DEPARTMENT OF THE ARMY TECHNICAL MANUAL **TM 5-704**

DEPARTMENT OF THE AIR FORCE MANUAL **AFM 85-27**

CONSTRUCTION PRINT READING IN THE FIELD

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DEPARTMENTS OF THE ARMY AND THE AIR FORCE

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CONSTRUCTION PRINT READING IN THE FIELD

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CHAPTER 1

PRINCIPLES AND METHODS

Section I. INTRODUCTION

1-1. Purpose and Scope

This manual is written as a basic reference for all personnel whose duties require the reading and interpretation of engineering construction drawings and prints. The text explains the language of engineering drawings—lines, sections, symbols, dimensions, notes, specifications, and titles—and also contains a general discussion of the kinds and uses of construction prints. It covers architectural, utilities, and machine drawings together with heating, air conditioning and refrigeration plans, and bills of materials.

1-2. Changes

Users of this publication are encouraged to recommend changes and provide comments to improve the publication. Comments should be keyed to the specific page, paragraph, and line of text in which the change is recommended. Reasons will be provided for each comment to insure understanding and complete evaluation. Comments should be forwarded direct to the Commandant, US Army Engineer School, Fort Belvoir, Virginia 22060.

Section II. MEANING OF LINES

1-3. Drawings

a. A picture is worth a thousand words. Man has used pictures as a means of communication for many years. It would be almost impossible for an engineer or an inventor to describe the size and shape of a simple object without a drawing of some kind. For example, if an engineer designed a simple object such as that shown in the engineer's sketch in figure 1-1 it would be difficult to convey his idea to the person who is to fabricate the object without a drawing to show the shape, size, and location of the holes. A working drawing of the object also is shown in figure 1-1.

b. Drawing or sketching is the universal language used by engineers, technicians, and skilled craftsmen. Whether this drawing is made freehand or by the use of drawing instruments (mechanical drawing), it is needed to convey all the necessary information to the individual who will fabricate and assemble the object whether it be a building, ship, aircraft, or mechanical device.

1-4. Line Conventions

In order to include all the necessary information on a drawing in a meaningful manner, different types and weights of lines are used to represent the features of the object. The meaning of a line with certain characteristics has been standardized, and will be the same on any drawing. These line conventions must be understood in order to read drawings. The line conventions most often encountered in construction prints are described below and shown in figure 1-2. Application of these line conventions are demonstrated in figure 1-3.

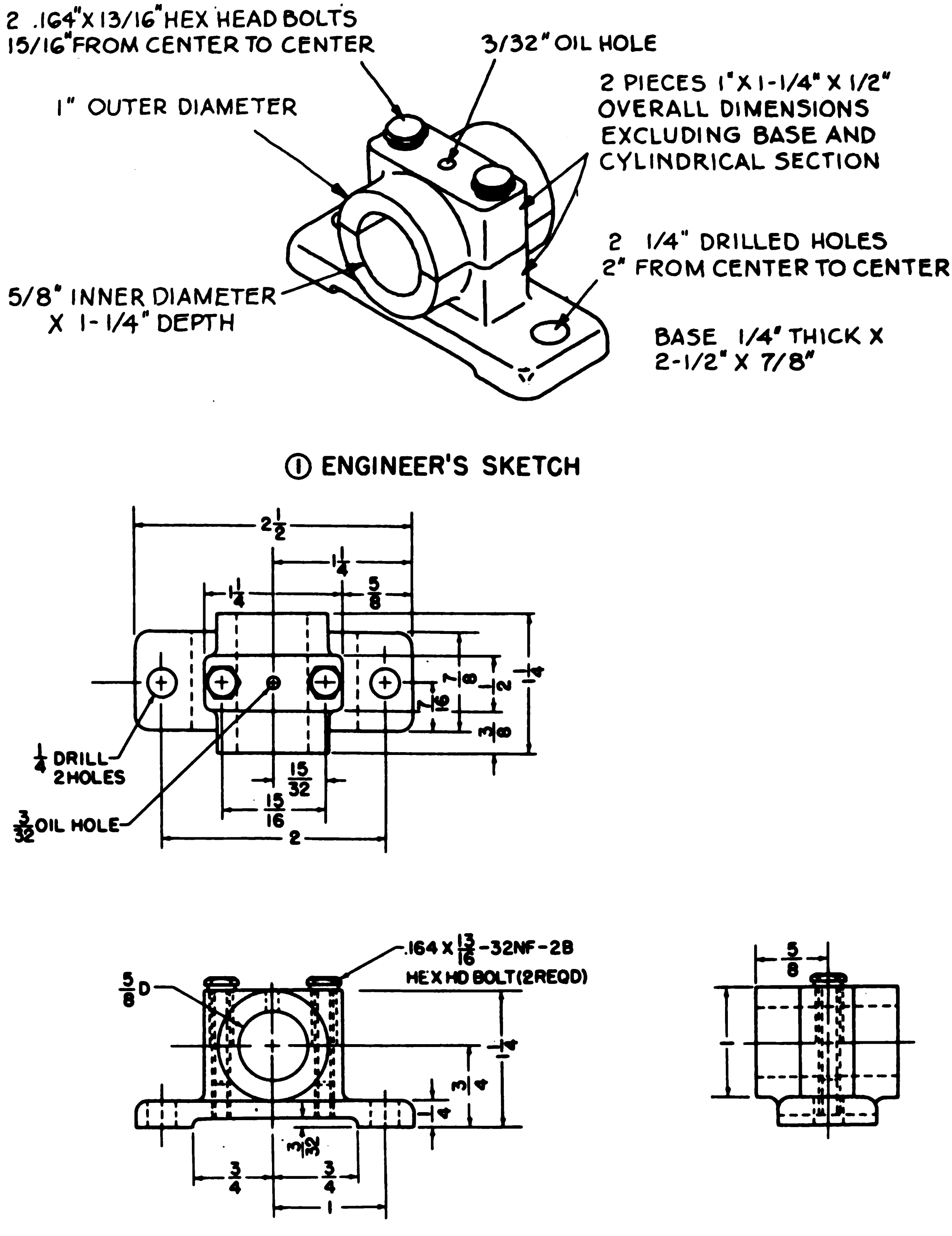


Figure 1-1. Engineer's sketch compared to working drawing.

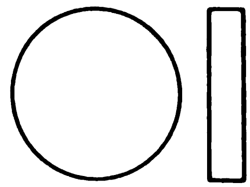
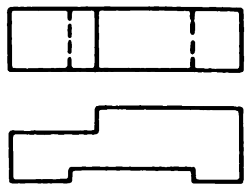
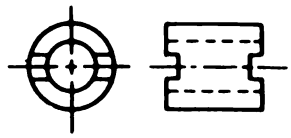
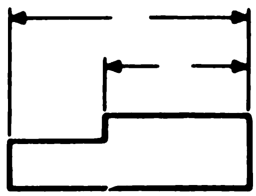
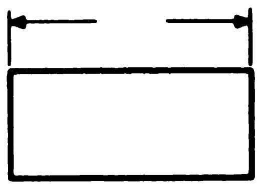
LINE CONVENTIONS			
NAME	CONVENTION	DESCRIPTION AND APPLICATION	EXAMPLE
VISIBLE LINES		HEAVY UNBROKEN LINES USED TO INDICATE VISIBLE EDGES OF AN OBJECT	
HIDDEN LINES		MEDIUM LINES WITH SHORT EVENLY SPACED DASHES USED TO INDICATE CONCEALED EDGES	
CENTER LINES		THIN LINES MADE UP OF LONG AND SHORT DASHES ALTERNATELY SPACED AND CONSISTENT IN LENGTH USED TO INDICATE SYMMETRY ABOUT AN AXIS AND LOCATION OF CENTERS	
DIMENSION LINES		THIN LINES TERMINATED WITH ARROWHEADS AT EACH END USED TO INDICATE DISTANCE MEASURED	
EXTENSION LINES		THIN UNBROKEN LINES USED TO INDICATE EXTENT OF DIMENSIONS	

Figure 1-2. Line conventions.

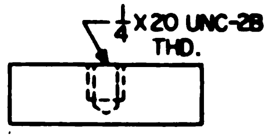
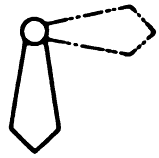
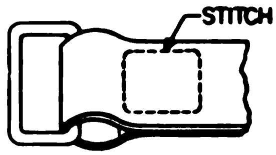
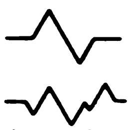
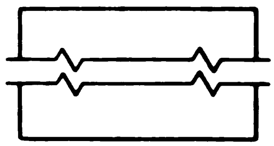
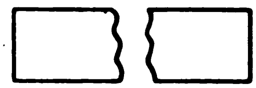
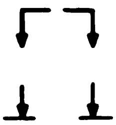
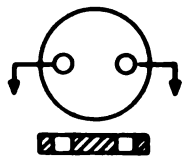
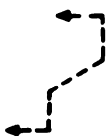
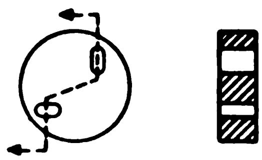
LINE CONVENTIONS			
NAME	CONVENTION	DESCRIPTION AND APPLICATION	EXAMPLE
LEADER		THIN LINE TERMINATED WITH ARROW-HEAD OR DOT AT ONE END USED TO INDICATE A PART, DIMENSION OR OTHER REFERENCE	
PHANTOM OR DATUM LINE		MEDIUM SERIES OF ONE LONG DASH AND TWO SHORT DASHES EVENLY SPACED ENDING WITH LONG DASH USED TO INDICATE: ALTERNATE POSITION OF PARTS, REPEATED DETAIL OR TO INDICATE A DATUM PLANE	
STITCH LINE		MEDIUM LINE OF SHORT DASHES EVENLY SPACED AND LABELED USED TO INDICATE STITCHING OR SEWING	
BREAK (LONG)	 (WOOD)	THIN SOLID RULED LINE WITH FREE-HAND ZIG-ZAGS USED TO REDUCE SIZE OF DRAWING REQUIRED TO DELINEATE OBJECT AND REDUCE DETAIL	
BREAK (SHORT)		THICK SOLID FREE-HAND LINES USED TO INDICATE A SHORT BREAK	
CUTTING OR VIEWING PLANE VIEWING PLANE OPTIONAL		THICK SOLID LINES WITH ARROWHEAD TO INDICATE DIRECTION IN WHICH SECTION OR PLANE IS VIEWED OR TAKEN	
CUTTING PLANE FOR COMPLEX OR OFFSET VIEWS		THICK SHORT DASHES USED TO SHOW OFFSET WITH ARROW-HEADS TO SHOW DIRECTION VIEWED	

Figure 1-2.—continued

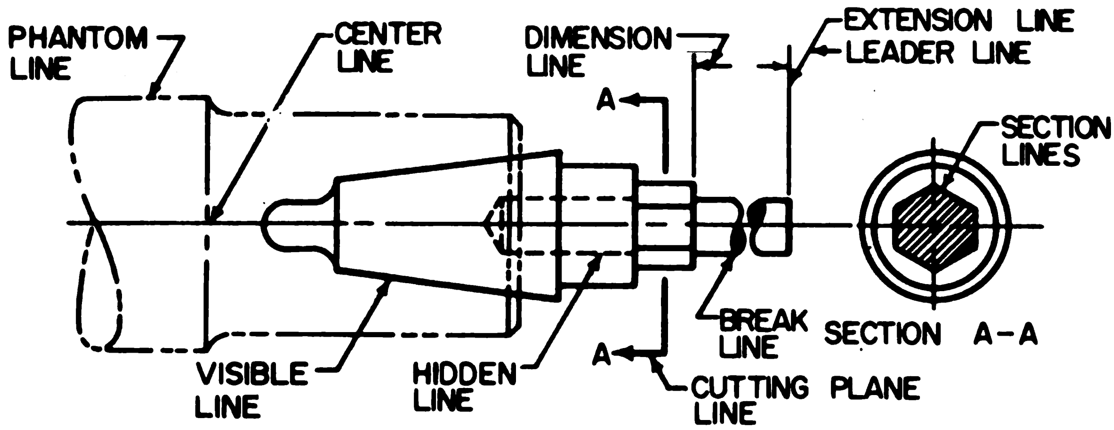


Figure 1-3. Application of line conventions.

a. Visible Lines. A heavyweight unbroken line is used for the primary feature of a drawing. For drawings of objects, this line convention represents the edges, the intersection of two surfaces, or the surface limit that is visible from the viewing angle of the drawing. This line is often called the outline.

b. Hidden Lines. A mediumweight line of evenly spaced short dashes represents an edge, the intersection of two surfaces, or the surface limit which is not visible from the viewing angle of the drawing.

c. Center Lines. A thin (light) line composed of alternate long and short dashes of consistent length is called a center line. It is used to signify the center of a circle or arc and to divide object into equal or symmetrical parts.

d. Dimension Lines. A solid continuous line terminating in arrowheads at each end. Dimension lines are broken only to permit writing in dimension. On construction drawings the dimension lines are unbroken. The points of the arrowheads touch the extension lines which mark the limits of the dimension. The dimension is expressed in feet and inches on architectural drawings and in feet and decimal fraction of a foot on engineering drawings.

e. Extension Lines. Extension line is a thin (light) unbroken line that is used to indicate the extent of the dimension lines. The extension line extends the visible lines of an object when it is not convenient to draw a dimension line directly between the visible lines. There is always a small space between the extension line and the visible line.

f. Leaders. A leader is a thin (light) line terminated with an arrowhead that is used to indicate the part or feature to which a number, note or other information refers.

g. Phantom Lines. A mediumweight line made of long dashes broken by two short dashes is called a phantom line and indicates one of three things: the relative position of an absent part, an alternative position of a part, or repeated detail which is not drawn.

h. Stitch Lines. A medium line made of short dashes evenly spaced and labeled used to indicate stitching or sewing.

i. Break Lines. A thin (light) line interrupted by a z-shaped symbol. The break line indicates that the object has been shortened to save space on the drawing. The true length is indicated by the dimension specified. The short break line convention varies with shape and material, figure 1-4, and indicates that part of the object has been cut away to show section detail or hidden features.

j. Cutting Plane Lines. A pair of short, heavy lines with arrowheads projected at 90° indicates the cutting plane when a drawing includes a section view. Letters (AA, BB, etc.) are usually placed at the arrowheads to identify the section view. The arrowheads show the viewing direction of the section view. Where necessary, the section lines may be connected by a line of short, heavy dashes indicating the exact path of the cutting plane.

