place outside the drawing area when it is not being used.

When drawing at home, it is best, if possible, to work in a room by yourself. A book can be placed under the upper portion of the drawing board to give the board a convenient inclination, or the study-table drawer may be pulled out and used to support the drawing board at a slant.

It is best to work in natural north light coming from the left and slightly from the front. Never work on a drawing in direct sunlight or in dim light, as either may be injurious to the eyes. If artificial light is needed, the light source should be such that shadows are not cast where lines are being drawn, and such that there will be as little reflected glare from the paper as possible. Special draftsman's fluorescent lamps are available with adjustable arms so that the light source may be moved to any desired position.* Drafting will not hurt eyes that are in normal condition, but the exacting work will often disclose deficiencies not previously suspected.

LEFT-HANDERS. Place the head of the T-square on the right, and arrange the light source from the right and slightly from the front.

2.4 Drawing Boards.

If the left edge of the drafting table top has a true straight edge and if the surface is hard and smooth (such as masonite), a drawing board is unnecessary, provided drafting tape is used to fasten the drawings. It is recommended that a *backing sheet* of heavy drawing paper be placed between the drawing and the table top.

However, in most cases a drawing board will be needed. These vary from 9" × 12" (for sketching and field work) up to 48" × 72" or larger. The recommended size for students is

*Dazor Mfg. Corp., St. Louis, Mo. 63110; Luxo Lamp Corp., Port Chester, N.Y. 10573, and Sausalito, Cal. 94965.

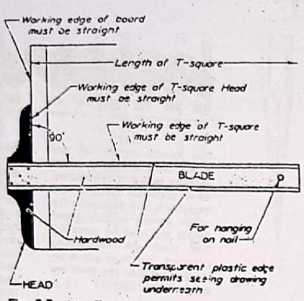


Fig. 2.3 The T-square.

20" × 24", Fig. 2.1, which will accommodate the largest sheet likely to be used.

Drawing boards traditionally have been made of soft woods, such as white pine, so that thumbtacks can be easily pushed down. However, after considerable use the board is likely to be full of objectionable thumbtack holes. Many draftsmen now prefer to use drafting tape, which in turn permits surfaces such as hardwood, masonite, linoleum, or other materials to be used for drawing boards.

The left-hand edge of the board is called the *working edge*, because the T-square head slides against it, Fig. 2.3. This edge must be straight, and you should test the edge with a framing square or with a T-square blade that has been tested and found straight, Fig. 2.4. If the edge of the board is not true, it should be run through a jointer or planed with a jack plane.

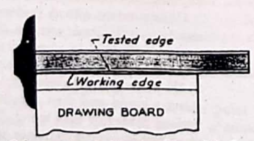


Fig. 2.4 Testing the Working Edge of the Drawing Board.

2.5 T-square.

The T-square, Fig. 2.3, is composed of a long strip, called the *blade*, fastened rigidly at right angles to a shorter piece called the *head*. The upper edge of the blade and the inner edge of the head are *working edges* and must be straight. The working edge of the head must not be convex or the T-square will rock when the head is placed against the board. The blade should have transparent plastic edges and should be free of nicks along the working edge. Transparent edges are recommended, since they permit the draftsman to see the drawing in the vicinity of the lines being drawn.

Do not use the T-square for any rough purpose. Never cut paper along its working edge, as the plastic is easily cut and even a slight nick will ruin the T-square.

2.6 Testing and Correcting the T-square.

To test the working edge of the head, see if the T-square rocks when the head is placed against a straight edge, such as a drawing board working edge that has already been tested and found true. If the working edge of the head is convex, remove the head and plane it by hand with a block plane until it tests straight. In replacing the blade on the head, use furniture glue in addition to the screws.

To test the working edge of the blade, Fig. 2.5, draw a sharp line very carefully with a hard pencil along the entire length of the working edge; then turn the T-square over and draw the line again along the same edge. If the edge is straight, the two lines will coincide; otherwise the space between the lines will be twice the error of the blade.

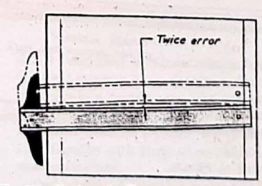


Fig. 2.5 Testing the T-square.

It is difficult to correct a crooked T-square blade, and if the error is considerable, it may be necessary to discard the T-square and obtain another. However, if care is taken, the blade may be made true by scraping the edge with a scraper or a sharp knife, as in truing a triangle, Fig. 2.25.

2.7 Fastening Paper to the Board.

The drawing paper should be placed close enough to the working edge of the board to reduce to a minimum any error resulting from a slight "give," or bending of the blade of the T-square, and close enough to the upper edge of the board to permit space at the bottom of the sheet for using the T-square and supporting the arm while drawing, Fig. 2.6.

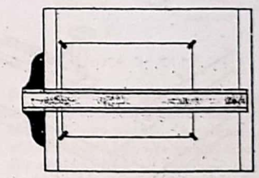


Fig. 2.6 Placing Paper on Drawing Board.

To fasten the paper in place, press the T-square head firmly against the working edge of the drawing board with the left hand, while the paper is adjusted with the right hand until the top edge coincides with the upper edge of the T-square. Then move the T-square to the position as shown and fasten the upper-left corner, and then the lower-right corner, and finally the remaining corners. Small sheets may require fastening only at the two upper corners, while large sheets may require additional fastening.

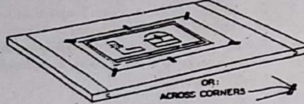


Fig. 2.7 Positions of Drafting Tape.

Many draftsmen prefer drafting tape, Fig. 2.7, for it does not damage the board and it will not damage the paper if it is removed by *pulling it off slowly toward the edge of the paper.*

Another method for fastening paper to the board is to use wire staples. A special draftsman's stapler is shown in Fig. 2.8.

Tracing paper should not be fastened directly to the board because small imperfections in the surface of the board will interfere with the line work. Always fasten a larger backing sheet of heavy drawing paper on the board first, then fasten the tracing paper over this sheet.

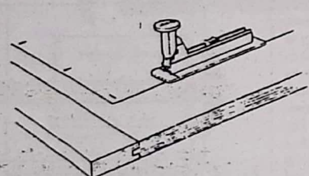


Fig. 2.8 Draftsman's Stapler.

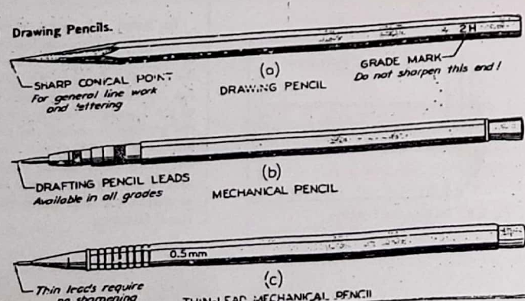
2.8 Drawing Pencils.

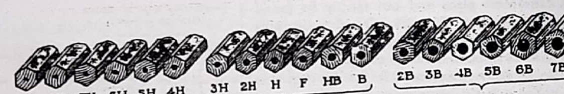
High-quality *drawing pencils*, Fig. 2.9 (a), should be used in technical drawing—never ordinary writing pencils.

Many makes of mechanical pencils are available, Fig. 2.9 (b), together with refill drafting leads of conventional size in all grades. Choose the holder that feels well in the hand and one that grips the lead firmly without slipping. Mechanical pencils have the advantage of maintaining a constant length of lead (no more need to draw with a stub!), of permitting use of a lead practically to the end, of being easily refilled with new leads, of affording a ready source for compass leads, of having no wood to be sharpened, and of easy sharpening of the lead by various mechanical pencil pointers now available.

Thin-lead mechanical pencils, Fig. 2.9 (c), are available with 0.3 mm, 0.5 mm, 0.7 mm, or 0.9 mm diameter drafting leads in several grades. These thin leads produce uniform width lines without sharpening.

Fig. 2.9 Drawing Pencils.





Hard
The harder pencils in this group (left) are used where extreme accuracy is required, as on graphical computations and charts and diagrams. The softer pencils in this group (right) are used by some for line work on engineering drawings, but their use is restricted because the lines are apt to be too light.

Medium
These grades are for general purpose work in technical drawing. The softer grades (right) are used for technical sketching, for lettering, arrowheads, and other freehand work on mechanical drawings. The harder pencils (left) are used for line work on machine drawings and architectural drawings. The H and 2H pencils are widely used on pencil tracings for blueprinting.

Soft
These pencils are too soft to be useful in mechanical drafting. Their use for such work results in smudged, rough lines which are hard to erase, and the pencil must be sharpened continually. These grades are used for art work of various kinds, and for full-size details in architectural drawing.

Fig. 2.10 Pencil Grade Chart.

Mechanical pencils are recommended for they are less expensive in the long run.

2.9 Choices of Grade of Pencil.

Drawing pencil leads are made of graphite with kaolin (clay) added in varying amounts to make eighteen grades from 9H (the hardest) down to 7B (the softest), Fig. 2.10. The uses of these different grades are shown in the figure. Note that small-diameter leads are used for the harder grades, while large-diameter leads are used to give more strength to the softer grades. Hence, the degree of hardness in the wood pencil can be roughly judged by a comparison of the diameters.

Specially formulated plastic-base leads are available also in several grades for use on the polyester films now used quite extensively in industry. See §2.64.

Unfortunately, pencil grades are not sufficiently standardized; one can depend on the grade marks only in a general way. Thus an F lead in one brand may be about the same as 2H in another. Therefore, it is necessary to select a brand and then experiment with the various grades of that brand. The draftsman must first know the character of line required and be able to tell at once by inspection whether or not the line is made with the correct pencil.

To select the grade of pencil, first take into consideration the type of linework required. For light construction lines, guide lines for lettering, and for accurate geometrical constructions or work where accuracy is of prime importance, use a hard pencil, such as 4H to 6H.

For mechanical drawings on drawing paper or tracing paper, the lines should be *black*, particularly for drawings to be reproduced. The pencil chosen must be soft enough to produce jet-black lines, but hard enough not to smudge too easily or permit the point to crumble under normal pressure. This pencil will vary from F to 2H, roughly, depending upon the paper and weather conditions. The same comparatively soft pencil is preferred for lettering and arrowheads.

Another factor to consider is the texture of the paper. If the paper is hard and has a decided tooth, it will be necessary generally to use harder leads. For smoother surfaces, softer leads can be used. Hence, to obtain dense black lines, the paper should not have too much tooth.

A final factor to consider is the humidity. On humid days the paper absorbs moisture from the atmosphere and becomes soft. This can be recognized because the paper expands and becomes wrinkled. It is necessary to select softer leads to offset the softening of the

Courtesy Eleard Manufacturing Co.

Fig. 2.11 Tru-Point Pencil Lead Pointer.

paper. If you have been using a 2H lead, for example, change to an F until the weather clears up.

2.10 Sharpening the Pencil.

Keep your pencil sharp! This is certainly the most frequent instruction needed by the beginning student. A dull pencil produces fuzzy, sloppy, indefinite lines, and is the mark of a dull and careless student. Only a *sharp pencil* is capable of producing clean-cut black lines that sparkle with clarity.

If a good mechanical pencil, Fig. 2.9 (b), is used, much time may be saved in sharpening, since the lead can be fed from the pencil as

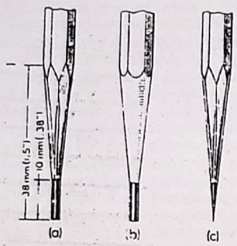


Fig. 2.12 Pencil Points.

needed. An excellent lead pointer for mechanical pencils is shown in Fig. 2.11. It has the advantages of one-hand manipulation and of collecting the loose graphite particles inside where they cannot soil the hands, the drawing, or other equipment.

If thin-lead mechanical pencils are used, no sharpening is required since the lead diameter determines the line width. Hence, several thin-lead mechanical pencils are required for the various line widths used in technical drawing. Each thin-lead mechanical pencil will accommodate only one diameter of lead.

If a wood drawing pencil is used, Fig. 2.9 (a), sharpen the unlettered end in order to preserve the identifying grade mark. First, the wood is removed with a knife or a special draftsman's pencil sharpener for about 38 mm (1.5") from the end with about 10 mm (.38") of uncut lead exposed, Fig. 2.12 (a) and (b). Next the lead is shaped to a sharp conical point and the point is wiped clean with cloth or paper tissue to remove loose particles of graphite.

The procedures for shaping the wood and the lead are illustrated in Fig. 2.13. Mechanical devices for removal of the wood are shown in Fig. 2.14 (a) and (b).

Never sharpen your pencil over the drawing or any of your equipment.

Many draftsmen burnish the point on a piece of hard paper to obtain a smoother, sharper point. However, for drawing visible lines the point should not be needle-sharp, but very slightly rounded. First sharpen the lead

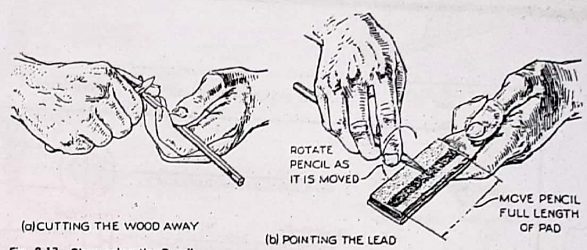


Fig. 2.13 Sharpening the Pencil.

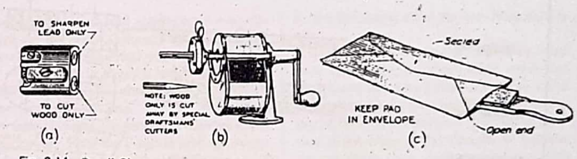


Fig. 2.14 Pencil Sharpeners.

to a needle point, then stand the pencil vertically, and with a few rotary motions on the paper, wear the point down slightly to the desired shape.

Keep the pencil pointer close by, as frequent pointing of the pencil will be necessary.

When the sandpaper pad is not in use, it should be kept in a container, such as an envelope, to prevent the particles of graphite from falling upon the drawing board or drawing equipment, Fig. 2.14 (c).

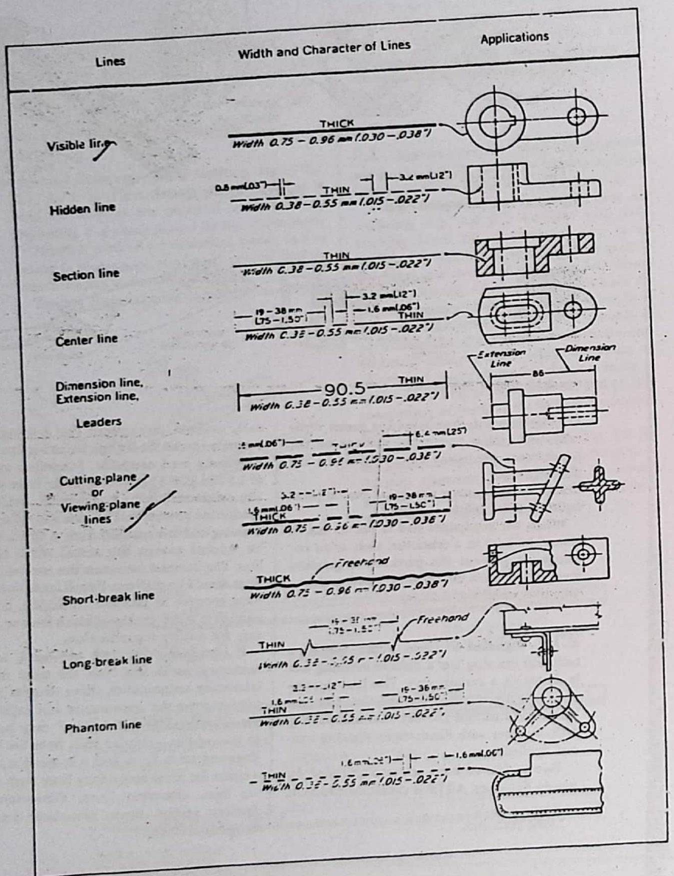
2.11 Alphabet of Lines.

Each line on a technical drawing has a definite meaning and is drawn in a certain way. The line conventions recommended by the American National Standards Institute (ANSI)* are used in Fig. 2.15, together with illustrations showing various applications.

Two widths of lines are recommended for use on drawings. All lines should be clean-cut, dark, uniform throughout the drawing, and properly spaced for legible reproduction by all commonly used methods. Minimum spacing of 1.5 mm (.06") between parallel lines is usually satisfactory for all reduction and/or reproduction processes. The size and style of the drawing and the smallest size to which it is to be reduced govern the actual width of each line. The contrast between the two widths of lines should be distinct. Pencil leads should be hard enought to prevent smudging, but soft enough to produce dense black lines so necessary for quality reproduction.

If photoreduction and blowback are not necessary, as is the case for most drafting laboratory assignments, three weights of lines may improve the appearance and legibility of the drawing. The "thin lines" may be made in two widths—regular thin lines for hidden lines and stitch lines and a somewhat thinner version for other secondary lines such as center lines, extension lines, dimension lines, leaders, section lines, phantom lines, and long-break lines.

*ANSI Y14.2-1973.



... Lines (Full Size).

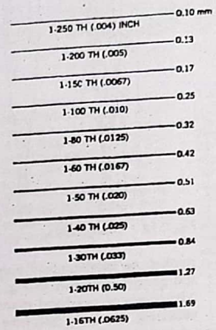


Fig. 2.16 Line Gage.

For the "thick lines"—visible, cutting plane, and short break—use a relatively soft lead such as F or H. All thin lines should be made with a sharp medium-grade lead such as H or 2H. All lines (except construction lines) must be *sharp and dark.* Make construction lines with a sharp 4H or 6H lead so thin that they barely can be seen at arm's length and need not be erased.

The high-quality photoreduction and reproduction processes used in the production of this book permitted the use of three weights of lines in many illustrations and drawings for increased legibility.

In Fig. 2.15, the ideal lengths of all dashes are indicated. It would be well to measure the first few hidden dashes and center-line dashes you make, and then thereafter to estimate the lengths carefully by eye.

The *line gage,* Fig. 2.16, is convenient when referring to lines of various widths.

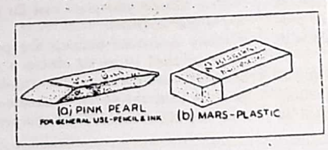


Fig. 2.17 Erasers.

2.12 Erasing.

Erasers are available in many degrees of hardness and abrasiveness. For general drafting the Pink Pearl or the Mars-Plastic is suggested, Fig. 2.17. These erasers are suitable for erasing pencil or ink linework. Best results are obtained if a hard surface, such as a triangle, is placed under the area being erased. If the surface has become badly grooved by the lines, the surface can be improved by burnishing with a hard smooth object or with the back of the fingernail.

Either eraser is recommended for general

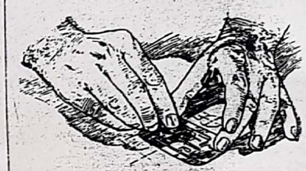
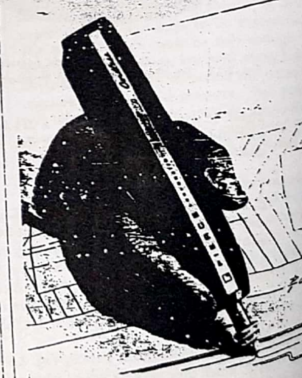


Fig. 2.18 Using the Erasing Shield.



Courtesy Pierce Corp.

Fig. 2.19 Electric Erasing Machine.

cleaning of large areas of a drawing or for removing pencil lines from an inked drawing.

The *erasing shield*, Fig. 2.18, is used to protect the lines near those being erased.

The *electric erasing machine*, Fig. 2.19, saves time and is essential if much drafting is being done. (For design details of the eraser, see §14.9.)

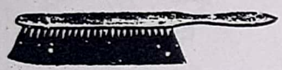


Fig. 2.20 **Draftsman's Dusting Brush.**

A *dusting brush*, Fig. 2.20, is useful for removing eraser crumbs without smearing the drawing.

2.13 Keeping Drawings Clean.

Cleanliness in drafting is very important and should become a habit. Cleanliness does not just happen; it results only from a conscious effort to observe correct procedures.

First, the draftsman's hands should be clean at all times. Oily or perspiring hands should be frequently washed with soap and water. Talcum powder on the hands tends to absorb excessive perspiration.

Second, all drafting equipment, such as drawing board, T-square, triangles, and scale, should be wiped frequently with a clean cloth. Water should be used sparingly and dried off immediately. A soft eraser may also be used for cleaning drawing equipment.

Third, the largest contributing factor to dirty drawings is *not dirt, but graphite* from the pencil; hence the draftsman should observe the following precautions:

1. Never sharpen a pencil over the drawing or any equipment.
2. Always wipe the pencil point with a clean cloth or cleansing tissue, after sharpening or pointing, to remove small particles of loose graphite.
3. Never place the sandpaper pad or file in contact with any other drawing equipment unless it is completely enclosed in an envelope or similar cover, Fig. 2.14 (c).
4. Never work with the sleeves or hands resting upon a penciled area. Keep such parts of the drawing covered with clean paper (not a cloth). In lettering a drawing, always place a piece of paper under the hand.
5. Avoid unnecessary sliding of the T-square or triangles across the drawing. Pick up the triangles by their tips and tilt the T-square blade upward slightly before moving. A very light sprinkling of powdered Artgum on the drawing helps to keep the drawing clean by picking up the loose graphite particles as you work. It should be brushed off and replaced occasionally.
6. Never rub across the drawing with the palm of the hand to remove eraser particles; use a dust brush, Fig. 2.20, or flick—don't rub—the particles off with a clean cloth.

When the drawing is completed, it is not necessary to clean it if the above rules have been observed. The practice of making a pencil drawing, scrubbing it with a soft eraser and then retracing the lines is poor technique and a waste of time, and this habit should not be acquired.

At the end of the period or of the day's work, the drawing should be covered with paper or cloth to protect it from dust.

2.14 Horizontal Lines.

To draw a horizontal line, Fig. 2.21 (a), press the head of the T-square firmly against the working edge of the board with the left hand; then slide the left hand to the position shown, so as to press the blade tightly against the paper. Lean the pencil in the direction of the line at an angle of approximately 60° with the paper, (b), and draw the line from left to right. Keep the pencil in a vertical plane, (b) and (c); otherwise, the line may not be straight. While drawing the line, let the little finger of the hand holding the pencil glide lightly on the blade of the T-square, and rotate the pencil slowly, except for the thin-lead pencils, between the thumb and forefinger so as to distribute the wear uniformly on the lead and maintain a symmetrical point.

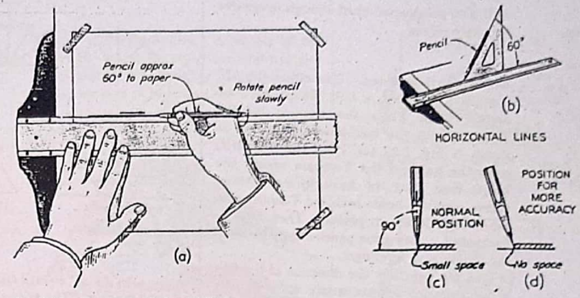


Fig. 2.21 **Drawing a Horizontal Line.**

When great accuracy is required, the pencil may be "toed in" as shown at (d) to produce a perfectly straight line.

Left-Handers. In general, reverse the above procedure. Place the T-square head against the right edge of the board, and with the pencil in the left hand, draw the line from right to left.

Triangles and T-squares, especially when new, often have very sharp edges which tend to cut into the pencil lead and cause a trail of graphite on the drawing. To prevent smearing of these particles, blow them off at intervals. If the edges of the triangles or T-square are too sharp, they can be sanded *very lightly*

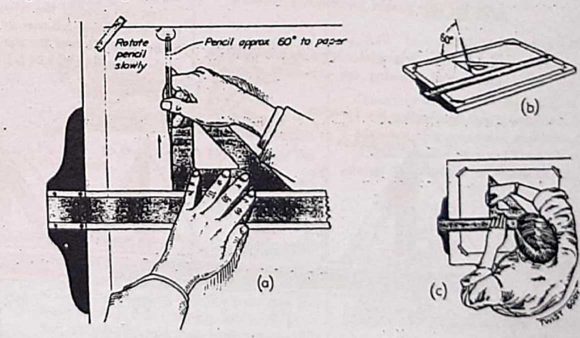


Fig. 2.22 **Drawing a Vertical Line.**

with #00 sandpaper—just enough to remove the sharp edges.

2.15 Vertical Lines. Use either the 45° triangle or the 30° × 60° triangle to draw vertical lines. Place the triangle on the T-square with the *vertical edge on the left* as shown in Fig. 2.22 (a). With the left hand, press the head of the T-square against the board, then slide the hand to the position shown where it holds both the T-square and the triangle firmly in position. Then *draw the line upward*, rotating the pencil slowly between the thumb and forefinger.

Lean the pencil in the direction of the line at an angle of approximately 60° with the paper and in a vertical plane, (b). Meanwhile, the upper part of the body should be twisted to the right, as shown at (c).

LEFT-HANDERS. In general, reverse the above procedure. Place the T-square head on the right and the vertical edge of the triangle on the right; then, with the right hand, hold the T-square and triangle firmly together, and with the left hand draw the line upward.

The only time it is permissible for right-handers to turn the triangle so that the vertical edge is on the right is when drawing a vertical line near the right end of the T-square. In this case, the line would be drawn downward.

2.16 The Triangles. Most inclined lines in mechanical drawing are drawn at standard

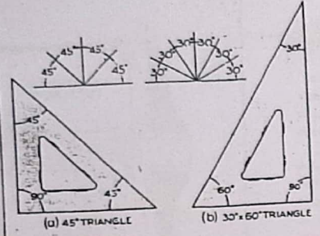


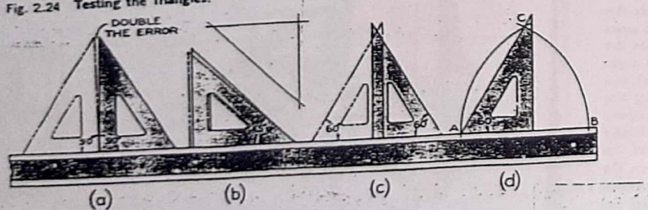
Fig. 2.23 Triangles.

angles with the 45° *triangle* and the 30° × 60° *triangle*, Fig. 2.23. The triangles are made of transparent plastic so that lines of the drawing can be seen through them. A good combination of triangles is the 30° × 60° triangle with a long side of 10", and a 45° triangle with each side 8" long.

2.17 Testing and Correcting the Triangles. Triangles are subject to warping and should be tested immediately after purchase to determine if they are true. If they are not found to be correct, they should be returned to the dealer.

Test the sides of the triangles for straightness in the same manner as for the T-square blade, §2.6. To test the right angle of either of the triangles, Fig. 2.24 (a), place the triangle

Fig. 2.24 Testing the Triangles.



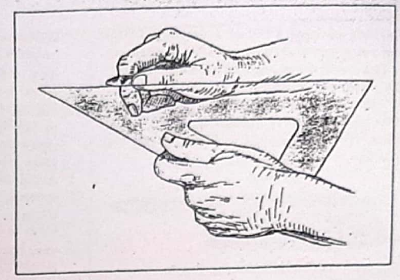


Fig. 2.25 Scraping the Triangle.

on the T-square and draw a vertical line; then turn the triangle over (like turning a page in a book) and draw the line again along the same edge. If the two lines thus drawn do not coincide, the right angle is not 90° and the error is equal to half the angle between the two lines.

To test the 45° angle, place the triangle on the T-square, as at (b), and draw a line along the hypotenuse; then turn the triangle over, and using the other 45° angle of the triangle, draw a line along the hypotenuse. If the two lines do not coincide, there is an error in one or both 45° angles. A direct test of the 45° angle can be made by drawing a right triangle. The sides adjacent to the 90° angle will be equal if the two 45° angles are correct (assuming the 90° angle to be correct).

To test the 60° angle of the 30° × 60° triangle, draw an equilateral triangle, as shown at (c). If all three sides are not exactly equal in length, the 60° angle is incorrect. Another method of testing the 60° angle, (d), is to draw a horizontal line AB slightly shorter than the hypotenuse of the triangle, and to draw arcs with A and B as centers and AB as radius, intersecting at C. When the triangle is placed as shown, its hypotenuse should pass through C.

To true up the edge of a triangle, make a rough cut by scraping the edge with a sharp knife, Fig. 2.25. Or place the triangle in a vise and plane with a sharp block plane set for a very shallow cut. Then hold the triangle flat against the edge of a table top, with the edge of the triangle level with it, and sand the edge with #00 sandpaper wrapped around a block.

2.18 Inclined Lines. The positions of the triangles for drawing lines at all of the possible angles are shown in Fig. 2.26. In the figure it is understood that the triangles in each case are resting upon the blade of the T-square. Thus, it is possible to divide 360° into twenty-four 15° sectors with the triangles used singly or in combination. Note carefully the directions for drawing the lines, as indicated by the arrows, and that all lines in the left half are drawn *toward the center*, while those in the right half are drawn *away from the center*.

2.19 Protractors. For measuring or setting off angles other than those obtainable with the triangles, the *protractor* is used. The best protractors are made of nickel silver and are capable of most accurate work, Fig. 2.27 (a). For ordinary work the plastic protractor is satisfactory and is much cheaper, (b). To set off angles with greater accuracy, use one of the methods presented in §4.21.

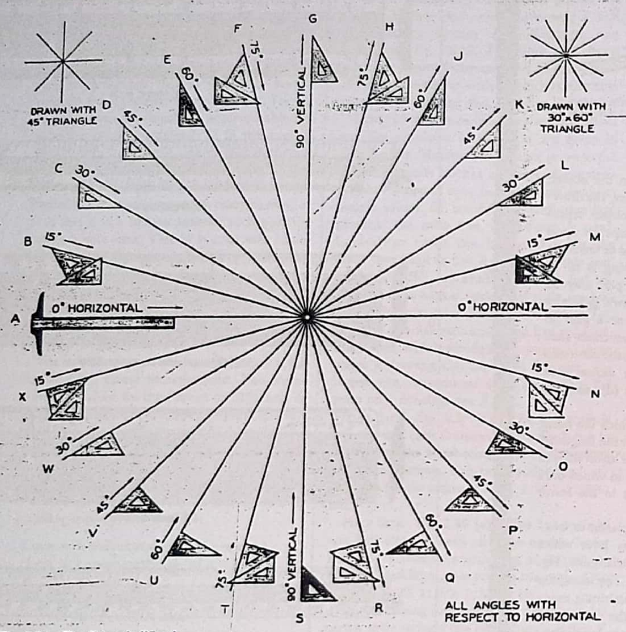
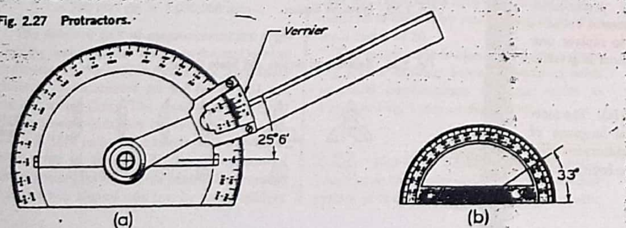


Fig. 2.26 The Triangle Wheel.

Fig. 2.27 Protractors.



2.20 Drafting Angles.

A variety of devices combining the protractor with triangles to produce great versatility of use are available, one type of which is shown in Fig. 2.28.

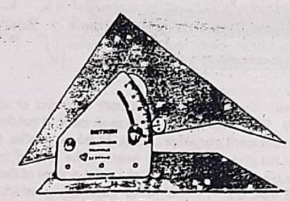


Fig. 2.28 Adjustable Triangle.

2.21 To Draw a Line Through Two Points.

To draw a line through two points, Fig. 2.29, place the pencil vertically at one of the points, and move the straightedge about the pencil point as a pivot until it lines up with the other point; then draw the line along the edge.

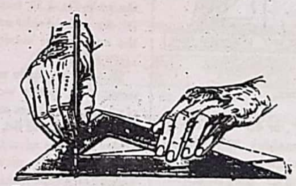


Fig. 2.29 To Draw a Pencil Line Through Two Given Points.

2.22 Parallel Lines.

To draw a line parallel to a given line. Fig. 2.30, move the triangle and T-square as a unit until the hypotenuse of the triangle lines up with the given line, (a); then, holding the T-square firmly in position, slide the triangle away from the line, (b), and draw the required line along the hypotenuse, (c).

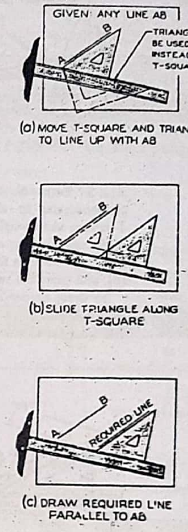


Fig. 2.30 To Draw a Line Parallel to a Given Line.

Obviously any straightedge, such as one of the triangles, may be substituted for the T-square in this operation, as shown at (a).

To draw parallel lines at 15° with horizontal, arrange the triangles as shown in Fig. 2.31.

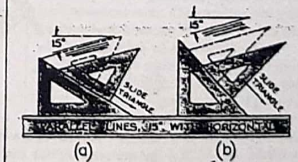
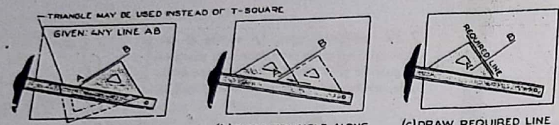


Fig. 2.31 Parallel Lines.



(a) MOVE T-SQUARE AND TRIANGLE TO LINE UP WITH AB (b) SLIDE TRIANGLE ALONG T-SQUARE (c) DRAW REQUIRED LINE PERPENDICULAR TO AB

Fig. 2.32 *To Draw a Line Perpendicular to a Given Line.*

2.23 Perpendicular Lines. To draw a line perpendicular to a given line, move the T-square and triangle as a unit until one edge of the triangle lines up with the given line, Fig. 2.32 (a); then slide the triangle across the line, (b), and draw the required line, (c).

To draw perpendicular lines when one of the lines makes 15° with horizontal, arrange the triangles as shown in Fig. 2.33.

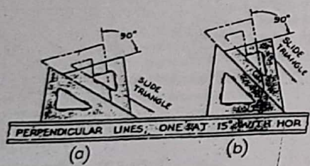


Fig. 2.33 **Perpendicular Lines.**

2.24 Lines at 30°, 60°, or 45° with Given Line. To draw a line making 30° with a given line, arrange the triangle as shown in Fig. 2.34. Angles of 60° and 45° may be drawn in a similar manner.

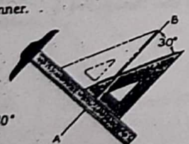


Fig. 2.34 Line at 30° with Given Line.

2.25 Scales. A drawing of an object may be the same size as the object (full size), or it may be larger or smaller than the object; in most cases, if not drawn full size, the drawing is made smaller than the object represented. The ratio of reduction depends upon the relative sizes of the object and of the sheet of paper upon which the drawing is to be made. For example, a machine part may be half size; a building may be drawn $\frac{1}{48}$ size; a map may be drawn $\frac{1}{1200}$ size; or a gear in a wrist watch may be drawn ten-times size.

Scales, Fig. 2.35, are classified as the *metric scale* (a), the *engineers scale* (b), the *decimal scale* (c), the *mechanical engineers scale* (d), and the *architects scale* (e).

A *full-divided scale* is one in which the basic units are subdivided throughout the length of the scale, Fig. 2.35, except for the lower scale at (e). An open *divided scale* is one in which only the end unit is subdivided, as in the lower scale at (e).

Scales are usually made of plastic or boxwood. The better wood scales have white plastic edges. Scales are either triangular, Fig. 2.36 (a) and (b), or flat, (c) to (f). The triangular scales have the advantage of combining many scales on one stick, but the user will waste much time looking for the required scale if a *scale guard*, (g), is not used. The flat scale is almost universally used by professional draftsmen because of its convenience, but several flat scales are necessary to replace one triangular scale, and the total cost is greater.

2.26 Metric Scales. Fig. 2.35 (a). The metric system is an international language of measurement that, despite modifications over the past 200 years, has been the foundation of

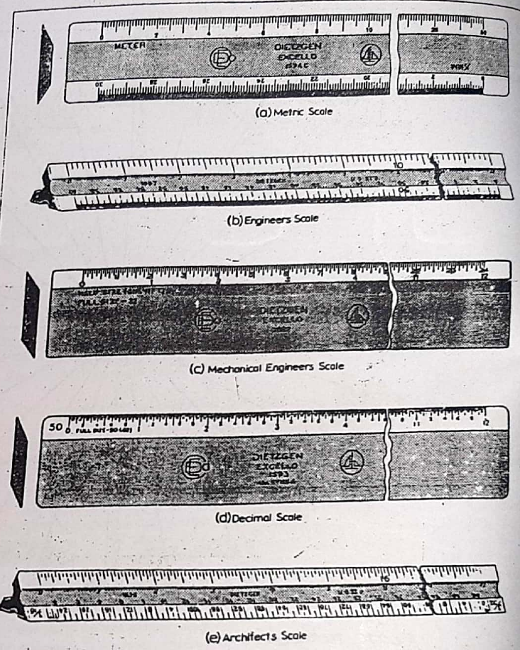
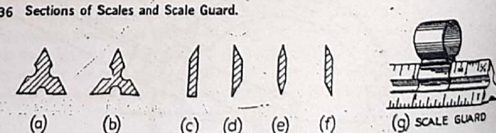


Fig. 2.35 **Types of Scales.**

Fig. 2.36 **Sections of Scales and Scale Guard.**



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science and industry, and is clearly defined. The modern form of the metric system is "The International System of Units," commonly referred to as SI (from the French name, Le Système International d'Unités). It is important to remember that SI differs in several respects from former metric systems. For example, cc was previously an accepted abbreviation for cubic centimeter; in SI the symbol used is cm^3. In the past, degree centigrade was accepted as an alternative name for degree Celsius; in SI only degree Celsius is used. Probably the most important characteristic of SI is that it is a unique system; each quantity has only one unit. The SI system was established in 1960 by international agreement and is now considered the standard international language of measurement. Many countries are converting from nonmetric systems to SI; or are in the process of changing their metric practices to conform to SI.

The *metric scale* is used when the meter is the standard for linear measurement. The meter was established by the French in 1791 and its length represents one ten-millionth of the distance from the earth's equator to the pole. The meter is equal to 39.37 inches or approximately 1.1 yards.

The metric system for linear measurement is a decimal system similar to our system of counting money. For example,

1 mm = 1 millimeter ($\frac{1}{1000}$ of a meter)
1 cm = 1 centimeter ($\frac{1}{100}$ of a meter)
= 10 mm
1 dm = 1 decimeter ($\frac{1}{10}$ of a meter)
= 10 cm = 100 mm
1 m = 1 meter = 100 cm = 1000 mm
1 km = 1 kilometer = 1000 m
= 100 000 cm = 1 000 000 mm

The primary unit of measurement for engineering drawings and design in the mechanical industries is the millimeter (mm). Secondary units of measurement are the meter (m) and the kilometer (km). The centimeter (cm) and the decimeter (dm) are rarely used.

Much U.S. industry has converted, even at great cost, to the use of the SI system of measurement following the Metric Conversion Act that was signed into law by the president in 1975. During this changeover period, the auto and other industries have used a dual dimensioning system of millimeters and inches; see Fig. 14.22. The large agricultural machinery manufacturers have elected to use *all metric* dimensions with the inch equivalents given in a table on the drawing, Fig. 14.22.

Many of the dimensions in the illustrations and the problems in this text are given in metric units. Dimensions that are given in the customary units (inches and feet, either decimal or fractional) may be converted easily to metric values. In accordance with standard practice, the ratio 1 in. = 25.4 mm is used. Equivalents tables can be found inside the front cover and in the Appendix of this text.

Metric scales are available in flat and triangular styles with a variety of scale graduations. The triangular scale illustrated in Fig. 2.37 has one full-size scale and five reduced-size scales, all full divided. By means of these scales a drawing can be made full size, enlarged size, or reduced size. To specify the scale on a drawing, see §2.32.

FULL SIZE. Fig. 2.37 (a). The 1:1 scale is full size and each division is actually 1 mm in width with the numbering of the calibrations at 10 mm intervals. This same scale is convenient also for the ratios of 1:10, 1:100, 1:1000, etc.

HALF SIZE. Fig. 2.37 (a). The 1:2 scale is one-half size and each division equals 2 mm with the calibration numbering at 20-unit intervals. In addition, this scale is convenient for ratios of 1:20, 1:200, 1:2000, etc.

The remaining four scales on this triangular metric scale include the typical scale ratios of 1:5, 1:25, 1:33⅓, and 1:75, as illustrated at (b) and (c). These ratios also may be enlarged or reduced as desired by multiplying or dividing by a factor of 10.

The metric scale is also used in map drawing and in drawing force diagrams or other graphical constructions to such scales as 1 mm = 1 kg, 1 mm = 500 kg, etc.

2.27 Inch-Foot Scales.

Several scales based upon the customary (English) inch-foot system of measurement continue in domestic

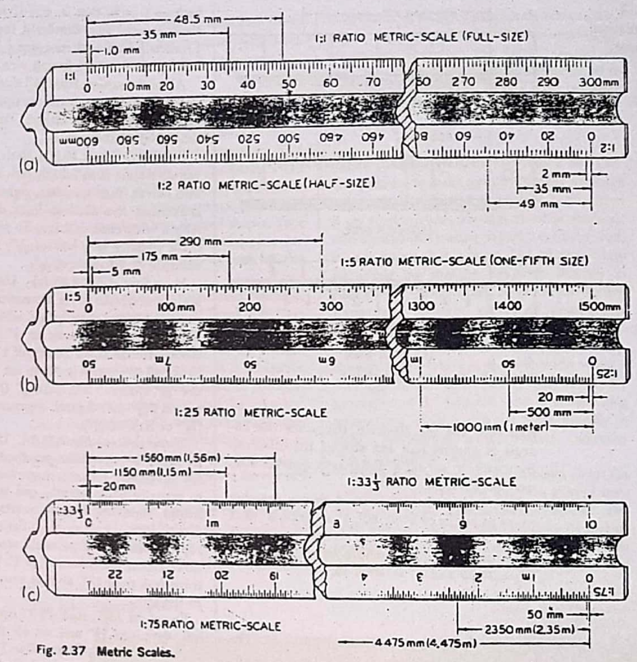


Fig. 2.37 Metric Scales.

use today along with the worldwide accepted metric system of measurement for science, technology, and international trade.

2.28 Engineers Scale.

Fig. 2.35 (b). The *engineers scale* is graduated in the decimal system. It is also frequently called the *civil engineers scale* because it was originally used mainly in civil engineering. The name *chain scale* also persists because it was derived from the surveyors' chain composed of 100 links, used for land measurements. The name *engineers scale* is perhaps best; because the scale is used generally by engineers of all kinds.

The engineers scale is graduated in units of one inch divided into 10, 20, 30, 40, 50, and 60 parts. Thus, the engineers scale is convenient in machine drawing to set off dimensions expressed in decimals. For example, to set off 1.650" full size, Fig. 2.38 (a), use the 10-scale and simply set off one main division plus 6½ subdivisions. To set off the same dimension

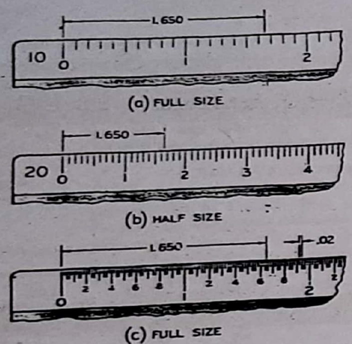


Fig. 2.38 Decimal Dimensions.

half size, use the 20-scale, (b), since the 20-scale is exactly half the size of the 10-scale. Similarly, to set off a dimension quarter size, use the 40-scale.

The engineers scale is used also in drawing maps to scales of 1" = 50', 1" = 500', 1" = 5 miles, etc., and in drawing stress diagrams or other graphical constructions to such scales as 1" = 20 lb and 1" = 4000 lb.

2.29 Architects Scale.

Fig. 2.35 (e). The *architects scale* is intended primarily for drawings of buildings, piping systems, and other large structures which must be drawn to a reduced scale to fit on a sheet of paper. The full-size scale is also useful in drawing relatively small objects, and for that reason the architects scale has rather general usage.

The architects scale has one full-size scale and ten overlapping reduced-size scales. By means of these scales a drawing may be made to various sizes from full size to $\frac{1}{128}$ size. *Note particularly: In all of the reduced scales the major divisions represent feet, and their subdivisions represent inches and fractions thereof.* Thus, the scale marked $\frac{3}{4}$ means $\frac{3}{4}$ inch = 1 foot, not $\frac{3}{4}$ inch = 1 inch; that is, one-sixteenth size, not three-fourths size. Similarly, the scale marked $\frac{1}{2}$ means $\frac{1}{2}$ inch = 1 foot, not $\frac{1}{2}$ inch = 1 inch; that is, one-twenty-fourth size, not half-size.

All of the scales, from full size to $\frac{1}{128}$ size, are shown in Fig. 2.39. Some are upside down, just as they may occur in use. These scales are described as follows:

FULL SIZE. Fig. 2.39 (a). Each division in the full-size scale is $\frac{1}{16}$". Each inch is divided first into halves, then quarters, eighths, and finally sixteenths, the division lines diminishing in length with each division. To set off $\frac{1}{32}$", estimate visually one half of $\frac{1}{16}$"; to set off $\frac{1}{64}$", estimate one fourth of $\frac{1}{16}$".

HALF SIZE. Fig. 2.39 (a). Use the full-size scale, and divide every dimension mentally by two (do not use the $\frac{1}{2}$" scale, which is intended for drawing to a scale of $\frac{1}{2}$" = 1', or one-twenty-fourth size). To set off 1", measure $\frac{1}{2}$"; to set off 2", measure 1"; to set off $3\frac{1}{4}$", measure $1\frac{1}{2}$" (half of 3"), then $\frac{1}{8}$" (half of $\frac{1}{4}$"); to set off $2\frac{13}{16}$" (see figure), measure 1", then $\frac{13}{32}$" ($\frac{6\frac{1}{2}}{16}$" or half of $\frac{13}{16}$").

QUARTER SIZE. Fig. 2.39 (b). Use the 3" scale in which 3" = 1'. The subdivided portion to the left of zero represents one foot compressed to actually 3" in length, and is divided into inches, then half inches, quarter inches, and finally eighth inches. Thus the entire portion representing one foot would actually measure three inches; therefore, 3" = 1'. To set off anything less than 12", start at zero and measure to the left.

To set off $10\frac{1}{8}$", read off 9" from zero to the left, then add $1\frac{1}{8}$" and set off the total $10\frac{1}{8}$", as shown. To set off more than 12", for example, 1'-$9\frac{3}{8}$" (see your scale), find the 1' mark to the right of zero and the $9\frac{3}{8}$" mark to the left of zero; the required distance is the distance between these marks, and represents 1'-$9\frac{3}{8}$".

EIGHTH SIZE. Fig. 2.39 (b). Use the $1\frac{1}{2}$" scale in which $1\frac{1}{2}$" = 1'. The subdivided portion to the right of zero represents 1', and is divided into inches, then half inches, and finally quarter inches. The entire portion, representing 1', actually is $1\frac{1}{2}$"; therefore $1\frac{1}{2}$" = 1'. To set off anything less than 12", start at zero and measure to the right.

DOUBLE SIZE. Use the full-size scale, and multiply every dimension mentally by two. To set off 1", measure 2"; to set off $3\frac{1}{4}$", measure $6\frac{1}{2}$", and so on. The double-size scale is occasionally used to represent small objects. In such cases, a small actual-size outline view should be shown near the bottom of the sheet to help the shop man visualize the actual size of the object.

OTHER SIZES. Fig. 2.39. The other scales besides those described above are used chiefly by architects. Machine drawings are customarily made only double size, full size, $\frac{1}{2}$ size, $\frac{1}{4}$ size, or $\frac{1}{8}$ size.

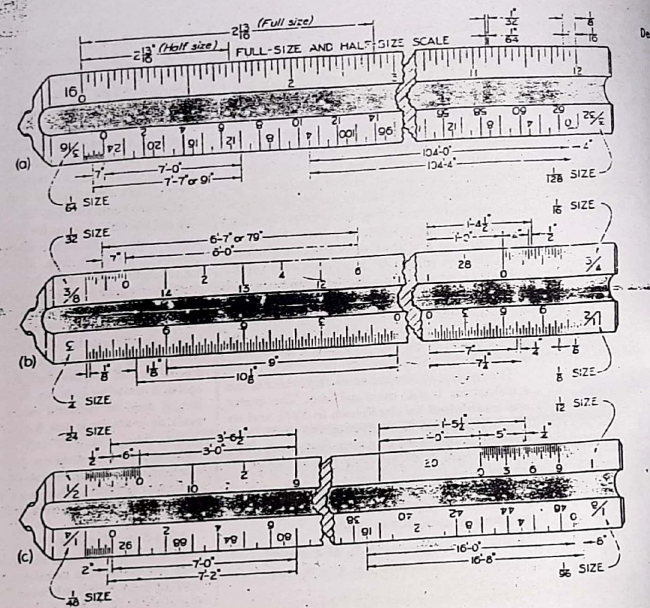


Fig. 2.39 Architects Scales.

2.30 Decimal Scale.

Fig. 2.35 (c). The increasing use of decimal dimensions has brought about the development of a scale specifically for that use. On the full-size scale, each inch is divided into fiftieths of an inch, or .02", as shown in Fig. 2.38 (c); and on the half- and quarter-size scales the inches are compressed to half size or quarter size, and then are divided into ten parts, so that each subdivision stands for .1".

The complete decimal system of dimensioning, in which this scale is used, is described in §11.10.

2.31 Mechanical Engineers Scale. Fig. 2.35 (c). The objects represented in machine drawing vary in size from small parts, an inch or smaller in size, to machines of large dimensions. By drawing these objects full size, half size, quarter size, or eighth size, the drawings will readily come within the limits of the standard-size sheets. For this reason the mechanical engineers scales are divided into units representing inches to full size, half size, quarter size, or eighth size. To make a drawing of an object to a scale of one-half size, for example, use the mechanical draftsmans scale marked half size, which is graduated so that every $\frac{1}{2}$" represents 1". Thus, the half-size scale is simply a full-size compressed to one-half size.

These scales are also very useful in dividing dimensions. For example, to draw a $3\frac{11}{16}$" dia. circle full size, we need half of $3\frac{11}{16}$" to use as radius. Instead of using arithmetic to find half of $3\frac{11}{16}$", it is easier to set off $3\frac{11}{16}$" on the half-size scale.

Triangular combination scales are available which include the full and half-size mechanical draftsmans scales, several architects scales, and an engineers scale.

2.32 To Specify the Scale on a Drawing. For machine drawings the scale indicates the ratio of the size of the drawing of the part or machine to its actual size irrespective of the unit of measurement used. The recommended practice is to letter FULL SIZE or 1:1; HALF SIZE or ~~1:2~~; and similarly for other reductions. Expansion or enlargement scale are given as 2:1 or 2X; 3:1 or 3X; 5:1 or 5X; 10:1 or 10X; etc.

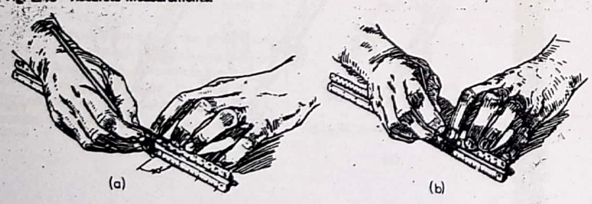
The various scale calibrations available on the metric scales and the engineers scale provide almost unlimited scale ratios. The preferred metric scale ratios appear to be 1:1, 1:2, 1:5, 1:10, 1:20, 1:50, 1:100, and 1:200. For examples of how scales may be shown on machine drawings, see Figs. 14.26 and 14.27.

Map scales are indicated in terms of fractions, as Scale $\frac{1}{62500}$, or graphically as 400 0 400 800 Ft. See also Fig. 3.38 and Fig. 23.2.

2.33 Accurate Measurements. Accurate drafting depends considerably upon the correct use of the scale in setting off distances. Do not take measurements directly off the scale with the dividers or compass, as damage will result to the scale. Place the scale on the drawing with the edge parallel to the line on which the measurement is to be made and, with a sharp pencil having a conical point, make a short dash at right angles to the scale and opposite the correct graduation mark, as shown in Fig. 2.40 (a). If extreme accuracy is required, a tiny prick mark may be made at the required point with the needle point or stylus, as shown at (b), or with one leg of the dividers.

Avoid cumulative errors in the use of the scale. If a number of distances are to be set off end-to-end, all should be set off at one setting of the scale by adding each successive measurement to the preceding one, if possible. Avoid setting off the distances individually by moving the scale to a new position each time, since slight errors in the measurements may accumulate and give rise to a large error.

Fig. 2.40 Accurate Measurements.



2.34 Drawing Instruments. *Drawing instruments* are generally sold in sets, in cases, but they may be purchased separately. The principal parts of high-grade instruments are usually made of nickel silver, which has a silvery luster, is corrosion-resistant, and can be readily machined into desired shapes. Tool steel is used for the blades of ruling pens, for spring parts, for divider points, and for the various screws.

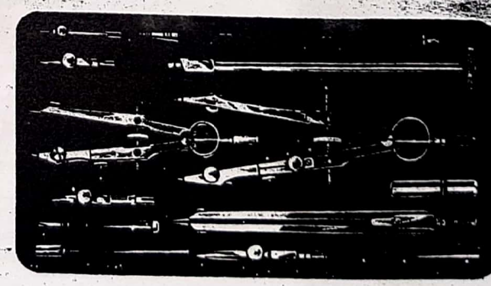
In technical drawing, accuracy, neatness, and speed are essential, §2.2. These objectives are not likely to be obtained with cheap or inferior drawing instruments. For the student or the professional draftsman it is advisable, and in the end more economical, to purchase the best instruments that can be afforded. Good instruments will satisfy the most rigid requirements, and the satisfaction, saving in time, and improved quality of work that good instruments can produce will more than justify the higher price.

Unfortunately, the qualities of high-grade instruments are not likely to be recognized by the beginner, who is not familiar with the performance characteristics required and who is apt to be attracted by elaborate sets containing a large number of shiny low-quality instruments. Therefore, the student should obtain the advice of his drafting instructor, of an experienced draftsman, or of a reliable dealer.

2.35 Giant Bow Set. Formerly it was general practice to make pencil drawings on detail paper and then to make an inked tracing from it on tracing cloth. As reproduction methods and transparent tracing papers were improved, it was found that a great deal of time could be saved by making drawings directly in pencil with dense black lines on the tracing paper and making prints or photocopies therefrom, thus doing away with the preliminary pencil drawing on detail paper. Today, though inked tracings are still made when a fine appearance is necessary and where the greater cost is justified, the overwhelming proportion of drawings are made directly in pencil on tracing paper, vellum, polyester films, or pencil tracing cloth.

These developments have brought about the present giant bow sets that are offered now by all the major manufacturers, Fig. 2.41. The sets contain various combinations of instruments, but all feature a large bow compass in place of the traditional large compass. The

Fig. 2.41 Giant Bow Set. Courtesy Frank Oppenheimer.



large bow instrument is much sturdier and is capable of taking the heavy pressure necessary to produce dense black lines without losing the setting.

Most of the large bows are of the center-wheel type, Fig. 2.42 (a). Several manufacturers now offer different varieties of quick-acting bows. The large bow compass shown at (b) can be adjusted to the approximate setting by simply opening or closing the legs in the same manner as for the old style compass.

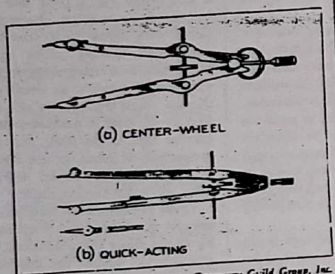


Fig. 2.42 Giant Bow Compass.

2.36 The Compass. The giant bow compass, Fig. 2.41, has a socket joint in one leg that permits the insertion of either pencil or pen attachments. A *lengthening bar* or a *beam attachment* is often provided to increase the radius. For production drafting, in which it is necessary to make dense black lines to secure clear legible reproductions, the giant bow, or an appropriate template, Fig. 2.81, is preferred.

2.37 Using the Compass. These instructions apply generally both to the old style and the giant bow compasses. The compass, with pencil and inking attachments, is used for drawing circles of approximately 25 mm (1") radius or larger, Fig. 2.43. Most compass needle points have a plain end for use when the compass is converted into dividers, and a shoulder end for use as a compass. Adjust the needle point with the shoulder end out and so that the small point extends *slightly* farther than the pencil lead or pen nibs, Fig. 2.45 (d).

To draw a penciled circle, Fig. 2.43: (1) set off the required radius on one of the center lines, (2) place the needle point at the exact intersection of the center lines, (3) adjust the compass to the required radius (25 mm or more), (4) lean the compass forward and draw the circle clockwise while rotating the handle between the thumb and forefinger. To obtain sufficient weight of line, it may be necessary to repeat the movement several times.

Any error in radius will result in a doubled error in diameter; hence, it is best to draw a trial circle first on scrap paper or on the backing sheet and then check the diameter with the scale.

On drawings having circular arcs and tangent straight lines, draw the arcs first, whether in pencil or in ink, as it is much easier to connect a straight line to an arc than the reverse.

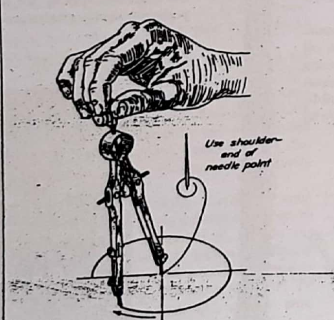


Fig. 2.43 Using the Giant Bow Compass.

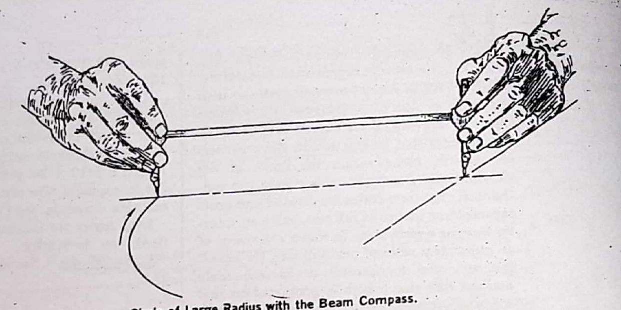


Fig. 2.44 Drawing a Circle of Large Radius with the Beam Compass.

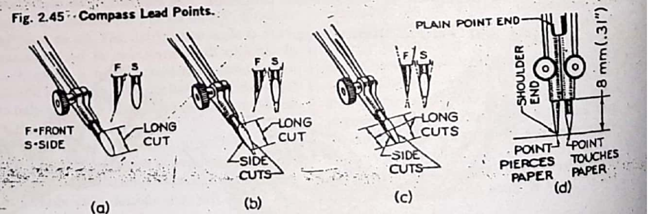
For very large circles a beam compass is preferred, or use the lengthening bar to increase the compass radius. Use both hands, as shown in Fig. 2.44, but be careful not to jar the instrument and thus change the adjustment.

When using the compass to draw construction lines, use a 4H to 6H lead so that the lines will be very dim. For required lines, the arcs and circles must be black, and softer leads must be used. However, since heavy pressure cannot be exerted on the compass as it can on a pencil, it is usually necessary to use a compass lead that is about one grade softer than the pencil used for the corresponding line work. For example, if a 2H lead is used for visible lines drawn with the pencil, then an F lead might be found suitable for the compass work. The hard leads supplied with the compass are usually unsatisfactory for most line work except construction lines. In summary, use leads in the compass that will produce arcs and circles that *match* the straight pencil lines.

It is necessary to exert pressure on the compass to produce heavy "reproducible" circles, and this tends to enlarge the compass center hole in the paper, especially if there are a number of concentric circles. In such cases, use a *horn center*, or center tack, in the hole, and place the needle point in the hole in the tack.

2.38 Sharpening the Compass Lead. Various forms of compass lead points are illustrated in Fig. 2.45. At (a) a single elliptical face has been formed by rubbing on the sand-

Fig. 2.45 Compass Lead Points.



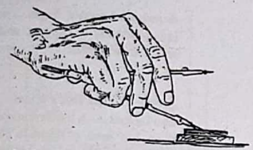


Fig. 2.46 Sharpening Compass Lead.

paper pad, as shown in Fig. 2.46. At (b) the point is narrowed by small side cuts. At (c) two long cuts and two small side cuts have been made so as to produce a point similar to that on a screwdriver. At (d) the cone point is prepared by chucking the lead in a mechanical pencil and shaping it in a pencil pointer. Avoid using leads that are too short to be exposed as shown.

In using the compass, *never use the plain end of the needle point*. Instead, use the shoulder end, as shown in Fig. 2.45 (d), adjusted so that the tiny needle point extends about half-way into the paper when the compass lead just touches the paper.

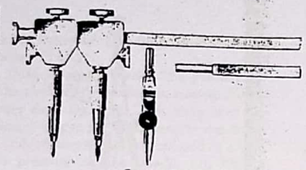
2.39 Beam Compass.

The *beam compass*, or *trammel*, Fig. 2.47, is used for drawing arcs or circles larger than can be drawn with the regular compass and for transferring distances too great for the regular dividers. Besides steel points, pencil and pen attachments are provided. The beams may be made of nickel silver, steel, or wood, and are procurable in various lengths.

2.40 Dividers.

The dividers are similar to the compass in construction, and are made in square, flat, and round forms.

The friction adjustment for the pivot joint should be loose enough to permit easy manipulation with one hand, as shown in Fig. 2.48. If the pivot joint is too tight, the legs of the compass tend to spring back instead of stopping at the desired point when the pressure of



Courtesy Gramercy Guild Group, Inc.

Fig. 2.47 Beam Compass.

the fingers is released. To adjust the tension, use a small screwdriver.

Many dividers are made with a spring and thumbscrew in one leg so that minute adjustments in the setting can be made by turning the small thumbscrew.

2.41 Using the Dividers.

The dividers, as the name implies, are used for *dividing* distances into a number of equal parts. They are used also for *transferring distances* or for *setting off* a series of equal distances. The dividers are used for spaces of approximately 25 mm (1″) or more. For less than 25 mm spaces, use the bow dividers, Fig. 2.52 (a). *Never use the large dividers for small spaces when the bow dividers can be used; the latter are more accurate.*

To divide a given distance into a number

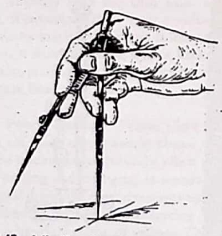
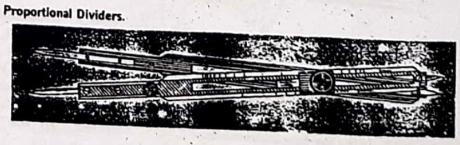


Fig. 2.48 Adjusting the Dividers.

Fig. 2.49 Using the Dividers.

of equal parts, Fig. 2.49, the method is one of trial and error. Adjust the dividers with the fingers of the hand that holds them, to the approximate unit of division, estimated by eye. Rotate the dividers counterclockwise through 180°, and then clockwise through 180°, and so on, until the desired number of units has been stepped off. If the last prick of the dividers falls short of the end of the line to be divided, increase the distance between the divider points proportionately. For example, to divide the line AB, Fig. 2.49, into three equal parts, the dividers are set by eye to approximately one-third the length AB. When it is found that the trial radius is too small, the distance between the divider points is increased by one-third the remaining distance. If the last prick of the dividers is beyond the end of the line, a similar decreasing adjustment is made.

Fig. 2.50 Proportional Dividers.



The student should avoid *cumulative errors*, which may result when the dividers are used to set off a series of distances end to end. To set off a large number of equal divisions, say 15, first set off 3 equal large divisions and then divide each into 5 equal parts. Wherever possible in such cases, use the scale instead of the dividers, as described in §2.33, or set off the total and then divide into the parts by means of the parallel-line method, §§4.15 and 4.16.

2.42 Proportional Dividers.

For enlarging or reducing a drawing, proportional dividers, Fig. 2.50, are convenient. They may be used also for dividing distances into a number of equal parts, or for obtaining a percentage reduction of a distance. For this purpose, points of division are marked on the instrument so as to secure the required subdivisions readily. Some instruments are calibrated to obtain special ratios, such as $1:\sqrt{2}$, the diameter of a circle to the side of an equal square, and feet to meters.

2.43 The Bow Instruments.

The bow instruments are classified as the *bow dividers, bow pen*, and *bow pencil*. A combination pen and pencil bow, usually with center-wheel adjustment, Fig. 2.51, and separate instruments with either side-wheel or center-wheel adjustment, Fig. 2.52, are available. The choice is a matter of personal preference.

2.44 Using the Bow Instruments.

The bow pencil and bow pen are used for drawing circles of approximately 25 mm (1″) radius or

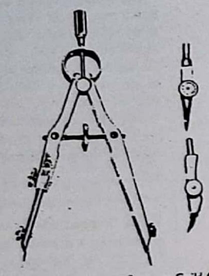


Fig. 2.51 Combination Pen and Pencil Bow.

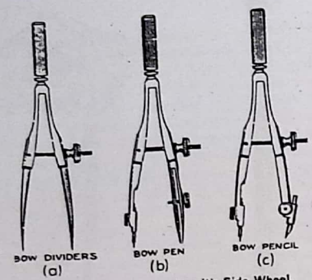


Fig. 2.52 Bow Instruments with Side Wheel.

smaller. The bow dividers are used for the same purpose as the large dividers, but for smaller (approximately 25 mm or less) spaces and more accurate work.

Whether the center-wheel or side-wheel instrument is used, the adjustment should be made with the thumb and finger of the hand that holds the instrument, Fig. 2.53 (a). The instrument is manipulated by twirling the head between the thumb and fingers, (b).

The lead is sharpened in the same manner as for the large compass, §2.38, except that for small radii, the inclined cut may be turned *inside* if preferred, Fig. 2.54 (a). For general use, the lead should be turned to the outside, as shown at (b). In either case, always keep the compass lead sharpened. *Avoid stubby compass leads*, which cannot be properly sharpened. At least 6 mm ($\frac{1}{4}$") of lead should extend from the compass at all times.

In adjusting the needle point of the bow pencil or bow pen, be sure to have the needle extending slightly longer than the pen or lead, Fig. 2.45 (d), the same as for the large compass.

In drawing small circles, greater care is necessary in sharpening and adjusting the lead and the needle point, and especially in accurately setting the desired radius. If a 6.35 mm ($\frac{1}{4}$") diameter circle is to be drawn, and if the radius is "off" only 0.8 mm ($\frac{1}{32}$") the total error on diameter is approximately 25 percent, which is far too much error.

Appropriate templates may be used also for drawing small circles. See Fig. 2.81.

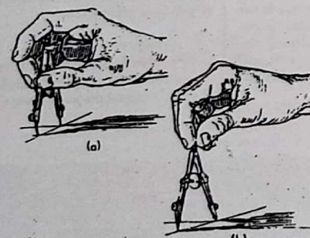


Fig. 2.53 Using the Bow Instruments.

2.45 Drop Spring Bow Pencil and Pen.

These compasses, Fig. 2.55, are designed for drawing multiple identical small circles, such as drill holes or rivet heads. A central pin is made to move easily up and down through a tube to which the pen or pencil unit is attached. To use the instrument, hold the knurled head of the tube between the thumb and second finger, placing the first finger on top of the knurled head of the pin. Place the point of the pin at the desired center, lower the pen or pencil until it touches the paper, and twirl the instrument clockwise with the thumb and second finger. Then lift the tube independently of the pin, and finally lift the entire instrument.

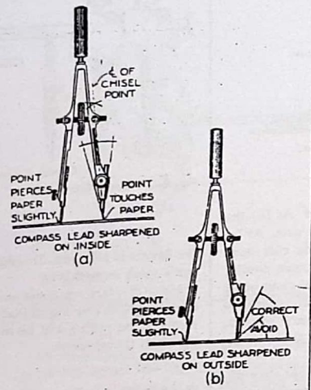


Fig. 2.54 Compass-Lead Points.

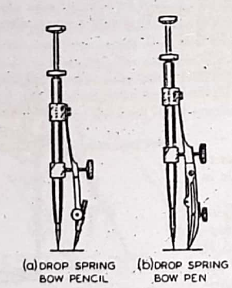


Fig. 2.55 Drop Spring Bow Instruments.

2.46 To Lay Out a Sheet.

Fig. 2.56. (See also Layout A-2, inside back cover.) After the sheet has been attached to the board, as explained in §2.7, proceed as follows:

I. Using the T-square, draw a horizontal *trim line* near the lower edge of the paper; and then using the triangle, draw a vertical trim line near the left edge of the paper. Both should be *light construction lines*.

II. Place the scale along the lower trim line with the full-size scale up. Draw short light dashes *perpendicular* to the scale at the required distances. See Fig. 2.40 (a).

III. Place the scale along the left trim line with the full-size scale to the left, and mark the required distances with short light dashes perpendicular to the scale.

IV. Draw horizontal construction lines with the aid of the T-square through the marks at the left of the sheet.

V. Draw vertical construction lines, *from the bottom upward*, along the edge of the triangle through the marks at the bottom of the sheet.

VI. Retrace the border and the title strip to make them heavier. Notice that the layout is made independently of the edges of the paper.*

2.47 Technique of Pencil Drawing.

By far the greater part of commercial drafting is executed in pencil. Most prints or photocopies are made from pencil tracings, and all ink tracings must be preceded by pencil drawings. It should therefore be evident that skill in drafting chiefly implies skill in pencil drawing.

Technique is a style or quality of drawing imparted by the individual draftsman to his work. It is characterized by crisp black line-

* In industrial drafting rooms the sheets are available, cut to standard sizes, with border and title strips already printed. Drafting supply houses can supply such papers, printed to order, to schools for little extra cost.

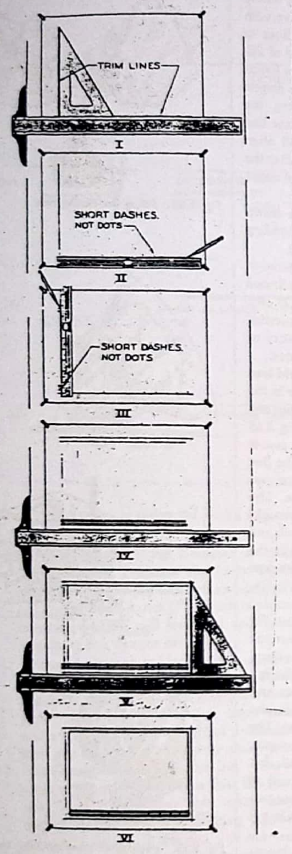


Fig. 2.56 To Lay Out a Sheet
(Layout A-2; see inside back cover).

work and lettering. Technique in lettering is discussed in §3.12.

1. DARK, ACCENTED LINES. The pencil lines of a finished pencil drawing or tracing should be very dark, Fig. 2.57. Dark crisp lines are necessary to give punch or snap to the drawing. Ends of lines should be accented by a little extra pressure on the pencil, (a). Curves should be as dark as other lines, (b). Hidden-line dashes and center-line dashes should be carefully estimated as to length and spacing, and should be of uniform width throughout their length, (c) and (d).

Dimension lines, extension lines, section lines, and center lines also should be dark. The difference between these lines and visible lines is mostly in width—there is very little difference, if any, in blackness.

A simple way to determine whether your lines on tracing paper or cloth are dense black is to hold the tracing up to the light, Fig. 2.58. Lines that are not opaque black will not print clearly by blueprinting or otherwise.

Construction lines should be made with a sharp, hard pencil and *should be so light that they need not be erased* when the drawing is completed.

2. CONTRAST IN LINES. Contrast in pencil lines should be similar to that of ink lines; that is, the difference between the various lines should be mostly in the *widths* of the lines, with little if any difference in the degree of darkness, Fig. 2.59. The visible lines should contrast strongly with the thin lines of the drawing. If necessary, draw over a visible line several times to get the desired thickness and darkness. A short retracing stroke backwards (to the left), producing a jabbing action, results in a darker line.

2.48 Pencil Tracing.

While some pencil tracings are made of a drawing placed underneath the tracing paper (usually when a great deal of erasing and changing is necessary on the original drawing), most drawings today are made directly in pencil on tracing paper, pencil tracing cloth, films, or vellum. These are not tracings but pencil drawings, and the methods and technique are the same as previously described for pencil drawing.

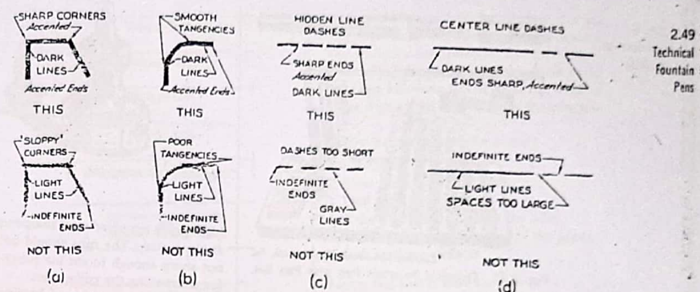


Fig. 2.57 Technique of Lines (Enlarged).

In making a drawing directly on a tracing medium, a smooth sheet of heavy white drawing paper should be placed underneath. Such a sheet is known as a *backing sheet*. The whiteness of the backing sheet improves the visibility of the lines, and the hardness of the surface makes it possible to exert pressure on the pencil and produce dense black lines without excessive grooving of the paper.

These tracings, or drawings, are intended to be reproduced by blueprinting or by other kindred processes, Chapter 15, and all lines must be dark and cleanly drawn.

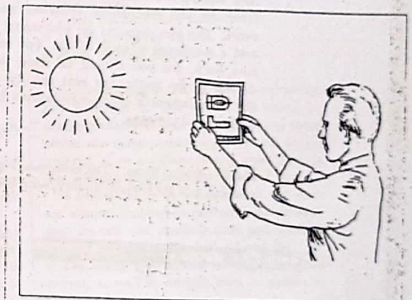
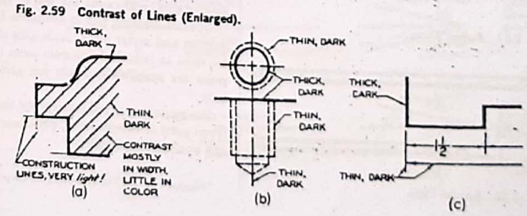


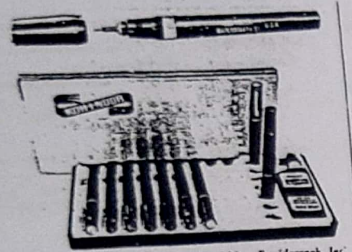
Fig. 2.58 Testing Density of Lines.

2.49 Technical Fountain Pens.

The *technical fountain pen*, Fig. 2.60, with the tube and needle point, is available in several line

Fig. 2.59 Contrast of Lines (Enlarged).





Courtesy Koh-I-Noor Rapidograph, Inc.

Fig. 2.60 Technical Fountain Pen and Pen Set.

widths. Many prefer this type of pen, for the line widths are fixed and it is suitable for freehand and mechanical lettering and line work. The pen requires an occasional filling and a minimum of skill to use. For uniform line work, the pen should be used perpendicular to the paper. For best results, follow the manufacturer's recommendations for operation and cleaning.

2.50 Ruling Pens.

The *ruling pen*, Fig. 2.61, should be of the highest quality, with blades of high-grade tempered steel sharpened properly at the factory. The nibs should be sharp, but not sharp enough to cut the paper. See §2.56 for sharpening the ruling pen.

The *detail pen*, capable of holding a considerable quantity of ink, is extremely useful for drawing long heavy lines, (b). This type of pen is preferred for small amounts of ink work as the pen is easily adjusted for the desired line width and is readily cleaned after use.

For methods using the ruling pen, see §2.53.

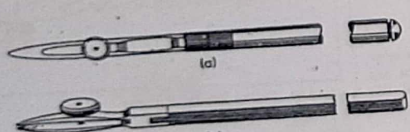


Fig. 2.61 Ruling Pens.

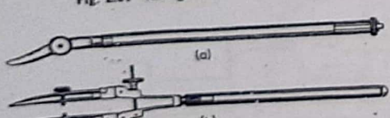


Fig. 2.62 Special Pens.

Fig. 2.63 Drawing Ink.

2.51 Special Pens.

The *contour pen*, Fig. 2.62 (a), is used for tracing freehand curves, such as contour lines on maps. The *railroad pen*, (b), is used for drawing two parallel lines straight or moderately curved, as for roads and railroads.

2.52 Drawing Ink.

Drawing ink, Fig. 2.63, is composed chiefly of carbon in colloidal suspension and gum. The fine particles of carbon give the deep, black luster to the ink, and the gum makes it waterproof and quick to dry. The ink bottle should not be left uncovered, as evaporation will cause the ink to thicken.

Special drawing ink is available for use on acetate and mylar films. Such inks should not be used in technical fountain pens unless the pens are specifically made for acetate-based inks.

For removing dried waterproof drawing ink from pens or instruments, pen-cleaning fluids are available at dealers.*

*Higgins Pen Cleaner or Leroy Pen Cleaning Fluid.

2.53 Use of the Ruling Pen.

The ruling pen, Fig. 2.61, is used to ink lines drawn with instruments, never to ink freehand lines or freehand lettering. The proper method of filling the pen is shown in Fig. 2.64. The hands may be steadied by touching the little fingers together. Twisting instead of pulling the stopper from a new bottle of ink, or one that has not been used for some time, will often save the stopper from being broken. After the pen has been filled, the ink should stand about 6 mm ($\frac{1}{4}$") deep in the pen.

Horizontal lines and vertical lines are drawn in the same manner as for the corresponding pencil lines, Figs. 2.21 (a) and 2.22 (a).

Practically all the difficulties encountered in the use of the ruling pen may be attributed to (1) incorrect position of the pen, (2) lack of allowance for the quick-drying properties of drawing ink, and (3) improper control of thickness of lines and incorrect junctures.

1. Position of the Pen. The pen should lean at an angle of about 60° with the paper in the direction in which the line is being drawn and in a vertical plane containing the line, Fig. 2.65 (a) and (b). In general, the more the pen is leaned toward the paper, the thicker the line will be; and the more nearly vertical the pen is held, the thinner the line will be. The thumbscrew is faced away from the straight edge, and is adjusted, (c), with the thumb and forefinger of the same hand that holds the instrument. The correct position of the pen and the resulting correct line are shown in Fig. 2.66 (a).

If the nibs are pulled tightly against the T-square or triangle, the effect is to close the nibs and thus reduce the thickness of the lines, (b). If the pen is held as shown at (c), the ink will come in contact with the T-square and paper at the same time and will run under the T-square and cause a blot on the drawing. The same result may occur if, in filling the pen, ink is deposited on the outside of the nib that touches the T-square. If the pen is held as shown at (d), the outside nib of the ruling pen may not touch the paper, and the line is apt to be ragged.

When the line has been correctly drawn, care must be exercised not to touch the wet

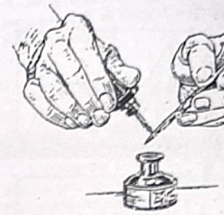


Fig. 2.64 Filling the Ruling Pen.

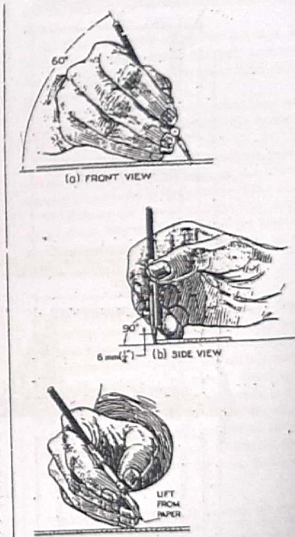


Fig. 2.65 Position of Hand in Using the Ruling Pen.

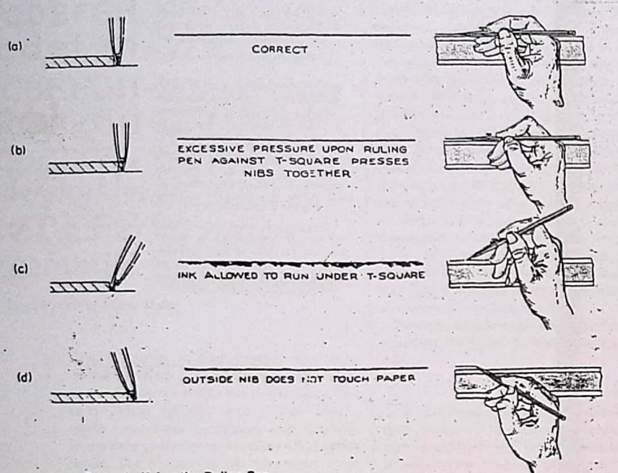


Fig. 2.66 Errors in Using the Ruling Pen.

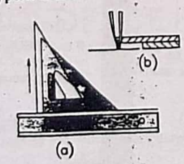
ink when removing the T-square or triangle. The triangle or T-square should be carefully moved away from the line before being picked up. If more than 6 mm ($\frac{1}{4}$") of ink is placed in the pen, the ink will flow too readily, thus increasing the danger of a blot.

Some draftsmen prefer to place another triangle under the one being used, as shown in Fig. 2.67, to raise the first triangle above the paper and thus prevent ink from running under the edge. This is especially useful if the lines are heavy and blots may easily occur.

2. Correct Use of Drawing Ink. One of the most common difficulties is that the pen will not "feed." A clogged pen often may be started by touching it to drafting tape or the back of a finger. If the pen will not make a fine line, the nibs have been screwed too close together, the ink has been allowed to partially dry and thicken in the pen, the ink in the bottle is too thick from age and exposure to air, or the pen is dull and needs sharpening.

The pen should never be filled until the draftsman is ready to use it, because the ink dries quickly when not flowing from the pen. *Ink should never be allowed to dry in any instrument. Never lay a ruling pen down with ink in it.* Some drawing inks have an acid content that will "pit" a ruling pen if left to dry in the pen repeatedly. The student should clean the pen frequently by slipping a stiff blotter or a folded cloth between the nibs. *Sandpaper should never be used to remove dry ink.* Dry ink should be removed by scraping very lightly with a pen knife. Ruling pens constructed so that the

Fig. 2.67 Inking.



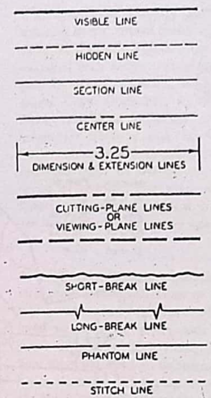


Fig. 2.68 Alphabet of Ink Lines (Full Size).

nibs will separate for cleaning are available in a number of good designs.

The stopper should always be kept in the bottle when it is not in use, since exposure of the ink to the air causes it to become thick and difficult to use.

3. How to Control Thickness of Lines. The various widths of lines used for inked drawings or tracings are shown in Fig. 2.68. The draftsman must first develop a trained eye to distinguish fine variations, and must also acquire skill in producing the desired widths. The student must remember that the thumbscrew alone does not control the width of the line. The following factors affect the width of a line with a given setting of the thumbscrew.

Factors that tend to make line heavier:

1. Excess ink in the pen.
2. Slow movement of the pen.
3. Dull nibs.
4. Caked particles of ink on the nibs.
5. Leaning the pen more toward the paper.
6. Soft working surface.

Factors that tend to make line finer:

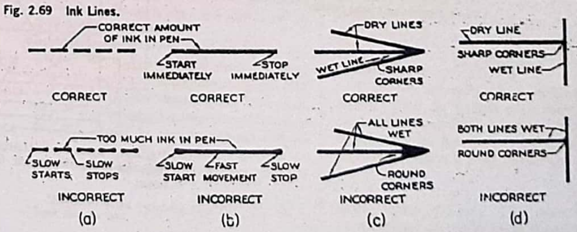
1. Small amount of ink in the pen.
2. Rapid movement of the pen.
3. Sharp nibs.
4. Fresh ink and clean pen.
5. Pen more nearly vertical.
6. Hard working surface.

Before making a new ink line on a drawing, the thickness of line should be tested by drawing a test line on a separate piece of paper under the same conditions. *Never test the pen freehand, or on a different kind of paper.* Always use a straightedge, and use identical paper.

If excess ink is in the pen or if wet lines are allowed to intersect previously drawn lines that are still wet, teardrop ends and rounded corners will result, Fig. 2.69 (a) and (b).

The ruling pen is used in inking irregular curves, as well as straight lines, as shown in

Fig. 2.69 Ink Lines.



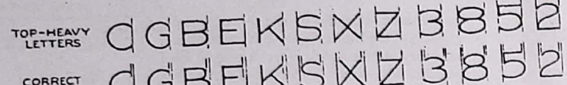


Fig. 3.5 Stability of Letters.

black areas are carefully balanced to produce a pleasing effect. Letters are designed to *look* well and some allowances must be made for errors in perception. Note that in Fig. 3.18 the width of the standard H is less than its height to eliminate a square appearance; the numeral 8 is narrower at the top to give it stability; and the width of the letter W is greater than its height for the very acute angles in the W give it a compressed appearance. Such acute angles should be avoided in good letter design.

3.9 Stability.

If the upper portions of certain letters and numerals are equal in width to the lower portions, the characters appear top-heavy. To correct this, the upper portions are reduced in size where possible, thereby producing the effect of *stability* and a more pleasing appearance, Fig. 3.5.

If the central horizontal strokes of the letters B, E, F, and H are placed at midheight, they will appear to be below center. To overcome this optical illusion, these strokes should be drawn slightly above the center.

3.10 Lettering Pencils.

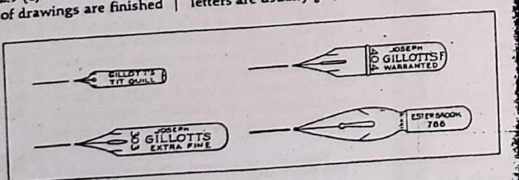
Pencil letters can be best made with a medium-soft lead with a conical point, Fig. 2.12 (c), or with a suitable thin-lead pencil, Fig. 2.9 (c).

Today the majority of drawings are finished in pencil and reproduced as blueprints, ammonia prints, or other reproductions. To reproduce well by any process, the pencil lettering must be dense black, as should all other final lines on the drawing. The right lead to use depends largely upon the amount of tooth in the paper, the rougher papers requiring the harder pencils. The lead should be soft enough to produce jet-black lettering, yet hard enough to prevent excessive wearing down of the point, crumbling of the point, and smearing of the graphite.

3.11 Lettering Pens.

The choice of a pen for lettering is determined by the size and style of the letters, the thickness of stroke desired, and the personal preference of the draftsman. These conditions vary so much that it is impossible to specify any certain pen to use. The student who is zealous in his efforts to develop his ability to letter will learn by experience which pen is best suited to his purpose. Fig. 3.6 shows a variety of the best pen points in a range from the *tit-quill*, the finest, to the *ball-pointed*, the coarsest. The widths of the lines made by the several pens are shown full size. The medium widths, represented by the Gillott's 303 and 404 (or equivalent) are suitable for lettering notes and dimensions on drawings, in which case the letters are usually $\frac{1}{8}$" (3.2 mm) high. For lettering $\frac{3}{16}$" (4.8 mm) to $\frac{1}{4}$" (6.4 mm), as for titles, the ball-pointed pens may be used.

Fig. 3.6 Pen Points (Full Size).



Letters more than $\frac{1}{2}$" (12.7 mm) in height generally require a special pen, Fig. 3.7. The *Speedball* pens are excellent for Gothic letters, Fig. 3.1, and are often used for titles and for the large drawing numbers in the corner of the title block, Figs. 14.15 to 14.17. Other styles of Speedball pens are suitable for Roman or text letters. These pens have the additional advantage of being low in cost. The *Barch-Payzant Lettering Pen* is available in eleven sizes ranging from 000 (very coarse) to 8 (very fine). The size 5 pen produces a stroke fine enough to be used for the usual lettering on technical drawings.

The *Henry Tank Pen* is available in both plain and ball points, and has a simple device under the pen to hold ink and prevent the nibs from spreading.

The *Leroy Pen* is also available in a wide range of sizes, and is highly recommended. It can be used in a regular pen staff for freehand lettering, or in the scriber for mechanical lettering, Fig. 3.31.

Fig. 3.7 Special Pens for Freehand Lettering.

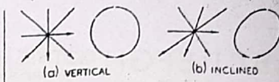


Fig. 3.8 Basic Lettering Strokes.

The Koh-I-Noor "Rapidograph" or similar technical fountain pens are of a different type in which the point is a small tube. See §2.48. A small automatic plunger rod keeps the ink flowing.

Any lettering pen must be kept clean. All of these pens should be frequently cleaned with cleaning fluid to keep them in service. Drawing ink corrodes the point of the pen if allowed to dry and builds up the width of the point, so that it has to be cleaned anyway. To remove dried drawing ink from any instrument, scrape carefully with a knife or use a special pen-cleaning fluid.*

3.12 Technique of Lettering.

Any normal person can learn to letter if he is persistent and intelligent in his efforts. While it is true that "practice makes perfect," it must be understood that practice alone is not enough; it must be accompanied by *continuous effort to improve.*

Lettering is freehand drawing and not writing. Therefore, the six fundamental strokes and their direction for freehand drawing are basic to lettering, Fig. 3.8. The horizontal strokes are drawn to the right, and all vertical, inclined, and curved strokes are drawn downward.

Good lettering is always accomplished by conscious effort and is never done well otherwise, though good muscular coordination is of great assistance. Ability to letter has little relationship to writing ability; excellent letterers are often poor writers.

There are three necessary steps in learning to letter:

1. Knowledge of the proportions and forms of the letters and the order of the strokes. No one can make a good letter who does not

*Higgins Ink Co. or Keuffel & Esser Co.

have a clear mental image of the correct form of the letter.

2. Knowledge of composition—the spacing of letters and words. Rules governing composition should be thoroughly mastered, §3.24.
3. Persistent practice, with *continuous effort to improve.*

First, sharpen the pencil to a needle point; then dull the point *very slightly* by marking on paper while holding the pencil vertically and rotating the pencil to round off the point.

Pencil lettering should be executed with a fairly soft pencil, such as an F or H for ordinary paper; and the strokes should be *dark* and *sharp*, not gray and blurred. Many draftsmen acquire "snap" in their lettering by accenting or "bearing down" at the beginning and the end of each stroke. Beginners should be careful not to overdo this trick or to try it without first acquiring the ability to form letters of correct shape. After a few letters are made, the pencil will tend to become dull. In order to wear the lead down uniformly and thereby to keep the lettering sharp, turn the pencil frequently to a new position.

The correct position of the hand in lettering is shown in Fig. 3.9. In general, draw vertical strokes downward or toward you with a finger movement, and draw horizontal strokes from left to right with a wrist movement without turning the paper.

The forearm should be approximately at right angles to the line of lettering, and *resting on the board*—never suspended in mid-air. If the board is small, revolve it counterclockwise about 45°, until the line of lettering is approximately perpendicular to the forearm. If the board is larger and cannot be moved, shift your body around toward the left side of the board to approximate this position as nearly as possible.

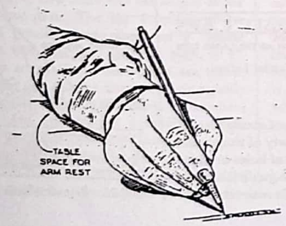


Fig. 3.9 Position of Hand in Lettering.

Since practically all pencil lettering will be reproduced by blueprinting or otherwise, the letters should be dense black. Avoid hard pencils that, even with considerable pressure, produce gray lines. Use a fairly soft pencil and keep it sharp by frequent dressing of the point on the sandpaper pad or file. An example (full size) of pencil lettering exhibiting correct technique is shown in Fig. 3.10.

In ink lettering, most beginners have a tendency toward excessive pressure on the pen point, thus producing strokes of varying widths. Select a pen point that will make strokes of correct thickness without spreading the nibs. The correct position of the pen is shown in Fig. 3.9. Move the pen with light uniform pressure, and allow the ink to *flow off* the point instead of being forced off by pressure upon the point.

Before an inked tracing is lettered, all guide lines should be drawn in pencil directly upon the tracing paper or cloth if the guidelines underneath are too indistinct to serve their purpose well as a guide for inking.

3.13 Left-Handers.

All evidence indicates that the left-handed draftsman is just as skillful as the right-hander, and this includes skill in lettering. The most important step in learning to letter is to learn the correct shapes and proportions of letters, and these can be learned as well by the left-hander as by anyone else. The left-hander does have a problem of developing a system of strokes that seems most suitable for himself. The strokes shown in Figs. 3.18 and 3.19 are for right-handers. The left-hander should experiment with each letter to find out which strokes are best for him. The habits of left-handers vary so much that it is futile to suggest a standard system of strokes for all left-handers.

THE IMPORTANCE OF GOOD LETTERING CANNOT BE OVER-EMPHASIZED. THE LETTERING CAN EITHER MAKE OR BREAK AN OTHERWISE GOOD DRAWING.

PENCIL LETTERING SHOULD BE DONE WITH A FAIRLY SOFT SHARP PENCIL AND SHOULD BE CLEAN-CUT AND DARK. ACCENT THE ENDS OF THE STROKES.

Fig. 3.10 Pencil Lettering (Full Size).

The left-hander, in developing his own system of strokes, should decide upon strokes he can make best with the pen, and he should then use the same strokes for pencil lettering. Pen strokes can be drawn in the direction the pen is leaned, or at right angles to this, or in curved paths between the two. The pen should never be jabbed in the direction contrary to the way the pen is leaned, as the point has a tendency to dig into the paper. The strokes should, therefore, be those which are in harmony with the natural and intended use of the pen point.

The regular left-hander assumes a natural position exactly opposite to that of the right-hander, but he will be able to use many of the same strokes as shown for right-handers, with perhaps some minor differences. As prescribed for right-handers, he will draw all vertical strokes downward, and may also draw all horizontal strokes from left to right. He may, however, prefer to draw horizontal strokes from right to left, and he should do this if it seems more natural to him. Also he may wish to change the order of drawing horizontal strokes, so that in the case of the E, for example, the top stroke would be drawn first and the bottom stroke drawn last. If this is done, the pen or pencil will not tend to hide strokes already drawn. Curved strokes will be essentially the same as for right-handers, with perhaps some adjustments of the starting and ending points of the curves.

The hooked-wrist left-hander has a more serious problem, and each such person will have to adopt a system that seems best for his own particular habits. Vertical strokes may be drawn downward as for right-handers, but many hooked-wrist left-handers will find it easier to draw vertical strokes upward. Horizontal strokes will most certainly be drawn from right to left with a finger movement, for the pencil or pen will dig into the paper if pushed in the other direction. Furthermore, the order of horizontal strokes will be to do those at the bottom first, and those at the top last, as described above for the letter E. Since a sheet is lettered from the top downward, the hooked-wrist left-hander must move his hand over lines of lettering previously made. Therefore, a piece of paper should be placed over the lettered areas so that smearing of the graphite cannot occur.

If you are left-handed, advise your instructor at once. On examinations in which lettering is tested, use strokes that you have found most suitable for your own use, and letter a statement in the margin to the effect that you are left-handed.

3.14 Guide Lines.

Extremely light horizontal guide lines are necessary to regulate the height of letters. In addition, light vertical or inclined guide lines are needed to keep the letters uniformly vertical or inclined. Guide lines are absolutely essential for good lettering, and should be regarded as a welcome aid, not as an unnecessary requirement. Paradoxically, the better draftsman always uses guide lines, while the unskilled letterer who needs them most is inclined to slight this important step. See Fig. 3.11.

Make guide lines for finished pencil letter-

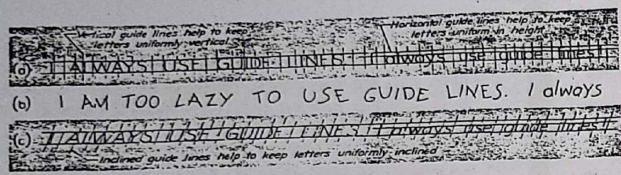


Fig. 3.11 Guide Lines.

ing *so lightly that they need not be erased*, as indeed they cannot be after the lettering has been completed. Guide lines should be barely visible at arm's length. Use a relatively hard pencil, such as a 4H to 6H, with a long, sharp, conical point, Fig. 2.12 (c). If the letters are inked, the guide lines may be removed with the Artgum after the ink is dry, Fig. 2.17 (b).

In preparation for ink lettering, complete guide lines should be drawn, and the letters first drawn lightly in pencil. Experienced letterers often draw the complete guide lines, and then letter directly in ink, without first penciling the letters.

3.15 Guide Lines for Capital Letters.

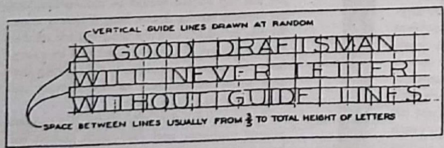
Guide lines for vertical capital letters are shown in Fig. 3.12. On working drawings, capital letters are commonly made ⅛" (3.2 mm) high, with the space between lines of lettering from three-fifths to the full height of the letters. The vertical guide lines are not used to space the letters (as this should always be done by eye while lettering), but only to keep the letters uniformly vertical, and they should accordingly be drawn at random. Where several lines of letters are to be made, these vertical guide lines should be continuous from top to bottom of the lettered area, as shown.

Guide lines for inclined capital letters are shown in Fig. 3.13. The spacing of horizontal guide lines is the same as for vertical capital lettering. The American National Standard slope of 2 in 5 (or 68.2° with horizontal) may be established by drawing a "slope triangle," as shown at (a), and drawing the guide lines at random with the T-square and triangle, as shown at (b). Special triangles for the purpose may be used, as shown at (c), or the lines may be drawn with the Braddock-Rowe Lettering Triangle, Fig. 3.16, or the Ames Lettering Guide, Fig. 3.17.

A simple method of spacing horizontal guide lines is to use the scale, as shown in Fig. 3.14 (a), and merely set off a series of ⅛" spaces, making both the letters and the spaces between lines of letters ⅛" high. Another method of setting off equal spaces, ⅛" or otherwise, is to use the bow dividers, as shown at (b).

If it is desired to make the spaces between lines of letters less than the height of the letters, the methods shown at (c) and (d) will be convenient. At (c) the scale is placed diagonally, the letters in this case being four units

Fig. 3.12 Guide Lines for Vertical Capital Letters.



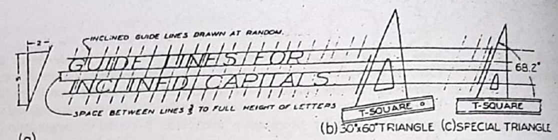


Fig. 3.13 Guide Lines for Inclined Capital Letters.

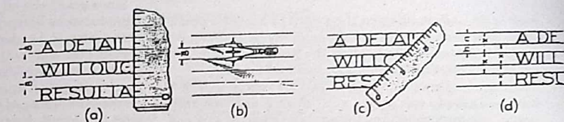


Fig. 3.14 Spacing of Guide Lines.

high and the spaces between lines of lettering being three units. If the scale is rotated clockwise about the zero mark as a pivot, the height of the letters and the spaces between lines of letters diminish but remain proportional. If the scale is moved counterclockwise, the spaces are increased. The same unequal spacing may be accomplished with the bow dividers, as shown at (d). Let distance $x = a + b$, and set off x-distances, as shown.

When large and small capitals are used in combination, the small capitals should be three-fifths to two-thirds as high as the large capitals, Fig. 3.15. This is in conformity with the guide-line devices described below, §§3.16 and 3.17.

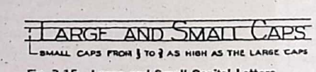


Fig. 3.15 Large and Small Capital Letters.

3.16 Lettering Triangles.

Lettering triangles, which are available in a variety of shapes and sizes, are provided with sets of holes in which the pencil is inserted and the guide lines produced by moving the triangle with the pencil point along the T-square. The *Braddock-Rowe Lettering Triangle*, Fig. 3.16, is convenient for drawing guide lines for lettering and dimension figures, and also for drawing section lines. In addition, the triangle is used as a utility 45° triangle. The numbers at the bottom of the triangle indicate heights of letters in thirty-seconds of an inch. Thus, to draw guide lines for ⅛" (3.2 mm) capitals, use the No. 4 set of holes. For lower-case letters, draw guide lines from every hole; for capitals, omit the second hole in each group. The spacing of holes is such that the lower portions of lower-case letters are two-thirds as high as the capitals,

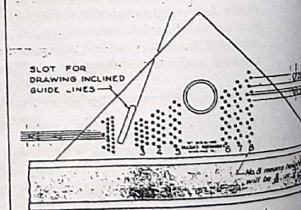


Fig. 3.16 Braddock-Rowe Lettering Triangle.

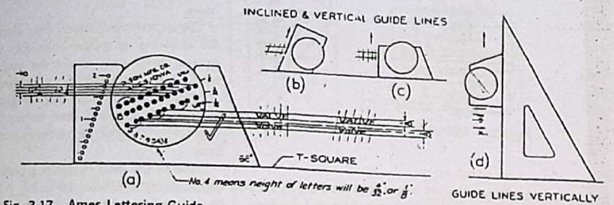


Fig. 3.17 Ames Lettering Guide.

and the spacing between lines of lettering is also two-thirds as high as the capitals.

The column of holes at the extreme left is used to draw guide lines for dimension figures $\frac{1}{8}$" (3.2 mm) high and fractions $\frac{1}{4}$" (6.4 mm) high, and also for section lines $\frac{1}{16}$" (1.6 mm) apart.

3.17 Ames Lettering Guide.

The *Ames Lettering Guide*, Fig. 3.17, is an ingenious transparent plastic device composed of a frame holding a disc containing three columns of holes. The vertical distances between the holes may be adjusted quickly to the desired spacing for guide lines or section lines by simply turning the disc to one of the settings indicated at the bottom of the disc. These numbers indicate heights of letters in thirty-seconds of an inch. Thus, for $\frac{1}{8}$" high letters, the No. 4 setting would be used. The center column of holes is used primarily to draw guide lines for numerals and fractions, the height of the whole number being two units and the height of the fraction four units. The No. 4 setting of the disc will provide guide lines for $\frac{1}{8}$" whole numbers, with fractions twice as high, or $\frac{1}{4}$", as shown at (a). Since the spaces are equal, these holes can also be used to draw equally spaced guide lines for lettering, or to draw section lines. For desired equivalent metric spacing, the Ames Lettering Guide with metric calibrations is used for the disc setting.

The two outer columns of holes are used to draw guide lines for capitals or lower-case letters, the column marked three-fifths being used where it is desired to make the lower portions of lower-case letters three-fifths the total height of the letters, and the column marked two-thirds being used where the lower portion is to be two-thirds the total height of the letters. In each case, for capitals, the middle hole of each set is not used. The two-thirds and three-fifths also indicate the spaces between lines of letters.

The sides of the guide are used to draw vertical or inclined guide lines, as shown at (b) and (c).

The Ames Lettering Guide is also available with metric graduations.

3.18 Vertical Capital Letters and Numerals.

Fig. 3.18. For convenience in learning the proportions of the letters and numerals, each character is shown in a grid 6 units high. Numbered arrows indicate the order and direction of strokes. The widths of the letters can be easily remembered. The letter I, or the numeral 1, has no width. The W is 8 units wide ($1\frac{1}{3}$ times the height) and is the widest letter in the alphabet. All the other letters or numerals are either 5 or 6 units wide, and it is easy to remember the 6-unit letters because when assembled they spell TOM Q. VAXY. All numerals, except the 1, are 5 units wide.

All horizontal strokes are drawn to the right, and all vertical, inclined, and curved strokes are drawn downward, Fig. 3.8. Most of the strokes are natural and easy to remember. All

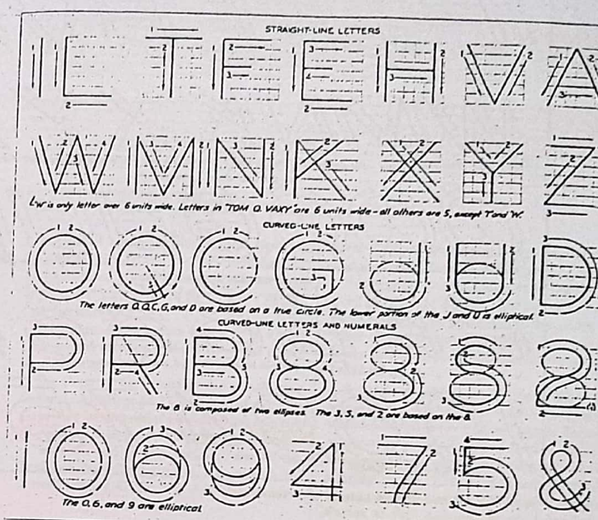


Fig. 3.18 Vertical Capital Letters and Numerals.

the strokes and proportions should be thoroughly learned in the beginning, and it is recommended that this be done by practice sketching the vertical capital letters on cross-section paper, making the letters 6 squares high.

As shown in Fig. 3.18, the letters are classified as *straight-line letters* or *curved-line letters*. On the third row, the letters O, Q, C, and G are all based on the circle. The lower portions of the J and U are semiellipses, and the right sides of the D, P, R, and B are semicircular. The 8, 3, S, and 2 are all based on the figure 8, which is composed of a small ellipse over a larger ellipse. The 6 and 9 are based on the elliptical zero. The lower part of the 5 is also elliptical in shape.

3.19 Inclined Capital Letters and Numerals.

Fig. 3.19. The order and direction of the strokes and the proportions of the inclined capital letters and numerals are the same as those for the vertical characters. The methods of drawing guide lines for inclined capital letters are given in §3.15, and for numerals in §3.20.

Inclined capitals may be regarded as oblique projections, §§17.1 and 17.2, of vertical capitals. In the inclined letters, the circular parts become elliptical, the major axes of the ellipses based on the O making an angle of 45° with horizontal. The letters are classified as *straight-line letters* or *curved-line letters*, most of the curves being elliptical in shape. Therefore, skill in inclined lettering depends somewhat

Space between words = letter "O" — Space "O" after comma

SPACE O WORDS WELL APART, O AND LETTERS CLOSELY.
(a)

AVOIDTHISKINDOFSPACING:IT'SHARDTOREAD
(b)

Lower-case O words also should be kept well apart.
Space = letter "O"
(c)

Fig. 3.29 Spacing Words.

which is frequently the case in titles, Figs. 3.35 to 3.37, number the letters as shown, with the space between words considered as one letter. Then place the middle letter on center, making allowance for narrow letters (I's) or wide letters (W's) on either side. The X at (b) is placed slightly to the left of center to compensate for the letter I, which has no width. Check with the dividers to make sure that distances a are exactly equal.

Another method is to letter roughly a trial line of lettering along the bottom edge of a scrap of paper, place it in position immediately above, as shown at (c), and then letter the line in place. Be sure to use guide lines for the trial lettering.

If the lettering is being done on tracing paper or cloth, the trial letters can be placed underneath, arranged for lettering to a stop line or "on center," and then lettered directly over or with slight improvement as may be desired, Fig. 3.35.

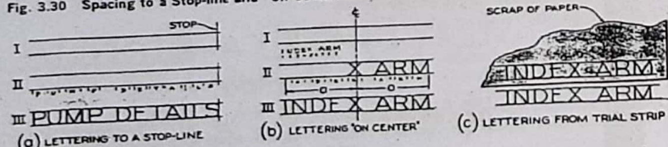
3.25 Lettering Devices.

The *Leroy Lettering Instrument,* Fig. 3.31, is perhaps the most widely used lettering device. A guide pin follows grooved letters in a template, and the inking point moves on the paper. By adjusting the arm on the instrument, the letters may be made vertical or inclined. A number of templates and sizes of pens is available, including templates for a wide variety of "built-up" letters similar to those made by the Varigraph and Letterguide, described below. Inside each pen is a cleaning pin used to keep the small tube open. These pins are easily broken, especially the small ones, when the pen is not promptly cleaned. To clean a pen, draw it across a blotter until all ink has been absorbed; then insert the pin and remove it and wipe it with a cloth. Repeat this until the pin remains clean. If the ink has dried, the pens may be cleaned with Leroy pen-cleaning fluid, available at dealers.

The *Wrico Lettering Guide,* Fig. 3.32, consists of a scriber and templates similar to the Leroy system. Wrico letters more closely resemble American National Standard letters than do the Leroy letters.

The *Varigraph* is a more elaborate device for making a wide variety of either single-stroke letters or "built-up" letters. As shown in Fig. 3.33, a guide pin (lower right) is moved along

Fig. 3.30 Spacing to a Stop-line and "on Center."



the grooves in a template, and the pen (upper left) forms the letters. The *Letterguide* scriber, Fig. 3.34, is a much simpler instrument, which also makes a large variety of styles and sizes of letters when used with the various templates available. It also operates with a guide pin moving in the grooved letters of the template, while the pen, which is mounted on an adjustable arm, makes the letters in outline.

Various forms of press-on lettering and special lettering devices (typewriters, etc.) are available. In whatever way the lettering is applied to the drawing and whatever style of lettering is used, the lettering must meet the requirements for legibility and microfilm reproduction.

Courtesy Keuffel & Esser Co.

Fig. 3.31 Leroy Lettering Instrument.

Courtesy Wood-Regan Instrument Co., Inc.

Fig. 3.32 Wrico Lettering Guide.

Courtesy The Varigraph Co., Inc.

Fig. 3.33 The Varigraph.

Courtesy Letterguide

Fig. 3.34 Letterguide.

3.26 Titles.

The composition of titles on machine drawings is relatively simple. In most cases, the title and related information are lettered in "title boxes" or "title strips," which are printed directly on the drawing paper, tracing paper, or cloth, Figs. 14.24 and 14.26 to 14.28. The main drawing title is usually centered in a rectangular space. This may be done by the method shown in Fig. 3.30 (b); or if the lettering is being done on tracing paper or cloth, the title may be lettered first on scrap paper and then placed underneath the tracing, as shown in Fig. 3.35, and then lettered directly over.

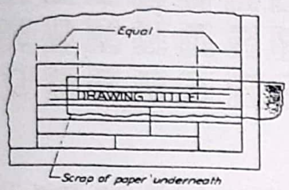


Fig. 3.35 Centering Title in Title Box.

If a title box is not used, the title of a machine drawing may be lettered in the lower-right corner of the sheet as a "balanced title," Fig. 3.36. A balanced title is simply one that is arranged symmetrically about an imaginary center line. These titles take such forms as the rectangle, the oval, the inverted pyramid, or any other simple symmetrical form.

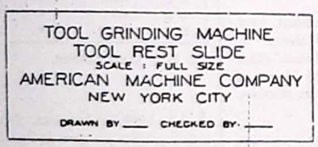


Fig. 3.36 Balanced Machine-Drawing Title.

On display drawings, or on highly finished maps or architectural drawings, titles may be composed of filled-in letters, usually Gothic or Roman, Fig. 3.37.

In any kind of title, the most important words are given the most prominence by making the lettering larger, heavier, or both. Other data, such as scale and date, are not so important and should not be prominently displayed.

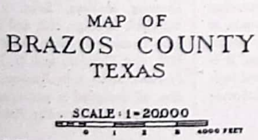


Fig. 3.37 Balanced Map Title.

3.27 Gothic Letters. Fig. 3.38. Among the many forms of Gothic styles, including Old English and German Gothic, the so-called *sans-serif* Gothic letter is the only one of interest to engineers. It is from this style that the modern single-stroke engineering letters, discussed in the early part of this chapter, are derived. While they are admittedly not as beautiful as many other styles, they are very legible and comparatively easy to make.

Sans-serif Gothic letters should be used on drawings where legibility and not beauty is the determining factor. They should be drawn in outline and then filled in, Fig. 3.39, with the thickness of the stems from one-fifth to about one-tenth the height of the letter. An attractive letter may be produced by making heavy outlines and not filling in, as for the letter H shown at (a). A slight spur may be added to the ends of the stem, as for the letter T at (a). An example of condensed Gothic is shown at (b).

3.28 Old Roman Letters. Fig. 3.40. The Old Roman letter is the basis of all of our letters, and is still regarded as the most beautiful. The letters on the base of Trajan's Column in Rome are regarded by many as the finest example of Old Roman letters.

The Old Roman letter is used mostly by architects. Because of its great beauty, it is used almost exclusively on buildings and for inscriptions on bronze or stone. Full-size "details" of the letter are usually drawn for such inscriptions.

Originally, this letter was made on manuscripts with a broad-point reed pen, Fig. 1.8; the wide stems were produced by downward strokes, and the narrow portions by horizontal strokes. A brief examination of any Roman letter will show why certain strokes are wide, while others are narrow.

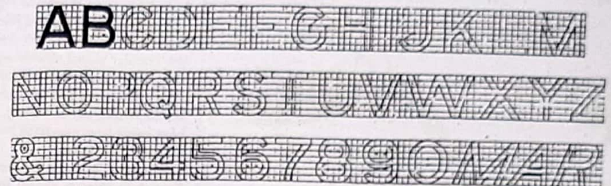


Fig. 3.38 Gothic Capital Letters.

Fig. 3.39 Gothic Letter Construction.

Fig. 3.40 Old Roman Capitals, with Numerals and Lower-case of Similar Design.

Several styles of steel broad-nib pens are available and are suitable for making Roman, Gothic, or Text letters, Figs. 3.1 and 3.41. If necessary, an ordinary pen may be used to "touch up" after using the broad-nib pen, or to add fine-line flourishes, as in Text letters.

As in the case of Gothic, Old Roman letters may be drawn in outline and filled in, or may be left in outline.

3.29 Modern Roman Letters. Figs. 3.42 and 3.43. The Modern Roman, or simply "Roman," letters were evolved during the eighteenth century by the type founders; the letters used in most modern newspapers, magazines, and books are of this style. The text of this book is set in Modern Roman Letters. These letters are often used on maps, especially for titles. They may be drawn in

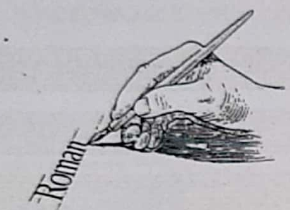


Fig. 3.41 Use of Broad-Nib Pen.

outline and then filled in, as shown in Fig. 3.42, or they may be produced with one of the broad-nib pens shown in Fig. 3.7.

If drawn in outline and filled in, the straight lines may be drawn with the ruling pen, and the circular curves drawn with the bow pen. The fillets and other noncircular curves are drawn freehand. The thickness of the stem, or broad stroke, varies widely, the usual thickness being from one-sixth to one-eighth of the height of the letter.

A typical example of the use of Modern Roman in titles is shown in Fig. 3.37. Their use on maps is discussed below.

Lower-case Modern Roman letters are shown in Fig. 3.43. The lower-case italics are known as *stump letters*. They are easily made freehand, and are often used on maps and on Patent Office drawings, §14.26.

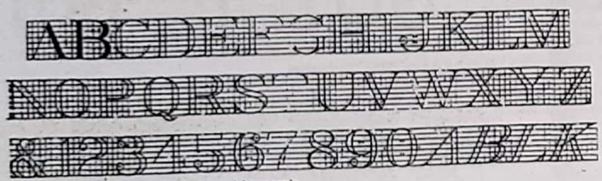
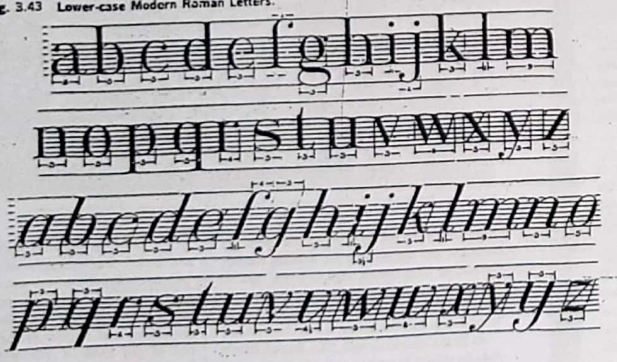


Fig. 3.42 Modern Roman Capitals and Numerals.

Fig. 3.43 Lower-case Modern Roman Letters.



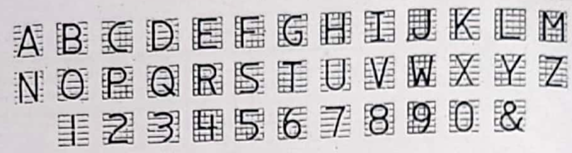


Fig. 3.44 Microfont Alphabet.

3.30 Lettering on Maps.

Modern Roman letters are generally used on maps, as follows:

1. *Vertical Capitals.* Names of states, countries, townships, capital cities, large cities, and titles of maps. See §3.26.
2. *Vertical Lower-case.* (First letter of each word a capital.) Names of small towns, villages, post offices, and so forth.
3. *Inclined Capitals.* Names of oceans, bays, gulfs, sounds, large lakes, and rivers.
4. *Inclined Lower-case, or "Stump Letters."* (First letter of each word a capital.) Names of rivers, creeks, small lakes, ponds, marshes, brooks, and springs.

Prominent land features, such as mountains, plateaus, and canyons, are lettered in vertical Gothic, Fig. 3.18, while the names of small land features, such as small valleys, islands, and ridges, are lettered in vertical lower-case Gothic, Fig. 3.26. Names of railroads, tunnels, highways, bridges, and other public structures are lettered in inclined Gothic capitals, Fig. 3.19.

3.31 Microfont Alphabet.

The microfont alphabet, Fig. 3.44, is a recent adaptation of the single-stroke Gothic characters developed by the National Microfilm Association. It is designed for general usage and increased legibility in reproduction. Only the vertical style is shown.

3.32 Greek Alphabet.

Greek letters are often used as symbols in both mathematics and technical drawing by the engineer. A Greek alphabet, showing both upper-case and lower-case letters, is given for reference purposes in Fig. 3.45.

Α α	alpha	Ι ι	iota	Ρ ρ	rho
Β β	beta	Κ κ	kappa	Σ σ	sigma
Γ γ	gamma	Λ λ	lambda	Τ τ	tau
Δ δ	delta	Μ μ	mu	Υ υ	upsilon
Ε ε	epsilon	Ν ν	nu	Φ φ	phi
Ζ ζ	zeta	Ξ ξ	xi	Χ χ	chi
Η η	eta	Ο ο	omicron	Ψ ψ	psi
Θ θ	theta	Π π	pi	Ω ω	omega

Fig. 3.45 Greek Alphabet.

3.33 Lettering Exercises.

Layouts for lettering practice are given in Figs. 3.46 to 3.49. Draw complete horizontal and vertical or inclined guide lines *very lightly.* Draw the vertical or inclined guide lines through the full height of the lettered area of the sheet. For practice in ink lettering, the last two lines and the title strip on each sheet may be lettered in ink, if assigned by the instructor. Omit all dimensions.

Lettering sheets in convenient form for lettering practice may be found in *Technical Drawing Problems, Series 1,* by Giesecke, Mitchell, Spencer, Hill, and Dygdon; in *Technical Drawing Problems, Series 2,* by Spencer, Hill, and Dygdon; and in *Technical Drawing Problems, Series 3,* by Spencer, Hill, and Dygdon, all designed to accompany this text and published by Macmillan Publishing Co., Inc.

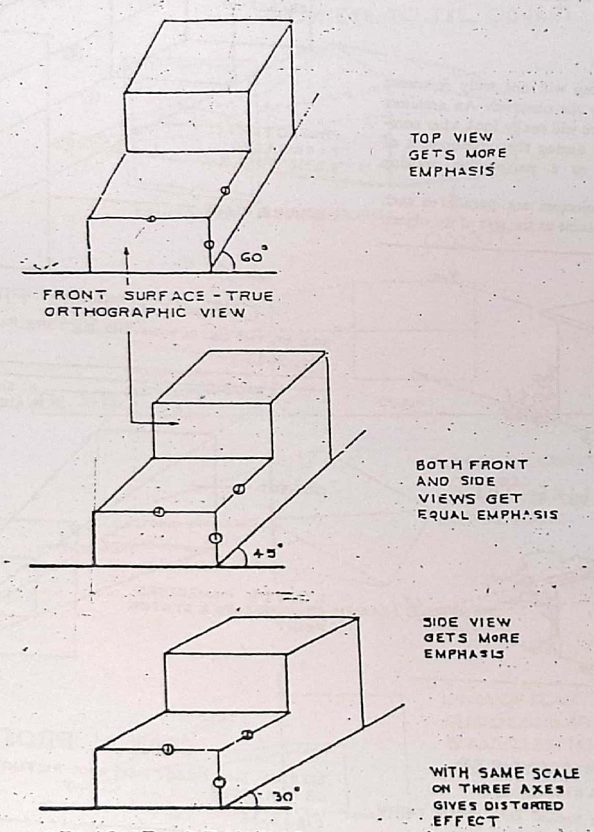


Fig. 3–9

(1) Turn the plan so that the main axes are at any given angle to the T. Square, e.g. 45°, 60°, 30° or any convenient angle.
(2) Keep tracing paper on the plan.
(3) Use 90° set-square for projecting up the verticals which are drawn to the same scale of the plan.

OBLIQUE DRAWING BY REDUCING DEPTH

Oblique drawing is drawn by reducing depth to 1/2. Lines on the front surface are drawn – with full scale. Drawing with 1/2 reduction is known as cabinet drawing.

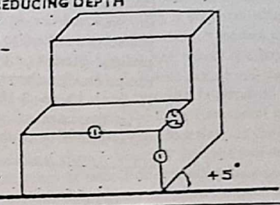
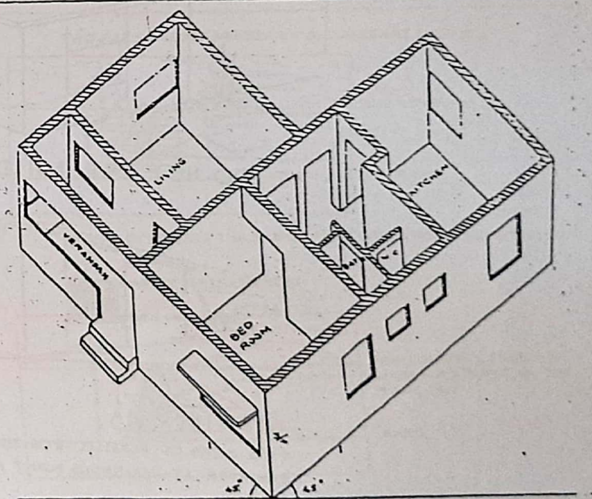


Fig. 3–10



AXONOMETRIC VIEW OF HOUSE — OBLIQUE DRAWING

Fig. 3–11

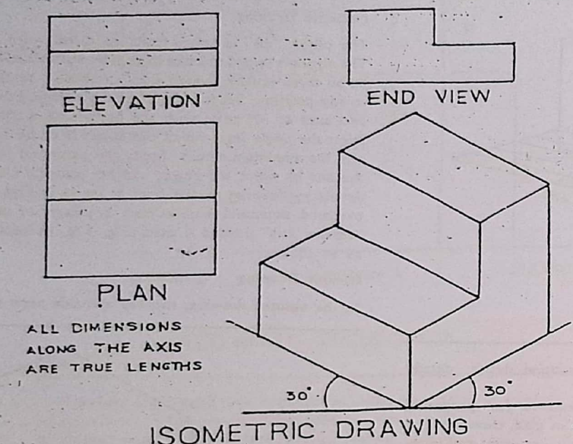


Fig. 3–7

jecting oblique lines from a frontal orthographic view, i.e. elevation (Fig. 3-9). Angles commonly used for the oblique axis are 30°, 45°, and 60°; 30° axis from the horizontal shows side view with more emphasis; 45° axis gives importance to both the sides; and 60° axis gives emphasis to the top view. The axis may be projected on the right or left side according to the requirement and, if required, it can be projected below the horizontal.

If the oblique drawing is drawn using the same scale for all axes, then a distorted view is obtained. Hence, for a more realistic appearance, the depth along the oblique axis is reduced by 1/4, 1/3, or 1/2, and the lines on the frontal plane are drawn with the full scale. Circles and irregular shapes are drawn in the front plane or elevation conveniently. In oblique drawing, long dimension line is placed on the front elevation for the sake of convenience. If circular shapes are on the oblique axis, they are drawn elliptical in the same way as isometric circles (Fig. 3-10).

Axonometric Drawing

Axonometric and oblique drawings are similar in nature. Parallel lines in any direction are drawn parallel in both methods. It is easy to draw three dimensional drawing with these methods as compared to the perspective drawing. They serve the purpose of explanatory drawing for showing interiors of buildings and rooms and for details of furniture pieces, entrances, and structural details.

An axonometric projection is an orthographic projection. The drawing shown in Fig. 3-11 is drawn according to the following stages:

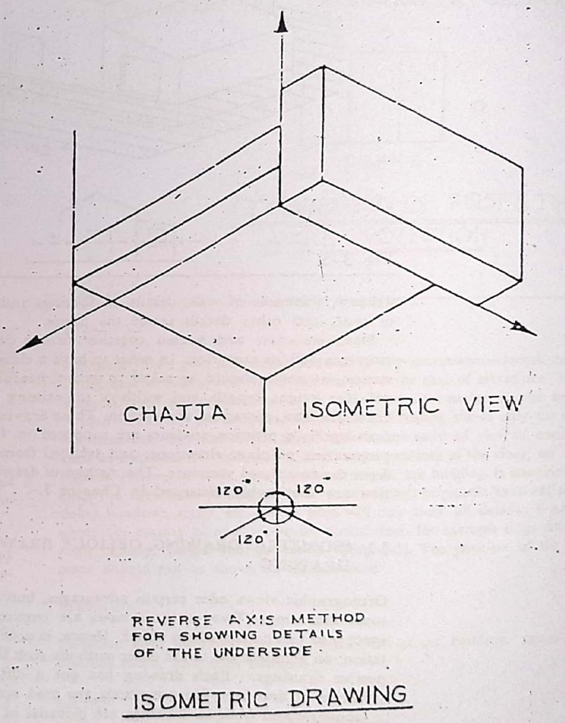


Fig. 3–8

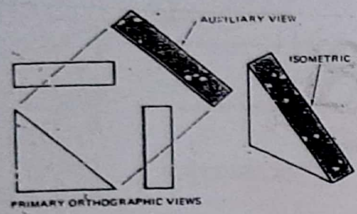


FIG. 18-2 The auxiliary view

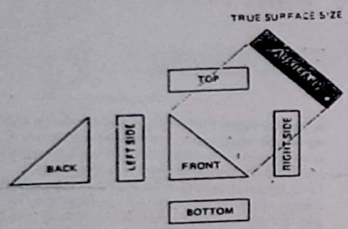


FIG. 18-3 No primary orthographic view will show the true surface

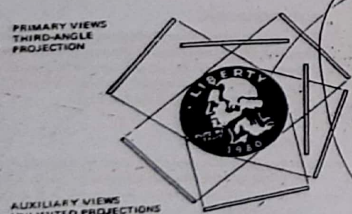


FIG. 18-4 Primary and auxiliary views

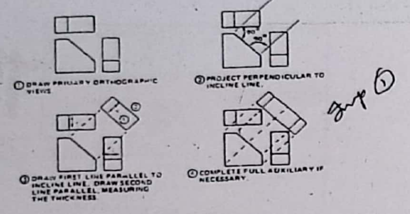


FIG. 18-5 The steps of projection

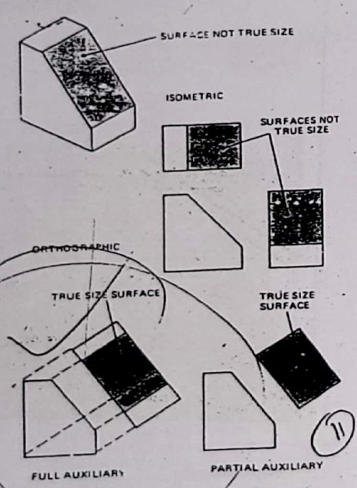


FIG. 18-6 Projection is perpendicular to an inclined surface

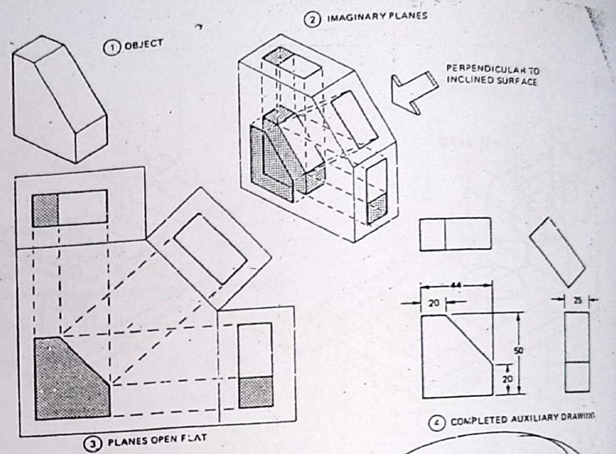


FIG. 18-7 Line of sight is perpendicular to the inclined surface

Figure 18-5. An auxiliary is simply another orthographic view projected perpendicular to the inclined surface (Fig. 18-6). The line of sight must be at right angles to the inclined surface, with the edges of the auxiliary view parallel to the edge of the inclined surface (Fig. 18-7).

TRANSFERRING AUXILIARY MEASUREMENTS

Measurements can be transferred to the auxiliary view in two ways. One method is to transfer measurements directly from the views with a divider as shown in Figure 18-8. The other method is to use the reference lines from the imaginary planes of projection as shown in Figure 18-9.

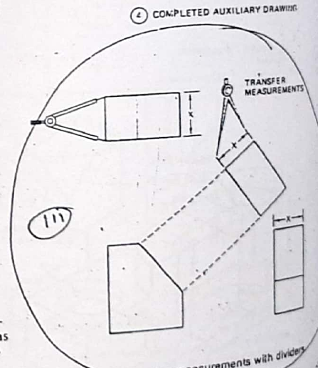


FIG. 18-8 Transferring measurements with dividers

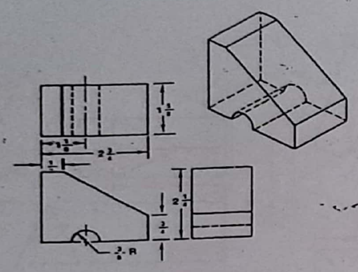


FIG. 11-53 Problem

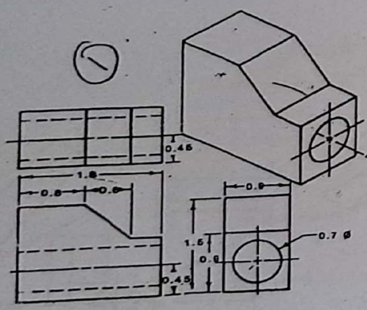


FIG. 11-54 Problem

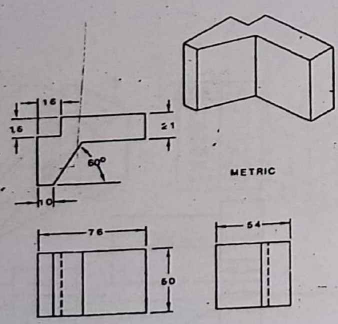


FIG. 11-55 Problem

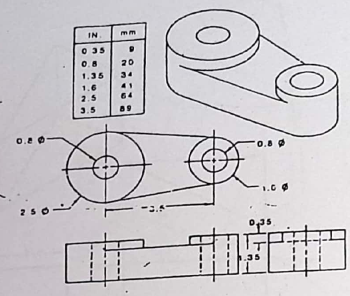


FIG. 11-56 Problem

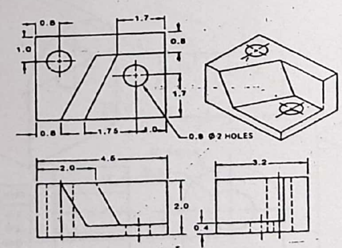


FIG. 11-57 Problem

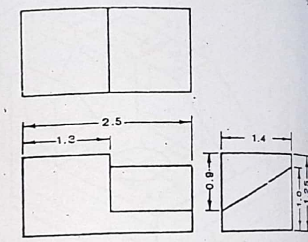


FIG. 11-58 Problem

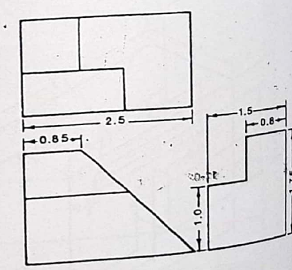


FIG. 11-59 Problem

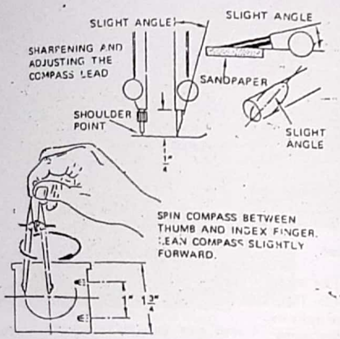


FIG. 5-16 Use of the compass

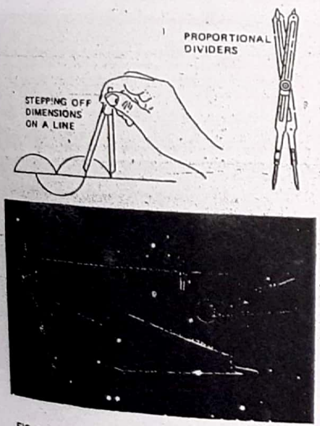


FIG. 5-17 Dividers (Teledyne Post)

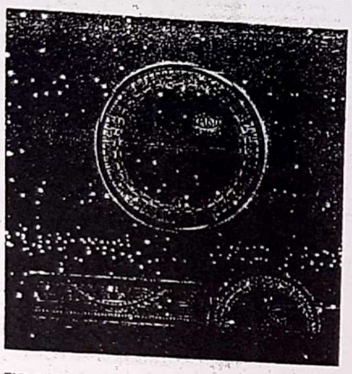


FIG. 5-18 Protractors (Teledyne Post)

Dividers (Fig. 5-17) are used to transfer measurements and divide lines. A proportional divider can be adjusted to different ratios on the opposite end.

Protractors (Fig. 5-18) are used to measure angles.

Templates (Fig. 5-19) are used to reduce drawing time. A tremendous variety of templates are available. Some of the types of templates are:

1. Circles and ellipses
2. Architectural
3. Nut and bolt
4. Lettering
5. Electrical
6. Guide line
7. Math and scientific symbols
8. Piping

Irregular curves (Fig. 5-20) are used to darken irregular lines. A good deal of practice is needed to darken irregular lines smoothly. Irregular curves come in a variety of shapes and forms. A *flexible* curve can be used for long irregular curves. For many long, smooth curves (aircraft and ship drafting) a set of lofting curves can be used. *Lofting* curves are very long to allow for full size drawings.

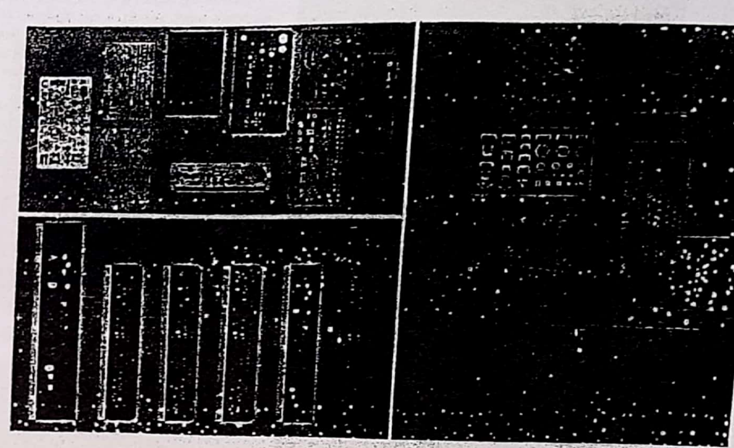


FIG. 5-19 Templates (Teledyne Post, RapiDesign, Inc., Olson Mfg. Co.)

FIG. 5-20 Irregular curves (Teledyne Post)

FIG. 5-21 Drafting machines (Teledyne Post)

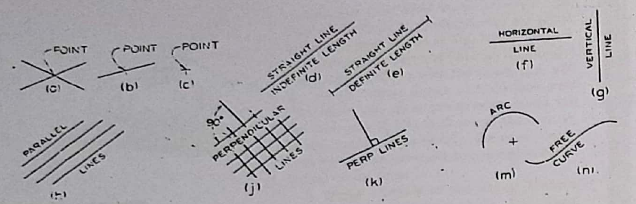


Fig. 4.1 Points and Lines.

and has no width, height, or depth. A point is represented by the intersection of two lines, (a), by a short crossbar on a line, (b), or by a small cross, (c). Never represent a point by a simple dot on the paper.

A line is defined by Euclid as "that which has length without breadth." A *straight line* is the shortest distance between two points and is commonly referred to simply as a "line." If the line is indefinite in extent, the length is a matter of convenience, and the end points are not fixed, (d). If the end points of the line are significant, they must be marked by means of small mechanically drawn crossbars, (e). Other common terms are illustrated from (f) to (h). Either straight lines or curved lines are parallel if the shortest distance between them remains constant. A common symbol for parallel lines is ‖, and for perpendicular lines is ⊥ (singular) or ⊥s (plural). Two perpendicular lines may be marked with a "box" to indicate perpendicularity, as shown at (k). Such symbols may be used on sketches, but not on production drawings.

4.3 Angles. Fig. 4.2.

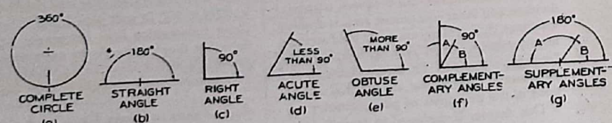
An *angle* is formed by two intersecting lines. A common symbol for angle is ∠ (singular) or ∠s (plural). There are 360 *degrees* (360°) in a full circle, as shown at (a). A degree is divided into 60 *minutes* (60′), and a minute is divided into 60 *seconds* (60″). Thus, 37° 26′ 10″ is read: 37 degrees, 26 minutes, and 10 seconds. When minutes alone are indicated, the number of minutes should be preceded by 0°, as 0° 20′.

The different kinds of angles are illustrated in (b) to (e). Two angles are *complementary*, (f), if they total 90°, and are *supplementary*, (g), if they total 180°. Most angles used in technical drawing can be drawn easily with the T-square and triangles, Fig. 2.26. To draw odd angles, use the protractor, Fig. 2.27. For considerable accuracy, use a *vernier protractor*, or the *tangent*, *sine*, or *chord* methods, §4.21.

4.4 Triangles. Fig. 4.3.

A *triangle* is a plane figure bounded by three straight sides, and the sum of the interior angles is always 180°. A right triangle, (d), has one 90° angle, and the square of the hypotenuse is equal to the sum of the squares of the two sides, (e). As shown at (f), any triangle inscribed in a semicircle is a *right triangle* if the hypotenuse coincides with the diameter.

Fig. 4.2 Angles.



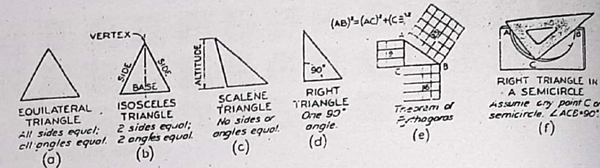


Fig. 4.3 Triangles.

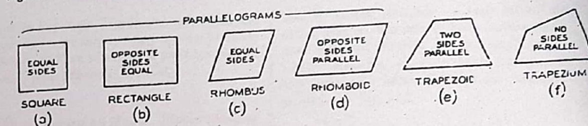


Fig. 4.4 Quadrilaterals.

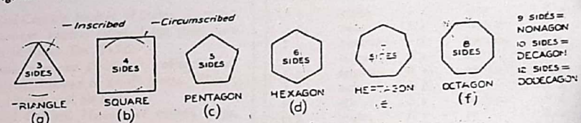


Fig. 4.5 Regular Polygons.

4.5 Quadrilaterals. Fig. 4.4.

A *quadrilateral* is a plane figure bounded by four straight sides. If the opposite sides are parallel, the quadrilateral is also a *parallelogram*.

4.6 Polygons. Fig. 4.5.

A *polygon* is any plane figure bounded by straight lines. If the polygon has equal angles and equal sides, it can be *inscribed* in or *circumscribed* around a circle, and is called a *regular polygon*.

4.7 Circles and Arcs. Fig. 4.6.

A *circle*, (a), is a closed curve all points of which are the same distance from a point called the *center*. *Circumference* refers to the circle or to the distance around the circle. This distance equals

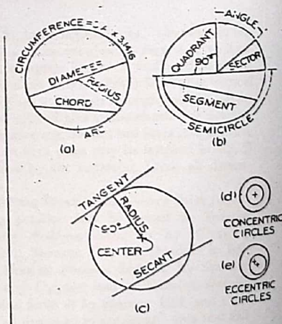


Fig. 4.6 The Circle.

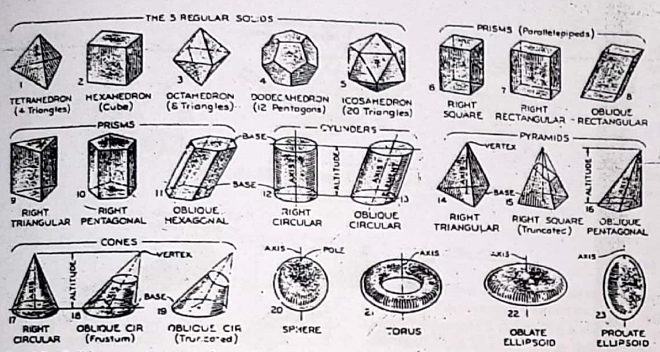


Fig. 4.7 Solids.

the diameter multiplied by π (called *pi*) or 3.1416. Other definitions are illustrated in the figure.

4.8 Solids. Fig. 4.7.

Solids bounded by plane surfaces are *polyhedra*. The surfaces are called *faces*, and if these are equal regular polygons, the solids are *regular polyhedra*.

A *prism* has two *bases*, which are parallel equal polygons, and three or more lateral faces, which are parallelograms. A *triangular prism* has a triangular base; a *rectangular prism* has rectangular bases, etc. If the bases are parallelograms, the prism is a *parallelepiped*. A *right prism* has faces and lateral edges perpendicular to the bases; an *oblique prism* has faces and lateral edges oblique to the bases. If one end is cut off to form an end not parallel to the bases, the prism is said to be *truncated*.

A *pyramid* has a polygon for a base and triangular lateral faces intersecting at a common point called the *vertex*. The center line from the center of the base to the vertex is the *axis*. If the axis is perpendicular to the base, the pyramid is a *right pyramid*; otherwise it is an *oblique pyramid*. A *triangular pyramid* has a triangular base, a *square pyramid* has a square base, etc. If a portion near the vertex has been cut off, the pyramid is *truncated*, or referred to as a *frustum*.

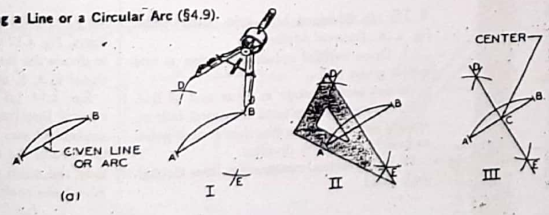
A *cylinder* is generated by a straight line, called the *generatrix*, moving in contact with a curved line and always remaining parallel to its previous position or to the axis. Each position of the generatrix is called an *element* of the cylinder.

A *cone* is generated by a straight line moving in contact with a curved line, and passing through a fixed point, the vertex of the cone. Each position of the generatrix is an *element* of the cone.

A *sphere* is generated by a circle revolving about one of its diameters. This diameter becomes the *axis* of the sphere, and the ends of the axis are *poles* of the sphere.

A *torus* is generated by a circle (or other curve) revolving about an axis which is eccentric to the curve.

Fig. 4.8 Bisecting a Line or a Circular Arc (§4.9).



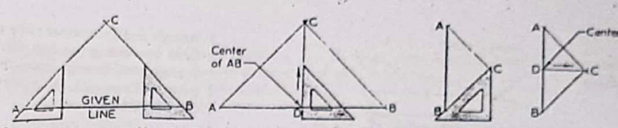


Fig. 4.9 Bisecting a Line with Triangle and T-square (§4.10).

4.9 To Bisect a Line or a Circular Arc. Fig. 4.8.

Given line or arc AB, as shown at (a), to be bisected.

I. From A and B draw equal arcs with radius greater than half AB.

II. and III. Join intersections D and E with a straight line to locate center C.

4.10 To Bisect a Line with Triangle and T-square. Fig. 4.9.

From end points A and B, draw construction lines at 30°, 45°, or 60° with the given line; then through their intersection C, draw line perpendicular to the given line to locate the center D, as shown.

To divide a line with the dividers, see §2.41.

4.11 To Bisect an Angle. Fig. 4.10.

Given angle BAC, as shown at (a), to be bisected.

I. Strike large arc R.

II. Strike equal arcs r with radius slightly larger than half BC, to intersect at D.

III. Draw line AD, which bisects angle.

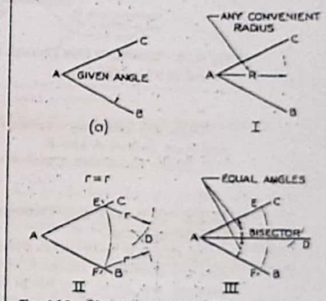
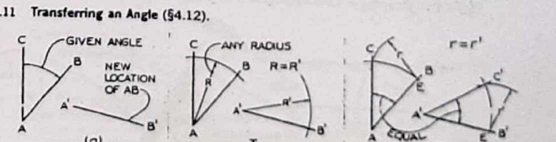


Fig. 4.10 Bisecting an Angle (§4.11).

4.12 To Transfer an Angle. Fig. 4.11.

Given angle BAC, as shown at (a), to be transferred to the new position at A'B'.

Fig. 4.11 Transferring an Angle (§4.12).



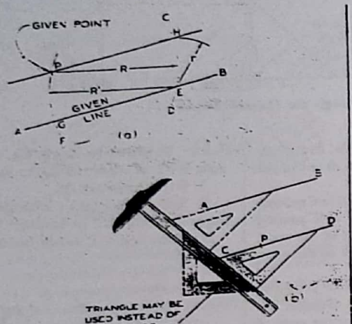


Fig. 4.12 Drawing a Line Through a Point Parallel to a Line (§4.13).

I. Use any convenient radius R, and strike arcs from centers A and A′.

II. Strike equal arcs r, and draw side A′C′.

4.13 To Draw a Line Through a Point and Parallel to a Line.

Fig. 4.12 (a). With given point P as center, and any convenient radius R, strike arc CD to intersect the given line AB at E. With E as center and the same radius, strike arc R′ to intersect the given line at G. With PG as radius, and E as center, strike arc r to locate point H. The line PH is the required line.

Fig. 4.12 (b). Preferred Method. Move the triangle and T-square as a unit until the triangle lines up with given line AB; then slide the triangle until its edge passes through the given point P. Draw CD, the required parallel line. See also §2.22.

4.14 To Draw a Line Parallel to a Line and at a Given Distance.

Let AB be the line and CD the given distance.

Fig. 4.13 (a). With points E and F near A and B respectively as centers, and CD as radius, draw two arcs. The line GH, tangent to the arcs, is the required line.

Fig. 4.13 (b). Preferred Method. With any point E of the line as center and CD as radius, strike an arc JK. Move the triangle and T-square as a unit until the triangle lines up with the given line AB; then slide the triangle until its edge is tangent to the arc JK, and draw the required line GH.

Fig. 4.13 (c). With centers selected at random on the curved line AB, and with CD as radius, draw a series of arcs; then draw the required line tangent to these arcs as explained in §2.59.

4.15 To Divide a Line into Equal Parts.

Fig. 4.14.

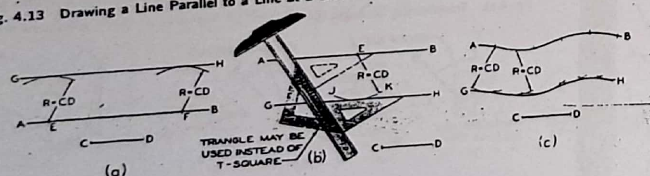
I. Draw light construction line at any convenient angle from one end of line.

II. With dividers or scale, set off from intersection of lines as many equal divisions as needed, in this case three.

III. Connect last division point to other end of line, using triangle and T-square, as shown.

IV. Slide triangle along T-square and draw

Fig. 4.13 Drawing a Line Parallel to a Line at a Given Distance (§4.14).



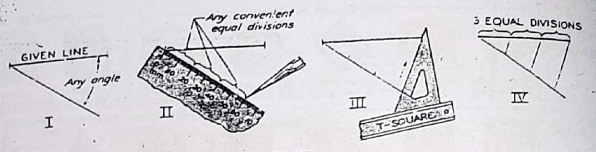


Fig. 4.14 Dividing a Line into Equal Parts (§4.15).

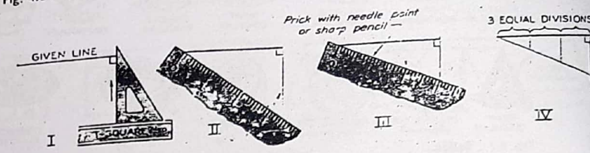


Fig. 4.15 Dividing a Line into Equal Parts (§4.16).

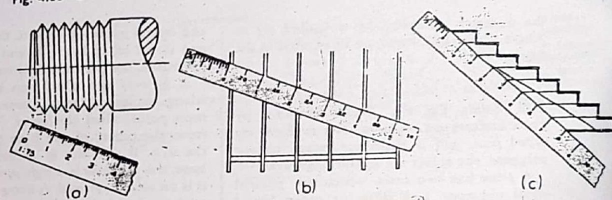


Fig. 4.16 Practical Applications of Dividing a Line into Equal Parts (§4.16).

parallel lines through other division points, as shown.

4.16 To Divide a Line into Equal Parts.

Fig. 4.15 *Preferred Method.*

I. Draw vertical construction line at one end of given line.

II. Set zero of scale at other end of line.

III. Swing scale up until third unit falls on vertical line, and make tiny dots at each point, or prick points with dividers.

IV. Draw vertical construction lines through each point.

Some practical applications of this method are shown in Fig. 4.16.

4.17 To Divide a Line into Proportional Parts.

Fig. 4.17 (a) and (b). Let it be required to divide the line AB into three parts proportional to 2, 3, and 4.

Fig. 4.17 (a). Preferred Method. Draw a vertical line from point B. Select a scale of convenient size for a total of 9 units and set the zero of the scale at A. Swing the scale up until the ninth unit falls on the vertical line. Along the scale, set off points for 2, 3, and

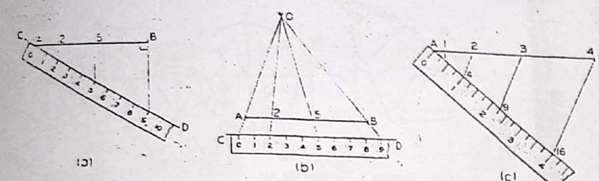


Fig. 4.17 Dividing a Line into Proportional Parts (§4.17).

4 units, as shown. Draw vertical lines through these points.

Fig. 4.17 (*b*). Draw a line CD parallel to AB and at any convenient distance. On this line, set off 2, 3, and 4 units, as shown. Draw lines through the ends of the two lines to intersect at the point O. Draw lines through O and the points 2 and 5 to divide AB into the required proportional parts.

Constructions of this type are useful in the preparation of graphs (Chapter 26).

Fig. 4.17 (*c*). Given AB, to divide into proportional parts, in this case proportional to the square of X, where X = 1, 2, 3, ... Set zero of scale at end of line and set off divisions 4, 9, 16, ... Join the last division to the other end of the line, and draw parallel lines as shown. This method may be used for any power of X. The construction is used in drawing nomographic charts (Chapter 27).

4.18 To Draw a Line Through a Point and Perpendicular to a Line.

Given the line AB and a point P.

When the Point Is Not on the Line. Fig. 4.18 (a). From P draw any convenient inclined line, as PD. Find center C of line PD, and draw arc with radius CP. The line EP is the required perpendicular.

Fig. 4.18 (*b*). With P as center, strike an arc to intersect AB at C and D. With C and D as centers, and radius slightly greater than half CD, strike arcs to intersect at E. The line PE is the required perpendicular.

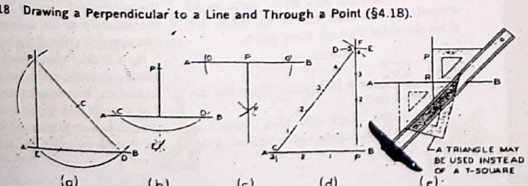
When the Point Is on the Line. Fig. 4.18 (c). With P as center and any radius, strike arcs to intersect AB at D and G. With D and G as centers, and radius slightly greater than half DG, strike equal arcs to intersect at F. The line PF is the required perpendicular.

Fig. 4.18 (*d*). Select any convenient unit of length, for example, 6 mm or $\frac{1}{4}$". With P as center, and 3 units as radius, strike an arc to intersect given line at C. With P as center, and 4 units as radius, strike arc DE. With C as center, and 5 units as radius, strike an arc to intersect DE at F. The line PF is the required perpendicular.

This method is frequently used in laying off rectangular foundations of large machines, buildings, or other structures. For this purpose a steel tape may be used and distances of 30, 40, and 50 feet measured as the three sides of the right triangle.

Fig. 4.18 (*e*). *Preferred Method.* Move the triangle and T-square as a unit until the triangle lines up with AB; then slide the triangle until its edge passes through the point P (whether P is on or off the line), and draw the required perpendicular.

Fig. 4.18 Drawing a Perpendicular to a Line and Through a Point (§4.18).



4.19 To Draw a Triangle with Sides Given.

Fig. 4.19. Given the sides A, B, and C, as shown at (a):

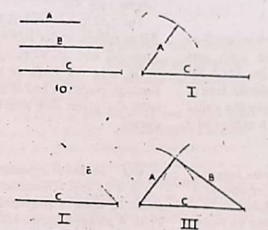


Fig. 4.19 Drawing a Triangle with Sides Given (§4.19).

I. Draw one side, as C, in desired position, and strike arc with radius equal to given side A.

II. Strike arc with radius equal to given side B.

III. Draw sides A and B from intersection of arcs, as shown.

4.20 To Draw a Right Triangle with Hypotenuse and One Side Given.

Fig. 4.20. Given sides S and R. With AB as a diameter equal to S, draw semicircle. With A as center, and R as radius, draw an arc intersecting the semicircle at C. Draw AC and CB to complete the right triangle.

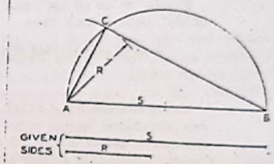


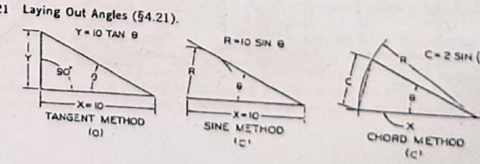
Fig. 4.20 Drawing a Right Triangle (§4.20).

4.21 To Lay Out an Angle.

Fig. 4.21. Many angles can be laid out directly with the triangle, Fig. 2.26; or they may be laid out with the protractor, Fig. 2.27. Other methods, where considerable accuracy is required, are as follows:

Tangent Method. Fig. 4.21 (a). The tangent of angle θ is $\frac{Y}{X}$, and $Y = X \tan \theta$. To construct the angle, assume a convenient value for X, preferably 10 units of convenient length, as shown. (The larger the unit, the more accurate will be the construction.) Find the tangent of

Fig. 4.21 Laying Out Angles (§4.21).



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angle θ in a table of natural tangents, multiply by 10, and set off $Y = 10 \tan \theta$.

Example: To set off $31\frac{1}{2}°$, find the natural tangent of $31\frac{1}{2}°$, which is .6128. Then

$$Y = 10 \text{ units} \times .6128 = 6.128 \text{ units}$$

SINE METHOD. Fig. 4.21 (b). Draw line X to any convenient length, preferably 10 units as shown. Find the sine of angle θ in a table of natural sines, multiply by 10, and strike arc $R = 10 \sin \theta$. Draw the other side of the angle tangent to the arc, as shown.

Example: To set off $25\frac{1}{2}°$, find the natural sine of $25\frac{1}{2}°$, which is .4305. Then

$$R = 10 \text{ units} \times .4305 = 4.305 \text{ units}$$

CHORD METHOD. Fig. 4.21 (c). Draw line X to any convenient length, draw arc with any convenient radius R, say 10 units. Find the chordal length C in a table of chords (see a machinists' handbook), and multiply the value by 10, since the table is made for a radius of 1 unit.

Example: To set off 43° 20′, the chordal length C for 1 unit radius, as given in a table of chords = .7384, and if R = 10 units, then C = 7.384 units. If a table is not available, the chord C may be calculated by the formula $C = 2 \sin \frac{\theta}{2}$.

Example: Half of 43° 20′ = 21° 40′. The sine of 21° 40′ = .3692. C = 2 × .3692 = .7384 for a 1 unit radius. For a 10 unit radius, C = 7.384 units.

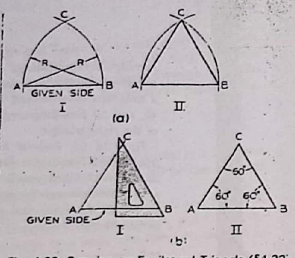


Fig. 4.22 Drawing an Equilateral Triangle (§4.22).

4.22 To Draw an Equilateral Triangle. Given side AB.

Fig. 4.22 (a). With A and B as centers and AB as radius, strike arcs to intersect at C. Draw lines AC and BC to complete the triangle.

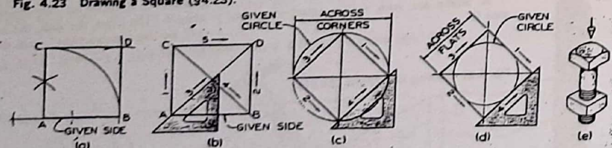
Fig. 4.22 (b). Preferred Method. Draw lines through points A and B making angles of 60° with the given line and intersecting at C, as shown.

4.23 To Draw a Square. Fig. 4.23.

Fig. 4.23 (a). Given one side AB. Through point A, draw a perpendicular, Fig. 4.18 (c). With A as center, and AB as radius, draw the arc to intersect the perpendicular at C. With B and C as centers, and AB as radius, strike arcs to intersect at D. Draw lines CD and BD.

Fig. 4.23 (b). Preferred Method. Given one side AB. Using the T-square and 45° triangle, draw lines AC and BD perpendicular to AB, and the lines AD and BC at 45° with AB. Draw line CD with the T-square.

Fig. 4.23 Drawing a Square (§4.23).



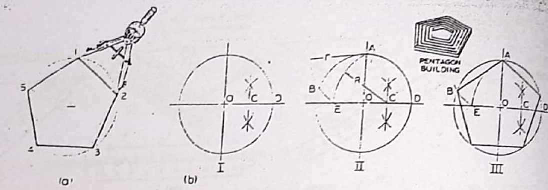


Fig. 4.24 Drawing a Pentagon (§4.24).

Fig. 4.23 (c). Preferred Method. Given the circumscribed circle (distance "across corners"). Draw two diameters at right angles to each other. The intersections of these diameters with the circle are vertexes of an inscribed square.

Fig. 4.23 (d) Preferred Method. Given the inscribed circle (distance "across flats," as in drawing bolt heads). Using the T-square and 45° triangle, draw the four sides tangent to the circle. See Fig. 13.31.

4:24 To Draw a Regular Pentagon. Given the circumscribed circle.

Fig. 4.24 (a). Preferred Method. Divide the circumference of the circle into five equal parts with the dividers, and join the points with straight lines.

GEOMETRICAL METHOD. Fig. 4.24 (b).

I. Bisect radius OD at C.

II. With C as center, and CA as radius, strike arc AE. With A as center, and AE as radius, strike arc EB.

III. Draw line AB; then set off distances AB around the circumference of the circle, and draw the sides through these points.

4.25 To Draw a Hexagon. Given the circumscribed circle.

Fig. 4.25 (a). Each side of a hexagon is equal to the radius of the circumscribed circle.

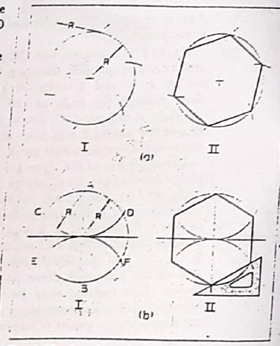


Fig. 4.25 Drawing a Hexagon (§4.25).

Therefore, using the compass or dividers and the radius of the circle, set off the six sides of the hexagon around the circle, and connect the points with straight lines. As a check on the accuracy of the construction, make sure that opposite sides of the hexagon are parallel.

Fig. 4.25 (b). Preferred Method. This construction is a variation of the one shown at (a). Draw vertical and horizontal center lines. With A and B as centers and radius equal to that of the circle, draw arcs to intersect the circle at C, D, E, and F, and complete the hexagon as shown.

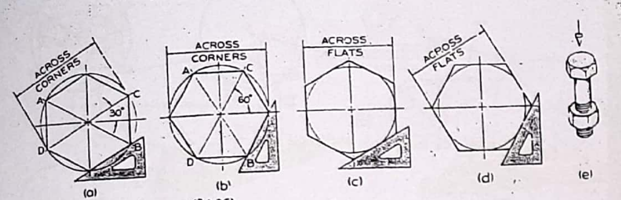


Fig. 4.26 Drawing a Hexagon (§4.26).

4.26 To Draw a Hexagon.

Given the circumscribed or inscribed circle. *Both Preferred Methods.*

Fig. 4.26 (a) and (b). Given the circumscribed circle (distance "across corners"). Draw vertical and horizontal center lines, and then diagonals AB and CD at 30° or 60° with horizontal; then with the 30° × 60° triangle and the T-square, draw the six sides as shown.

Fig. 4.26 (c) and (d). Given the inscribed circle (distance "across flats"). Draw vertical and horizontal center lines; then with the 30° × 60° triangle and the T-square, draw the six sides tangent to the circle. This method is used in drawing bolt heads and nuts, §13.26. For maximum accuracy, diagonals may be added as at (a) and (b).

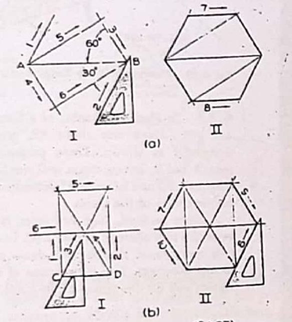


Fig. 4.27 Drawing a Hexagon (§4.27).

4.27 To Draw a Hexagon.

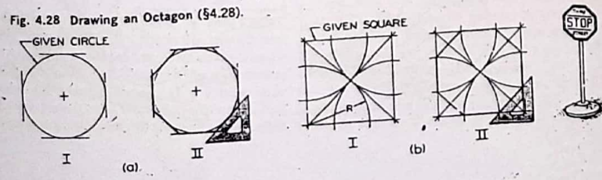
Fig. 4.27. Using the 30° × 60° triangle and the T-square, draw lines in the order shown at (a) where the distance AB ("across corners") is given, or as shown at (b) where a side CD is given.

4.28 To Draw an Octagon.

Fig. 4.28 (a). Preferred Method. Given inscribed circle, or distance "across flats." Using the T-square and 45° triangle, draw the eight sides tangent to the circle, as shown.

Fig. 4.28 (b). Given circumscribed square, or distance "across flats." Draw diagonals of square; then with the corners of the given square as centers, and with half the diagonal as radius, draw arcs cutting the sides as shown at I. Using the T-square and 45° triangle, draw the eight sides as shown at II.

Fig. 4.28 Drawing an Octagon (§4.28).



4.29 To Transfer Plane Figures by Geometric Methods.

To Transfer a Triangle to a New Location. Fig. 4.29 (a) and (b). Set off any side, as AB, in the new location, (b). With the ends of the line as centers and the lengths of the other sides of the given triangle, (a), as radii, strike two arcs to intersect at C. Join C to A and B to complete the triangle.

To Transfer a Polygon by the Triangle Method. Fig. 4.29 (c). Divide the polygon into triangles as shown, and transfer each triangle as explained above.

To Transfer a Polygon by the Rectangle Method. Fig. 4.29 (d). Circumscribe a rectangle about the given polygon. Draw a congruent rectangle in the new location and locate the vertexes of the polygon by transferring location measurements a, b, c, etc., along the sides of the rectangle to the new rectangle. Join the points thus found to complete the figure.

To Transfer Irregular Figures. Fig. 4.29 (e). Figures composed of rectangular and circular forms are readily transferred by enclosing the elementary features in rectangles and determining centers of arcs and circles. These may then be transferred to the new location.

To Transfer Figures by Offset Measurements. Fig. 4.29 (f). *Offset location measurements* are frequently useful in transferring figures composed of free curves. When the figure has been enclosed by a rectangle, the sides of the rectangle are used as reference lines for the location of points along the curve.

To Transfer Figures by a System of Squares. Fig. 4.29 (g). Figures involving free curves are easily copied, enlarged, or reduced by the use of a system of squares. For example, to enlarge a figure to double size, draw the containing rectangle and all small squares double their original size. Then draw the lines through the corresponding points in the new set of squares. See also Fig. 5.18.

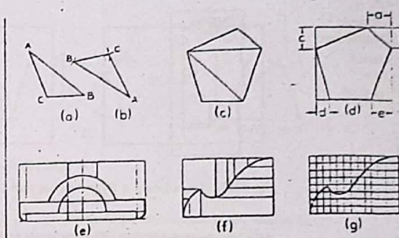


Fig. 4.29 Transferring a Plane Figure (§4.29).

4.30 To Transfer Drawings by Tracing-Paper Methods.

To transfer a drawing to an opaque sheet, the following procedures may be used:

Prick-Point Method. Lay tracing paper over the drawing to be transferred. With a sharp pencil, make a small dot directly over each important point on the drawing. Encircle each dot so as not to lose it. Remove the tracing paper, place it over the paper to receive the transferred drawing, and maneuver the tracing paper into the desired position. With a needle point (such as a point of the dividers), prick through each dot. Remove the tracing paper and connect the prick-points to produce the lines as on the original drawing.

To transfer arcs or circles, it is only necessary to transfer the center and one point on the circumference. To transfer a free curve, transfer as many prick-points on the curve as desired.

Tracing Method. Lay tracing paper over the drawing to be transferred, and make a pencil tracing of it. Turn the tracing paper over and mark over the lines with short strokes of a soft pencil so as to provide a coating of

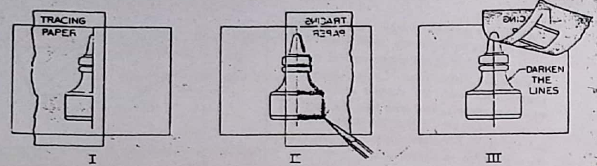


Fig. 4.30 Transferring a Symmetrical Half (§4.30).

graphite over every line. Turn tracing face up and fasten in position where drawing is to be transferred. Trace over all lines of the tracing, using a hard pencil. The graphite on the back acts as a carbon paper and will produce dim but definite lines. Heavy in the dim lines to complete the transfer.

Fig. 4.30. If one half of a symmetrical object has been drawn, as for the ink bottle at I, the other half may be easily drawn with the aid of tracing paper as follows:

I. Trace the half already drawn.

II. Turn tracing paper over and maneuver to the position for the right half. Then trace over the lines freehand or mark over the lines with short strokes as shown.

III. Remove the tracing paper, revealing the dim imprinted lines for the right half. Heavy in these lines to complete the drawing.

4.31 To Enlarge or Reduce a Drawing.

Fig. 4.31 (a). The construction shown is an adaptation of the parallel-line method, Figs. 4.14 and 4.15, and may be used whenever it is desired to enlarge or reduce any group of dimensions to the same ratio. Thus if full-size dimensions are laid off along the vertical line, the enlarged dimensions would appear along the horizontal line, as shown.

Fig. 4.31 (b). To enlarge or reduce a rectangle (say, a sheet of drawing paper), a simple method is to use the diagonal, as shown.

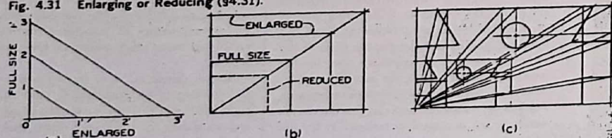
Fig. 4.31 (c). A simple method of enlarging or reducing a drawing is to make use of radial lines, as shown. The original drawing is placed underneath a sheet of tracing paper, and the enlarged or reduced drawing is made directly on the tracing paper.

4.32 To Draw a Circle Through Three Points. Fig. 4.32 (a).

I. Let A, B, and C be the three given points not in a straight line. Draw lines AB and BC, which will be chords of the circle. Draw perpendicular bisectors EO and DO, Fig. 4.8, intersecting at O.

II. Through center O, draw required circle through the points.

Fig. 4.31 Enlarging or Reducing (§4.31).



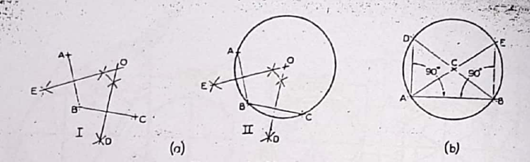


Fig. 4.32 Finding Center of Circle (§§4.32 and 4.33).