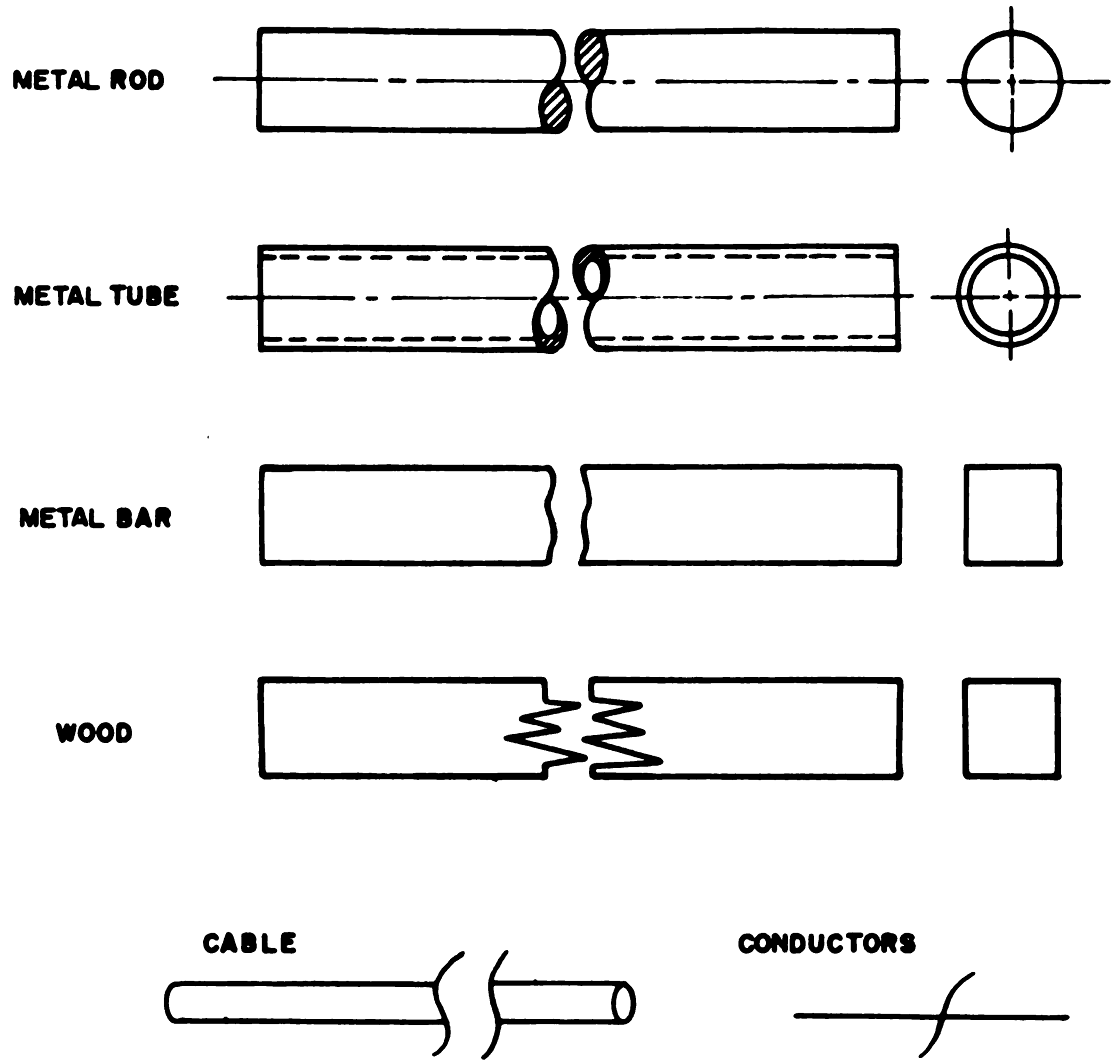


Figure 1-4. Short break conventions.

k. Sectioning Lines. When a drawing includes a section, the surface or surfaces which are in the cutting plane are indicated by section lines. When the object sectioned is all one material, the section lines are usually closely spaced parallel lines of medium thickness. Where different materials are involved, different section conventions are used to distinguish between them. These section conventions are covered more fully in chapter 2.

Section III. PROJECTIONS, VIEWS AND DIMENSIONS

1-5. Introduction

In learning to read a construction print, you must develop the ability to visualize the object, figure 1-5. This is done by learning to properly interpret the various types of lines, dimensions, sections, details, symbols, and other media that are used to describe the object or parts of an object on a construction print.

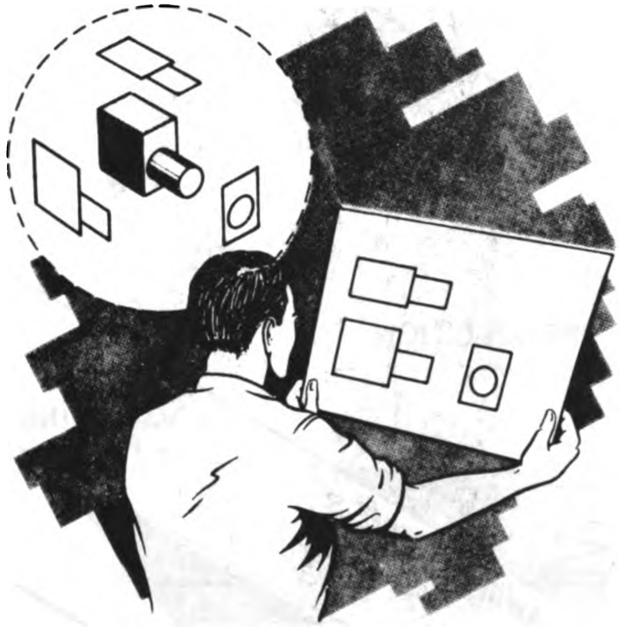


Figure 1-5. Visualizing from a print.

1-6. Projections

An object can be viewed and therefore drawn from an infinite number of positions. Some views are easier to draw and interpret than others. It is common to present an object on a drawing as an orthographic projection or as a pictorial drawing. In an orthographic projection, the object is presented as if it were viewed through a transparent drawing plane from an infinite distance (fig. 1-6). An orthographic projection is made by projecting each point on the object perpendicular to the drawing plane. A pictorial drawing, such as the perspective projection in figure 1-6, presents the object as it would appear to the eye.

a. Orthographic Projection. Almost all drawings intended for production or construction are drawn by orthographic projection.

(1) The major advantage of an orthographic projection is that it shows every part of an object that is parallel to the drawing plane in true relative size and position.

(2) The numbers of views to be used in projecting a drawing is governed by the complexity of the shape of the drawing. Complex objects are normally drawn showing six views; that is both ends, front, top, rear, and bottom. Figure 1-7 shows an object placed in a transparent box. The projections of the object on the sides of the box are the views seen by looking straight at the object through each side. If the outlines are scribed on each surface and the box opened and laid flat, the result is a six-view, orthographic projection drawing. It should be noted that the rear view may appear in any one of four positions (to the right of the right side view or left of the left side view, above the top view or below the bottom view).

(3) As a general rule, you will find that most drawings will be presented in three views. For a simple object, three views are adequate to completely describe the object when dimensions are added (fig. 1-8). Occasionally, you will see two-view drawings, particularly cylindrical objects. The most common three-view drawing arrangement shows the front, top and right side view of an object.

(4) In a three-view drawing, the front view shows the most characteristic feature of the object. Note in figure 1-8 that the right side or end view is projected to the right of the front. Also notice that all the horizontal outlines of the front view are extended horizontally to make up the side view and all the vertical outlines of the front view are extended vertically to make up the top view. By studying the drawing you should obtain the following information about the object: the shape of the object, its overall length (2 1/8 inches), its width (1½ inches), and its height (1⅜ inches). It is notched 1⅛ inches from

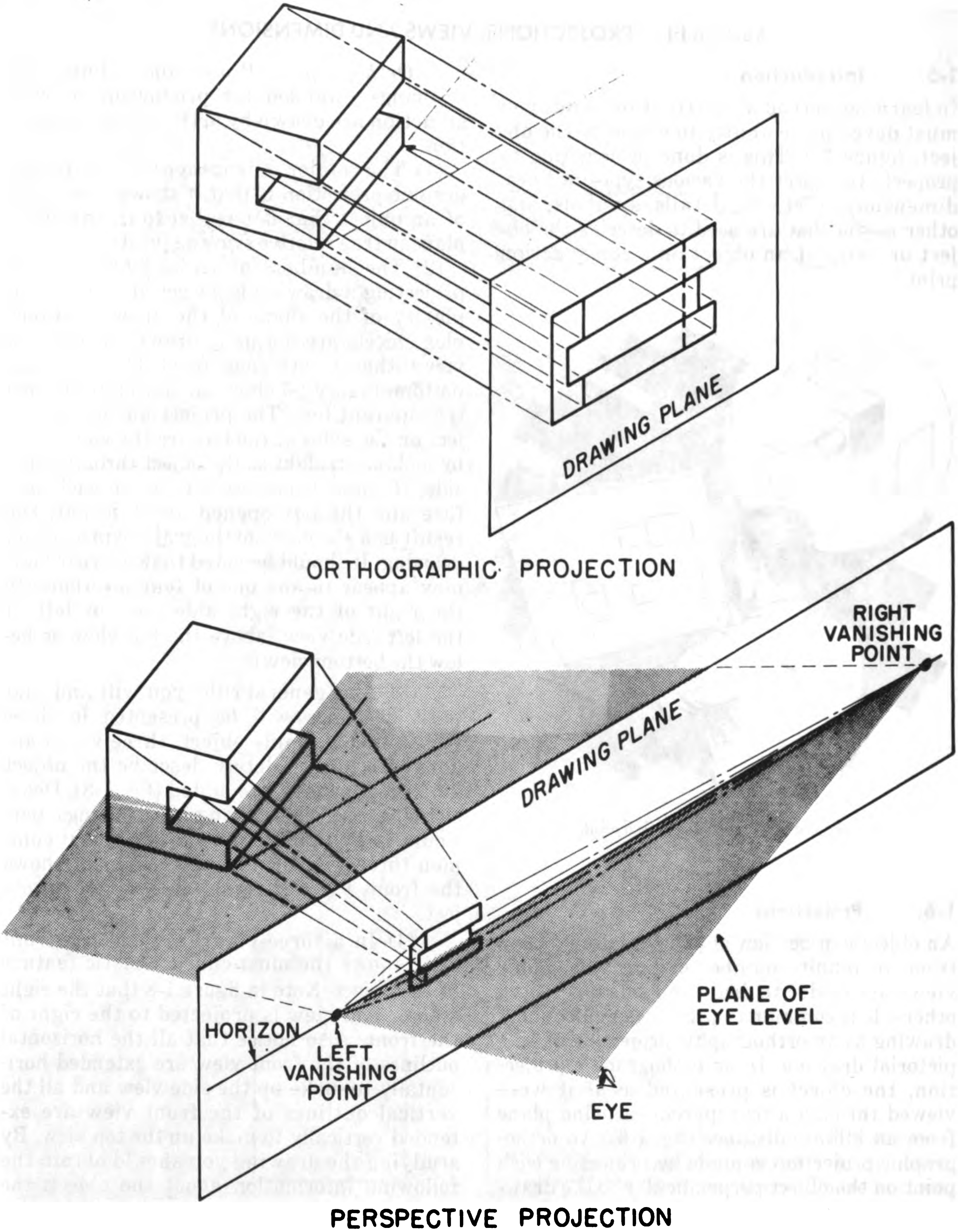


Figure 1-6. Orthographic versus perspective projection.

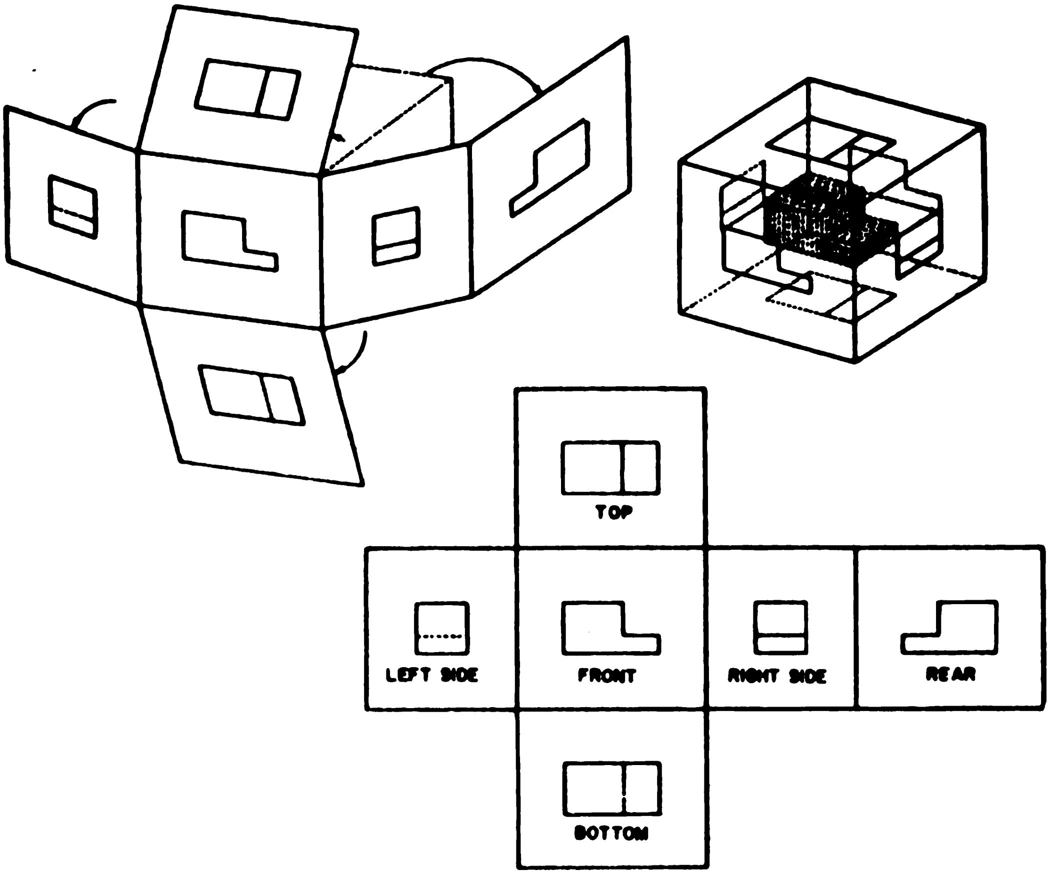


Figure 1-7. Third angle orthographic projection.