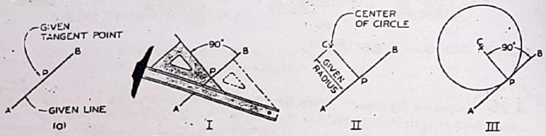


Fig. 4.33 Drawing a Circle Tangent to a Line (§4.34).

4.33 To Find the Center of a Circle. Fig. 4.32 (b).

Draw any chord AB, preferably horizontal as shown. Draw perpendiculars from A and B, cutting circle at D and E. Draw diagonals DB and EA whose intersection C will be the center of the circle.

Another method, slightly longer, is to reverse the procedure of Fig. 4.32 (a). Draw any two nonparallel chords and draw perpendicular bisectors. The intersection of the bisectors will be the center of the circle.

4.34 To Draw a Circle Tangent to a Line at a Given Point. Fig. 4.33.

Given a line AB and a point P on the line, as shown at (a).

I. At P erect a perpendicular to the line.

II. Set off the radius of the required circle on the perpendicular.

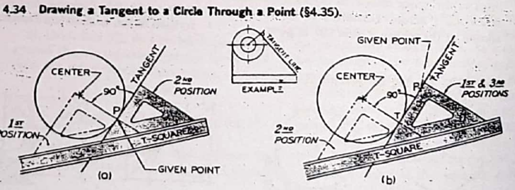
III. Draw circle with radius CP.

4.35 To Draw a Tangent to a Circle Through a Point. *Preferred Method.*

Fig. 4.34 (a). Given point P on the circle. Move the T-square and triangle as a unit until one side of the triangle passes through the point P and the center of the circle; then slide the triangle until the other side passes through point P, and draw the required tangent.

Fig. 4.34 (b). Given point P outside the circle. Move the T-square and triangle as a

Fig. 4.34 Drawing a Tangent to a Circle Through a Point (§4.35).



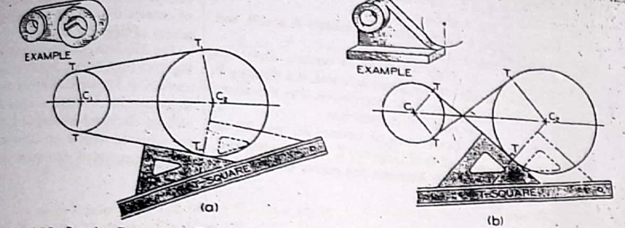


Fig. 4.35 Drawing Tangents to Two Circles (§4.36).

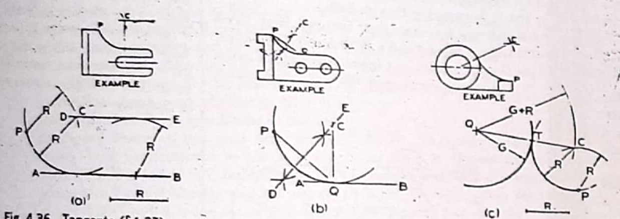


Fig. 4.36 Tangents (§4.37).

unit until one side of the triangle passes through point P and, by inspection, is tangent to the circle; then slide the triangle until the other side passes through the center of the circle, and lightly mark the point of tangency T. Finally move the triangle back to its starting position, and draw the required tangent.

In both constructions either triangle may be used. Also, a second triangle may be used in place of the T-square.

4.36 To Draw Tangents to Two Circles.

Fig. 4.35 (a) and (b). Move the triangle and T-square as a unit until one side of the triangle is tangent, by inspection, to the two circles; then slide the triangle until the other side passes through the center of one circle, and lightly mark the point of tangency. Then slide the triangle until the side passes through the center of the other circle, and mark the point of tangency. Finally slide the triangle back to the tangent position, and draw the tangent lines between the two points of tangency. Draw the second tangent line in a similar manner.

4.37 To Draw an Arc Tangent to a Line or Arc and Through a Point.

Fig. 4.36 (a). Given line AB, point P, and radius R. Draw line DE parallel to given line at distance R from it. From P draw arc with radius R, cutting line DE at C, the center of the required tangent arc.

Fig. 4.36 (b). Given line AB, with tangent point Q on the line, and point P. Draw PQ, which will be a chord of the required arc.

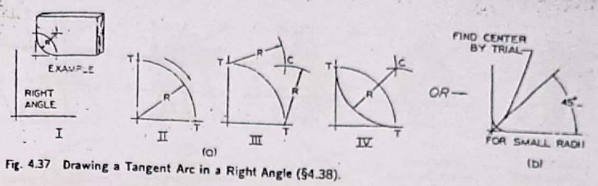


Fig. 4.37 Drawing a Tangent Arc in a Right Angle (§4.38).

Draw perpendicular bisector DE, and at Q erect a perpendicular to the line to intersect DE at C, the center of the required tangent arc.

Fig. 4.36 (c). Given arc with center Q, point P, and radius R. From P strike arc with radius R. From Q strike arc with radius equal to that of the given arc plus R. The intersection C of the arcs is the center of the required tangent arc.

4.38 To Draw a Tangent Arc to Two Lines at Right Angles. Fig. 4.37 (a).

I. Given two lines at right angles to each other.

II. With given radius R, strike arc intersecting given lines at tangent points T.

III. With given radius R again, and with points T as centers, strike arcs intersecting at C.

IV. With C as center and given radius R, draw required tangent arc.

For Small Radii. Fig. 4.37 (b). For small radii, such as ⅛R for fillets and rounds, it is not practicable to draw complete tangency constructions. Instead, draw a 45° bisector of the angle and locate the center of the arc by trial along this line, as shown.

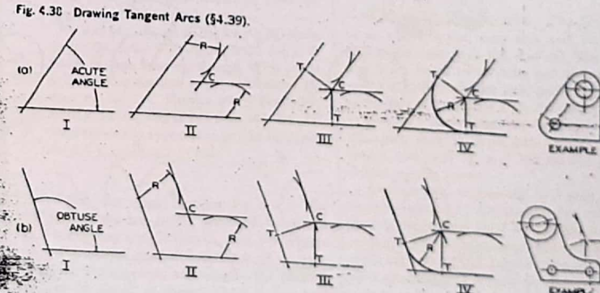
4.39 To Draw a Tangent Arc to Two Lines at Acute or Obtuse Angles. Fig. 4.38 (a) or (b).

I. Given two lines not making 90° with each other.

II. Draw lines parallel to given lines at distance R from them, to intersect at C, the required center.

III. From C drop perpendiculars to the given lines respectively to locate points of tangency T.

Fig. 4.38 Drawing Tangent Arcs (§4.39).



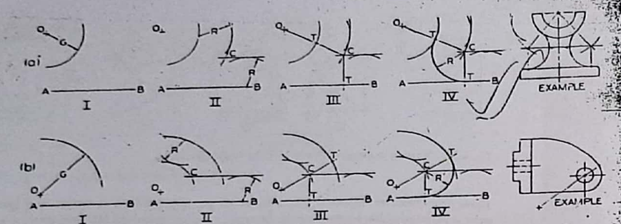


Fig. 4.39 Drawing Tangent Arcs (§4.40).

IV. With C as center and with given radius R, draw required tangent arc between the points of tangency.

4.40 To Draw Tangent Arc to an Arc and a Straight Line. Fig. 4.39 (a) or (b).

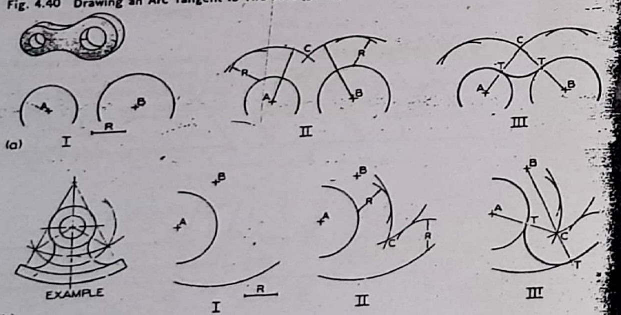
I. Given arc with radius G and straight line AB.

II. Draw straight line and an arc parallel respectively to the given straight line and arc at the required radius distance R from them, to intersect at C, the required center.

III. From C drop a perpendicular to the given straight line to obtain one point of tangency T. Join the centers C and O with a straight line to locate the other point of tangency T.

IV. With center C and given radius R, draw required tangent arc between the points of tangency.

Fig. 4.40 Drawing an Arc Tangent to Two Arcs (§4.41).



4.41 To Draw an Arc Tangent to Two Arcs. Fig. 4.40 (a) or (b).

I. Given arcs with centers A and B, and required radius R.

II. With A and B as centers, draw arcs parallel to the given arcs and at a distance R from them; their intersection C is the center of the required tangent arc.

III. Draw lines of centers AC and BC to locate points of tangency T, and draw required tangent arc between the points of tangency, as shown.

4.42 To Draw an Arc Tangent to Two Arcs and Enclosing One or Both.

THE REQUIRED ARC ENCLOSES BOTH GIVEN ARCS. Fig. 4.41 (a). With A and B as centers, strike arcs HK − r (given radius minus radius of small circle) and HK − R (given radius minus radius of large circle) intersecting at G, the center of the required tangent arc. Lines of centers GA and GB (extended) determine points of tangency T.

THE REQUIRED ARC ENCLOSES ONE GIVEN ARC. Fig. 4.41 (b). With C and D as centers, strike arcs HK + r (given radius plus radius of small circle) and HK − R (given radius minus radius of large circle) intersecting at G, the center of the required tangent arc. Lines of centers GC and GD (extended) determine points of tangency T.

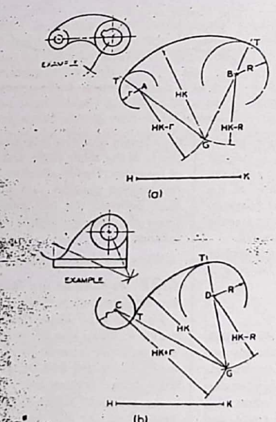


Fig. 4.41 Drawing Tangent Arcs (§4.42).

4.43 To Draw a Series of Tangent Arcs Conforming to a Curve. Fig. 4.42.

First sketch lightly a smooth curve as desired. By trial, find a radius R and a center C, producing an arc AB which closely follows that portion of the curve. The successive centers D, E, etc., will be on lines joining the centers with the points of tangency, as shown.

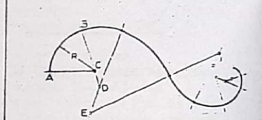


Fig. 4.42 A Series of Tangent Arcs (§4.43).

4.44 To Draw an Ogee Curve.

CONNECTING TWO PARALLEL LINES. Fig. 4.43 (a). Let NA and BM be the two parallel lines. Draw AB, and assume inflection point T (at midpoint if two equal arcs are desired). At A and B erect perpendiculars AF and BC. Draw perpendicular bisectors of AT and BT. The intersections F and C of these bisectors and the perpendiculars, respectively, are the centers of the required tangent arcs.

Fig. 4.43 (b). Let AB and CD be the two parallel lines, with point B as one end of the curve, and R the given radii. At B erect perpendicular to AB, make BG = R, and draw arc as shown. Draw line SP parallel to CD at dis-

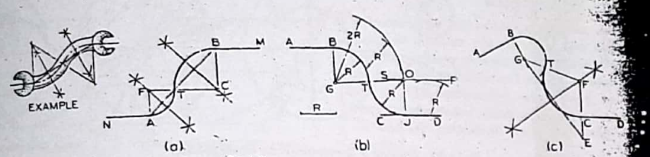


Fig. 4.43 Drawing an Ogee Curve (§4.44).

tance R from CD. With center G, draw arc of radius 2R, intersecting line SP at O. Draw perpendicular OJ to locate tangent point J, and join centers G and O to locate point of tangency T. Using centers G and O and radius R, draw the two tangent arcs as shown.

CONNECTING TWO NONPARALLEL LINES. Fig. 4.43 (c). Let AB and CD be the two nonparallel lines. Erect perpendicular to AB at B. Select point G on the perpendicular so that BG equals any desired radius, and draw arc as shown. Erect perpendicular to CD at C and make CE = BG. Join G to E and bisect it. The intersection F of the bisector and the perpendicular CE, extended, is the center of the second arc. Join centers of the two arcs to locate tangent point T, the inflection point of the curve.

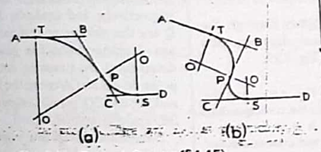


Fig. 4.44 Tangent Curves (§4.45).

4.45 To Draw a Curve Tangent to Three Intersecting Lines. Fig. 4.44 (a) and (b).

Let AB, BC, and CD be the given lines. Select point of tangency P at any point on line BC. Make BT equal to BP, and CS equal to CP, and erect perpendiculars at the points P, T, and S. Their intersections O are the centers of the required tangent arcs.

4.46 To Rectify a Circular Arc.

To *rectify* an arc is to lay out its true length along a straight line. The constructions are approximate, but well within the range of accuracy of drawing instruments.

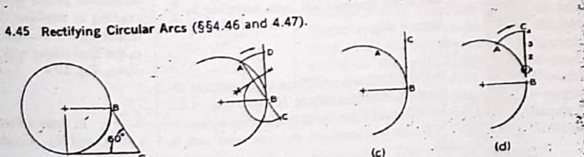
TO RECTIFY A QUADRANT OF A CIRCLE, AB. Fig. 4.45 (a). Draw AC tangent to the circle and BC at 60° to AC, as shown. The line AC is almost equal to the arc AB, the difference in length being about 1 in 240.

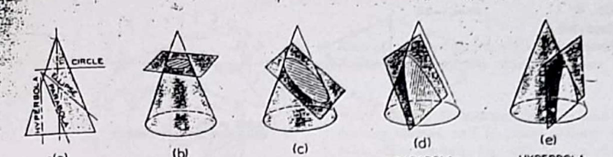
TO RECTIFY ARC AB. Fig. 4.45 (b). Draw tangent at B. Draw chord AB and extend it to C, making BC equal to half AB. With C as center and radius CA, strike the arc AD. The tangent BD is slightly shorter than the given arc AB. For an angle of 45° the difference in length is about 1 in 2866.

Fig. 4.45 (c). Use the bow dividers, and beginning at A, set off equal distances until the division point nearest to B is reached. At this point, reverse the direction and set off an equal number of distances along the tangent to determine point C. The tangent BC is slightly shorter than the given arc AB. If the angle subtended by each division is 10°, the error is approximately 1 in 830.

Note: If the angle θ subtending an arc of radius R is known, the length of the arc is $2\pi R\frac{\theta}{360°} = 0.01745R\theta$.

Fig. 4.45 Rectifying Circular Arcs (§§4.46 and 4.47).





(a) View of cone showing cutting planes.
(b) CIRCLE Plane perpendicular to axis.
(c) ELLIPSE Plane oblique to axis, but making greater angle with axis than elements.
(d) PARABOLA Plane oblique to axis, and making same angle with axis as elements.
(e) HYPERBOLA Plane making smaller angle with axis than elements.

Fig. 4.46 Conic Sections (§4.48).

4.47 To Set Off a Given Length Along a Given Arc.

Fig. 4.45 (c). Reverse the method described above so as to transfer distances from the tangent line to the arc.

Fig. 4.45 (d). To set off the length BC along the arc BA, draw BC tangent to the arc at B. Divide BC into four equal parts. With center at 1, the first division point, and radius 1C, draw the arc CA. The arc BA is practically equal to BC for angles less than 30°. For 45° the difference is approximately 1 in 3232, and for 60° it is about 1 in 835.

4.48 The Conic Sections. Fig. 4.46.

The *conic sections* are curves produced by planes intersecting a right circular cone. Four types of curves are produced: the *circle, ellipse, parabola,* and *hyperbola,* according to the position of the planes, as shown. These curves were studied in detail by the ancient Greeks, and are of great interest in mathematics, as well as in technical drawing. For equations, see any text on analytic geometry.

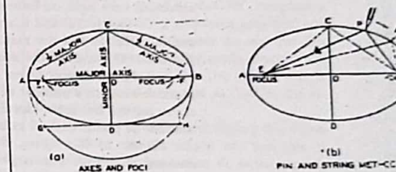


Fig. 4.47 Ellipse Constructions (§4.49).

4.49 Ellipse Construction.

The long axis of an ellipse is the *major axis,* and the short axis is the *minor axis,* Fig. 4.47 (a). The *foci* E and F are found by striking arcs with radius equal to half the major axis and with center at the end of the minor axis. Another method is to draw a semicircle with the major axis as diameter, then to draw GH parallel to the major axis, and GE and HF parallel to the minor axis, as shown.

An ellipse may be generated by a point moving so that the sum of its distances from two points (the foci) is constant and equal to the major axis. For example, Fig. 4.47 (b), an ellipse may be constructed by placing a looped string around the foci E and F, and around C, one end of the minor axis, and moving the pencil point P

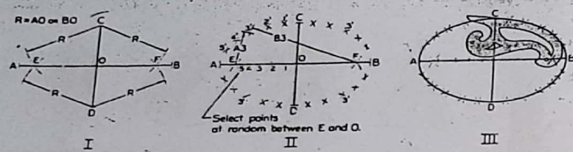


Fig. 4.48 Drawing a Foci Ellipse (§4.50).

along its maximum orbit while the string is kept taut.

4.50 To Draw a Foci Ellipse. Fig. 4.48. Let AB be the major axis, and CD the minor axis. This method is the geometrical counterpart of the pin-and-string method. Keep the construction very light, as follows:

I. To find foci E and F, strike arcs R with radius equal to half the major axis and with centers at the ends of the minor axis.

II. Between E and O on the major axis, mark at random a number of points (spacing those on the left more closely), equal to the number of points desired in each quadrant of the ellipse. In this figure, five points were deemed sufficient. For large ellipses, more points should be used—enough to insure a smooth, accurate curve. Begin construction with any one of these points, such as 3. With E and F as centers and radii A3 and B3, respectively (from the ends of the major axis to point 3), strike arcs to intersect at four points 3', as shown. Using the remaining points 1, 2, 4, and 5, for each find four additional points on the ellipse in the same manner.

III. Sketch the ellipse lightly through the points; then heavy in the final ellipse with the aid of the irregular curve, Fig. 2.79.

4.51 To Draw a Trammel Ellipse. Fig. 4.49. A "long trammel" or a "short trammel" may be prepared from a small strip of stiff paper or thin cardboard, as shown. In both cases, set off on the edge of the trammel distances equal to the semimajor and semiminor axes. In one case these distances overlap; in the other they are end to end. To use either method, place the trammel so that two of the points are on the respective axes, as shown; the third point will then be on the curve and can be marked with a small dot. Find additional points by moving the trammel to other positions, always keeping the two points exactly on the respective axes. Extend the axes to use the long trammel. Find enough points to insure a smooth and symmetrical ellipse. Sketch the ellipse lightly through the points; then heavy in the ellipse with the aid of the irregular curve, Fig. 2.79.

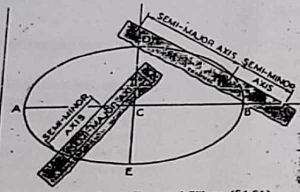


Fig. 4.49 Drawing a Trammel Ellipse (§4.51).

4.52 To Draw a Concentric-Circle Ellipse. Fig. 4.50. If a circle is viewed so that the line of sight is perpendicular to the plane of the circle, as shown for the silver dollar at (a), the circle will appear as a circle, in true size and shape. If the circle is viewed at an angle, as shown at (b), it will appear as an ellipse. If the circle is viewed edgewise, it appears as a straight line, as shown at (c). The case shown at (b) is the basis for the construction of an ellipse by the *concentric-circle method*, as follows (keep the construction very light):

I. Draw circles on the two axes as diameters, and draw any diagonal XX through center O. From the points X, in which the diagonal intersects the large circle, draw lines XE parallel to the minor axis; and from points H, in which it intersects the small circle, draw lines HE parallel to the major axis. The intersections E are points on the ellipse. Two additional points, S and R, can be found by extending lines XE and HE, giving a total of four points from the one diagonal XX.

II. Draw as many additional diagonals as needed to provide a sufficient number of points for a smooth and symmetrical ellipse, each diagonal accounting for four points on the ellipse. Notice that where the curve is sharpest (near the ends of the ellipse), the points are constructed closer together to better determine the curve.

III. Sketch the ellipse lightly through the points; then heavy in the final ellipse with the aid of the irregular curve, Fig. 2.79.

Note: It is evident at I, Fig. 4.50, that the ordinate EZ of the ellipse is to the corresponding ordinate XZ of the circle as b is to a, where b represents the semiminor axis and a the semimajor axis. Thus, the area of the ellipse is equal to the area of the circumscribed circle multiplied by $\frac{b}{a}$; hence it is equal to πab.

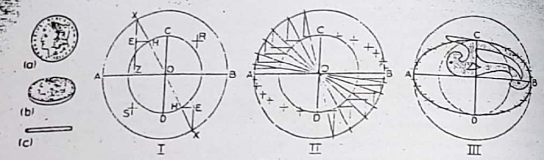


Fig. 4.50 Drawing a Concentric-Circle Ellipse (§4.52).

4.53 To Draw an Ellipse on Conjugate Diameters. Oblique Circle Method. Fig. 4.51. Let AB and DE be the given conjugate diameters. *Two diameters are conjugate when each is parallel to the tangents at the extremities of the other.* With center at C and radius CA, draw a circle; draw the diameter GF perpendicular to AB, and draw lines joining the points D and F, and G and E.

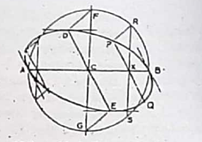


Fig. 4.51 Oblique-Circle Ellipse (§4.53).

Assume that the required ellipse is an oblique projection of the circle just drawn; the points D and E of the ellipse are the oblique projections of the points F and G of the circle, respectively; and similarly, the points P and Q are the oblique projections of the points R and S, respectively. The points P and Q are determined by assuming the point X at any point on AB and drawing the lines RS and PQ, and RP and SQ, parallel respectively to GF and DE, and FD and GE.

Determine at least five points in each quadrant (more for larger ellipses) by assuming additional points on the major axis and proceeding as explained for point X. Sketch the ellipse lightly through the points: then heavy in the final ellipse with the aid of the irregular curve, Fig. 2.79.

4.54 To Draw a Parallelogram Ellipse. Fig. 4.52 (a) and (b). Given the major and minor

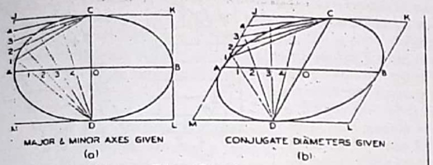


Fig. 4.52 Parallelogram Ellipse (§4.54).

axes, or the conjugate diameters AB and CD, draw a rectangle or parallelogram with sides parallel to the axes, respectively. Divide AO and AJ into the same number of equal parts, and draw *light* lines through these points, as shown. The intersection of like-numbered lines will be points on the ellipse. Locate points in the remaining three quadrants in a similar manner. Sketch the ellipse lightly through the points; then heavy in the final ellipse with the aid of the irregular curve, Fig. 2.79.

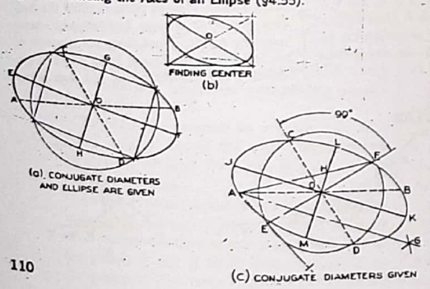
4.55 To Find the Axes of an Ellipse, with Conjugate Diameters Given.

Fig. 4.53 (a). Conjugate diameters AB and CD and the ellipse are given. With intersection O of the conjugate diameters (center of ellipse) as center, and any convenient radius, draw a circle to intersect the ellipse in four points. Join these points with straight lines, as shown; the resulting quadrilateral will be a rectangle whose sides are parallel, respectively, to the required major and minor axes. Draw the axes EF and GH parallel to the sides of the rectangle.

Fig. 4.53 (b). Ellipse only is given. To find the center of the ellipse, draw a circumscribing rectangle or parallelogram about the ellipse; then draw diagonals to intersect at center O, as shown. The axes are then found as shown at (a).

Fig. 4.53 (c). Conjugate diameters AB and CD only are given. With O as center and CD as diameter, draw a circle. Through center O and perpendicular to CD, draw line EF. From points E and F, where this perpendicular intersects the circle, draw lines FA and EA to form angle FAE. Draw the bisector AG of this angle. The major axis JK will be parallel to this bisector, and the minor axis LM will be perpendicular to it. The length AH will be one half the major axis, and HF one half the minor axis. The resulting major and minor axes are JK and LM, respectively.

Fig. 4.53 Finding the Axes of an Ellipse (§4.55).



4.56 To Draw a Tangent to an Ellipse.

Concentric Circle Construction. Fig. 4.54 (a). To draw a tangent at any point on the ellipse, as E, draw the ordinate at E to intersect the circle at V. Draw a tangent to the circle at V, §4.35, and produce it to intersect the major axis produced at G. The line GE is the required tangent.

To draw a tangent from a point outside the ellipse, as P, draw the ordinate PY and extend it. Draw DP, intersecting the major axis at X. Draw FX and extend it to intersect the ordinate through P at Q. Then, from similar triangles, QY:PY = OF:OD. Draw tangent to the circle from Q, §4.35, find the point of tangency R, and draw the ordinate at R to intersect the ellipse at Z. The line ZP is the required tangent. As a check on the drawing, the tangents RQ and ZP should intersect at a point on the major axis extended. Two tangents to the ellipse can be drawn from point P.

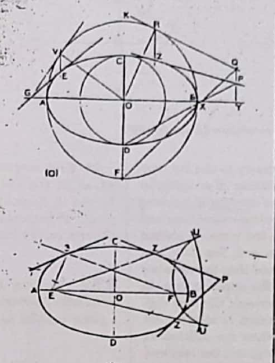


Fig. 4.54 Tangents to an Ellipse (§4.56).

Foci Construction. Fig. 4.54 (b). To draw a tangent at any point on the ellipse, such as point 3, draw the focal radii E3 and F3, extend one, and bisect the exterior angle, as shown. The bisector is the required tangent.

To draw a tangent from any point outside the ellipse, such as point P, with center at P and radius PF, strike an arc as shown. With center at E and radius AB, strike an arc to intersect the first arc at points U. Draw the lines EU to intersect the ellipse at the points Z. The lines PZ are the required tangents.

4.57 Ellipse Templates.

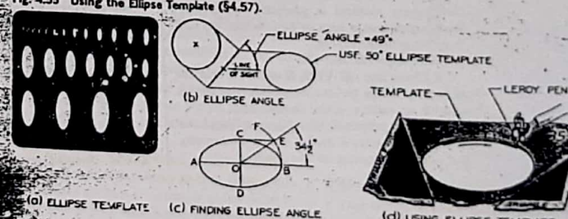
To save time in drawing ellipses, and to insure uniform results, *ellipse templates*, Fig. 4.55 (a), are often used. These are plastic sheets with elliptical openings in a wide variety of sizes, and usually come in sets of six or more sheets.

Ellipse guides are usually designated by the *ellipse angle*, the angle at which a circle is viewed to appear as an ellipse. In Fig. 4.55 (b) the angle between the line of sight and the edge view of the plane of the circle is found to be about 49°; hence the 50° ellipse template is indicated. Ellipse templates are generally available in ellipse angles at 5° intervals, as 15°, 20°, 25°, etc. On this 50° template a variety of sizes of 50° ellipses is provided, and it is only necessary to select the one that fits. If the ellipse angle is not easily determined, you can always look for the ellipse that is approximately as long and as "fat" as the ellipse to be drawn.

A simple construction for finding the ellipse angle when the views are not available is shown at (c). Using center O, strike arc BF; then draw CE parallel to the major axis. Draw diagonal OE, and measure angle EOB with the protractor, §2.19. Use the ellipse template nearest to this angle; in this case a 35° template is selected.

Since it is not practicable to have ellipse openings for every exact size that may be

Fig. 4.55 Using the Ellipse Template (§4.57).



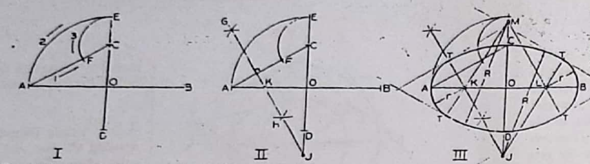


Fig. 4.56 Drawing an Approximate Ellipse (§4.58).

required, it is often necessary to use the template somewhat in the manner of an irregular curve. For example, if the opening is too long and too "fat" for the required ellipse, one end may be drawn and then the template shifted slightly to draw the other end. Similarly, one long side may be drawn and then the template shifted slightly to draw the opposite side. In such cases, leave gaps between the four segments, to be filled in freehand or with the aid of an irregular curve. When the differences between the ellipse openings and the required ellipse are small, it is only necessary to lean the pencil or pen slightly outward or inward from the guiding edge to offset the differences.

For inking the ellipses, the Leroy, Rapidograph, or Wrico pens are recommended. The Leroy pen is shown in Fig. 4.55 (d). Place triangles under the ellipse template, as shown, so as to lift the template from the paper and prevent ink from spreading under the template; or better still, place a larger opening of another ellipse guide underneath.

4.58 To Draw an Approximate Ellipse. Fig. 4.56.

For many purposes, particularly where a small ellipse is required, the approximate circular-arc method is perfectly satisfactory. Such an ellipse is sure to be symmetrical and may be quickly drawn.

Given axes AB and CD.

I. Draw line AC. With O as center and OA as radius, strike the arc AE. With C as center and CE as radius, strike the arc EF.

II. Draw perpendicular bisector GH of the line AF; the points K and J, where it intersects the axes, are centers of the required arcs.

III. Find centers M and L by setting off OL = OK and OM = OJ. Using centers K, L, M, and J, draw circular arcs as shown. The points of tangency T are at the junctures of the arcs on the lines joining the centers.

4.59 To Draw a Parabola.

The curve of intersection between a right circular cone and a plane parallel to one of its elements, Fig. 4.16 (d), is a parabola. *A parabola may be generated by a point moving so that its distances from a fixed point, the focus, and from a fixed line, the directrix, remain equal.* For example:

Fig. 4.57 (a). Given focus F and directrix AB. A parabola may be generated by a pencil guided by a string, as shown. Fasten the string at F and C; its length is GC. The point C is selected at random, its distance from G depending on the desired extent of the curve. Keep the string taut and the pencil against the T-square, as shown.

Fig. 4.57 (b). Given focus F and directrix AB. Draw a line DE parallel to the directrix and at any distance CZ from it. With center at F and radius CZ, strike arcs to intersect the line DE in the points Q and R, which are points on the parabola. Determine as many additional points as are necessary to draw the parabola accurately, by drawing additional lines parallel to line AB and proceeding in the same manner.

A tangent to the parabola at any point G bisects the angle formed by the focal line FG and the line SG perpendicular to the directrix.

Fig. 4.57 (c). Given the rise and span of the parabola. Divide AO into any number of equal parts, and divide AD into a number of equal parts amounting to the square of that number. From line AB, each point on the parabola is offset by a number of units equal to the square of the number of units from point O. For example, point 3 projects 9 units (the square of 3). This method is generally used for drawing parabolic arches.

Fig. 4.57 (d). Given points P, R, and V of a parabola, to find the focus F. Draw tangent at P, making a = b. Draw perpendicular bisector of AP, which intersects the axis at F, the focus of the parabola.

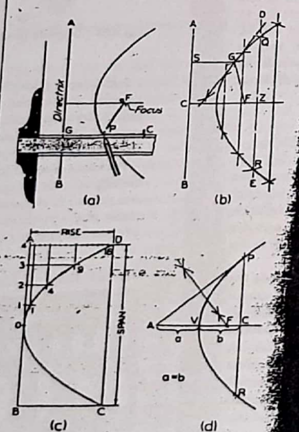


Fig. 4.57 Drawing a Parabola (§4.59).

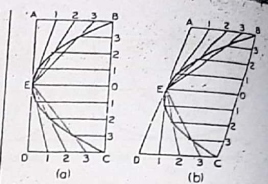


Fig. 4.58 Drawing a Parabola (§4.59).

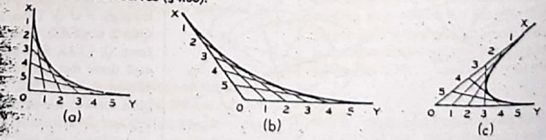
Fig. 4.58 (a) or (b). Given rectangle or parallelogram ABCD. Divide BC into any even number of equal parts, and divide the sides AB and DC each into half as many parts, and draw lines as shown. The intersections of like-numbered lines are points on the parabola.

PRACTICAL APPLICATIONS. The parabola is used for reflecting surfaces for light and sound, for vertical curves in highways, for forms of arches, and approximately for forms of the curves of cables for suspension bridges. It is also used to show the bending moment at any point on a uniformly loaded beam or girder.

4.60 To Join Two Points by a Parabolic Curve. Fig. 4.59.

Let X and Y be the given points. Assume any point O, and draw tangents XO and YO. Divide XO and YO into the same number of equal parts, number the division points as shown, and connect corresponding points. These lines are tangents of the required parabola and form its envelope. Sketch a light smooth curve, and then heavy

Fig. 4.59 Parabolic Curves (§4.60).



in the curve with the aid of the irregular curve, §2.59.

These parabolic curves are more pleasing in appearance than circular arcs and are useful in machine design. If the tangents OX and OY are equal, the axis of the parabola will bisect the angle between them.

4.61 To Draw a Hyperbola.

The curve of intersection between a right circular cone and a plane making an angle with the axis smaller than that made by the elements, Fig. 4.46 (e), is a *hyperbola*. *A hyperbola is generated by a point moving so that the difference of its distances from two fixed points, the foci, is constant and equal to the transverse axis of the hyperbola.*

Fig. 4.60 (a). Let F and F be the foci and AB the transverse axis. The curve may be generated by a pencil guided by a string, as shown. Fasten a string at F' and C; its length is FC minus AB. The point C is chosen at pleasure; its distance from F depends on the desired extend of the curve.

Fasten the straightedge at F. If it is revolved about F, with the pencil point moving against it and with the string taut, the hyperbola may be drawn as shown.

Fig. 4.60 (b). To construct the curve geometrically, select any point X on the transverse axis produced. With centers at F and F' and BX as radius, strike the arcs DE. With the same centers and AX as radius, strike arcs to intersect the arcs first drawn in the points Q, R, S, and T, which are points of the required hyperbola. Find as many additional points as necessary to draw the curves accurately by selecting other points similar to point X along the transverse axis, and proceeding as described for point X.

To draw the tangent to a hyperbola at a given point P, bisect the angle between the focal radii FP and F'P. The bisector is the required tangent.

To draw the asymptotes HCH of the hyperbola, draw a circle with the diameter FF' and erect perpendiculars to the transverse axis at the points A and B to intersect the circle in the points H. The lines HCH are the required asymptotes.

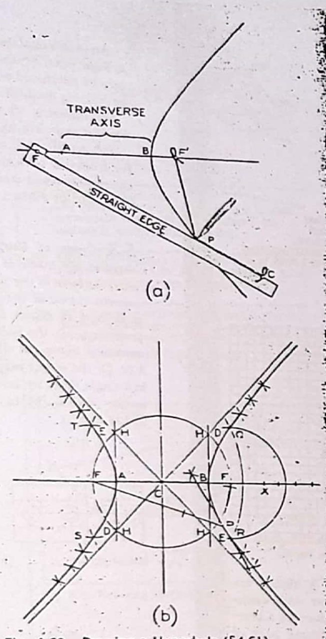


Fig. 4.60 Drawing a Hyperbola (§4.61).

4.62 To Draw an Equilateral Hyperbola.

Fig. 4.61. Let the asymptotes OB and OA, at right angles to each other, and the point P on the curve be given.

Fig. 4.61 (a). In an equilateral hyperbola the asymptotes, at right angles to each other, may be used as the axes to which the curve is referred. If a chord of the hyperbola is extended to intersect the axes, the intercepts between the curve and the axes are equal. For example, a chord through given point P intersects the axes at points 1 and 2, intercepts P–1 and 2–3 are equal, and point 3 is a point on the hyperbola. Likewise, another chord through P provides equal intercepts P–1' and 3'–2', and point 3' is a point on the curve. All chords need not be drawn through given point P, but as new points are established on the curve, chords may be drawn through them to obtain more points. After enough points are found to insure an accurate curve, the hyperbola is drawn with the aid of the irregular curve, §2.59.

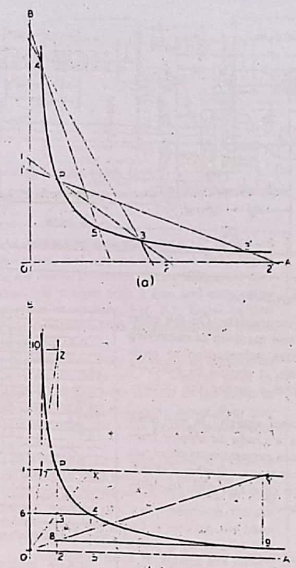


Fig. 4.61 Equilateral Hyperbola (§4.62).

Fig. 4.61 (b). In an equilateral hyperbola, the coordinates are related so that their products remain constant. Through given point P, draw lines 1–P–Y and 2–P–Z parallel, respectively, to the axes. From the origin of coordinates O, draw any diagonal intersecting these two lines at points 3 and X. At these points draw lines parallel to the axes, intersecting at point 4, a point on the curve. Likewise, another diagonal from O intersects the two lines through P at points 8 and Y, and lines through these points parallel to the axes intersect at point 9, another point on the curve. A third diagonal similarly produces point 10 on the curve, and so on. Find as many points as necessary for a smooth curve, and draw the parabola with the aid of the irregular curve, §2.59. It is evident from the similar triangles O–X–5 and O–3–2 that lines P–1 × P–2 = 4–5 × 4–6.

The equilateral hyperbola can be used to represent varying pressure of a gas as the volume varies, because the pressure varies inversely as the volume, that is, pressure × volume is constant.

4.63 To Draw a Spiral of Archimedes.

Fig. 4.62. To find points on the curve, draw lines through the pole C, making equal angles with each other, such as 30° angles, and beginning with any one line, set off any distance, such as 2 mm or $\frac{1}{16}$"; set off twice that distance on the next line, three times on the third, and so on. Through the points thus determined, draw a smooth curve, using the irregular curve, §2.59.

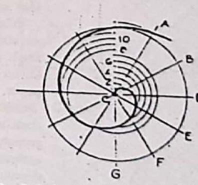


Fig. 4.62 Spiral of Archimedes (§4.63).

4.64 To Draw a Helix.

Fig. 4.63. *A helix is generated by a point moving around and along the surface of a cylinder or cone with a uniform angular velocity about the axis, and with a uniform*

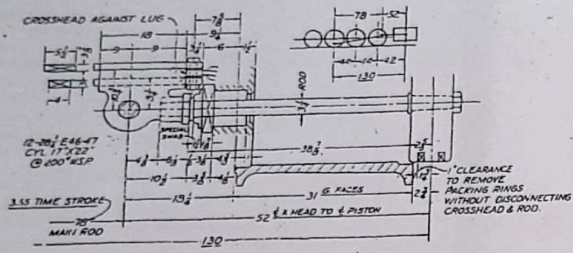


Fig. 5.1 Typical Design Sketch.

may be rough and incomplete. On the other hand, if a sketch is the medium of conveying important and precise information to engineers or to craftsmen, it should be executed as carefully as possible under the circumstances.

The term "freehand sketch" is too often understood to mean a crude or sloppy freehand drawing in which no particular effort has been made. On the contrary, a freehand sketch should be made with care and with attention to correct line widths.

5.2 Sketching Materials.

One of the advantages of freehand sketching is that it requires only pencil, paper, and eraser—items that anyone has for ready use.

When sketches are made in the field, where an accurate record is required, a small notebook or sketching pad is frequently used. Often clip boards are employed to hold the paper.

Cross-section paper is helpful to the sketcher, especially to the beginner or to the person who cannot sketch reasonably well without guide lines. It is available in rolls, sheets, and in pad form. Paper with 4, 5, 8, or 10 squares per inch is recommended. Such paper is convenient for sketching to scale since values can be assigned to the squares, and the squares counted to secure proportional distances, as shown in Fig. 5.2.

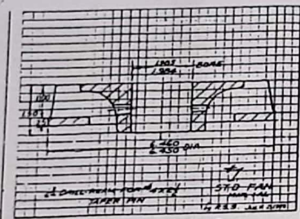


Fig. 5.2 Sketch on Cross-Section Paper.

Where multiple copies of a sketch are needed, a special tracing paper with cross-section lines that do not reproduce on a blueprint can be used. Also, sketching pads of plain tracing paper are available, accompanied by a master cross-section sheet. The draftsman places a blank sheet over the master grid and sketches while following the squares, which he can see through the transparent sheet.

An excellent procedure is to draw, with instruments, a master cross-section sheet, using India ink, making the squares either 10 mm or .250" as desired. Ordinary bond typewriter paper is then placed over the master sheet and the sketch made thereon. Such a sketch is not only more uniform and "true," but shows up better because the cross-section lines are absent.

An excellent plain white paper for sketching is *ledger paper*, which is heavier than bond and may be purchased at low cost from a stationer or printing establishment.

For isometric sketching, a specially ruled *isometric paper* is available, Fig. 5.26.

Soft pencils, such as HB or F, should be used for freehand sketching. For carefully made sketches, two soft erasers are recommended, a Pink Pearl or a Mars-Plastic, Fig. 2.17.

5.3 Types of Sketches.

Since technical sketches are made of three-dimensional objects, the form of the sketch conforms approximately to one of the four standard types of projection, as shown in Fig. 5.3. In *multiview* projection, (a), the object is described by its necessary views, as discussed in §§5.11 to 5.24. Or the object may be shown pictorially in a single view, by *axonometric, oblique*, or *perspective sketches*, (b) to (d), as discussed in §§5.25 to 5.31.

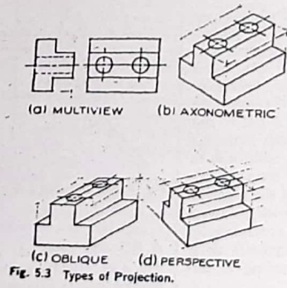


Fig. 5.3 Types of Projection.

5.4 Scale.

Sketches usually are not made to any scale. Objects should be sketched in their correct proportions as accurately as possible, by eye. However, cross-section paper provides a ready scale (by counting squares) that may be used, if only to assist in sketching to correct proportions. The size of the sketch is purely

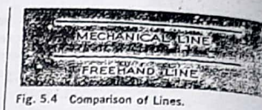


Fig. 5.4 Comparison of Lines.

optional, depending upon the complexity of the object and the size of paper available. Small objects are often sketched oversize so as to show the necessary details clearly.

5.5 Technique of Lines.

The chief difference between an instrumental drawing and a freehand sketch lies in the character or *technique* of the lines. A good freehand line should not be rigidly straight or exactly uniform, as an instrumental line. While the effectiveness of an instrumental line lies in exacting uniformity, the quality of freehand line lies in its *freedom* and *variety*, Figs. 5.4 and 5.7.

Conventional lines, drawn instrumentally, are shown in Fig. 2.15, and the corresponding freehand renderings are shown in Fig. 5.5. The freehand construction line is a very light rough

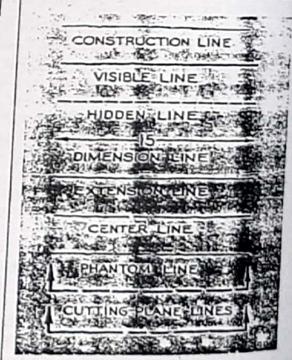


Fig. 5.5 Sketch Lines.

line in which some strokes may overlap. All other lines should be dark and clean-cut. Accent the ends of all dashes, and maintain a sharp contrast between the line thicknesses. Especially, make visible lines heavy so the outline will stand out clearly, and make hidden lines, center lines, dimension lines, and extension lines *thin*.

5.6 Sharpening Sketching Pencils.

Use a soft pencil, such as HB or F, or a mechanical pencil with an HB or F lead, and sharpen it to a conical point, as shown in Fig. 2.12 (c). Use this sharp point for center lines, dimension lines, and extension lines. For visible lines, hidden lines, and cutting-plane lines, round off the point slightly to produce the desired thickness of line, Fig. 5.6. Make all lines dark, with the exception of construction lines, which should be very light.

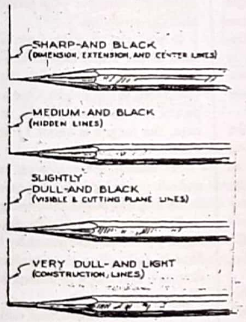


Fig. 5.6 Pencil Points.

The use of thin-lead mechanical pencils with suitable diameters and grades of leads minimizes the need for sharpening and point dressing.

5.7 Straight Lines.

Since the majority of lines on the average sketch are straight lines, it is necessary to learn to make them well.

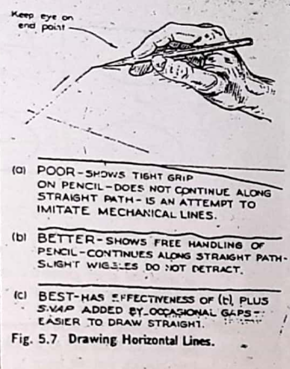


Fig. 5.7 Drawing Horizontal Lines.

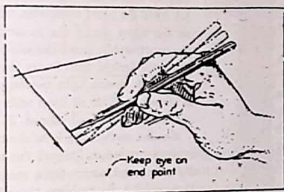


Fig. 5.8 Drawing Vertical Lines.

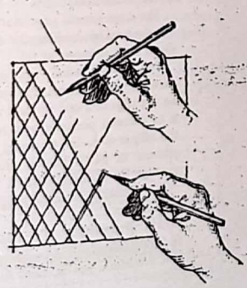


Fig. 5.9 Drawing Inclined Lines.

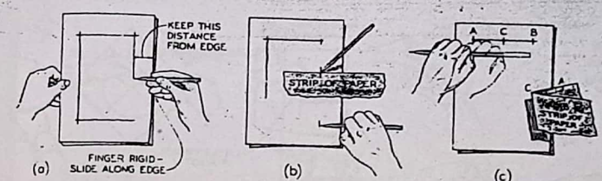


Fig. 5.10 Blocking In Horizontal and Vertical Lines.

Hold the pencil naturally about $1\frac{1}{2}''$ back from the point, and approximately at right angles to the line to be drawn. Draw horizontal lines from left to right with a free and easy wrist-and-arm movement, Fig. 5.7. Draw vertical lines downward with finger-and-wrist movements, Fig. 5.8.

Inclined lines may be made to conform in direction to horizontal or vertical lines by shifting position with respect to the paper or by turning the paper slightly; hence, they may be drawn with the same general movements, Fig. 5.9.

In sketching long lines, mark the ends of the line with light dots, then move the pencil back and forth between the dots in long sweeps, keeping the eye always on the dot toward which the pencil is moving, the point of the pencil touching the paper lightly, and each successive stroke correcting the defects of the preceding strokes. When the path of the line has been established sufficiently, apply a little more pressure, replacing the trial series with a distinct line. Then, dim the line with a soft eraser and draw the final line clean-cut and dark, keeping the eye now on the point of the pencil.

An easy method of blocking in horizontal or vertical lines is to hold the hand and pencil rigidly and glide the finger tips along the edge of the pad or board, as shown in Fig. 5.10.

Another method, (b), is to mark the distance on the edge of a card or a strip of paper and transfer this distance at intervals, as shown; then draw the final line through these points. Or the pencil may be held as shown at the lower part of (b), and distance marks made on the paper at intervals by tilting the lead down to the paper. It will be seen that both methods of transferring distances are substitutes for the dividers and will have many uses in sketching.

To find the midpoint of a line AB at (c), hold the pencil in the left hand with the thumb gaging the estimated half-distance. Try this distance on the left and then on the right until the center is located by trial, and mark the center C, as shown. Another method is to mark the total distance AB on the edge of a strip of paper and then to fold the paper to bring points A and B together, thus locating center C at the crease. To find quarter points, the folded strip can be folded once more.

5.8 Circles and Arcs.

Small circles and arcs can be easily sketched in one or two

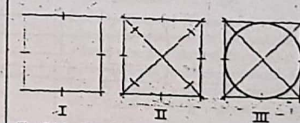


Fig. 5.11 Sketching a Circle.

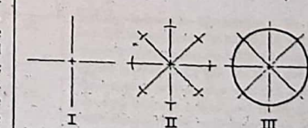


Fig. 5.12 Sketching a Circle.

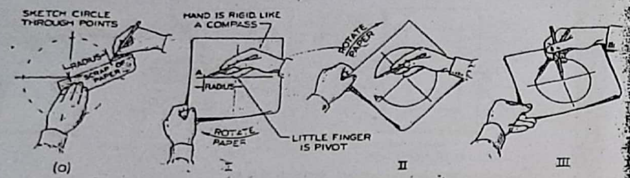


Fig. 5.13 Sketching Circles.

strokes, as for the circular portions of letters, without any preliminary blocking in.

One method of sketching a larger circle, Fig. 5.11, is first to sketch lightly the enclosing square, mark the midpoints of the sides, draw light arcs tangent to the sides of the square, and then heavy in the final circle.

Another method, Fig. 5.12, is to sketch the two center lines, add light 45° radial lines, sketch light arcs across the lines at the estimated radius distance from the center, and finally to sketch the required circle heavily.

In both methods, dim all construction lines with a soft eraser before heavying in the final circle.

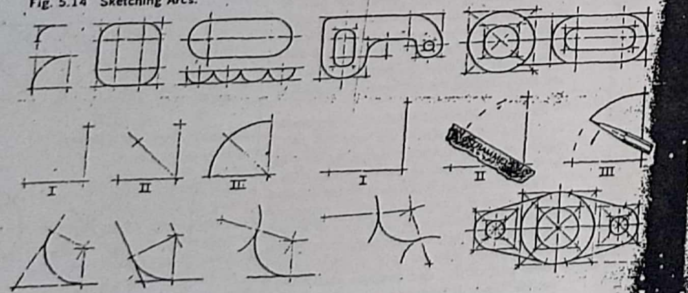
An excellent method, particularly for large circles, Fig. 5.13 (a), is to mark the estimated radius on the edge of a card or scrap of paper, to set off from the center as many points as desired, and to sketch the final heavy circle through these points.

The clever draftsman will prefer the method at I and II, in which the hand is used as a compass. Place the tip of the little finger, or the knuckle joint of the little finger, at the center; "feed" the pencil out to the desired radius, hold this position rigidly, and carefully revolve the paper with the other hand, as shown. If you are using a sketching pad, place the pad on your knee and revolve the entire pad on the knee as a pivot.

At III, two pencils are held rigidly like a compass and the paper is slowly revolved.

Methods of sketching arcs, Fig. 5.14, are adaptations of those used for sketching circles. In general, it is easier to sketch arcs with the hand and pencil on the concave side of the curve. In sketching tangent arcs, always keep

Fig. 5.14 Sketching Arcs.



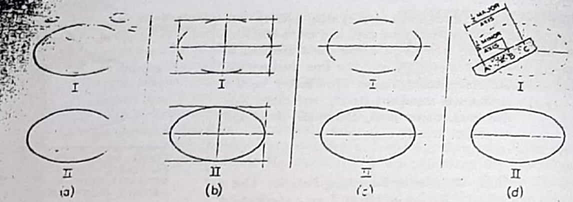


Fig. 5.15 Sketching Ellipses.

in mind the above geometric constructions, carefully approximating all points of tangency.

5.9 Ellipses. If a circle is viewed obliquely, Fig. 4.50 (b), it appears as an ellipse. With a little practice, you can learn to sketch small ellipses with a free arm movement, Fig. 5.15 (a). Hold the pencil naturally, rest the weight on the upper part of the forearm, and move the pencil rapidly above the paper in the elliptical path desired; then lower the pencil so as to describe several light overlapping ellipses, as shown at I. Dim all lines with a soft eraser and heavy in the final ellipse, II.

Another method (b), is to sketch lightly the enclosing rectangle I, mark the midpoints of the sides, and sketch light tangent arcs, as shown. Then, II, complete the ellipse lightly, dim all lines with a soft eraser, and heavy in the final ellipse.

The same general procedure shown at (b) may be used in sketching the ellipse upon the given axes, as shown at (c).

The *trammel method*, (d), is excellent for sketching large ellipses. Prepare a "trammel" on the edge of a card or strip of paper, move it to different positions, and mark points on the ellipse at A. The trammel method is explained in §4.51. Sketch the final ellipse through the points as shown.

For sketching isometric ellipses, see §5.13.

5.10 Proportions. *The most important rule in freehand sketching is to keep the sketch in proportion.* No matter how brilliant the technique or how well the small details are drawn, if the proportions—especially the large over-all proportions—are bad, the sketch will be bad. First, the relative proportions of the height to the width must be carefully established; then as you proceed to the medium-size areas and the small details, constantly compare each new estimated distance with established distances already set down.

If you are working from a given picture, such as the utility cabinet in Fig. 5.16 (a), it is first necessary to establish the relative width compared to the height. One way is to use the pencil as a measuring stick, as shown. In this case, the height is about $1\frac{3}{4}$ times the width. Then:

I. Sketch the enclosing rectangle in the correct proportion. In this case, the sketch is to be slightly larger than the given picture.

II. Divide the available drawer space into three parts with the pencil by trial, as shown. Sketch light diagonals to locate centers of drawers, and block in drawer handles. Sketch all remaining details.

III. Dim all construction with a soft eraser, and heavy in all final lines.

Another method of estimating distances is illustrated in Fig. 5.17. On the edge of a card or strip of paper, mark an arbitrary unit. Then see how many units wide and how many units high the desk is. If you are working from the actual object, you could use a scale, a piece of paper, or the pencil itself as a unit to determine the proportions.

To sketch an object composed of many

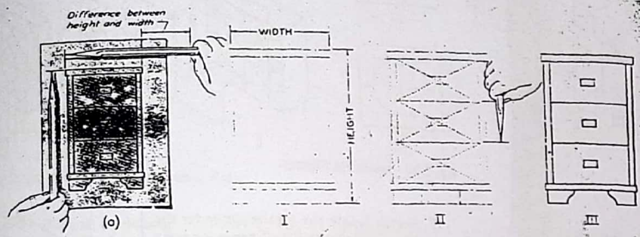


Fig. 5.16 Sketching a Utility Cabinet.

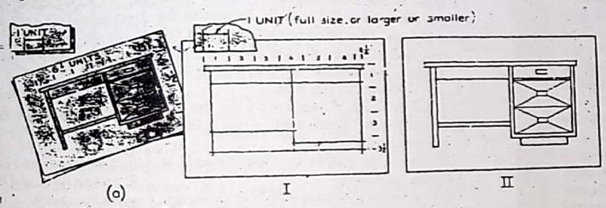


Fig. 5.17 Sketching a Desk.

curves to the same scale or to a larger or smaller scale, the method of "squares" is recommended, Fig. 5.18. On the given picture, rule accurate grid lines to form squares of any convenient size. It is best to use a scale and some convenient spacing, such as either .50" or 10 mm. On the new sheet, rule a similar grid, making the spacing of the lines proportional to the original, but reduced or enlarged as desired. Make the final sketch by drawing the lines in and across the grid lines as in the original, as near as you can estimate by eye.

In sketching from an actual object, you can easily compare various distances on the object

Fig. 5.18 Squares Method.

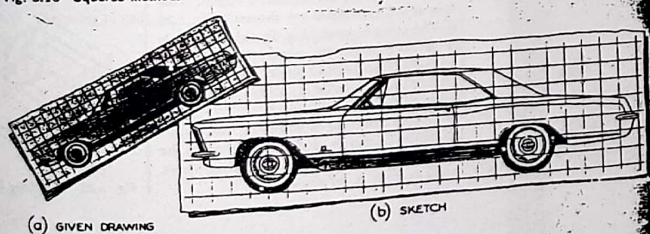
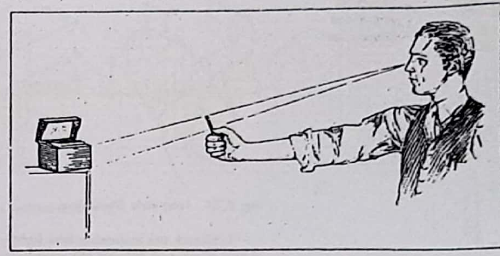


Fig. 5.19 Estimating Dimensions.



by using the pencil to compare measurements as shown in Fig. 5.19. While doing this, do not change your position, and always hold your pencil at arm's length. The length sighted can then be compared in similar manner with any other dimension of the object. If the object is small, such as a machine part, you can compare distances in the manner of Fig. 5.16, by actually placing the pencil against the object itself.

In establishing proportions, the blocking-in method is recommended, especially for irregular shapes. The steps for blocking in and completing the sketch of a Shaft Hanger are shown in Fig. 5.20. As always, first give attention to the main proportions, next to the general sizes and direction of flow of curved shapes, and finally to the snappy lines of the completed sketch.

In making sketches from actual machine parts, it is necessary to use the measuring tools used in the shop, especially those needed to determine dimensions that must be relatively accurate. For a discussion of these methods, see §10.21.

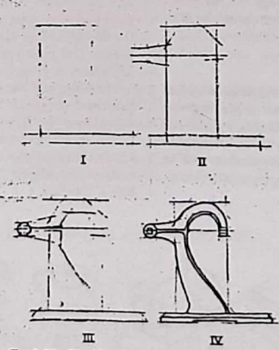


Fig. 5.20 Blocking In an Irregular Object (Shaft Hanger).

5.11 Pictorial Sketching.

We shall now examine several simple methods of preparing *pictorial* sketches that will be of great assistance in learning the principles of multiview projection. A detailed and more scientific treatment of pictorial drawing is given in Chapters 16, 17, and 18.

5.12 Isometric Sketching.

To make an *isometric* sketch from an actual object, hold the object in your hand and tilt it toward you, as shown in Fig. 5.21 (a). In this position, the front corner will appear vertical, and the two receding bottom edges and those parallel to them, respectively, will appear at about 30° with horizontal, as shown. The steps in sketching are:

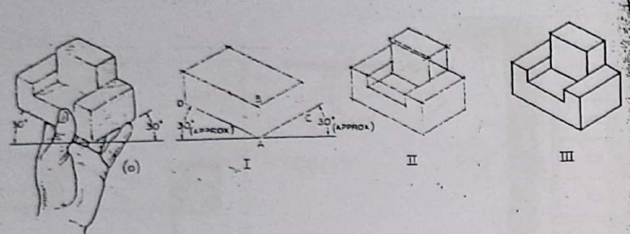


Fig. 5.21 Isometric Sketching.

I. Sketch the enclosing box lightly, making AB vertical, and AC and AD approximately 30° with horizontal. These three lines are the *isometric axes*. Make AB, AC, and AD approximately equal in length to the actual corresponding edges on the object. Sketch the remaining lines parallel, respectively, to these three lines.

II. Block in the recess and the projecting block.

III. Dim all construction lines with a soft eraser, and heavy in all final lines.

Note: The angle of the receding lines may be less than 30°, say 20° or 15°. Although the result will not be an isometric sketch, the sketch may be more pleasing and effective in many cases.

5.13 Isometric Ellipses.

As shown in Fig. 4.50 (b), a circle viewed at an angle appears as an ellipse. When objects having cylindrical or conical shapes are placed in the isometric or other oblique positions, the circles will be viewed at an angle and will appear as ellipses, Fig. 5.22.

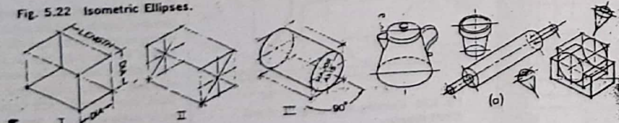
The most important rule in sketching isometric ellipses is: *The major axis of the ellipse is always at right angles to the center line of the cylinder, and the minor axis is at right angles to the major axis and coincides with the center line.*

Two views of a block with a large cylindrical hole are shown in Fig. 5.23 (a). The steps in sketching the object are:

I. Sketch the block and the enclosing parallelogram for the ellipse, making the sides of the parallelogram parallel to the edges of the block and equal in length to the diameter of the hole. Draw diagonals to locate the center of the hole, and then draw center lines AB and CD. Points A, B, C, and D will be midpoints of the sides of the parallelogram, and the ellipse will be tangent to the sides at those points. The major axis will be on the diagonal EF, which is at right angles to the center line of the hole, and the minor axis will fall along the short diagonal. Sketch long flat elliptical sides CA and BD, as shown.

II. Sketch short small-radius arcs CB and AD to complete the ellipse. Avoid making the ends of the ellipse "squared off," or pointed like a football.

Fig. 5.22 Isometric Ellipses.



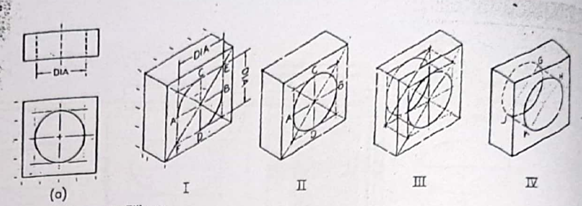


Fig. 5.23 Isometric Ellipses.

III. Sketch lightly the parallelogram for the back ellipse, and sketch the ellipse in the same manner as the front ellipse.

IV. Draw lines GH and JK tangent to the two ellipses. Dim all construction with a soft eraser, and heavy in all final lines.

Another method for determining the back ellipse is shown in Fig. 5.24.

I. Select points at random on the front ellipse and sketch "depth lines" equal in length to the depth of the block.

II. Sketch the ellipse through the ends of the lines, as shown.

Two views of a Bearing with a semicylindrical opening are shown in Fig. 5.25 (a). The steps in sketching are:

I. Block in the object, including the rectangular space for the semicylinder.

II. Block in the box enclosing the complete cylinder. Sketch the entire cylinder lightly.

III. Dim all construction lines, and heavy in all final lines, showing only the lower half of the cylinder.

5.14 Sketching on Isometric Paper.

Two views of a Guide Block are shown in Fig. 5.26 (a). The steps in sketching illustrate not only the use of isometric paper, but also the sketching of individual planes or faces of the object in order to build up pictorially a visualization of the given views.

I. Sketch isometric of enclosing box, counting off the isometric grid spaces to equal the corresponding squares on the given views. Sketch surface A, as shown.

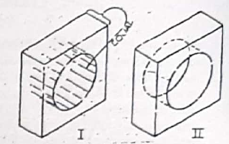


Fig. 5.24 Isometric Ellipses.

II and III. Sketch additional surfaces B, C, E, and so forth, and the small ellipse, to complete the sketch.

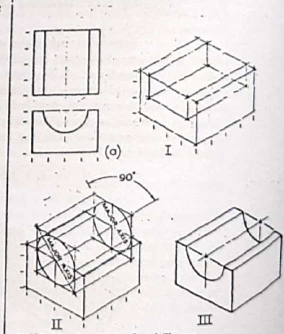


Fig. 5.25 Sketching Semiellipses.

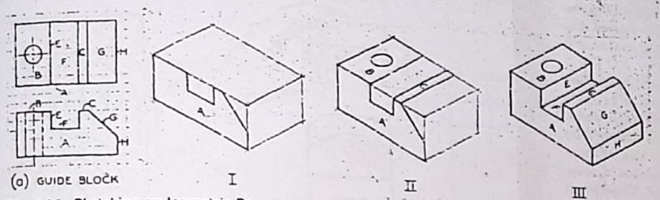


Fig. 5.26 Sketching on Isometric Paper.

5.15 Oblique Sketching.

Another simple method for sketching pictorially is *oblique* sketching, Fig. 5.27. Hold the object in your hand, as shown at (a).

I. Block in the front face of the Bearing, as if you were sketching a front view.

II. Sketch receding lines parallel to each other and at any convenient angle, say 30° or 45° with horizontal, approximately. Cut off receding lines so that the depth appears correct. These lines may be full length, but a more natural appearance results if they are cut to three-quarters or one-half size, approximately. If they are full length, the sketch is a *cavalier* sketch. If half size, the sketch is a *cabinet* sketch. See §17.4.

III. Dim all construction lines with a soft eraser and heavy in the final lines.

Note: Oblique sketching is a less suitable method for any object having circular shapes in or parallel to more than one plane of the object, because ellipses result when circular shapes are viewed obliquely. Therefore, place the object with most or all of the circular shapes toward you, so that they will appear as true circles and arcs in oblique sketching, as in Fig. 5.27.

5.16 Oblique Sketching on Cross-Section Paper.

Ordinary cross-section paper is suitable and convenient for oblique sketching. Two views of a Bearing Bracket are shown in Fig. 5.28 (a). The dimensions are determined simply by counting the squares.

I. Sketch lightly the enclosing box construction. Sketch the receding lines at 45° diagonally through the squares. To establish the depth at a reduced scale, sketch the receding lines diagonally through half as many squares as the given number shown at (a).

II. Sketch all arcs and circles.

III. Heavy in all final lines.

5.17 Perspective Sketching.

The Bearing sketched in oblique in Fig. 5.27 can easily be sketched in *one-point perspective* (one vanishing point), as shown in Fig. 5.29.

I. Sketch the true front face of the object, just as in oblique sketching. Select the vanishing point (VP) for the receding lines. In most cases, it is desirable to place VP above and to the right of the picture, as shown, although it can be placed anywhere in the vicinity of the picture. But if it is placed too close to the center, the lines will converge too sharply, and the picture will be distorted.

II. Sketch the receding lines toward VP.

III. Estimate the depth to look well, and sketch in the back portion of the object. Note that the back circle and arc will be slightly smaller than the front circle and arc.

IV. Dim all construction with a soft eraser, and heavy in all final lines. Note the similarity between the perspective sketch and the oblique sketch in Fig. 5.27.

Two-point perspective (two vanishing points) is the most true to life of all pictorial methods, but requires some natural sketching ability or considerable practice for best results. A simple method is shown in Fig. 5.30 that can be used successfully by the nonartistic student:

I. Sketch front corner of desk in true height, and locate two *vanishing points* (VPL and VPR) on a *horizon* line (eye level). The distance CA may vary—the greater it is, the higher the eye level will be and the more we will be looking down on top of the object. A good rule of thumb is to make C-VPL one third to one fourth of C-VPR.

II. Estimate depth and width, and sketch enclosing box.

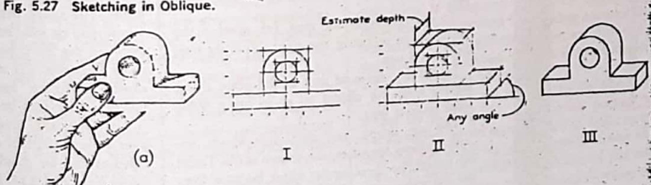
III. Block in all details. Note that all parallel lines converge toward the same vanishing point.

IV. Dim the construction lines with a soft eraser as necessary, and heavy in all final lines. Make the outlines thicker and the inside lines thinner, especially where they are close together.

5.18 Views of Objects.

A pictorial drawing or a photograph shows an object as it *appears* to the observer, but not as it is. Such

Fig. 5.27 Sketching in Oblique.



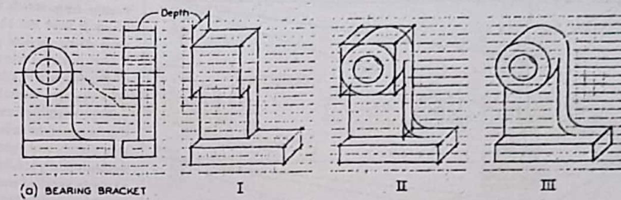
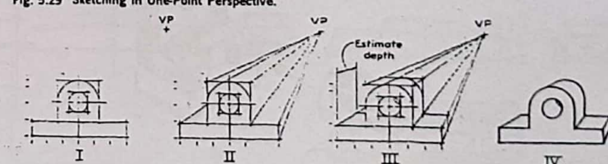


Fig. 5.28 Oblique Sketching on Cross-Section Paper.

Fig. 5.29 Sketching in One-Point Perspective.



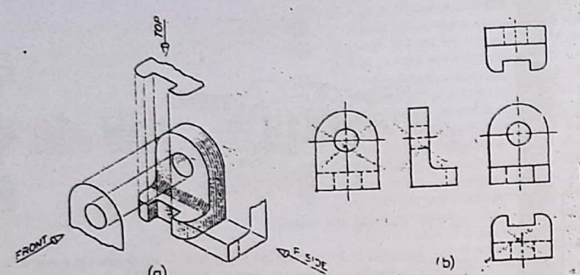


Fig. 5.36 Choice of Views.

object. These minimum required views are referred to as the *necessary views*. In selecting views, the draftsman should choose those that show best the essential contours or shapes and should give preference to those with the least number of hidden lines.

As shown in Fig. 5.36 (a), there are three distinctive features of this object that need to be shown on the drawing:

1. Rounded top and hole, seen from the front.
2. Rectangular notch and rounded corners, seen from the top.
3. Right angle with filleted corner, seen from the side.

Another way to choose necessary views is to eliminate unnecessary views. At (b) a "thumbnail sketch" of the six views is shown. Both the front and rear views show the true shapes of the hole and the rounded top, but the front view is preferred because it has no hidden lines. Therefore, the rear view (which is seldom needed) is crossed out.

Both the top and bottom views show the rectangular notch and rounded corners, but the top view is preferred because it has fewer hidden lines.

Both the right-side and left-side views show the right angle with the filleted corner. In fact, in this case the side views are identical, except reversed. In such instances, it is customary to choose the right-side view.

The necessary views, then, are the three remaining views: the top, front, and right-side views. These are the three regular views referred to in connection with Fig. 5.32.

More complicated objects may require more than three views, or in many cases special views such as partial views, §6.9; sectional views, Chapter 7; auxiliary views, Chapter 8.

5.23 Two-View Drawings.

Often only two views are needed to describe clearly the shape of an object. In Fig. 5.37 (a), the right-side view shows no significant contours of the object, and is crossed out. At (b) the top and front views are identical, so the top view is eliminated. At (c), no additional information not already given in the front and top views is shown in the side view, so the side view is unnecessary.

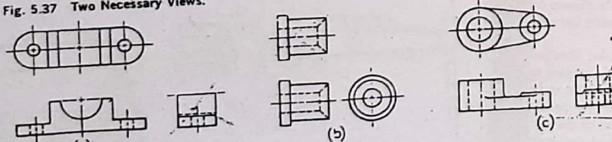
The question often arises: What are the absolute minimum views required? For example, in Fig. 5.35, the top view might be omitted, leaving only the front and right-side views. However, it is more difficult to "read" the two views or visualize the object, because the characteristic "Z" shape of the top view is omitted. In addition, one must assume that corners A and B (top view) are square and not filleted. In this example, all three views are necessary.

If the object requires only two views, and the left-side and right-side views are equally descriptive, the right-side view is customarily chosen, Fig. 5.39. If contour A were omitted, then the presence of slot B would make it necessary to choose the left-side view in preference to the right-side view.

If the object requires only two views, and the top and bottom views are equally descriptive, the top view is customarily chosen, Fig. 5.40.

If only two views are necessary, and the top view and right-side view are equally descriptive, the combination chosen is that which spaces best on the paper, Fig. 5.41.

Fig. 5.37 Two Necessary Views.



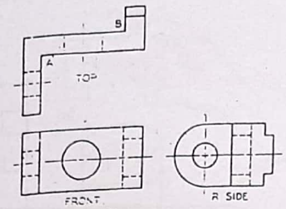


Fig. 5.38 Three Views.

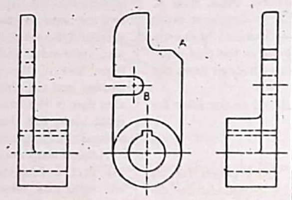


Fig. 5.39 Choice of Right-Side View.

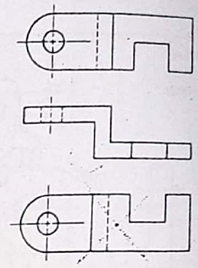
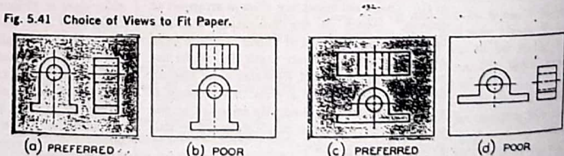


Fig. 5.40 Choice of Top View.

Fig. 5.41 Choice of Views to Fit Paper.



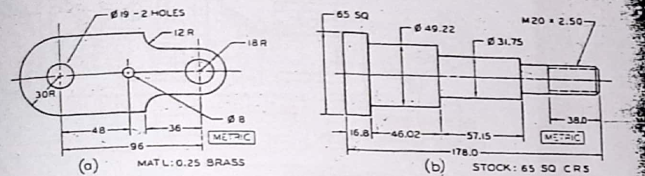
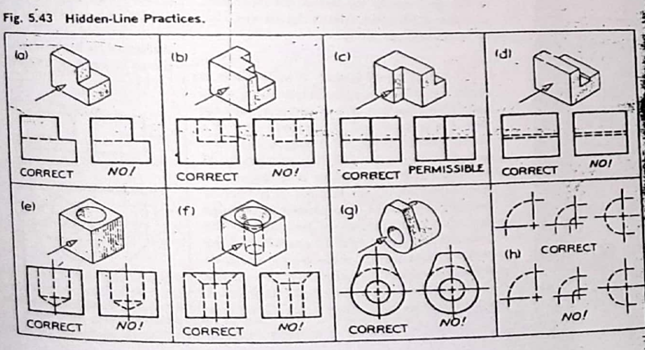


Fig. 5.42 One-View Drawings.

5.24 One-View Drawings. Frequently a single view supplemented by a note or lettered symbols is sufficient to describe clearly the shape of a relatively simple object. In Fig. 5.42 (a), one view of the Shim, plus a note indicating the thickness as 0.25 mm, is sufficient. At (b), the left end is 65 mm square, the next portion is 49.22 mm diameter, the next is 31.75 mm diameter, and the portion with the thread is 20 mm diameter, as indicated in the note. Nearly all shafts, bolts, screws, and similar parts can and should be represented by single views in this manner.

5.25 Hidden Lines. Correct and incorrect practices in drawing hidden lines are illustrated in Fig. 5.43. In general, a hidden line should join a visible line except when it causes the visible line to extend too far, as shown at (a). In other words, *leave a gap whenever a hidden-line dash forms a continuation of a visible line.* Hidden lines should intersect to form L and T corners, as shown at (b). A hidden line preferably should "jump" a visible line when possible, (c). Parallel hidden lines should be drawn so that the dashes are staggered, in a manner similar to bricklaying, as at (d). When two or three hidden lines meet at a point, the dashes should join, as shown for the bottom of the drilled hole at (e), and for the top of a countersunk hole, (f). The example at (g) is similar to (a) in that hidden lines should not join visible lines when it makes the visible line

Fig. 5.43 Hidden-Line Practices.



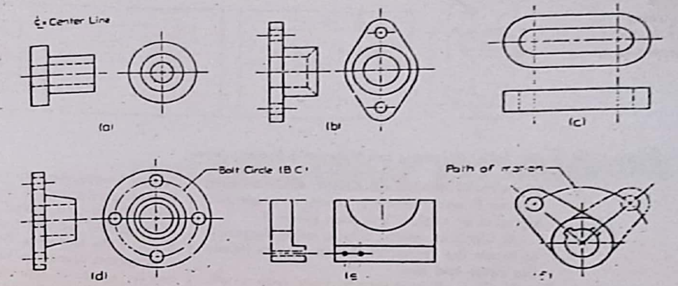


Fig. 5.44 Center-Line Applications.

extend too far. Correct and incorrect methods of drawing hidden arcs are shown at (h).

Poorly drawn hidden lines can easily spoil a drawing. Each dash should be carefully drawn about 5 mm long and spaced only about 1 mm apart, by eye. Accent the beginning and end of each dash by pressing down on the pencil, whether drawn freehand or mechanically.

In general, views should be chosen that show features with visible lines, so far as possible. After this has been done, hidden lines should be used wherever necessary to make the drawing clear. Where they are not needed for clearness, hidden lines should be omitted, so as not to clutter the drawing any more than necessary and in order to save time. The beginner, however, would do well to be cautious about leaving out hidden lines until experience shows him when they can be safely omitted.

5.26 Center Lines. *Center lines* (symbol: ℄) are used to indicate axes of symmetrical objects or features, bolt circles, and paths of motion. Typical applications are shown in Fig. 5.44. As shown at (a), a single center line is drawn in the longitudinal view and crossed center lines in the circular view. The small dashes should cross at the intersections of center lines. Center lines should extend uniformly about 8 mm outside the feature for which they are drawn.

The long dashes of center lines may vary from 20 mm to 40 mm or more in length, depending upon the size of the drawing. The short dashes should be about 5 mm long, with spaces about 2 mm. Center lines should always start and end with long dashes. Short center lines, especially for small holes, as at (e), may be made solid as shown. Always leave a gap as at (e) when a center line forms a continuation of a visible or hidden line. Center lines should be thin enough to contrast well with the visible and hidden lines, but dark enough to reproduce well.

Center lines are useful mainly in dimensioning and should be omitted from unimportant rounded or filleted corners and other shapes that are self-locating.

5.27 Sketching Two Views. The Support Block in Fig. 5.45 (a) requires only two views. The steps in sketching are:

I. Block in lightly the enclosing rectangles for the two views. Sketch horizontal lines 1 and 2 to establish the height of the object, while making spaces A approximately equal. Sketch vertical lines 3, 4, 5, and 6 to establish the width and depth in correct proportion to

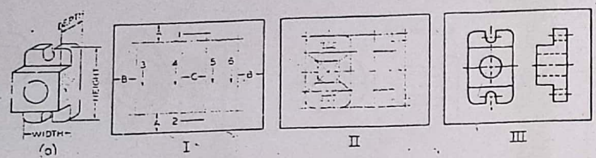


Fig. 5.45 Sketching Two Views of a Support Block.

the already established height, while making spaces B approximately equal, and space C equal to or slightly less than space B.

II. Block in smaller details, using diagonals to locate the centers, as shown. Sketch lightly the circle and arcs.

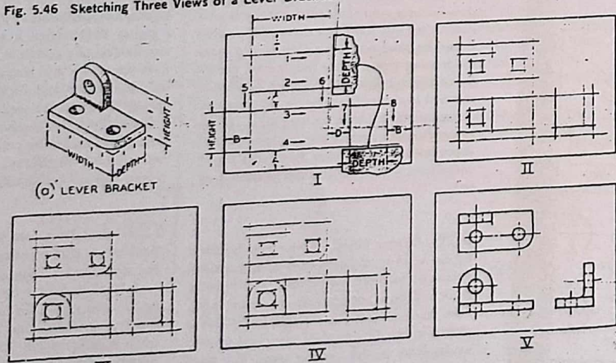
III. Dim all construction lines with a soft eraser, and heavy in all final lines.

5.28 Sketching Three Views.

A Lever Bracket requiring three views is shown in Fig. 5.46 (a). The steps in sketching the three views are as follows:

I. Block in the enclosing rectangles for the three views. Sketch horizontal lines 1, 2, 3, and 4 to establish the height of the front view and the depth of the top view, while making spaces A approximately equal, and space C equal to or slightly less than space A. Sketch vertical lines 5, 6, 7, and 8 to establish the width of the top and front views, and the depth of the side view. Make sure that this is in correct proportion to the height, while making spaces B approximately equal and space D equal to or slightly less than one space B. Note that spaces C and D are not necessarily equal, but are independent of each other. Similarly, spaces A and B are not necessarily equal. To transfer the depth dimension from the top view to the side view, use the edge of a card or strip of paper, as shown; or transfer the distance by using the pencil as a measuring stick, as shown in Fig. 5.10 (b) and (c). *Note that the depth in the top and side views must always be equal.*

Fig. 5.46 Sketching Three Views of a Lever Bracket.



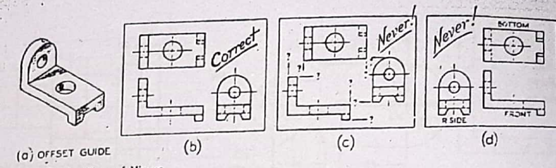


Fig. 5.47 Position of Views.

II. Block in all details lightly.

III. Sketch all arcs and circles lightly.

IV. Dim all construction lines with a soft eraser.

V. Heavy in all final lines so that the views will stand out clearly.

5.29 Alignment of Views.

Errors in arranging the views are so commonly made by students that it is necessary to repeat the views must be drawn in accordance with the American National Standard arrangement, Fig. 5.33. In Fig. 5.47 (a) an Offset Guide is shown that requires three views. These three views, correctly arranged, are shown at (b). The top view must be directly above the front view, and the right-side view directly to the right of the front view—not out of alignment, as at (c). Also, never draw the views in reversed positions, with the bottom over the front view, or the right-side to the left of the front view, as shown at (d), even though the views do line up with the front view.

5.30 Meaning of Lines.

A visible line or a hidden line has three possible meanings, Fig. 5.48: (1) intersection of two surfaces, (2) edge view of a surface, and (3) contour view of a curved surface. Since *no shading is used on a working drawing*, it is necessary to examine all the views to determine the meaning of the lines. For example, the line AB at the top of the front view might be regarded as the edge view of a flat surface if we look at only the front and top views and do not observe the curved surface on top of the object as shown in the right-side view. Similarly, the vertical line CD in the front view might be regarded as the edge view of a plane surface if we look

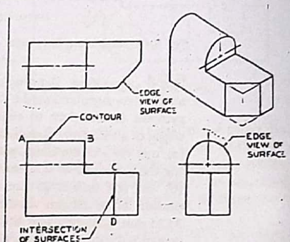


Fig. 5.48 Meaning of Lines.

at only the front and side views. However, the top view shows that the line represents the intersection of an inclined surface.

5.31 Precedence of Lines.

Visible lines, hidden lines, and center lines often coincide on a drawing, and it is necessary for the draftsman to know which line to show. As shown in Fig. 5.49, a visible line always takes

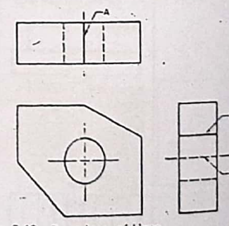


Fig. 5.49 Precedence of Lines.

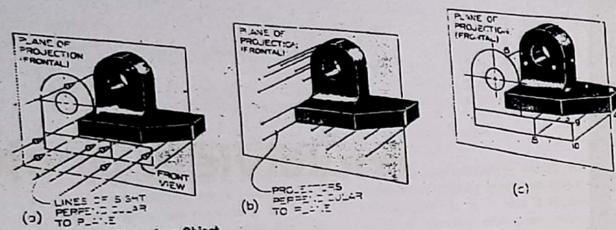


Fig. 6.1 Projection of an Object.

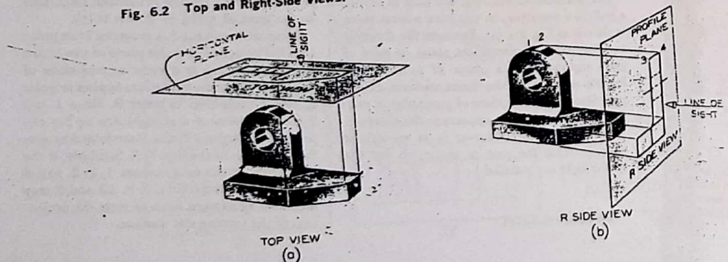
The same procedure can be applied to curved lines—for example, the top curved contour of the object. A point, 5, on the curve is projected to the plane at 6. The projection of an infinite number of such points, a few of which are shown at (b), on the plane of projection results in the projection of the curve. If this procedure of projecting points is applied to all edges and contours of the object, a complete view or projection of the object results. This view is necessary in the shape description because it shows the true curvature of the top and the true shape of the hole.

A similar procedure may be used to obtain the top view, Fig. 6.2 (a). This view is necessary in the shape description because it shows the true angle of the inclined surface. In this view, the hole is invisible and its extreme contours are represented by hidden lines, as shown.

The right-side view, (b), is necessary because it shows the right-angled characteristic shape of the object and shows the true shape of the curved intersection. Note how the cylindrical contour on top of the object appears when viewed from the side. The extreme or contour element 1–2 on the object is projected to give the line 3–4 on the view. The hidden hole is also represented by projecting the extreme elements.

The plane of projection upon which the front view is projected is called the *frontal plane*, that upon which the top view is projected, the *horizontal plane*, and that upon which the side view is projected, the *profile plane*.

Fig. 6.2 Top and Right-Side Views.