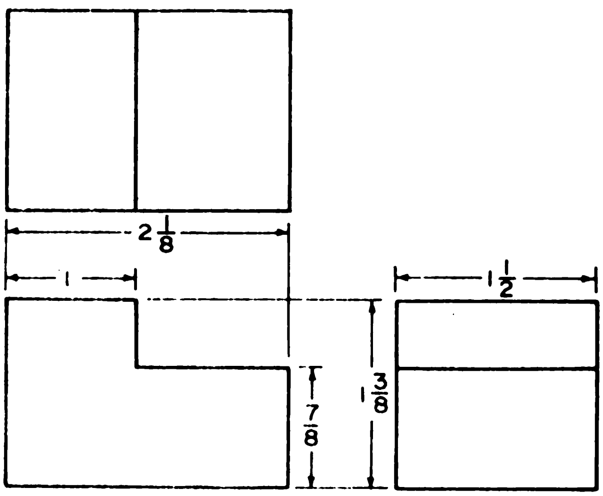


Figure 1-8. Three-view drawing.

the right side and ⅞ inch from the bottom. After having studied each view of the object, you should be able to visualize the object as it appears in figure 1-9. If a hole is drilled in the notched portion of the object, the drawing would appear as in figure 1-10. The position of the hole is indicated by hidden lines in the front and side views and as a circle in the top view. The location of the center of the drilled hole is indicated by a center line.

b. Pictorial Drawings. It is easier to visualize an object if its features can be shown in a single view. Where it is necessary for the drawing to show the appearance of an object with more than one side visible in a single view, pictorial drawings are used. Three types of pictorial drawings may be encountered: projections, oblique drawings, and perspective drawings.

(1) *Projections.* The principle of pictorial projections is the same as orthographic projection, but the object is rotated and tilted so that more than one face is projected on the drawing plane as shown in figure 1-11. Since the faces of the object are not parallel to the drawing plane, lines are foreshortened and do not appear in true length. If each object plane forms a different angle with the drawing plane, the amount of foreshortening is different along each axis of the drawing. This is called a trimetric projection (fig. 1-11) and three different scales must be used. If the object is rotated so that two planes form the same angle with the drawing plane, the amount of foreshortening will be the same along two axes. This is called a dimetric projection (fig. 1-11) since only two scales are used. If the object is tilted so that all three planes form the same angle with the drawing plane, the scale will be the same along all three axes. This is called an isometric projection (fig. 1-11), and is the most common type in technical work. All lines parallel with one of the three principal axes are foreshortened by the same amount (to about 81 percent of true length) on an isometric projection. In isometric drawing (fig. 1-11) the common practice is to enlarge the scale factor so that lines appear in true length. Remember, however, that this applies only to lines which are parallel to one of the axes.

(2) *Oblique drawings.* In oblique drawings (fig. 1-12) the front face of the object is drawn in orthographic form, full scale. One or more sides are then added at an angle to the front face, either full scale, or foreshortened. Any angle and scale may be used.

(a) *Cavalier drawing.* An oblique drawing in which the receding or oblique lines are

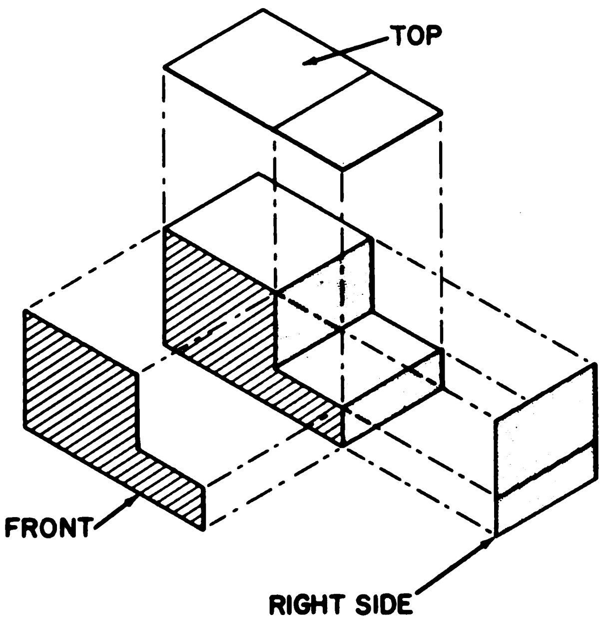


Figure 1-9. Interpretation of a three-view drawing.

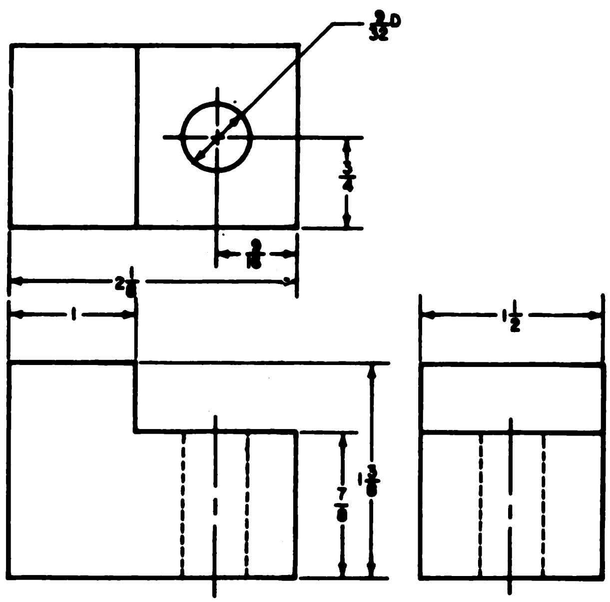


Figure 1-10. Hidden lines in a three-view drawing.

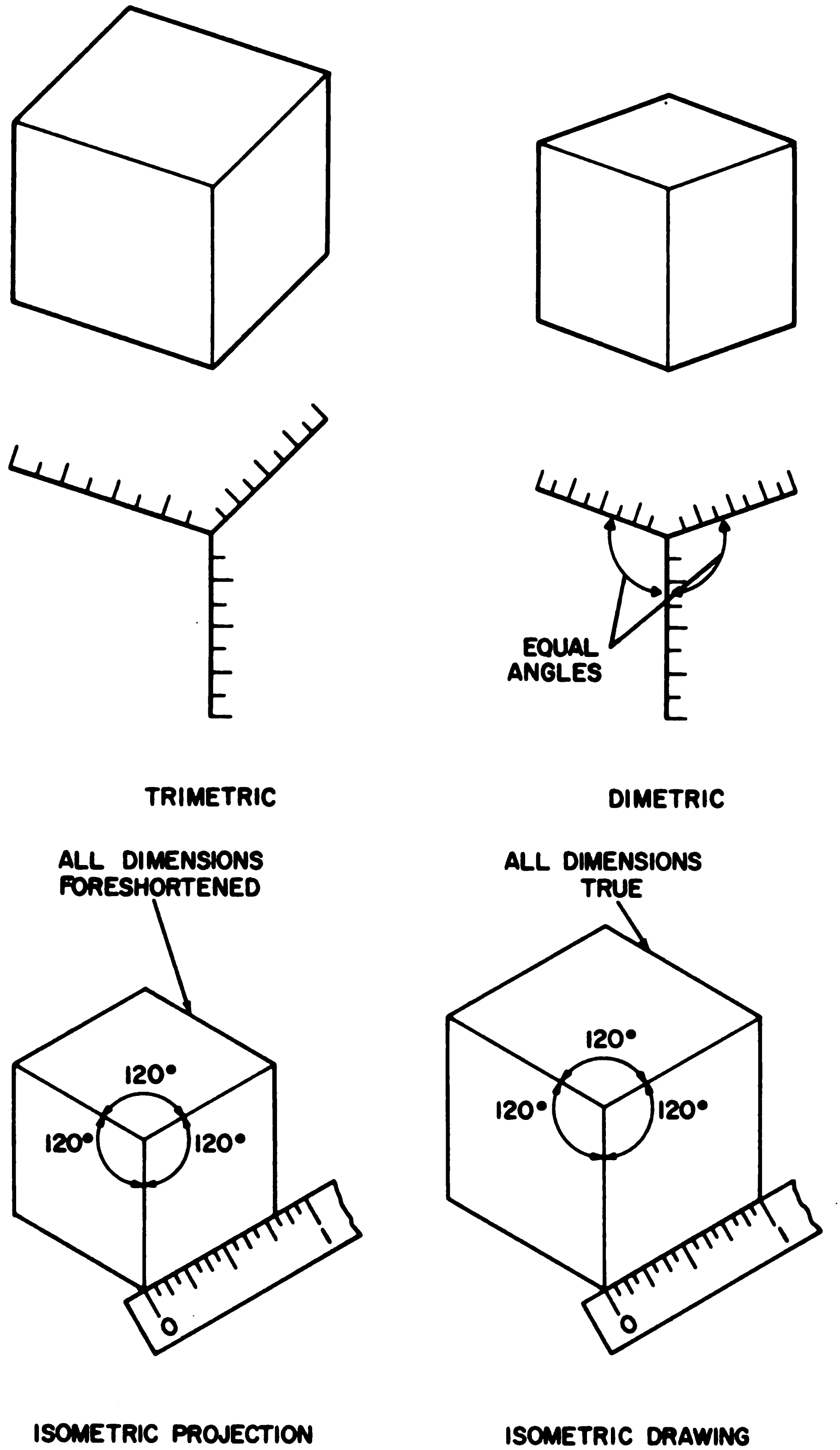


Figure 1-11. Pictorial projections of a cube.

drawn full-scale at 45° is called a cavalier drawing (fig. 1-12). The result does not create a realistic appearance, but allows the use of one scale for the entire drawing.

(b) *Cabinet drawing.* A cabinet drawing is an oblique drawing which uses half-scale measurements on the oblique sides (fig. 1-12). These drawings are commonly drawn with the oblique lines at 30° or 45° to the front plane. The name comes from the fact that it is often used for drawings of cabinet work.

(3) *Perspective drawing.* The most realistic pictorial is the perspective drawing. In this type of drawing, the receding lines converge at a vanishing point on a horizon, just as they appear to do when you look at an object. The perspective may be two-point (two vanishing points) as illustrated in figure 1-13 or one-point (one vanishing point) as illustrated in figure 1-14. In a one-point perspective, the front face appears as if you were looking at it headon. The viewing angle may be changed by the selection of different position relative to the horizon (fig. 1-14). Perspective drawings are more difficult to draw than projections or oblique drawings, because the scale changes continuously along the receding lines; for this reason, they are not practical for construction drawings.

1-7. SPECIAL VIEWS

When complex objects are involved, three-view drawings are often not sufficient to convey all the necessary details. Special views are added to provide additional information. The special views which may be encountered are auxiliary and rotation views, sections, phantom views, developments, and exploded views.

a. *Auxiliary Views.* If a feature of an object is in a plane which is not parallel to one of the drawing planes, it will not appear in true size or shape in any of the three normal views. The sloping surface of the object in figure 1-15, for example, appears in both the top and right side views but is foreshortened in both. In this case, an auxiliary projection is added. The auxiliary view is obtained by pro-

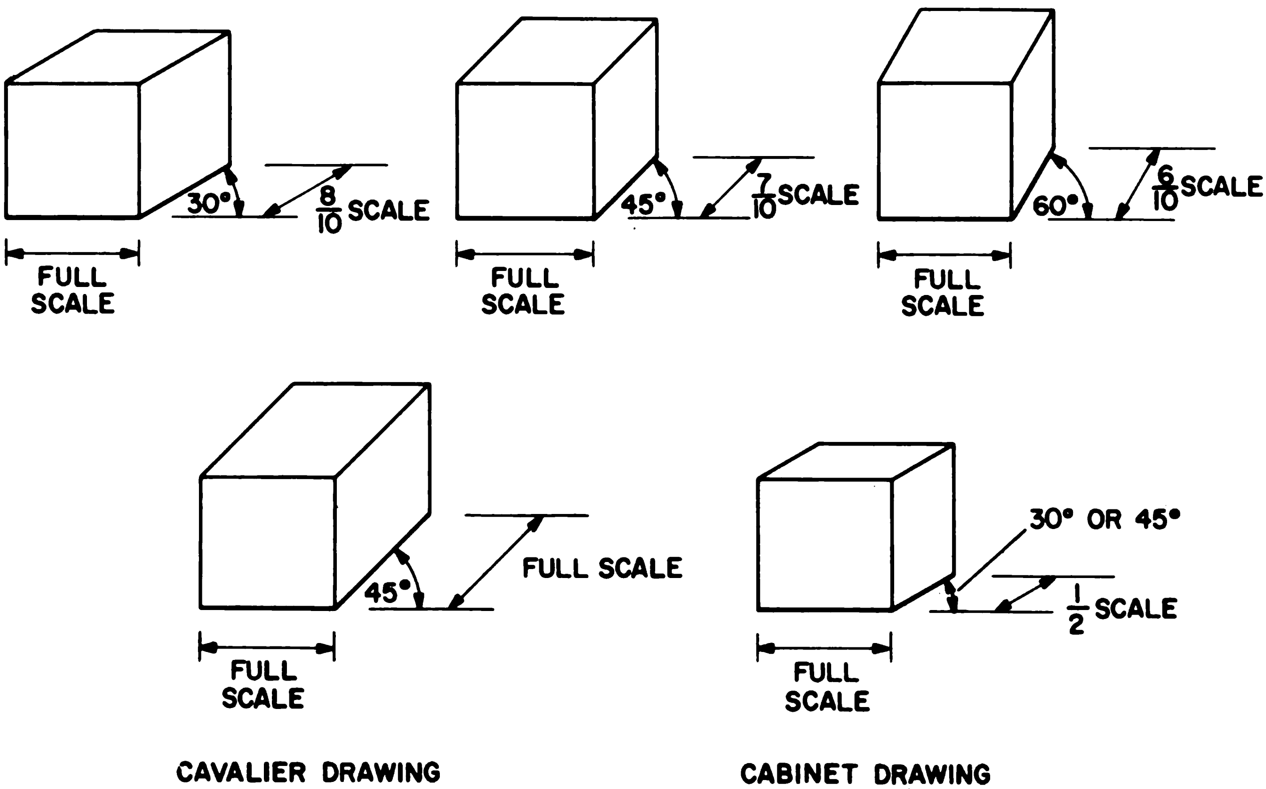


Figure 1-12. Oblique drawings of a cube.