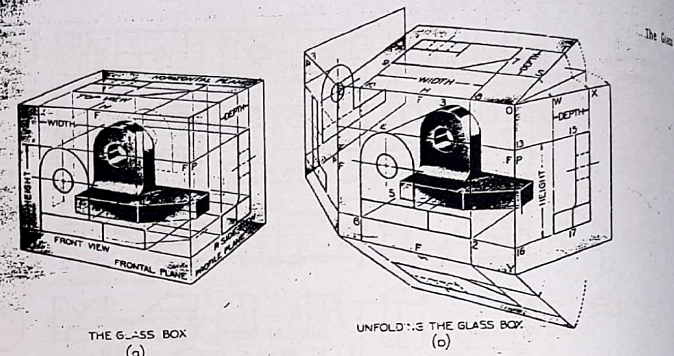


Fig. 6.3 The Glass Box.

6.2 The Glass Box. If planes of projection are placed parallel to the principal faces of the object, they form a "glass box," as shown in Fig. 6.3 (a). Notice that the observer is always *on the outside looking in*, so that the object is seen through the planes of projection. Since the glass box has six sides, six views of the object are obtained.

Note that the object has three principal dimensions: *width*, *height*, and *depth*. These are fixed terms used for dimensions in these directions, regardless of the shape of the object. See §5.18.

Since it is required to show the views of a solid or three-dimensional object on a flat sheet of paper, it is necessary to unfold the planes so that they will all lie in the same plane, Fig. 6.3 (b). All planes except the rear plane are hinged upon the frontal plane, the rear plane being hinged to the left-side plane.* Each plane revolves outwardly from the original box position until it lies in the frontal plane, which remains stationary. The hinge lines of the glass box are known as *folding lines*.

*Except as explained in §6.8.

The positions of these six planes, after they have been revolved, are shown in Fig. 6.4. Carefully identify each of these planes and corresponding views with its original position in the glass box, and repeat this mental procedure, if necessary, until the revolutions are thoroughly understood.

In Fig. 6.3 (b), observe that lines extend around the glass box from one view to another upon the planes of projection. These are the *projections of the projectors* from points on the object to the views. For example, the projector 1–2 is projected on the horizontal plane at 7–8 and on the profile plane at 16–17. When the top plane is folded up, lines 9–10 and 7–8 will become vertical and line up with 10–6 and 8–2, respectively. Thus, 9–10 and 10–6 form a single straight line 9–6, and 7–8 and 8–2 form a single straight line 7–2, as shown in Fig. 6.4. This explains why the top view is the same width as the front view and why it is placed directly above the front view. The same relation exists between the front and bottom views. Therefore, *the front, top, and bottom views all line up vertically and are the same width.*

In Fig. 6.3 (b), when the profile plane is folded out, lines 4–13 and 13–15 become a

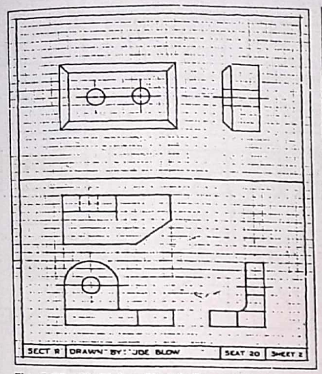


Fig. 5.50 Multiview Sketch (Layout A–1).

precedence over (covers up) a center line or a hidden line, as shown at A and B. A hidden line always takes precedence over a center line, as at C. Note that at A and C the ends of the center line are shown, but are separated from the view by short gaps.

5.32 Sketching Problems.

Figures 5.51 and 5.52 present a variety of objects from which the student is to sketch the necessary views. Using 8.5" × 11.0" cross-section paper, sketch a border and title strip and divide the sheet into two parts as shown in Fig. 5.50. Sketch two assigned problems per sheet, as shown. On the problems in Fig. 5.51, "ticks" are given that indicate .50" or .25" spaces. Thus, measurements may be easily spaced off on cross-section paper having .12" or .25" grid spacings.

If desired, the "ticks" on the problems in Fig. 5.51 may be used to indicate 10 mm and 5 mm spaces. Thus, metric measurements may be easily utilized on appropriate metric-grid cross-section paper.

On the problems in Fig. 5.52, no indications of size are given. The student is to sketch the necessary views of assigned problems to fit the spaces comfortably, about as shown in Fig. 5.50. It is suggested that the student prepare a small paper scale, making the divisions equal to those on the paper scale in Prob. 1. This scale can be used to determine the approximate sizes. Let each division equal either .50" or 10 mm on your sketch.

Missing-line and missing-view problems are given in Figs. 5.53 and 5.54, respectively. These are to be sketched, two problems per sheet, in the arrangement shown in Fig. 5.50. If the instructor so assigns, the missing lines or views may be sketched with a colored pencil. The problems given in Figs. 5.53 and 5.54 may be sketched in isometric on isometric paper or in oblique on cross-section paper.

Sketching problems in convenient form for solution are available in *Technical Drawing Problems, Series 1,* by Giesecke, Mitchell, Spencer, Hill, and Dygdon; *Technical Drawing Problems, Series 2,* by Spencer, Hill, and Dygdon; and *Technical Drawing Problems, Series 3,* by Spencer, Hill, and Dygdon, all designed to accompany this text and published by Macmillan Publishing Co., Inc.

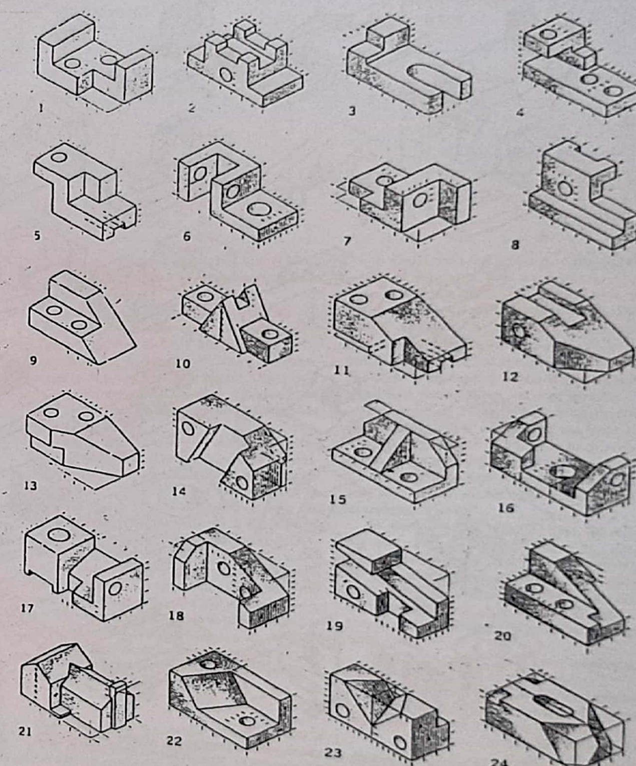


Fig. 5.51 Multiview Sketching Problems. Sketch necessary views, using Layout A–1 or A4–1 adjusted (freehand), on cross-section paper or plain paper, two problems per sheet as in Fig. 5.50. The units shown may be either .50" and .25" or 10 mm and 5 mm. See §5.32. All holes are through holes.

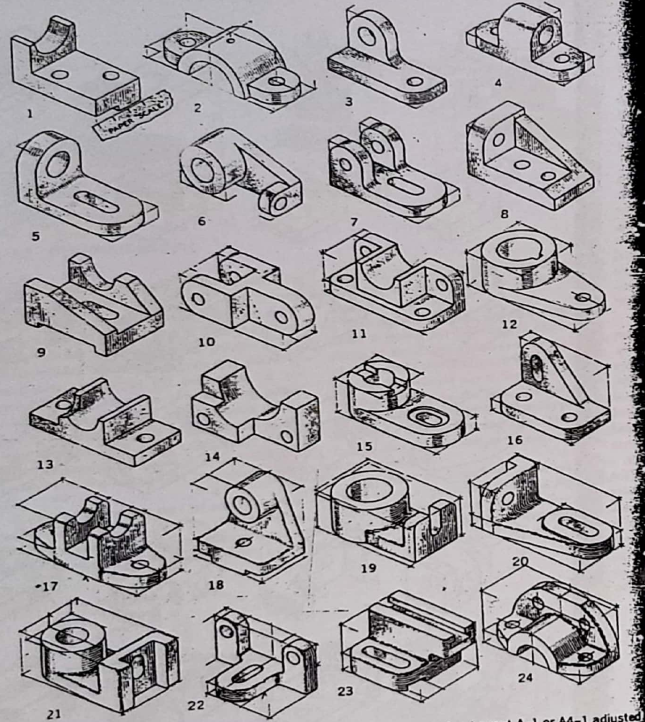


Fig. 5.52 Multiview Sketching Problems. Sketch necessary views, using Layout A–1 or A4–1 adjusted (freehand), on cross-section paper or plain paper, two problems per sheet as in Fig. 5.50. Prepare paper scale with divisions equal to those in Prob. 1, and apply to problems to obtain approximate sizes. Let each division equal either .50" or 10 mm on your sketch. See §5.32. For Probs. 17 to 24, study §§6.34 to 6.36.

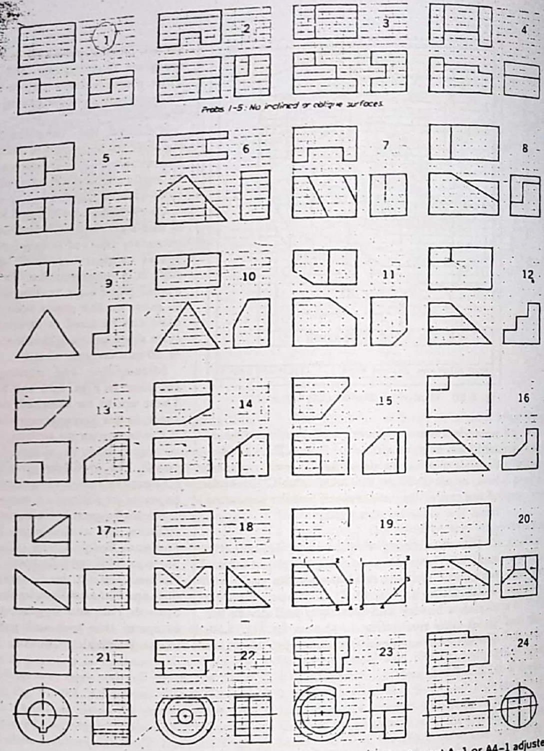


Fig. 5.53 Missing-Line Sketching Problems. (1) Sketch given views, using Layout A–1 or A4–1 adjusted (freehand), on cross-section paper or plain paper, two problems per sheet as in Fig. 5.50. Add missing lines. The squares may be either .25" or 5 mm. See §5.32. (2) Sketch in isometric on isometric paper or in oblique on cross-section paper.

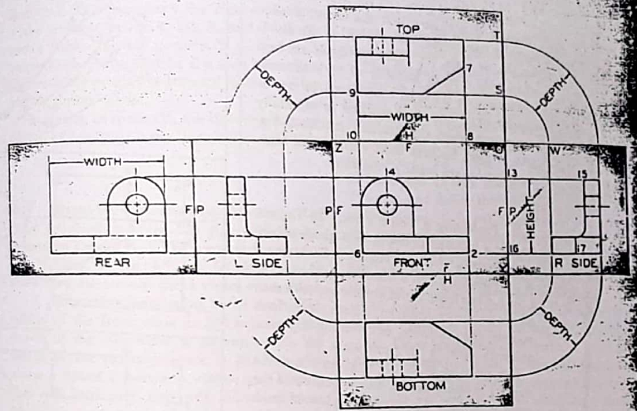


Fig. 6.4 The Glass Box Unfolded.

single straight line 4–15, and lines 2–16 and 16–17 become a single straight line 2–17 as shown in Fig. 6.4. The same relation exists between the front, left-side, and rear views. Therefore, *the rear, left-side, front, and right-side views all line up horizontally, and are the same height.*

In Fig. 6.3 (b), note that lines OS and OW and lines ST and WX are respectively equal. These lines of equal length are shown in the unfolded position in Fig. 6.4. Thus, it is seen that the top view must be the same distance from the folding line OZ as the right-side view is from the folding line OY. Similarly, the bottom view and the left-side view are the same distance from their respective folding lines as are the right-side view and the top view. Therefore, *the top, right-side, bottom, and left-side views are all equidistant from the respective folding lines, and are the same depth.* Note that in these four views that surround the front view, the front surfaces of the object are faced inward, or toward the front view. Observe also that the left-side and right-side views and the top and bottom views are the reverse of each other in outline shape. Similarly, the rear and front views are the reverse of each other.

6.3 Folding Lines.

The three views of the object discussed above are shown in Fig. 6.5 (a), with folding lines between the views. These folding lines correspond to the hinge lines of the glass box, as we have seen. The H/F folding line, between the top and front views, is the intersection of the horizontal and frontal planes. The F/P folding line, between the front and side views, is the intersection of the frontal and profile planes. See Figs. 6.3 and 6.4.

The distances X and Y, from the front view to the respective folding lines, are not necessarily equal, since they depend upon the relative distances of the object from the horizontal and profile planes. However, as explained in §6.2, distances D_1, from the top and side views to the respective folding lines, must always be equal. Therefore, the views may be any desired distance apart, and the folding lines may be drawn anywhere between them, so long as distances D_1 are kept equal and the folding lines are at right angles to the projection lines between the views.

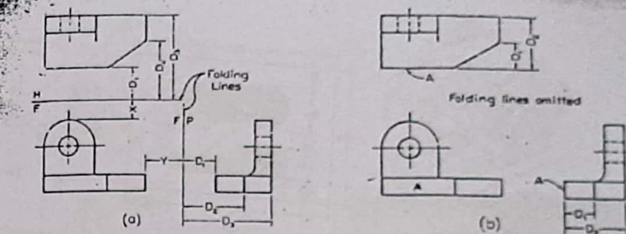


Fig. 6.5 Folding Lines.

It will be seen that distances D_2 and D_3, respectively, are also equal and that the folding lines H/F and F/P are in reality reference lines for making equal *depth* measurements in the top and side views. Thus, any point in the top view is the same distance from H/F as the corresponding point in the side view is from F/P.

While it is necessary to understand the folding lines, particularly because they are useful in solving graphical problems in descriptive geometry, they are as a rule omitted in industrial drafting. The three views, with the folding lines omitted, are shown in Fig. 6.5 (b). Again, the distances between the top and front views and between the side and front views are not necessarily equal. Instead of using the folding lines as reference lines for setting off depth measurements in the top and side views, we may use the front surface A of the object as a reference line. In this way, D_1, D_2, and all other depth measurements are made to correspond in the two views in the same manner as if folding lines were used.

6.4 Two-View Mechanical Drawing.

Let it be required to draw, full size with instruments on Layout A-2, the necessary views of the Operating Arm shown in Fig. 6.6 (a). In this case, as shown by the arrows, only the front and top views are needed.

I. Determine the spacing of the views. The width of the front and top views is approximately 152 mm (6"),* and the width of the working space is approximately 266 mm ($10\frac{1}{2}$"). As shown at (b), subtract 152 mm from 266 mm and divide the result by 2 to get the value of space A. To set off the spaces, place the scale horizontally along the bottom of the sheet and make short vertical marks.

The depth of the top view is approximately 64 mm ($2\frac{1}{2}$") and the height of the front view is 45 mm ($1\frac{3}{4}$"), while the height of the working space is 194 mm ($7\frac{5}{8}$"). Assume a space C, say 25 mm (1"), between views that will look well and that will provide sufficient space for dimensions, if any.

As shown at (b), add 64 mm, 25 mm, and 45 mm, subtract the total from 194 mm, and divide the result by 2 to get the value of space B. To set off the spaces, place the scale vertically along the left side of the sheet with the full-size scale on the left, and make short marks perpendicular to the scale. See Fig. 2.56 (III).

II. Locate center lines from spacing marks. Construct arcs and circles lightly.

III. Draw horizontal and then vertical construction lines in the order shown. Allow construction lines to cross at corners.

IV. Add hidden lines and heavy in all final lines, clean-cut and dark. The visible lines should be heavy enough to make the views stand out. The hidden lines and center lines

*25.4 mm equals one inch (1").

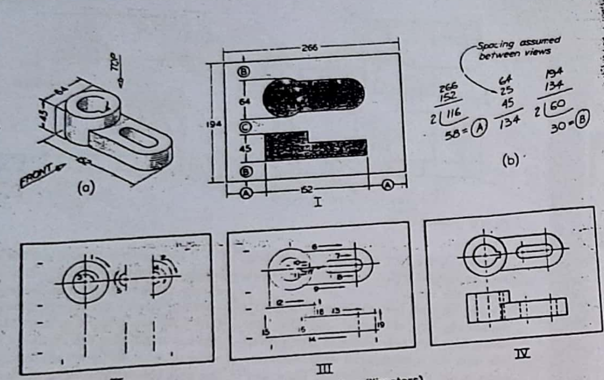


Fig. 6.6 Two-View Mechanical Drawing (dimensions in millimeters).

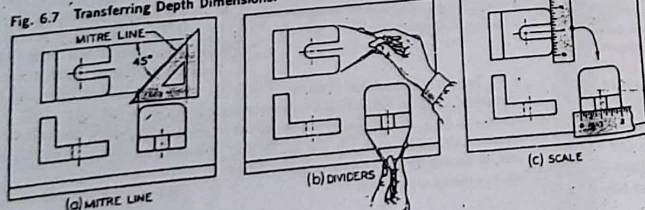
should be sharp in contrast to the visible lines, but dark enough to reproduce well. See §2.47 for technique of pencil drawing. Construction lines need not be erased if drawn lightly. If you are working on tracing paper, hold the sheet up to the light to see if the density of your lines is sufficient to reproduce well, Fig. 2.58.

6.5 Transferring Depth Dimensions.

Since all depth dimensions in the top and side views must correspond point for point, accurate methods of transferring these distances, such as D_1 and D_2, Fig. 6.5 (b), must be used.

The 45° *mitre line* method, Fig. 6.7 (a), is a convenient method, especially when transferring a large number of points, as when plotting a curve, Fig. 6.35. Note that the right-side view may be moved to the right or left, or the top view may be moved upward or downward, by shifting the 45° line accordingly. It is not necessary to draw continuous lines between the top and side views via the mitre line. Instead, make short dashes across the mitre line and project from these.

Fig. 6.7 Transferring Depth Dimensions.



In practice it is generally recommended, for the sake of accuracy, that the depth dimensions be transferred with the aid of the dividers, (b), or scale, (c). These methods are best when only a small number of very accurate measurements are to be transferred, as is usually the case. The scale method is especially convenient when the drafting machine, Fig. 2.82, is used, because both vertical and horizontal scales are readily available.

6.6 Projecting a Third View.

In Fig. 6.8 (top) is a pictorial drawing of a given object, three views of which are required. Each corner of the object is given a number, as shown. At I, the top and front views are shown, with each corner properly numbered in both views. Each number appears twice, once in the top view and once again in the front view.

If a point is visible in a given view, the number is placed *outside* the corner, but if the point is *invisible*, the numeral is placed *inside* the corner. For example, at I point 1 is visible in both views, and is therefore placed outside the corners in both views. However, point 2 is visible in the top view and the number is placed outside, while in the front view it is invisible and is placed inside.

This numbering system, in which points are identified by the same numbers in all views, is useful in projecting known points in two views to unknown positions in a third view. Note that in this numbering system a given point has the same number in all views, and should not be confused with the numbering system used in Fig. 6.23 and others, in which a point has different numbers in each view.

In Fig. 6.8, before starting to project the right-side view, try to visualize the view as seen in the direction of the arrow (see pictorial drawing). Then construct the right-side view point by point, using a hard pencil and very light lines.

As shown at I, locate point 1 in the side view by projecting from point 1 in the top view and point 1 in the front view. In space II, project points 2, 3, and 4 in a similar manner to complete the vertical end surface of the object. In space III, project points 5 and 6 to

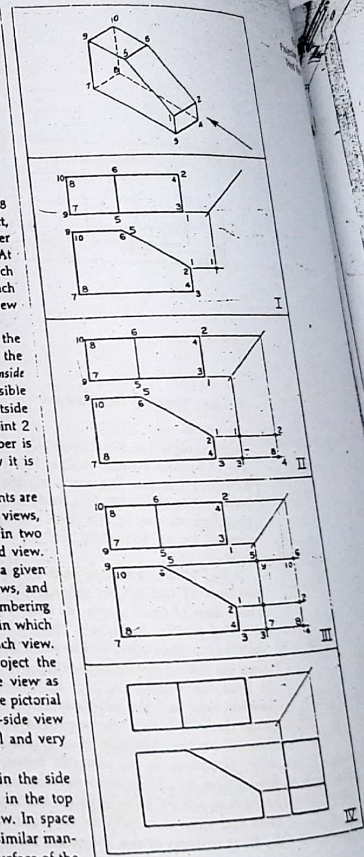


Fig. 6.8 Use of Numbers.

complete the side view of the inclined surface 5-6-2-1. This completes the right-side view, since invisible points 9, 10, 8, and 7 are directly behind visible corners 5, 6, 4, and 3, respectively. Note that in the side view also, the invisible points are lettered *inside*, and the visible points *outside*.

As shown in space IV, the drawing is completed by heavying in the lines in the right-side view.

6.7 Three-View Mechanical Drawing.

Let it be required to draw, full size with instruments on Layout A–2, the necessary views of the V-Block in Fig. 6.9 (a). In this case, as shown by the arrows, three views are needed.

I. Determine the spacing of the views. The width of the front view is 108 mm, and the depth of the side view is 58 mm, while the width of the working space is 266 mm. Assume a space C between views, say 32 mm, that will look well and will allow sufficient space for dimensions, if any.

As shown at (b), add 108 mm, 32 mm, and 58 mm, subtract the total from 266 mm, and divide the result by 2 to get the value of space A. To set off these horizontal spacing measurements, place the scale along the bottom of the sheet and make short vertical marks.

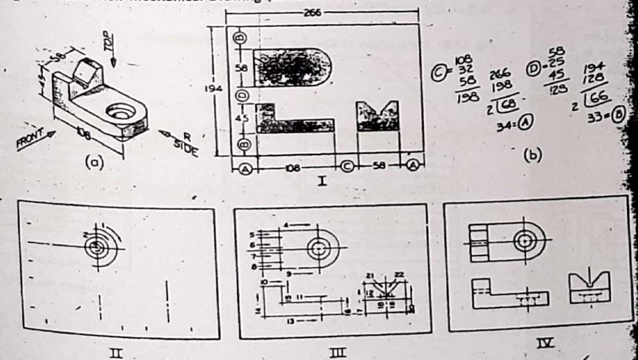
The depth of the top view is 58 mm, and the height of the front view is 45 mm, while the height of the working space is 194 mm. Assume a space D between views, say 25 mm. As shown in §6.3, space D need not be the same as space C. As shown at (b), add 58 mm, 25 mm, and 45 mm, subtract the total from 194 mm, and divide the result by 2 to get the value of space B. To set off these vertical spacing measurements, place the scale along the left side of the sheet with the scale used on the left, and make short marks perpendicular to the scale. Allow for dimensions, if any.

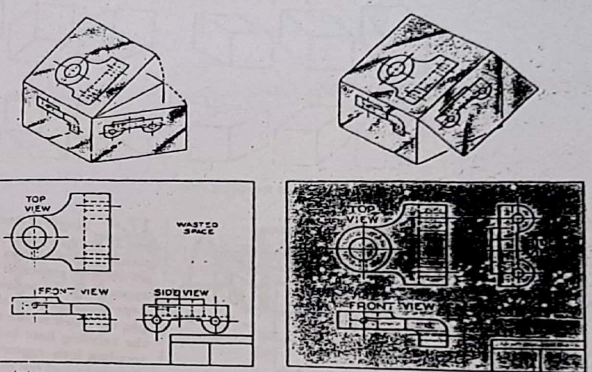
II. Locate the center lines from the spacing marks. Construct lightly the arcs and circles.

III. Draw horizontal, then vertical, then inclined construction lines, in the order shown. Allow construction lines to cross at the corners. Do not complete one view at a time; construct the views simultaneously.

IV. Add hidden lines and heavy in all final lines, clean-cut and dark. A convenient method of transferring a hole diameter from the top view to the side view is to use the compass with the same setting used for drawing the hole. The visible lines should be heavy enough to make the views stand out. The hidden lines and center lines should be sharp in contrast to the visible lines, but dark enough to reproduce well. Construction lines need not be erased if they are drawn lightly. If you are working on tracing paper, hold the sheet up to the light to see if the density of your lines is sufficient to reproduce well. See §2.47 and Fig. 2.58.

Fig. 6.9 Three-View Mechanical Drawing (dimensions in millimeters).





(a) POOR ARRANGEMENT OF VIEWS

(b) APPROVED ARRANGEMENT OF VIEWS

Fig. 6.10 Position of Side View.

6.8 Alternate Positions of Views.

If three views of a wide flat object are drawn, using the conventional arrangement of views, Fig. 6.10 (a), a large wasted space is left on the paper, as shown. In such cases, the profile plane may be considered hinged to the horizontal plane instead of the frontal plane, as shown at (b). This places the side view beside the top view, which results in better spacing and in some cases makes the use of a reduced scale unnecessary.

It is also permissible in extreme cases to place the side view across horizontally from the bottom view, in which case the profile plane is considered hinged to the bottom plane of projection. Similarly, the rear view may be placed directly above the top view or under the bottom view, if necessary, in which case the rear plane is considered hinged to the horizontal or bottom plane, as the case may be, and then rotated into coincidence with the frontal plane.

6.9 Partial Views.

A view may not need to be complete but may show only what is necessary in the clear description of the object. Such a view is a *partial view*, Fig. 6.11. A break line, (a), may be used to limit the partial view; the contour of the part shown may limit the view, (b); or if symmetrical, a half-view may be drawn on one side of the center line (c), or a partial view, "broken out," may be drawn

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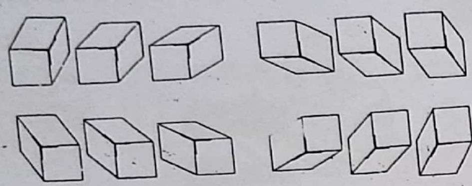


Fig. 17.5 Variation in Direction of Receding Axis.

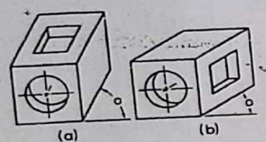


Fig. 17.6 Angle of Receding Axis.

17.3 Angles of Receding Lines.

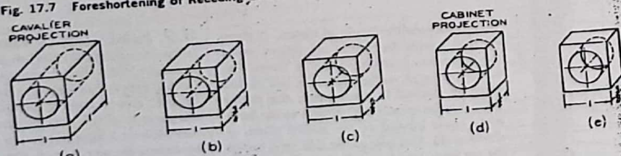
The receding lines may be drawn at any convenient angle. Some typical drawings with the receding lines in various directions are shown in Fig. 17.5. The angle that should be used in an oblique drawing depends upon the shape of the object and the location of its significant features. For example, in Fig. 17.6 (a) a large angle was used in order to obtain a better view of the rectangular recess on the top, while at (b) a small angle was chosen to show a similar feature on the side.

17.4 Length of Receding Lines.

Since the eye is accustomed to seeing objects with all receding parallel lines appearing to converge, an oblique projection presents an unnatural appearance, the seriousness of the distortion depending upon the object shown. For example, the object shown in Fig. 17.7 (a) is a cube, the receding lines being full length; but the receding lines appear to be too long and to diverge toward the rear of the block. A striking example of the unnatural appearance of an oblique drawing when compared with the natural appearance of a perspective is shown in Fig. 17.8. This example points up one of the chief limitations of oblique projection: objects characterized by great length should not be drawn in oblique with the long dimension perpendicular to the plane of projection.

The appearance of distortion may be materially lessened by decreasing the length of the receding lines (remember, we established in §17.2 that they could be any length). In Fig. 17.7 a cube is shown in five oblique drawings with varying degrees of foreshortening of the

Fig. 17.7 Foreshortening of Receding Lines.



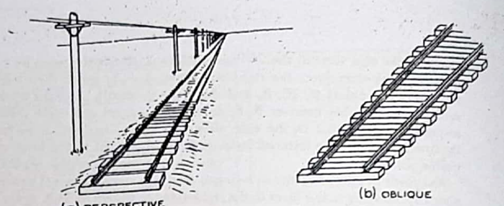


Fig. 17.8 Unnatural Appearance of Oblique Drawing.

receding lines. The range of scales chosen is sufficient for almost all problems, and most of the scales are available on the architects scale.

When the receding lines are true length—that is, when the projectors make an angle of 45° with the plane of projection—the oblique drawing is called a *cavalier projection*, Fig. 17.7 (a). Cavalier projections originated in the drawing of medieval fortifications and were made upon horizontal planes of projection. On these fortifications the central portion was higher than the rest and it was called *cavalier* because of its dominating and commanding position.

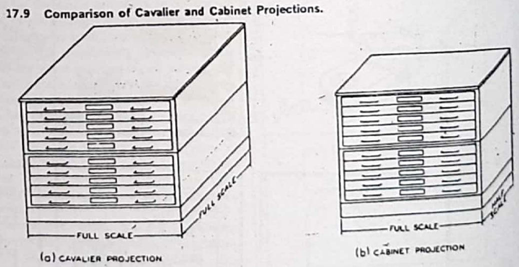
When the receding lines are drawn to half size, as at (d), the drawing is commonly known as a *cabinet projection*. The term is attributed to the early use of this type of oblique drawing in the furniture industries. A comparison of cavalier projection and cabinet projection is shown in Fig. 17.9.

17.5 Choice of Position.

The face of an object showing the essential contours should generally be placed parallel to the plane of projection, Fig. 17.10. If this is done, distortion will be kept at a minimum and labor reduced. For example, at (a) and (c) the circles and circular arcs are shown in their true sizes and shapes and may be quickly drawn with the compass, while at (b) and (d) these curves are not shown in their true sizes and shapes and must be plotted as free curves or in the form of ellipses.

The longest dimension of an object should

Fig. 17.9 Comparison of Cavalier and Cabinet Projections.



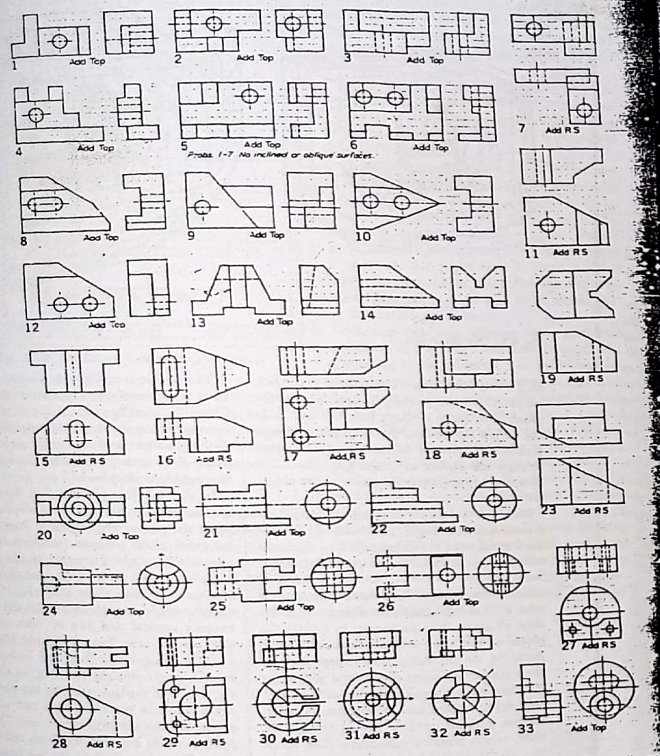


Fig. 5.54 Third-View Sketching Problems. (1) Using Layout A–1 or A4–1 adjusted (freehand), on cross-section paper or plain paper, two problems per sheet as in Fig. 5.50, sketch the two given views and add the missing views, as indicated. The squares may be either .25" or 5 mm. See §5.32. The given views are either front and right-side views or front and top views. Hidden holes with center lines are drilled holes. (2) Sketch in isometric on isometric paper or in oblique on cross-section paper.

6 multiview projection

6.1 Multiview Projection.* A view of a part for a design is known technically as a *projection*. A projection is a view conceived to be drawn or projected onto a plane known as the *plane of projection*.

The method of viewing the part to obtain a *multiview projection*, in this case a front view, is shown in Fig. 6.1 (a). Between the observer and the part, a transparent plane or pane of glass representing a plane of projection is located parallel to the front surfaces of the part. Shown on the plane of projection in outline is how the design appears to the observer. Theoretically, the observer is at an infinite distance from the part or object, so that the *lines of sight* are parallel.

In more precise terms, this view is obtained by drawing perpendiculars, called *projectors*, from all points on the edges or contours of the part or object to the plane of projection, (b). The collective piercing points of these projectors, being infinite in number, form lines on the pane of glass, as shown at (c).

Thus, as shown at (c), a projector from point 1 on the object pierces the plane of projection at point 7, which is a view or projection of the point. The same procedure applies to point 2, whose projection is point 9. Since 1 and 2 are end points of a straight line on the object, the projections 7 and 9 are joined to give the projection of the line 7–9. Similarly, if the projections of the four corners 1, 2, 3, and 4 are found, the projections 7, 9, 10, and 8 may be joined by straight lines to form the projection of the rectangular surface.

*See ANSI Y14.3–1975.

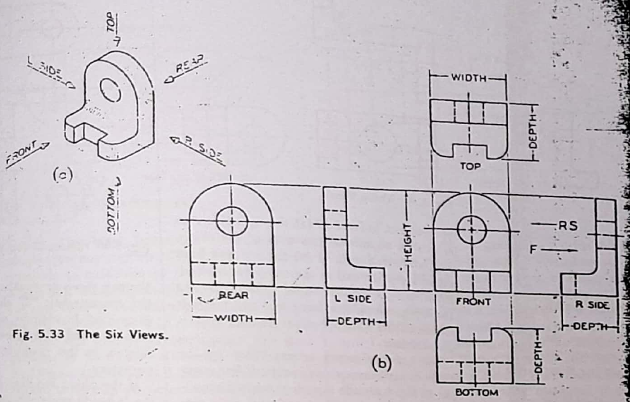


Fig. 5.33 The Six Views.

ble line 5-6 in the top view, and as a hidden line 15-16 in the side view. Also, hole A, which appears as a circle in the front view, shows as hidden lines 1-4 and 2-3 in the top view, and 11-12 and 13-14 in the side view. For a complete discussion of hidden lines, see §5.25.

Also, at (d) note the use of center lines for the hole. See §5.26.

5.20 The Six Views.

Any object can be viewed from six mutually perpendicular directions, as shown in Fig. 5.33 (a). Thus, six views may be drawn if necessary, as shown at (b). These six views are always arranged as shown,* which is the American National Standard arrangement of views. The *top, front,* and *bottom views* line up vertically, while the *rear, left-side, front,* and *right-side views* line up horizontally. To draw a view out of place is a very serious error, generally regarded as one of the worst mistakes one can make in this subject. See Fig. 5.47.

Note that the height is shown in the rear, left-side, front, and right-side views; the width is shown in the top, front, and bottom views; and the depth is shown in the four views that surround the front view, namely the left-side, top, right-side, and bottom views. In each view, two of the principal dimensions are shown, and the third is not shown. Observe also that in the four views that surround the front view, the front of the object is faced toward the front view.

Adjacent views are reciprocal. If the front view, Fig. 5.33, is imagined to be the object itself, the right-side view is obtained by looking toward the right side of the front view, as shown by the arrow RS. Likewise, if the right-side view is imagined to be the object, the front view is obtained by looking toward the left side of the right-side view, as shown by the arrow F. The same relation exists between any two adjacent views.

Obviously, the six views may be obtained either by shifting the object with respect to the observer, as we have seen, Fig. 5.32, or by shifting the observer with respect to the object, Fig. 5.33. Another illustration of the second method is given in Fig. 5.34; showing six views of a house. The observer can walk around the house and view its front, sides, and rear, and he can imagine the top view as seen from an airplane and the bottom or "worm's-eye view" as seen from underneath.* Notice the use of the terms *plan,* for the top view, and *elevation,* for all views showing the height of the building. These terms are regularly used in architectural drawing and, occasionally, with reference to drawings in other fields.

*Except as explained in §6.8.

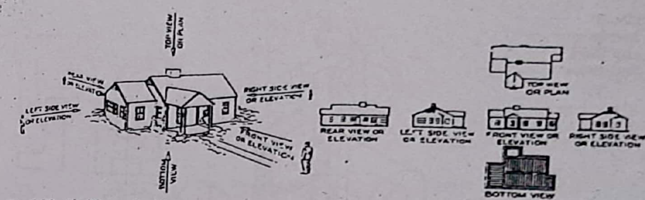


Fig. 5.34 Six Views of a House.

5.21 Orientation of Front View.

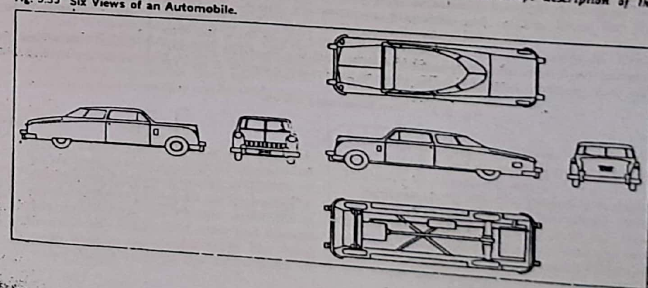
Six views of a vintage automobile are shown in Fig. 5.35. The view chosen for the front view in this case is the side, not the front of the automobile. In general, the front view should show the object in its operating position, particularly of familiar objects such as the house shown above and the automobile. A machine part is often drawn in the position it occupies in the assembly. However, in most cases this is not important and the draftsman may assume the object to be in any convenient position. For example, an automobile connecting rod is usually drawn horizontally on the sheet, Fig. 14.37. Also, it is customary to draw screws, bolts, shafts, tubes, and other elongated parts in a horizontal position, not only because they are usually manufactured in this position but also because they can be presented more satisfactorily on paper in this position.

*Architects usually draw the views of a building on separate sheets because of the large sizes of the drawings. When two or more views are drawn together, they are usually drawn in first-angle projection, §6.38.

5.22 Choice of Views.

A drawing for use in production should contain only those views needed for a clear and complete shape description of the

Fig. 5.35 Six Views of an Automobile.



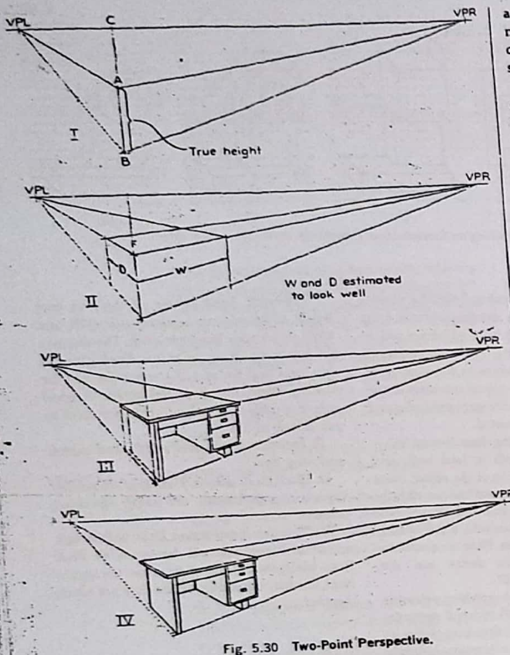
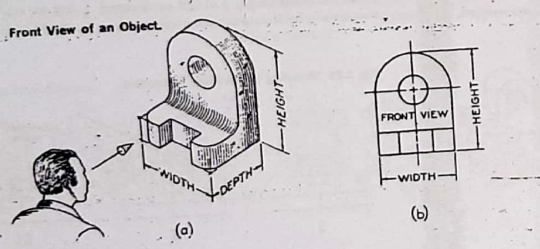


Fig. 5.30 **Two-Point Perspective.**

Fig. 5.31 **Front View of an Object.**



a picture cannot describe the object fully, no matter from which direction it is viewed, because it does not show the exact shapes and sizes of the several parts.

In industry, a complete and clear description of the shape and size of an object to be made is necessary, to make certain that the object will be manufactured exactly as intended by the designer. In order to provide this information clearly and accurately, a number of *views*, systematically arranged, are used. This system of views is called *multiview projection*. Each view provides certain definite information if the view is taken in a direction perpendicular to a principal face or side of the object. For example, as shown in Fig. 5.31 (a), if the observer looks perpendicularly toward one face of the object, he obtains a true view of the shape and size of that side. This view as seen by the observer is shown at (b). (The observer is theoretically at an infinite distance from the object.)

An object has three principal dimensions: *width, height*, and *depth*, as shown at (a). In technical drawing, these fixed terms are used for dimensions taken in these directions, regardless of the shape of the object. The terms "length" and "thickness" are not used because they cannot be applied in all cases. Note at (b) that the front view shows only the height and width of the object and not the depth. In fact, *any one view of a three-dimensional object can show only two dimensions; the third dimension will be found in an adjacent view.*

5.19 Revolving the Object.

To obtain additional views, revolve the object as shown

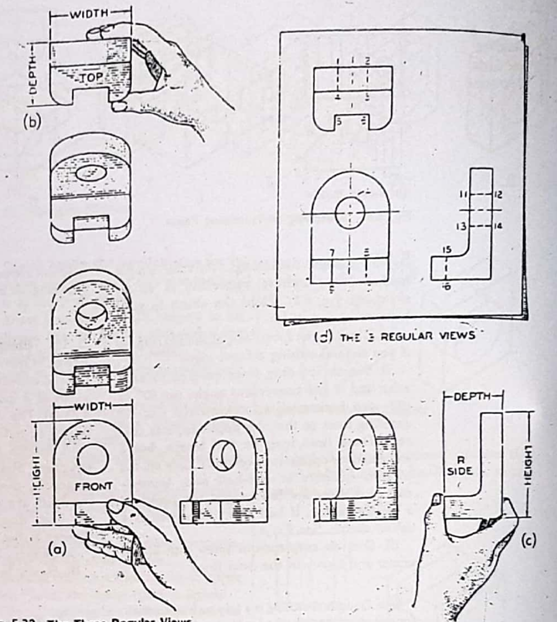


Fig. 5.32 **The Three Regular Views.**

in Fig. 5.32. First, hold the object in the front-view position, as shown at (a).

To get the *top view*, (b), revolve the object so as to bring the *top of the object up and toward you*.

To get the *right-side view*, (c), revolve the object so as to bring the *right side to the right and toward you*.

To obtain views of any of the other sides, merely turn the object so as to bring those sides toward you.

The top, front, and right-side views, arranged closer together, are shown at (d). These are called the *three regular views*, because they are the views most frequently used.

At this stage we can consider spacing between views as purely a matter of appearance. The views should be spaced well apart and yet close enough to appear related to each other. The space between the front and top views may or may not be equal to the space between the front and side views. If dimensions (Chapter 11) are to be added to the sketch, sufficient space for them between views will have to be allowed.

An important advantage that a view has over a photograph of an object is that hidden features can be clearly shown by means of *hidden lines*, Fig. 2.15. In Fig. 5.32 (d), surface 7-8-9-10 in the front view appears as a visi-

4 geometric constructions

4.1 Geometric Constructions. Many of the constructions used in technical design drawing are based upon plane geometry, and every draftsman or engineer should be sufficiently familiar with them to be able to apply them to the solutions of problems. Pure geometry problems may be solved only with the compass and a straightedge, and in some cases these methods may be used to advantage in technical drawing. However, the draftsman or designer has available the T-square, triangles, dividers, and other equipment, such as drafting machines, that in many cases can yield accurate results more quickly by what we may term "*preferred* methods." Therefore, many of the solutions in this chapter are practical adaptations of the principles of pure geometry.

This chapter is designed to present definitions of terms and geometric constructions of importance in technical drawing, suggest simplified methods of construction, point out practical applications, and afford opportunity for practice in accurate instrumental drawing. In the latter sense, the problems at the end of this chapter may be regarded as a continuation of those at the end of Chapter 2.

In drawing these constructions, accuracy is most important. Use a sharp medium-hard lead (H to 3H) in your pencil and compasses. Draw construction lines extremely light—so light that they can hardly be seen when your drawing is held at arm's length. Draw all given and required lines medium to thin but dark.

4.2 Points and Lines. Fig. 4.1. A *point* represents a location in space or on a drawing,

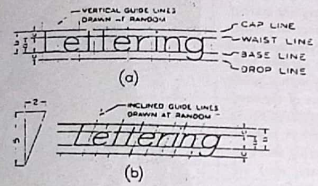


Fig. 3.24 Guide Lines for Lower-case Letters.

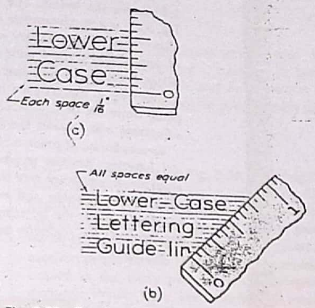


Fig. 3.25 Spacing with the Scale.

but remain equal, (b). Thus, this method may be easily used for various heights of lettering.

The Braddock-Rowe Triangle, Fig. 3.16, and the Ames Lettering Guide, Fig. 3.17, produce guide lines for lower-case letters as described here, and are highly recommended.

In addition to horizontal guide lines, vertical or inclined guide lines, drawn at random, should always be used to keep the letters uniformly vertical or inclined, Fig. 3.24.

3.22 Vertical Lower-case Letters. Fig. 3.26.

Vertical lower-case letters are used largely on map drawings, and very seldom on machine drawings. The shapes are based upon a repetition of the circle or circular arc and the straight line, with some variations. The lower part of the letter is usually two-thirds the height of the capital letter.

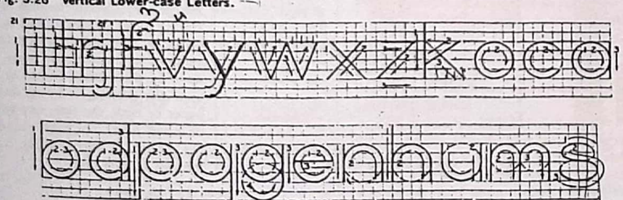
Stroke 3 of the e is slightly above mid-height. The crosses on the f and t are on the waist line and are symmetrical with respect to strokes 1. The curved strokes of h, m, n, and r intersect strokes 1 approximately two-thirds of the distance from the base line to the waist line.

The descenders of the g, j, and y terminate in curves that are tangent to the drop line, while those of p and q terminate in the drop line without curves.

3.23 Inclined Lower-case Letters. Fig. 3.27.

The order and direction of the strokes and the proportions of inclined lower-case letters are the same as those of vertical lower-case letters. The inclined lower-case letters may be regarded, like the inclined capital letters, as oblique projections of vertical letters,

Fig. 3.26 Vertical Lower-case Letters.



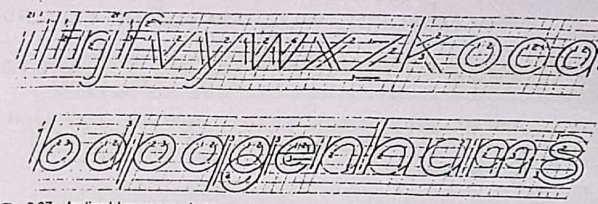


Fig. 3.27 Inclined Lower-case Letters.

in which all circles in the vertical alphabet become ellipses in the inclined alphabet. As in the inclined capital letters, all ellipses have their major axes inclined at an angle of 45° with horizontal.

The forms of the letters c, o, s, v, w, x, and z are almost identical with those of the corresponding capitals.

The slope of the letters is the same as for inclined capitals, or 68.2° with horizontal. The slope may be determined by drawing a "slope triangle" of 2 in 5, as shown in Fig. 3.24 (b), or with the aid of the inclined slot in the Braddock-Rowe Triangle, Fig. 3.16, or with the Ames Lettering Guide, Fig. 3.17 (b).

3.24 Spacing of Letters and Words.

Uniformity in spacing of letters is a matter of equalizing spaces by eye. *The background areas between letters, not the distances between them, should be approximately equal.* In Fig. 3.28 (a) the actual distances are equal, but the letters do not appear equally spaced. At (b) the distances are intentionally unequal, but the background areas between letters are approximately equal, and the result is an even and pleasing spacing.

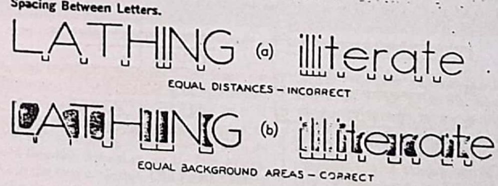
Some combinations, such as LT and VA, may even have to be slightly overlapped to secure good spacing. In some cases the width of a letter may be decreased. For example, the lower stroke of the L may be shortened when followed by A.

Space words well apart, but space letters closely within words. Make each word a compact unit well-separated from adjacent words. For either upper-case or lower-case lettering, make the spaces between words approximately equal to a capital O, Fig. 3.29. Avoid spacing letters too far apart and words too close together, as shown at (b). Samples of good spacing are shown in Fig. 3.10.

When it is necessary to letter to a stop-line as in Fig. 3.30 (a), space each letter from *right to left*, as shown in step II, estimating the widths of the letters by eye. Then letter from *left to right*, as shown at III, and finally erase the spacing marks.

When it is necessary to space letters symmetrically about a center line, Fig. 3.30 (b),

Fig. 3.28 Spacing Between Letters.



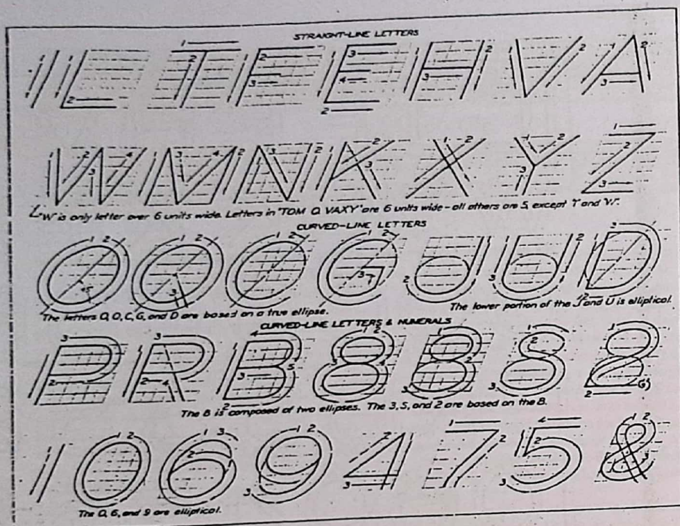


Fig. 3.19 **Inclined Capital Letters and Numerals.**

upon the ability to form smooth ellipses that appear to "lean" properly to the right.

The letters having sloping sides, such as the *V, A, W, X,* and *Y*, are also a source of difficulty for many beginners. The letters should be made symmetrically about an imaginary inclined center line. If this is done, the left side of the *V* and the right side of the *A* will be practically vertical, while the opposite sides will slope at less than 60° with horizontal.

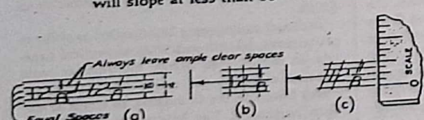


Fig. 3.20 **Guide Lines for Dimension Figures.**

3.20 Guide Lines for Whole Numbers and Fractions.

Complete guide lines should be drawn for whole numbers and fractions, especially by beginners. This means that both horizontal and vertical guide lines, or horizontal and inclined guide lines, should be drawn. Even the expert letterer will be able to do better lettering if he uses guide lines, and for this reason he is more likely to use them than the beginner who considers them "too much trouble." The guide lines, of course, should be drawn very lightly, with a hard pencil, 4H to 6H.

Draw five equally spaced guide lines for whole numbers and fractions, Fig. 3.20. Thus, fractions are twice the height of the corresponding whole numbers. Make the numerator and the denominator each about three-fourths as high as the whole number, to allow ample clear space between them and the fraction bar, as shown.

For dimensioning, the most commonly used height for whole numbers is $\frac{1}{8}$" (3.2 mm), and for fractions $\frac{1}{4}$" (6.4 mm), as shown at (a) and (c). These spaces may be easily set off directly with the scale, as shown. After the horizontal guide lines have been drawn, add vertical or inclined guide lines spaced at random, (b) and (c).

If the Braddock-Rowe Triangle is used, the column of holes at the left produces five guide lines, each $\frac{1}{16}$" (1.6 mm) apart, Fig. 3.21.

If the Ames Lettering Guide, Fig. 3.17, is used with the No. 4 setting of the disc, the same five guide lines, each $\frac{1}{16}$" (1.6 mm) apart, may be drawn from the central column of holes.

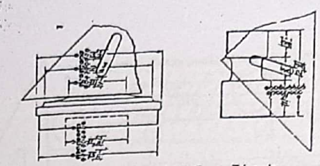
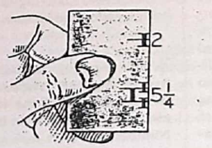


Fig. 3.21 **Use of Braddock-Rowe Triangle.**

The experienced letterer may dispense with the drawing of guide lines for dimension figures, particularly where the most finished work is not required, by preparing a small card with marks indicating heights of numerals, Fig. 3.22, and then holding the card in place while lettering without actual guide lines.

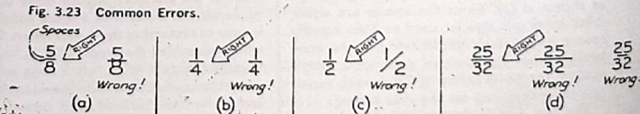


Courtesy Prof. Albert Jorgensen

Fig. 3.22 **Letter-Height Indicator.**

Some of the most common errors in lettering fractions are illustrated in Fig. 3.23. Never let numerals touch the fraction bar, (a). Center the denominator under the numerator, (b). Never use an inclined fraction bar, (c), except when lettering in a narrow space, as in a parts list. Make the fraction bar slightly longer than the widest part of the fraction, (d).

Fig. 3.23 **Common Errors.**



3.21 Guide Lines for Lower-case Letters.

Lower-case letters have four horizontal guide lines, called the *cap line, waist line, base line,* and *drop line*, Fig. 3.24 (a). Strokes of letters that extend up to the cap line are called *ascenders*, and those that extend down to the drop line, *descenders*. Since there are only five letters that have descenders, the drop line is little needed and is usually omitted. In spacing horizontal guide lines, space *a* may vary from three-fifths to two-thirds of space *b*. Spaces *c* are equal, as shown.

If it is desired to set off guide lines for letters $\frac{3}{16}$" (4.8 mm) high with the scale (using two-thirds ratio) it is only necessary to set off equal spaces each $\frac{1}{16}$" (1.6 mm), Fig. 3.25 (a). The lower portion of the letter thus would be $\frac{1}{8}$" (3.2 mm), and the space between lines of letters would also be $\frac{1}{8}$" (3.2 mm). If the scale is placed at an angle, the spaces will diminish

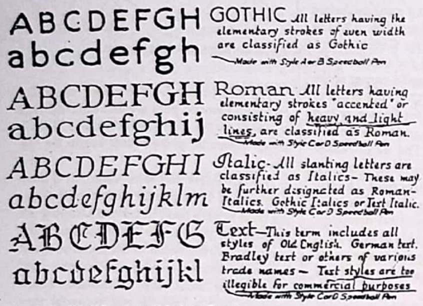


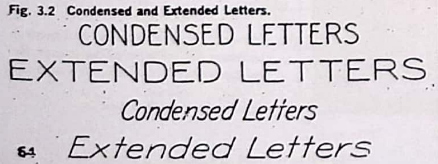
Fig. 3.1 Classification of Letter Styles.

became known as Old English. The early German printers adopted the Old English letters, and they are still in use in Germany. The early Italian printers used Roman letters, which were later introduced into England, where they gradually replaced the Old English letters. The Roman capitals have come down to us virtually in their original form.

3.2 Letter Styles. A general classification of letter styles is shown in Fig. 3.1. They were all made with Speedball pens, as indicated, and are therefore largely single-stroke letters.

If the letters are drawn in outline and filled in, they are referred to as *filled-in* letters, Figs. 3.39 and 3.42. The plainest and most legible style is the GOTHIC, from which our single-stroke engineering letters are derived. The

Fig. 3.2 Condensed and Extended Letters.



term ROMAN refers to any letter having wide downward strokes and thin connecting strokes, as would result from the use of a wide pen, while the ends of the strokes are terminated with spurs called *serifs*. Roman letters include Old Roman and Modern Roman, and may be vertical or inclined. Inclined letters are also referred to as *Italic*, regardless of the letter style; those shown in Fig. 3.1 are inclined Modern Roman. *Text* letters are often loosely referred to as 𝔒𝔩𝔡 𝔈𝔫𝔤𝔩𝔦𝔰𝔥, although these letters as well as the other similar letters, such as German Text, are actually Gothic. The Commercial Gothic shown at the top of Fig. 3.1 is a relatively modern development, which originates from the earlier Gothic forms. German Text is the only commercially used form of medieval Gothic in use today.

For more extensive and detailed information regarding the styles of letters, see §§3.27 to 3.29.

3.3 Extended and Condensed Letters. To meet design or space requirements, letters may be narrower and spaced closer together, in which case they are called *compressed* or *condensed* letters. If the letters are wider than normal, they are referred to as *extended* letters, Fig. 3.2.

3.4 Lightface and Boldface Letters. Letters also vary as to the thickness of the stems or strokes. Letters having very thin stems are called LIGHTFACE, while those having heavy stems are called BOLDFACE, Fig. 3.3.

Fig. 3.3 Lightface and Boldface Letters.

3.5 Single-Stroke Gothic Letters. During the latter part of the nineteenth century the development of industry and of technical drawing in the United States made evident a need for a simple legible letter that could be executed with single strokes of an ordinary pen. To meet this need C. W. Reinhardt, formerly Chief Draftsman for the *Engineering News*, developed alphabets of capital and lower-case inclined and "upright" letters,* based upon the old Gothic letters, Fig. 3.38. For each letter he worked out a systematic series of strokes. The single-stroke Gothic letters used on the technical drawings today are based upon Reinhardt's work.

3.6 Standardization of Lettering. The first step toward standardization of technical lettering was made by Reinhardt when he developed single-stroke letters with a systematic series of strokes, §3.5. However, since that time there has been an unnecessary and confusing diversity of lettering styles and forms, and the American National Standards Institute in 1935 suggested letter forms that are now generally considered as standard. The present Standard (ANSI Y14.2–1973) is practically the same as that given in 1935, except that vertical lower-case letters have since been added.

The letters in this chapter and throughout this text conform to the American National Standard. Vertical letters are perhaps slightly more legible than inclined letters, but are more difficult to execute. Both vertical and inclined letters are standard, and the engineer or draftsman may be called upon to use either. Students should, therefore, learn to execute both forms well, though they may give more attention to the style they like and in which they can do better.

Lettering on drawings must be legible and suitable for easy and rapid execution. The single-stroke Gothic letters shown in Figs. 3.18 and 3.19 meet these requirements. Either vertical or inclined lettering may be used but only one style should be used throughout a drawing. Drawings for microfilm reproduction require well-spaced lettering to prevent "fill-ins." Background areas between letters in words should appear approximately equal, and words should be clearly separated by a space equal to the height of the lettering. Only when special emphasis is necessary should the lettering be underlined.

It is not desirable to vary the size of the lettering according to the size of the drawing except when a drawing is to be reduced in reproduction.

*Published in the *Engineering News* about 1893, and in book form in 1895.

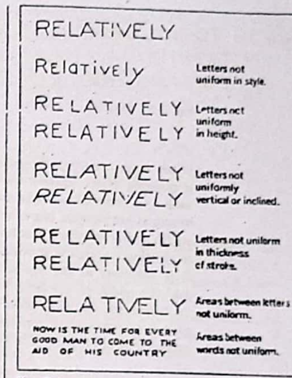


Fig. 3.4 Uniformity in Lettering.

3.7 Uniformity. In any style of lettering, *uniformity* is essential. Uniformity in height, proportion, inclination, strength of lines, spacing of letters, and spacing of words insures a pleasing appearance, Fig. 3.4.

Uniformity in height and inclination is promoted by the use of light guide lines, §3.14. Uniformity in strength of lines can be obtained only by the skillful use of properly selected pencils and pens, §§3.10 and 3.11.

3.8 Optical Illusions. Good lettering involves artistic design, in which the white and

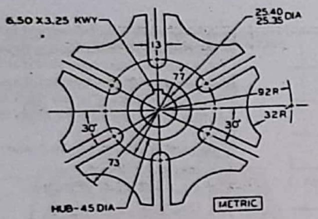


Fig. 2.91 Geneva Cam. Using Layout A-2 or A4-2 (adjusted), draw in pencil. Omit dimensions and notes.

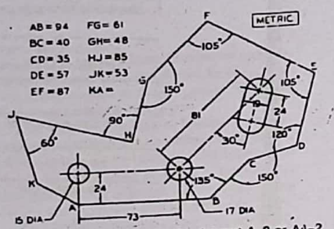


Fig. 2.92 Shear Plate. Using Layout A-2 or A4-2 (adjusted), draw accurately in pencil. Give length of KA. Omit other dimensions and notes.

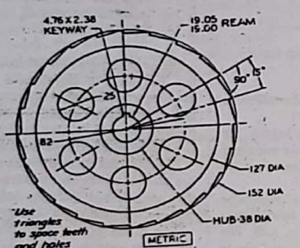


Fig. 2.93 Ratchet Wheel. Using Layout A-2 or A4-2 (adjusted), draw in pencil. Omit dimensions and notes.

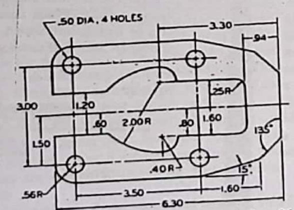


Fig. 2.94 Latch Plate. Using Layout A-2 or A4-2 (adjusted), draw in pencil. Omit dimensions and notes.

letterin

3.1 Origin of Letter Forms. The designs of modern alphabets had their origin in Egyptian hieroglyphics, Fig. 1.3, which were developed into a cursive hieroglyphic or hieratic writing. This was adopted by the Phoenicians and was developed by them into an alphabet of twenty-two letters. This Phoenician alphabet was later adopted by the Greeks, but it evolved into two distinct types in different sections of Greece: an Eastern Greek type, used also in Asia Minor, and a Western Greek type, used in the Greek colonies in and near Italy. In this manner the Western Greek alphabet became the Latin alphabet about 700 B.C. The Latin alphabet came into general use throughout the Old World.

Originally the Roman capital alphabet consisted of twenty-two characters, and these have remained practically unchanged to this day. They may still be seen on Trajan's Column and other Roman monuments. The letter V was used for both U and V until the tenth century. The last of the twenty-six characters, J, was adopted at the end of the fourteenth century as a modification of the letter I. The dot over the lowercase j still indicates its kinship to the i; in Old English the two letters are very similar. The numerous modern styles of letters were derived from the design of the original Roman capitals.

Before the invention of printing by Gutenberg in the fifteenth century, all letters were made by hand, and their designs were modified and decorated according to the taste of the individual writer. In England these letters

* *Lettering*, not "printing," is the correct term for making letters by hand. *Printing* means the production of printed material on a printing press.

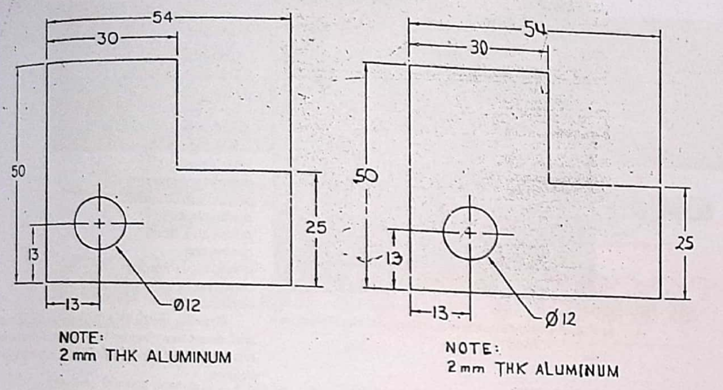


FIG. 4-36 A comparison of lettering qualities

sentences, you will have excellent lettering technique. To achieve this skill requires continual practice, careful observation, determination, and patience. Beginning level draftspersons are usually not hired if their lettering quality and speed are poor. Many people feel that lettering reflects the quality of a drawing and of the draftsperson. People reading a poorly lettered engineering drawing will not have much faith in the drawing or the draftsperson. What feelings do you get from Figure 4-36? The drawings are identical except for the lettering. A good measure of the drawings in Figure 4-36 would be to microfilm then, blow them back up to full size, then see if the lettering is still legible.

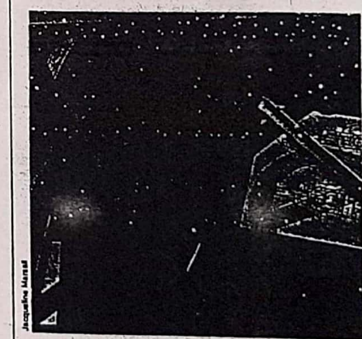
EXERCISES

1. Draw up a sheet with ⅛ inch guide lines, and practice vertical lettering.
2. Draw up a sheet with ⅛ inch guide lines, and practice inclined lettering.
3. Draw up a sheet with ⅛ inch guide lines, and practice microfont lettering.

5

Chapter

Drafting Equipment



INTRODUCTION

Twenty thousand years ago prehistoric people were scratching drawings on walls with sticks and bones (Fig. 5-2). The pyramids were designed on papyrus by scribing a line, then tracing over the mark with a reed pen and a colored liquid. The Greeks and Romans wrote in wax with a sharp stylus, and later used a piece of metal for scribing lines on a surface. Leonardo da Vinci drew with charcoal on paper, and then went over the lines with a quill pen and ink. Graphite was discovered around 1400 and was used for crude drawings. In the 1600s the graphite was encased in wood holders. Later, clay was added to the graphite to stop it from smearing.

As drawings became more technical, more accurate drawing instruments were developed and improved upon. Drawing became an accurate communication medium for conveying manufacturing and construction ideas. The advancement of technology is related to the accuracy of the available instruments, tools, and products (Fig. 5-3).

As you read this chapter, you should learn how to:

1. Care for and use instruments.
2. Test your T-squares and triangles for accuracy.
3. Use the T-square to draw horizontal lines.
4. Draw vertical and inclined lines using the T-square and triangles.
5. Select the proper grades of pencils used in drawing.

FIG. 5-2 Drawing in prehistoric times

6. Sharpen your pencils correctly.
7. Hold the pencil correctly to produce good line quality.
8. Square up and fasten paper to the drawing board.
9. Make simple corrections on drawings.
10. Draw circles and arcs.
11. Sharpen and adjust a compass lead.
12. Select the proper media on which to make different types of drawings.

MODERN DRAFTING EQUIPMENT

The different types of drawing instruments and equipment used in today's drafting room are quite numerous (Fig. 5-4). They may be divided into three groups:

Beginning student
drawing paper
tracing paper
drafting pencils
erasers
erasing shield
drafting boards
drafting tape
pencil sharpeners
T-squares
triangles
scales
compasses
dividers
protractor
templates (circle, isometric)
irregular curve
dusting brush

Advanced student
drafting machine
drawing surface cover
parallel slide
vellum
adjustable triangle
flexible curve
templates, as needed
lettering templates
guide line template
mechanical pencils
technical pens
ink
transfer letters
shading tones

Professional draftsperson:
track drafting machine
drawing table
electric eraser
drawing film
lofting curves
lettering set
drop bow compass
proportional dividers
drafting lamp
perspective board
pantograph
templates, as needed
computer
duplicator

FIG. 5-3 Drawing in today's world (Teledyne Post)

FIG. 5-4 Modern drafting instrument kits (Teledyne Post)

Drawing media (Fig. 5-5) are available in rolls and sheets (see Chapter 9 for sizes). There are many types of drawing media available. A few are listed below:

1. *Drawing paper* comes in white, buff, and green.
2. *Tracing paper* is thin, inexpensive, and translucent.
3. *Vellum* is heavier than tracing paper, treated with chemical additives, costlier, and translucent.
4. *Polyester film* is an indestructible plastic film, transparent, and very expensive.

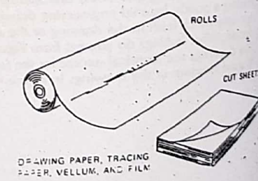


FIG. 5-5 Drafting media

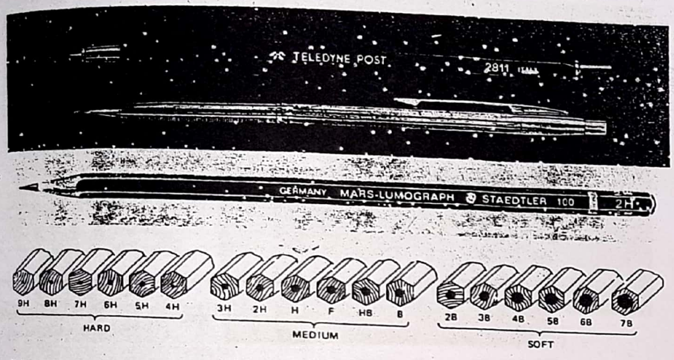


FIG. 5-6 Drafting pencils (J. S. Staedtler, Inc. (Teledyne Post)

5. *Graph paper* is squared drawing paper or vellum with light, nonreproducible lines, available in all sizes

Drafting pencils (Fig. 5-6) or leads are divided into three groups: hard, medium, and soft.

Hard pencils range from 9H to 4H. They leave a very sharp, but light line, and will not smear easily. They are used for first draft outlines.

Medium pencils range from 3H to B. They are used for all finished line work in engineering drawings. Experience is needed to select the best pencil.

Soft pencils range from 2B to 7B. These pencils are too soft to use on engineering drawings. They are used in renderings and general art work.

A special *plastic lead pencil* is used for drawing on polyester film.

The *lead holder* grips individual drafting leads.

The *ultra-thin lead mechanical pencil* needs no sharpening. It can hold various drafting leads of 0.5 mm diameter.

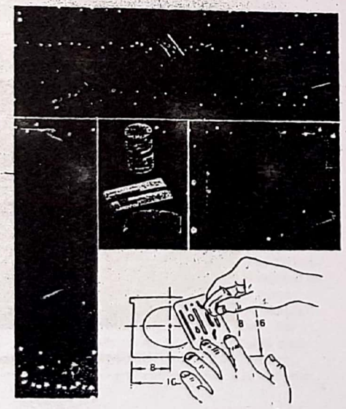


FIG. 5-7 Drawing cleaning equipment (Teledyne Post)

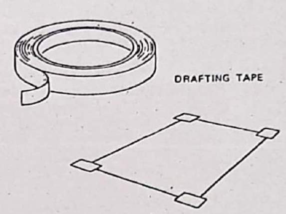


FIG. 5-8 Drafting tape

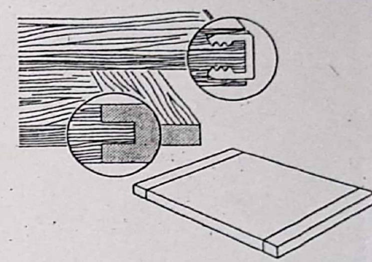


FIG. 5-9 Drafting boards

Cleaners (Fig. 5-7) play a large part in the production of quality drawings. Some cleaning aids are:

1. Basic *white eraser* for all-purpose uses.
2. *Artgum eraser* for erasing light lines and smudges.
3. *Kneaded eraser* for picking up loose graphite that may cause smudging. It is soft and pliable.
4. *Dry cleaner* for cleaning light smudges. It is a powder in a small cloth bag that may be sprinkled on the drawing while doing layout work. The instruments will ride on the powder and keep the drawing clean.
5. *Erasing shield* for protecting parts of line work that are not to be erased.
6. *Electric eraser* for fast and efficient erasing. It does little damage to the surface of the drawing media.
7. *Dusting brush* for removing foreign matter from the drawing. It is cleaner to use a brush than to blow or wipe off foreign matter by hand.

Drafting tape (Fig. 5-8) is the approved method of attaching a drawing to a drawing surface. The tape will not damage the surface.

Drafting boards (Fig. 5-9) come in a variety of sizes. A good size for the beginning student is 20 inches by 26 inches. Larger boards are available for larger size drawings. The board allows the drawing to be easily stored, freeing the desk for other work.

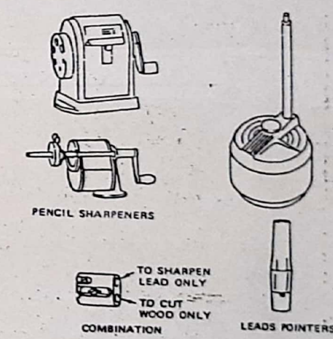


FIG. 5-10 Pencil sharpeners

Pencil sharpeners (Fig. 5-10) are available in many styles. There are two types of mechanical pencil sharpeners for the wood-encased drafting

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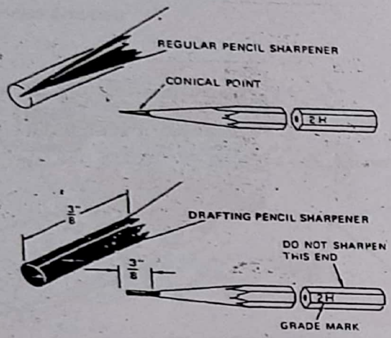


FIG. 5-11 Methods of sharpening pencils

pencil. One sharpener will sharpen with a long smooth sharp point. The drafting sharpener will remove only the wood. Another operation called pointing the lead is then necessary. A lead pointer will sharpen the exposed end of the drafting lead. Figure 5-11 shows the proper way to sharpen a drafting pencil.

T-squares (Fig. 5-12) come in a variety of sizes to match drafting board sizes. They are used to draw horizontal lines and as a guide for other drafting instruments. The parallel slide is a straight edge that is permanently attached to the drawing board. It can be moved quickly and will not slip.

Triangles (Fig. 5-13) are used with the T-square to draw angular and vertical lines.

Scales (Fig. 5-14) come in many different shapes and lengths. Chapter 7 explains the uses of metric scales.

Compasses (Fig. 5-15) come in a variety of shapes and sizes. Using the compass and sharpening the compass lead are shown in Figure 5-16.

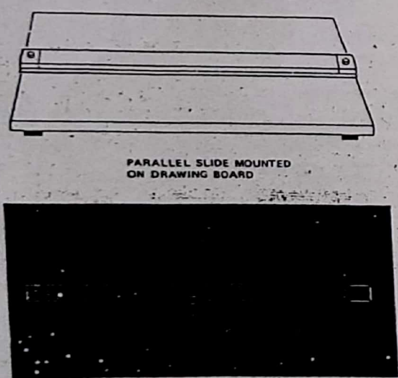
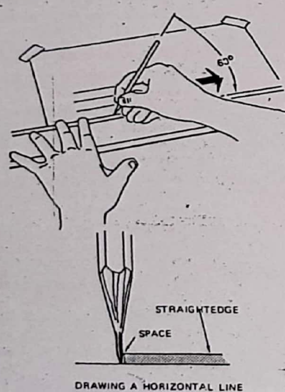


FIG. 5-12 T-square (Teledyne Post)



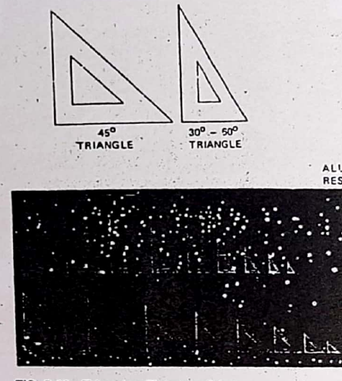
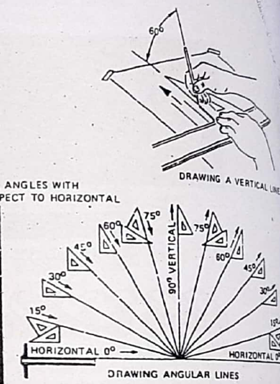


FIG. 5-13 Triangles (Teledyne Post)



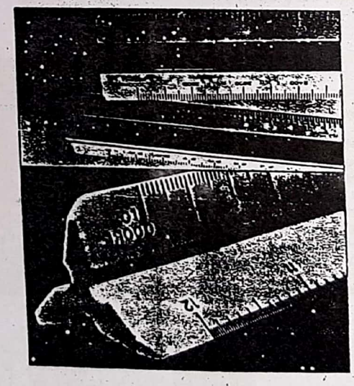


FIG. 5-14 Scales (Clark E. Smith) (Blundell Harling)

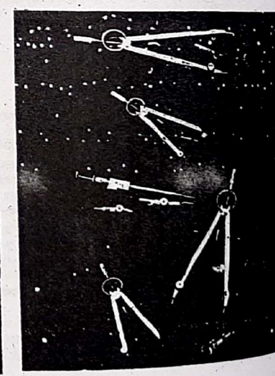


FIG. 5-15 Compasses (Teledyne Post)

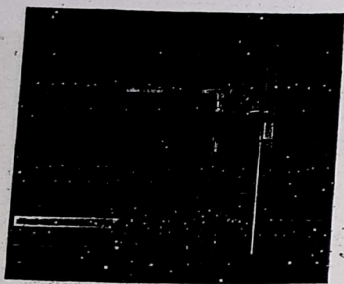


FIG. 5-22 Track drafting machine (Teledyne Post)

FIG. 5-23 Drafting tables (Teledyne Post)

Drafting machines (Fig. 5-21) are used to speed up drawing time. They take the place of T-squares, triangles, scales, and protractors. The arms and scales come in various lengths to accommodate any size drawing board.

Track drafting machines (Fig. 5-22) allow smoother and faster movement than the standard drafting machine. Various sizes of tracks and scales will fit any drafting board and drawing.

Drafting tables (Fig. 5-23) are the draftsperson's work station. Most students will work on drafting boards placed on the table. The professional draftsperson will work directly on the table surface. Tables come in many different sizes to handle any size drawings.

Drawing surface covers (Fig. 5-24) provide a smoother drawing surface. A sheet of drawing paper will make an inexpensive, temporary cover. Laminated vinyl is a permanent, almost perfect drawing surface. There is no glare, it cleans easily, and small holes seal themselves. Vinyl covers are easily attached with two-sided tape.

Adjustable triangles (Fig. 5-25) allow different angles to be drawn quickly in conjunction with the T-square.

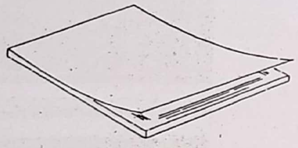


FIG. 5-24 Drawing surface cover

FIG. 5-25 Adjustable triangle (Teledyne Post)

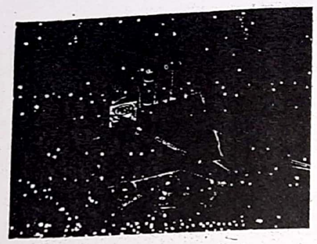


FIG. 5-26 Technical pens (Teledyne Post)

Technical pens (Fig. 5-26) are used for ink drawings. Each pen has its own line width. The most common ink used is black, opaque India ink.

Transfer letters, symbols, and shading tones (Fig. 5-27) are used by the technical illustrator for lettering heads and shading drawings (see Chapter 23). An unlimited number of letter styles, sizes, and variations of shading are available.

FIG. 5-27 Transfer symbols (Teledyne Post)

Lettering sets (Fig. 5-28) are mechanical methods for producing precise lettering. The Leroy and Unitech sets are most common.

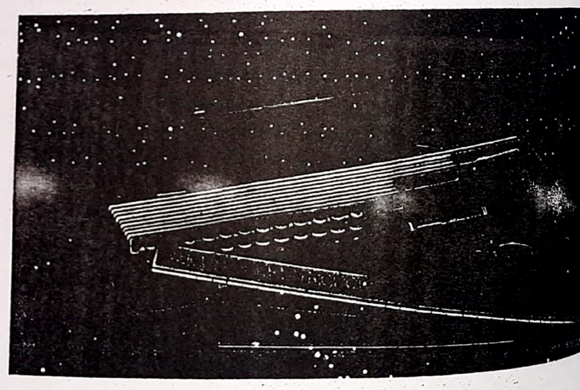


FIG. 5-28 Lettering sets (Teledyne Post)

FIG. 5-29 D

FIG. 5-30 Per Occ

FIG. 5-29 Drafting lamp (Teledyne Post)

Drafting lamps (Fig. 5-29) are necessary if *drafting room* lighting is not adequate.

Perspective boards (Fig. 5-30) are used to make perspective drawings more rapidly.

Pantographs (Fig. 5-31) are used to copy and change the scale of an original drawing.

Computer drafting (Fig. 5-32) is now being used in the larger drafting rooms. See Chapter 33 for detailed information on computer drafting.

Duplicators (Fig. 5-33) are any machines that can copy a drawing. See Chapter 35 for different methods of reproduction.

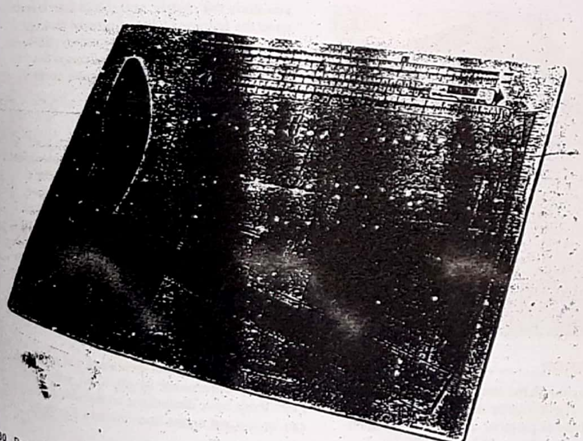


FIG. 5-30 Perspective drawing board (Fiberesin, Oconomowoc, Wi.)

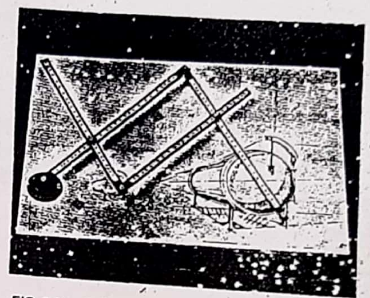


FIG. 5-31 Pantograph (Teledyne Post)

FIG. 5-33 Duplicators (Teledyne Post)

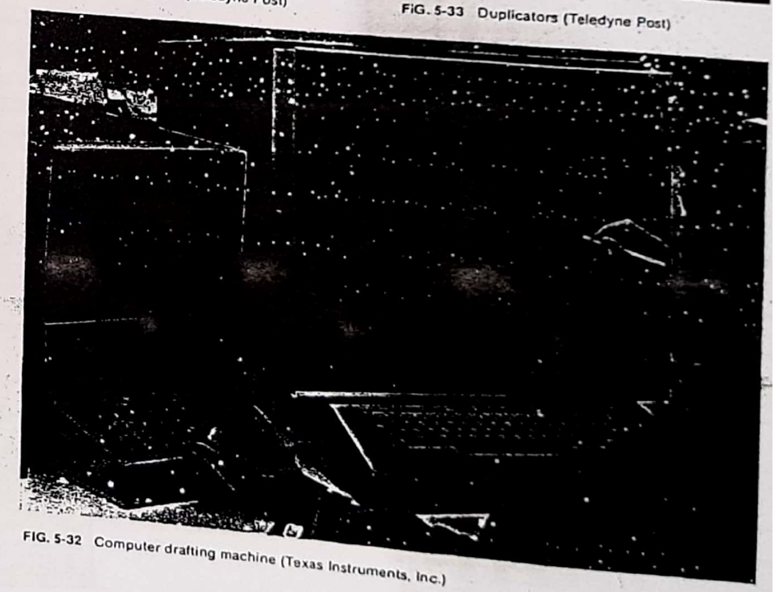
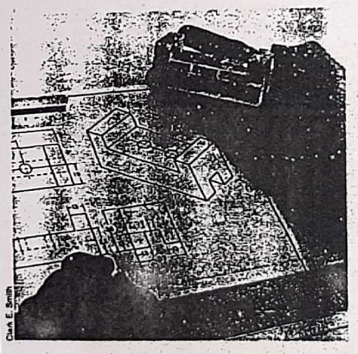


FIG. 5-32 Computer drafting machine (Texas Instruments, Inc.)

11

Chapter

Isometric / Pictorials



INTRODUCTION

Pictorial drawing is the simplest type of drawing to understand. The isometric drawing is the simplest and fastest type of pictorial drawing to draw. As you study this chapter, you should learn to understand the following types of pictorial drawings: isometric, dimetric, trimetric, cavalier, cabinet, two point perspective, and one point perspective. You should also develop the skill to make isometric drawings.

PICTORIAL

A single drawing that shows more than one side of an object is called a pictorial drawing. Pictorial drawings are divided into *axonometric*, *oblique*, and *perspective* drawings (Fig. 11-2). The fastest and most efficient pictorial drawing is an *isometric* drawing. All the lines in an isometric drawing of a rectangular object will be vertical or 30 degree angular lines. The axes will form 120 degree angular lines (Fig. 11-3).

ISOMETRIC DRAWING

All objects, regardless of their shape and size, have three basic dimensions: length, width, and height. From these basic dimensions an isometric drawing can be laid out on the *isometric axes* (Fig. 11-4).

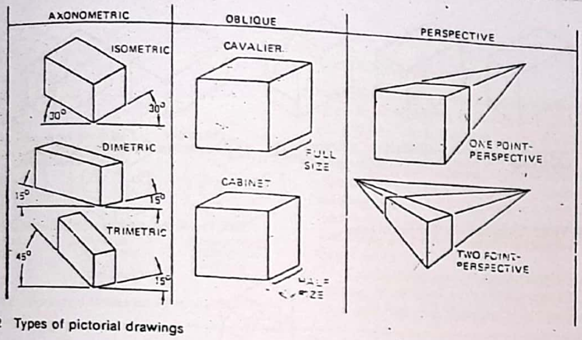


FIG. 11-2 Types of pictorial drawings

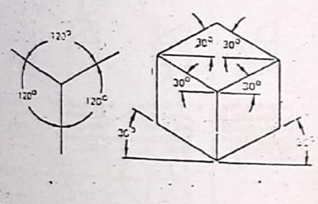


FIG. 11-3 Isometric axes

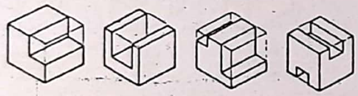


FIG. 11-5 Parts drawn within the isometric block

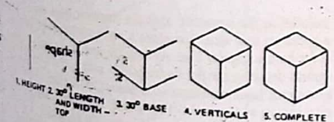


FIG. 11-4 Steps in drawing an isometric block

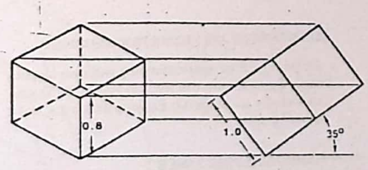


FIG. 11-6 Side view shows the actual angle of an isometric drawing

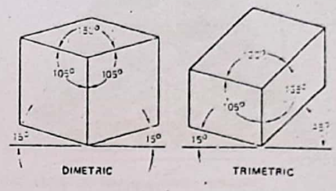


FIG. 11-7 Dimetric and trimetric axonometric drawings

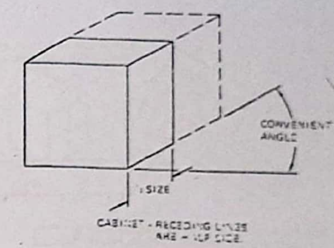


FIG. 11-9 The cabinet oblique

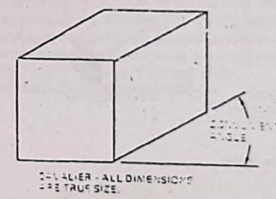


FIG. 11-8 The cavalier oblique

This blocking-in is the starting point for all isometric drawings. Once the overall isometric form is blocked in with the correct dimensions, the actual shape of the object can be drawn with less chance of error (Fig. 11-5).

In an isometric drawing, all vertical and 30 degree lines are drawn true size for convenience and speed. Because the top surface is usually seen in reality, the top, front corner should be slanted forward. This forward slant is slightly over 35 degrees (Fig. 11-6). This is why isometric templates are set at 35 degrees.

Axonometric Drawings

The isometric drawing is one form of axonometric drawings. The other axonometric drawings are the *dimetric* and *trimetric* drawings (Fig. 11-7). Dimetric and trimetric drawings are more difficult to draw than isometric drawings, therefore the isometric drawing is used most often.

Oblique Drawings

The two oblique drawings are called cavalier and cabinet drawings. Oblique means inclined. The *cavalier* (Fig. 11-8) has its front face drawn true size and shape. The receding lines are drawn at any convenient angle between 15 and 45 degrees. All dimensions are drawn to true size. A cavalier drawing will look distorted in shape. To correct this distortion, a cabinet drawing can be used (Fig. 11-9).

The procedure for making a *cabinet* drawing is the same as for the cavalier. However, the receding lines are drawn one-half actual size. Note how the cube in Figure 11-9 now looks like a cube even though the side dimensions are one-half size.

Perspective

The last type of pictorial drawing you will be concerned with is perspective drawing, illustrated in Figure 11-2. Chapter 22 explains how to make perspective drawings.

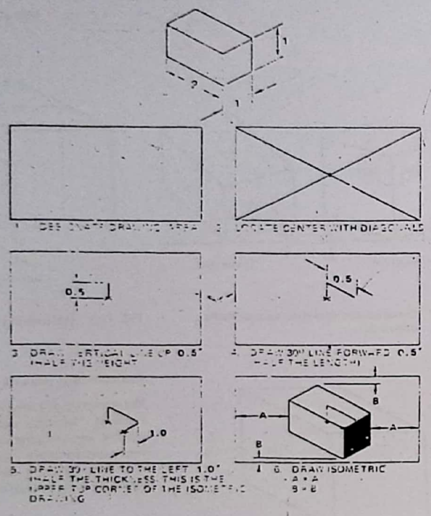


FIG. 11-10 Centering an isometric drawing on the paper

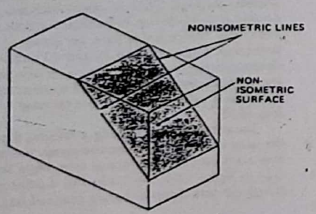


FIG. 11-11 Nonisometric lines and surfaces

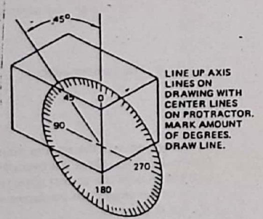


FIG. 11-12 Use of an isometric protractor

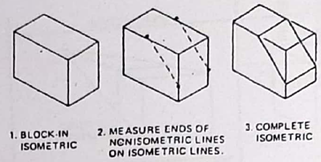


FIG. 11-13 Locating nonisometric lines

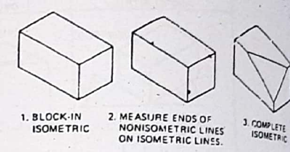


FIG. 11-14 An oblique nonisometric surface

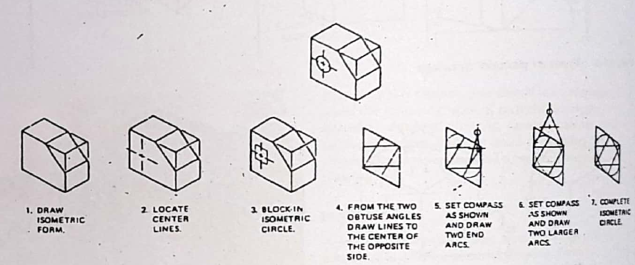


FIG. 11-15 Construction of an isometric circle

CENTERING AN ISOMETRIC DRAWING

Centering an isometric drawing will save layout time. By following the steps in Figure 11-10 you can center an isometric drawing within a specific drawing area.

NONISOMETRIC LINES

Nonisometric lines are lines that are not parallel to the isometric axes (Figure 11-11). All lines that are parallel to the isometric axes are isometric lines and are drawn true size. Therefore a nonisometric line must be an angular line. An angular line on an isometric drawing cannot be measured with a protractor (unless an isometric protractor like the one shown in Figure 11-12 is used). The fastest way to draw an angular line is to measure the location of its ends on the isometric lines (Fig. 11-13). An oblique surface can be drawn in the same manner (Fig. 11-14).

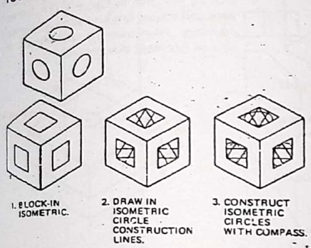


FIG. 11-16 Isometric circles on other surfaces

ISOMETRIC CIRCLES

Isometric circles are required on many drawings. A circle in an isometric drawing will appear as a 35° 16' ellipse. The procedure for constructing an isometric circle is shown in Figure 11-15. This procedure can be used to construct isometric circles on any of the three isometric faces of a drawing (Fig. 11-16). Drawing a circle on a nonisometric surface will require plotting several points and using a French curve to darken in the circle (Fig. 11-17).

Constructing an isometric circle is time consuming. Since industry is concerned with cutting costs and reducing drawing time, many drafting technicians use an isometric circle template (Fig. 11-18). To draw an isometric circle with a template simply line up the center lines on the drawing with the center lines on the template (Fig. 11-19). Semicircles and quarter rounds are prepared and drawn in the same manner, using the same isometric template (Fig. 11-20). Draw only the part of the isometric circle that is required.

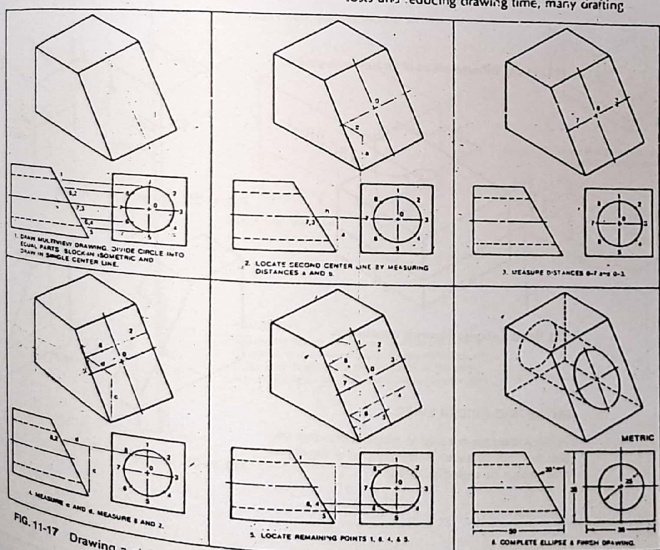


FIG. 11-17 Drawing a circle on a nonisometric surface

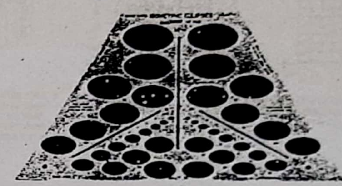


FIG. 11-18 An isometric circle template (RapiDesign, Inc.)

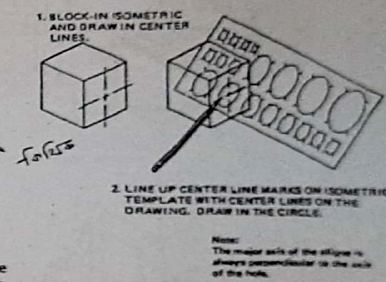


FIG. 11-19 Use of the isometric template for circles

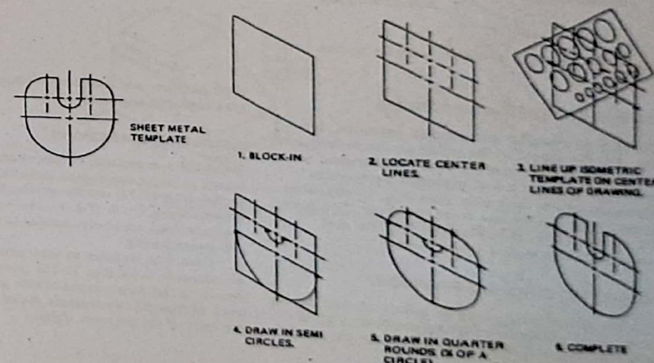


FIG. 11-20 Use of the isometric template for arcs

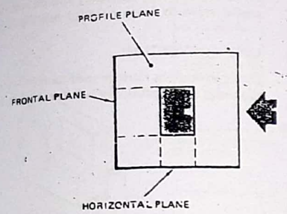


FIG. 12-7 First-angle projection views the object from in front of the planes

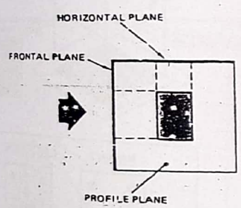


FIG. 12-8 Third-angle projection views the object from behind the planes

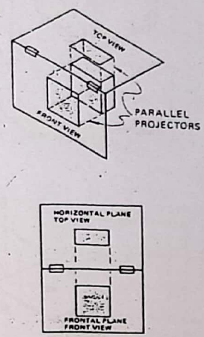


FIG. 12-9 Planes are perpendicular to projectors

Orthographic projection is a method of representing an object by a line drawing on a projection plane that is perpendicular to parallel projectors (Fig. 12-9). The adjacent planes are at 90 degrees. The parallel projectors are at 90 degrees to the planes.

MULTIVIEW DRAWINGS

Multiview drawings in first or third-angle of projection can have two to six views (Fig. 12-10). The views most often used in first-angle projection are front, top, and left profile views (Fig. 12-11). The views most often used in third-angle projection are the front, top, and right profile views (Fig. 12-12). To define which type of projection is used for a multiview drawing, a small explanatory sketch is placed on the drawing paper (Fig. 12-13).

The majority of engineers and draftspersons in the United States will use the third-angle projection method because of its clarity. The objection to first-angle projection is that when the planes are revolved away from the object, the top view appears below the front view, the right side view appears to the left of the front view, and the left side view appears to the right of the front view. This makes visualization difficult. Most multiview drawings in this text will be third-angle projection.

The theory of projecting from an object to a projection plane, then swinging the plane to a flat surface is important to understand. Most draftspersons find it faster and easier to draw each view as an actual picture as seen with a line of sight perpendicular to each particular plane of projection. To see the front view, using third-angle projection, the draftsperson should imagine he is in front of the

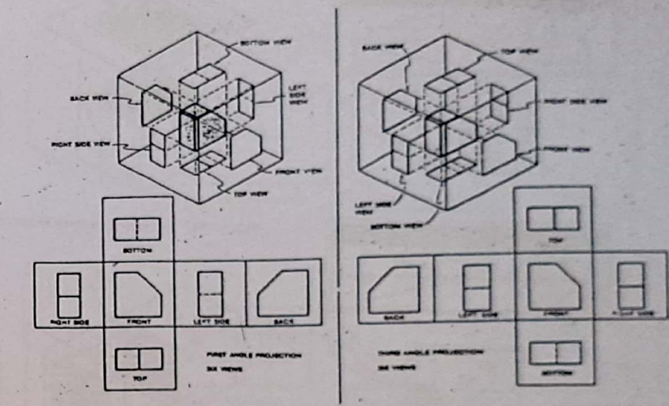


FIG. 12-10 Six possible orthographic views from first- and third-angle projections

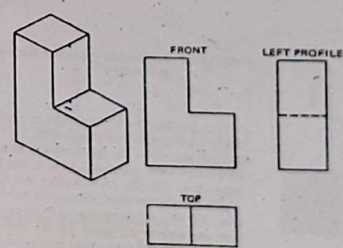


FIG. 12-11 Common views used in first-angle projection

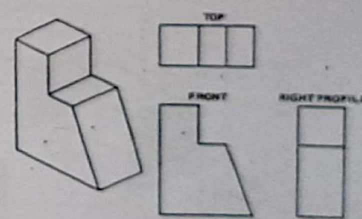


FIG. 12-12 Common views used in third-angle projection

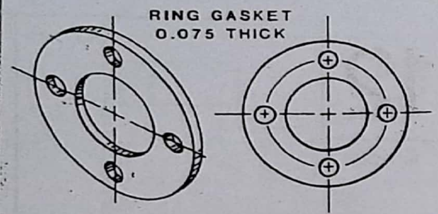


FIG. 12-2 Single view for flat objects

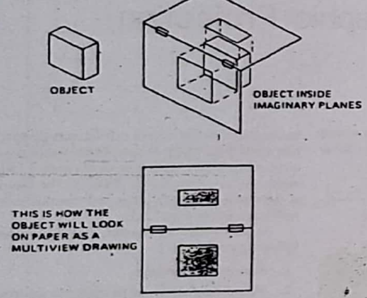


FIG. 12-3 Multiview drawing

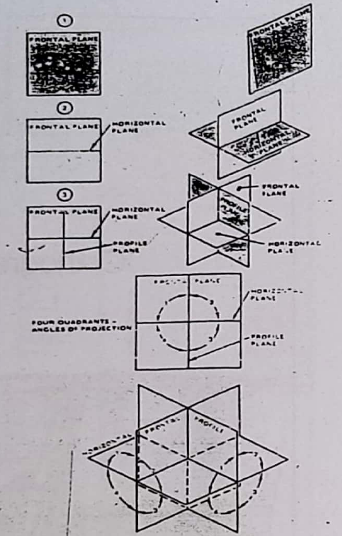


FIG. 12-4 Three planes of orthographic projection

ORTHOGRAPHIC PROJECTION

The projection of orthographic views was developed by a Frenchman named Gaspard Monge. He developed a system called Monge's planes of projection around 1795. The planes are frontal, horizontal, and profile (Fig. 12-4). Monge's system of multiview drawings is an arrangement of orthographic views on a single plane, represented by the drawing paper. The principle is that any two adjacent views lie on perpendicular planes of projection. All adjacent planes are at right angles to each other. The two arrangements of views used in mechanical drawing are *first-angle projection* (Fig. 12-5) and *third-angle projection* (Fig. 12-6). In first-angle projection the object is viewed in *front* of the planes and projected back to the planes (Fig. 12-7). In third-angle projection the object is viewed from *behind* and projected forward to the planes (Fig. 12-8).

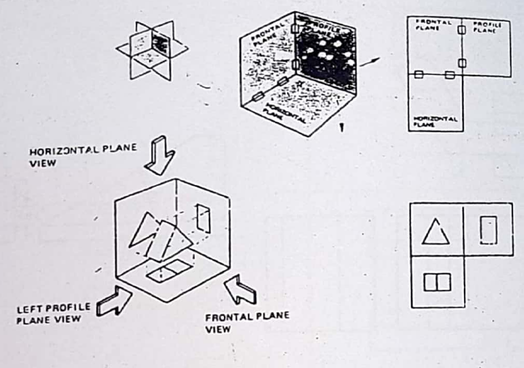


FIG. 12-5 First-angle projection—3 views

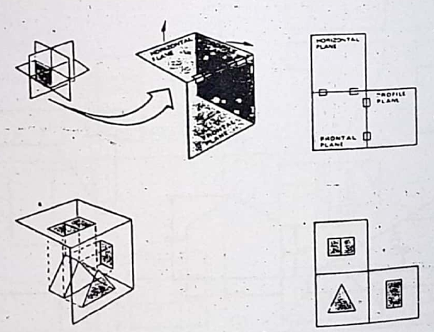


FIG. 12-6 Third-angle projection—3 views

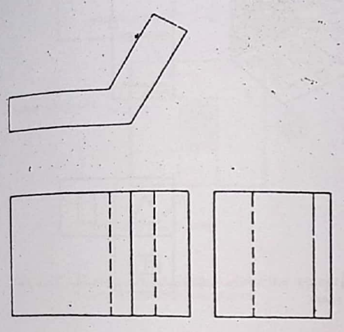


FIG. 11-73 Problem

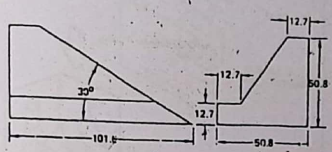


FIG. 11-75 Problem

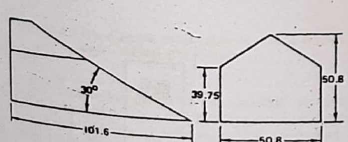


FIG. 11-74 Problem

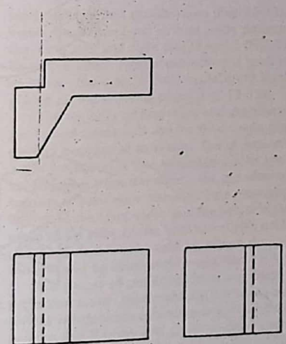
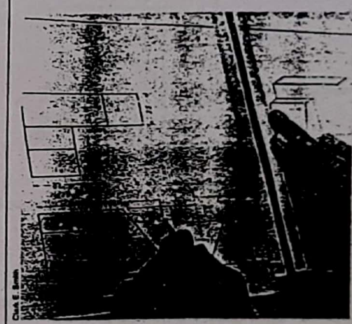


FIG. 11-76 Problem

12

Chapter

Orthographic Projection



INTRODUCTION

A *working drawing* is a communication between the designer and the fabricator of the object to be built. A simple flat object can be represented by one view (Fig. 12-2). A complicated object will require more views. This type of drawing is called a multiview or orthographic drawing. The views are at right angles to each other and directly in line with each other (Fig. 12-3).

As you study this chapter, you should learn the following concepts:

1. Planes of projection.
2. Visualizing views of an object to determine the best method of presenting them graphically.
3. Selection of views for a two-view drawing.
4. Selection of views for a three-view drawing.
5. Making a multiview drawing using the third angle of projection.
6. Making a multiview drawing using the first angle of projection.
7. Methods of projecting multiview drawings.
8. Proper use of line conventions on a multiview drawing.
9. Dimensioning a multiview drawing (Chapter 13).

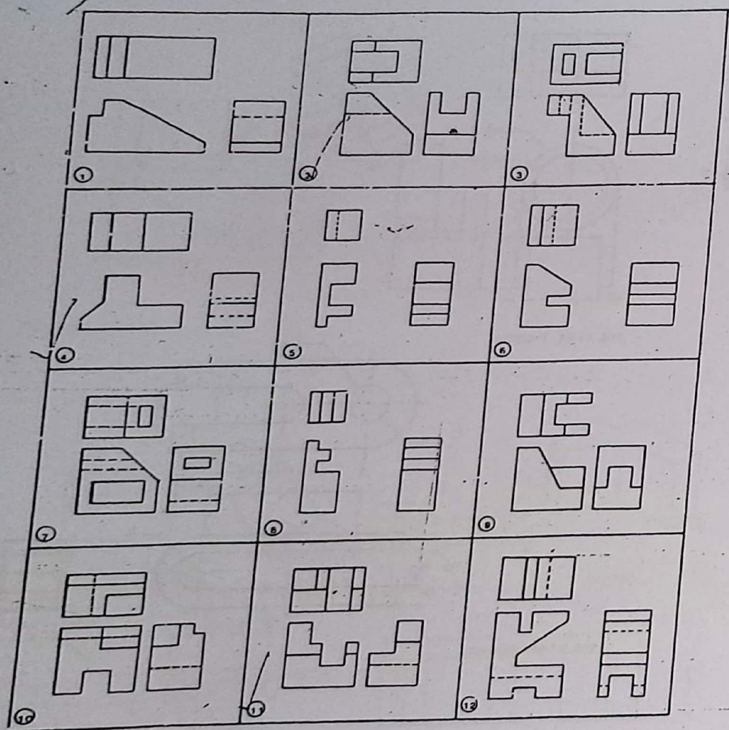


FIG. 11-66 Problem

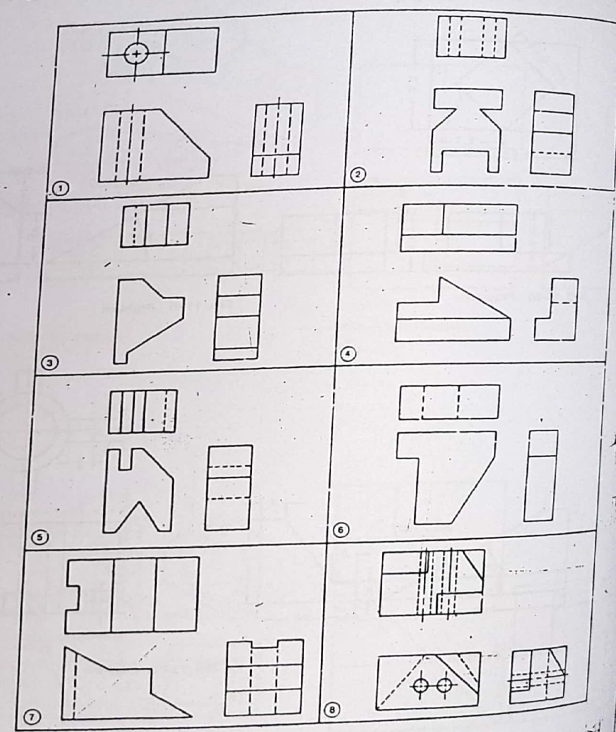
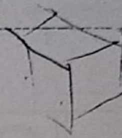


FIG. 11-67 Problem



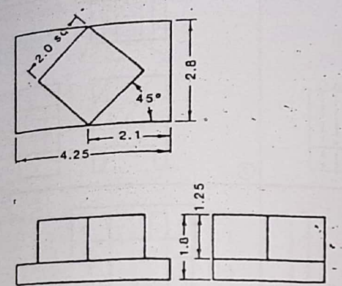


FIG. 11-60 Problem

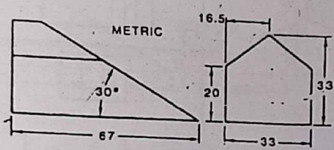


FIG. 11-61 Problem

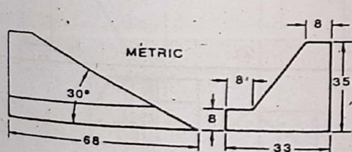


FIG. 11-62 Problem

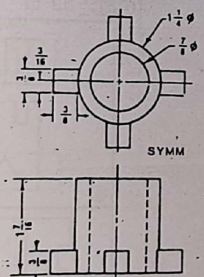


FIG. 11-63 Problem

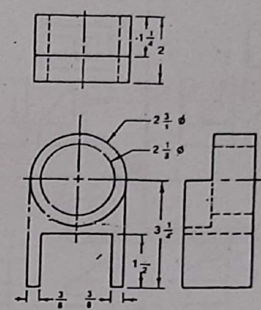


FIG. 11-64 Problem

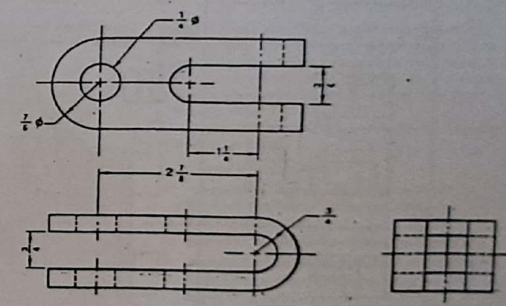


FIG. 11-65 Problem

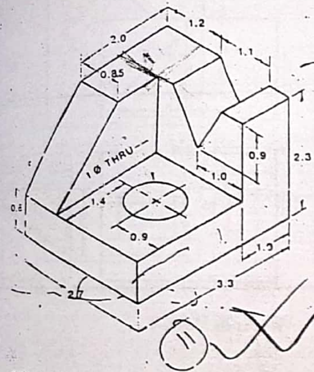


FIG. 11-45 Problem

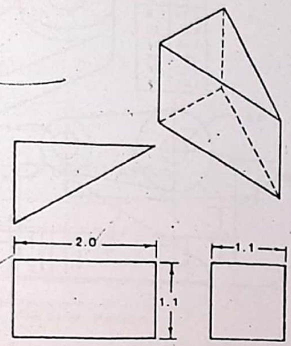


FIG. 11-47 Problem

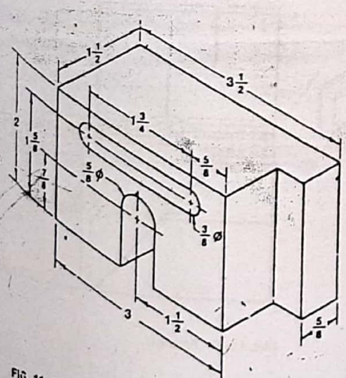
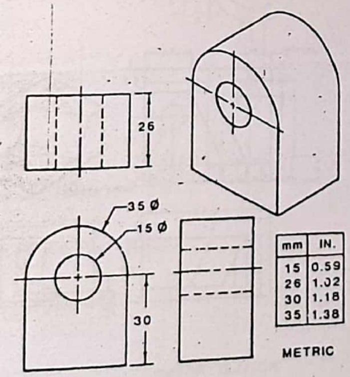


FIG. 11-46 Problem



mm	IN.
15	0.59
26	1.02
30	1.18
35	1.38

FIG. 11-48 Problem

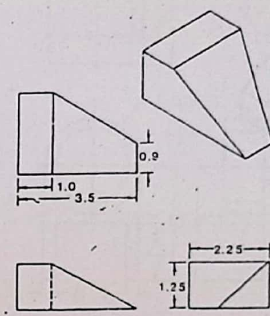


FIG. 11-49 Problem

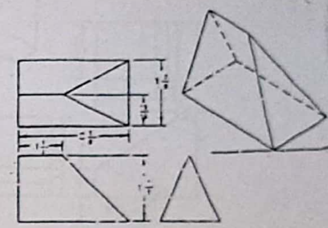
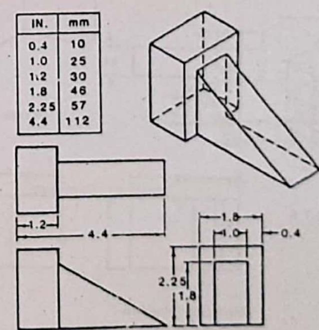


FIG. 11-51 Problem



IN.	mm
0.4	10
1.0	25
1.2	30
1.8	46
2.25	57
4.4	112

FIG. 11-50 Problem

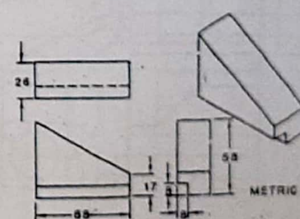


FIG. 11-52 Problem

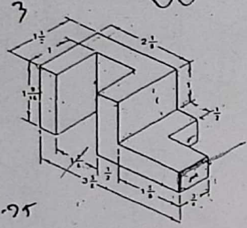


FIG. 11-37 Problem

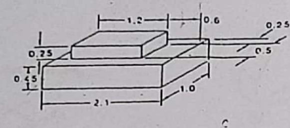


FIG. 11-39 Problem

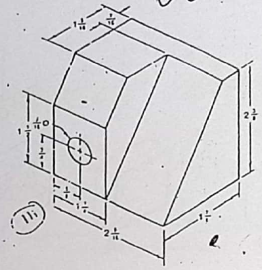


FIG. 11-41 Problem

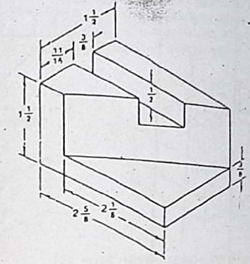


FIG. 11-43 Problem

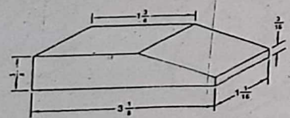


FIG. 11-38 Problem

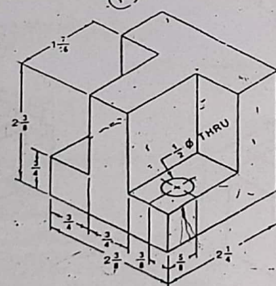


FIG. 11-40 Problem

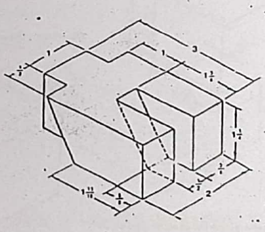


FIG. 11-42 Problem

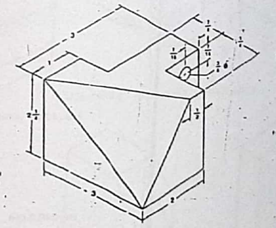


FIG. 11-44 Problem

Frederick E. Giesecke

M.E., B.S. in ARCH., C.E., Ph.D., Late Professor Emeritus of Drawing, Texas A&M University

Alva Mitchell

B.C.E., Late Professor Emeritus of Engineering Drawing, Texas A&M University

Henry Cecil Spencer

A.B., B.S. in ARCH., M.S., Late Professor Emeritus of Technical Drawing, Formerly Director of Department, Illinois Institute of Technology

Ivan Leroy Hill

B.S., M.S., Professor Emeritus of Engineering Graphics, Formerly Chairman of Department, Illinois Institute of Technology

John Thomas Dygdon

B.S., M.B.A. Associate Professor of Engineering Graphics, Director, Division of Academic Services and Office of Special Programs, Illinois Institute of Technology

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same dimension can create a confusing situation that is difficult to interpret. Leader lines pointing to the center of a circle should be directed toward but not extended into the circle center. Figure 9-15.

Arrowheads

An arrowhead is the most commonly used termination symbol for dimension and leader lines. Arrowheads should be approximately three times as long as they are wide. They should be large enough to be seen, but small enough that they do not detract from the appearance of the drawing. A commonly accepted length for arrowheads is one-eighth inch. Arrowheads may be slightly larger or smaller than this but, regardless of their size, they should be uniform throughout a drawing. Figure 9-16. Although the same standard applies to drawings prepared on a CAD system, arrowheads do not have to be filled in on drawings prepared using automated processes. Some CAD systems fill in arrowheads and some do not. Either open or filled in arrowheads have been considered acceptable since the advent of CAD.

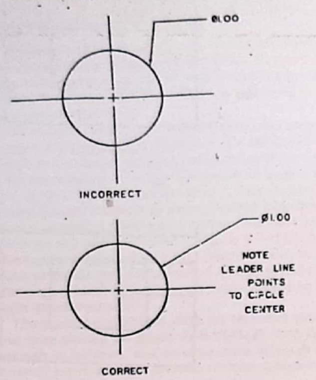


Figure 9-15 Leader lines point at the center of a circle

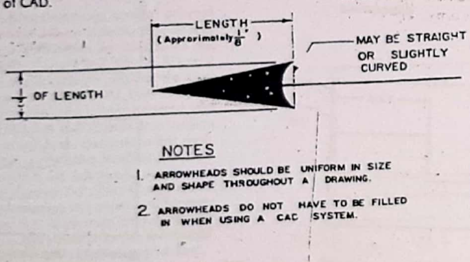


Figure 9-16 Proper size and shape of arrowheads

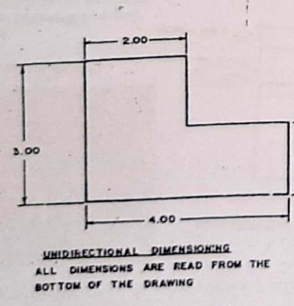


Figure 9-17 Unidirectional dimensioning

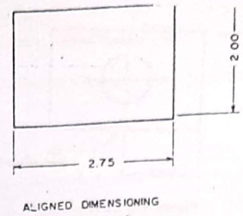


Figure 9-18 Aligned dimensioning

General Rules of Dimensioning

A number of specific rules of dimensioning are used for dealing with the various individual dimensioning situations that arise. The specific situations are covered in this chapter. However, before dealing with specific rules, the general rules which apply in all cases should be examined. Following are these general rules of dimensioning.

1. Unidirectional placement of dimensions on drawings is the preferred method. This means that all dimensions can be read from the bottom of the drawing. Figure 9-17.
2. Aligned dimensioning is the less preferred method for placing dimensions on drawings. When aligned dimensions are used, they should be placed so that they can be read from the bottom or right side of the drafting sheet. Figure 9-18.
3. When an overall dimension is given, one intermediate dimension may be either left off or placed in parentheses to indicate that it is a reference dimension. Figure 9-19.
4. Dimensions should be placed outside of the outline of an object, except in cases where the required extension and/or leader lines would be unusually long.
5. Unnecessary dimensioning should be avoided. Only those dimensions required to manufacture the part should be given, but given only once.
6. Enough dimensions should be provided so that the various tradespeople who will be using the drawing do not have to calculate, scale or estimate.
7. Features of an object should be dimensioned on the view or views where they appear true size and true shape.
8. Avoid dimensioning a feature where it appears as a hidden line. Figure 9-20.

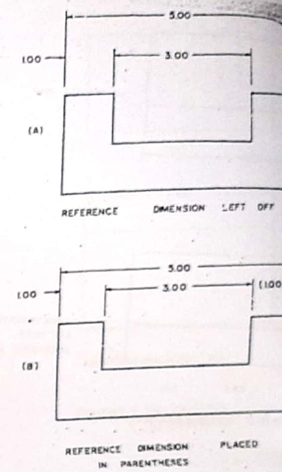


Figure 9-19 Reference dimensions

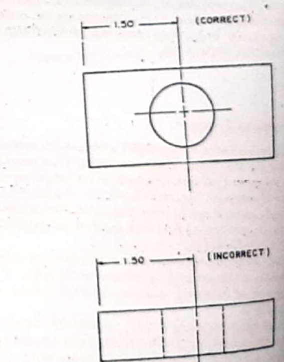
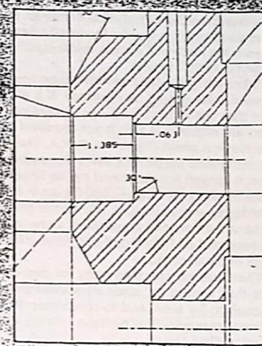


Figure 9-20 Avoid dimensioning hidden lines

Review

1. What is a transitional piece and which kind of development would be used to develop a pattern?
2. What are the two major kinds of notches used in a development?
3. What does a gage number represent?
4. In parallel line development, at what angle to the fold lines must the baseline be projected?
5. Why is it important to develop the pattern or template with the inside surface up?
6. List the three major kinds of developments used to develop a pattern of an object.
7. Why are tabs used?
8. What is bend allowance, and why is it used?
9. Explain what must be done if a transitional piece does not have fold lines.
10. What is a true-length diagram and why is it used?
11. Why is the gage system of calling out the thickness of a material being phased out?
12. What two elements must be located or laid out before a development can be actually started?



This chapter covers in depth the fundamentals of dimensioning and notation. All dimensioning techniques presented are in accordance with ANSI Y14.5M-1982, the latest edition of the dimensioning standard. Major topics covered include specifying the scale, dimensioning systems, general rules of dimensioning, specific dimensioning techniques, rules for applying notes to drawings, general notes, detail notes, writing notes, note specifications, and sample notes.

CHAPTER NINE

Dimensioning and Notation

One of the most fundamental drafting tasks is to meet the requirements of the engineering definition of the part, while providing for the most economical production process and the interchangeability considerations. All of this is accomplished by the use of proper dimensioning and notation on drawings. *Dimensioning* is the process wherein size and location data for the subject of a technical drawing are provided. *Notation* is the process wherein needed information not covered by dimensions is placed on a technical drawing.

It is critical that drafters, designers, and engineers be proficient in standard dimensioning practices. The most widely accepted dimensioning standard is American National Standards Institute document Y14.5M-1982 (ANSI Y14.5M-1982). Similar standards are produced by the International Standards Organization (ISO). However, unless otherwise specified, ANSI Y14.5M-1982 is the standard used for guiding dimensioning practices.

Modern dimensioning practices described in ANSI Y14.5M-1982 apply in most instances where interchangeability of parts is a major consideration. The concept dictates that parts produced from a drawing at one manufacturing site will be interchangeable with those produced at another manufacturing site. Automotive parts are an excellent example of production for interchangeability. Some parts are manufactured in America, some in Europe, and some in Japan, but they must all fit together in one car during assembly. Although interchangeability is not a factor with all parts that are produced, the drafter should still use the basic dimensioning principles of ANSI Y14.5M-1982. This is particularly important when the parts will be produced by such ever increasing automated or semiautomated processes as numerical control or computer-aided manufacturing.

Specifying the Scale

As has already been learned, technical drawings are usually made to scale. When this is the case, the scale should be indicated in the appropriate space in the title block. On occasion, one or more dimensions on a technical drawing may be made NOT TO SCALE (NTS). Any NTS dimensions should be distinguished from scaled dimensions. This is accomplished

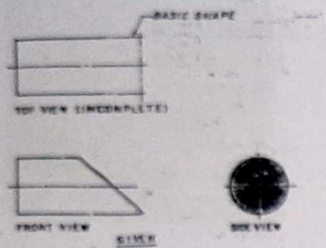


Figure 6-8 Projecting a round surface from an inclined surface

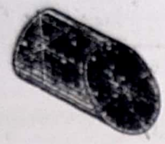


Figure 6-9 Pictorial view of an object

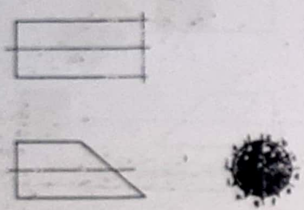


Figure 6-10A Step 1

Step 1. Divide the rounded view into equal spaces. In this example, using a 30° triangle, the right-side view is rounded and divided into 12 equal parts. Figure 6-10A. Letter each point clockwise, as shown in the figure.

Step 2. Construct a vertical reference line in the right-side view so it passes through the center; in this example, through points a and g. (Always place the reference line through the center of any symmetrical object.) Construct a reference line in the top view which runs through the center, as illustrated in Figure 6-10B.

Step 3. Draw light projection lines from the 12 points in the right-side view to the inclined edge in the front view. Project these same 12 points directly up to the top view from the inclined edge in the front view. Notice points a and g are on the reference line. Figure 6-10C.

Step 4. In the right-side view, measure the distance each point is from the reference line.

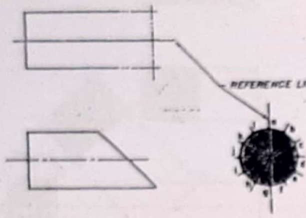


Figure 6-10B Step 2

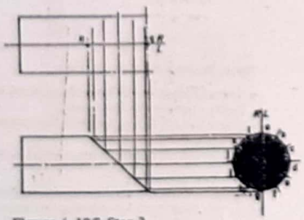


Figure 6-10C Step 3

Transfer each of these distances from the right-side view reference line to the top view reference line. Label each point lightly as each is found. Figure 6-10D.

Step 5. Lightly connect all points and, if correct, darken in all views. This completes the top view. Figure 6-10E. Always darken in the compass and irregular curve layout work first. This completes the top view.

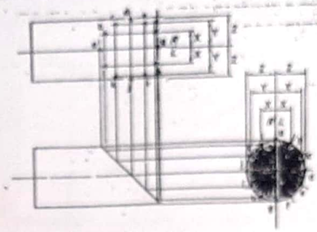


Figure 6-10D Step 4

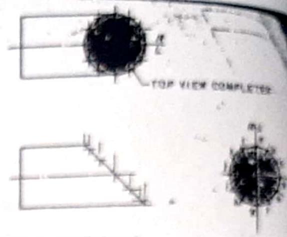


Figure 6-10E Step 5

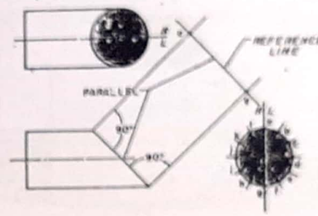


Figure 6-10F Step 6

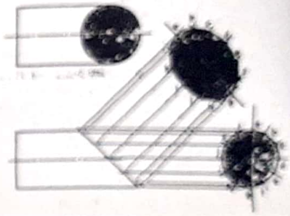


Figure 6-10G Step 7

How to Draw an Auxiliary View of a Round Surface

Step 6. Draw light projection lines 90° from the inclined surface of the front view. Construct the reference line *parallel* to the inclined surface at any convenient distance. Label the points that are on the reference line; in this example, a and g. Figure 6-10F.

Step 7. Draw light projection lines from the 12 points in the right-side view to the inclined edge in the front view (Step 3). Project these same 12 points directly up to the auxiliary view from the inclined edge in the front view. Again, notice points a and g are on the reference line. Figure 6-10G. In the right-side view, measure the distance each point is from the reference line. Transfer each of these distances from the right-side view reference line to the auxiliary view reference line. Label each point lightly as each is found.

Step 8. Lightly connect all points and, if correct, darken in the auxiliary view. This completes the auxiliary view. Figure 6-10H. Notice that only the inclined surface has been projected into the auxiliary view.

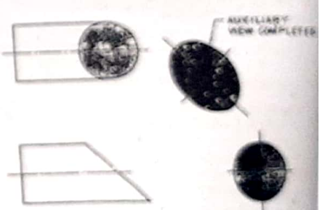


Figure 6-10H Step 8 finished drawing

How to Plot an Irregular Curved Surface

Given: The usual three views; front view (incomplete), top view, and the right-side view. Figure 6-11. This is an example of a top view auxiliary

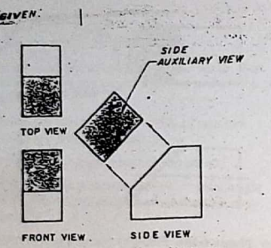


Figure 6-3 Side view auxiliary view

auxiliary. An auxiliary view projected from the right-side view would appear as it does in Figure 6-3. This is referred to as a *side view auxiliary.* Note in each case that the auxiliary view is projected 90° from the inclined or slanted surface, and is viewed from a line of sight 90° to the inclined or slanted surface, or as viewed looking directly down upon the inclined surface.

Hidden Lines in an Auxiliary View

Hidden lines should be omitted in an auxiliary view, unless they are needed for clarity. This is the drafter's prerogative or decision.

How To Draw an Auxiliary View

Given: The pictorial view of an object, Figure 6-4. Notice the inclined surface. As the inclined surface is on the front view, this will be a front view auxiliary. The usual three views of an object, front view, top view and right-side view, are shown in Figure 6-5.

Step 1. Label all important points of the auxiliary view, as illustrated in Figure 6-6A.

Step 2. Construct a *reference* line, which is also the edge view of a reference plane, in the right-side view. Always construct a reference line so that it is vertical and passes through as many points as possible. In this example, it passes through points a-d, Figure 6-6B.

Step 3. Draw light projection lines 90° from the inclined surface, and construct a reference line *parallel* to the inclined surface at any convenient distance, as shown in Figure 6-6C. Label all important points established thus far. Notice points a and d are *on* the reference line.

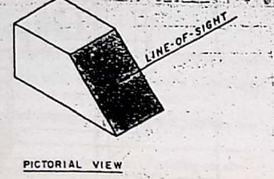


Figure 6-4 Drawing an auxiliary view

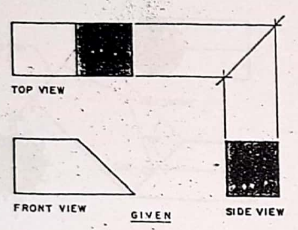


Figure 6-5 Given: Three views of an object

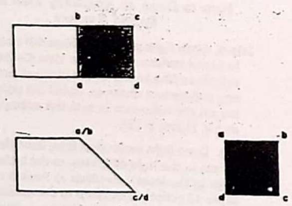


Figure 6-6A Step 1

Step 4. In the right-side view, measure the distance each point is *from* the reference line. Project these distances back to the inclined surface of the front view and up 90° from the inclined surface to the reference line above. Transfer each distance, and lightly label each point as illustrated in Figure 6-6D.

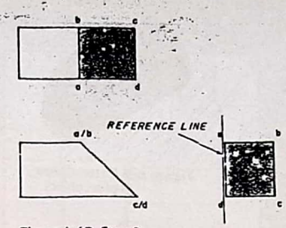


Figure 6-6B Step 2

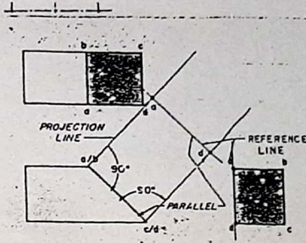


Figure 6-6C Step 3

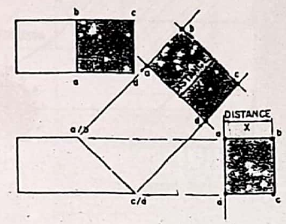


Figure 6-6D Step 4

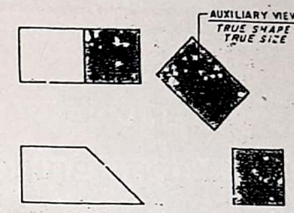


Figure 6-6E Step 5 finished drawing

Step 5. Recheck all work. Be sure:

- The projection is 90° from the inclined surface, in this example the front view.
- The reference line is *parallel* to the inclined surface of the front view.
- All distances have been transferred accurately.

If correct, carefully darken in and complete all views. The final finished drawing will appear as it does in Figure 6-6E. Notice that *only* the inclined surface is projected into the auxiliary view. Anything else would be foreshortened and, thus, not of true size or shape, and therefore of no use. Good drafting practice is to project *only* the surface of the inclined line, Figure 6-7.

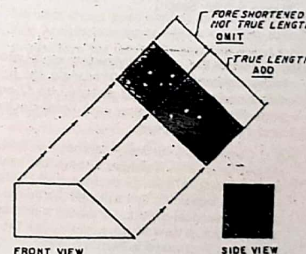


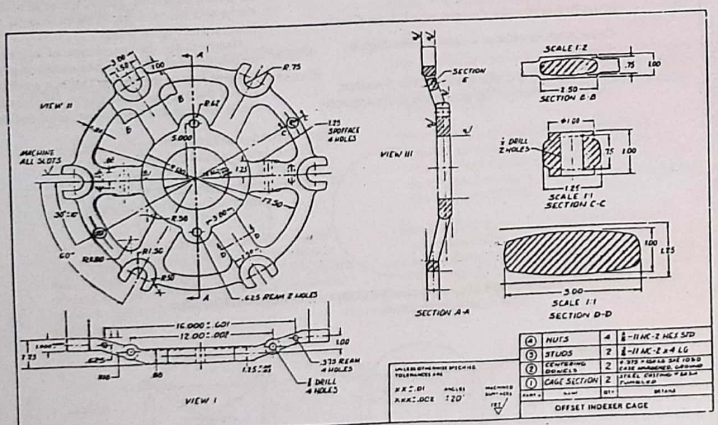
Figure 6-7 Draw only the inclined surface in the auxiliary view

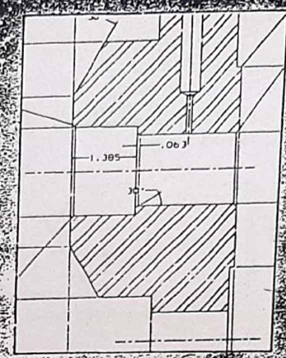
How To Project a Round Surface from an Inclined or Slanted Surface

Given: The usual three views of an object, front view, right-side view and unfinished top view, are shown in Figure 6-8. (The usual 45° projection angle line will be omitted, as a slightly newer projection method will be used to complete the top view.) Refer also to the pictorial drawing of this object, Figure 6-9.

Chapter Five Industry Print

1. What type of section is Section A-A?
2. What type of section is Section E?
3. What type of section is Section C-C?
4. What type of section is Section D-D?
5. What is the width of the rib at Section D-D?
6. What is the diameter of the through hole at Section C-C?
7. How many sections are cut on View II?
8. How many surfaces in Section A-A are to be machined?
9. What is the depth of the part in Section C-C?
10. What is the depth of the rib at Section B-B?





This chapter also is an extension of Chapter 4, Multiview Drawings, with the addition of an auxiliary view to show the true size and shape of a surface not on the usual planes of projection. The beginning drafter must fully understand how to lay out an auxiliary view and, if necessary, to add a secondary auxiliary view. The student must know the various standard drafting practices associated with auxiliary views.

CHAPTER SIX Auxiliary Views

Auxiliary Views Defined

Many objects have inclined surfaces that are not always parallel to the regular planes of projection. For example, in Figure 6-1, the front view is correct as shown, but the top and right-side views do *not* correctly represent the inclined surface. To truly represent the inclined surface and to show its true shape, an auxiliary view must be drawn. An *auxiliary view* has a line of sight that is perpendicular to the inclined surface, as viewed looking directly at the inclined surface. Auxiliary views are always projected 90° from the inclined surface.

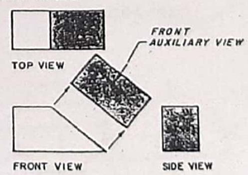


Figure 6-1 Front view auxiliary view

An auxiliary view serves three purposes:

- It illustrates the true size of a surface.
- It illustrates the true shape of a surface, including all true angles and/or arcs.
- It is used to project and complete other views.

An auxiliary view can be constructed from any of the regular views. An auxiliary view projected from the front view would appear as it does in Figure 6-1. This is referred to as a *front view auxiliary*. An auxiliary view projected from the top view would appear as it does in Figure 6-2. This is referred to as a *top view*

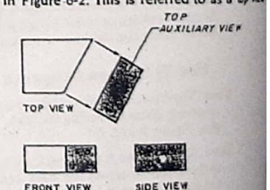


Figure 6-2 Top view auxiliary view

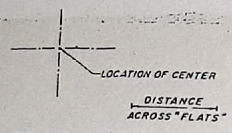


Figure 3-36A How to draw a hexagon

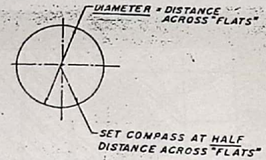


Figure 3-36B Step 1

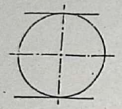


Figure 3-36C Step 2

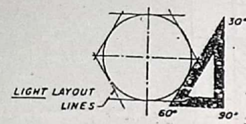


Figure 3-36D Step 3

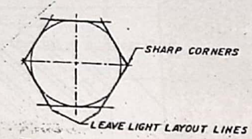


Figure 3-36E Step 4

How To Draw a Hexagon (6 Sides)

Given: The location of the required center and the required distance across the "flats" of a hexagon. Figure 3-36A.

Step 1. Lightly draw a circle with a diameter equal to the distance across the "flats" of the hexagon. Set the compass at half the required diameter. Figure 3-36B.

Step 2. Draw two horizontal lines tangent to the curve, or two vertical lines if the hexagon is to be oriented at 90° to the illustrated position. Figure 3-36C.

Step 3. Using a 30°-60° triangle, lightly complete the hexagon by constructing tangent lines to the circle. Figure 3-36D. Allow the light construction lines to extend as shown; do not erase them.

Step 4. Check to see that there are six equal sides and, if so, darken in the actual hexagon using correct line thickness and taking care to construct six sharp corners. Figure 3-36E. Again, do *not* erase the light construction lines.

How To Draw an Octagon (8 Sides)

Given: The location of the required center and the required distance across the "flats" of an octagon. Figure 3-37A.

Step 1. Lightly draw a circle with a diameter equal to the distance across the "flats" of the octagon. Set the compass at half the required diameter. Figure 3-37B.

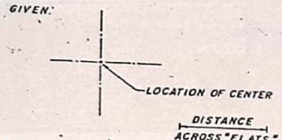


Figure 3-37A How to draw an octagon

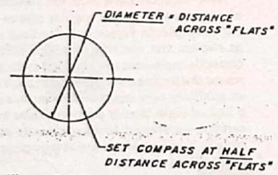


Figure 3-37B Step 1

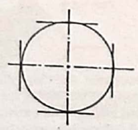


Figure 3-37C Step 2

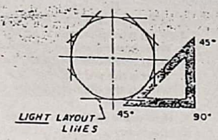


Figure 3-37D Step 3

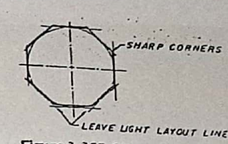


Figure 3-37E Step 4

Step 2. Lightly draw two horizontal lines and two vertical lines tangent to the circle, as illustrated in Figure 3-37C.

Step 3. Using a 45° triangle, lightly complete the octagon by constructing tangent lines to the circle. Figure 3-37D. Allow the light lines to extend.

Step 4. Check that there are eight equal sides and, if so, darken in the actual octagon using correct line thickness and taking care to construct eight sharp corners. Figure 3-37E. Again, do not erase the light construction lines.

Circular Construction

How To Locate the Center of a Given Circle

Given: A circle without a center point. Figure 3-38A.

Step 1. Using the drafting machine or T-square, draw a horizontal line across the circle approximately halfway between the *estimated* center of the given circle and the uppermost point on the circumference. Label the end points of the chord thus formed as A and B. Figure 3-38B.

Step 2. Draw perpendicular lines (90°) downward from points A and B. Locate points C and D where these two lines pass through the circle. Figure 3-38C.

Step 3. Carefully draw a straight line from point A to point D and from point C to point B. Where these lines cross is the exact center of the given circle. Place a compass point on the center point; adjust the lead to the edge of the circle and swing an arc to check that the center is accurate. Figure 3-38D.

Alternatively, the intersection of perpendicular bisectors of any two nonparallel chords serve to locate the center. This is a modification of the previous construction for passing a circle through any three nonaligned points.

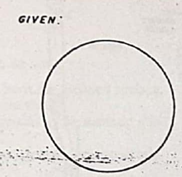


Figure 3-38A How to locate the center of a given circle

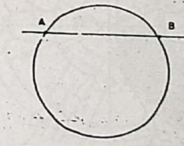


Figure 3-38B Step 1

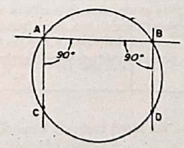


Figure 3-38C Step 2

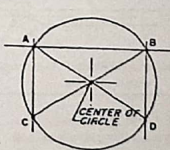
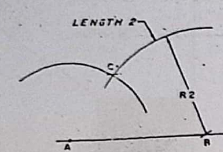


Figure 3-38D Step 3

Figure 3-32C
Step 2



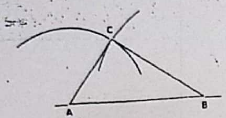


Figure 3-32D
Step 3

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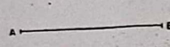


Figure 3-33A How to draw an equilateral triangle

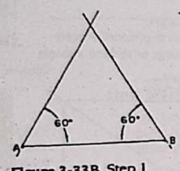


Figure 3-33B Step 1

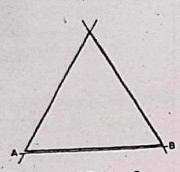


Figure 3-33C Step 2

Step 3. Connect A to C and B to C to complete the triangle. Figure 3-32D.

How To Draw an Equilateral Triangle

Given: A baseline and the given length of each side. Figure 3-33A.

Step 1. Either adjust the drafting machine angle to 60° or use a 30°-60° triangle and project from points A and B at 60° using light lines. Figure 3-33B. Allow light construction lines to cross as shown: do not erase them.

Step 2. Check to see that there are three equal sides and, if so, darken in the actual triangle using correct line thickness. Figure 3-33C. Care should be exercised in constructing the sharp corners. Again, do *not* erase the light construction lines.

How To Draw a Square

Given: The location of the center and the required distance across the "flats" of a square. Figure 3-34A.

Step 1. Lightly draw a circle with a diameter equal to the distance across the "flats" of the square. Set the compass at half the required diameter. Figure 3-34B.

Step 2. Using a triangle, lightly complete the square by constructing tangent lines to the circle. Allow the light construction lines to project from the square, as shown, without erasing them. Figure 3-34C.

Step 3. Check to see that there are four equal sides and, if so, darken in the actual square using the correct line thickness. Figure 3-34D. Care should be exercised in constructing the sharp corners. Again, do *not* erase the light construction lines.

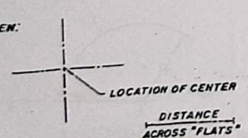


Figure 3-34A How to draw a square

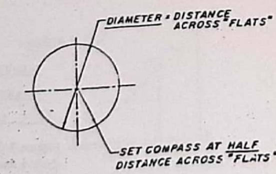
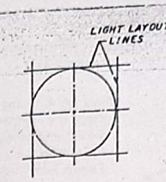


Figure 3-34B Step 1

Figure 3-34C Step 2



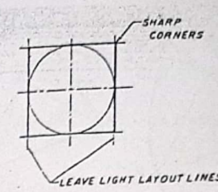


Figure 3-34D
Step 3

How To Draw a Pentagon (5 Sides)

Given: The location of the pentagon center, and the diameter that will circumscribe the pentagon. Figure 3-35A.

Step 1. Locate point A at the top-center of the circle and, using a drafting machine, position an angle of 72° (360/5) from the horizontal (or 18° from the vertical) through point A to locate point B where the angle crosses the circumference of the circle. Figure 3-35B.

Step 2. Draw a horizontal line from point B to locate point C on the circumference of the circle on the opposite side. Figure 3-35C.

Step 3. Set the compass at the distance from point B to point C, and swing this distance from the points as illustrated in Figure 3-35D to locate points X and Y.

Step 4. Lightly connect the points. Check to see that there are five equal sides and, if correct, darken in the actual pentagon taking care to construct five sharp corners. Figure 3-35E.

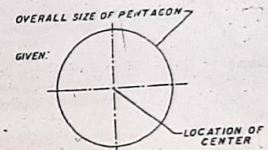
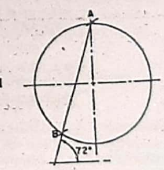


Figure 3-35A How to draw a pentagon

Figure 3-35B Step 1



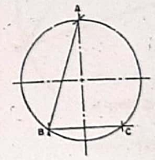


Figure 3-35C Step 2

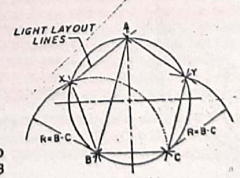


Figure 3-35D
Step 3

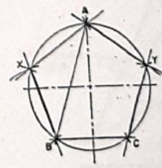


Figure 3-35E
Step 4

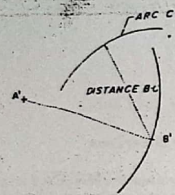


Figure 3-29D Step 3

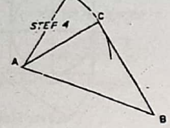


Figure 3-29E Step 4

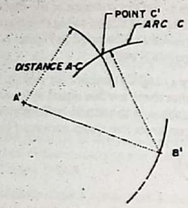


Figure 3-29F Step 5

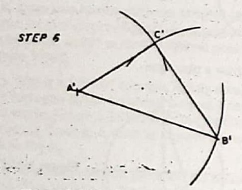


Figure 3-29G Step 6

Step 3. Transfer this distance, B-C, to the layout, Figure 3-29D.

Steps 4 and 5. Going back to the original object, place the compass point at letter A, Figure 3-29E, and extend the compass lead to letter C. Transfer the distance A-C as illustrated in Figure 3-29F. Locate and letter each point.

Step 6. Connect points A', B', and C' with light, straight lines. This completes the transfer of the object, Figure 3-29G. Recheck all work and, if correct, darken lines to the correct line weight.

How To Transfer Complex Shapes

A complex shape can be transferred in exactly the same way by reducing the shape into simple triangles and transferring each triangle using the foregoing method.

Given: An odd shape, A, B, C, D, E, F, G, Figure 3-30A. Letter or number the various corners and point locations of the odd shape in clockwise order around the perimeter, Figure 3-30A. Use the longest line or any convenient line as a starting point. Line A-B is chosen here as the example.

Step 1. Lightly divide the shape into triangle divisions, using the baseline if possible. Transfer each triangle in the manner described in Figures 3-29A through 3-29G. Suggested triangles to be used in example Figure 3-30A are ABC, ABD, ABE, ABF, and ABG, Figure 3-30B.

Step 2. This completes the transfer. Check all work and, if correct, darken in lines to correct line thickness. See Figure 3-30C.

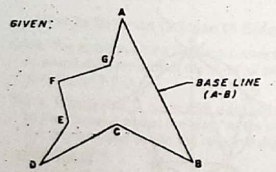


Figure 3-30A How to transfer complex shapes

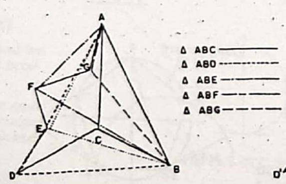


Figure 3-30B Step 1

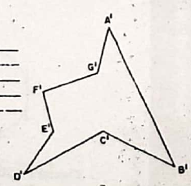


Figure 3-30C Step 2

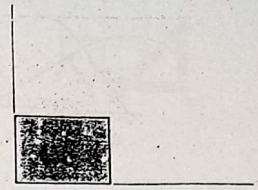


Figure 3-31A How to proportionately enlarge or reduce a shape

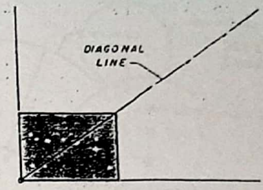


Figure 3-31B Step 1

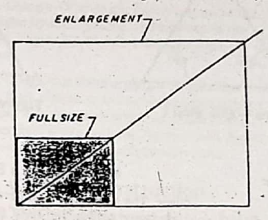


Figure 3-31C Step 2

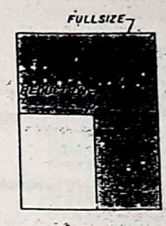


Figure 3-31D Step 1

How To Proportionately Enlarge or Reduce a Shape

Given: A rectangle, Figure 3-31A. *Problem:* To enlarge or reduce its size proportionately.

Step 1. Draw a line from corner to corner diagonally, and extend it as shown in Figure 3-31B.

Step 2. The rectangle is enlarged to any size proportionately if the vertical and horizontal sides are located from the extended diagonal line, Figure 3-31C.

Step 1. The rectangle is reduced proportionately if the vertical and horizontal lines are located on the unextended diagonal line, Figure 3-31D.

Polygon Construction

How To Draw a Triangle with Known Lengths of Sides

Given: Lengths 1, 2, and 3, Figure 3-32A.

Step 1. Draw the longest length line, in this example length 3, with endpoints A and B, Figure 3-32B. Swing an arc (R1) from point A whose radius is either length 1 or length 2; in this example, length 1.

Step 2. Using the radius length *not* used in Step 1, swing an arc (R2) from point B to intercept the arc swung from point A at point C, Figure 3-32C.

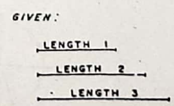


Figure 3-32A How to draw a triangle with known lengths of sides

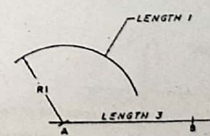


Figure 3-32B Step 1

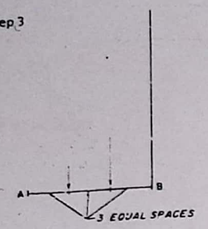


Figure 3-26D Step 3

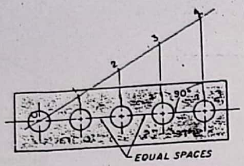


Figure 3-26E An example of equal spacing within a given length

Step 2. Place a scale with its zero at point A of the given line. If three equal parts are required, pivot the scale until the three-inch measurement (or any length representing three equal units of measure: 30, 60 and 90 mm, for example) is on the perpendicular line drawn in Step 1. Place a short dash at these points. The example in Figure 3-26C shows these dashes at the 1-inch and 2-inch marks.

Step 3. Project lines downward from these points and add short hash marks where these projected lines cross the original given line A-B. This divides the line A-B into three exact equal parts. Check all work, comparing your final step with Figure 3-26D. An example of equal spacing, where equally spaced holes are required within a given length, is illustrated in Figure 3-26E.

How To Divide a Line into Proportional Parts

Given: Line A-B, Figure 3-27A. *Problem:* Locate point X at 2/3 of the distance from point A to point B.

Step 1. Draw a line 90° from either end of the line. A 90° line from point B is illustrated in Figure 3-27B.

Step 2. Place a scale with its zero on point A of the given line. Because a 2/3 proportion is required, pivot the scale until any multiple of three units of measure intersects the perpendicular line drawn in Step 1. In this example, 6 is used, representing three 2-unit increments. The 2/3 position of this length is two 2-unit increments, or the 4 position, where a hash mark is made, as shown in Figure 3-27C. Projecting this point downward to line A-B, it becomes point X, which is 2/3 the overall distance from point A.

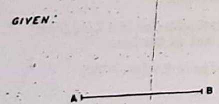


Figure 3-27A How to divide a line into proportional parts

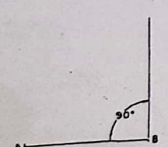


Figure 3-27B Step 1

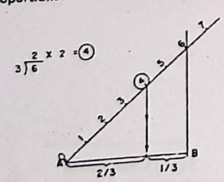


Figure 3-27C Step 2

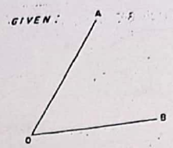


Figure 3-28A How to transfer an angle

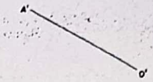


Figure 3-28B Given: Point O'

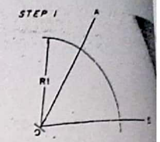


Figure 3-28C Step 1

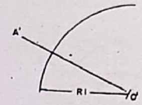


Figure 3-28D Transferred angle

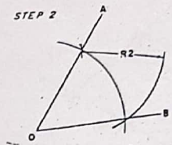


Figure 3-28E Step 2

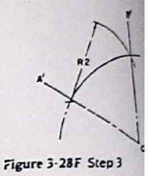


Figure 3-28F Step 3

How To Transfer an Angle

Given: An angle formed by two straight lines, OA-OB, Figure 3-28A, and one location of where the transferred angle begins (point O'), Figure 3-28B.

Step 1. Refer to Figure 3-28C. Draw an arc through both legs of a given angle (R1) and then duplicate this radius at the transferred angle location, Figure 3-28D.

Step 2. Transfer the chord length between the two angle legs at the intersection of the arc (R2) to the arc at the transfer angle location.

Step 3. A line from the arc center to the intersection of arc and chord length forms the second line, forming an angle equal to the original, Figures 3-28E and 3-28F.

How To Transfer an Odd Shape

Given: Triangle ABC, Figure 3-29A.

Step 1. Letter or number the various corners and point locations of the odd shape in counterclockwise order around its perimeter. In this example, place the compass point at point A of the original shape and extend the lead to point B. Refer back to Figure 3-29A. Swing a light arc at the new desired location, Figure 3-29B. Letter the center point as A' and add letter B' at any convenient location on the arc. It is a good habit to lightly letter each point as you proceed.

Step 2. Place the compass point at letter B of the original shape, Figure 3-29C, and extend the compass lead to letter C of the original shape.

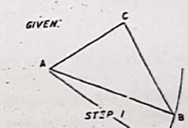


Figure 3-29A How to transfer an odd shape

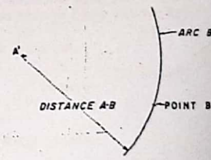


Figure 3-29B Step 1

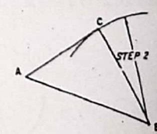


Figure 3-29C Step 2

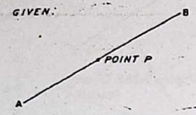


Figure 3-23A
How to draw a perpendicular to a line at a point (method 1)

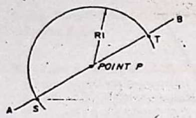


Figure 3-23B
Step 1

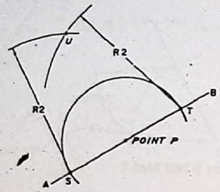


Figure 3-23C
Step 2

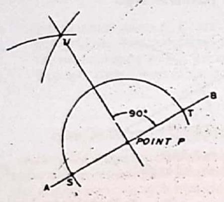


Figure 3-23D
Step 3

How To Draw a Perpendicular to a Line at a Point (Method 1)

Given: Line A-B with point P on the same line. Figure 3-23A.

Step 1. Using P as the center, make two arcs of equal radius or one continuous arc (R1) to intercept line A-B on either side of point P, at points S and T. Figure 3-23B.

Step 2. Swing larger but equal arcs (R2) from each of points S and T to cross each other at point U. Figure 3-23C.

Step 3. A line from U to P is perpendicular to line A-B at point P. Figure 3-23D.

How To Draw a Perpendicular to a Line at a Point (Method 2)

Given: Line A-B with point P on the line. Figure 3-24A.

Step 1. Swing an arc of any convenient radius whose center O is at any convenient location NOT on line A-B, but positioned to make the arc cross line A-B at points P and Q. Figure 3-24B.

Step 2. A line from point Q through center O intercepts the opposite side of the arc at point R. Figure 3-24C.

Step 3. Line R-P is perpendicular to line A-B. (A right triangle has been inscribed in a semicircle.) See Figure 3-24D.

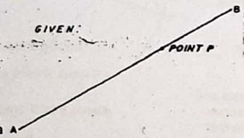


Figure 3-24A
How to draw a perpendicular to a line at a point (method 2)

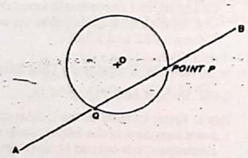


Figure 3-24B
Step 1

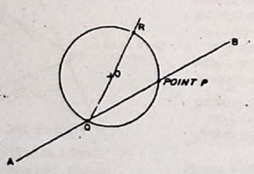


Figure 3-24C
Step 2

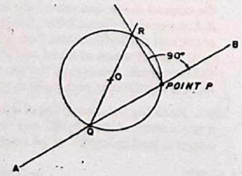


Figure 3-24D
Step 3

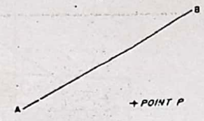


Figure 3-25A How to draw a perpendicular to a line from a point not on the line

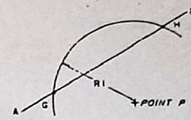


Figure 3-25B Step 1

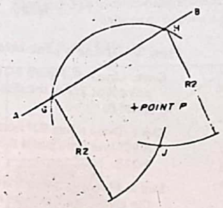


Figure 3-25C Step 2

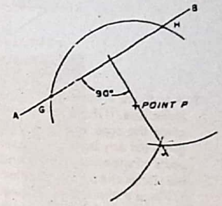


Figure 3-25D Step 3

How To Draw a Perpendicular to a Line from a Point Not on the Line

Given: Line A-B and point P. Figure 3-25A.

Step 1. Using P as a center, swing an arc (R1) to intercept line A-B at points G and H. Figure 3-25B.

Step 2. Swing larger, but equal length arcs (R2) from each of the points G and H to intercept each other at point J. Figure 3-25C.

Step 3. Line P-J is perpendicular to line A-B. Figure 3-25D.

How To Divide a Line into Equal Parts

Given: Line A-B. Figure 3-26A.

Step 1. Draw a line 90° from either end of the given line. A 90° line from point B is illustratec in Figure 3-26B, but either end or either direction will work as well.

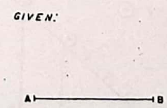


Figure 3-26A How to divide a line into equal parts

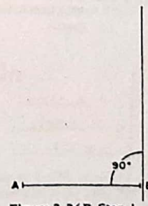


Figure 3-26B Step 1

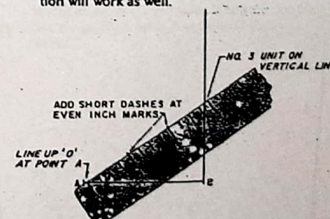


Figure 3-26C Step 2

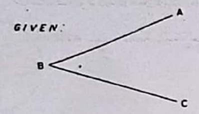


Figure 3-19A How to bisect an angle

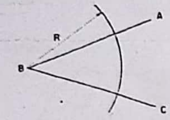


Figure 3-19B Step 1

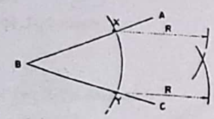


Figure 3-19C Step 2

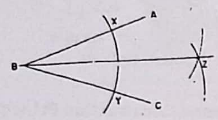


Figure 3-19D Step 3

How To Bisect an Angle

To *bisect* an angle means to divide it in half or to cut it into two equal angles.

Given: Angle ABC, Figure 3-19A.

Step 1. Set the compass at any convenient radius and swing an arc from point B, Figure 3-19B.

Step 2. Locate points X and Y on the legs of the angle, and swing two arcs of the same identical length from points X and Y, respectively. Figure 3-19C.

Step 3. Where these arcs intersect, locate point Z. Draw a straight line from B to Z. This line will bisect angle ABC and establish two equal angles: ABZ and ZBC, Figure 3-19D.

How To Draw an Arc or Circle (Radius) through Three Given Points

Given: Three points in space at random: A, B, and C, Figure 3-20A.

Step 1. With straight lines, lightly connect points A to B, and B to C, Figure 3-20B.

Step 2. Using the method outlined for bisecting a line, bisect lines A-B and B-C, Figure 3-20C.

Step 3. Locate point X where the two extended bisectors meet. Point X is the exact center of the arc or circle, Figure 3-20D.

Step 4. Place the point of the compass on point X and adjust the lead to any of the points A, B, or C (they are the same distance), and swing the circle. If all work is done correctly, the arc or circle should pass through each point, as shown in Figure 3-20E.

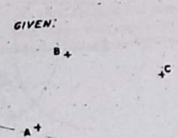


Figure 3-20A How to draw an arc or circle (radius) through three given points

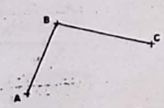


Figure 3-20B Step 1

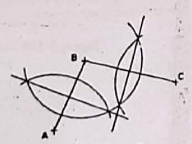


Figure 3-20C Step 2

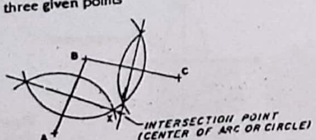


Figure 3-20D Step 3

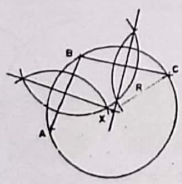


Figure 3-20E Step 4

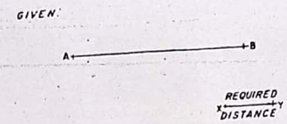


Figure 3-21A How to draw a line parallel to a straight line at a given distance

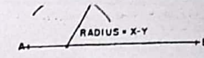


Figure 3-21B Step 1

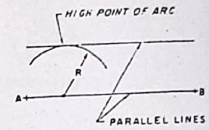


Figure 3-21C Step 2

How To Draw a Line Parallel to a Straight Line at a Given Distance

Given: Line A-B, and a required distance to the parallel line, Figure 3-21A.

Step 1. Set the compass at the required distance to the parallel line. Place the point of the compass at any location on the given line, and swing a light arc whose radius is the required distance, Figure 3-21B.

Step 2. Adjust the straightedge of either a drafting machine or an adjustable triangle so that it lines up with line A-B, slide the straightedge up or down to the extreme high point of the arc, then draw the parallel line, Figure 3-21C.

Note: The distance between parallel lines is measured on any line that is perpendicular to both.

How To Draw a Line Parallel to a Curved Line at a Given Distance

Given: Curved line A-B, and a required distance to the parallel line, Figure 3-22A.

Step 1. Set the compass at the required distance to the parallel line. Starting from either end of the curved line, place the point of the compass on the given line, and swing a series of light arcs along the given line, Figure 3-22B.

Step 2. Using an irregular curve, draw a line along the extreme high points of the arcs, Figure 3-22C.

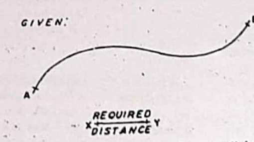


Figure 3-22A How to draw a line parallel to a curved line at a given distance

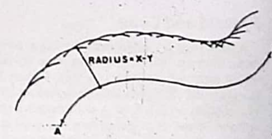


Figure 3-22B Step 1

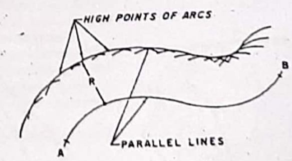


Figure 3-22C Step 2

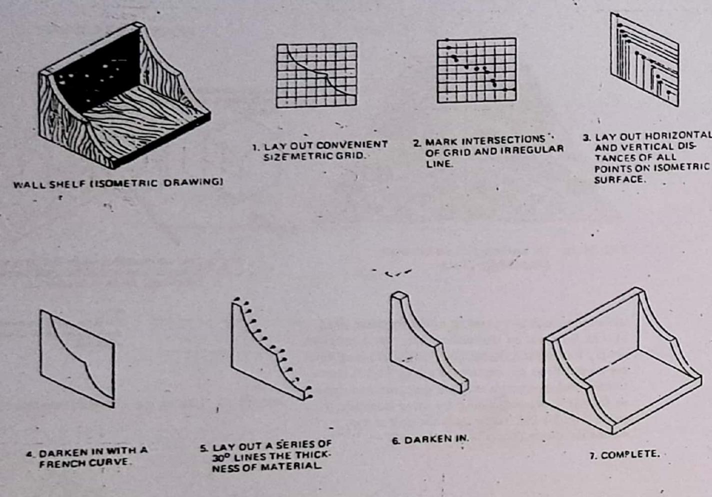


FIG. 11-21 Drawing isometric irregular curves

ISOMETRIC IRREGULAR CURVES

To draw an irregular curve on an isometric drawing, plot the points of the curve on the orthographic view, and then transfer them to the isometric surface. The irregular curve is plotted from points measured on the isometric lines (Fig. 11-21). The more points plotted, the truer the curve. The points are connected by sketching them lightly and darkening them with a French curve.

ISOMETRIC DRAWING POSITIONS

An isometric drawing may be placed so that the object can be viewed in different positions (Fig. 11-22). The axes will never change their angles, only their position, and will always remain at 120 degree included angles.

ISOMETRIC DIMENSIONS

There are two methods of dimensioning an isometric drawing, the aligned isometric dimensioning system (Fig. 11-23) and the unidirectional isometric dimensioning system (Fig. 11-24). Note that the dimension lines are always parallel to the edge they are dimensioning.

Care must be taken to draw arrowheads within an isometric frame (Fig. 11-25). Isometric arrowheads can be drawn freehand with practice. The back of isometric arrowheads should be parallel to the edge of the isometric object.

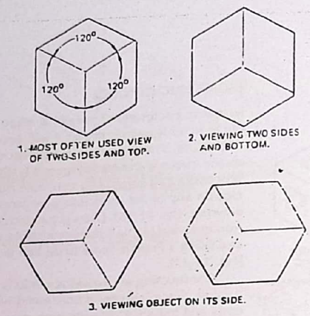


FIG. 11-22 Different views of an isometric object

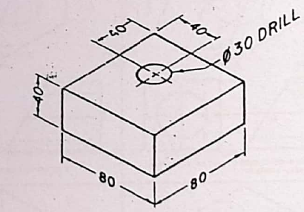


FIG. 11-23 Aligned isometric dimensions

ISOMETRIC HIDDEN LINES

Hidden lines are not used in pictorial drawings unless they are necessary to identify part of the object that cannot be seen (Fig. 11-26).

REVIEW OF ISOMETRIC DRAWING PROCEDURE

The normal procedure for making an isometric drawing is shown in Figure 11-27. Following these steps will ensure fast and accurate isometric drawings. (Nonisometric arrowheads are acceptable on isometric dimensions.)

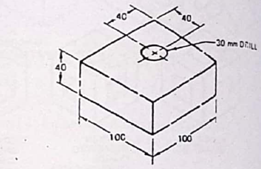


FIG. 11-24 Unidirectional isometric dimensions

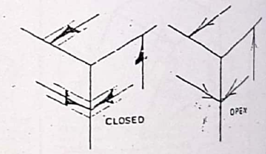


FIG. 11-25 Isometric arrowheads

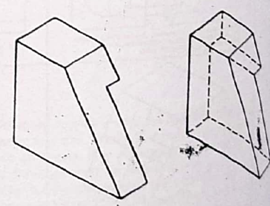


FIG. 11-26 Isometric hidden lines

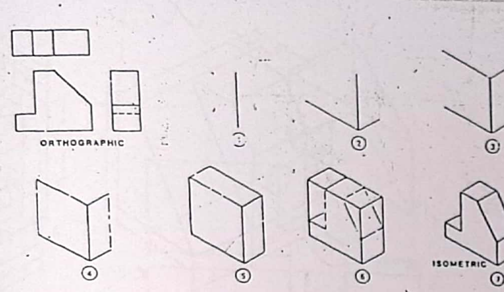


FIG. 11-27 Basic drawing steps for an isometric drawing

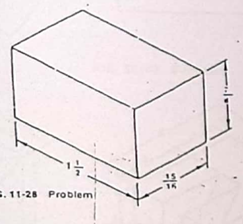


FIG. 11-28 Problem

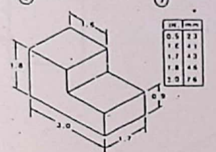


FIG. 11-29 Draw the isometric, cabinet, and cavalier with millimetre units of measure

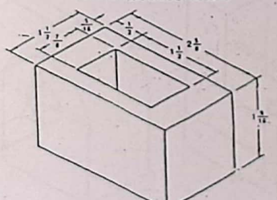


FIG. 11-30 Problem

PROBLEMS

Follow the instructions given for each problem. Check with your instructor as to dimensioning, additions, or deletions to the instructions. For additional problems, see the problems in Chapter 12.