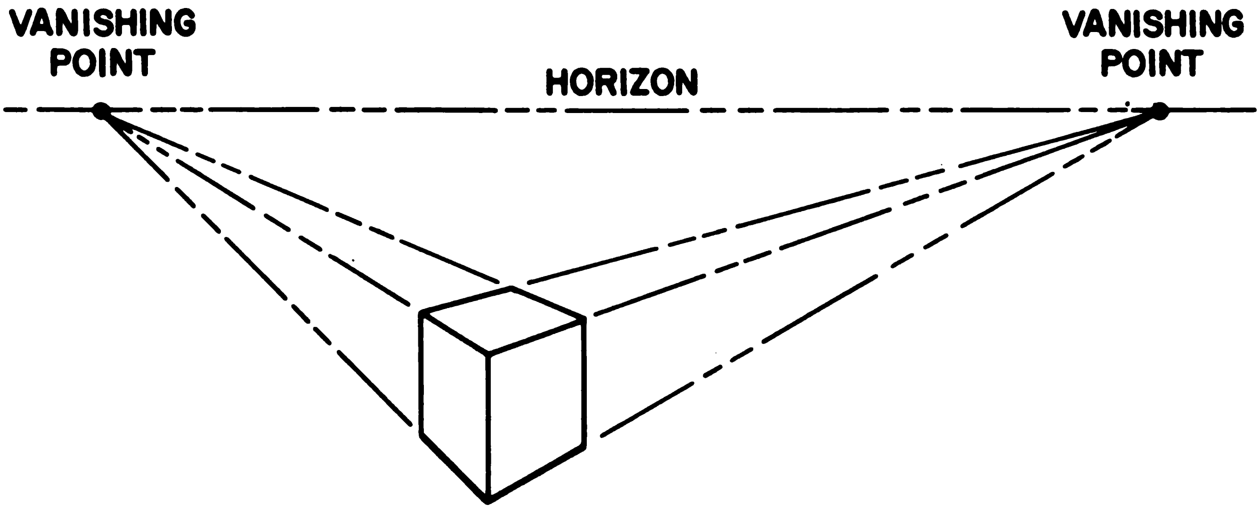


Figure 1-13. Two-point perspective drawing.

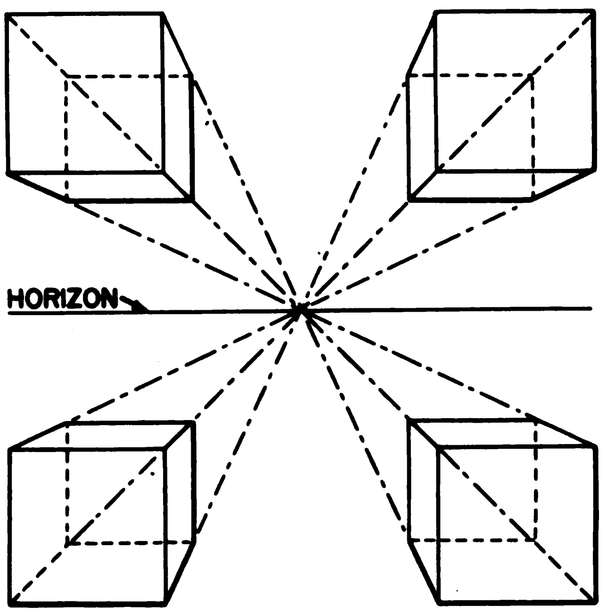


Figure 1-14. One-point perspective drawings.

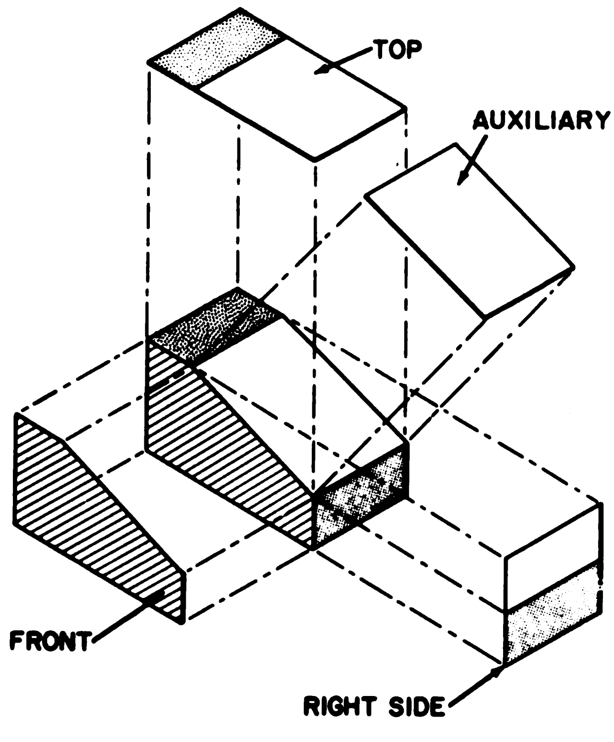


Figure 1-15. Auxiliary projection principle.

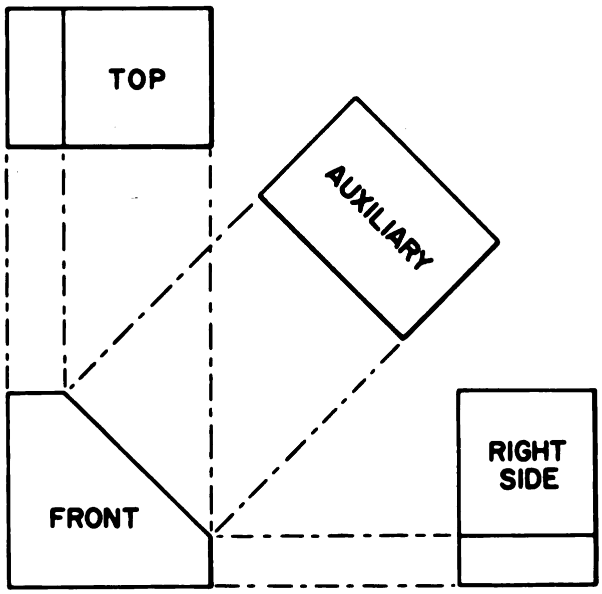


Figure 1-16. Auxiliary view arrangement.

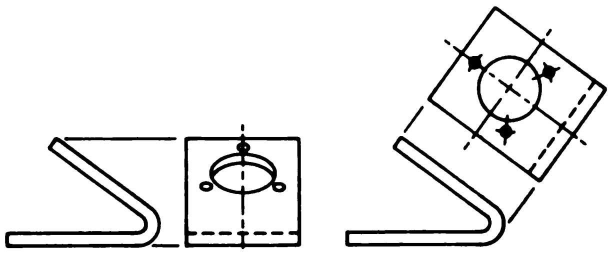


Figure 1-17. Auxiliary and side views compared.

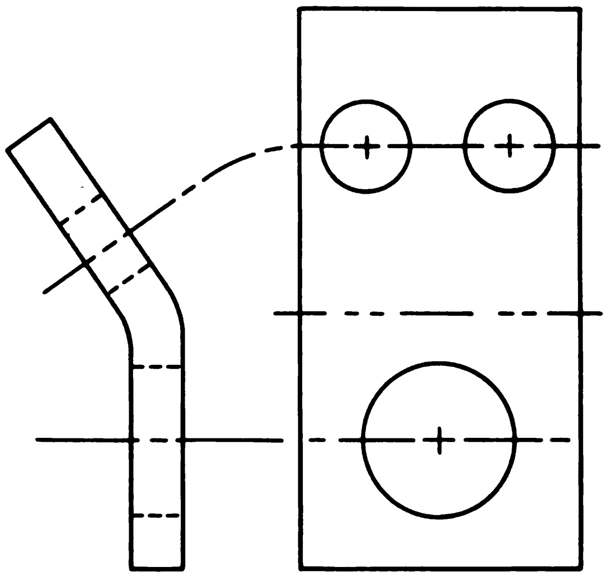


Figure 1-18. Rotation.

jecting lines to a drawing plane which is parallel to the slanted face. The auxiliary view is normally placed alongside a view which shows the true length of the edge of the slanted surface as shown in figure 1-16. In this case, the auxiliary view is related to the front view in the same way as the top or right side view is related to the front view. If the feature to be covered in an auxiliary view is not in a plane perpendicular to one of the normal orthographic drawing planes, or if there is not enough room in the normal position, the auxiliary view will be placed somewhere else on the drawing. In this case, the auxiliary view will usually be labeled as "view A" (or B, C, etc.) with an arrow pointing to the face. Auxiliary views do not usually show the entire object as seen from the auxiliary view angle; only the surface parallel to the auxiliary drawing plane is covered. Figure 1-17 shows an auxiliary view compared with a right side view of the same object. Note that the circles appear as ellipses in the right side view, and the distance between centers are foreshortened. The auxiliary view only shows the slanted face of the object, the holes appear in true shape, and the distances in true length.

b. *Rotation.* Occasionally, if no confusion will result from the practice, a separate auxiliary view is omitted and a side or top view is provided, drawn as if the object was bent to bring the slanted surface parallel to the drawing plane (fig. 1-18). This is called a rotation, and the fact that it has been done will be indicated in some manner on the drawing. In figure 1-18, for example, the fact that one view is higher than the other, plus the curvature of the upper center line shows immediately that the right hand view is a rotation.

c. *Sections.* Section views are used to give a clear view of the interior or hidden features of the object which normally cannot be clearly observed in conventional outside views. A section view is obtained by cutting away part of an object to show the shape and construction at the cutting plane. The most common position of the cutting plane is through the longest dimension, or main longitudinal axis and parallel to the front view as shown in figure 1-19. The cutting plane may be drawn parallel to any plane of projection if it shows the required features of the object. When section views are drawn, the part that is cut by the cutting plane is marked with closely spaced, parallel (section) lines. The section lines indicate the surfaces which were created by the cutting plane and which do not exist on the uncut object. When two or more parts are cut in one view, a different slant or style of section line is used for each part. All rules of projection apply, but hidden lines complete understanding of the view. Notice how the cutting plane is shown on a drawing as illustrated in [1] figure 1-19. The cutting plane in [2] illustrates where the imaginary cut is made. The object as it would look if it were cut in half is shown in [3]. The section view as it would appear on a drawing is shown in [4].

(1) Full-sections. When the cutting plane is a single continuous plane passing entirely through the object, the resulting view is called a full-section view [1] fig. 1-20). The cutting plane is usually taken straight through on the main axis or center line.

(2) Half-sections. The cutting plane will not always be taken completely through the object. [2] Figure 1-20 shows a half-section. The cutting plane passes only half-way through the object. This is common practice for symmetrical objects. In the case illustrated, the top half, if sectioned, would be identical to the bottom half, providing no additional information. The half-section permits both the internal and external features to be shown and their relationship to one another.

(3) Offset section. A section view which has the cutting plane changing direction backward and forward (zig-zag), so as to pass through features that are important to show, is known as an offset section. The offset cutting plane in figure 1-21 is arranged so that the hole on the right side will be shown in section. The sectional view is the front view, and the top views show the offset cutting plane line. Notice that there is no line on the section view at the point where the cutting plane goes straight back.

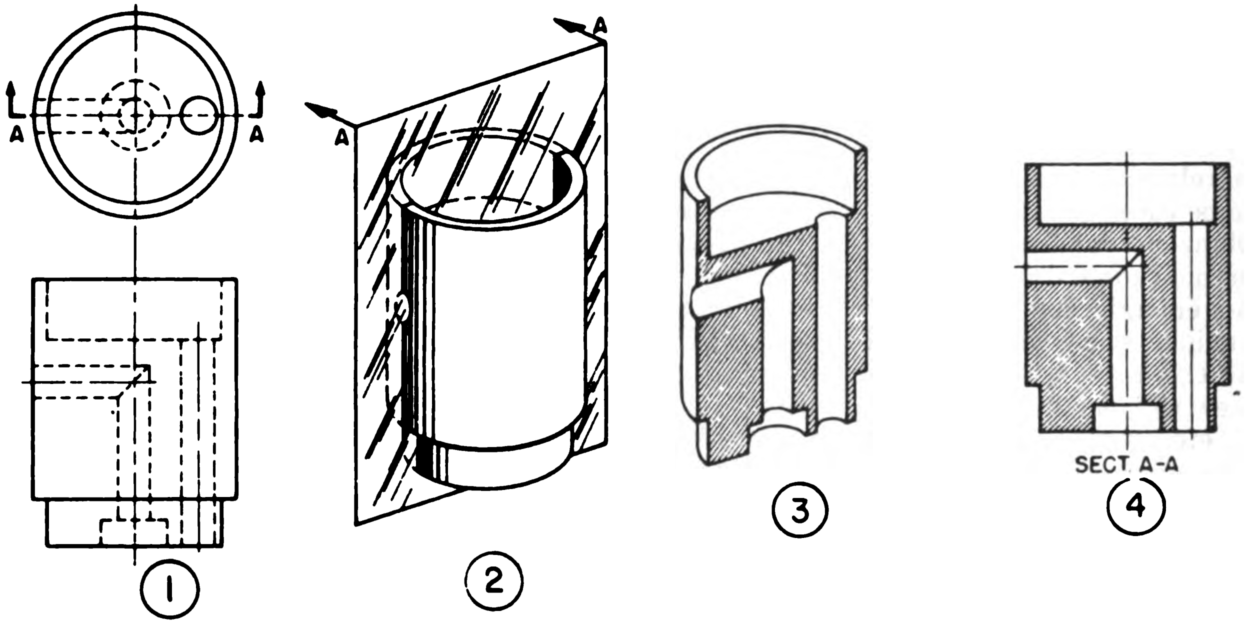


Figure 1-19. Action of the cutting plane.

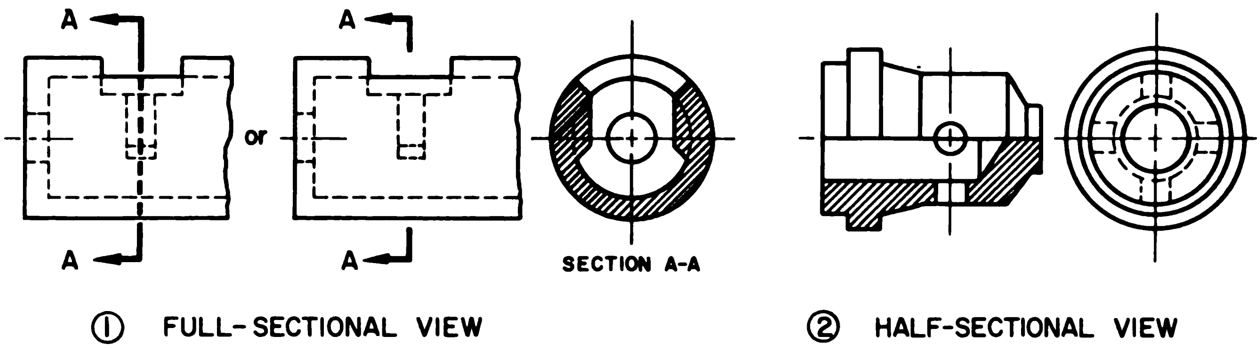


Figure 1-20. Full-and half-sectional views.