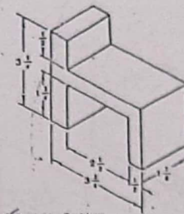


FIG. 11-31 Problem

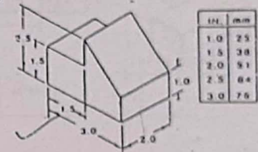


FIG. 11-32 Draw the isometric with the inch/decimal system
Draw the cabinet and cavalier with metric units

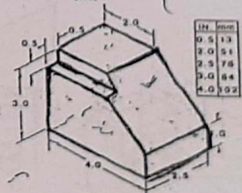


FIG. 11-33 Draw the isometric with the inch/decimal system
Draw the cabinet and cavalier with metric units

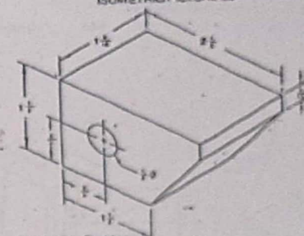


FIG. 11-34 Problem

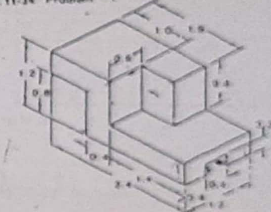


FIG. 11-35 Draw the isometric, cabinet, and cavalier

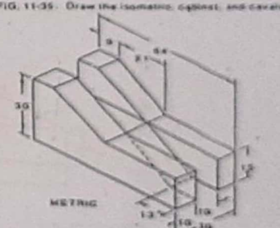


FIG. 11-36 Draw the isometric, cabinet, and cavalier

Scanned with CamScanner

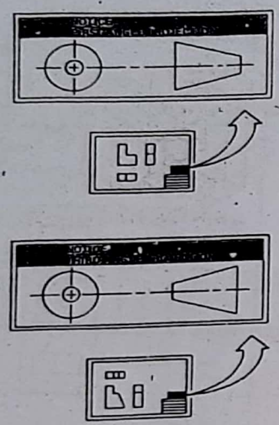


FIG. 12-13 Note block for projection angle

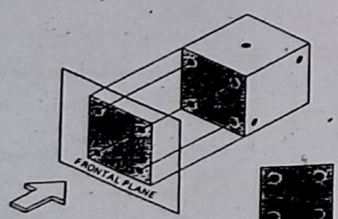


FIG. 12-14 Front view of a third-angle projection

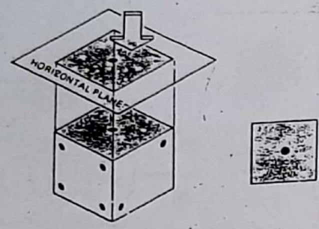


FIG. 12-15 Top view of a third-angle projection

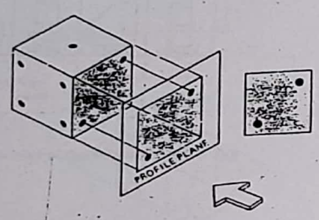


FIG. 12-16 Right side view of a third-angle projection

object, so that the line of sight is perpendicular to the frontal projection plane (Fig. 12-14). To visualize the top view, the observation should be a bird's-eye view perpendicular to the horizontal plane (Fig. 12-15). To visualize the right profile view, the observation should be from the right side (Fig. 12-16). All three views in third-angle projection are shown in Figure 12-17. The same process using first-angle projection is shown in Figure 12-18.

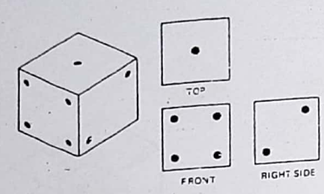


FIG. 12-17 Three-view orthographic with third-angle projection

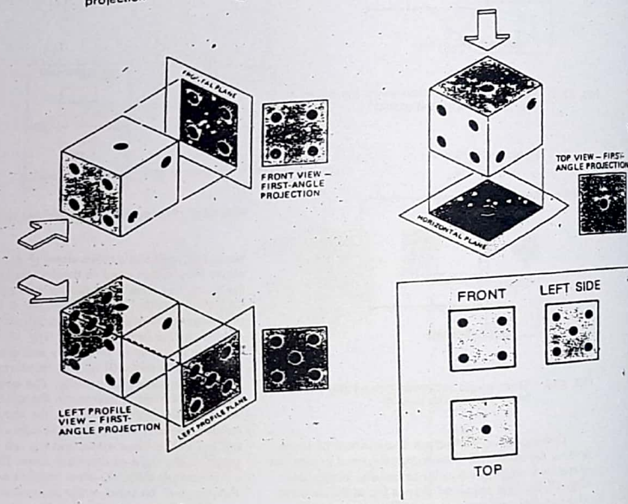


FIG. 12-18 Three-view orthographic with first-angle projection

INCREASING DRAWING SPEED

To reduce drawing time, the third view of an orthographic drawing can be projected as shown in Figure 12-19. The end view is developed by projecting lines from the top and front views. The process can be reversed by projecting from the front and profile views to develop the top view (Fig. 12-20).

LINE CONVENTION

Line conventions must be used correctly in working drawings so the fabricator will have no difficulty

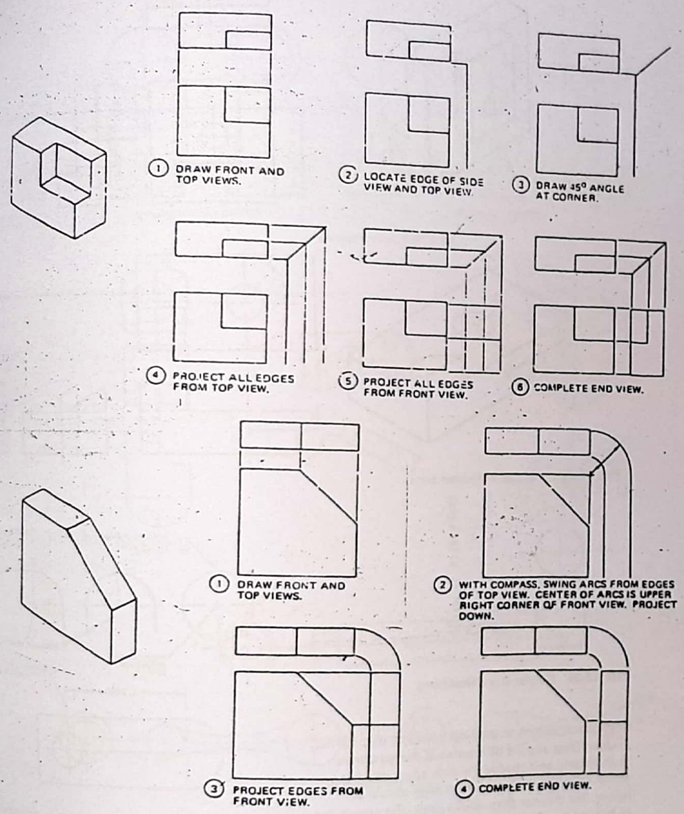


FIG. 12-19 Projecting lines for the end view

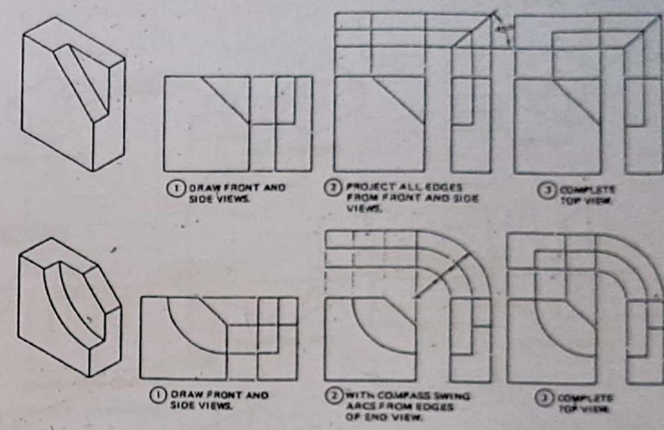


FIG. 12-20 Projecting lines for the top view

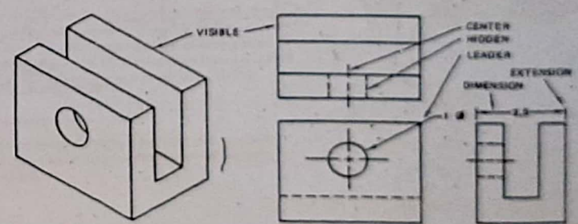


FIG. 12-21 Line conventions

reading the drawing (see Chapter 6). Figure 12-21 is an example of the language of lines used in an orthographic drawing. Carefully note the weight of the lines. It is important that the lines be of uniform thickness and dark enough to reproduce well.

Hidden Lines

Hidden lines are used to show parts of an object that are not visible. It is important for an orthographic drawing to have concise and neat hidden

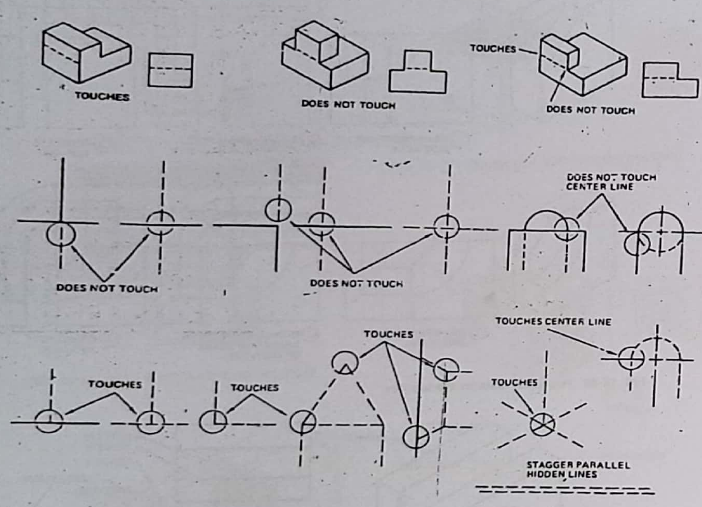


FIG. 12-22 Hidden line standards

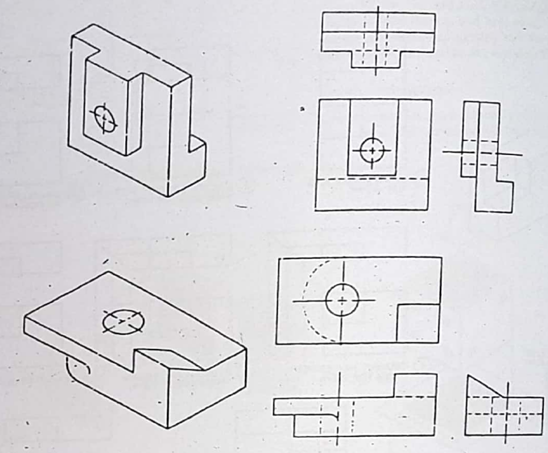


FIG. 12-23 The use of hidden lines

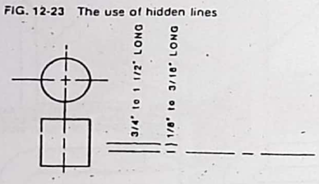


FIG. 12-24 Center line dimensions

lines that conform to drafting standards (Fig. 12-22). Hidden lines should be a series of dashes drawn ⅛ inch long and spaced 1/32 inch apart, or a near visual estimate of that. Hidden lines should be heavy, but thinner than object lines. The proper use of hidden lines is shown in Figure 12-23.

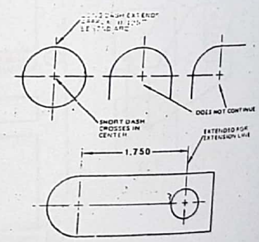


FIG. 12-25 The proper use of center lines

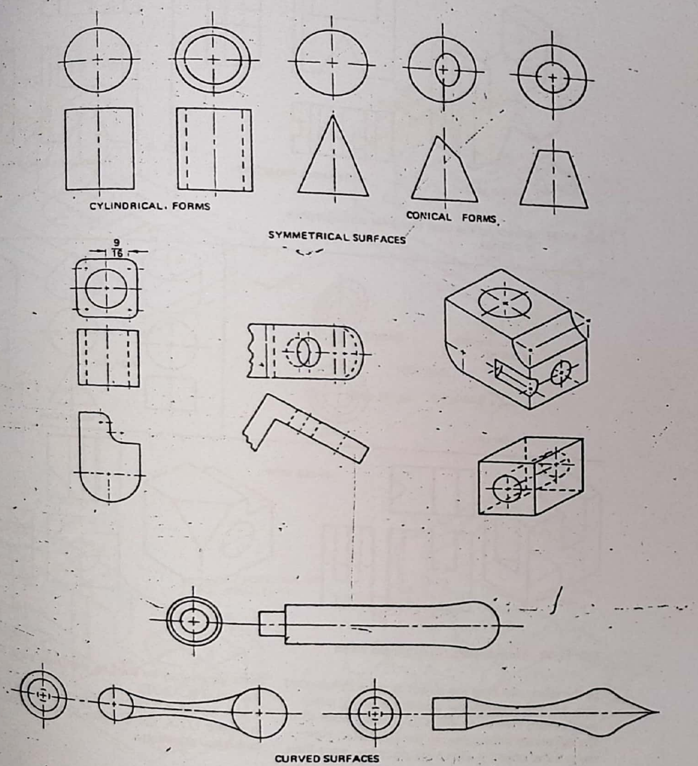


FIG. 12-26 Applications of center lines

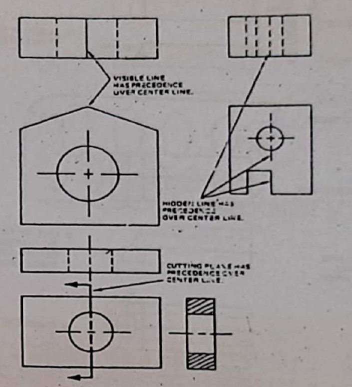


FIG. 12-27 Overlapping lines

Center Lines

Center lines locate the centers of symmetrical round objects. They are a series of thin long and short dashes (Fig. 12-24). The proper use of center lines is shown in Figure 12-25. Center lines may be used to show the centers of many forms (Fig. 12-26).

Overlapping Lines

The precedence of overlapping lines in any view follows the rule of showing the darker of the two (Fig. 12-27).

Ellipses

A circle that is not projected at a right angle will appear as an ellipse (Fig. 12-28). Methods of constructing an ellipse are shown in Figure 12-29. To save time, an ellipse template may be used as shown in Figure 12-30. Ellipse templates come in many sizes and angles.

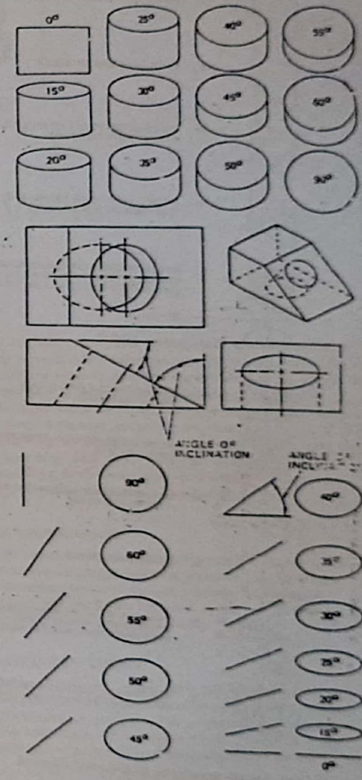


FIG. 12-28 Ellipses at various angles of inclination

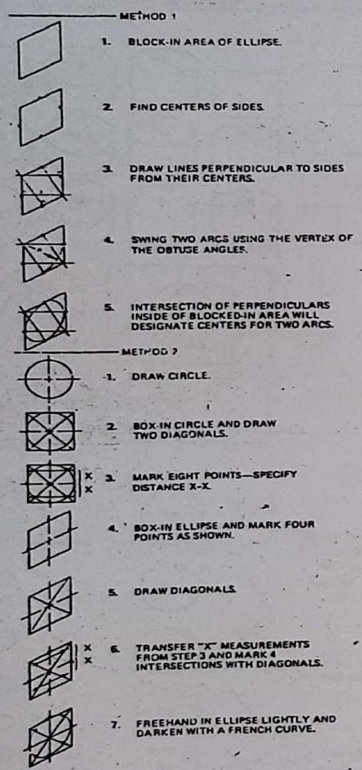


FIG. 12-29 Methods of drawing ellipses

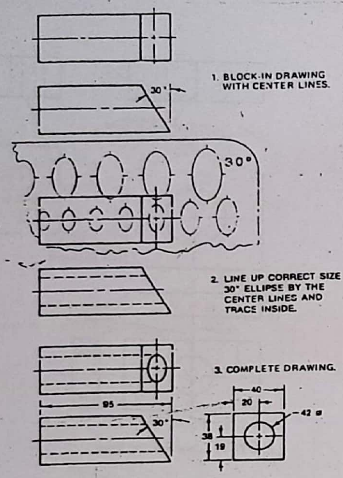


FIG. 12-30 Drawing ellipses with a template

VIEW SELECTION

The correct selection of views is important for a properly drawn multiview drawing. The general rule is to select that part of the object which shows its shape best as the front view, and then project other views of the multiview drawing (Fig. 12-31).

Because of the value of saving time in industry, it is important to not draw unnecessary views. Draw only those views necessary to communicate to the fabricator how the object is to be constructed (Fig. 12-32). A multiview working drawing rarely needs more than three views to communicate all of the necessary information to the fabricator. However, if the object is extremely complex, more than three views may be used to eliminate errors in production (Fig. 12-33).

A typical industrial multiview drawing is shown in Figure 12-34. See Chapter 30 for more detailed multiview drawings.

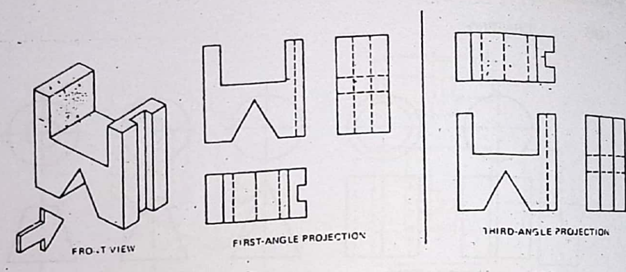


FIG. 12-31 Selecting the best views for orthographic drawings

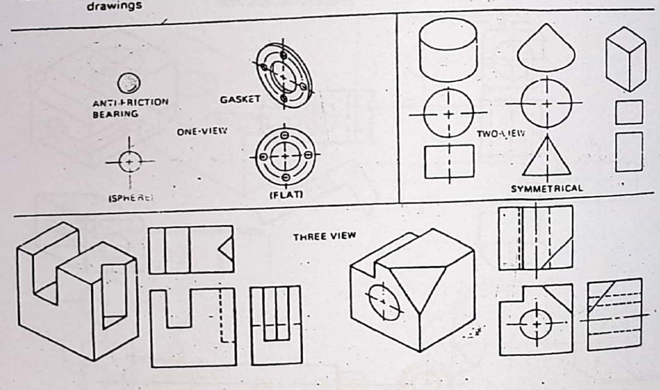


FIG. 12-32 Most objects require three views

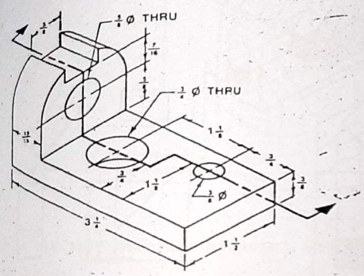


FIG. 17-78 Problem

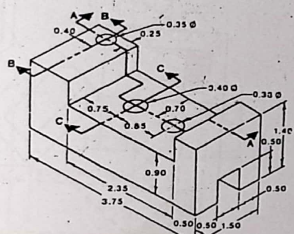


FIG. 17-80 Problem

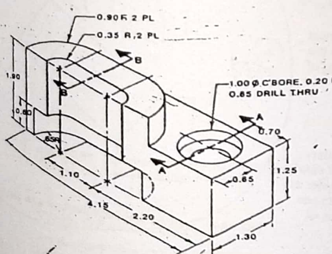


FIG. 17-79 Problem

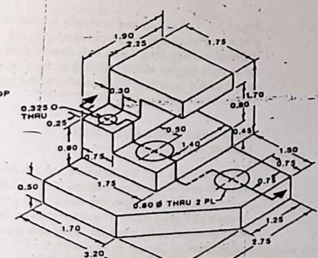
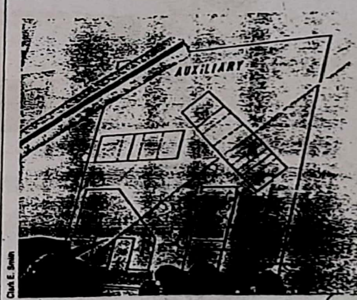


FIG. 17-81 Problem

18

Chapter

Auxiliary Views



INTRODUCTION

A drawing must clearly explain the true shape of an object. Each surface must be shown in a manner which communicates all the necessary information to the fabricator. The orthographic multiview drawing is most often used for this communication. An auxiliary view is another view that may be added to a primary orthographic multiview drawing (Fig. 18-2). Its purpose is to make the object graphically clearer, ensuring accurate and fast fabrication of the part. As you study this chapter, you should gain the knowledge and skills required to make auxiliary drawings, and understand the difference between primary and secondary auxiliaries.

ORTHOGRAPHIC

The regular views of an orthographic drawing will describe all perpendicular surfaces in true shape. However, none of the six primary orthographic views will show an inclined surface in its true shape (Fig. 18-3). (See Chapter 12.)

AUXILIARY VIEWS

An auxiliary is a projected view in addition to the six primary orthographic views (Fig. 18-4). All the principles of orthographic projection will apply to the projection of auxiliary views. The steps in applying the principles of projection are shown in

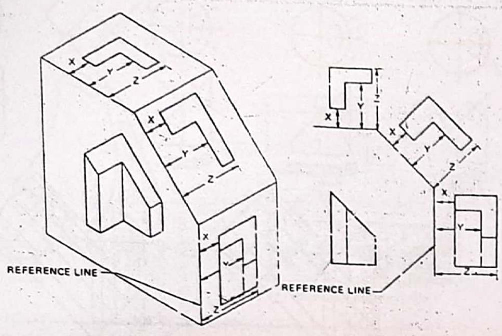


FIG. 18-9 Transferring measurements by reference lines

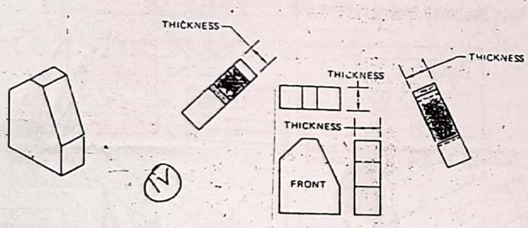


FIG. 18-10 Auxiliaries projected from the front view will show true thickness

TYPES OF AUXILIARIES

An auxiliary view can be taken from any primary orthographic view at any angle. An auxiliary taken off the front view will show the true thickness of the object (Fig. 18-10). An auxiliary taken off the top view will show the true height of the object (Fig. 18-11). An auxiliary taken off the side view will show the true length of the object (Fig. 18-12).

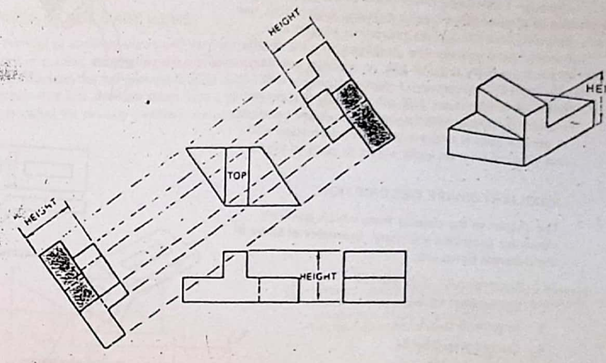


FIG. 18-11 Auxiliaries projected from the top view will show true height

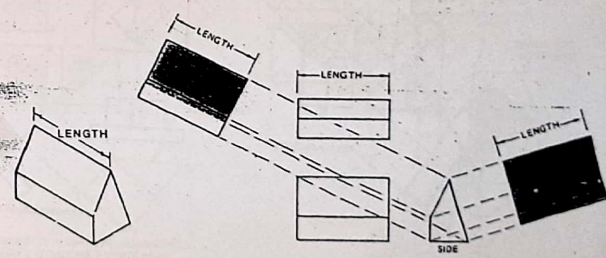


FIG. 18-12 Auxiliaries projected from the side view will show true length

FULL AND PARTIAL AUXILIARY

Although a complete description of the part being drawn is essential, an extra drawing which does not help this communication represents wasted time, material, and money. The draftsperson must decide if a full auxiliary (Fig. 18-13), or a partial auxiliary (Fig. 18-14) is necessary. A partial auxiliary will leave off hidden lines and other details that do not make a direct contribution to the auxiliary's surface. A general rule is to draw enough information without wasting time on extra views or parts of views.

AUXILIARY SHAPE DESCRIPTION

The shapes of the objects from which auxiliary views are projected will vary. Examples of some of the different forms are:

1. Perpendicular (Fig. 18-15)
2. Round (Fig. 18-16)
3. Angular (Fig. 18-17)
4. Curved (Fig. 18-18)

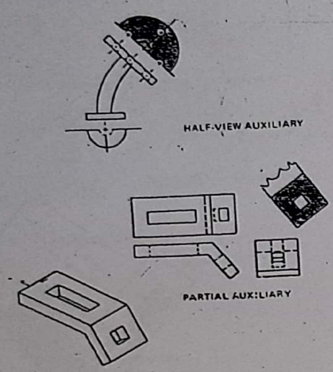


FIG. 18-14 Partial auxiliaries

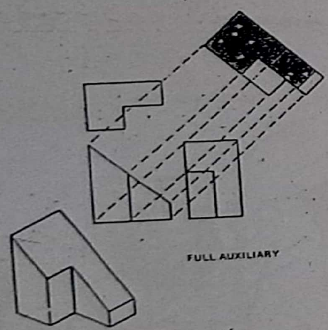


FIG. 18-13 A full auxiliary

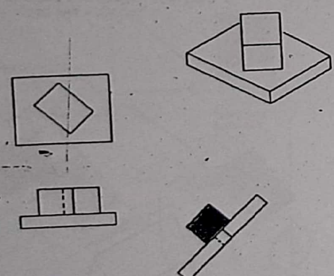


FIG. 18-15 Perpendicular surface auxiliary

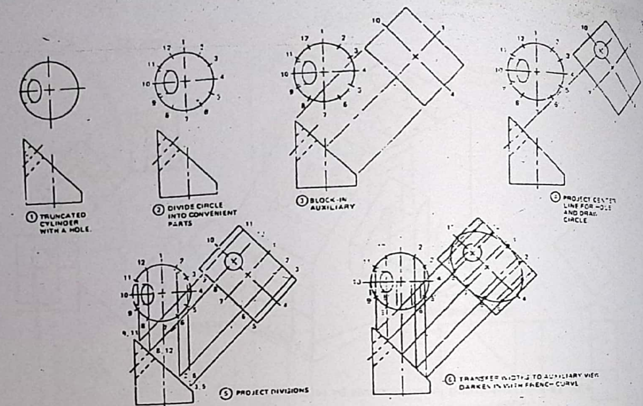


FIG. 18-16 Round auxiliary view

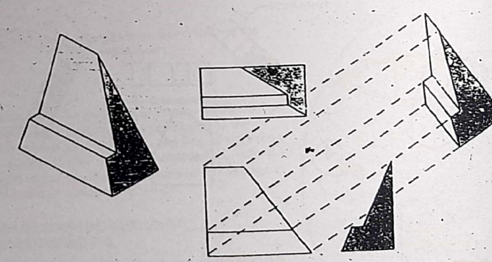


FIG. 18-17 Angular auxiliary view

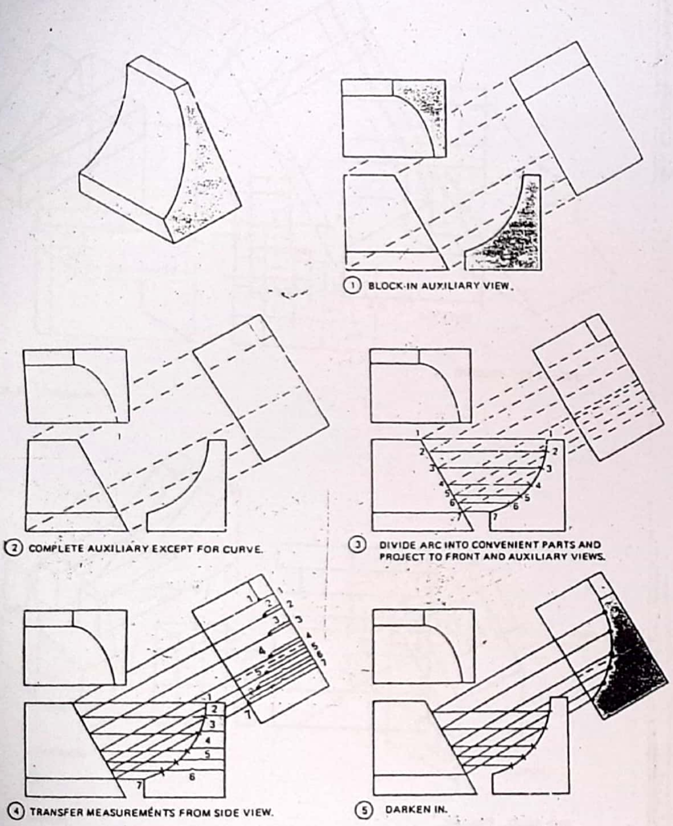


FIG. 18-18 Curved auxiliary view

NUMBER OF AUXILIARY VIEWS

The number of auxiliary views will vary with the amount of graphic information the draftsperson feels is necessary for full communication with the fabricator. The first auxiliary taken from a primary view is called the primary auxiliary. An auxiliary taken from a primary auxiliary is called a secondary auxiliary. A secondary auxiliary is sometimes necessary to obtain a true view of an oblique surface (Fig. 18-19). The reference line system of projection is used for the secondary auxiliary (see Chapter 19). If more are needed, successive auxiliaries can be drawn indefinitely (Fig. 18-20).

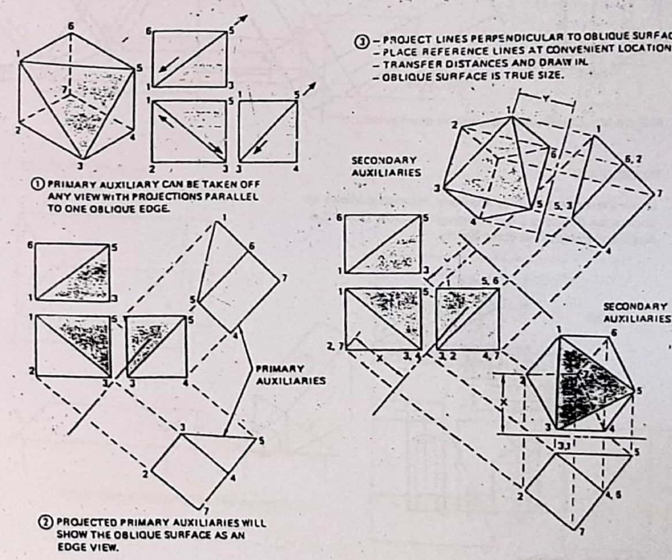


FIG. 18-19 Primary and secondary auxiliaries

- USE REFERENCE LINE FOR PROJECTION.
- AUXILIARIES CAN BE PROJECTED AT ANY POSITION.
- PROJECTION LINES ARE PERPENDICULAR TO REFERENCE LINE.
- SUCCESSIVE AUXILIARIES CAN BE CONTINUED INDEFINITELY.

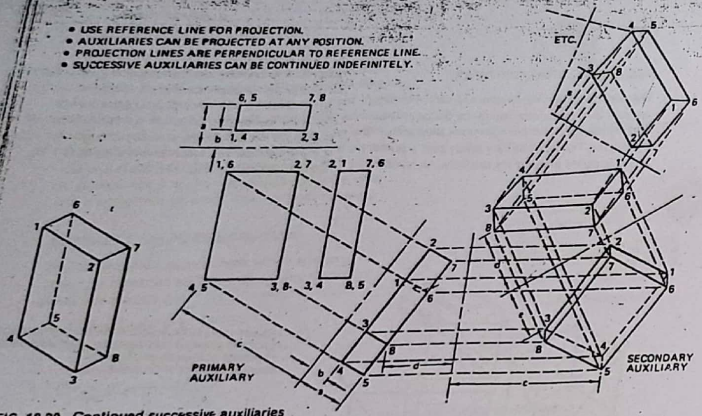


FIG. 18-20 Continued successive auxiliaries

PROBLEMS

Draw the orthographic, auxiliary, isometric views as shown for (Figures 18-21 through 18-30). Show the auxiliary projection lines lightly.

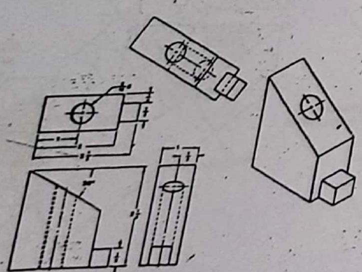


FIG. 18-21 Problem

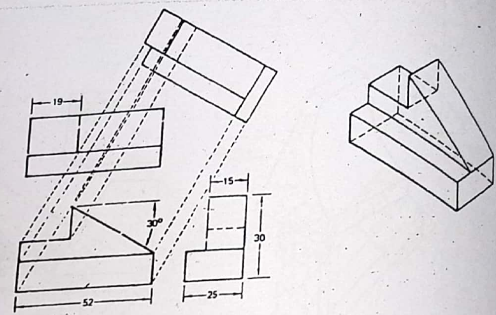


FIG. 18-22 Problem

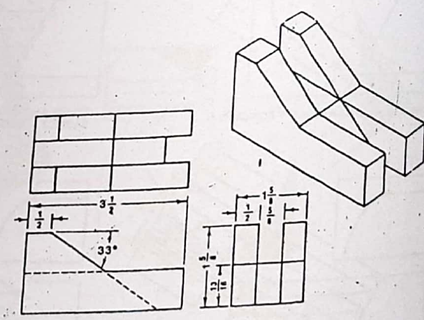


FIG. 18-23 Problem

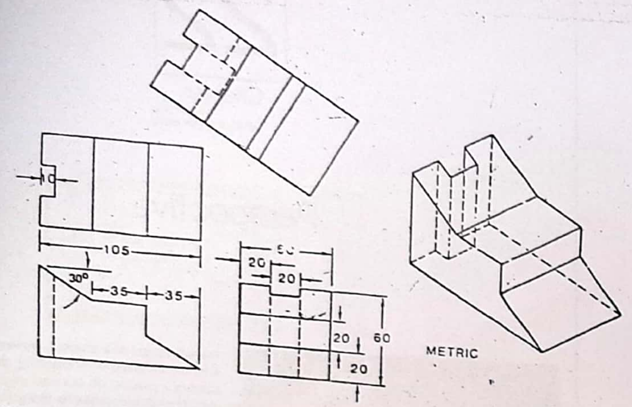


FIG. 18-24 Problem

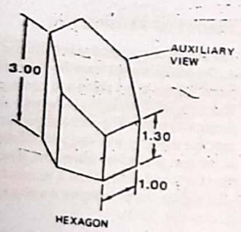


FIG. 18-25 Problem

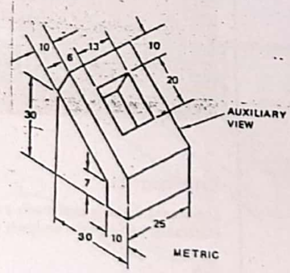


FIG. 18-2S Problem

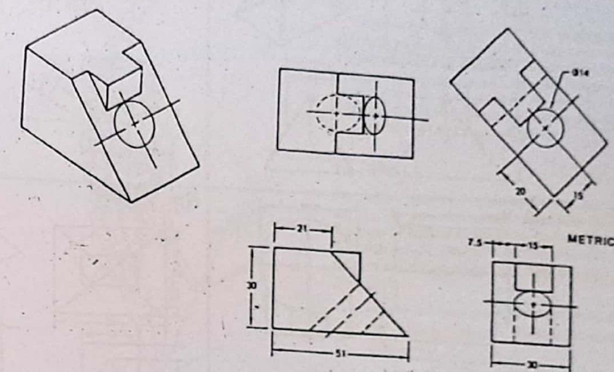


FIG. 18-27 Problem

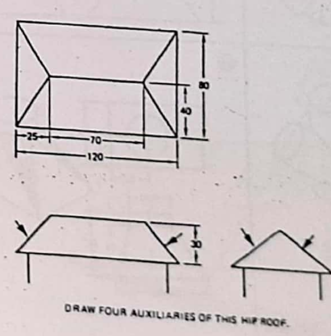


FIG. 18-28 Problem

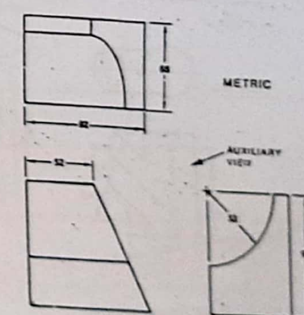


FIG. 18-29 Problem

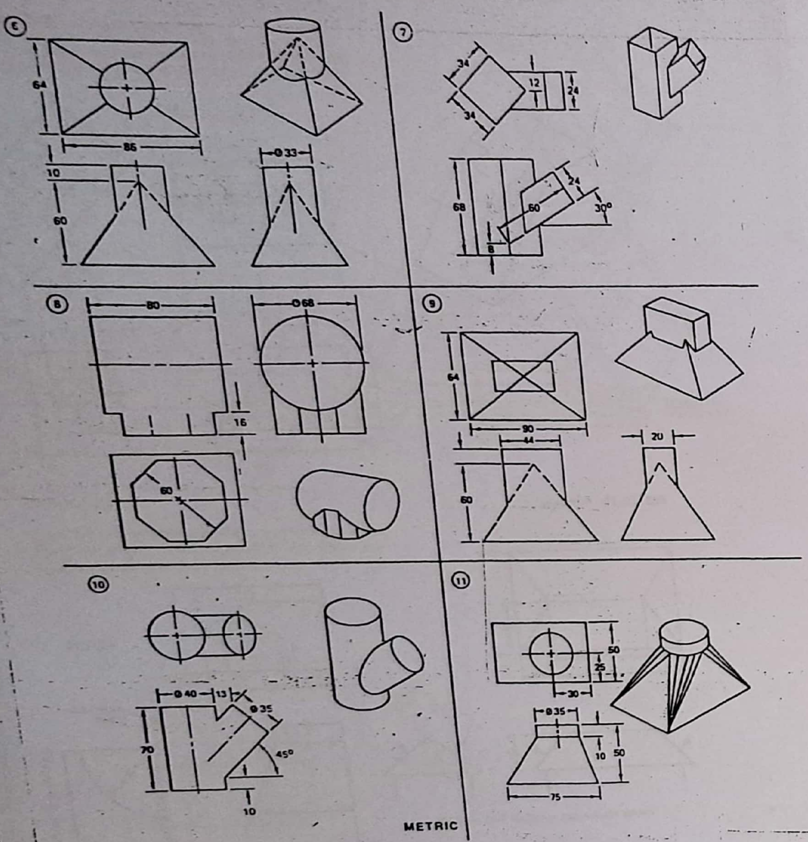


FIG. 21-44 Problems (Cont.)

22

Chapter

Perspective

INTRODUCTION

Engineering drawing is primarily a method of communication between the designers and the manufacturers of a product. However, the people who are involved with financing, development, and sales of a product do not read engineering drawings. It is advantageous for this group to have a drawing as lifelike as possible.

Perspective drawings (Fig. 22-2) help lay persons visualize the finished product. The perspective drawing is a two-dimensional representation of a three-dimensional object as it appears to the eye or as it would appear in a photograph (Fig. 22-3). As you study this chapter, you should learn to draw simple forms with one-point, two-point, and three-point types of perspective drawings.

THEORY OF PERSPECTIVE

The theory of perspective is illustrated in Figure 22-4. The projectors go from the object through the projection (picture) plane and converge at the eye. The perspective drawing is the view as seen on the projection plane. The size and position of the perspective drawing will vary with different positions of the eye, projection plane, and object. The size of the object will diminish as it recedes from the eye, which gives the perspective drawing its lifelike quality (Fig. 22-5).

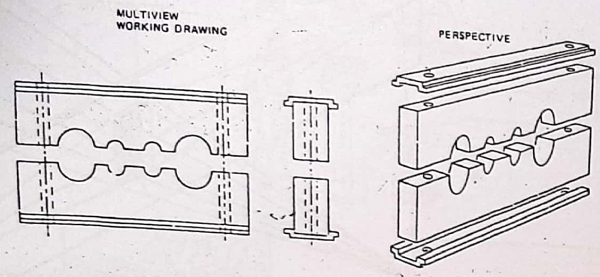


FIG. 22-2 Perspective drawing for visualization

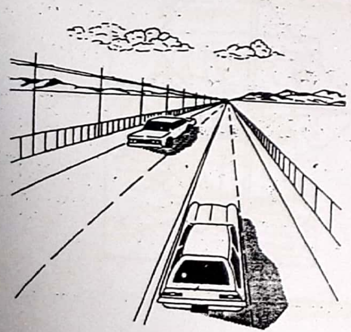


FIG. 22-3 Depth effect in perspective

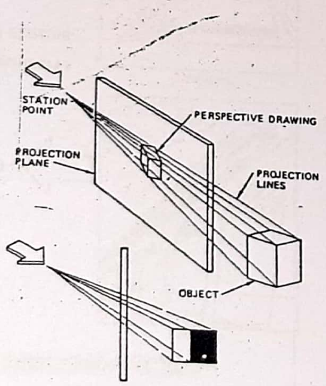


FIG. 22-4 Theory of perspective

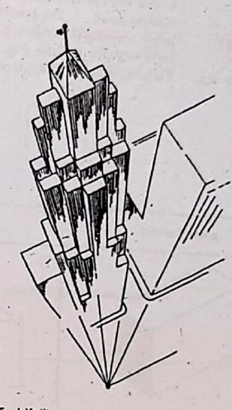


FIG. 22-5 Lifelike perspective

Perspective projection can be as exacting as descriptive geometry (Fig. 22-6). Exact sizes are not critical because the purpose of perspective drawing is to present lay people with a realistic image of an object, and the drawing will not be used in manufacturing. Using the rules of perspective drawing, an approximation of sizes will suffice.

PICTORIALS

Perspective drawing is pictorial drawing (see Chapter 11). The word "pictorial" comes from the word "picture." Pictorial drawings are "picture-like" drawings which show the object in one view. Pictorial drawings are placed into three groups (Fig. 22-7):

1. perspective (one-point, two-point, three-point)
2. axonometric (isometric, dimetric, trimetric)
3. oblique (cavalier, cabinet)

As the pictorials in Figure 22-7 show, the perspective drawing is more lifelike than axonometric

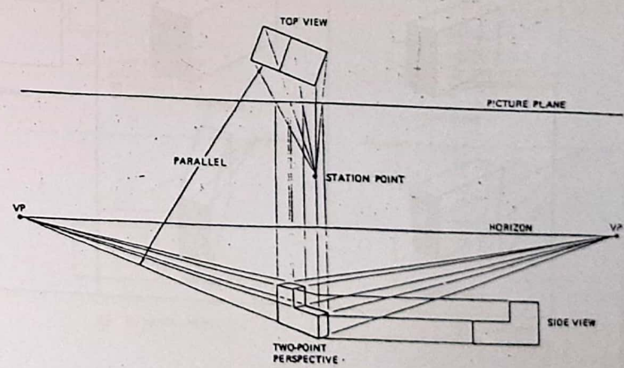


FIG. 22-6 Accuracy in perspective drawing using two-point perspective

and oblique drawings because the projectors are not parallel or perpendicular to the picture plane.

PERSPECTIVE TERMINOLOGY

A perspective drawing consists of the following parts (Fig. 22-8):

Horizon The line that separates the land (or sea) from the sky. The horizon is at the viewer's eye level.

Vanishing points The points on the horizon where lines of an object will converge.

Station point The position of the viewer's eye when viewing the object. The eye level is always level with the horizon (Fig. 22-9).

Picture plane The plane on which the

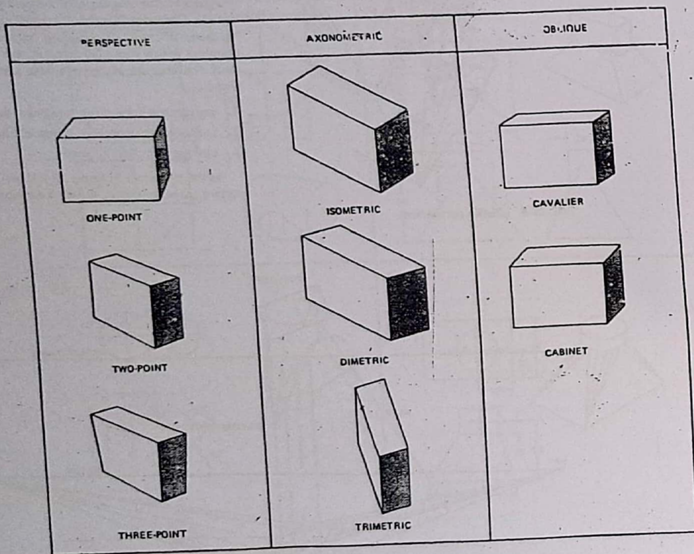


FIG. 22-7 Pictorial drawing types

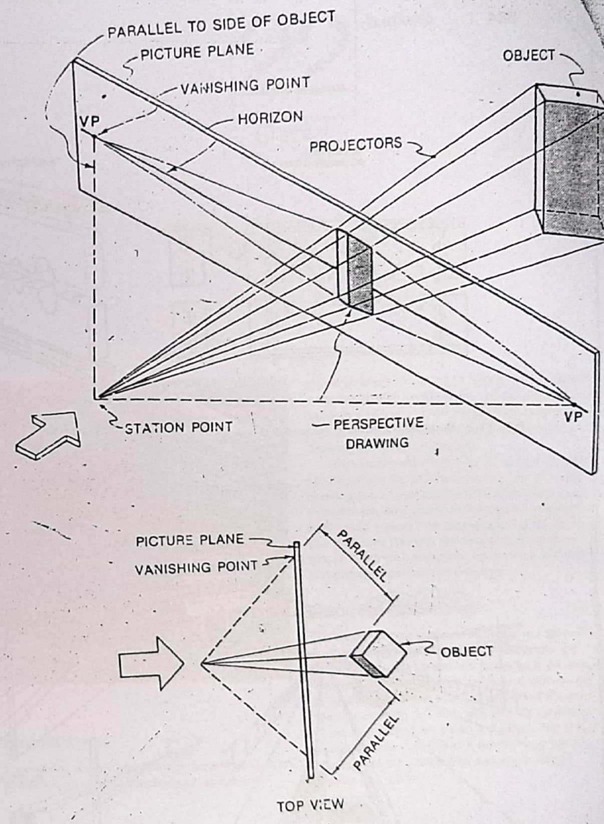


FIG. 22-8 Terminology of perspective drawings

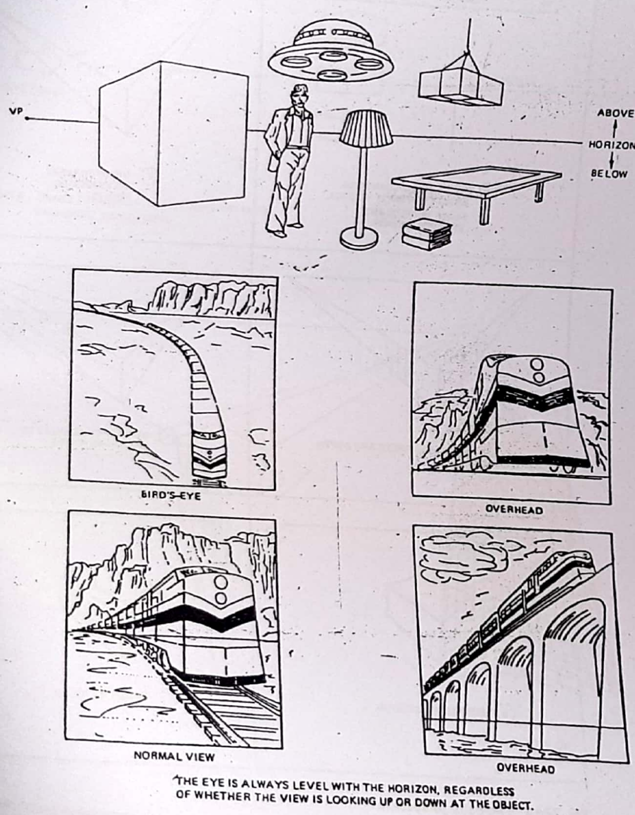


FIG. 22-9 Eye level and the horizon

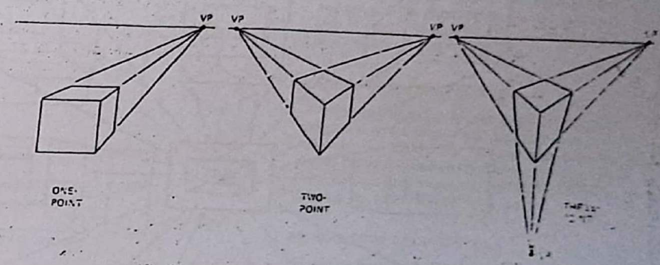


FIG. 22-10 Types of perspective

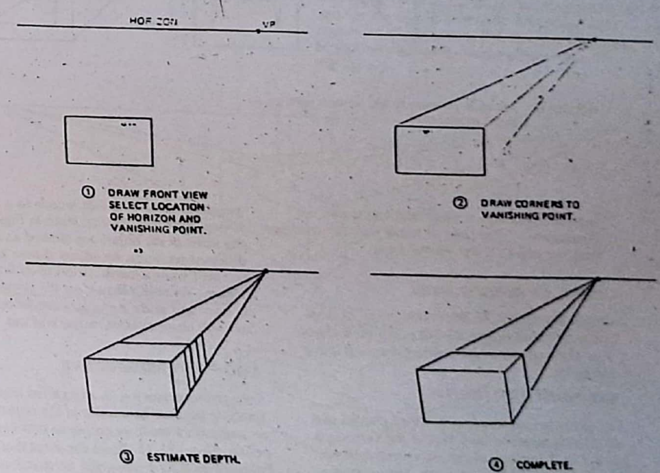


FIG. 22-11 One-point perspective

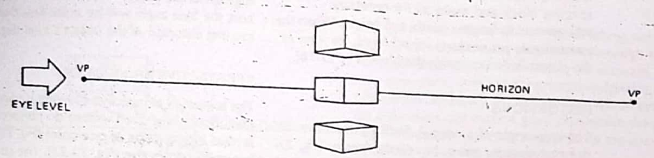


FIG. 22-14 Views in relation to the horizon with two-point perspective

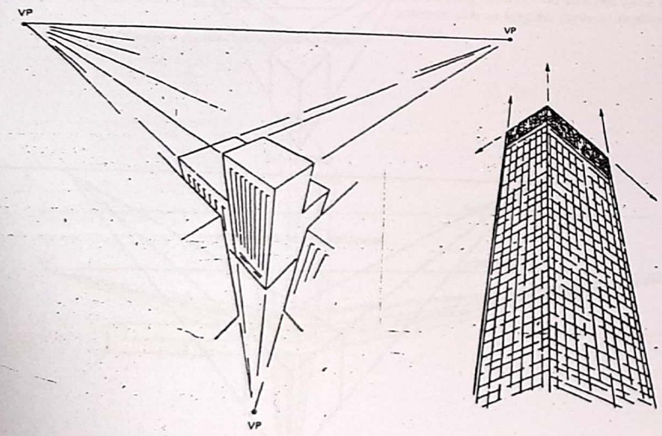


FIG. 22-15 Three-point perspective

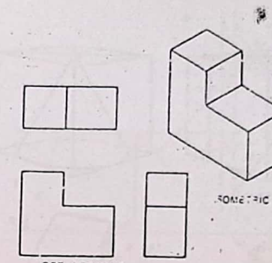


FIG. 22-16 True-size drawings

the object above the horizon will show its sides and bottom. The object on the horizon will show only its sides. The object below the horizon will show its sides and top (Fig. 22-14).

THREE-POINT PERSPECTIVE

Three-point perspective is used to give a more life-like quality to drawings of tall objects such as buildings (Fig. 22-15). The third vanishing point is placed in line with the station point (viewer's position). The further it is placed above or below the drawing, the less distortion there will be.

PERSPECTIVE PROPORTIONS

All objects have three dimensions: length, width, and height. These three dimensions will form a rectangular prism. Orthographic and isometric drawings are true size (Fig. 22-16). A two-point perspective drawn with true basic dimensions will appear out of proportion. The receding sides must be shortened to obtain lifelike proportions (Fig. 22-17).

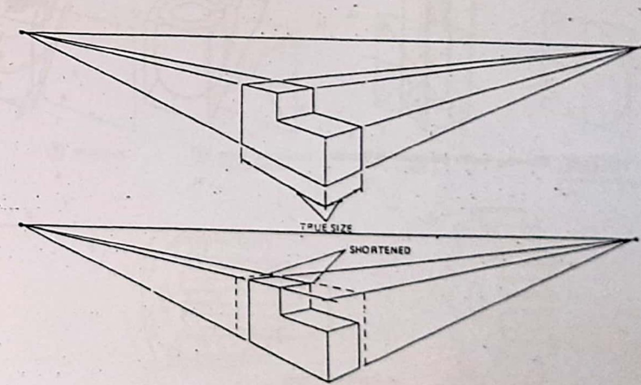


FIG. 22-17 Receding sides are shortened

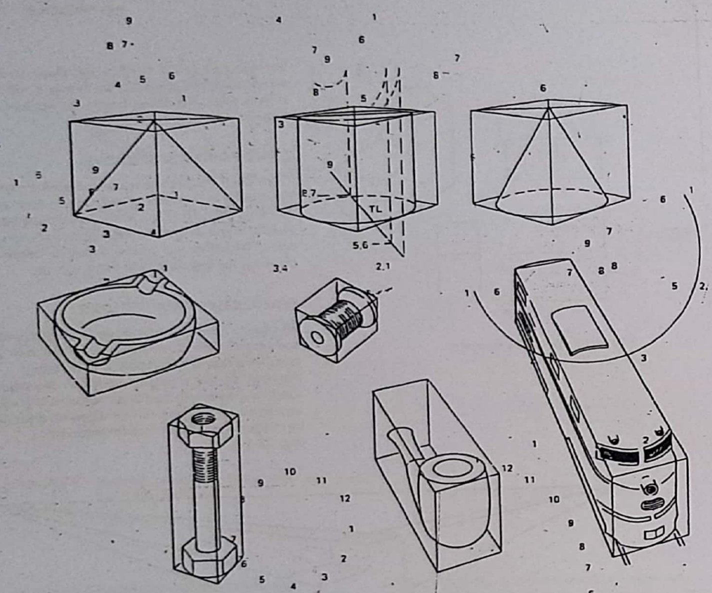


FIG. 22-18 Drawing inside perspective blocks

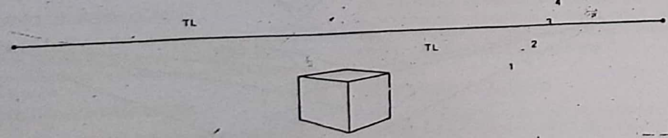


FIG. 22-19 Good perspective

The first step in making a perspective drawing is to draw the boundaries of the object with a perspective block and make all the necessary adjustments to length, width, and height. When the approximate proportions are achieved, the form of the object is drawn inside the block (Fig. 22-18).

DISTORTIONS

The base angle of a normal, lifelike perspective drawing must be more than ninety degrees (Fig. 22-19). An obtuse angle more than 90° will be assured when the vanishing points are spread out as far as possible and/or the object is placed close to the horizon. When the vanishing points are too close together or the object is too far away from the horizon, the base angle will be acute (less than 90°), causing distortion of the object's form (Fig. 22-20).

PERSPECTIVE PROJECTION

The science of perspective drawing is very complex. Books have been written on perspective layouts by projection of one-point (Fig. 22-21) and two-point perspective (Fig. 22-22). The concepts of these projection methods should be understood, es-

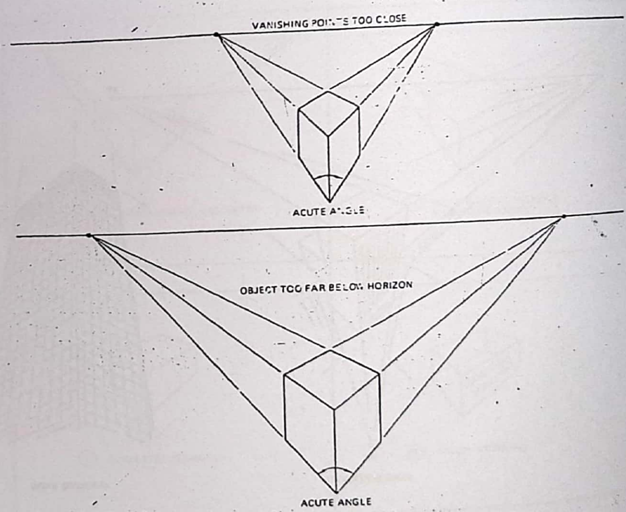


FIG. 22-20 Distortion in perspective drawings

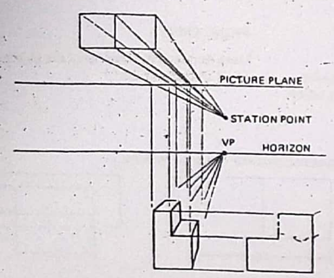


FIG. 22-21 One-point perspective projection layout

pecially the technique of locating vanishing points (Fig. 22-23). But because perspective drawings are not used for production processes, the accurate, time consuming method of perspective drawing is not always necessary. A draftsperson with an eye for estimation can make a good perspective drawing in a fraction of the time required by the one- or two-point projection procedure.

A circle in a perspective drawing will appear as an ellipse. To draw a perspective circle, start by blocking in a perspective square the size of the circle. By sketching a circle tangent to the center of each side, an accurate appearing perspective circle can be drawn (Fig. 22-24). This sketched circle can be darkened with an irregular curve or an ellipse template.

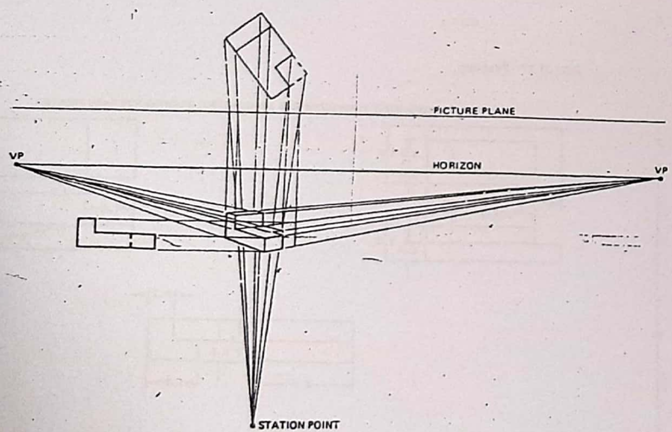


FIG. 22-22 Perspective projection

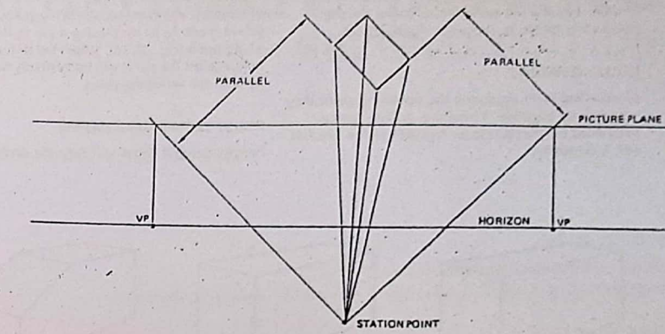


FIG. 22-23 Location of vanishing points

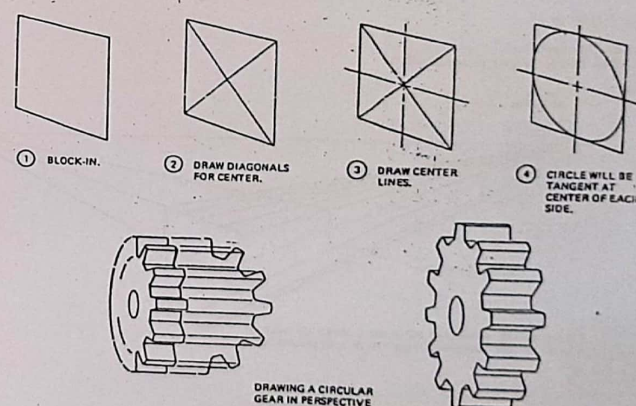


FIG. 22-24 Freehand perspective circle layout

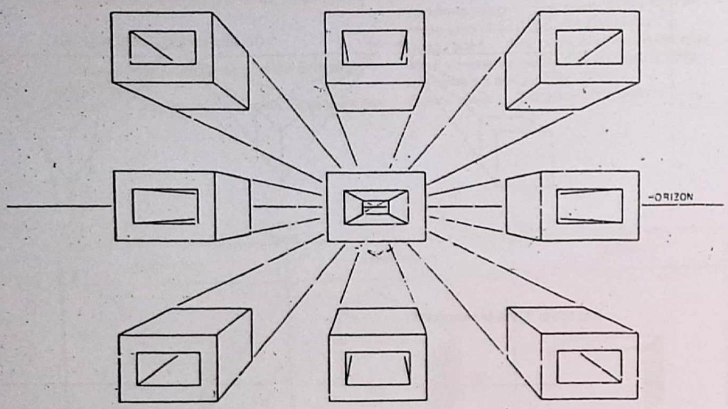


FIG. 22-12 Views in relation to the horizon with one-point perspective

perspective image is visualized and drawn.

Projectors The lines or visual rays that converge from the object to the viewer's eye.

TYPES OF PERSPECTIVES

The draftsperson can select one-, two-, or three-point perspective (Fig. 22-10) to represent the object. The majority of perspective drawings are two-point.

ONE-POINT PERSPECTIVE

One-point perspective is also called parallel perspective because the front face of the drawing is parallel to the picture plane. As an orthographic view, this face is drawn true size. The sides of a perspective drawing will recede to a single vanishing point (Fig. 22-11). Note in Figure 22-12 how the sides of the object are viewed as it is placed in different positions. An object drawn *above* the horizon will show a combination of its front, sides, and bottom. An object drawn *on* the horizon will show its front and sides. An object drawn *below* the horizon will show its front, sides, and top.

TWO-POINT PERSPECTIVE

Two-point perspective is also called angular perspective because both sides of the object recede at an angle from the front corner to two vanishing points. Figure 22-13 shows the steps that must be followed to draw a two-point perspective. Placing

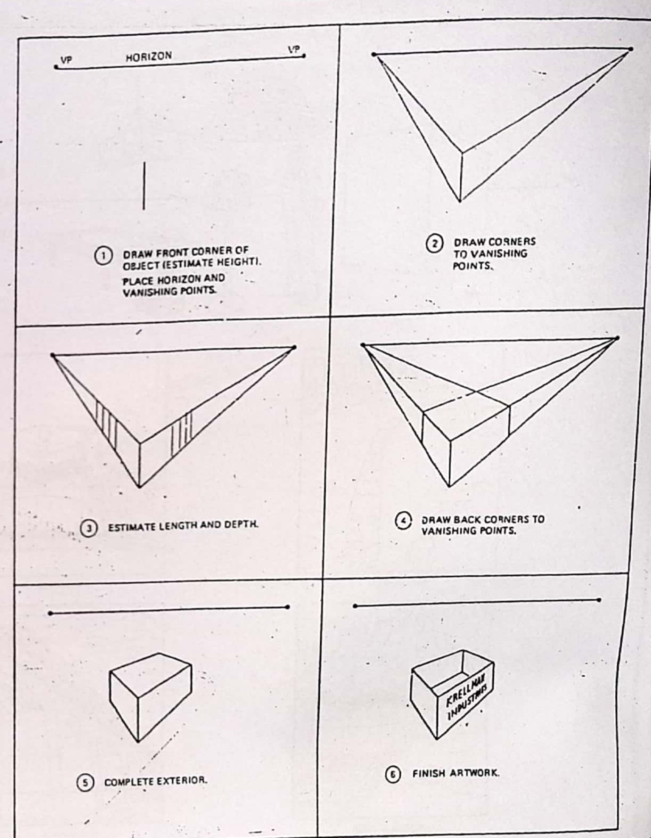


FIG. 22-13 Two-point perspective

ANGULAR LINES

The location and angle of angular lines must be estimated. Lay out the ends of the angles on the perspective prism as shown in Figure 22-25.

EQUAL SPACING

As receding lines approach the vanishing point they come closer together. Therefore, equally spaced parts must be placed closer together so the spacing will look normal.

PIN IN VANISHING POINT

A perspective drawing that requires a large number of lines to be drawn to a vanishing point can be drawn much faster by placing a pin in the vanishing point (Fig. 22-26). When the straight-edge is held against the pin it will consistently be lined up with the vanishing point.

PERSPECTIVE GRID PAPER

Perspective grid paper will help the draftsperson

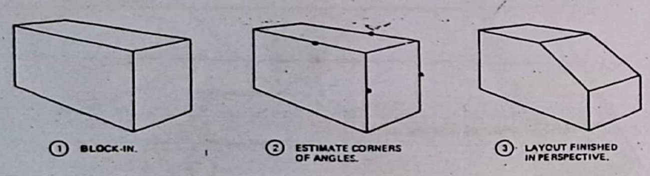


FIG. 22-25 Angles in perspective

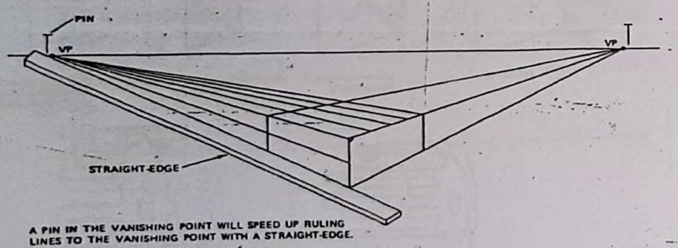


FIG. 22-26 Use of a pin in the vanishing point

make fast, freehand perspective sketches. The main disadvantages of perspective grid paper are the extra cost and the limitation of the perspective angles of grid paper.

PERSPECTIVE BOARDS

There are several types of perspective drawing boards. They have a rotating straight edge which will radiate from a vanishing point. These boa[rds] are expensive, but they reduce perspective draw[ing] time.

PROBLEMS

Make perspective drawings of the objects in Figures 22-27 through 22-29.

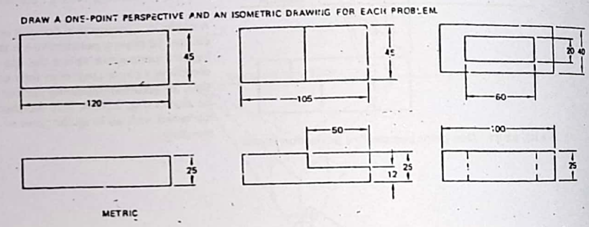


FIG. 22-27 Problem

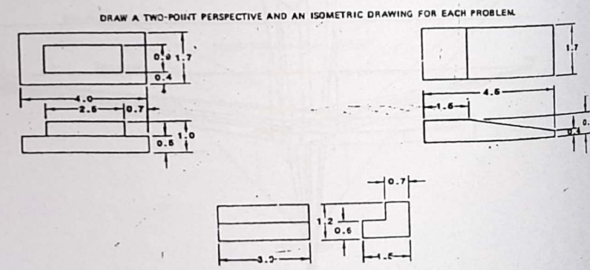


FIG. 22-28 Problem

BUILDING DRAWING
SECOND EDITION

M G SHAH
Principal, College of Engineering, Karad
Formerly, Principal, College of Engineering, Pune and Aurangabad

C M KALE
Consulting Engineer, Pune
Formerly, Lecturer, College of Engineering, Karad

S Y PATKI
College of Engineering, Pune

Tata McGraw-Hill Publishing Company Limited
New Delhi

3

METHOD OF DRAWING

Tradition can be the starting point for creativity, but it must not be the point to which it returns.

KAZOO SHINOHARA
Japanese Architect

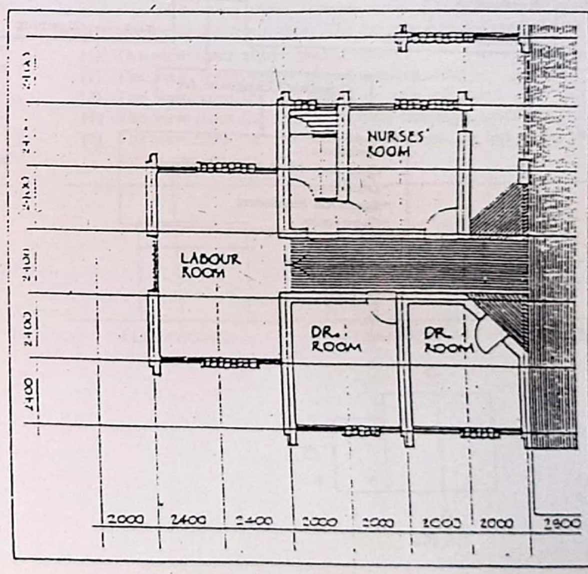


CHART 3-1

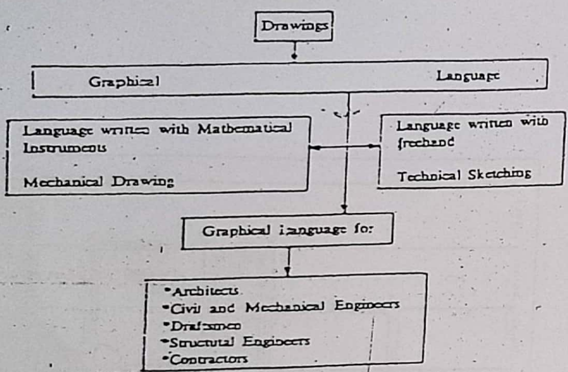
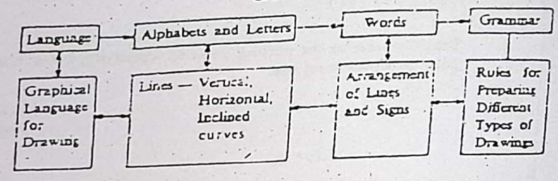


CHART 3-2



3.1 ORTHOGRAPHIC METHOD

Method of Drawing

Pictorial drawing showing the proposed building, garden, road, etc. in the most realistic way is the requirement of the owner; but from the construction point of view such a beautiful drawing without any dimension and construction notes is of no use. To render the required technical description graphically, 'graphic language' using the method of 'Orthographic Projection' is used. It is found to be a very clear method of expression (Charts 3-1 & 3-2).

Multi-view Projection

"Ortho" means 'perpendicular' or 'at right angles'. Horizontal, vertical, and profile planes are extended beyond their line of intersection and four different quadrants are formed. An object is assumed to be placed in one quadrant as shown in Fig. 3-1 and rays parallel to each other and perpendicular to the object are drawn to meet the different planes. These parallel rays are known as "projectors" and the final image created by these projectors on the planes is known as an orthographic projection.

If the object, say a building, is kept in one of the quadrants, for example in the first or third quadrants, as shown in Fig. 3-1, then the orthographic projections on the different planes will be Plan and Elevations.

First Angle Projection

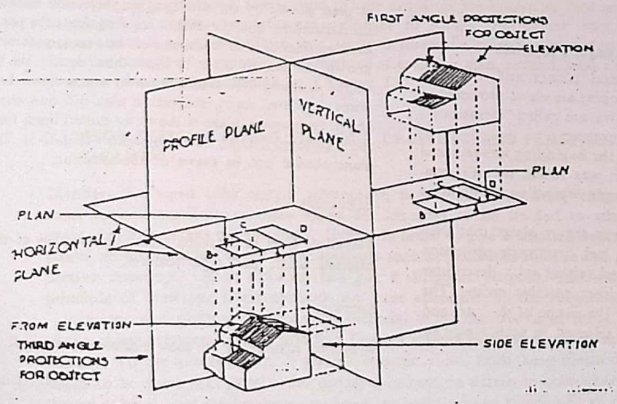
First angle projection is that in which the view is so placed that it represents the side of the object remote from it in the adjacent view with reference to the front view (Fig. 3-2). The other views are arranged as follows:

(1) The view from above placed underneath;
(2) The view from below placed above;
(3) The view from the left placed on the right side;
(4) The view from the right placed on the left side; and
(5) The view from the rear may be placed on the left or on the right as found convenient.

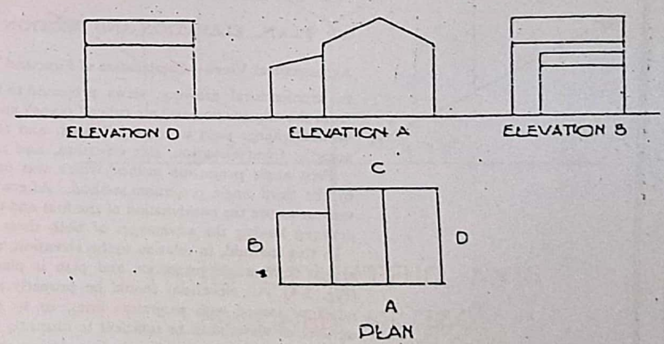
Third Angle Projection

If the same object is now kept in the third quadrant, the orthographic projections on the different planes will be as shown in Fig. 3-3. Third angle projection is that in which each view is placed so that it represents the side of the object near to it in the adjacent view. This method has the important advantage that the features of adjacent views are in juxtaposition. It is thus easier than the first angle projection in projecting one view from the other while drawing and also is easier in associating those features when dimensioning or reading drawings with reference to the front view. The other views are arranged as follows:

(1) The view from above placed above;
(2) The view from below placed underneath;
(3) The view from the left placed on the left side;
(4) The view from the right placed on the right side; and
(5) The view from the rear may be placed on the left or on the right side as found convenient.



MULTI VIEW PROJECTION



FIRST ANGLE PROJECTION

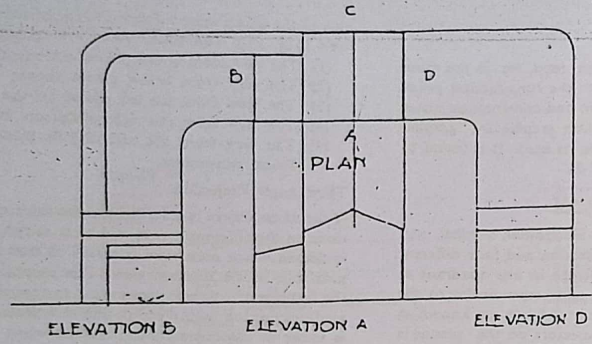


Fig. 3-3

The third angle projection is generally recommended as a standard method of projection. While drawing these different views, hidden surfaces are shown by dashed lines, having uniform dashes, leaving very little space between each dash. The ends of each dash should be made prominent.

3.2 PLAN, ELEVATION AND SECTION

Architectural Views—Combination of First and Third Angle Projection

In architectural drawing, views projected to horizontal planes and observed from the top (or bottom) are called "plans" and orthographic views projected to vertical planes such as the front, side, and rear views, are called "elevations", such as front elevation, side elevation, and rear elevation.

First angle projection method which was used in the beginning was replaced by the third angle projection method. Afterwards, it was found that it is convenient to use the combination of the first and third angle projection for building drawing having the advantages of both these methods.

In this method, in relation to the elevation, end-views are so placed that they are in third angle projection and plan is placed as per first angle projection (Fig. 3-4). All elevations should be properly identified, either with descriptive notes or joined with projection lines, or by some other suitable means. The number of views shall be sufficient to illustrate clearly the shape of the part and there should be no misunderstanding. Views shall be selected in such a way so as to read as few hidden lines as possible.

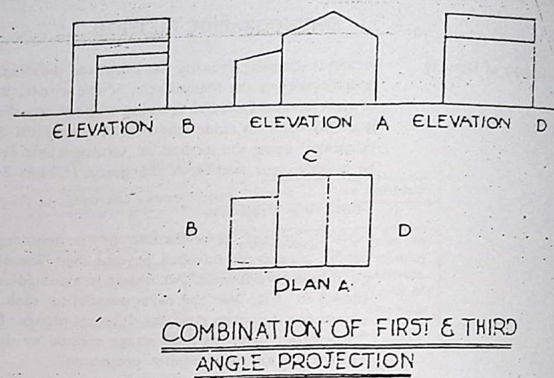


Fig. 3-4

PLAN

All these views give information regarding two dimensions—length and width in the case of plans, and length and height in the case of elevations. From the point of view of construction, some additional information is also necessary. A plan drawn by the orthographic projection method shows only the shape of the structure, but the details required from the point of view of construction such as thickness of walls, size of the room, positions of the door, etc. are not known. Hence, in order to show these details, the building is imagined to be cut by a horizontal cutting plane at a convenient height, so as to cut all walls, doors, windows, stairs, etc. such a plan will now show all details. Whatever is above the cutting plane is shown by dotted lines, for example ridge line of the roof, canopy, *chajja*, roof projection (Fig. 3-5). The position of the cutting plane should not be shown on the elevation.

ELEVATION

Elevation gives information regarding the view of the building, materials for external finish, and other features.

SECTION

A section is necessary to show internal details such as height of the door and

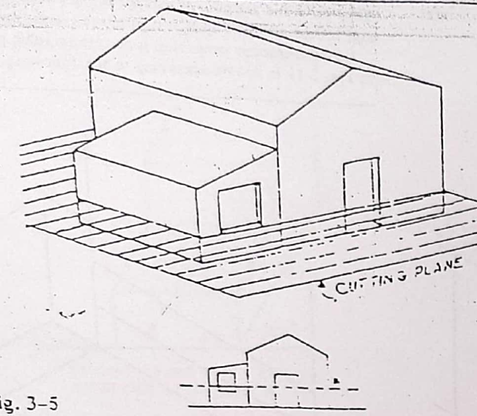


Fig. 3–5

window, thickness of wall, details of footings and foundation depth, details of roof, and other details inside the house.

Plan, elevation and section together furnish data required for preparing estimates and for execution. In order to have a clear idea of plan, elevation and section, students should be asked to record measurements—external and internal—for height, length, and width of the existing building. They should then draw the plan, elevation, and section. These drawings are known as "measured drawings". In practice, students are supposed to follow the reverse way, i.e. preparation of plan, elevations, and sections from the given line plan and not from the completed structure. The method of drawing plan, section, and elevation are thoroughly discussed in Chapter 5.

3.3 ISOMETRIC DRAWING, OBLIQUE DRAWING AND PERSPECTIVE DRAWING

Orthographic views offer certain advantages, but at the same time, there are some limitations. Two or three views are required to be studied to get the exact idea and details of the object. Hence, in order to give a detailed representation, an architect has to use other methods such as isometric, oblique and perspective drawings. Each drawing has got a different purpose, method and principle of drawing. These methods are used according to the requirements.

Isometric and oblique drawings are pictorial in nature. As such, three sides of the object are seen and the principal lines of each side or plane are measured directly. To the average man, it gives a realistic view. Both these methods are found to be quick and suitable for giving construction details to coworkers. On the other hand, perspective drawing shows the building and surroundings as will be seen by the observer after the completion of structure in the most natural and pleasing way.

Isometric Drawing

The prefix "iso" is taken from the Greek word "isos", which means equal. The object is turned to make three sides visible and in such a way that they should lie on three equally divided axes cut about a centre. The axes may be turned in any position, but it is found that by keeping one axis vertical and the other two axes at 30° angle with the horizontal, a pleasing view is obtained. First select the angle from which the object is to be viewed to get the required and also the maximum details. Study the geometric form of the object and imagine the box in which the object can be placed. Draw the axis lines and other details by drawing parallel lines as shown in Figs. 3-6 and 3-7. In order to draw overhead structural features such as joinery of members of timber roof work, "reverse axis" method is used (Fig. 3-8). In isometric drawing a circle appears as an ellipse.

Oblique Drawing

In the oblique drawing, the top and side view of the object is shown by pro-

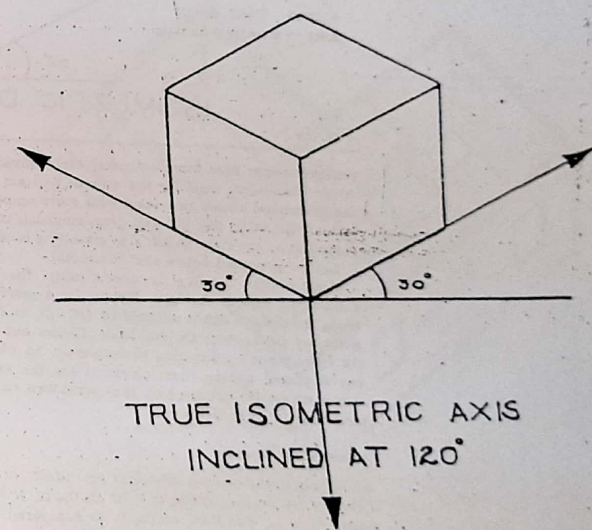


Fig. 3–6

(4) Mark plinth, window sill, door and window top level on vertical line and complete the drawing by drawing projections for all windows, doors, cupboards, etc.

Sometimes one or two external walls are omitted in order to show internal details.

Perspective Drawing

Isometric drawing or oblique drawing for a building will not truly represent the view of the building as will be actually seen by the observer. An architect is also interested to know how the proposed structure will really look after completion. Hence, right from the planning stage and during the development of elevation, he draws sketches of perspective view or a perspective drawing (Figs. 3-12 to 3-16).

In the case of orthographic projection, the projectors are parallel to each other and size of the orthographic view remains the same as the size of the object.

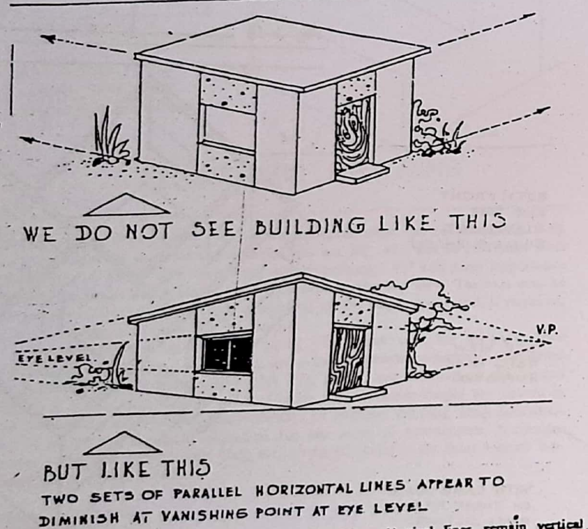


Fig. 3–12

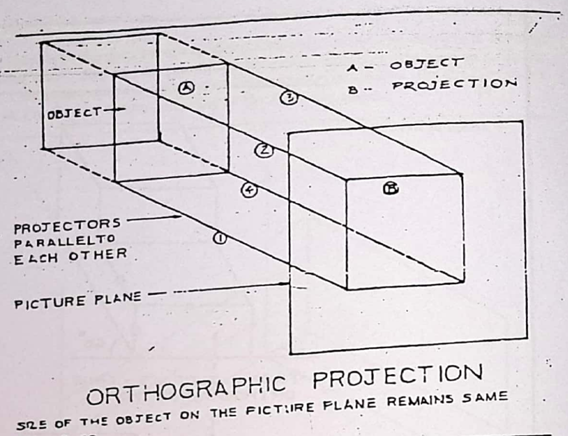


Fig. 3–13

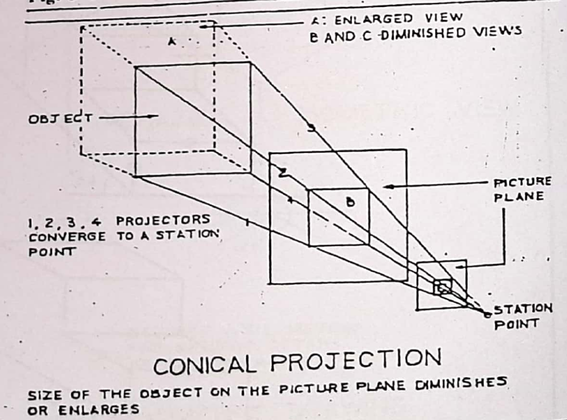


Fig. 3–14

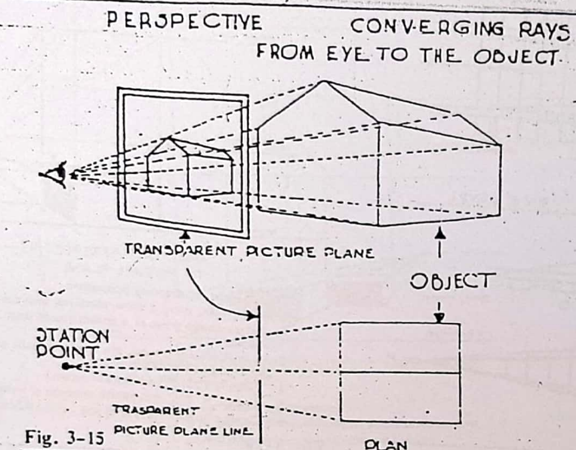


Fig. 3-15

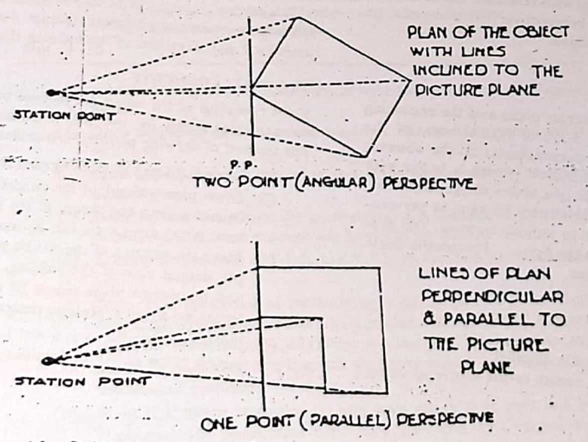


Fig. 3-16

The principle of the perspective drawing is that of conical projection. Rays are coming from one point of observation, i.e. eye to the object and the perspective view is obtained on the picture plane. In this method, size of view will depend upon the position of the picture plane or the transparent plane.

Centre of Vision, Horizon and Vanishing Point

If we stand between two rails, then it will be seen that the two rails appear to meet at one point, though they are separated by a constant distance (Fig. 3-17). Such a point where two parallel lines appear to meet is known as the "Vanishing Point". It is situated on the horizon, i.e. on a line where the sky appears to meet the ground. When we look towards the different points on the rails nearer or away from the place where we stand, then our eye is required to adjust simultaneously for different angles in the vertical and the horizontal plane (Fig. 3-18). This is the reason why we see the two rails meeting at the vanishing point. If we stand in front of a building, then it appears that the two sets of the parallel horizontal lines of the walls meet at two different vanishing points on the right and the left side. These two vanishing points are also situated at the eye level of the observer, i.e. the horizon.

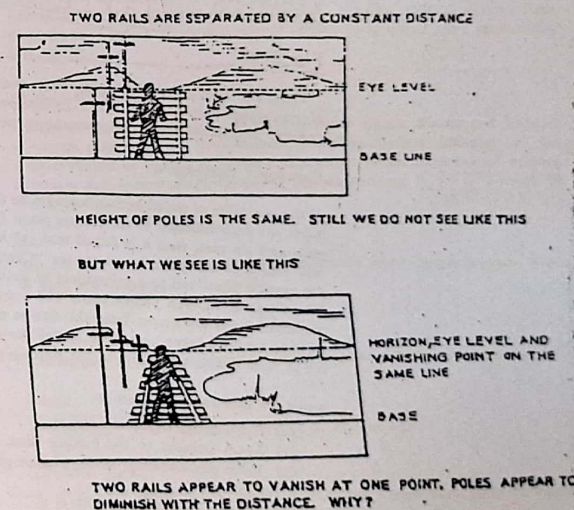


Fig. 3-17

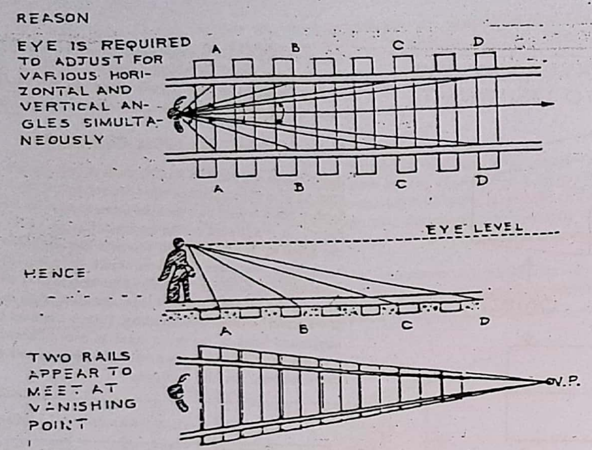
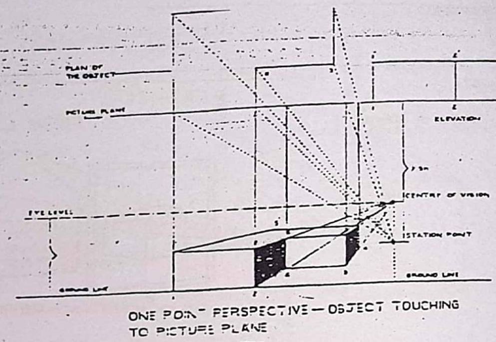


Fig. 3-18



ONE POINT PERSPECTIVE—OBJECT TOUCHING TO PICTURE PLANE

NOTE: Steps for drawing perspective

1. Draw plan, picture plane, elevation with convenient scale
2. Select station point at a distance more than 3H i.e. three times the height of the object
3. Draw lines for ground, eye level and mark point of centre of vision on eye level and in line with station point
4. Lines 1, 1', 2, 2', etc. remain vertical
5. Lines 2, 6, 2'-6', etc. vanish to centre of vision, complete perspective
6. Change height of eye level and see the difference in perspective

Fig. 3-19

There are three types of the perspective drawings with reference to the number of vanishing points. They are : (i) one-point perspective, (ii) two-point or angular perspective, and (iii) three-point perspective.

One-point Perspective

If the two sides of the object are parallel to the picture plane and the remaining sides are perpendicular to the picture plane (Fig. 3-19) or as in the case of the rails and sleepers, then it is found that all lines perpendicular to the observer will vanish to one point known as the "Centre of Vision" which is in line with the station point and at a convenient or desired height above the ground level. The distance between picture plane and ground level may be kept as per convenience. Rays are drawn from the station point to various corners. The projections are then taken on ground line as shown in the figure. Perspective drawing is then drawn according to the following rules.

Rules for One-point Perspective

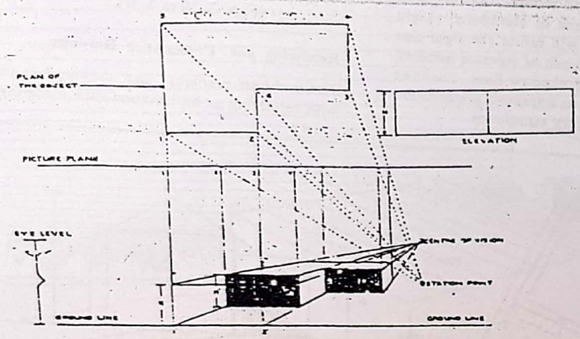
(1) Vertical lines remain vertical.
(2) Lines parallel to the picture plane remain parallel.
(3) Lines perpendicular to the picture plane vanish to the centre of vision.

This method is found to be convenient to show interiors of auditorium, plan showing furniture arrangements, interior decoration, street views, and sometimes for front elevations of the building (Fig. 3-19 and 3-20).

Two-point Perspective

If the two sides of the object are inclined to the picture plane, then there are two vanishing points for two sets of horizontal lines as shown in Fig. 3-21. The method of drawing perspective is explained below.

(1) Draw the line representing picture plane.
(2) Draw plan inclined to the picture plane with convenient angle. It is better to keep one corner of the building touching the picture plane, so that the same scale can be used for perspective and plan.
(3) Mark the position of the station point, i.e. position of the observer as per desired view of the building. Distance between the station point and the picture plane should be more than three times the height of the object to get a pleasing perspective.
(4) Draw lines parallel to 1, 6 and 1, 2 from the station point to cut the picture plane in V.P.R. (vanishing point right) and V.P.L. (vanishing



ONE POINT PERSPECTIVE–OBJECT AWAY FROM THE PICTURE PLANE

Note: Steps for drawing perspective
1. Draw plan, picture plane, elevation, select station point
2. Draw ground line, eye level and centre of vision
3. Extend line 5, 1 to 1' and 6, 2 to 2' to meet picture plane
4. Draw 1' 1", 2' 2" vertical lines equal to H and vanish to Centre of Vision
5. Project X and Y to get the reduced height (H)' of the object
6. Compare the two perspectives

Fig. 3–20

point left). These are the positions of vanishing points on the picture plane.

(5) Draw rays to all corners, doors, windows, etc. from the station point as shown.

(6) Draw line representing ground level at a convenient distance from the picture plane.

(7) Draw horizon line above the ground line at a distance of 1.5 m for normal eye level, or at more or less height as per desired view.

(8) Transfer the positions of V.P.R. and V.P.L. on eye level, i.e. the horizon line.

(9) Point (1) of the corner of the building is on the picture plane. Draw vertical line by projecting point (1) on ground line. All vertical measurements for plinth window sill, door, window top, eaves level, etc., should be marked on this line and then they should be transferred to the required positions.

(10) Mark 1, 1' height at corner (1) and then vanish it to right and left. Then mark the projections 6,6', 2,2', 3,3', and 4,4'. Vertical lines will remain vertical. Parallel lines 1,6, 3,2, and 4,5 will vanish to point V.P.L. (Eye level) and parallel lines 1,2, 3,4, and 6,5 will vanish to V.P.R. (Eye level).

(11) For roof project line 7,8 to out picture plane in X. Draw vertical XX' on ground line and mark true height of roof top as per scale.

Then vanish the line 7,8 to V.P.L.2. Similarly mark 9,10 and 11,12.

Two point perspective or angular perspective method is used for buildings. By changing the height of the eye level, i.e. horizon, bird's eye view is obtained.

Three-point Perspective

In this case, not only vertical lines do not appear to be vertical but they also vanish to a point. This happens while viewing a skyscraper from a road or from an aeroplane.

3.4 SHADES, SHADOWS, RENDERING AND PRESENTATION DRAWINGS

Perspective drawing is incomplete without showing natural surroundings of road, trees, garden, and the sky. In nature, we always observe shadows of various objects such as, *chajjas*, canopies, roof overhangs, tree, etc. The introduction of shades and shadows to a perspective drawing adds a pleasing three dimensional view on a two-dimensional surface by giving a solid appearance. (Fig. 3–26).

Shades and Shadows

Perspective drawing produces only the outlines of objects. Shades and shadows of various objects do not have uniform tone. Contrast and intensity of the shadow should be studied in nature and sketches should be drawn of existing structures and surroundings which will help an architect in giving a touch of reality to the drawing.

Sun

It is the source of illumination. It illuminates the object from a distance. Rays of light are assumed to be parallel.

Shadow

It is the part of a surface from which light is excluded by an opaque object.

Shade

It is the part of an object not exposed to rays of light.

Dividing Line

It is the line which divides the illuminated and shaded portions of an object (Figs. 3–27 & 3–28).

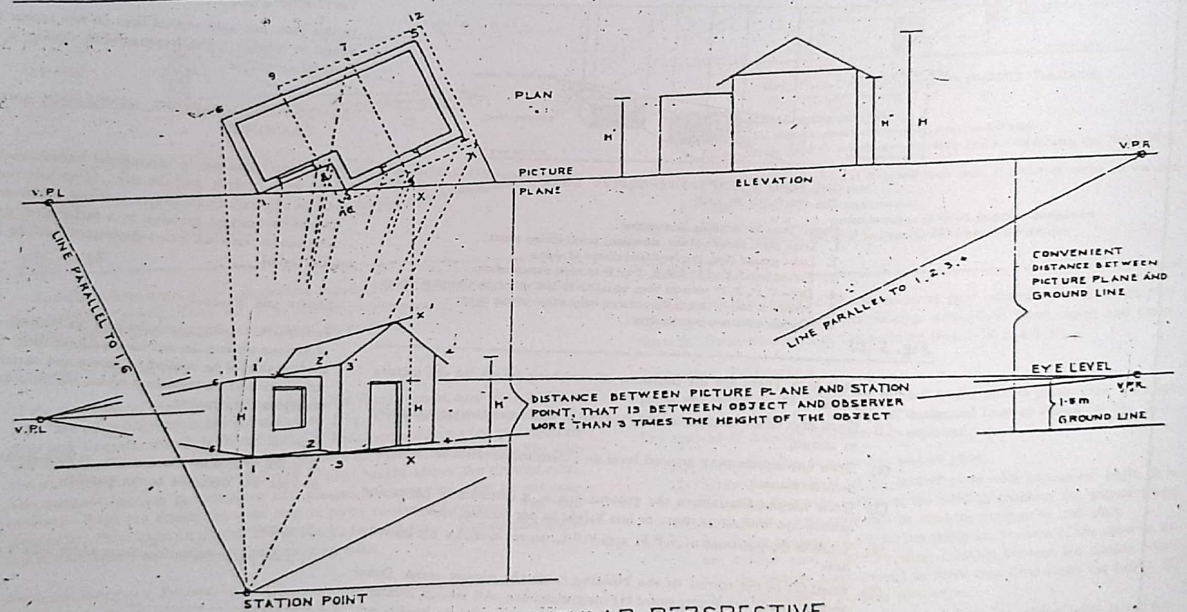
CONVENTIONAL LIGHTING

In architectural drawing, it is useful and customary to assume that the light comes from one direction, i.e. the upper left side in case of elevations. Light appears as a 45° line on elevation and plan. Shadow will fall to the right side and below the object. Shadow will clearly indicate the depth of recessed features. A 45° set-square can be conveniently used in drawing shadow lines. Shadows are also shown on the front elevation and it becomes an attractive presentation drawing. Casting of shadows is affected by the following conditions.

(1) The direction of the light source
(2) The shape of the object
(3) The manner and shape of the surface upon which the shadow will fall (Figs. 3-29 to 3-31).

Rendering and Presentation Drawings

The architect prepares plan showing furniture arrangement and a perspective with rendering or an elevation with rendering, i.e. he shows different features



TWO POINT OR ANGULAR PERSPECTIVE

NOTE: 1. Arrange plan, picture plane, station point in such a way so that V.P.R., V.P.L. will be on the drawing paper 2. Draw only required details of the plan.

Fig. 3-21

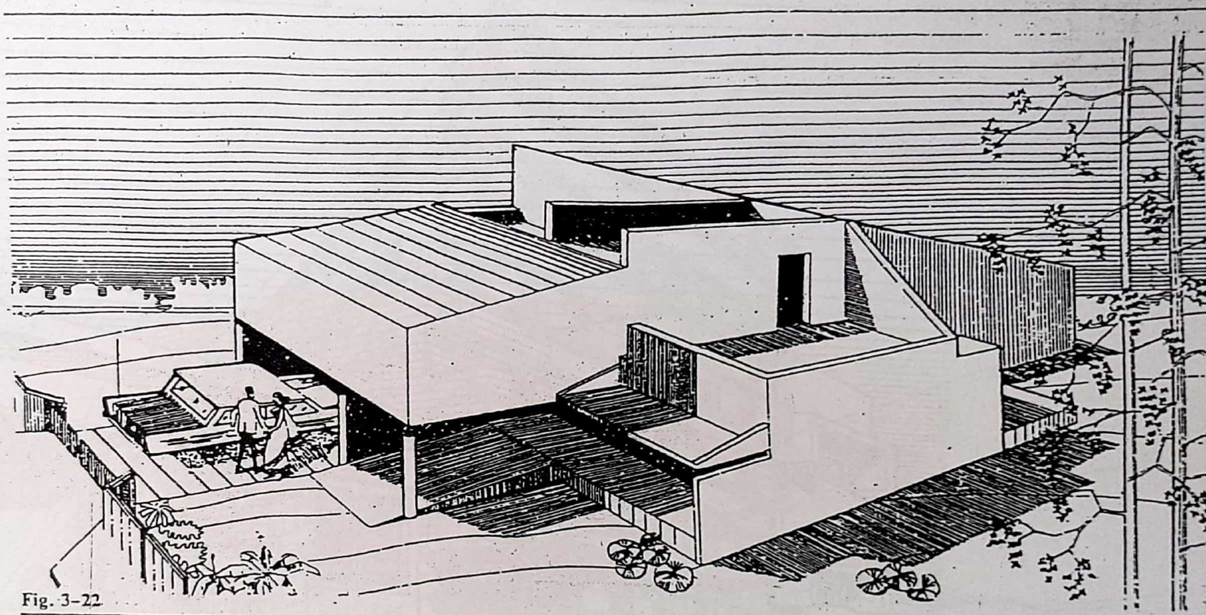


Fig. 3-22

and their texture using strokes of soft pencils giving different pressure. These drawings give a clear idea of the would-be structure to the client, to the assistants of the architects who help in preparing submission and working drawings, and also to the contractor and his workmen. Presentation drawing includes (1) perspective drawing, (2) floor plan and rendered elevation, and (3) plot plan showing proposed orientation of the building and surrounding garden, road and entrance. Presentation drawings are prepared in different media. Pencil, pen, ink, coloured pencils, water colour, pastel and charcoal pencils are used. Each medium has got some advantages and some limitations. Ink work requires more time compared to pencil work. The combination of pencil or ink line work with transparent water-colour wash is used by many architects (Figs. 3-2 to 3-34).

READING EXERCISE (FIG. 3-22)

PERSPECTIVE

(1) What type of perspective drawing is drawn—(a) one-point or (b) two-point perspective?
(2) What is the advantage of drawing the bird's eye view?
(3) Study shades and shadows, trees, and method of presentation.

READING EXERCISE (FIG. 3-23)

PERSPECTIVE OF BUNGALOW

(1) What type of perspective drawing is drawn—(a) one-point or (b) two-point perspective?
(2) Study shades, shadows, projections of canopies, terrace, parapet, and treatment of ground in front and on the sides.

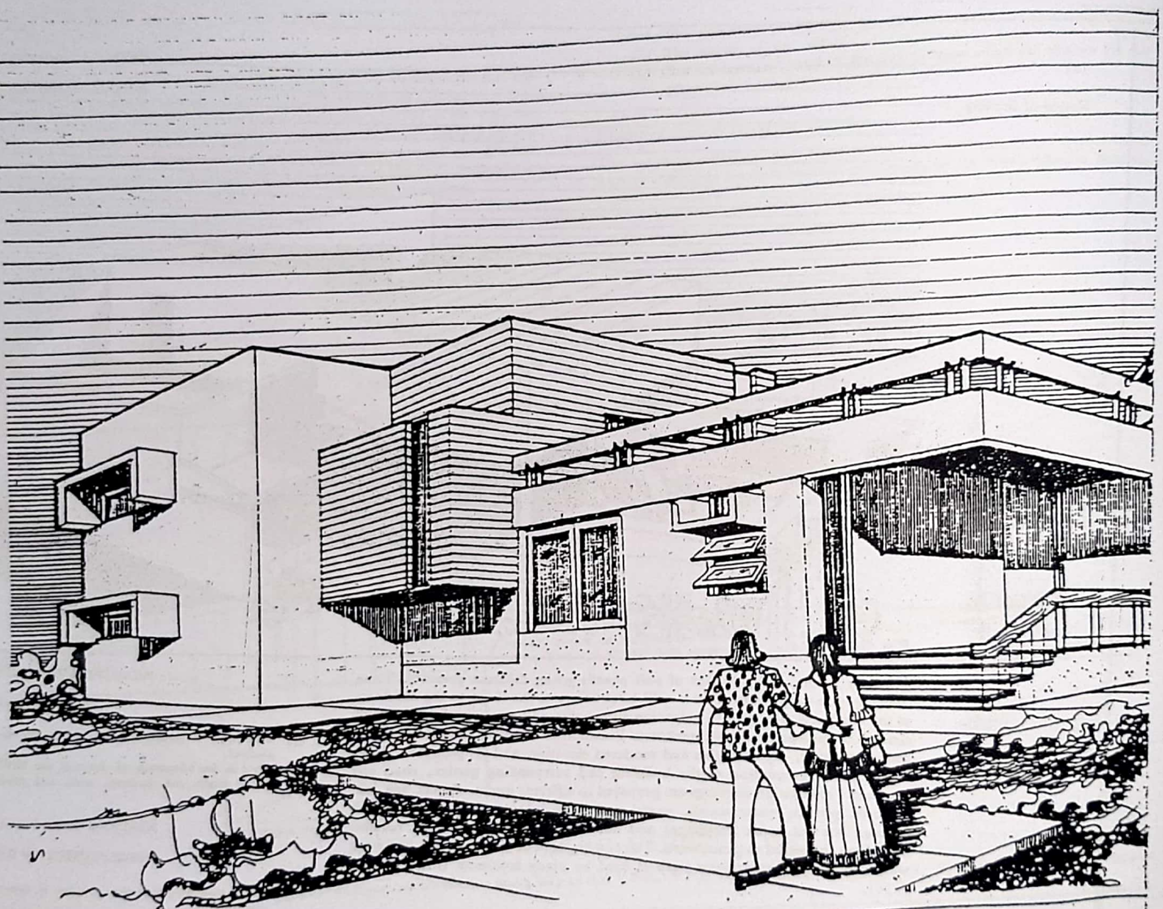


Fig. 3-23

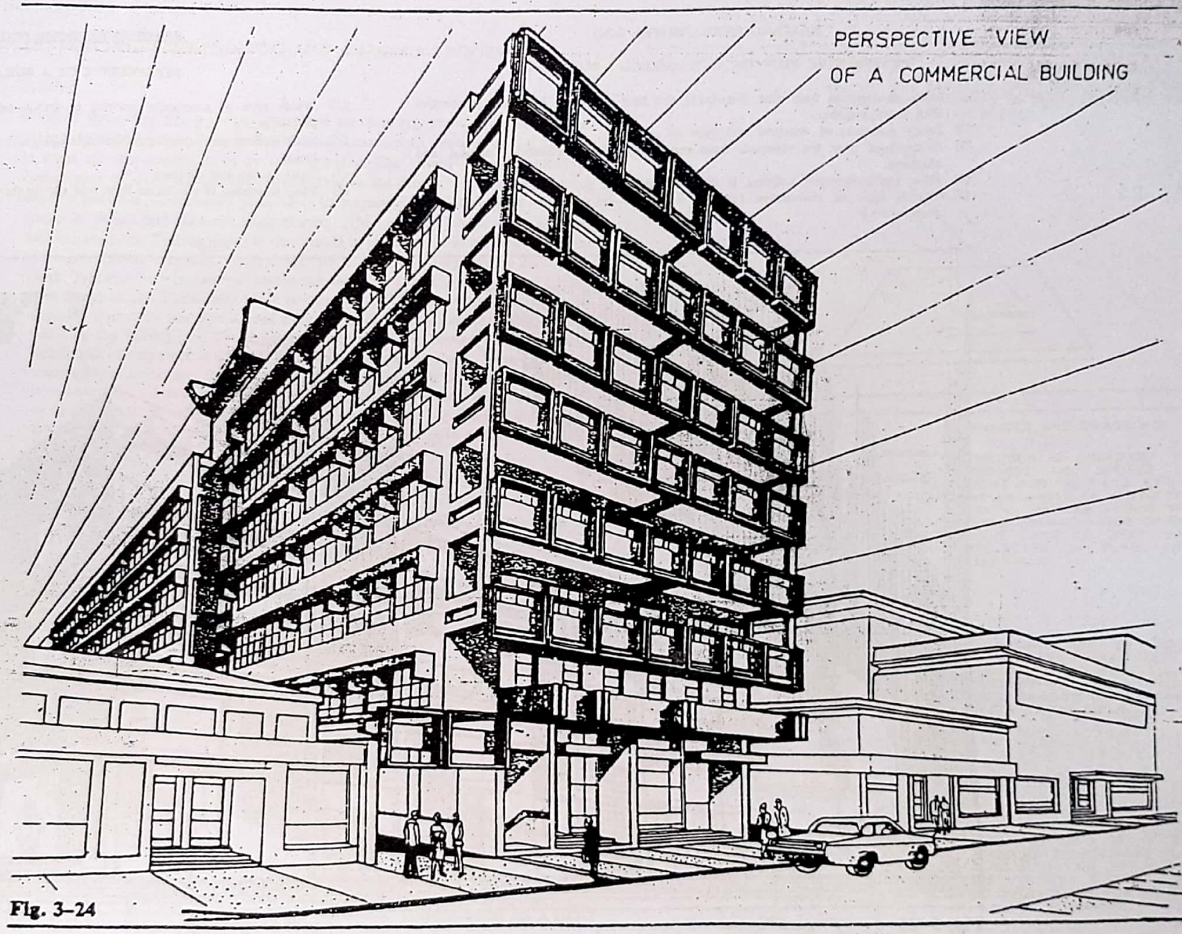


Fig. 3–24

READING EXERCISE (FIG. 3-24)

PERSPECTIVE VIEW OF A COMMERCIAL BUILDING

(1) Study the ground floor plan (Fig. 2-13), first floor plan (Fig. 2-14) and perspective (Fig. 3-24) together.
(2) Study locations of windows and type of *chajja*.
(3) Study roof over the staircase, front and side elevations, projections, shades, and shadows.
(4) How many storeyed building is this? Ground floor + ...floors.
(5) Which type of perspective drawing is drawn—(*a*) one-point or (*b*) two-point perspective?

READING EXERCISE (FIG. 3-25)

PERSPECTIVE OF A BUILDING

(1) Which type of perspective drawing is drawn—(*a*) one-point or (*b*) two-point perspective?
(2) Study various projections of balconies, *chajjas*, and roof provided over the staircase room.
(3) Study shades and shadows.
(4) Study treatment of ground on front side and for the sky.

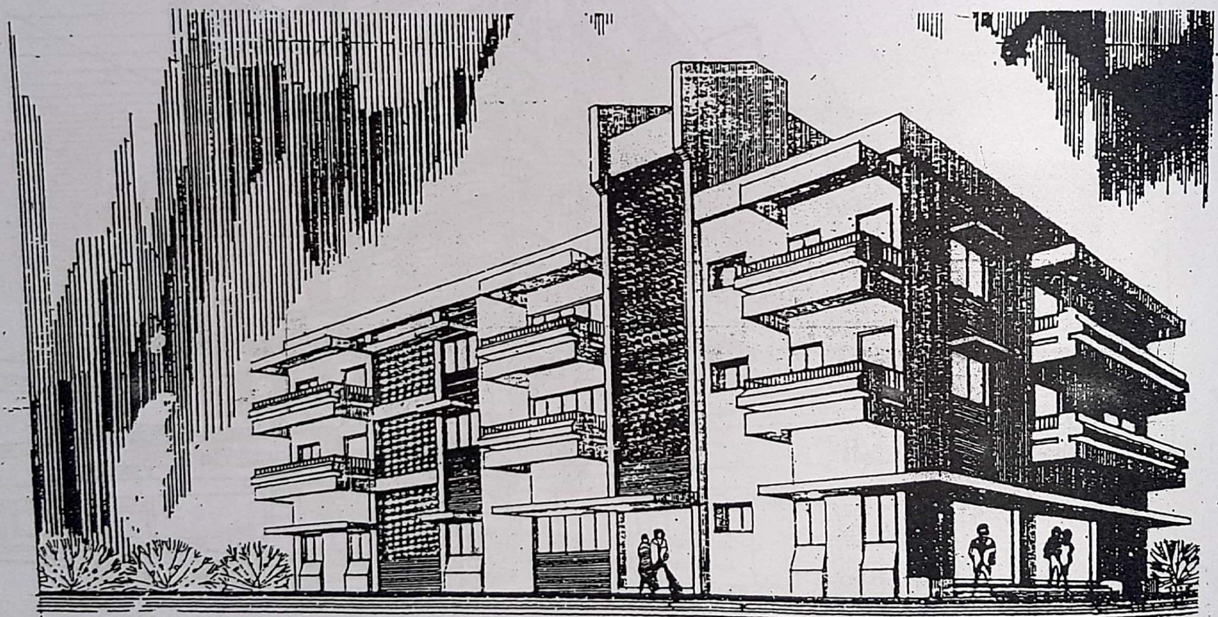


Fig. 3–25

3.5 TRACING, BLUE-PRINTING AND AMMONIA PRINTING

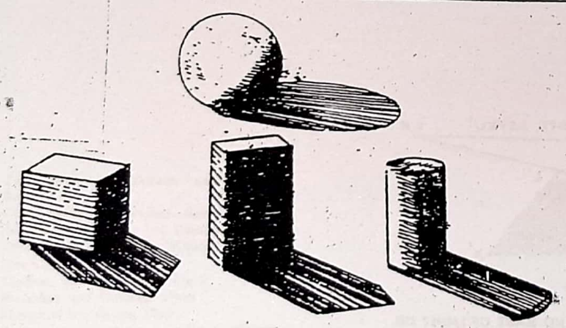
Method of Drawing

Tracing

Original drawings are generally prepared on drawing paper. In order to get several copies required for submission and construction, tracing of the drawing is done on the tracing cloth or tracing paper. The choice depends upon the importance of drawing and the requirement in the future. Tracing on tracing cloth is durable. Commercial practice is to prepare direct drawing on tracing paper in pencil and take out many prints. This is found to be easy, efficient, and economical. Tracing paper is obtainable in sheets or in rolls, while tracing cloth is obtainable in rolls. Waterproof ink is used for doing tracing on tracing cloth. Tracing cloth is stretched on the drawing board, and is then dusted lightly with french chalk. The surplus chalk powder snould be removed by a soft duster ensuring that only fine film is kept over the surface as too much chalk powder will clog the inking pen. The shiny or glazed surface is turned to the drawing board and inking work is done on the dull surface of the cloth. Erasing on the tracing paper or tracing cloth must be done carefully. Ink on the tracing cloth is removed by a fine razor blade or ink remover paste. A bow-pen, crow-quill or grapho-pen is used for doing inking work. Line work and lettering on tracing cloth or tracing paper must be opaque and distinct in order to produce legible copies.

Blue-Prints

Blue-print is obtained by using ferropaper. Ordinary paper is dipped in a



SHADES AND SHADOWS EXIST WHEN THERE IS LIGHT. RAYS OF LIGHT COMING FROM THE SUN ARE CONSIDERED TO BE PARALLEL. THE RAYS COMING FROM ARTIFICIAL SOURCE SUCH AS A LIGHT BULB ARE OF RADIAL TYPE

Fig. 3–26

ASSUMING 45° AS THE ANGLE OF THE LIGHT RAY THE LENGTH OF SHADOW IS EQUAL TO THE LENGTH OF PENCIL. THE PARALLEL LIGHT RAYS COMING FROM THE LEFT ARE PARALLEL TO THE OBSERVER'S FACE AND TO THE PICTURE PLANE

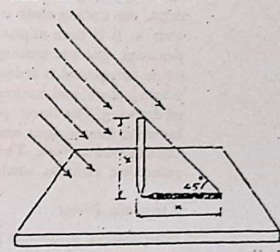
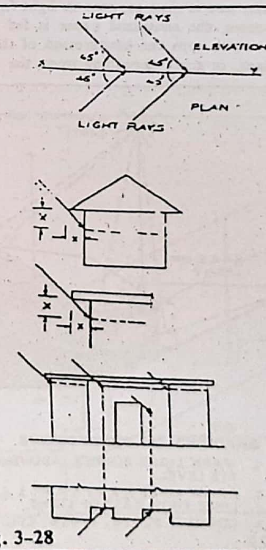


Fig. 3–27



SHADES AND SHADOWS

THE SUN IS SUPPOSED TO PROVIDE THE SOURCE OF LIGHT AND THE RAYS STRIKE AT AN ANGLE OF 45° TO THE EARTH. PICTURE SHOWS THE DIRECTION AND ANGLE OF THE LIGHT RAYS AS THEY ARE PROJECTED ON PLAN AND ELEVATION

SHADOWS CAST BY ROOF PROJECTIONS ARE EASILY SHOWN BY DRAWING LIGHT RAYS AT 45° ANGLE WHICH GIVES SHADOW OF THE SAME DEPTH AS THE PROJECTION

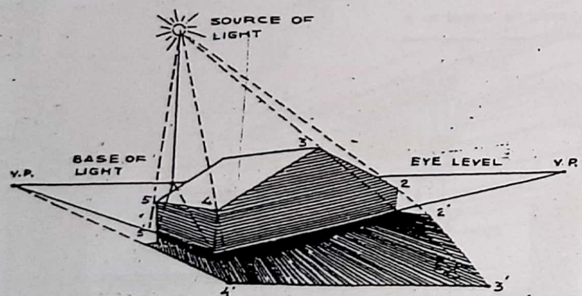
DRAW IN LINES OF 45° FOR VARIOUS PROJECTIONS PLAN AND ELEVATION. PROJECTION OF VERTICAL DOTTED LINES SHOWS LOCATION OF SHADOW LINE ON ELEVATION

Fig. 3–28

solution of ferric ammonium citrate and potassium ferricyanide. It is thus coated with these two salts and also by the ferric ferricyanide which is formed by the interaction of the two. The blue colour is due to the formation of the latter. After applying the solutions, the paper is dried in the dark. For taking out a print, the tracing cloth is kept in the blue-printing frame and ferro paper is kept over it. It is then exposed to sunlight. The light then passes through the blank portions, but not through the black portion of the line work and lettering. The ferric compound is reduced to the ferrous state wherever light passes through the tracing cloth and strikes the paper; but no change takes place below the line of drawing. The ferro paper is then developed by dipping it in water. A reaction between ferrous ions and ferricyanide ion takes place forming insoluble blue on the exposed surface. The portion below the lines where there had been no reduction remains unchanged. The paper is then dried.

Ammonia Prints

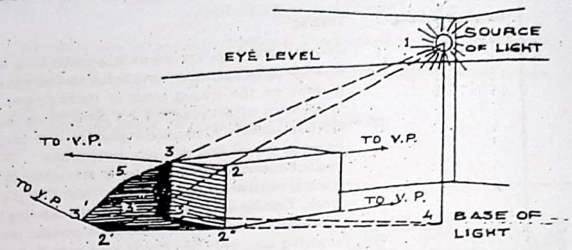
Now-a-days, ammonia prints are found to be convenient and economical as compared to the blue-prints. The original paper is coated on one side with light-sensitive diazo chemicals. The sensitive paper is kept in contact with the tracing in machine and is then exposed to light for a controlled amount of time. After the exposure, the sensitized paper is fed into a dry developer, i.e. ammonia vapours which turn the background of the print white and of the lines either blue, black, or sepia depending upon the chemical used.



SHADOWS ON PERSPECTIVE

1. MARK LIGHT SOURCE ABOVE EYE LEVEL AND BASE OF LIGHT ON EYE LEVEL.
2. DRAW LINES 1, 2, 2', 1, 3, 3'; 1, 4, 4'; 1, 5, 5', ETC. TO CUT RADIATING LINES FROM BASE OF LIGHT.
3. CONNECT 2', 3', 3', 4', 4', 5', ETC. AND COMPLETE THE SHADOW.

Fig. 3–29



SHADOWS FROM ARTIFICIAL LIGHT

1. MARK EYE LEVEL, LIGHT SOURCE, AND BASE OF LIGHT.
2. DRAW LINES 1, 2, 2' TO CUT 4.2", 2'.
3. DRAW 4, 3", 3"' TO MEET THE WALL, DRAW VERTICAL LINE JOINING 3"' TO 5 TO CUT 1, 3 PRODUCED.

Fig. 3–30

5

PREPARATION OF SUBMISSION AND WORKING DRAWINGS

Three things are to be looked to in a building, that it stands on the right spot, that it be securely founded, that it be successfully executed.

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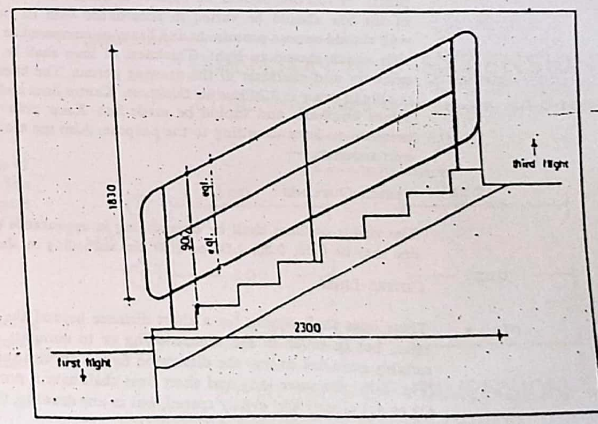


5.1 CONVENTIONS, ABBREVIATIONS AND GRAPHICAL SYMBOLS

Conventions and Necessity of Conventions in Drafting

The preparation of drawings becomes an important part of architectural service. Ideas are converted into drawings so as to give information to tradesmen, estimator, contractor, and all concerned persons for the construction of a building. Draftsman should put himself in the place of these persons. Then only will he be in a position to realize correctly the importance of drawings with correct dimensions and clear notes. He must avoid likely misinterpretation and waste of time due to wrong dimensioning. Hence, it is absolutely necessary to adopt some measure of uniformity in the preparation of drawings. Indian Standards Specification—IS : 962–1967—specifies code of practice for Architectural and Building Drawings.

Conventions as per I.S. : 962–1967

This code of practice lays down recommendations for sizes and layout of drawings, methods of projections, sectioning and sectional views, sizes of lettering, dimensioning, abbreviations, and symbols used in architectural and building drawing office practice. These recommendations are given below.

Lines

All lines on a drawing should have significance or they have no reason for being on your drawing. All lines shall be dense, clean and black to produce good prints. A full line should be used to indicate visible outline, and the thickness of the line should be varied in accordance with its purpose. A line showing wall should appear prominent and heavy as compared to the guideline for dimension which should be light. Thickness of lines shall be in accordance with the accuracy and character of the drawing permit. The finest line that a draftsman is able to draw is 0.20 mm in thickness. Centre lines and extension lines require minor emphasis and should be made fine. Keep your pencil sharp, and vary pressure on lines according to the purpose. Also use a chisel point pencil whenever required.

Visible Outlines

The visible outlines shall be outstanding in appearance on the drawing. Thick line may be 0.60, 0.80, 1.00 or 1.30 mm according to the purpose (Fig. 5-1).

Centre Lines

These lines shall project for a short distance beyond the outline to which they refer, but in order to aid dimensioning or to correlate views, they shall be suitably extended so that the dimension figures are clear of the drawing outlines (Fig. 5-2). Alternate long and short lines shall have a proportion ranging from 6:1 to 4:1 closely and evenly spaced, but in any drawing, the ratio once adopted shall be maintained.

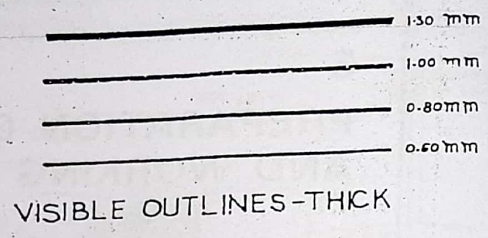


Fig. 5–1

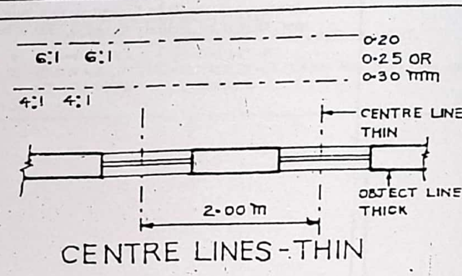


Fig. 5–2

Hidden Lines

These lines show hidden or interior surfaces or work to be removed (Fig. 5-3). They should be included only where their use definitely assists in the interpretation of the drawing. These lines, consisting of short dashes closely and evenly spaced, should be used to represent hidden lines. They should begin with a dash cutting the adjoining outline, and all lines should cross at corners. Broken lines are used on plan to show various lines of roof such as ridge, valley, eaves, gable board, truss, R.C.C. loft, canopy and chajja, etc.

Dimensions

Dimensions are given by drawing dimension and extension lines, arrow heads or dots and leaders.

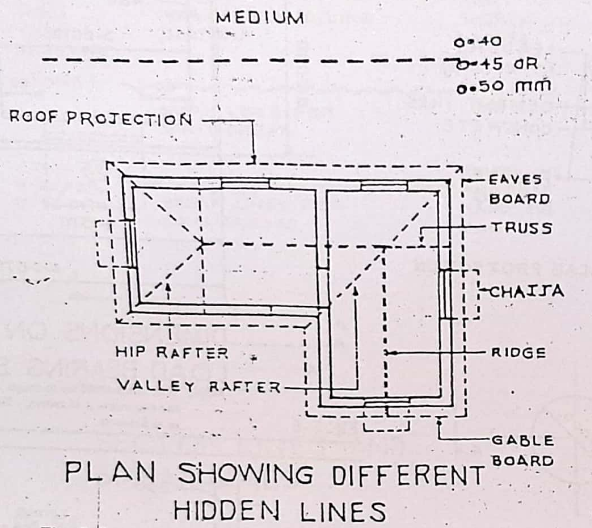


Fig. 5-3

Dimension Lines

These lines shall be thin full lines so as to contrast with the heavier outlines of the drawing, and should be placed outside the figure, wherever possible. The drawing is useful only when dimensions are correct and manner of placement is easy to read. Expensive mistakes are avoided and lot of time is saved by the use of correct dimensions (Fig. 5-4).

Extension Lines

These are light or thin lines drawn from the extremities of the feature requiring dimension. These lines should not touch the feature, but should start from a distance of 2 mm and the lines should extend about 4 mm beyond dimensioning line.

Arrow Heads or Dots

These are used to terminate dimension lines. The length of arrow head is about three times the depth. The space of arrow head should be filled in. When dot is used, it should be placed at the intersection of the extension line and dimension line. They should be neat and uniform with their points just touching the extension lines. Use sharp pencil to avoid 'spotty' appearance.

Leaders (Pointer lines)

Sometimes, it is not possible to write the note and the dimension figure near the feature of the drawing to which it relates. In such cases, it is written slightly away from the feature, and lines known as leaders or pointer lines, are drawn from notes and figures to show where the notes, figures, etc., apply (Fig. 5-5). These are thin straight lines terminated by arrow heads or dots. Arrow heads

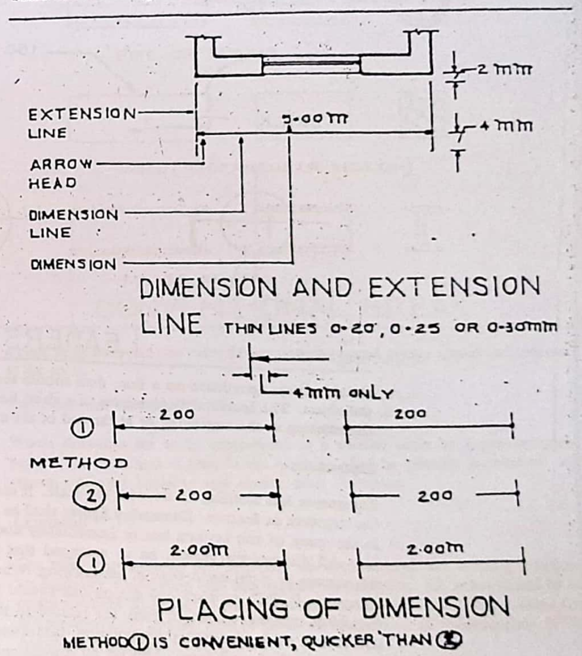


Fig. 5-4

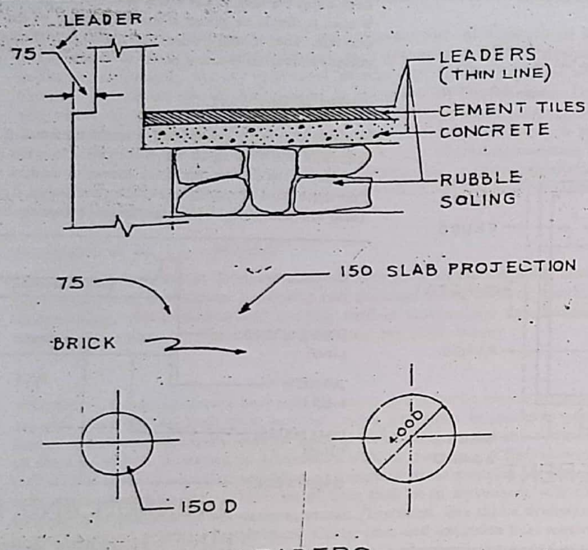
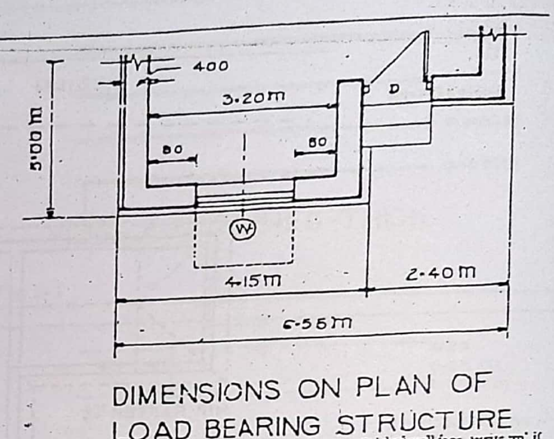
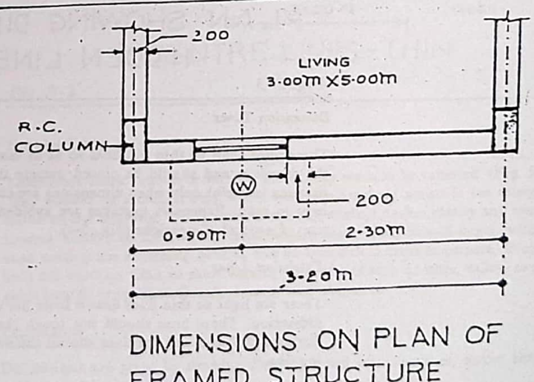


Fig. 5-5



Note: Give dimensions up to rough unfinished wall face. Write 'm' if the dimension is in metres. Do not write 'mm' for dimensions in millimetres.

Fig. 5-6



Note: Give dimensions up to centre of columns, windows, doors, etc.

Fig. 5-7

should always terminate on a line; dots should terminate within the outline of the object. The leader may terminate in a short horizontal bar at mid-height of the lettering at the beginning or at the end of the note.

Dimensions

Dimension has nothing to do with the scale. It should represent actual size of the structure or feature. Dimension figures shall be placed near the centre either in the space of the broken line or immediately above the unbroken dimension line. All dimensions should be so arranged that they may read either from the bottom or right hand edge of the drawing. Where the structure is a framed structure—R.C.C. or steel—all dimensions should be related to the column or stanchion centres, which, in turn, are related to the building line. Where the structure is of load bearing construction, dimensions should be related to the rough unfinished wall faces. Line up all dimensions so as to draw, write and read quickly, and to improve appearance of the drawing (Figs. 5-6 and 5-7).

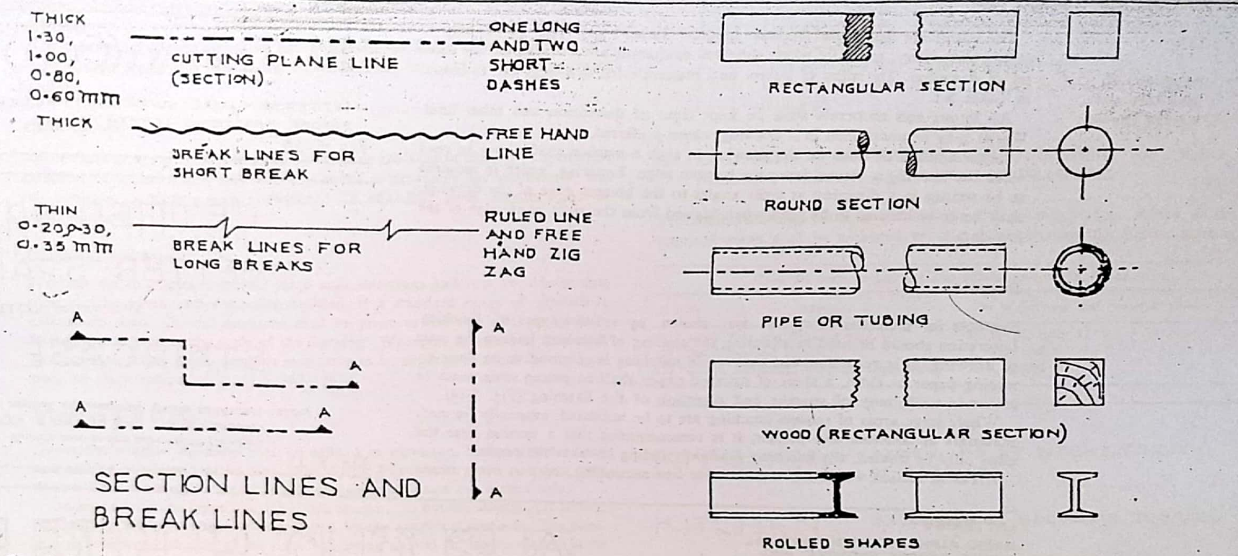


Fig. 5-8

Units of Dimensioning

Dimensioning shall be done in metres and millimetres. If the dimension is in metres, write 'm' and if it is in millimetres do not write 'mm' and give a note on drawing stating that all the dimensions are in mm.

Dimensions, dimension lines, and extension lines should not interfere with the other construction lines of drawing. If the drawing sheet is to be inked, red ink should be used for the dimension line.

Break Lines

Break lines may be used in drawings to show break of continuity (Fig. 5-8). For short break, it should be free hand line and for long breaks, it should be a ruled line and free hand zigzag.

Section Lines

The cutting plane on which a section has been taken should be indicated by a thick long dash and two short dashes alternately and evenly spaced and lettered at the ends.

Photographic Reproduction

Where drawings are to be reproduced to a smaller scale by a photographic process, the thickness of lines in the originals shall be suitably accentuated to ensure sufficient legibility and clarity after reduction.

Lettering

The main requirements for 'lettering' on architectural and building drawings are legibility, uniformity, ease and rapidity in execution. All letters should be in capitals except where lower case letters are accepted in international usage for abbreviations. If sloping type is used, an inclination of approximately 75° is recommended (Figs. 5-9 to 5-13).

5.8 ENGINEERING DRAWING AND ARCHITECTURAL DRAWING WITH ARCHITECTURAL STYLE

It is interesting to see the difference in the drawing prepared by a mechanical draftsman for a part of any machine and the drawing prepared by an architect for a building. Drawings of different architects are also prepared with what is known as 'different style in draftsmanship'. Pure line work and lettering is also done by a typical style giving 'professional touch' to the drawing. In order to acquire this pleasing style with ease and speed, one has to strive hard. An architect is supposed to draw free-hand drawing and geometrical drawings. Plans, elevations, and details are first drawn on a graph paper, or tracing paper, or an ordinary paper. This gives basic data for the imagination of the designer. Three-dimensional views are drawn and such a sketch helps in analising the elevations. Brain, eye and hand should simultaneously work on a graph paper to decide various features of the proposed structure. Joy of creation and pains for the same are experienced by the architect from this sketching stage. Sketching work must be done systematically and hand must be trained for sketching. The following guidelines will be useful in drawing sketches:

(1) Sketching or freehand drawing is simply drawing without the use of drawing instruments.
(2) Well-dimensioned sketches are used for preparing working drawing; hence, sketches must be proportionate and show sufficient details.
(3) Appearance of the sketch improves with experience.
(4) H or B pencils, tracing paper, graph paper, eraser, and sand paper should be used. For preliminary line work 2 H pencil should be used and 2 B for darker accents.
(5) Draw different parallel, vertical, horizontal, and inclined lines with conical and chisel points.
(6) Draw lines perpendicular to each other; draw squares, rectangles thereafter. Divide the lines into number of required divisions by visual comparison.
(7) Draw inclined lines with different angles like 30°, 45°, 60°, etc.
(8) Sketch circles and curves.
(9) Maintain proportion in a sketch by comparing length, width, and height of the object.
(10) Important lines in a sketch should be bold and other lines should be thin.
(11) Sketch-book containing different types of masonry, joints in wood work, types of doors, windows, staircase, and roof work should be prepared. Sketches should be first drawn on the graph paper and then the same sketches should be drawn on drawing paper which will show improvement in the line work (Fig. 5-27).

Engineering Drawing and Architectural Drawing

The difference in these drawings can be noted easily. Maximum accuracy, uniform thickness of lines, lettering work with solid block type for easy reading are the main features of the engineering drawing, while architectural drawing shows 'artistic touch' in line work and lettering, by varying thickness of lines and types of lettering with what is known as 'architectural style'. Slight pressure is given at the beginning and ending of pencil lines to make them sharp and distinct. Architectural line work looks more pleasing by extending it slightly at corners. This also helps in taking correct dimensions. This extension should be about 2 mm. Over elaboration is a waste of time. The main aim of a drawing is to make clear the ideas of designer, as also to give data and guidelines for an estimate and execution of work.

Lettering with Architectural Style

Quality of a drawing depends upon the quality of lettering and line work. Lettering and dimensioning should be done rapidly and easily. It should be pleasing and uniformity must be maintained. In order to give a pleasing artistic touch to the drawing, different styles in lettering have been developed by different architects. Students should study these different styles, and develop suitable

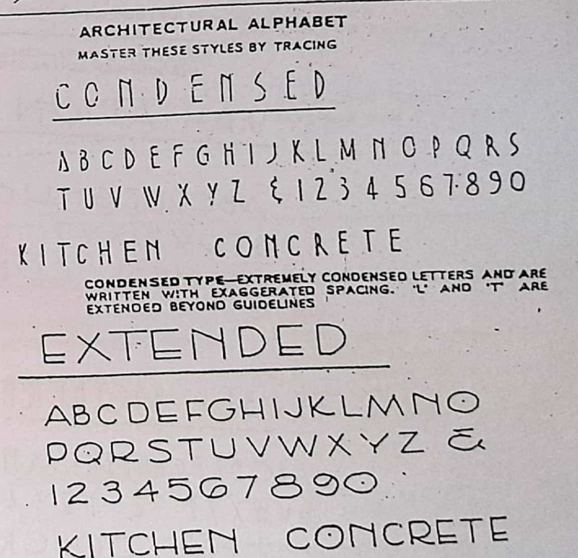


Fig. 5-28 EXTENDED TYPE—WIDE LETTERS, LITTLE SPACE AND LOW CENTRE STROKES

Figure 2-10 The proper spacing of letters and words

SPACING WITHIN WORDS SHOULD BE CLOSE.

SPACING BETWEEN WORDS SHOULD BE FAR.

THIS IS A PROPERLY SPACED SENTENCE.

THISISANIMPROPERLYSPACEDSENTENCE.

Figure 2-11 Spacing between words is important

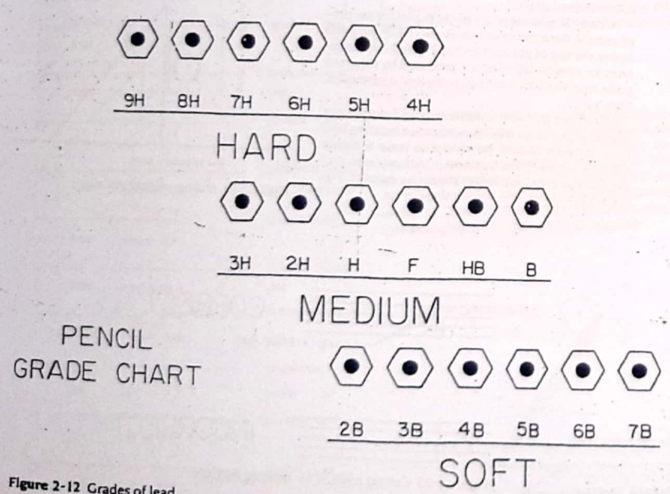


Figure 2-12 Grades of lead

TASK	LEAD
CONSTRUCTION LINES	3H, 2H
GUIDE LINES	3H, 2H
LETTERING	H, F, HB
DIMENSION LINES	2H, H
LEADERLINES	2H, H
HIDDEN LINES	2H, H
CROSSHATCHING LINES	2H, H
CENTERLINES	2H, H
PHANTOM LINES	2H, H
STITCH LINES	2H, H
LONG BREAK LINES	2H, H
VISIBLE LINES	H, F, HB
CUTTING PLANE LINES	H, F, HB
EXTENSION LINES	2H, H
FREEHAND BREAK LINES	H, F, HB

Figure 2-13 Lead-lines chart

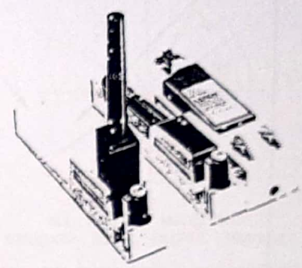


Figure 2-14 Modern technical pens (Courtesy Keuffel & Esser Co.)

and fast. Some drafters never reach this goal. Those who do, reach it through constant practice, coupled with continual efforts to improve.

Freehand Lettering Techniques

Freehand lettering techniques are learned by knowing what grades of lead to use, how to make the basic lettering strokes, and how to use guidelines; and by constantly practicing and trying to improve.

Figure 2-12 catagorizes the various grades of lead available to drafters. Figure 2-13 matches the lead grades with typical line styles. The actual choice of lead for a given situation in technical drawing is up to the user. The personal preference of one technician will differ from that of another. The specifications set forth in Figure 2-13 should be viewed as guidelines, rather than hard-and-fast rules.

Lettering in ink has been greatly simplified in recent years. Old-fashioned tools, such as adjustable nib ruling pens and speedball pens, have been replaced by the less cumbersome, easier-to-use technical pen, Figure 2-14. When lettering in ink, drafters still use light guidelines made with pencil lead. The actual lettering is done with the desired pen point size. Commonly used pen points for lettering in ink are sizes 0, 1, and 2, which are standard American sizes. In metrics, these point sizes represent line widths of 0.35 mm, 0.50 mm, and 0.60 mm.

All letters and numbers are created using six basic strokes, Figure 2-15. The first stroke is a single stroke made downward and to the right at approximately 45 degrees. The second stroke is made downward and to the left at approximately 45 degrees. The third stroke is vertical, and is made from top to bottom. Stroke number four is horizontal, and is made from left to right. The fifth stroke is a half-circular stroke to the left, made from top to bottom. The sixth stroke is a half-circular stroke to the right, made from top to bottom. All alphanumeric characters can be created using combinations of these six strokes. Figures 2-16 and 2-17 give examples of how these strokes are used for making selected characters.

Lettering Guidelines

Guidelines are a critical part of freehand lettering. Uniformity, neatness, and stability cannot be achieved without using guidelines. Guidelines can be made using a small plastic device called a lettering guide, Figure 2-18. The lettering guide shown is a device with a vertical side on the left, and a 68-degree inclined side on the right, the 2-to-5 incline needed for slanted lettering. In the center is a movable circular component containing three rows of variously spaced holes. The holes are used for the spacing of guidelines. A row of numbers on the bottom of the circular component allows drafters to set the guide for various heights of letters. The numbers – 2, 3, 4, 5, 6, 7, 8, and 10 – indicate 32nds of an inch. A setting of 4 means 4/32nds of an inch, or guidelines that will yield letters 1/8th of an inch in height.

A complete set of guidelines consists of three lines: a top line, a middle line, and a bottom line. Figure

THIS IS BLOCK FONT

THIS IS FAST FONT

THIS IS FUTURA FONT

THIS IS LEROY FONT

THIS IS OLD ENGLISH FONT

THIS IS RIVERQ FONT

THIS IS TIMES FONT

THIS IS HELVET FONT

BAUSCH & LOMB FONTS

Figure 2-2 Sample lettering fonts (*Courtesy Bausch & Lomb, Inc.*)

SINGLE-STROKE GOTHIC

LETTERING SAMPLE

Figure 2-3 Single-stroke Gothic lettering

UPPERCASE GOTHIC

lowercase Gothic

Figure 2-4 Uppercase and lowercase Gothic lettering

EXTENDED VARIATION

CONDENSED VARIATION

Figure 2-5 Extended and condensed variations of Gothic lettering

SAMPLE OF INCLINED LETTERING

Figure 2-6 Inclined Gothic lettering

SLOPPY LETTERING IS DIFFICULT TO READ

Figure 2-7 Sloppy lettering is difficult to read

Characteristics of Good Lettering

Good freehand lettering, regardless of whether it is uppercase or lowercase, condensed or extended or vertical or inclined, must have certain characteristics. These requisites include neatness, uniformity, stability, proper spacing, and speed.

Neat lettering is important so that the information being conveyed can be easily read. Few things detract from the appearance and quality of a technical drawing more than sloppy lettering, Figure 2-7.

For uniformity, all letters should be the same in height, proportion, and inclination. A necessary tactic for maintaining uniformity is the use of guidelines, Figure 2-8. The customary heights of characters in technical drawing are 1/8" (6 mm) for regular text, and 3/16" (9 mm) for headings and titles.

The proper stability or balance of letters is an important characteristic in freehand lettering. Each letter should appear balanced and firmly positioned to the human eye. Top-heavy letters are not balanced because they appear about to topple over, Figure 2-9.

The proper spacing of letters and words is important, and it takes a lot of practice to accomplish. A good rule of thumb to follow in terms of spacing is to use close spacing within words, and far spacing between words, Figure 2-10. The proper positions of letters relative to one another in words is accomplished by spacing the letters in the word equally in the area, not by trying to equalize the spacing between letters. This becomes automatic if the drafter concentrates on the word being lettered, not on each letter. Another rule of thumb for spacing is to allow the width of one round letter, such as O, C, O or G, between words. Figure 2-11 illustrates how this type of spacing can make the lettering much easier to read.

In the modern drafting room, because time is money, speed in freehand lettering is critical. Typically, freehand lettering is one of the slowest, most time-consuming tasks drafters must perform. It takes many hours of practice to develop freehand lettering that is neat, uniform, balanced, properly spaced.

UNIFORMITY — GUIDELINES

Figure 2-8 Guidelines improve uniformity

BEFR382 TOP HEAVY

BEFR382 CORRECT FORM

Figure 2-9 Top-heavy letters are not balanced

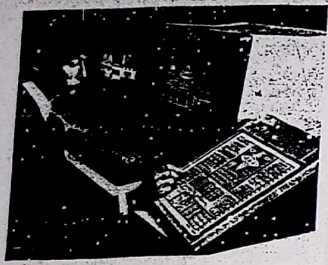


Figure 1-1 A computer-aided design system (*Courtesy Bausch & Lomb, Inc.*)

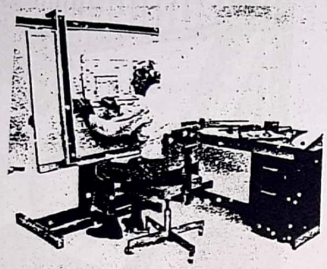


Figure 1-2 Drawing table and reference desk (*Courtesy Keuffel & Esser Co.*)

- India ink – black
- Pen cleaning solvent
- Lettering scriber
- Lettering template #100
- Lettering template #175
- Lettering template #290
- Compass adaptor for pen

Note that some specialized or expensive equipment is often furnished by the company.

CAD/CAM equipment is another drafting tool and is covered more fully in Chapters 10 and 11 in Section 3 of this text. For a very basic description, refer to Figure 1-1. The photo shows the following equipment, from left to right:

Printer – The printer is an output device used for producing printouts of alphanumeric data.

Workstation – (Text display, trackball, auxiliary keyboard, push-button menu board).

a. ***The text display***
   An output device for displaying user prompts which tell the user what to do and how to do it.

b. ***The trackball***
   A baseball-shaped input device used for creating horizontal, vertical, and diagonal lines, and for positioning the cursor.

c. ***Auxiliary keyboard***
   An input device for entering commands, text, annotation, and dimensions.

d. ***Push-button menu board***
   An input device for entering commands from a menu, and calling up stored data.

Graphics display – An ouput device for displaying drawings and other graphic data as they are being worked on.

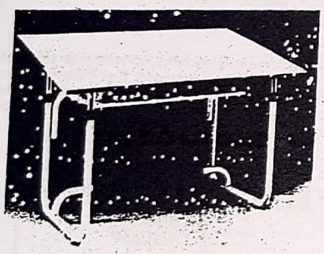


Figure 1-3 Small drawing table (*Courtesy Stacor Corp.*)

Digitizing table with puck – An input device used for entering graphic data into the system. Graphic data is converted to digital data (digitized) and entered into the system as X-Y coordinates.

Conventional Drafting Requisites

Drawing Table

Drawing tables are available in a variety of styles. Most are adjustable up and down, and can tilt to almost any angle from vertical 90° to horizontal. Figures 1-2 and 1-3.

Drawing Surface

The drawing surface, whether it is a drawing tabletop or drawing board, must be flat, smooth and large enough to accommodate the drawing and some drafting equipment. If a T-square is used on a drawing board, at least one edge of the board must be absolutely true. Most quality drafting boards have a metal edge to ensure against warpage and against which to hold the T-square securely.

Standard drafting boards range in size from small, 12" x 17" (30 cm x 43 cm), to large, 31" x 42" (78 cm x 105 cm). Standard drafting tabletops range in size from 31" x 42" (78 cm x 105 cm) to 37½" x 60" (94 cm x 150 cm).

Lighting It is important that the drawing surface be fully lighted without any shadows. Figure 1-4.

Top Cover The drafting board should have a top cover which protects the board surface and provides a perfect drawing surface. A good top cover actually seals over holes made by compass points, and it is easily cleaned. Figure 1-5.

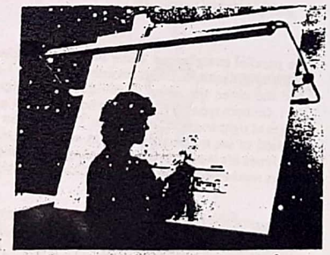


Figure 1-4 Fluorescent lamp for drawing surface (*Courtesy Waldmann Lighting Co.*)

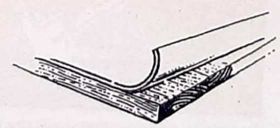


Figure 1-5 Drafting board top cover (*Courtesy Modern School Supplies, Inc.*)

Efficiency

To be fully efficient at drafting, all equipment must be clean, correctly adjusted and/or sharpened, and stored in a convenient location, ready for use at all times. It is good drafting practice to store each piece of equipment in a specific location and return it to its location after use. An organizer, such as the one shown in Figure 1-6, aids in keeping all equipment in its place.

Left-handed Drafters

Most drafting equipment is designed for the right-handed drafter, although left-handed types of drafting machines can be purchased. The T-square is simply placed on the right side of the drafting board by left-handed drafters, but everything else is right handed. The left-handed drafter has to adapt. The lettering scriber is especially difficult to manipulate.

T-Square

While T-squares are not used today in industry, they do provide a parallel straightedge for the beginning drafter. The T-square is used to draw horizontal lines. Draw lines only against the upper edge of the blade. Make sure the head is held securely against the left

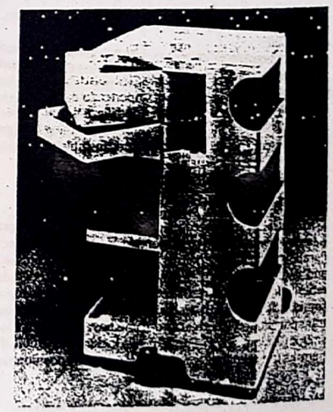


Figure 1-6 Equipment organizer (*Courtesy Stacor Corp.*)

The letters are designated by their heights. Stencils and letter-guides help to obtain uniformity, specially where different draftsmen are working on the same set of drawings. The sizes of letters and numerals for drawings are indicated in Table 5-1.

All letters and numerals shall be kept clear of dimension and other lines. Words may be underlined in a drawing where preferred.

Lettering shall be done on the drawing in such a manner that it may be read when the drawing is viewed from the bottom edge. Lettering, which is required to be written in a direction at right angles to the bottom edge of the drawing, shall be so written as to be read when viewed from the right hand edge of the drawing.

Symbols

Symbols for materials in section are shown by various types of hatching. Discretion should be used in adopting the spacing of hatching lines to the scale of drawing. It is recommended that when hatching is required to be done on tracing paper or cloth, a sheet of squared paper shall be placed underneath to maintain uniformity of spacing and direction of the hatching (Fig. 5-14).

Where large areas of section hatching are to be indicated, especially for such materials as concrete and plaster, it is recommended that a portion near the edge only be treated, the hatching gradually fading towards the centre.

Areas in section which are too thin for line sectioning, such as some metal

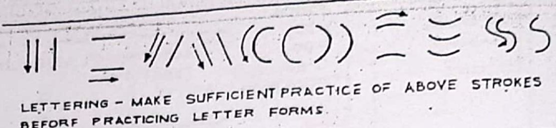
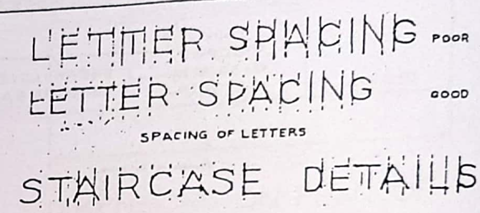


Fig. 5-10



NOTE: Use eye or optical judgement to provide uniform tone. Do not provide constant spacing. Each letter has a different profile and width. Avoid awkward appearance due to poor spacing

Fig. 5-11

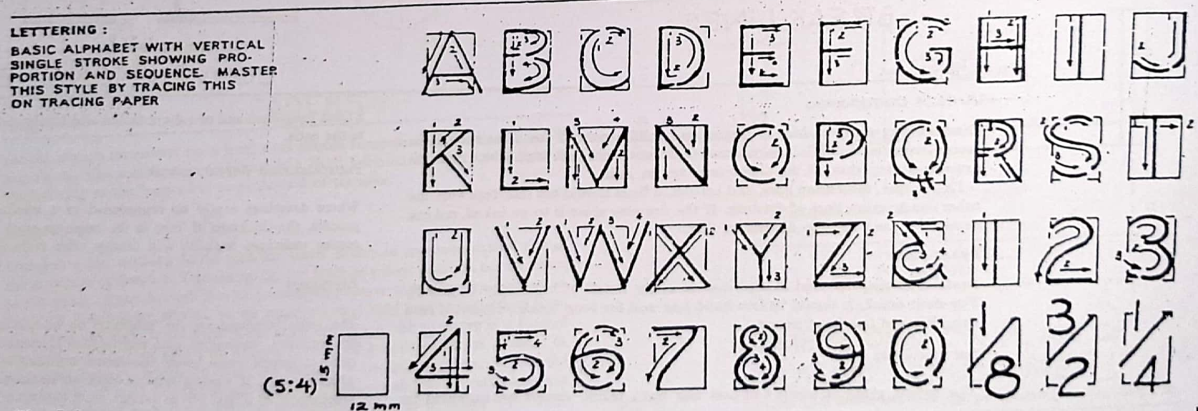


Fig. 5-9

sections, shall be blackened in solid, leaving a thin space between adjacent portions.

On a drawing showing existing and proposed work, the existing work may be distinguished from the new work by blackening in solid or by discretionary hatching.

Abbreviations

Abbreviations are generally used in drawing for the sake of clarity. A systematic notation of architectural and building terms is necessary for uniformity, and for avoiding confusion and ambiguity. I.S. 962-1967 gives standard list of abbreviations.

Graphical Symbols

Symbols are in constant use on small scale drawings and it is considered that time can be saved and confusion avoided, if a standard range of symbols is extensively used. Careful attention shall be given to the size of these symbols having due regard to the scale of the drawing. Wherever practicable, they shall be drawn to scale. Some symbols may have to be slightly enlarged for the purpose of clear indication (see I.S. 962–1967).

Windows and Doors

Generally, window openings shall be defined in elevation and of doors, screen and sliding windows on the plan (Fig. 5-15). For windows the point or apex of two lines crossing the ventilator or casement indicates the hinged side.

Doors of different types like (1) single shutter, (2) double shutter, (3) sliding, (4) folding, (5) revolving, etc. are shown by the graphical symbols. The direction in which the shutter of the door will swing should be shown clearly in the plan.

Service Pipes

Identification letters shall be used to denote the service. For example, we can use (1) Air-A, (2) Drainage-D, (3) Electricity-E, (4) Fire service-F, (5) Gas-G, (6) Oil-O, (7) Refrigeration-R, (8) Steam-S, (9) Water-W, etc. and a note shall be given in drawing about the letters used.

Scales

For the preparation of submission and working drawings, the following scales shall be used. Other scales for the preparation of different types of drawings are given in I.S. 962–1967.

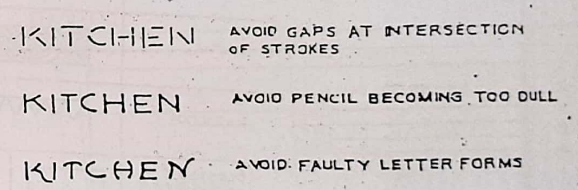
1 : 200 (5 mm = 1 m) For submission and working drawings;
1 : 100 (10 mm = 1 m) plans, elevation and sections
1 : 50 (20 mm = 1 m)
1 : 20 (50 mm = 1 m) For large scale drawings and general
1 : 10 (100 mm = 1 m) drawings
1 : 10 (100 mm = 1 m)
1 : 5 (200 mm = 1 m) For enlarged details
1 : 2 (500 mm = 1 m)
1 : 1 (full size)

5.2 COMPOSITION OF DRAWINGS—REQUIREMENT OF SUBMISSION, WORKING AND DETAILED DRAWINGS

Submission drawings are prepared with the scale 10 mm = 1 m. Hence, all the required views shall be arranged on one sheet conveniently. Before starting

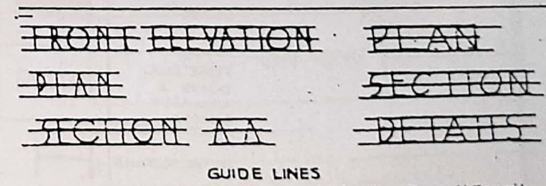
Table 5-1 Sizes of Letters and Numerals for Drawings

S. No.	Purpose	Size of lettering and numerals (mm)
(1)	Main Title and Drawing No.	6, 8, 10, and 12
(2)	Sub-Titles and Headings	3, 4, 5, and 6
(3)	Notes, Schedules, Materials, Dimensions	2, 3, 4, and 5



Note: Rotate pencil continuously between strokes to keep uniform pencil point.

Fig. 5-12



Note: Use guidelines to maintain straight lettering. Draw guidelines with a sharp pencil. Do not rub these lines. Guidelines may be two or more.

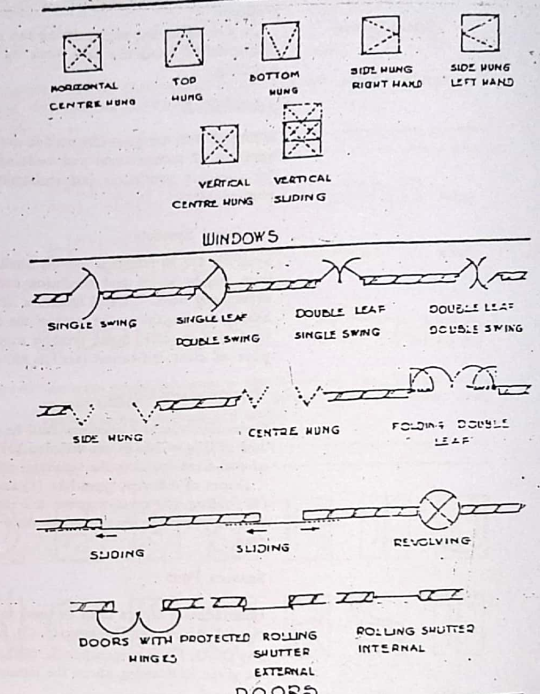
Fig. 5-13

MATERIAL	SYMBOL		COLOUR
BRICK			VERMILION
CONCRETE			HOOKERS GREEN
NATURAL OR RECONSTRUCTED STONE			COBALT BLUE
PARTITION BLOCKS			PAYNES GREY
WOOD			BURNT SIENNA
EARTH			SEPIA
HARDCORE			YELLOW OCHRE OR CHROME YELLOW
PLASTER & PLASTER PRODUCTS		APPLICABLE ONLY TO LARGE SCALES	GREEN
GLASS			BLUE
FIBRE BLDG. BOARD & INSULATION BOARDS			SEPIA
METAL SECTIONS			BLACK

SYMBOLS FOR MATERIALS IN SECTIONS

Fig. 5-14

GRAPHICAL SYMBOLS FOR DOORS AND WINDOWS

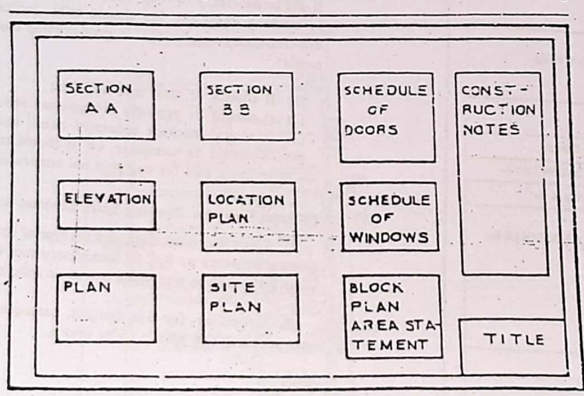


NOTE: WINDOW'S. NORMALLY POINT OF APEX OF TWO LINES CROSSING THE VENTILATOR OF CASEMENT INDICATES THE HINGED SIDE. IN CASE OF CENTRE HUNG WINDOWS THE LOCATION OF HINGES WOULD BE INDICATED BY DASHES. ALL THESE ARE DRAWN AS THE WINDOWS WOULD BE VIEWED FROM OUTSIDE THE BUILDING

Fig. 5-15

drawing work, rough sketch should be prepared taking into consideration, area required for plans, elevation, sections, schedules and site plan. The arrangement of all views should be done in an attractive way by providing uniform clear margin around these views and notes should be written conveniently in the remaining area. Students should develop an ability to 'compose the sheet' with proper balance in the views and giving a sense of continuity in a logical sense throughout the sheet (vide Fig. 5-16). Eye must move from one view to the other. Horizontal or vertical combinations will be pleasing depending upon the shape of the plan. Only the necessary information required for the construction should be given in the working drawings. Scaled measurements should agree with the written figures of dimensions. Working drawings should be related to the specifications. Information regarding design, locations, and dimensions is given by the working drawings, whereas information regarding quality of materials and workmanship is given by the specifications. Other details give information regarding shape of the various parts, method of joints, etc.

Plans, elevations, sections and details should be arranged in the minimum number of drawings. It may not always be possible to show all the above views and details in one drawing sheet. For working drawings, it will be convenient to group all plans separately from elevations and sections. Size of the drawing should be uniform and convenient to handle on the site. Several plans, elevations and sections should be given proper titles and cross references to each other. Notes should be minimum. A simple rule on the use of note is to ask first if the drawing conveys the designer's intent. If it is not, can the drawing then be improved or clarified still in a better way? If the drawing cannot be improved or clarified, then and then only the note is required. Schedule for columns, footings, windows, doors, hardware, room finishes, plumbing fixtures, lighting fixtures, etc. should be given. Choose convenient type of title block vide Figs. 5.17, 5.18 and 5.19.



COMPOSITION OF SUBMISSION DRAWING

NOTE: (1) Find the size of each block required for plan elevation, sections, with the scale 1 : 100, i.e. 10 mm = 1 m

(2) Arrange all views, schedules, etc. in a pleasant manner and using minimum size of tracing paper.

Fig. 5–16

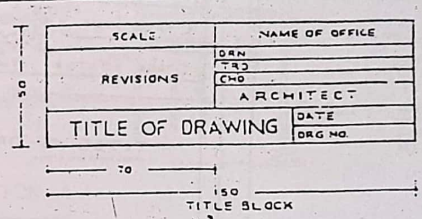
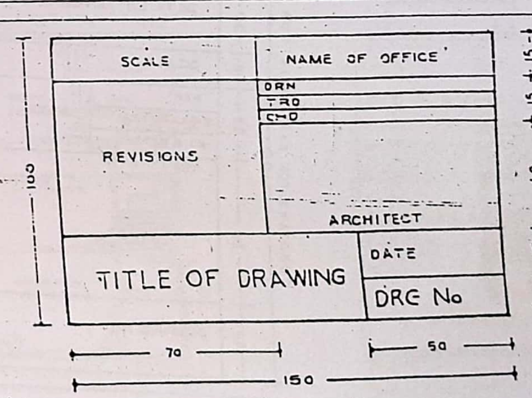


Fig. 5–17



DRN– DRAWING BY
TRD– TRACED BY
CHD–CHECKED BY

TITLE BLOCK

Fig. 5–18

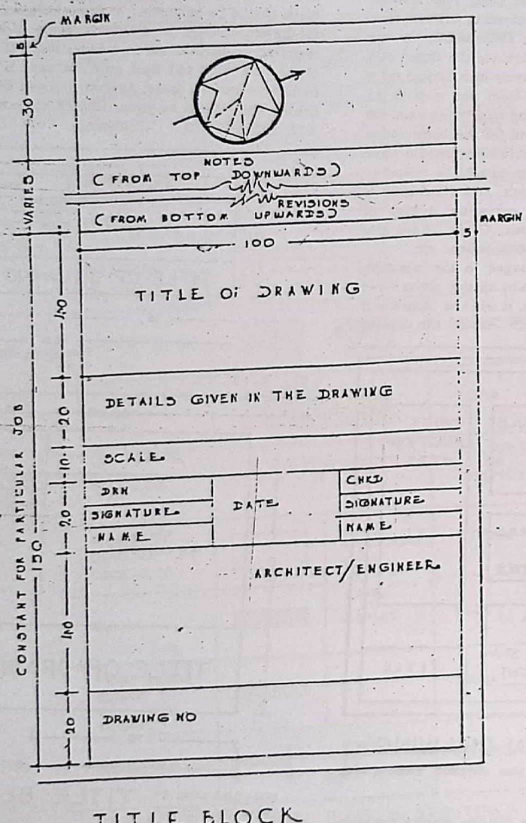


Fig. 5-19

5.3 PREPARING SUBMISSION AND WORKING DRAWINGS

Presentation drawings consisting of perspective, plan with furniture arrangement and layout of garden is prepared for the approval of the client. Once they are approved, the architect gives instructions, all sketches, and notes to the draftsman for preparing submission drawings. These drawings are drawn to the scale 10 mm = 1 m and include (1) different floor plans, (2) elevations, (3) sections, (4) location plan, (5) site plan, (6) schedule of doors, and windows, (7) area statement and block plan, and (8) construction notes. After these plans are approved by the sanctioning authority, working drawings are prepared to the scale of 20 mm = 1 m or even to a larger scale. These drawings include (1) different floor plans, (2) foundation plans, (3) all elevations, (4) typical sections, (5) staircase details, (6) doors and windows details, (7) canopy and chajja details, (8) grill work for windows, (9) entrance gates, and (10) electrical connection plans, etc. according to the requirement of the building.

The steps necessary for the preparation of the above drawings are explained below. It is necessary for the draftsman to study carefully line plan, sketches for elevations, perspective, and construction notes before the drawing work is taken on hand. Then he should prepare the sketch showing the composition of views for submission drawings, considering the area required for each view. It will be necessary to refer handbooks of construction while drawing the details in working drawings. He should refer Indian Standard Specifications while drawing both the drawings. A good drawing should satisfy the following requirements:

(1) It should be clear and accurate;
(2) It should be properly dimensioned with distinct figures;
(3) It should contain necessary notes; and
(4) It should be complete, i.e. it should contain all data for preparing an estimate and for carrying out construction.

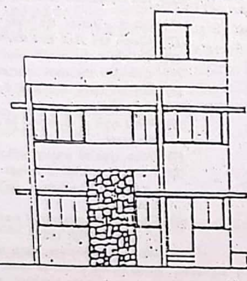
Different Steps for Drawing Plan, Elevation and Section

(1) Study line plan, data and the type of construction, i.e. whether it is a load bearing structure or R.C.C. framed structure, centre lines are shown and dimensions for columns and walls are given from centre to centre.

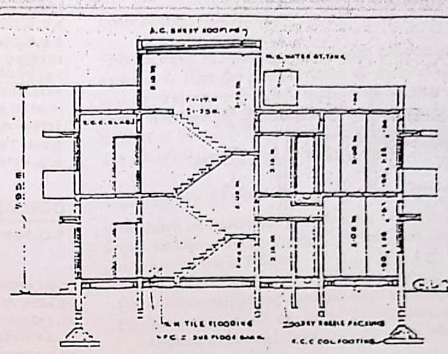
(2) Draw lines for side margins, name-plate or title, and rectangle or square area in which the plan is to be drawn.

Plan

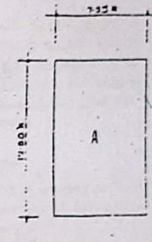
(1) Load bearing structure: Start from any convenient corner, preferably left hand bottom corner. Draw all exterior wall lines as light lines using 3 H or 4 H pencil. Thickness of the wall should be drawn as per given data. Study clear internal dimensions of the rooms and draw lines for internal walls with the given thickness. Draw complete lines through windows and door openings. Show plinth offset.