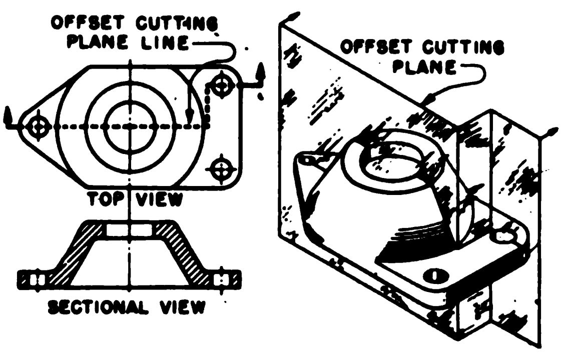


Figure 1-21. Offset section.

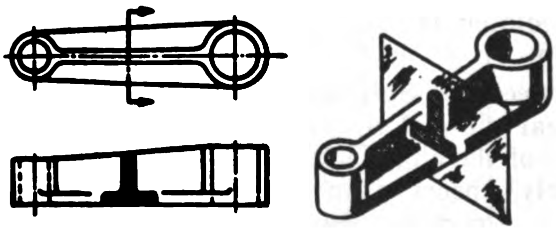


Figure 1-22. Revolved section.

(4) *Revolved section.* To eliminate drawing extra views of rolled shapes, ribs, and similar forms, a revolved section is used. It is a drawing within a drawing, and it clearly describes the object's shape at a certain cross-section station or point. The sectional view of the rib in figure 1-22 has been revolved so that you can look at it head-on.

(5) *Removed section.* Removed sections are normally used to illustrate particular parts of an object (fig. 1-23). They are drawn like the revolved section, except that they are placed at one side to bring out important details. They are often drawn to a larger scale than the view on which they are indicated.

(6) *Broken-out section.* A broken-out section is a partial section used on an exterior view to show some interior detail without drawing a complete full or half section. The limit of the broken-out section is indicated with an irregular break line. In figure 1-24, the inside of the fitting is better illustrated because of the broken-out section.

(7) *Alined section.* Look at the front view of the handwheel in figure 1-25 and notice the cutting plane line AA. When a true sectional view might be misleanding, parts such as ribs or spokes are drawn as if they are rotated into or out of the cutting plane. Notice that the spokes in the section at A-A are not sectioned. In some cases, though not in this figure, if the spokes were sectioned, the first impression would be that the wheel had a solid web rather than spokes.

d. Phantom Views. Phantom views are used to indicate the alternate position and path of motion of parts, repeated details, or the relative position of an absent part. Figure 1-26 shows the alternate position of a part as a phantom view (the part on the left side).

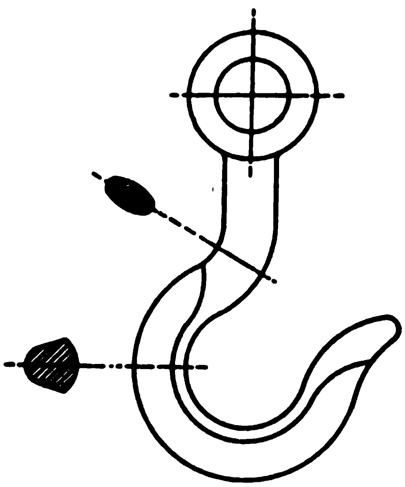


Figure 1-23. Removed section.

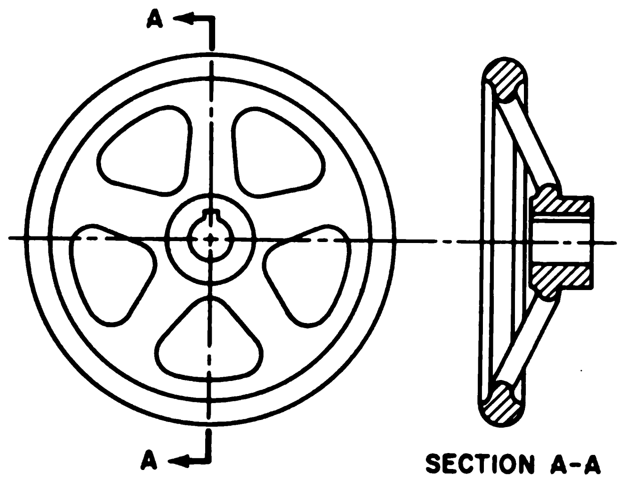


Figure 1-25. Alined section.

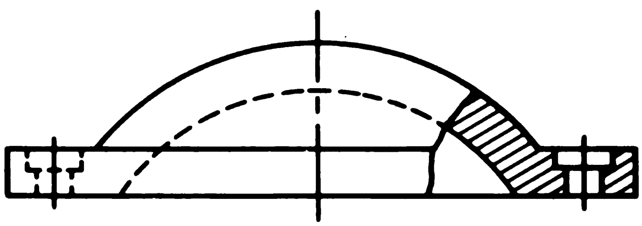


Figure 1-24. Broken-out section.

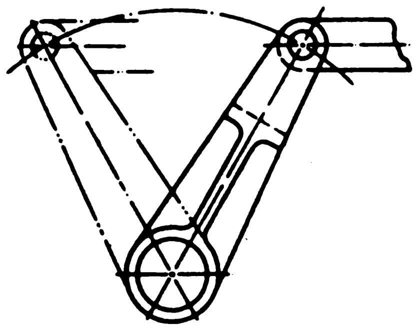


Figure 1-26. Phantom view.

e. *Development.* A development is a drawing which is used for objects which are made from flat materials by bending and joining, such as ducts. The development (also called a stretch-out or pattern drawing) shows the shape of the material before it is formed into the assembled object (fig. 1-27).

f. Exploded Views. Exploded views are used to illustrate the assembly or disassembly of a unit which has several removable parts. It is basically a pictorial view of each of the parts to the same scale, with the parts arranged in a relationship which corresponds to their relationship when assembled (fig. 1-28).

1-8. Dimensions

a. The item you will be most concerned with when reading prints is the dimensions. As previously stated, dimensions on architectural drawings are usually given in feet, inches and fractions of an inch. Engineering drawings often give dimensions in feet and decimal fractions of a foot. Metric dimensions are used on drawings of European origin, most drawings related to optical equipment, and a growing percentage of American machine drawings. During construction, you should use measuring instruments calibrated in the same system as used on the construction prints to eliminate the chance of error in conversion. Appendix D lists conversion factors for most units you are likely to encounter.

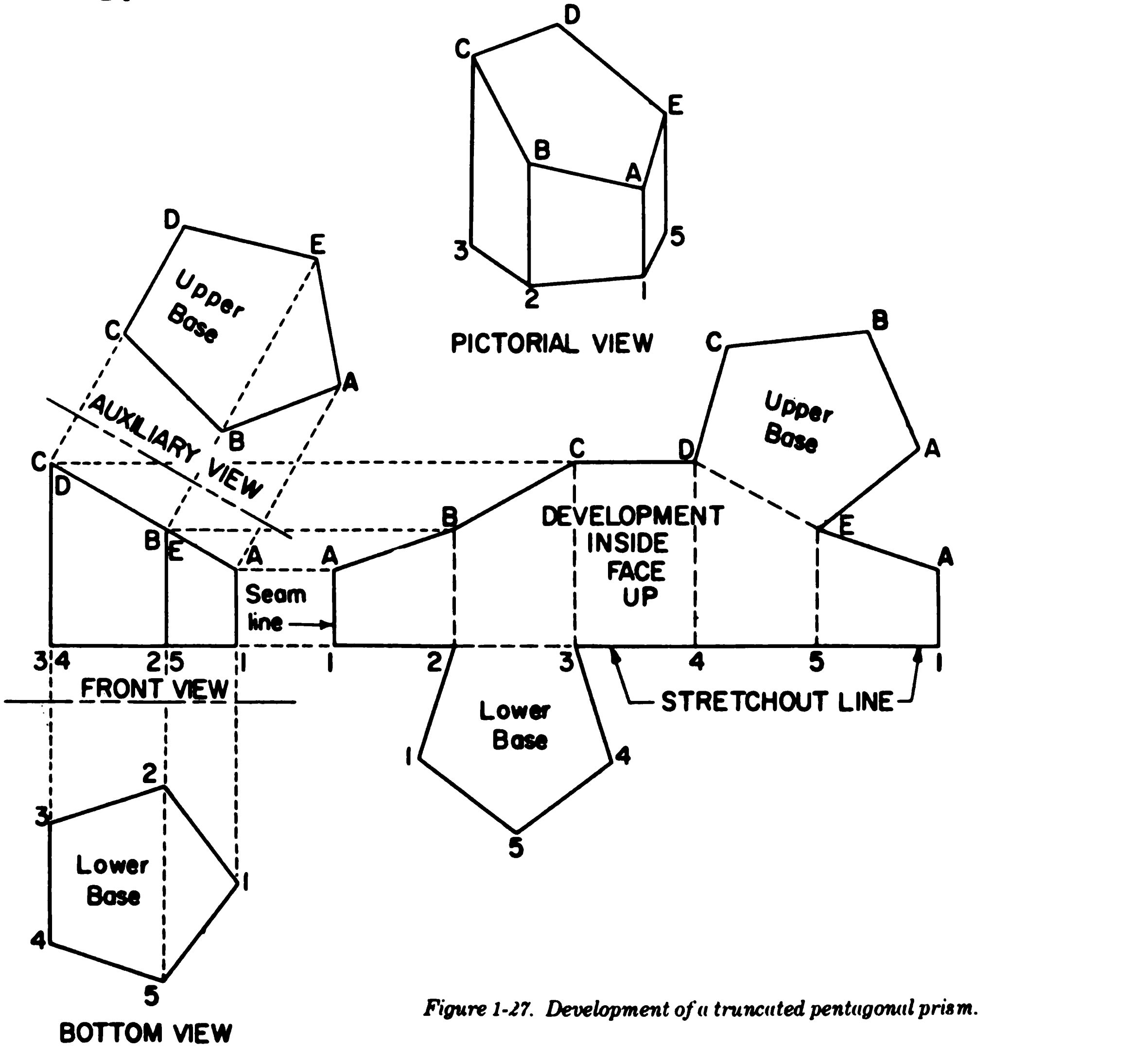


Figure 1-27. Development of a truncated pentagonal prism.

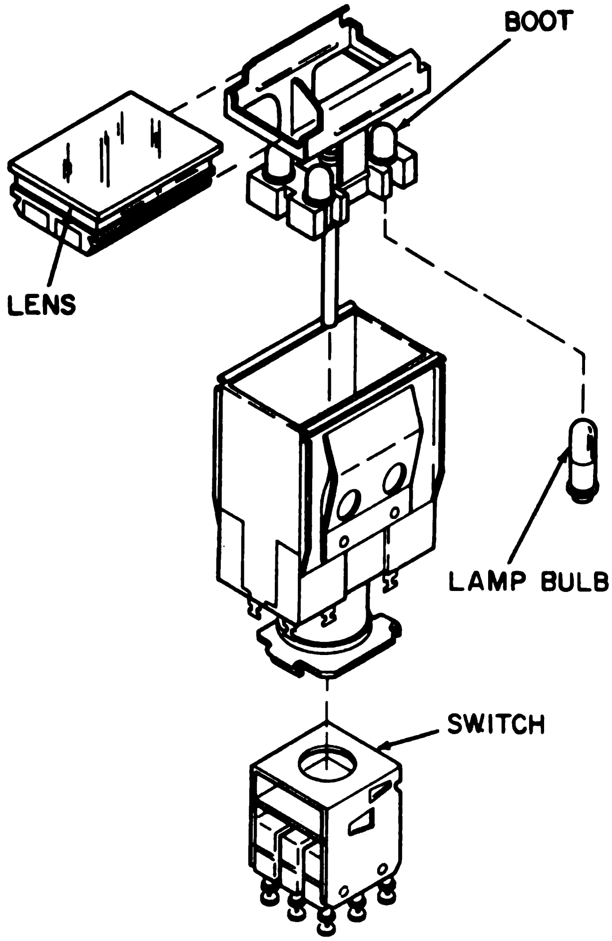


Figure 1-28. Exploded view.

b. The placement of dimensions on a drawing is not arbitrary. They are placed to indicate which dimensions are specified in the design of the object. Measurements for construction should always be made from the points indicated by the dimension lines on the print.

c. Figure 1-29 is a typical dimensioned drawing of a bearing journal and can be used to illustrate the proper way to make measurements from the points indicated by the dimension lines on the print. Let's consider the measurements required to locate the two mounting holes. If you were using this print and were drilling the mounting holes, you should notice in the front view that the center of the right hole is located 1 inch from the center of the large hole. The top view shows that the center of the left hole is 2 inches from the center of the right hole. This method of making measurements introduces two possible sources of error. There is some tolerance in the location of the right hand mounting hole, and some tolerance in the measurement you make to locate the lefthand mounting hole. Any other system of measurements will introduce additional sources of error. For example, it can be determined from the dimensions that the mounting holes are located ¼ inch from the edges and the centers could be located in this manner. However, this introduces three sources for error. There is some tolerance in the width of the journal (the 2½-inch dimension) and some tolerance in the location of the centers of the two mounting holes. These three sources for errors could accumulate and result in a significant error in the distance between the two mounting holes. This distance is critical to the mounting of the journal. It is also possible to locate the center of one hole ¼ inch from the edge and then measure the 2 inches to the center of the other hole. This procedure also introduces three possible sources of error. There is some tolerance in the width of the journal, in the location of one hole, and in the measurement made to locate the second hole. This method reduces the sources of error in the distance between the mounting holes. However, it does introduce possible error in the location of the main hole. It may not be centered between the mounting holes. These examples emphasize the importance of the location of the dimensions when making the measurements in construction.

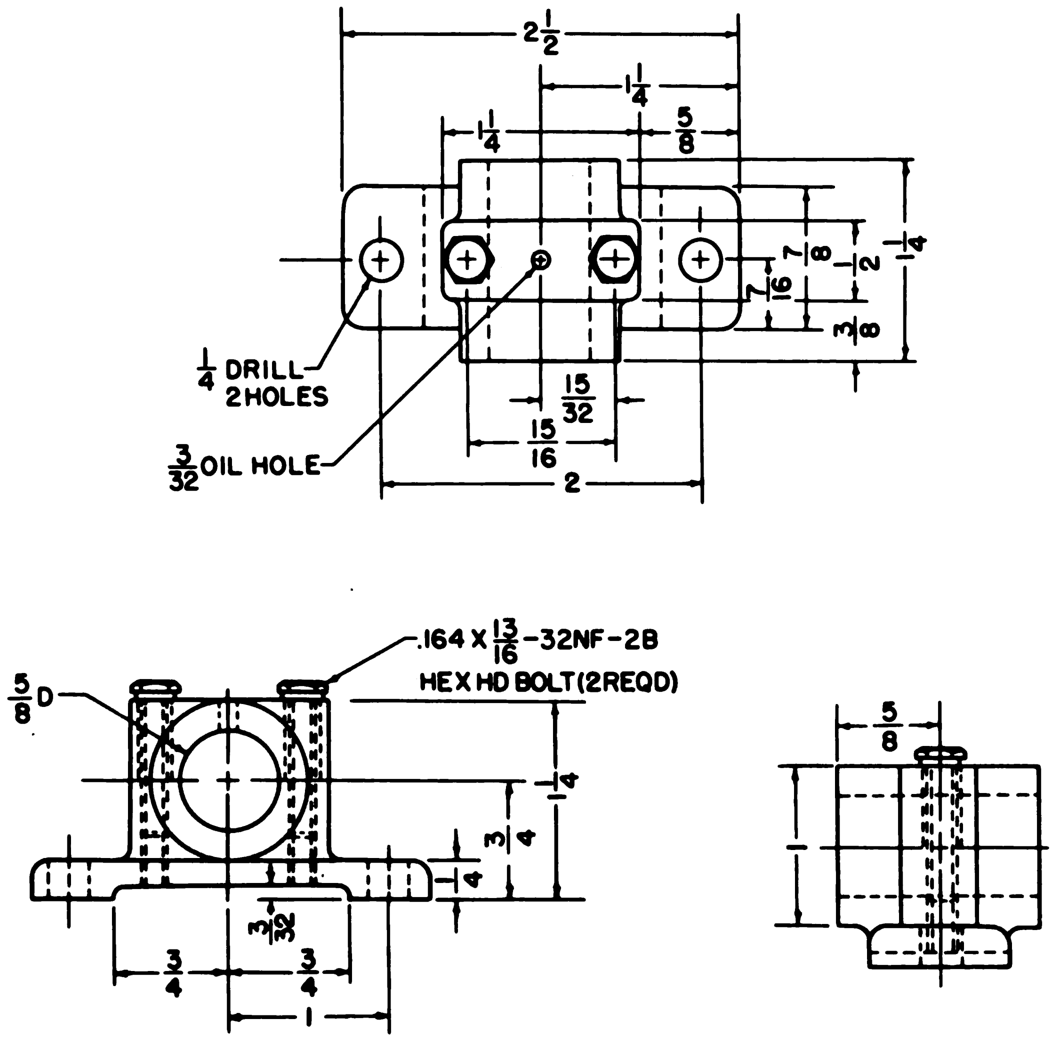


Figure 1-29. Typical working drawing.

Section IV. TYPES OF PRINTS

1-9. Classes of Drawings

Drawings are normally classified as original drawings, intermediate or reproducibles, or prints. The original drawing is the one produced by the draftsman. An intermediate is a copy of the original which is used to make prints. An intermediate is used to avoid the risk of damaging the original or because the original is not suitable for the type of reproduction process used for the making of prints. Prints may also be made directly from the original without using an intermediate drawing. A print is a working copy used on the job.

1-10. Production Processes

There are many processes used to make prints from originals or intermediates. They can be classified as either negative or positive contact processes or optical processes. Contact processes require a transparent or translucent original. Optical copies can be made from opaque originals. Contact processes are normally used in construction work. Optical copies are usually more expensive and introduce more distortion.

a. Negative Contact Processes.

(1) *Blueprints.* A blueprint is made by placing a tracing (transparent or translucent original) in contact with a sensitized paper and exposing the paper through the tracing. When the paper is developed, the unexposed portions where the light is blocked by lines on the original remain white, while the exposed portions turn dark blue. This produces a print with white lines on a blue background. Blueprints, in general, have better contrast than other commonly used processes of comparable cost but the wet developing process causes some distortion and marking the prints is difficult.

(2) *Brownprints.* The brownprint process (often called Van Dyke) is similar to the blueprint process except that the paper is transparent and exposed areas turn brown when developed. This yields transparent lines on a brown background. Brownprints are frequently used as intermediates producing a print which has blue lines on a white background and called a whiteprint.

b. Positive Contact Processes.

(1) *Ozalid prints.* The ozalid process is a contact process like blueprinting but the unexposed areas of the sensitized paper turn blue when developed in ammonia vapor, producing blue lines on a white background. Ozalid prints are also called blueline prints. Papers are also available which yield black lines (called blackline prints). The development in this process is dry, causing less distortion than the blueprint process, but the contrast is not usually as good.

Note: Machines are available which produce ozalid-process prints but which project and reduce the image optically instead of contact-printing. Prints produced by this process will usually be marked "Reduced Size Print - Do Not Scale."

(2) *Brownline prints.* Brownline prints have the same function in the ozalid process as the brownprints do in the blueprint process. They produce brown lines on a transparent background and are often used as an intermediate for making blueline prints. Brownline prints are often called sepia intermediates.

(3) *Special materials.* Materials are available for use with the ozalid process which produce a large variety of results, including many colored lines on white paper or colored lines on a clear plastic background.

c. Optical Processes.

(1) *Electrostatic.* An electrostatic copier (Xerox machine for example) projects an image of the original on paper and then causes an electrostatic charge to be deposited where the image of a line occurs. A black powdered "ink" is then applied to the paper and adheres where the electrostatic charge occurs. The image is then fused to the paper. This process produces a dark gray image on a white background. The amount of distortion depends on the type and qualify of the optical system which projects the image on the copy paper.

(2) *Photostat.* The photostat process is a photographic process which uses a special camera and film. The film is opaque paper instead of transparent film as in ordinary photography. Since the negative is opaque and cannot be viewed from the back, the camera is designed to produce an erect image instead

of a reversed image as with orginary cameras. The photostat process produces white lines on a black background (negative photostat) which can then be rephotographed to produce a black image on a white background (positive photostat). The image can be enlarged or reduced in the photostat process, usually to ½ or 2 times original size in each stage.

(3) *Microfilm.* For economy of storage space and for insurance against destruction of the original, many drawings are photographically copied on microfilm. When a drawing is no longer in frequent use, the original is often disposed of and only the microfilm copy is retained. Equipment is available for viewing microfilm copies (similar to a slide viewer) and for making prints directly from microfilm copies. Since the image must go through the original optical reduction, developing of the microfilm, enlargement, and the final print process, the chance of distortion is high.

1-11. Handling Prints

a. A completed drawing represents too much time and effort to be treated casually. It is a valuable record, and must be preserved with care. If an original drawing were to be used on the job and passed from man to man, it would soon become worn and too dirty to read. For this reason, working drawings used on the job are almost always reproductions of original drawing.

b. A little time spent in carefully folding and filing prints at the start will prevent a lot of inconvenience later on. The method of folding depends on the facilities available for storage. Some filing equipment commonly used is shown in figure 1-30. When manufactured filing equipment is not available in the field, storage facilities should be constructed. Prints should be folded so the drawing number is visible when the print is filed. If storage space is available to accommodate rolls, prints over 40 inches long are usually rolled instead of folded. Original drawings or intermediates used for contact process reproduction should never be folded; the creases will prevent close contact with the copy paper.

c. When using prints on the job, avoid long exposure to direct sunlight or the prints will fade. If it is necessary to mark a print, be neat and use a colored pencil. A red pencil is normally used to show additions and a yellow pencil is used to indicate deletions. After using a print, refold it carefully to avoid adding unnecessary creases.

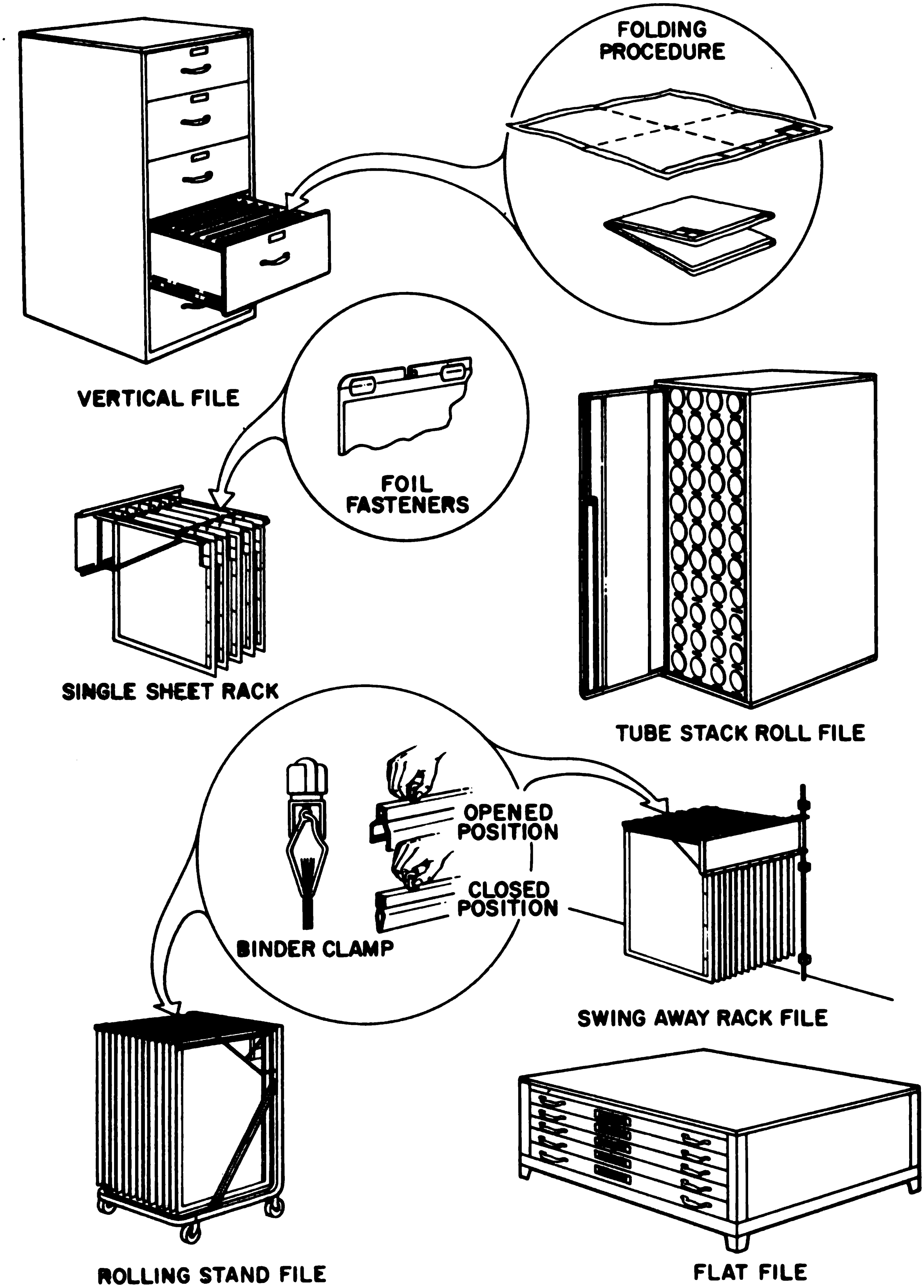


Figure 1-30. Print and drawing storage.

Section V. PARTS OF A PRINT

1-12. Drawing Formats

A drawing not only provides information about the size and shape of the object being represented but also provides information that enables the drawing to be identified, processed, and filed methodically. The systematic arrangement of the drawing sheet to provide a consistent location for this information is known as the format of a drawing. Sizes and formats for military drawings are arranged in accordance with certain standards.

a. Drawing Sizes. Military drawings are prepared in standard sizes, designated by letters. These sizes are listed in table 1-1. Roll size drawings are normally prepared with an extra 4-inch margin for protection if possible without exceeding the 144-inch length limit. Complete details on military drawings may be found in MIL-STD-100A.

Table 1-1. Finished Format Sizes (Inches)

SIZE	HEIGHT	LENGTH	MARGIN
	Flat Sizes		
A	8½	11	.25 & .38*
A	11	8½	.25 & .38*
B	11	17	.38
C	17	22	.50
D	22	34	.50
E	34	44	.50
F	28	40	.50
	Roll Sizes		
G	11	42 to 144	.38
H	28	48 to 144	.50
J	34	48 to 144	.50
K	40	48 to 144	.50

*Horizontal margins .38-inch vertical margins .25-inch *b. Title Block.* A typical title block as illustrated in figure 1-31 shows the name and address of the preparing agency (A), the title of the drawing (B), the drafting record (C), authentication and date (D), the scale and specification number (E), and the drawing number and sheet number for multiple-sheet drawings (F).

(1) *Drawing number.* Each drawing is identified by a drawing number, which appears in a number block. It may be shown in other places also; for example, near the top border line, in the upper corner, or on the reverse side at both ends so that it will be visible when a drawing is rolled up. The drawing number's purpose is to permit quick identification. If a drawing has more than one sheet, and each sheet has the same number, this information is included in the number block indicating the sheet number and the number of sheets in the series. When using construction drawings, always check to be sure that all necessary sheets are on hand. Some multiple-sheet construction drawings have a "schedule of drawings" near the title block which lists the contents of each sheet.

(2) *Scale.* The scale block will indicate the scale on the drawing, either as a ratio (for example: ¼ or 1:4 meaning 1 inch on the drawing equals 4 inches on the object, or 12" = 1" meaning 12 inches on the drawing equals 1 inch on the object) or as a graphic scale as shown in figure 1-32. Where the same scale is not used on all parts of a drawing, the scale block may be marked "as noted" or left blank, and the scale noted underneath each part of the drawing. If graphic scales are used, several scales may be shown with numbers (fig. 1-32) and the appropriate scale number noted alongside each part of the drawing. When reading drawings, always follow the dimensions specified on the drawing first, and use the scale on the drawing where no dimension is given. Do not measure with an architect's or engineer's scale directly on a print, since the print may be enlarged or reduced, or the paper may shrink during the copying process.