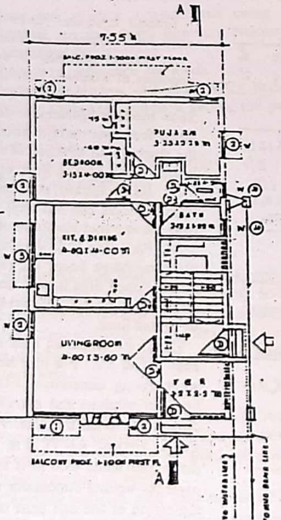
FRONT ELEVATION



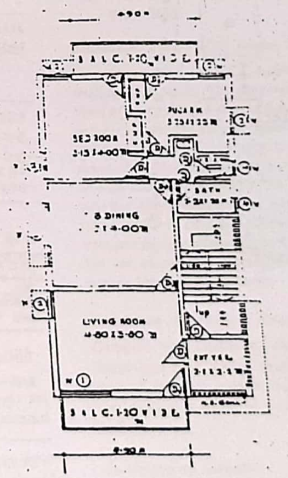
SECTION A-A



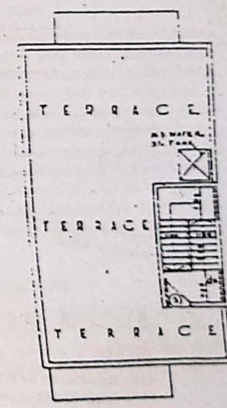
AREA KEY PLAN
A-7.55 x 12.50 =
AREA - 94.37 m²



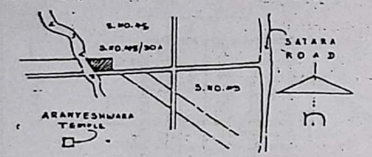
GROUND FLOOR PLAN



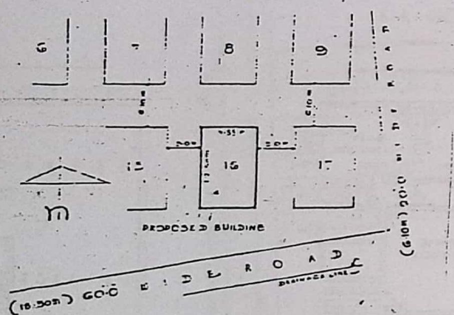
FIRST FLOOR PLAN



TERRACE FLOOR PLAN



SITE PLAN
SCALE: 1:660:6



BLOCK PLAN

NOTE

PLOT BOUNDARY SHOWN IN RED.
PROPOSED WORK SHOWN IN PINK.
MUN. WATER LINE SHOWN IN GREEN.
MUN. DRAIN. LINE SHOWN IN YELLOW.

BRIEF SPECIFICATIONS.

FOUNDATION UPTO HARD STRATA:
R.C.C. FRAME STRUCTURE.
R.C.C. STAIRCASE.
EXTERNAL WALLS - 20M. THICK. INT. WALLS - 15 TH
T.W. DOORS AND WINDOWS.
SANDFACED PLASTER EXTERNALLY.
INTERNAL PLASTER IN CEMENT MORTAR.
MARBLE MOSAIC TILE FLOORING.
INDIAN TYPE W.C. PAN.
M.S. WATER STORAGE TANK.

SCHEDULE OF DOORS & WINDOWS

T.W. DOORS. D - 1.10 X 2.15
D_1 - 0.90 X 2.15
D_2 - 0.75 X 2.15.
T.W. WINDOWS.
W1. 1.85 X 1.22 SILL AT .90 FROM FINISHED FL.
W2. 1.10 X 1.22 " .90 " "
W3. 2.45 X 0.60 " 1.50 " "
W4. 0.60 X 0.90 " 1.20 " "

AREA STATEMENT.

AREA OF THE PLINTH : 94.37 m^2
PROPOSED BUILT UP : 94.37 m^2

PROPOSED RESIDENTIAL BUILDING AT S.NO. 8/-30A, ON PLINTH NO. 16. PARWATI. ARUNA SAHAKARI GRIHA RACHANA SANSTHA. LTD.

SCALE 1:100

DRN.	DATE	CHKD
SIGNATURE		SIGNATURE
NAME	2017/72	NAME

BUILDWELL CONSTRUCTIONS
ENGINEERS & CONTRACTORS.
8-D DECCAN GYMK.
POONA - 4.

DRAWING NO. 25/C

READING EXERCISE (FIG. 5-20)

SUBMISSION DRAWING

Study the submission drawing prepared for approval:

(1) Make a list of the plans and other views shown in the drawing.
(2) Check the plan and section as per check-list given on page 78.
(3) Calculate the carpet area for the ground floor and first floor plan.
(4) Calculate the total area occupied by the doors and windows.
(5) Suggest suitable type of flooring for different rooms and work out the quantities of the same.
(6) What type of dado will be suitable for W.C. and bath? Work out the quantities of the same.
(7) What type of waterproofing treatment will you suggest for the terrace?
(8) Prepare detailed drawings for:
(*i*) doors, (*ii*) windows, (*iii*) balcony railing, (*iv*) staircase, (*v*) parapet, and (*vi*) handrail.
(9) Find out the quantity of water to be stored for two tenements and suggest suitable size of water storage tank.
(10) State the conditions which necessitates installation of pumping arrangement to store water in the overhead tank.
(11) Suggest suitable furniture arrangements for living and bedrooms.
(12) Study the plan with reference to the principles of planning. Can you suggest some changes from the functional planning point of view?

Framed structure: Draw centre line for all the walls and columns. Show walls and columns as per their thickness and size.

(2) Locate positions of doors and windows with centre lines. For fixing positions of windows, refer to elevations. If elevations are not finalized, then draw light lines for windows, and finalize their position after drawing elevation. Show masonry openings for doors as per given data. Study the movement in the house from one room to another room or passage through the door and show the shutter with direction of opening by symbol. All exterior doors must open inside. Erase lines in door opening.

(3) Draw kitchen otta, sink, built-in cupboards, W.C. pan, wash basin, staircase, front and rear steps. Chajjas on south, east and west side, and canopy over the entrance should be shown by dotted lines.

(4) Next step is to show the roof. Truss, ridge, valley and hip rafters, eave plate and barge board and roof projection away from the wall should be shown by the dotted lines in the case of pitch roof. In the case of R.C.C., beams, and slab projection should be shown by the dotted lines. R.C.C. loft should be shown by dotted lines.

(5) Draw extension lines and dimension lines on all sides as shown in the Figs. 5.6 & 5.7. For load bearing structure, plinth offset should be considered while giving dimensions. For framed structure, centre to centre dimension between columns and overall dimensions should be shown. Write clear room dimensions as per line plan. First dimension is the horizontal and second dimension is vertical, e.g. (3.50 m × 4.00 m). In this case 3.5 m is the horizontal dimension while 4.00 m is the vertical one. Take care while choosing correct place for writing dimensions so that they are legible and not crowded. Overall dimension of the side must tally with the sum of a dimensions in series. In case

of masonry structures, i.e. load bearing structures, give dimensions from wall surface to the opening for door or window. In case of framed structure, these dimensions should be from the centre of the column or the door or the window.

(6) Draw a line of 2 mm height, roughly at the centre of the room for titles. Write down room titles. Draw lines for notes wherever required and write notes in a systematic way as shown (Fig. 5-20). Write and complete the schedule for doors, windows, and floor finishes separately.

(7) Complete the hatching work by symbols for stone masonry, brick masonry, and concrete work.

Check List

Check your plan with the following check list for any omission—

(a) *Dimensions* : (1) Outside walls
(2) Rooms, passage, etc.
(3) Window and door centre lines
(4) Thickness of stone and brick masonry
(5) Arrow heads for dimension lines
(b) Door and window symbols and swing
(c) Staircase, up and down direction. Numbers for step 1, 2, 3, 4, etc. Dimensions for landings.
(d) Floor level difference by levels.
(e) Symbols for kitchen, otta, sink, W.C.; bath details—wash basin, tub, etc.
(f) Built-in cupboards, shutters, swings, rod position for clothes.
(g) Roof lines.
(h) Section lines.
(i) Titles for rooms and other areas.
(j) Floor finish schedule.
(k) Floor plan, title, scale.

First Floor Plan

In the case of the load bearing structures, wall thickness is less for first floor than for ground floor. In the case of R.C.C. frame structures, column sizes are normally reduced for the first and other top floors. While drawing first floor and other plans, these changes, if any, should be shown. If the building is a multi-storeyed structure, then only the ground floor plan and a typical floor plan should be drawn.

(1) Draw all external walls and internal walls.
(2) Draw centre lines of doors and windows. Mostly they will be as per ground floor plan. Show width of doors and windows, shutters and their direction of opening.
(3) Complete the plan with staircase as per instructions for the ground floor plan. In the case of structure of more than one storey, roof plan should be shown in the floor plan of the topmost floor.

Foundation Plan

Load Bearing Structure

Find the depth of foundation required as per trial pit results. It should rest on hard strata. Find the required width of the foundation trench as per thumb rules for masonry walls. Draw centre lines for all walls. Show the width of the trench, with internal and external dimensions, as also diagonals for checking at the time of line out. Check all the dimensions as accuracy of further construction entirely depends upon correct foundation plan.

R.C.C. Framed Structure

If the depth of foundation is more than 1–1.5 m, and if it is decided to have framed structure though the depth is less, then the preparation of foundation plan is carried out as follows:

(1) Draw centre lines of columns, walls and mark the distance between them;
(2) Show the size of the pit to be excavated for the columns. Structural engineer's drawings should be referred to while drawing sizes of pits and columns; and
(3) Number all columns as per structural engineer's drawings. (vide IS: 962–1967).

Foundation Plan—RCC Frame Structure (Fig. 5-21)

Foundation plan for RCC structure gives details regarding column positions, footings and walls. The accompanying foundation plan shows sizes and locations of columns and sizes of footings. The accuracy of the construction entirely depends upon the correct foundation plan and correct line out, and hence, in order to ensure this accuracy, the foundation plan is prepared. The new method shows 0.00 co-ordinates for top left hand corner of the wall. With reference to this co-ordinate, chainages for centres of various columns on north and west side are given. In the same way, assuming 0.00 chainages for bottom left hand corner and top right hand corner, chainage for centres for columns are given for columns on the south and east side. Note that the chainages for the end points are the same. This system ensures correct length, width of the building and correct location of columns.

Foundation Plan—RCC Framed Structure (Fig. 5-37)

Compare both foundation plans given in Fig. 5-21 and Fig. 5-37. In Fig. 5-37, foundation plan shows distance between centres of two columns. With this method, high accuracy is required in giving line-out, if the length and width of the building is more. In such a case, the method shown in Fig. 5-21 should be preferred.

Numbering of Columns

Column on the left hand top corner is marked as (1) and then the numbers are

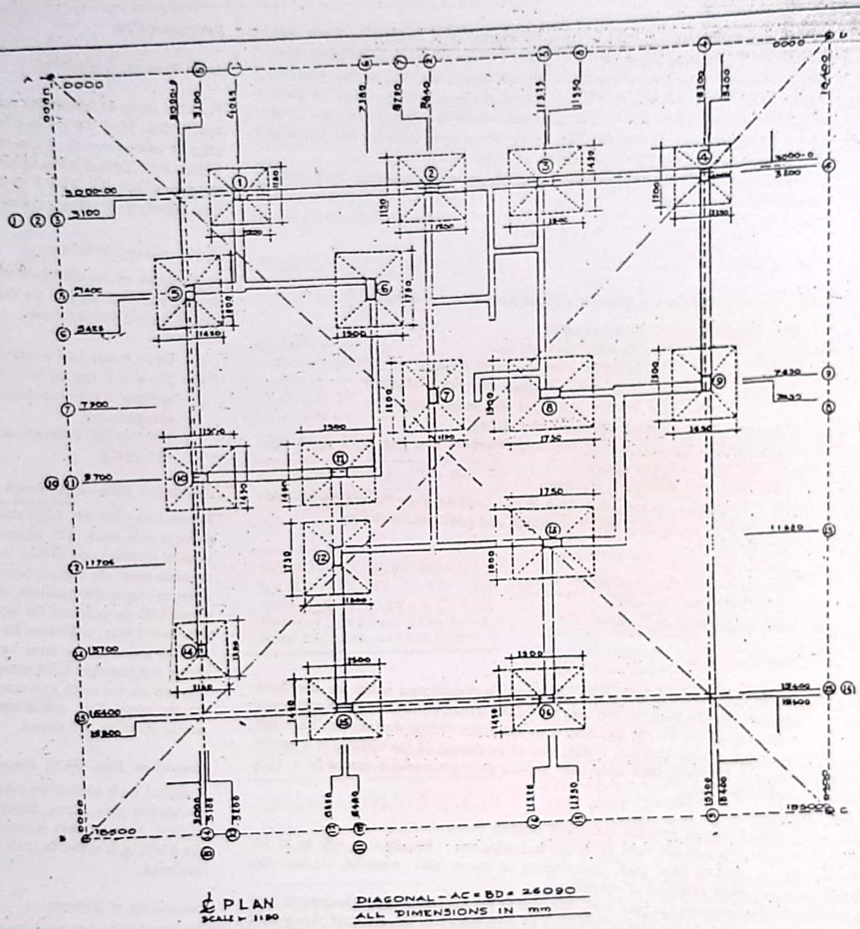


Fig. 5-21

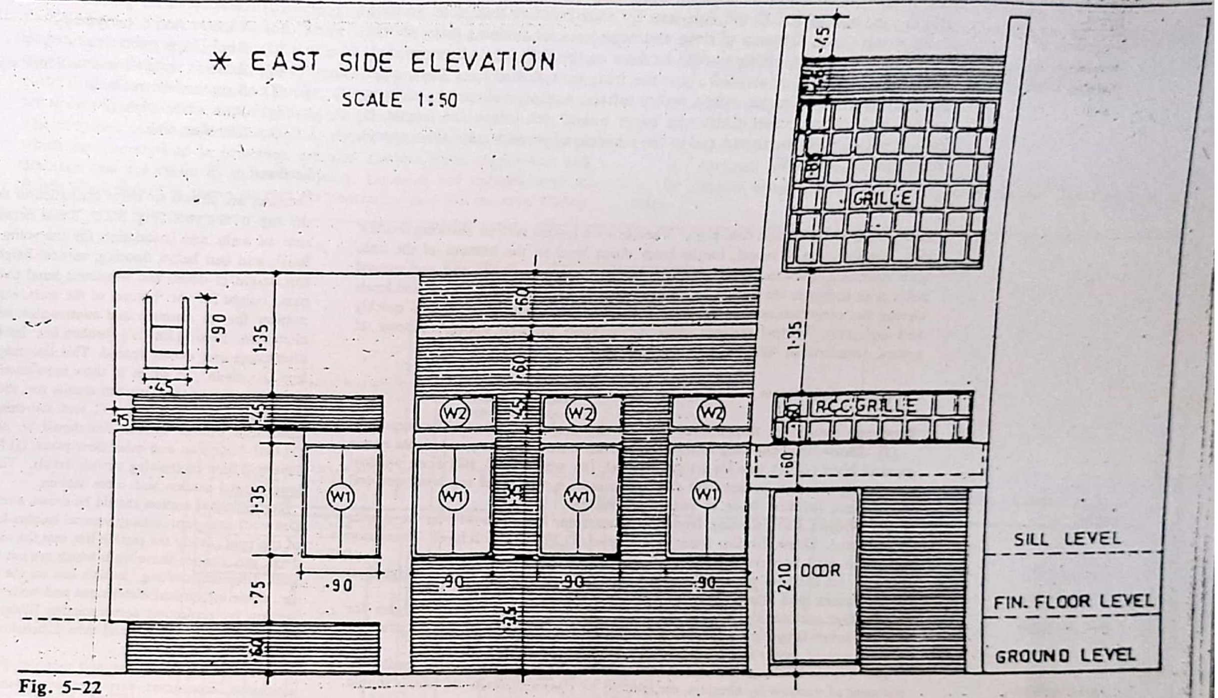


Fig. 5–22

given to the columns on the right hand 1 to 4. Again starting from the left hand side, numbers 5, 6, 7, 8, 9, etc. are given.

Dimensions

Dimensions should preferably be given in millimetres to avoid confusion due to incorrect placing of decimal point.

Roof Plan

Roof may be (1) flat roof, such as, R.C.C. slab (2) pitch roof with different types of roof covering—Mangalore tiles, country tiles, asbestos, or G.I. sheets. As per given data, show the details of the roof plan. Refer to roof Tables given in Chapter 7 for finding the sizes of various members of trusses, purlins, rafters, etc. according to the span of the truss.

(1) R.C.C. slab, if projecting from the wall, should be shown.

(2) If the staircase room and parapet are to be shown, draw details with reference to other plans.

(3) Show positions of R.C.C. beams by dotted lines.

(4) Show position of mild steel, R.C.C., or other precast tank's for water storage and the method of support. This is generally provided over W.C. or

bath. It may be combined or separate depending upon number of users.

(5) In the case of R.C.C. flat slab, note for waterproofing treatment, position of rain water pipes, direction of slope and ridge lines for draining water should be provided. Type of finishing work to be done on the slab should be mentioned.

(6) In the case of pitch roof, show the truss by a dotted line. Show other members such as, ridge, hip rafters, valley rafters, purlins, wall plates, common rafters, jack rafters, eaves plates and barge board, etc. Mark the lengths of each member, total length and size in the schedule of wood work. Give overall dimensions of the roof.

Elevations

Study the floor plans and roof plan. Then draw a typical section showing window sills, window, jamb, reveal, height from floor level to the bottom of the slab, slab thickness, parapet height, roof projection, canopy, chajja and give vertical heights as shown in the Fig. 5.22. These heights show different stages and levels during the construction and the same are useful for drawing elevations quickly and correctly. Typical sections may be passing through doors, windows of rooms, window of W.C. and bath. and staircase.

Drawing Elevation

Elevation should be drawn over the plan by projecting lines. The steps are:

(1) Draw lines showing different levels as below at proper heights above ground level (G.L.) line for (*i*) plinth level, (*ii*) window sill, (*iii*) door, window top level, (*iv*) slab bottom, (*v*) slab thickness, i.e. first floor top level, and (*vi*) other lines for first floor as per requirements.

(2) Project lines starting from left hand side. First line will be for plinth, if provided. Draw this line from ground level (G.L.) to plinth level. Then draw lines for wall corners, windows, doors, steps, chajjas, etc.

(3) From the roof plan, draw projections for roof and show top of ridge tiles, eaves plates, and barge boards.

(4) Dimensions on elevations should be minimum. Vertical heights for various levels from outside should be shown and the total height of the structure above ground level should be mentioned.

(5) Frame thickness for doors and windows, and lines showing ventilators, division of window by shutters, etc. should be shown. Details of panels should be shown in detailed drawing and not in elevation.

(6) Simple notes indicating exterior materials of finish for walls and steps should be provided.

(7) In the case of pitch roof, slope should be shown by parallel lines with varying distance giving the effect of inclination and shade.

(8) If the ground is sloping then it should be shown with proper gradient in all elevations. The ground line showing the finished level after filling should be shown with a note. Refer contour map of the plot for showing different levels.

Elevation provides a view of the building from ground to the top of the roof. Check this elevation view with reference to the following points:

(a) All vertical dimensions from the outside
(b) Grade line for ground
(c) Window and door symbols
(d) Roof slope indication
(e) Exterior material conventional signs and notes
(f) Steps and flower beds
(g) Rain water pipes
(h) Elevation title

Sections

Sections are drawn to show construction details from foundation bed level to the top of the roof (Fig. 5-23). These details give information regarding thickness of walls and foundation for the walls, slab thickness, flooring details for finish and bed below flooring, vertical heights above the floor for window sill, top height of doors and windows; lintel thickness, chajja project on and thickness, height for the bottom of the truss. etc. In short, a section gives all information for an estimate and construction which is not available on plan and elevation. Section line is a broken line having one long and two short dashes alternately and evenly spaced. This line may be straight or offset. Section line is given an offset to show more details. This should be drawn with due consideration to show interior details and should pass through doors, windows, cupboards, bathroom, W. C. and staircase. It should cut the roof to give maximum details. Section line should be shown on (1) ground floor plan, (2) first floor plan and other floor plans, (3) foundation plan, and (4) roof plan. This will help in showing correct details. There are two types of sections, viz. longitudinal section and cross section.

Longitudinal section should be drawn above the elevation by projecting lines. Draw all lines representing vertical heights from foundation bed level to the top of the roof. Study the section line and the objects it will cut, like window, chajja, door, etc. Project those walls which are cut by the section line. Use divider and take dimensions along section line on the plan. Show windows, doors, lintels, etc. Give all vertical dimensions and write notes. In the same way, draw cross-section by projecting corresponding horizontal lines for different heights used for longitudinal section and take dimensions by divider along the cross-section line on the plan.

Check plans, elevations and sections. Place yourself in the position of the estimator, contractor, carpenter, supervisor, mason and plumber. Make a list of details to be drawn to enlarged scale to clear ideas regarding joinery and other details with dimensions.

5.4 SITE PLAN

The plan of the plot showing the dimensions and shape of the boundary, issued by the City Survey Office, is supposed to be the essential and important document at the time of submission of the plans for approval.

Site plan is drawn using the above plan with dimensions. The architect studies the plan of the plot at the time of preparing the line plan, showing the proposed building in the plot and marginal distances from all sides. Site plan should show the proposed building, water supply and drainage connections, inspection chambers, man holes on the adjoining road, position of entrance gate, compound wall, north direction, survey number of the plot and the surrounding plots, drive ways, walk ways, and garage. Contour lines of the existing ground are shown by dotted lines and after filling the plot they are shown by full lines. The proposed building area is hatched or shown by red outline. Existing trees which are proposed to be preserved are also shown. Water supply line and drainage line are shown by different colours. Location and reduced level of Bench Mark should be shown, so that the contractor may use the same during construction. Check site plan with reference to the following essential points:

(1) All dimensions and marginal distances
(2) Survey numbers of the plot and surrounding plots
(3) North direction
(4) Steps and porch
(5) Contours
(6) Trees to be removed and to be kept
(7) Reduced level of bench mark
(8) Service connections—water supply and drainage (See Figs. 5-34 to 5-38).

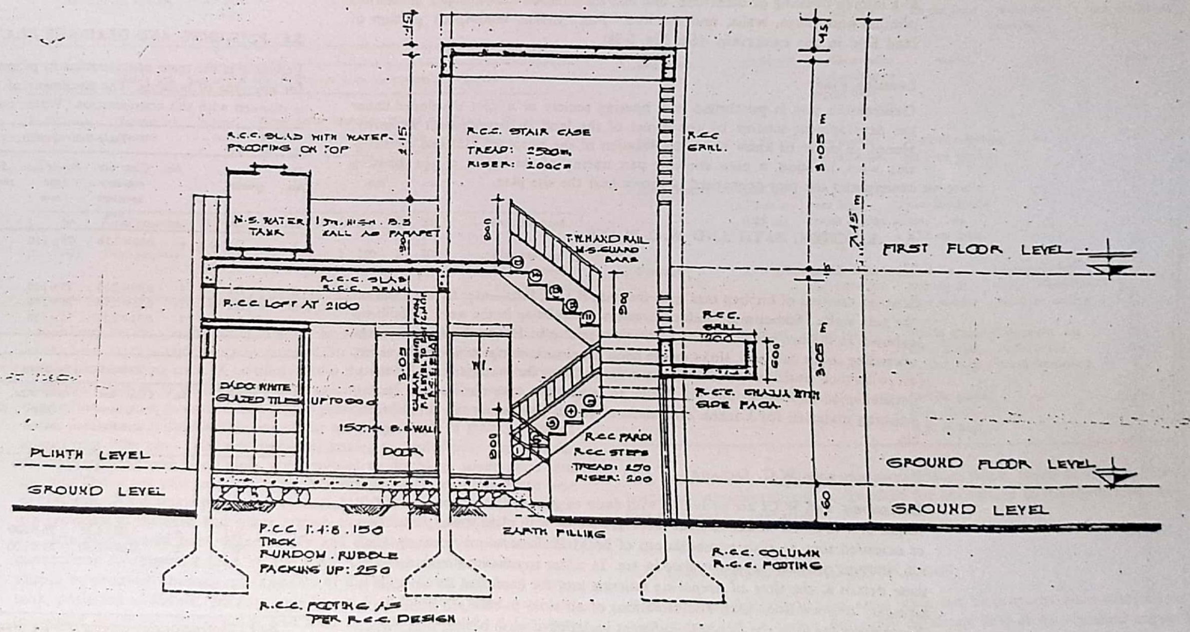


Fig. 5–23

*SECTION THRO': A B
• SCALE: 1:50

Block Plan

Block plan along with area statement is drawn near the site plan. It shows the area of the plot, area allowed to be built, and area proposed to be built. While calculating plinth area and area required for steps, porch and balcony is not taken into consideration. The meaning of "Built-up area" as given by the act states that it shall mean any area covered with a structure or structures of any sort either with plinth or otherwise. The area covered by open ottas, steps, fountains, compound walls, weather sheds, portions not more than 3 metres × 6 metres covered corridors connecting the main and subsidiary buildings and the like shall not be counted in calculating the built-up area. "Building" includes a house, out-house, stable shed, hut and other enclosure or structure whether of masonry, bricks, wood, mud, metal, or of any other material wherever used as a human dwelling or otherwise, and also includes verandah, fixed platforms, plinths, door steps, walls, and the like. "Plot" means continuous portion of land held in one ownership (See Fig. 5-38).

Location Plan

Generally, a plot is purchased in a housing society or a plot developed under the development scheme by the owner of the land or development authority. Hence, in order to know the exact location of the proposed plot and construction work location, a plan showing part tracing of the layout of the housing society and the plot concerned is shown near the site plan.

5.5 KITCHEN, BATH AND W.C. PLANS

KITCHEN DETAILS

Kitchen consists of kitchen otta with the sink, R.C.C. lofts—over the otta and on the side walls. Sometimes, sub-contractors specializing in the work of built-up cabinets in kitchen are entrusted with this special job. Hence, detailed drawings according to the cabinets, sinks, range hood, store unit, refrigeration, dishwasher, etc. with their positions are drawn. In order to know the proposed requirements, detailed plan and elevations are drawn to large scale with dimensions, stating finishing materials for kitchen otta, dado of glazed tiles, water tap connections, etc.

BATHROOM AND W.C. DETAILS

Bathrooms and W.Cs are provided with dado of glazed tiles. It may be of full height or 1 m or 1.5 m above floor level. It may be with plain white glazed tiles or coloured tiles or even combinations of both. Bathroom may contain bath tub, shower, different taps, towel rods, etc. In order to take into consideration these details at the time of preparing estimate and for execution of work, it is necessary to draw floor plan and elevations of all sides to enlarged scale with proper notes for different finishes. Different varieties of wash basins, tiles, W.C. pans, showers and mirrors are coming into the market every year, and hence, owner should be consulted before finalizing these drawings, as the cost varies with each type of item.

Schedules

For doors, windows and grill work—Schedules for doors, windows, and grill work—R.C.C. or mild steel to give consolidated information to the estimator and contractor are given in Tables 5-2 to 5-5. The information is given as regards size, symbol, type, finish, etc.

The schedule *for materials and finish for rooms* gives the information regarding finish of floor, walls, and ceiling for all rooms. The details should be written in a tabular form. For bath and W.C., either detailed drawing is prepared showing elevations of all sides with details of dado or information is written in schedule as per convenience (Table 5-6).

5.6 PLUMBING AND DRAINAGE PLANS

Economy is the main consideration in planning plumbing and drainage system for any type of building. The placement of bathroom, W.C. and kitchen sink is planned with this consideration. Water connection may be for direct supply

Table 5-2. SCHEDULE FOR DOORS

Sr No.	Door symbol	No.	Clear size masonry openings mm	Frame size type mm	Shutter thickness mm	Finish oil paint-polish	Remarks
1	D	4	0.90×2.10	75×150	30	Oil paint	C.C.T.W., single shutter, panelled door as per drawing
2	D1	1	0.90×2.10	75×150	30	Oil paint	–do–
3	D2	1	0.75×2.10	75×150	30	Oil paint	–do–
4	D3	1	0.75×2.10	75×150	30	Oil paint	–do–

Table 5-3. SCHEDULE FOR WINDOWS

Sr. No.	Window	No.	Clear size masonry opening mm	Frame size, type mm	Shutter thickness mm	Finish polish oil paint	Remarks
1	W	3	1.50×1.35	75×100	25	Oil paint	C.C.T.W. partly and glazed partly panelled with MS grill as per drawing
2	W1	4	1.00×1.35	75×100	25	Oil paint	–do–
3	W2	2	0.60×0.60	75×100	25	Oil paint	C.C.T.W. with glass louvers and MS grill as per drawing

Note : Separate detailed drawing showing plan, section, elevation is necessary for different types of doors and windows.

Check this elevation view with

Table 5-4. SCHEDULE FOR FIXTURES AND FASTENINGS: DOOR

Sr. No.	Door symbol	Type of shutter	Hinges No.	Hinges Size mm	Tower bolts No.	Tower bolts Size mm	Handles No.	Handles Size mm	Aldrops No.	Aldrops Size mm	Tadpatti No.	Tadpatti Size mm	Remarks
1.	D	Single shutter	4	100	1	250	2	150	1	300	1	300	(1) Iron-oxidized
2.	D1	Double shutter	8	100	1	250	2	150	1	300	1	300	Fixtures to be
3.	D2	Double shutter	6	100	—	—	2	150	1	300	1	300	approved by the owner.
4.	D3	Single shutter	4	100	—	—	2	150	1	300	1	300	(2) Door stopper to be used for D and D1

Table 5-5. SCHEDULE FOR FIXTURES AND FASTENINGS: WINDOW

Sr. No.	Window symbol	Number of shutters	Hinges No.	Hinges Size mm	Tower bolts No.	Tower bolts Size mm	Handles No.	Handles Size mm	Hooks & eyes No.	Hooks & eyes Size mm	Extra fixtures	Remarks
1.	W	Four shutters	12	100	2	200	4	150	4	200	—	Iron-oxidized
2.	W1	Two shutters	3	100	2	200	2	150	2	200	—	Fixtures to be approved by the owner

which may be for specific hours in a day or with separate pipe connection for water from storage tank which is supplied for 24 hr. Plumbing work is carried out as per plumbing code. A certificate from the plumber having corporation's licence is required to be submitted after execution of work. For water supply connection, 20 mm galvanised iron pipe is generally allowed. Water is supplied under pressure, but the drainage line works on the principle of gravity. Asphalt coated cast iron pipes (100 mm diameter) known as 'soil pipes' are used for drainage connections. Vent pipes are provided to discharge sewer gases into the air. The sewer pipe provided is of 200 mm diameter, concrete hume pipe or cast iron. All drainage pipes must be straight and direct. Inspection chambers are provided at the bend and where branch connection is provided.

Site plan should show water supply and drainage lines in plot and their connections to respective lines on the road. Detailed plan to enlarge scale should be prepared showing requirements of the taps—direct and from storage tank, positions of shower, drainage pipe line and its diameter, slope, man hole, inspection chamber—its positions and size. In bathroom and W.C., water supply pipes may be concealed in wall if walls are to be finished with glazed tiles, or they can be fitted directly on walls. I.S. symbols for sanitary installations are used for preparing these drawings. In the case of a multi-storey building, vertical section is shown for all connections. These drawings should be completed

Table 5-6. SCHEDULE FOR ROOM FINISH

Sr. No.	Room title	Carpet area	Tiles type size mm	Skirting type size	Colour for walls/ceiling distemper/oil bound distemper plastic emulsion etc.	Remarks
1.	Living room	11.10 m²	Marble mosaic tiles—white cement base 200 × 200	Half tile skirting tiles as per floor	Distemper for walls; white wash for ceiling	Tiles to be selected as per choice of owner
2.	Bed room	12.00 m²	Marble mosaic tiles with grey cement base 200 × 200	-do-	-do-	-do-
3.	Kitchen	15.54 m²	Blue tandur tiles 200 × 200	Half tile skirting of blue tandur	—	—
	Kitchen otta	1.62 m² (2.70 m × 0.60 m)	Black Kadappa with high polish 30 mm thick	White glazed tiles for Dado over Otta 1.35 m high	—	—
4.	Passage	3.70 m²	Blue tandur tiles 200 × 200	Half tile skirting of blue tandur	Distemper for walls; white wash for ceiling	—
5.	Bath	2.60 m²	Blue tandur tiles 200 × 200	White glazed tiles; Dado 1.50m, high	Distemper for walls; white wash for ceiling	—
6.	W.C.	1.20 m²	White glazed	White glazed tiles Dado 1.50 m high	-do-	—

with proper notes regarding material, diameter, slope, invert levels, etc. Corporation authorities should be consulted for connection to the street sewer before drawings are prepared.

5.7 ELECTRICAL INSTALLATION PLAN

For small residential buildings, these plans can be prepared after studying the requirements of the owner. For public buildings, help of the electrical engineer is taken. Drawings showing plan with various connections should be prepared as per electrical code. Positions of fans, and electrical points on ceilings and walls with switch boards should be shown by using electrical installation symbols (Refer Figs. 5-24, 5-25).

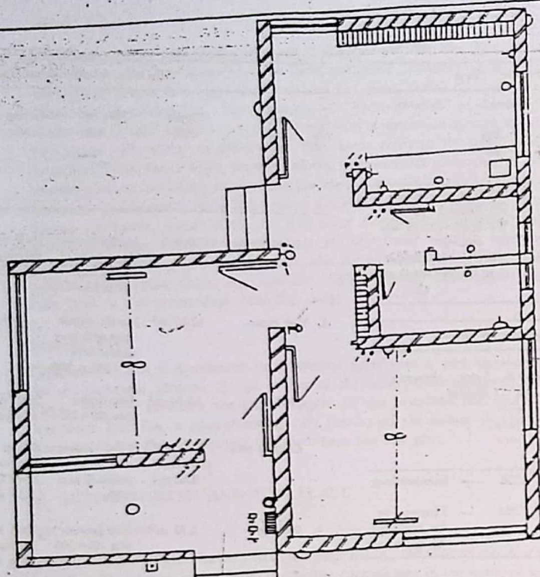


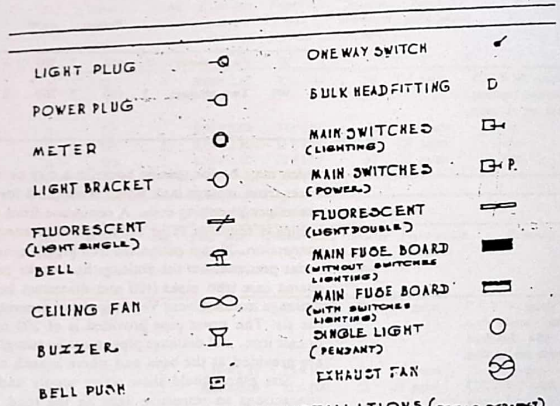
Fig. 5-24

The following points should be taken into consideration while preparing these drawings:

(1) Uniform lighting should be provided.
(2) For small rooms, ceiling fixtures are sufficient. For larger rooms, ceiling fixtures and additional points on wall should be provided.
(3) In dining room, ceiling fixtures may be provided over the dining table.
(4) Entrances and outdoor lights should be ample and their switches must be inside the building.
(5) Light switches are provided at a height of 1.5 m above the floor. Movements through rooms, passage, etc. should be considered while deciding the positions of switches.
(6) Power connections are provided for television, refrigerator, ironing, geyser, etc.
(7) Electric wiring may be both concealed and open; if concealed, conduit pipes are required to be fitted during casting of slab.

Table 5-7. ELECTRICAL INSTALLATION PLAN (FIG. 5-24)

1. Main switch Light—250 V 15 A. I.C.D.P.	1 no
2. Main switch Power 250 V 30 A. I.C.D.P. (Iron clad double pole)	1 no
3. Light points (a) Pendant—1 (b) Bracket—5 (c) Tube —2 40 Watt (d) Bulkhead—5 fitting (e) Fans —2 1200 sweep (f) Plug —3=1.5 (Plugs—half Points)	16.5 × 60 W = 1 kW Approx.
4. Power points 3 Pin power plug with indicator and switch with fuse	= 4 kW
	Light & power Total = 5 kW



SYMBOLS FOR ELECTRICAL INSTALLATIONS (SEE I.S. 962-1967)

Fig. 5-25

READING EXERCISE (FIG. 5-27)

SKETCH PLAN

(1) What is the necessity of drawing a sketch plan?
(2) Study the draftsmanship—thick and thin lines for walls, method for showing stone masonry, R.C.C. grill, paving, and different types of doors.
(3) What type of finish will you suggest for terrace?
(4) Prepare a sketch plan for the plan shown in Fig. 8-21.

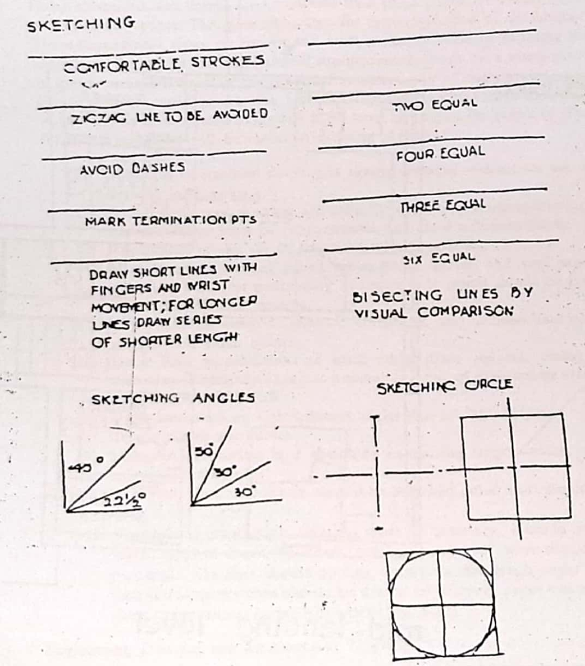


Fig. 5-26

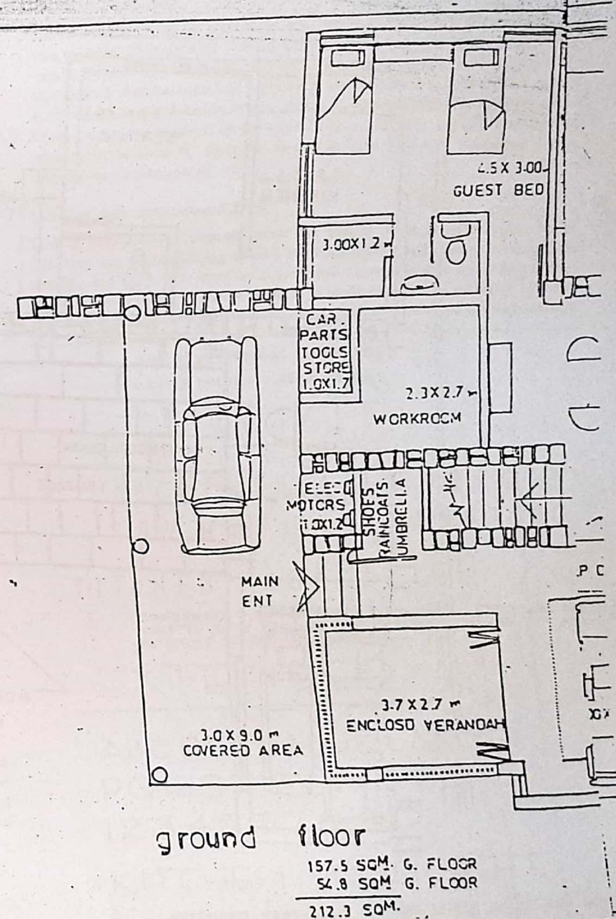
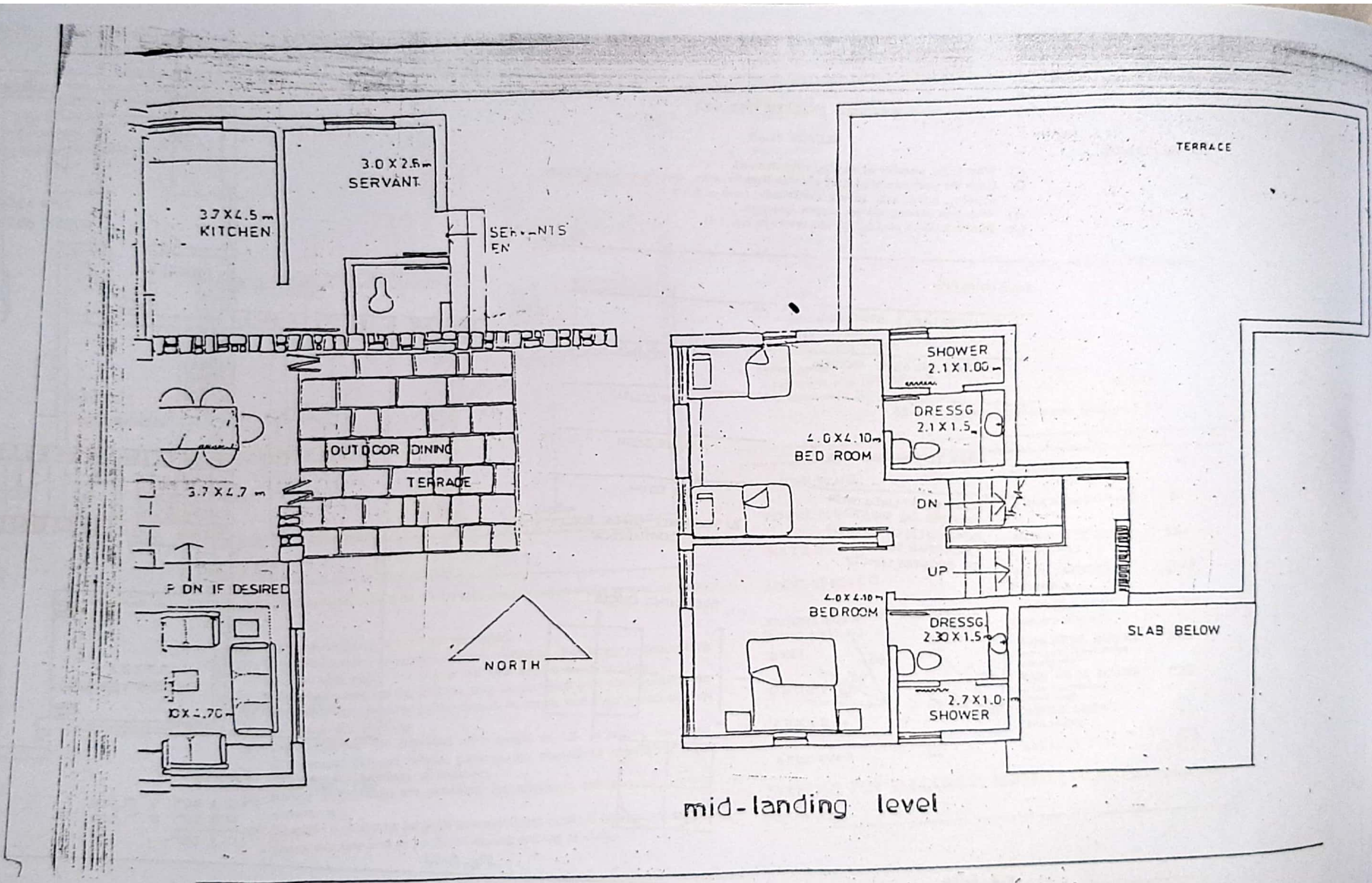


Fig. 5-27


3.0 X 2.6 m
SERVANT
3.7 X 4.5 m
KITCHEN
SERVANTS EN
OUTDOOR DINING
TERRACE
3.7 X 4.7 m
DN IF DESIRED
X 4.70
NORTH
TERRACE
SHOWER
2.1 X 1.00 m
DRESSG
2.1 X 1.5
4.0 X 4.10 m
BED ROOM
DN
UP
4.0 X 4.10 m
BEDROOM
DRESSG
2.30 X 1.5 m
2.7 X 1.0
SHOWER
SLAB BELOW
mid-landing level

style. Refined and polished style is a result of constant drawing work. Important styles (Figs. 5-28 and 5-29) are:

(1) Condensed;
(2) Extended;
(3) Variation; and
(4) Kabel Modern.

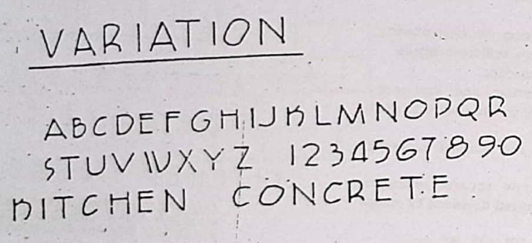
CONDENSED TYPE

Letters are condensed and are written with uniformly spread spacing. The letter 's' is written with one reverse curve stroke. End strokes for letters are marked with prominent points. The letters 'L' and 'T' are extended beyond guidelines.

EXTENDED TYPE

Letters are wide with little space between each letter opposite to the condensed

VARIATION TYPE—CIRCULAR STROKES WITH INCLINED CURVES AND HIGH CENTRE STROKES



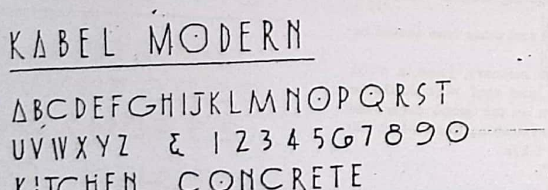


Fig. 5-29 KABEL MODERN TYPE—CONTRAST IN LETTERS. CIRCULAR LETTERS WITH TRUE CIRCLES AND OTHER LETTERS CONDENSED.

type. 'E', 'F', and 'H' have low centre strokes.

VARIATION TYPE

Curved strokes or inclined centre strokes are placed high. O and P are not having full round nature but are slightly rectangular.

KABEL MODERN

Kabel is the name of the designer of this type. He has provided contrast between the full round circular letters and other letters are kept as condensed. Spacing may be spread or tight. Sometimes, dot is marked in O, C, G and P.

5.9 TEACHING CIVIL ENGINEERING DRAWING

The following are the basic steps in teaching civil engineering drawing:
(1) Sketching, (2) Tracing, (3) Measured Drawing, and (4) Development of line plan.

The basic requirements of the student intending to work as a draftsman, civil engineer, or an architect is his artistic ability. He must know freehand sketching, as also perspective and orthographic drawings. He must have a good understanding of construction and construction materials.

Sketching

In order to develop confidence, ability, and architectural style in the drawing, the first part of the training should start with sketching which will help to understand the construction methods, joinery details, and various technical terms.

Tracing

The second step should include the tracing work on tracing paper first by using pencil and then ink. Drawing of different types of buildings such as load bearing and framed structures by different architects, should be studied, and then given for tracing. This will help in studying the composition of drawing sheet, plan, elevation, section details, and requirements of each view. Thus the students will get sufficient practice for lettering, dimensioning, and for writing notes and schedules.

Measured Drawing

The third step in training should involve measured drawing. First visit should be used for studying construction details and writing of construction notes, as also drawing elevation of all sides. Second visit should be used to take all external and internal measurements and preparation of sketch plan. Then section line should be marked on the plan and students should be asked to draw section. This method gives them confidence. They become familiar with the construction aspects and indirectly study different styles in architecture, elevation treatment, proportion, balance, shadow projections and symmetry in the structures. Afterwards, they should be asked to draw plan elevation and section first on graph

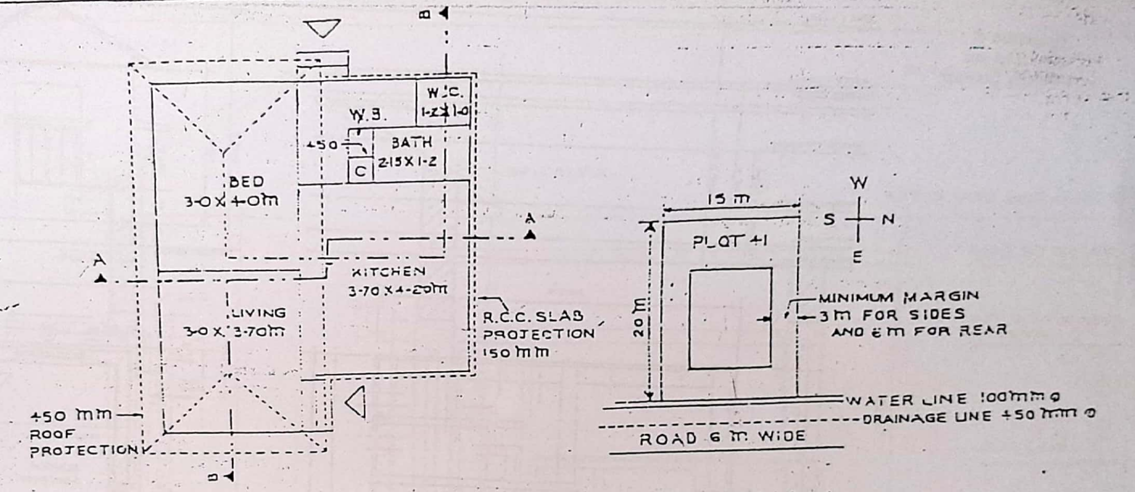


Fig. 5-30 LINE PLAN SITE PLAN

paper, and then on drawing sheet with appropriate composition.

Development of the Line Plan

The fourth step in teaching should include development of the line plan with the given data and construction notes. Sketches for plan, elevation, and section should be prepared first on graph paper and then on drawing paper. At this stage, the students should also study construction, building bye-laws, and design of structural members.

5.10 SPECIMEN WORKING DRAWING

Residential Building—Working Plans

Line plan, site plan (Fig. 5.30) and data for preparing working plans are given below. Method for developing the line plan and various steps for drawing plan, elevation and section is explained in Section 5.3. Study all these drawings, schedules carefully. The same method should be followed for small or large, single or multi-storeyed buildings.

DATA

Foundation	— On hard strata at a depth 1.5 m below G.L.
Plinth height	— 450 mm
Plinth and foundation masonry	— U.C.R. masonry in cement mortar 1 : 6 with cement plaster 1 : 3
Superstructure	— B. B. Masonry, 400 mm thick in cement mortar 1 : 6 with cement plaster 1 : 3 with neeru finish internally and sand faced externally. Partition walls for W.C. and bath 200 mm
Superstructure height	— Height of eaves board above plinth; bottom of R.C.C. slab above plinth
Flooring	— Cement tiles 25 mm thick over lime concrete 1 : 3 : 6 bedding 125 mm over rubble soling 200 mm
Doors and windows	— C.C.T.W. of suitable size and at suitable places

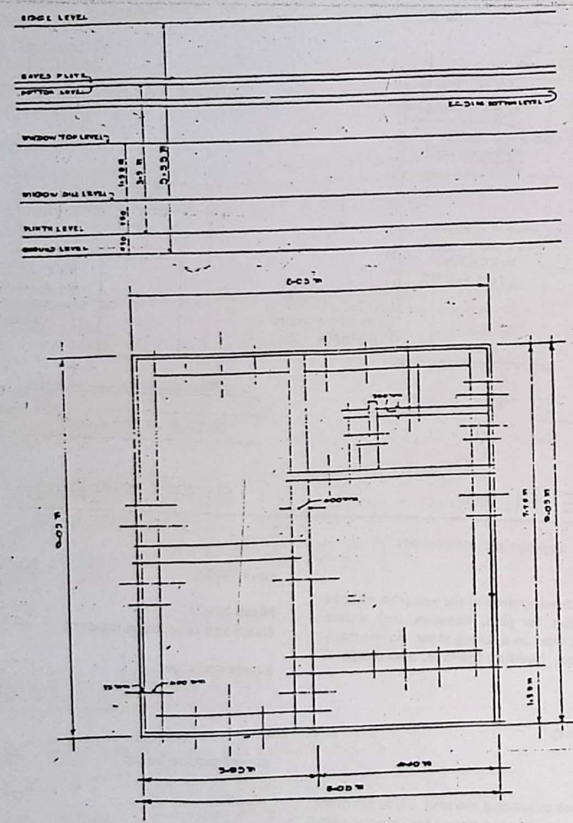


Fig. 5–31

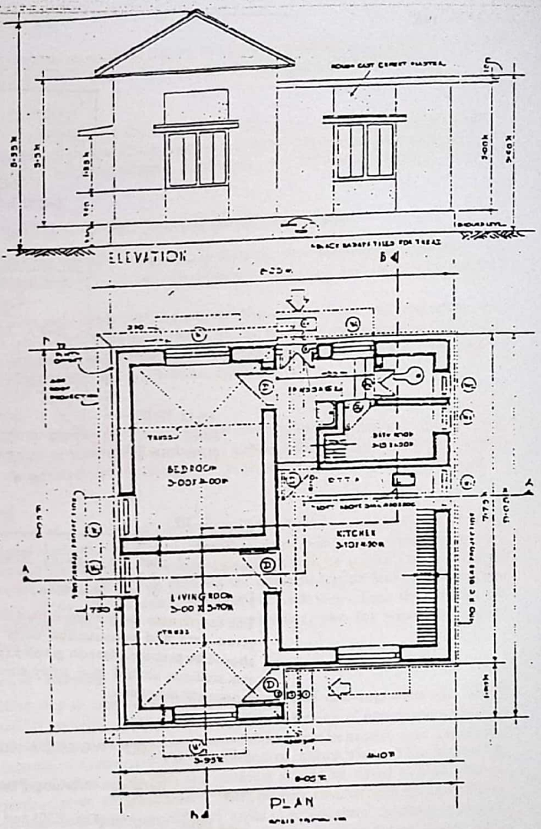
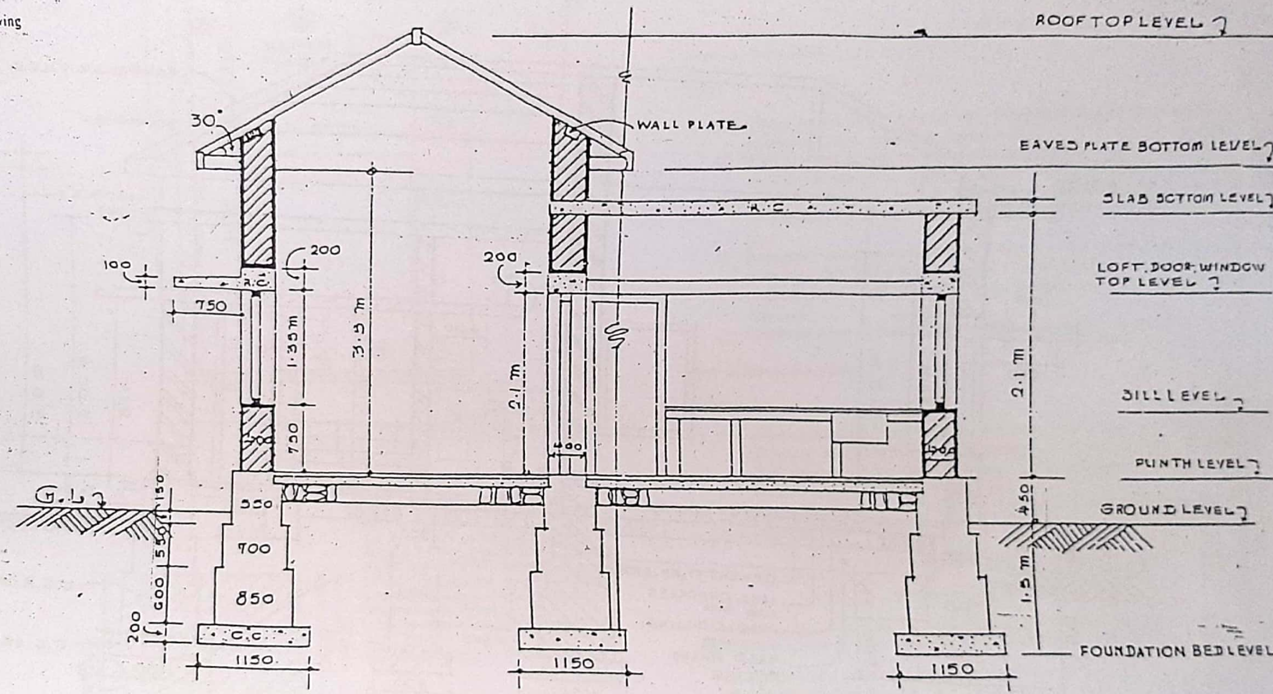
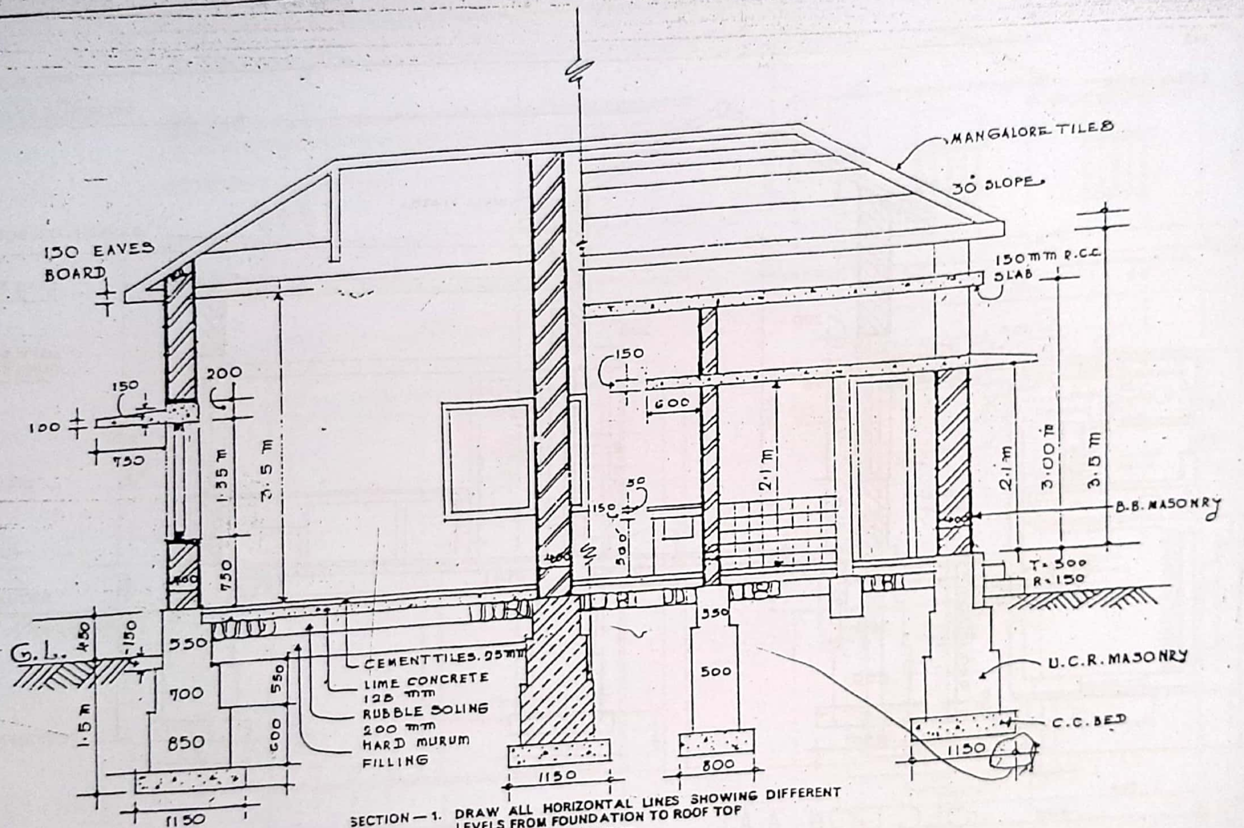


Fig. 5–32



SECTION A-A

Fig. 5-33



SECTION — 1. DRAW ALL HORIZONTAL LINES SHOWING DIFFERENT LEVELS FROM FOUNDATION TO ROOF TOP
2. MARK WALLS BY DIVIDER
3. PLACE YOURSELF IN THE POSITION OF MASON, CARPENTER ETC. AND SHOW ALL CONSTRUCTIONAL DETAILS. THICKNESS ETC.

SECTION B-B

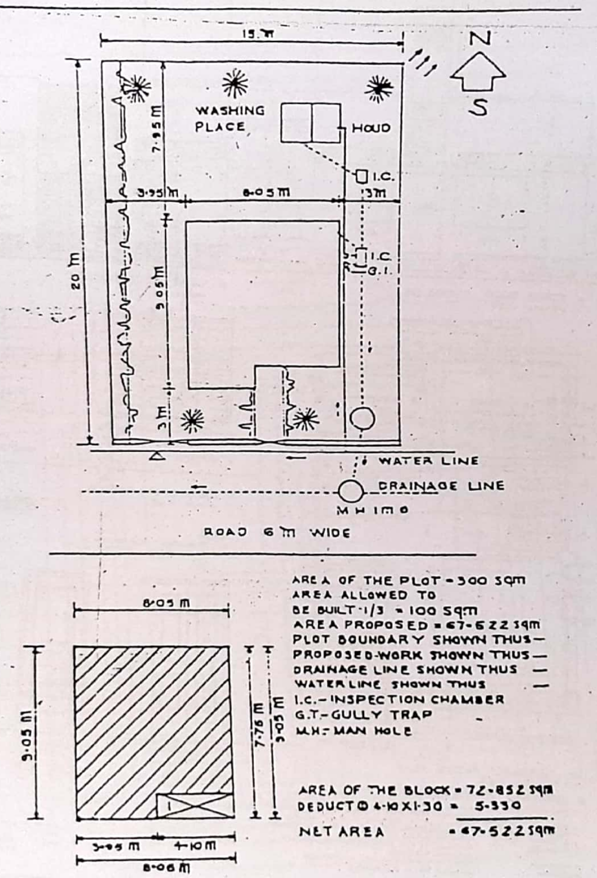


Fig. 5-34 SITE PLAN

Roof — Pitch and flat roof. Pitch roof covered with Mangalore tiles over C.C.T.W. work. Flat roof of R.C.C. slab 150 mm with water proofing treatment. Assume additional data, if required.

How to Draw Plan

Steps

(1) Complete the sketch of plan and elevation with all dimensions. Check permissible and proposed built-up area.

(2) Find the size of the suitable rectangle without considering offsets. In the case of the given plan the size is 8.05 m × 9.05 m.

(3) Draw the rectangle 8.05 m × 9.05 m with the scale 10 mm = 1 m for submission and 20 mm = 1 m for working drawing. Draw faint lines.

(4) Remember the principle—work from the whole to the part. Keep the scale near title block and use the divider to mark plinth offset 75 mm, external walls 300 mm and other internal walls of 200 mm and 100 mm.

(5) Complete other details step by step as explained in Section 5.3.

How to Draw Elevation

Steps

(1) Draw horizontal lines showing different levels from ground to ridge or top of roof according to the number of floors and type of roof—pitch or flat, with or without parapet, or combination of pitch and flat.

(2) Project vertical lines from the plan.

(3) Draw all details as explained in Section 5.7 dealing with elevations.

These steps are illustrated in Figs. 5-31 and 5-32.

READING EXERCISE (FIG. 5-35)

WORKING DRAWINGS

Working drawing shows plans, elevations, and section for estimating and constructing the proposed building. Study all drawings carefully with reference to the following points

(1) Dimensions in centre line plan and ground floor plan.

(2) Position of columns.

(3) Prepare schedule for room finish for flooring.

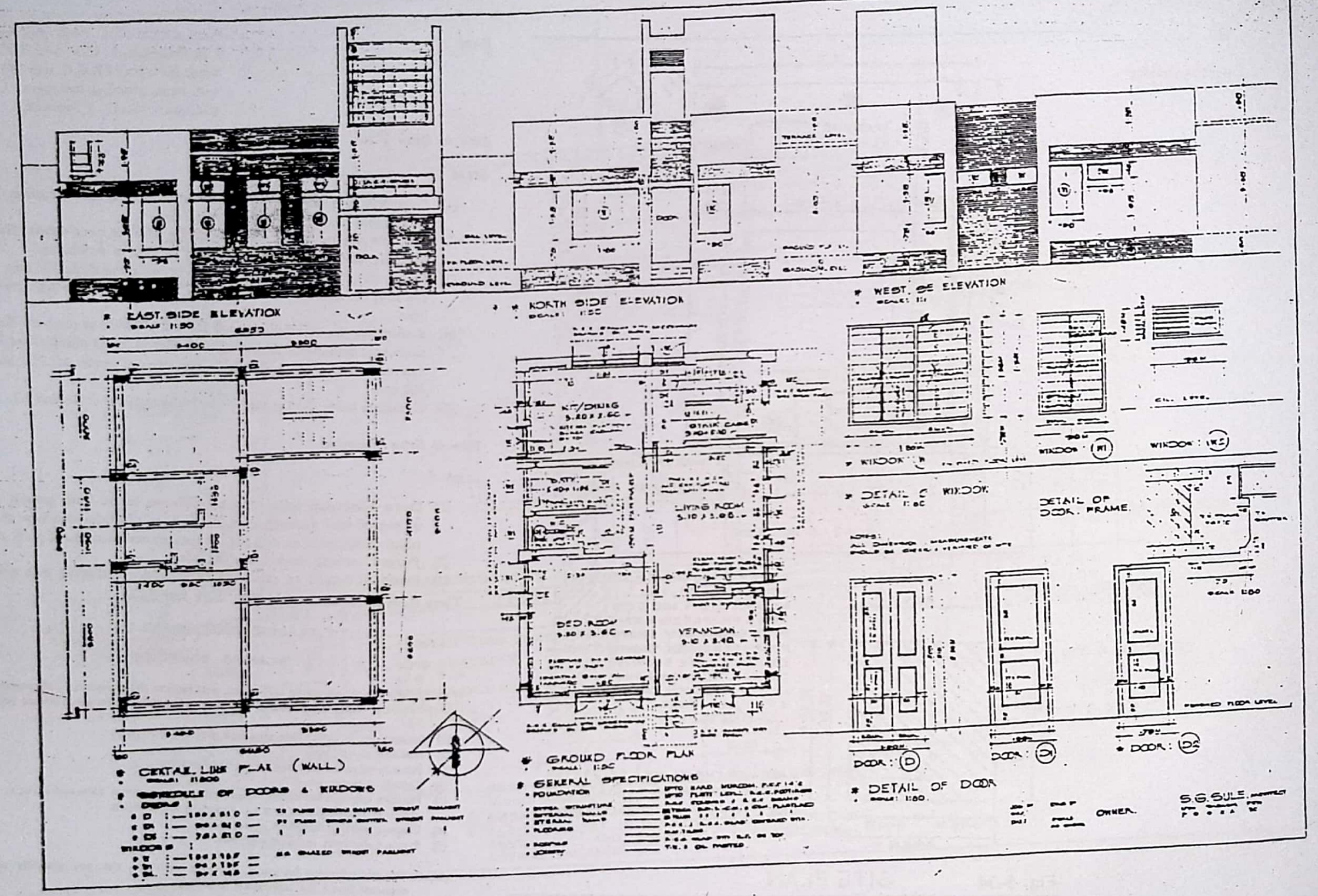
(4) Calculate carpet area.

(5) Prepare schedule for doors, windows, from the given data and make a list of the required additional data if not found in the drawing.

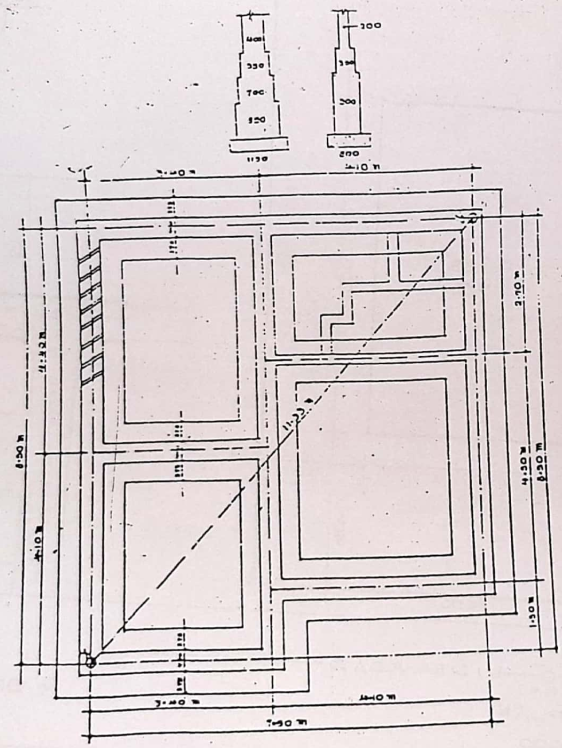
(6) Prepare suitable furniture layout plan.

(7) Prepare electrical installation plan.

Note : Working drawing for plans, elevation sections, etc. are generally prepared on separate sheets for convenient handling.


EAST SIDE ELEVATION
NORTH SIDE ELEVATION
WEST SIDE ELEVATION
CENTRE LINE PLAN (WALL)
SCHEDULE OF DOORS & WINDOWS
GROUND FLOOR PLAN
GENERAL SPECIFICATIONS
KIT/DINING
STAIR CASE
LIVING ROOM
BED ROOM
VERANDAH
DETAIL OF WINDOW
DETAIL OF DOOR FRAME
DETAIL OF DOOR
OWNER
S.G. SULE

NOTE : 1) WIDTH OF TRENCH FOR EXCAVATION a) 400 mm WALL-1150
b) 200 mm WALL-500
2) DIAGONAL XY - 11·35



FOUNDATION PLAN

SCALE : 2 cm = 1 m

Fig. 5-36

ROOF PLAN

NOTE : (1) R.C.C. SLAB 150 mm THK OVER PORTION (A)
(2) MANGALORE TILES PITCH ROOF OVER PORTION (B)
(3) WOOD WORK - 1) RIDGE — 75 X 180
2) WALL PLATE — 50 X 105
3) HIP RAFTER — 75 X 105
4) COMMON RAFTERS — 55 X 105 @ 450 mm C/C
5) EAVES BOARD — 155 X 15
6) BATTENS — 45 X 125 @ 315 mm C/C
7) JACK RAFTERS — 55 X 105 @ 450 mm C/C

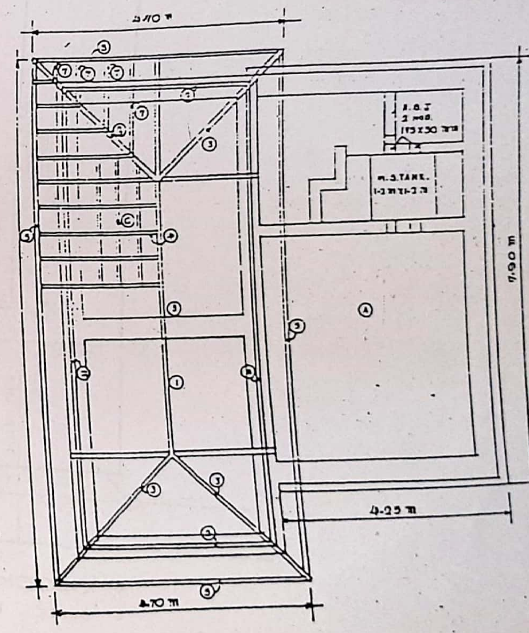


Fig. 5-37

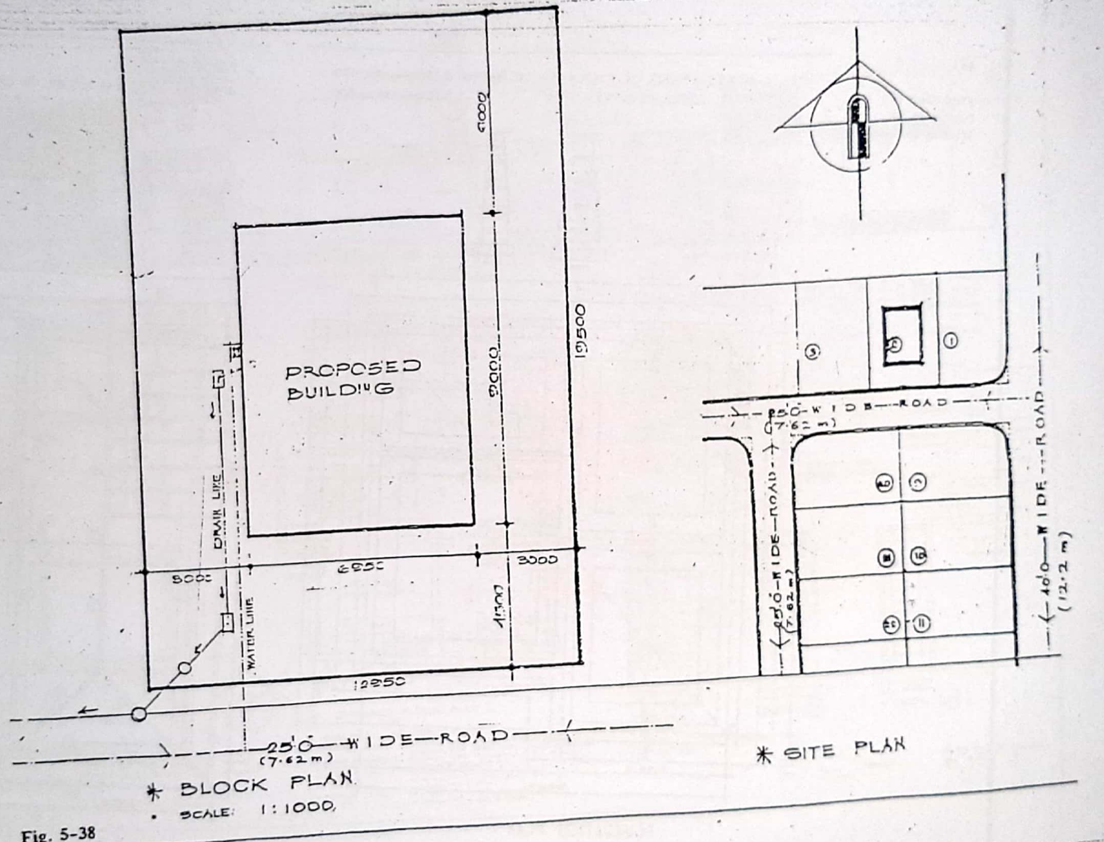
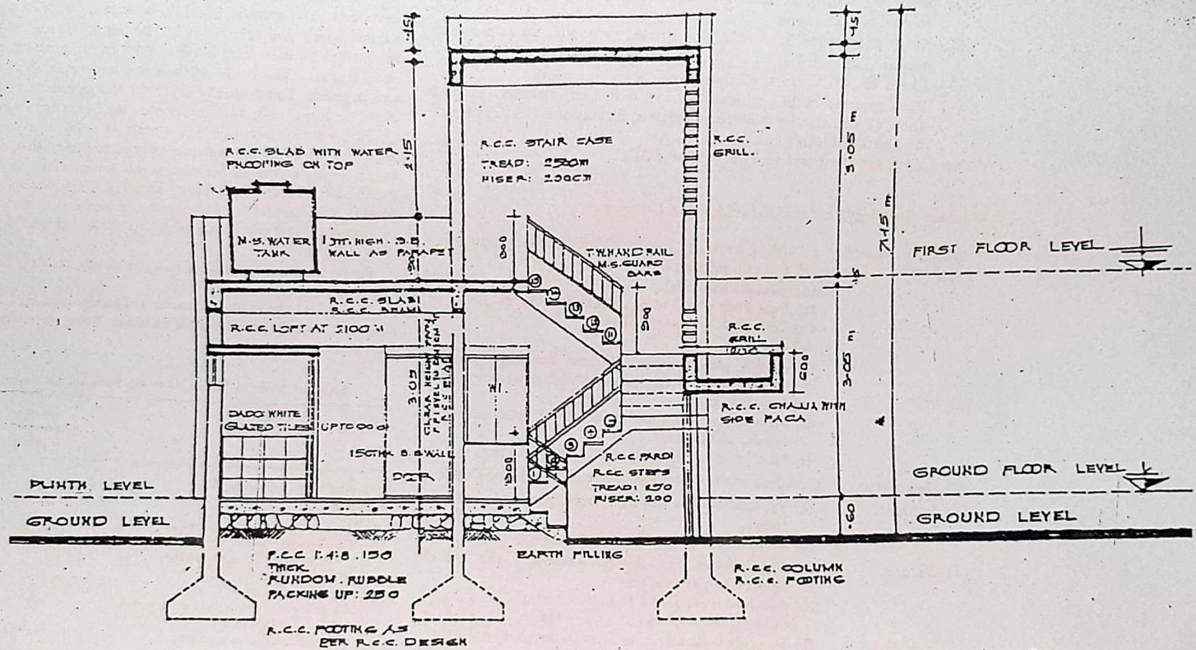

PROPOSED BUILDING
1000
9000
19500
DRAIN LINE
WATER LINE
3000
6950
3000
1500
12250
25'0" WIDE ROAD (7.62 m)
* BLOCK PLAN
SCALE: 1:1000
25'0" WIDE ROAD (7.62 m)
40'0" WIDE ROAD (12.2 m)
* SITE PLAN

Fig. 5-38



✱ SECTION THRO : A D

• SCALE: 1:50

How to Draw Section

Steps

(1) Draw all horizontal lines showing different levels from foundation to roof top as shown.
(2) Study the section line, walls, doors, windows, lofts, etc. cut by the section line.
(3) Use a divider to mark all details.
(4) Place yourself in the position of mason, carpenter, plumber, etc. and show all constructional details, thickness, dimensions, etc. Check section with the check list.

These steps are illustrated in Figs. 5-33 to 5-38.

Working Drawings, Detailed Drawings and Estimates

Working drawings of a building generally consist of the following drawings:

(1) *Plans*:
- (a) Foundation plan.
- (b) Ground floor plan.
- (c) First floor plan and plans for other floors.
- (d) Terrace floor plan/Roof plan.
- (e) Site plan.
- (f) Layout plan showing different buildings, garden, internal roads, water supply and drainage lines, etc.
- (g) Basement plan.
- (h) Structural plans showing details of RCC columns, beams, slabs, etc.
- (i) Plan for electric wiring with details of paints etc.

(2) *Elevations*: Elevations of all sides (front, back and both the sides).

(3) *Sections*:
- (a) Typical sections through doors, windows, and balconies.
- (b) Section through staircase and sanitary units.

(4) *Details*:
- (a) Door frames and shutters—material and list of fixtures and fastenings.
- (b) Window frames and shutters—material and list of fixtures and fastenings, grill work.
- (c) Staircase—Handrail, m.s. grill, method of fixing, rise, tread, etc.
- (d) Compound wall; gate.
- (e) Balcony railing; RCC vertical drops, pardi, etc.
- (f) Kitchen arrangement otta, sink, etc.
- (g) Bathroom, W.C., attached toilet.
- (h) Details of dado.
- (i) Sanitary and water supply fixtures, location and method of fixing, connection of water supply and drainage pipes, gully traps, inspection chambers, supply from overhead storage tank, etc.
- (j) Any other specific details as per type of building—furniture pieces, cupboards, etc.

While making working drawings, its utility and importance from the estimate and site supervision should be kept in mind. Table 5-1 gives details of various items and their units of measurement and payment. Quantities are required to be calculated in m^3 and m^2 or per running metre. Hence, students should have a knowledge of the items and respective units of measurement and payment. This naturally imparts a new practical vision to write and then check the dimensions so as to calculate the quantities in m^3/m^2/metre.

Such working drawings with a scale of 1 : 50 or even 1 : 25 or 1 : 10 with all dimensions, notes, and data as regards materials etc. are not only useful in preparing estimates, but also save a lot of time on site at the time of supervision. Correct estimation, accurate dimensioning, and desired specification details avoid unnecessary dispute and loss of time even at a later date.

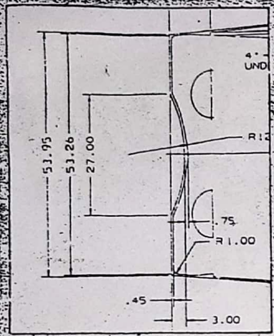
Figure 5-39 shows details of toilets. Study carefully the plan, notes and details shown.

Figure 5-40 shows details of staircase. Study carefully the plan for staircase, sections and details.

Figure 5-41 shows plan, elevation and section and Figs. 5-42, 5-43 and 5-44 show RCC details for residential buildings. Study carefully all drawings along with their reading exercises.

Table 5.1 Units of Measurement and Payment for Various Items of Works

S.No.	Item	Unit of Measurement in mks	Unit of Payment in mks
(1)	*Earthwork, excavation, filling*	m^3	per m^3
(2)	*Concrete*		
	(a) Lime concrete in foundation	m^3	per m^3
	(b) Cement concrete	m^3	per m^3
	(c) Reinforced cement concrete	m^3	per m^3
	(d) RCC chajja	m^3	per m^3
	(e) Precast CC or RCC	m^3	per m^3
	(f) Jali work (thickness to be specified)	m^2	per m^2
	(g) Damp-proof course (thickness to be specified)	m^2	per m^2
(3)	*Brick work*		
	(a) In foundation and plinth, super structure in arches, etc. in cement, lime or mud mortar	m^3	per m^3
	(b) Half brick work with or without reinforcement	m^2	per m^2
		m^2	per m^2
(4)	*Stone work*		
	Stone masonry—Random rubble, coursed rubble, ashlar masonry in walls, arches, etc.	m^3	per m^3



This introduction to Technical Drawing and Design presents the concept of technical drawing and traces its evolution from primitive manual techniques to modern computer-aided drafting (CAD) techniques. Major topics covered include: drawings described; types of drawings; types of technical drawings, their purpose, applications, and regulation; and a checklist of what students of technical drawing and drafting should learn.

Introduction

Drawings Described

A drawing is a graphic representation of an idea, a concept or an entity which actually or potentially exists in life. The drawing itself is 1) a way of communicating all necessary information about an abstraction, such as an idea or a concept; or 2) a graphic representation of some real entity, such as a machine part, a house, or a tool, for example.

Drawing is one of the oldest forms of communication, dating back even farther than verbal communication. Cave dwellers painted drawings on the walls of their caves thousands of years before paper was invented. These crude drawings served as a means of communicating long before verbal communications had developed beyond the grunting stage. In later years, Egyptian hieroglyphics were a more advanced form of communicating through drawings.

The old adage "one picture is worth a thousand words" is still the basis of the need for technical drawings.

Types of Drawings

There are two basic types of drawings: artistic and technical. Some experts believe there are actually three types: the two mentioned and another type which combines these two. The third type is usually referred to as an illustration or rendering.

Artistic Drawings

Artistic drawings range in scope from the most simple line drawings to the most famous paintings. Regardless of their complexity or status, artistic drawings are used to express the feelings, beliefs, philosophies or abstract ideas of the artist. This is why the lay person often finds it difficult to understand what is being communicated by a work of art.

In order to understand an artistic drawing, it is sometimes necessary to first understand the artist. Artists often take a subtle or abstract approach in communicating through their drawings. This gives rise to the various interpretations often associated with artistic drawings.

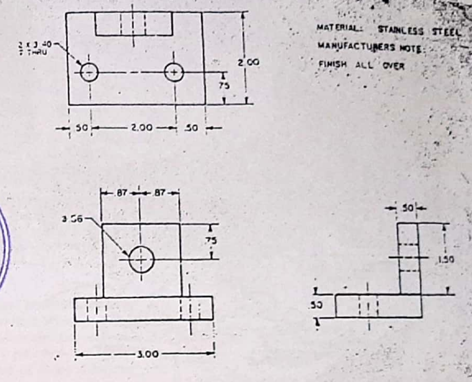
Technical Drawings

The technical drawing, on the other hand, is not subtle or abstract. It does not require an understanding of its creator; only an understanding of technical drawings. A *technical drawing* is a means of clearly and concisely communicating all of the information necessary to transform an idea or a concept into reality. Therefore, a technical drawing often contains more than just a graphic representation of its subject. It also contains dimensions, notes, and specifications.

The mark of a good technical drawing is that it contains all of the information needed by individuals for converting the idea or concept into reality. The conversion process may involve manufacturing, assembly, construction, or fabrication. Regardless of the process involved, a good technical drawing allows the conversion process to proceed without having to ask designers or drafters for additional information or clarification.

Figures 1-1 and 1-2 contain samples of technical mechanical drawings which are used as guides by the people involved in various phases of manufactur-

Figure 1-1 Technical drawing (mechanical)



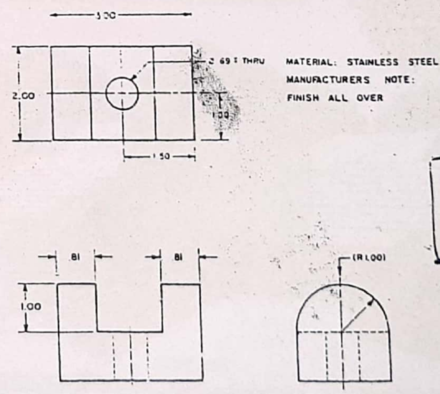


Figure 1-2 Technical drawing (mechanical)