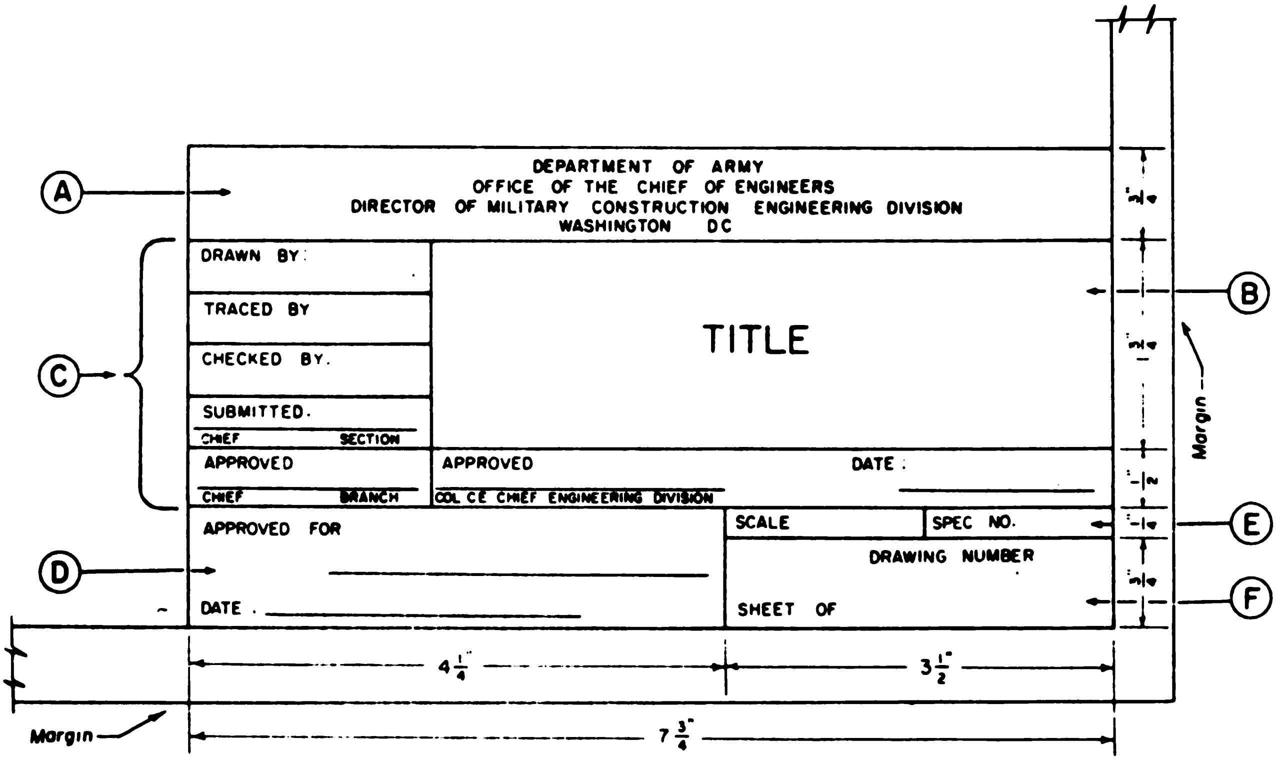


Figure 1-31. Typical title block.

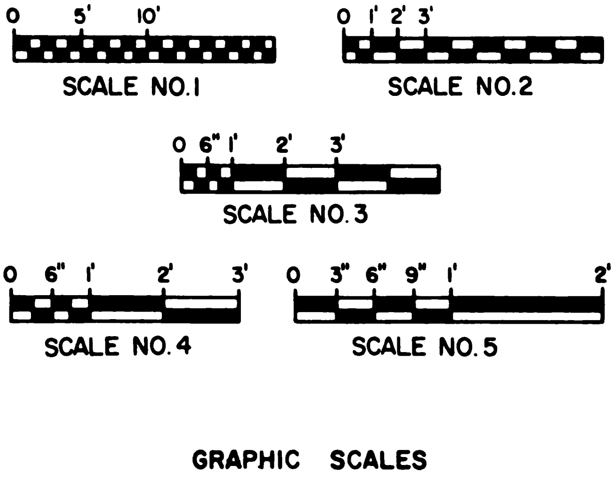


Figure 1-32. Graphic scales.

(3) *Specification number.* The specification number indicates the specification the draftsmen followed for assistance in interpreting the drawing.

c. Bill of Materials. A special block on the drawing may contain a list of the pieces of stock or standard parts necessary to construct the object on the drawing, and the quantity of each item required. This list may also be called a list of materials, schedule of equipment, or parts list. If several sheets are required for a particular object, the bill of materials may appear on a separate sheet(s).

d. Revision Block. Space is always left on a drawing to list revisions as they are made. The revision block will show the revision symbol, A, B, C, etc. consecutively as encountered, a brief description of the revision, the revision date and supervisor's approval, and sometimes the zone of the drawing in which the revision was made. If more than one copy of a drawing is available, the revision block should be checked to find the drawing with the latest revision.

e. Notes and Specifications. Notations explaining construction methods or specifying materials which are not indicated by symbols are called specifications. The notes may list allowable substitutions, special provisions for certain locations, additional reference material, and so forth. The notes must always be read before beginning construction.

1-13. Military Drawings

Military drawings are classified as construction or production drawings, depending on the method of manufacture of the object or assembly represented on the drawing or set of drawings. The format of each type is arranged differently, although sheet and margin sizes are common to both.

a. Construction Drawings. Construction drawings are drawings developed to illustrate the design of structures or other constructions and the services, utilities, approaches, or any other features involved. Maps (except those with construction drawings), reports, sketches, presentation drawings, or renderings are not considered to be construction drawings within the meaning of this standard. The basic construction drawing format consists of the margin, the title block with its various subdivisions, the revision block, and the block containing the list of material. Figure 1-33 shows the layout and dimensions of the typical construction drawing format.

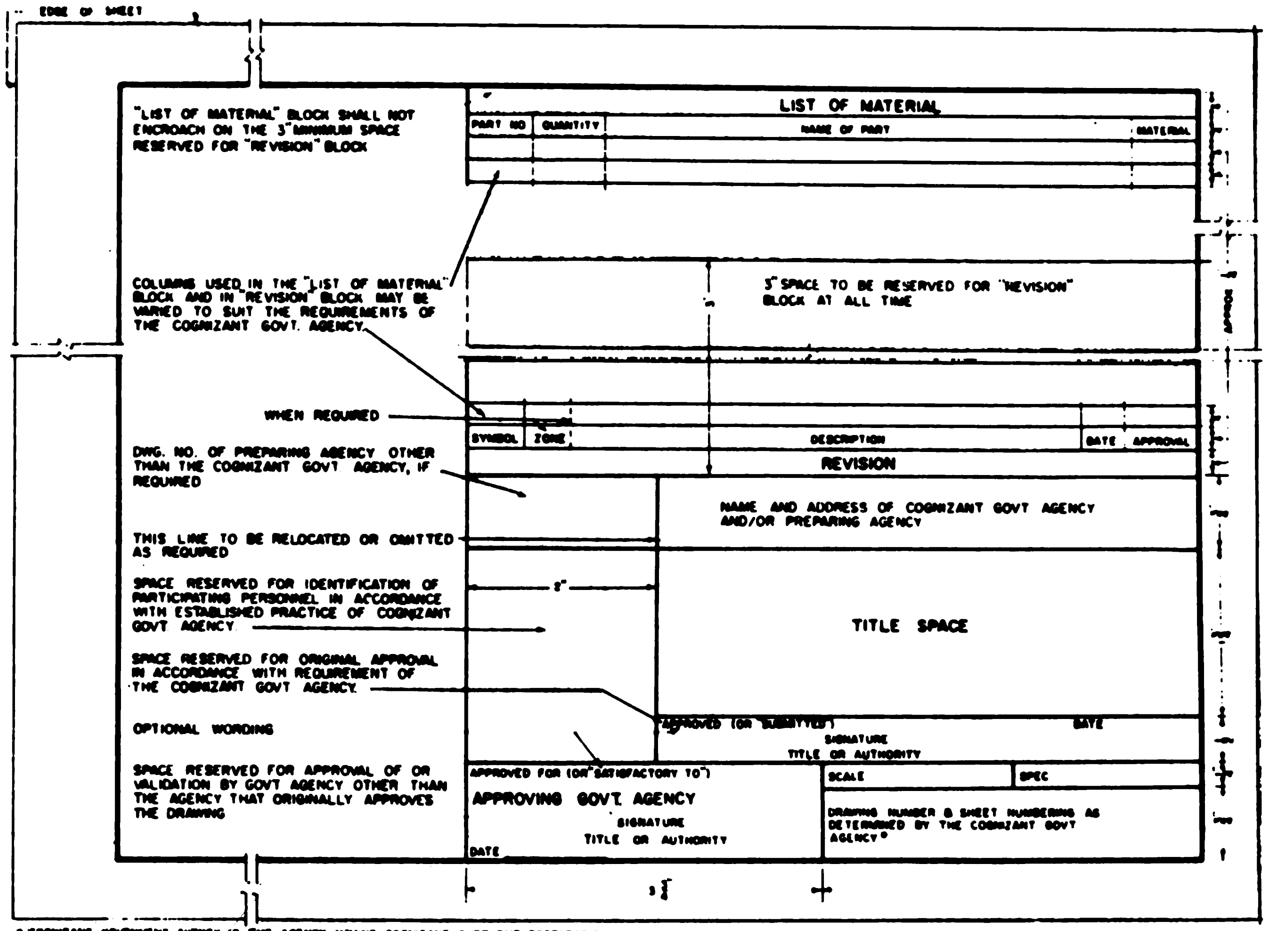
b. Production Drawings. Production drawings describe equipment or articles that are suitable for production in quantity. The same basic information is normally included on a production drawing format as on a construction drawing format although the arrangement is different.

(1) *Drawing number.* A production drawing used by a government agency will frequently have both a manufacturer's drawing number and a government agency drawing number. Be sure to use the government agency number when dealing within the military supply system. In addition, a production drawing will often have a five-digit identification code for the manufacturer, for the government agency, or both. This number is called a Federal Supply Code (FSC) and permits locating the name and address of the manufacturer or agency in Handbook H 4-1 and -2 "Federal Supply Code for Manufacturers". The name and address of the manufacturer and cognizant government agency are usually included on the drawing, but the FSC is helpful because drawings are seldom revised for a change of address whereas the handbook is updated regularly. If the manufacturer's drawing number is used for any

purpose, it should be prefixed by the FSC to indicate whose drawing number it is. It is also customary to add the latest revision letter to the number since the manufacturer may make additional revisions to his drawings after the item or drawing is supplied to the government. Revision D to drawing number 703145, by a manufacturer who FSC is 90222, would be specified as 90222-703145D. When the drawings of different sizes are filed separately, the drawing size letter (table 1-1) is often shown in front of the number.

(2) *Part number.* In most production drawing systems, a part number is the same as the drawing number for the part except where more than one part is included on a drawing. In this case "dash numbers" are used. Each part covered by a drawing will have a dash number assigned and noted on the drawing. The part number is the drawing number followed by -1 or -2 etc., as applicable.

(3) *Application or usage block.* Most production drawings include a block which shows "next assembly" and "used on" information, as shown in figure 1-34. The "next assembly" column will list each assembly which includes the part. The "used on" column will list each end product which includes the part. For example, one pipe section might be used in several compressor assemblies, and in two or three different air-conditioning models. Sometimes, the quantity required in each "next higher assembly" and in each end product is also listed.



* COGNIZANT GOVERNMENT AGENCY IS THE AGENCY HAVING COGNIZANT OVER THE PREPARATION OF THE DRAWING, WHETHER PREPARED BY IT OR BY ANOTHER PREPARING AGENCY UNDER ITS DIRECTION

Figure 1-33. Format for a construction drawing.

Section VI. INTERPRETATION OF DRAWINGS

1-14. Fundamentals of Interpretation

a. The objects used for illustrations thus far have been simple, and interpretation of the drawings nearly obvious. More complex or irregular drawing may require more effort to interpret. The principles introduced here along with the conventions peculiar to certain fields which are discussed in the following chapters will enable you to interpret any properly prepared drawing. The orthographic projection principles are fundamental to all fields and a thorough understanding of them is necessary if you are to read any type of physical prints.

b. The fundamental step in interpreting a drawing is relating the different views. If you pick a point on a front view, the same point on the right side view will be directly to the right of it. Similarly, the same point on the top view will be directly above the point on the front view. These relationships are illustrated in [1] by the horizontal and vertical datum lines between the views. The same relationship exists between the top and right side views but is not obvious because they are not hinged together. If the outside edges of both views are extended horizontally or vertically until they cross, as in [2], figure 1-35 and a line is drawn connecting these points of intersection, the relationship can be seen. The line connecting the points of intersection will be at a 45° angle with the horizontal. All other points in the views can be related by bending their project line at this 45° line. If the same point appears on three views, the three occurrences will be related as shown by point 1 in part [2] of figure 1-35. On complex drawings it is often helpful to draw this 45° line to be sure you are looking at the same point on all three views when interpreting the drawing.

c. Figure 1-36 is a three-view drawing of an object, along with an isometric outline of a box with the same overall dimensions of the object. Trace off the isometric outline and points on a separate piece of paper and sketch in the details as you read the paragraph. This will help you learn to visualize the object as you interpret a construction print. Looking at the right hand side of the front view, and the corresponding parts of the top and side views, interpretation of the part of the isometric diagram that has been completed should be apparent. Note the point marked *a* on the top view. From the projection indicated it must be the same as the point marked *a* on the right side view. Projecting these two points to the front view shows that the point marked *a* on all three views is the same point and is located at *a* on the isometric diagram. Next, look at the line *ah* on the front view. Point *h* on the front view may correspond to point *g* or point *f* on the top view, but there is no line from *a* to *f* on the top view. Line *ah*, therefore, must correspond to line *ag*, and transferring points to the right side view, to line *ae*. On the isometric view, this corresponds to the line from *a* to *n*, which can now be drawn on the isometric view. Line *ab* on the front view must correspond to line *ac* on the top view, and to line *ad* on the right side view. This translates as a line from *a* to *q* on the isometric view. At this stage, it is evident that line *el* (right side view) is the same as line *hj* (front view) and a line has been drawn from *p* to *n* on the isometric view. Similarly, line *fc* (top) is the same as line *hb* (front) and a line has been drawn from *m* to *q* on the isometric view. Line *cg* (top) may correspond to either *hb* or *ja* (front) but not to *ha* which has already been established. If *cg* corresponds to *ja*, it would also have to correspond to *la* in the right side view because point *a* has been established and *cg* does not project to *la* in the right side view. Therefore, *cg* corresponds to *hb* in the front view and to *ed* in the right side view. Line *cg* must correspond to a line from *n* to *g* on the isometric view. All that remains is to complete the isometric view with the only possible lines which do not contradict one or more of the three views; lines from *p* to *a*, from *a* to *r*, and from *r* to *q*, produce an isometric which should look like figure 1-37 at the end of the section.

NEXT ASSY	USED ON
APPLICATION	

Figure 1-34. Typical application or usage block.

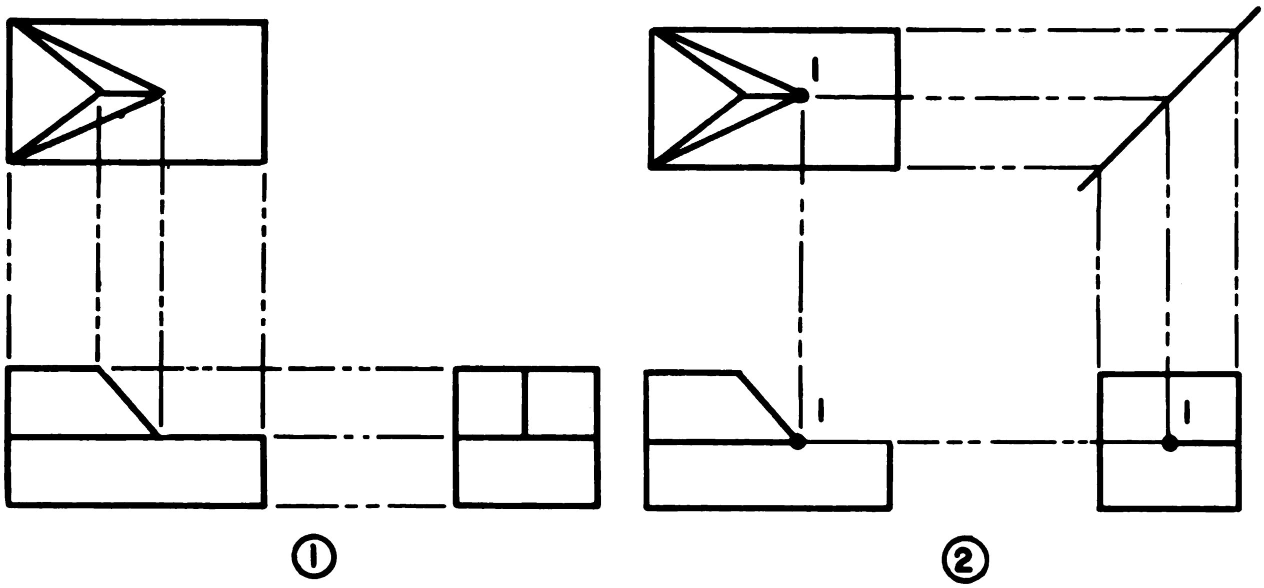


Figure 1-35. Relationships in orthographic projection.

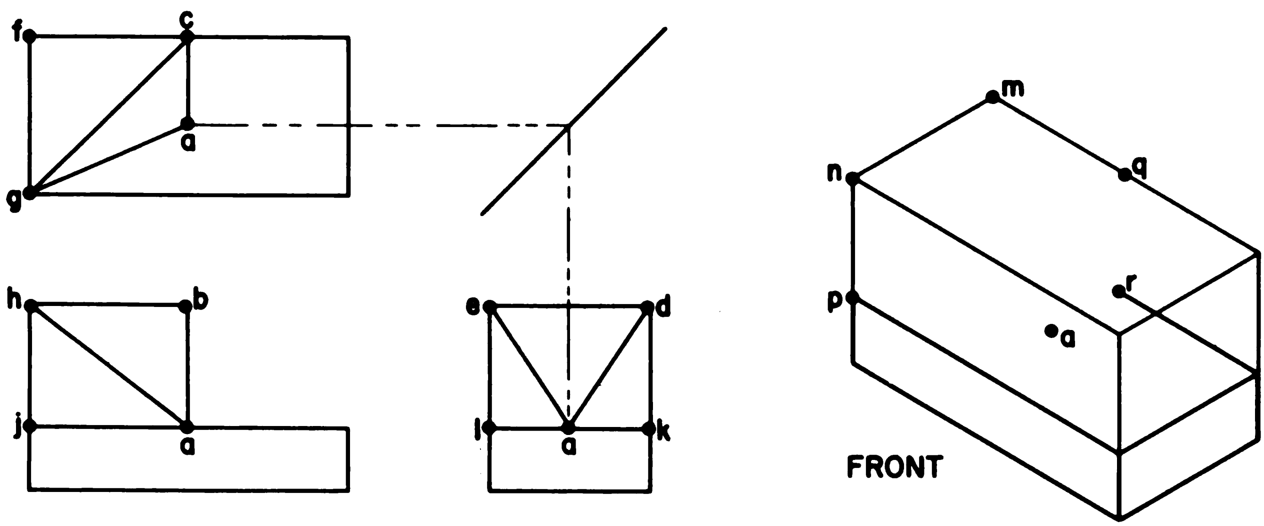


Figure 1-36. Exercise in interpretation.

1-15. Self-Test

To check your understanding of the previous material, answer the following questions about figure 1-38. The answers are given at the end of the chapter.

1. Which surface on the isometric drawing is represented by surface L on the front view?
   a. B
   b. D
   c. Not visible on the isometric view

2. Which surface on the isometric drawing is represented by surface P on the front view?
   a. B
   b. D
   c. Not visible on the isometric view

3. Which line on the isometric drawing is represented by line N on the front view?
   a. C
   b. F
   c. Not visible on the isometric view

4. Which line on the isometric view is represented by line S on the right side view?
   a. F
   b. E
   c. C

5. Which line on the isometric view is represented by line Q on the right side view?
   a. G
   b. F
   c. E
   d. Both G and F

6. Which line on the top view represents line E on the isometric view?
   a. H
   b. I
   c. J
   d. Not shown on the top view

7. In which of the following does the line which represents isometric line A appear i. true length?
   a. Top view
   b. Front view
   c. Right side view
   d. Both top and front views
   e. All three views

8. In which of the following does the line which represents isometric line E appear in true length?
   a. Top view
   b. Front view
   c. Right side view
   d. Both top and right side views

9. In which of the following does the line representing isometric line F appear in true length?
   a. Top view
   b. Front view
   c. Right side view
   d. Both top and right side views
   e. All three views
   f. Does not appear in true length in any view

Answer the following questions about figure 1-39.

10. Which circle on the top view represents the feature designated as P on the section?
   a. B
   b. C
   c. D
   d. E

11. Which circle on the top view represents the feature designated as T on the section?
   a. B
   b. C
   c. D
   d. E
   e. F

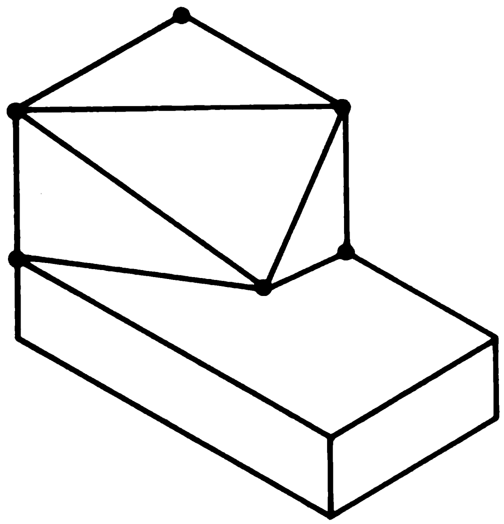


Figure 1-37. Completed exercise.

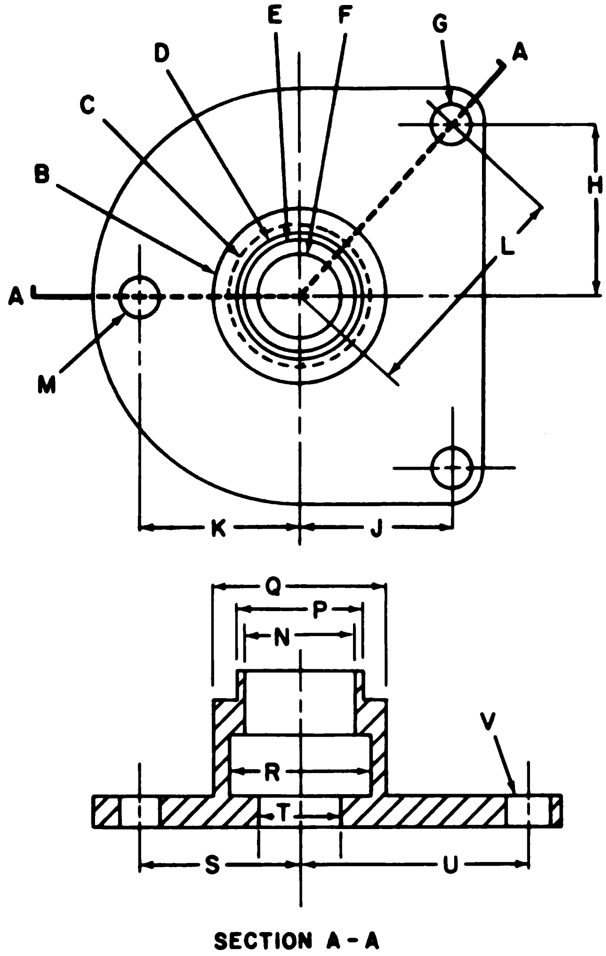


Figure 1-39. Section for self-test.

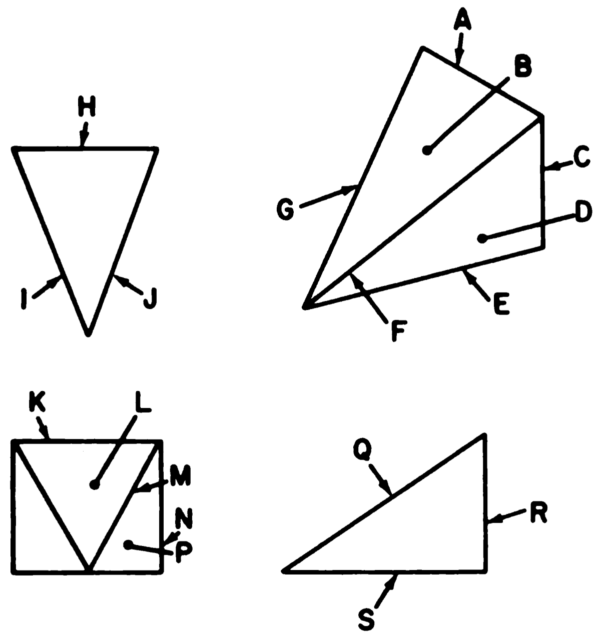


Figure 1-38. Drawing for self-test.

12. What is the shape of the feature designated as R on the section, when viewed from the top?
   a. Round
   b. Square
   c. Rectangular
   d. Cannot be determined from the drawing

13. Which designation on the top view represents the same dimension as S on the section?
   a. G
   b. H
   c. J
   d. K

14. Which designation on the top view represents the same dimension as U on the section?
   a. G
   b. H
   c. G plus H
   d. L
   e. J plus H

15. Which feature on the top view represents feature V on the section?
   a. F
   b. G
   c. M

16. Why is the section view wider than the top view?
   a. The scale is different
   b. It includes features not shown on the top view
   c. The cutting plane is offset
   d. It is not drawn to scale

1-16. Answers to Self-Test Questions

1. *a*	9. *f*
2. *b*	10. *c*
3. *a*	11. *e*
4. *b*	12. *a*
5. *d*	13. *d*
6. *c*	14. *d*
7. *d*	15. *b*
8. *a*	16. *c*

CHAPTER 2

READING ARCHITECTURAL DRAWINGS

Section I. WORKING DRAWINGS

2-1. Introduction

a. Working drawings plus specifications are the principal sources of information for supervisors and technicians responsible for the actual work of construction. The construction working drawing presents a complete graphic description of the structure to be erected, the construction site, the materials to be used, and the construction method to be followed. Most construction drawings consist of orthographic views. A set of working drawings includes both general and detail drawings. General drawings consist of plans and elevations, while detail drawings comprise sections and detail views.

b. Site plans, elevations, and floor plans are described in this section together with the most common architectural symbols and material conventions applicable to military use. Foundation plans, floor framing plans, roof framing plans, and section details, which are also included under the term architectural working drawing, are discussed in section II.

2-2. Architectural Symbols and Material Conventions

a. Architectural Symbols. Architectural symbols are used to indicate on the constructions plans the type and location of doors, windows, and other features. The symbol has the same general shape as the feature and shows any motion that may occur in the plan view. Figure 2-1 shows the symbol for single door (exterior) opening in, and the symbol for double hung window with a wood or metal sash in a frame wall. Each symbol has the same general shape of the feature and the direction of motion of the door is shown. The motion of the window is not shown in the symbol because it is in a direction perpendicular to the page. A more complete list of architectural symbols is included in appendix B.

b. Material Conventions. Material conventions are used to indicate the type of material used in the structure. Figure 2-2 illustrates the conventional symbols for the more common types of materials. The symbol selected normally represents a common characteristic of the material where possible. For example, the symbol for wood represents the grains in the wood. It is not always possible to use a common characteristic of the material for the symbol. You should become familiar with all these symbols for materials to enable proper interpretation of a construction print. You will eventually learn all the material conventions; however, a symbol should always be checked if there is a question in your mind on its meaning.

2-3. Site Plans

a. A site plan (also called plot plan) shows, as necessary, the property lines and locations, contours and profiles, existing and new utilities, sewer and waterlines, building lines, location of structures to be constructed, existing structures, approaches, finished grades, and other pertinent data. Figure 2-3 shows a typical site plan. Appropriate outlines indicate the locations of proposed facilities. The site plan is oriented with a north-pointing arrow to indicate site north (not magnetic north). Each facility has a number (or code letter) designation by which it is identified in the schedule of facilities. The contour lines indicate the elevation of the earth surfaces; all points on a contour have the same elevation. Distances are given between principal details and reference lines. (The coordinate reference lines on figure 2-3 are centerlines of the roads surrounding the area.) All distances indicated in a plan view simply express a horizontal measurement between two points and do not take into consideration terrain irregularities. Size of proposed facilities are given in the schedule of facilities.

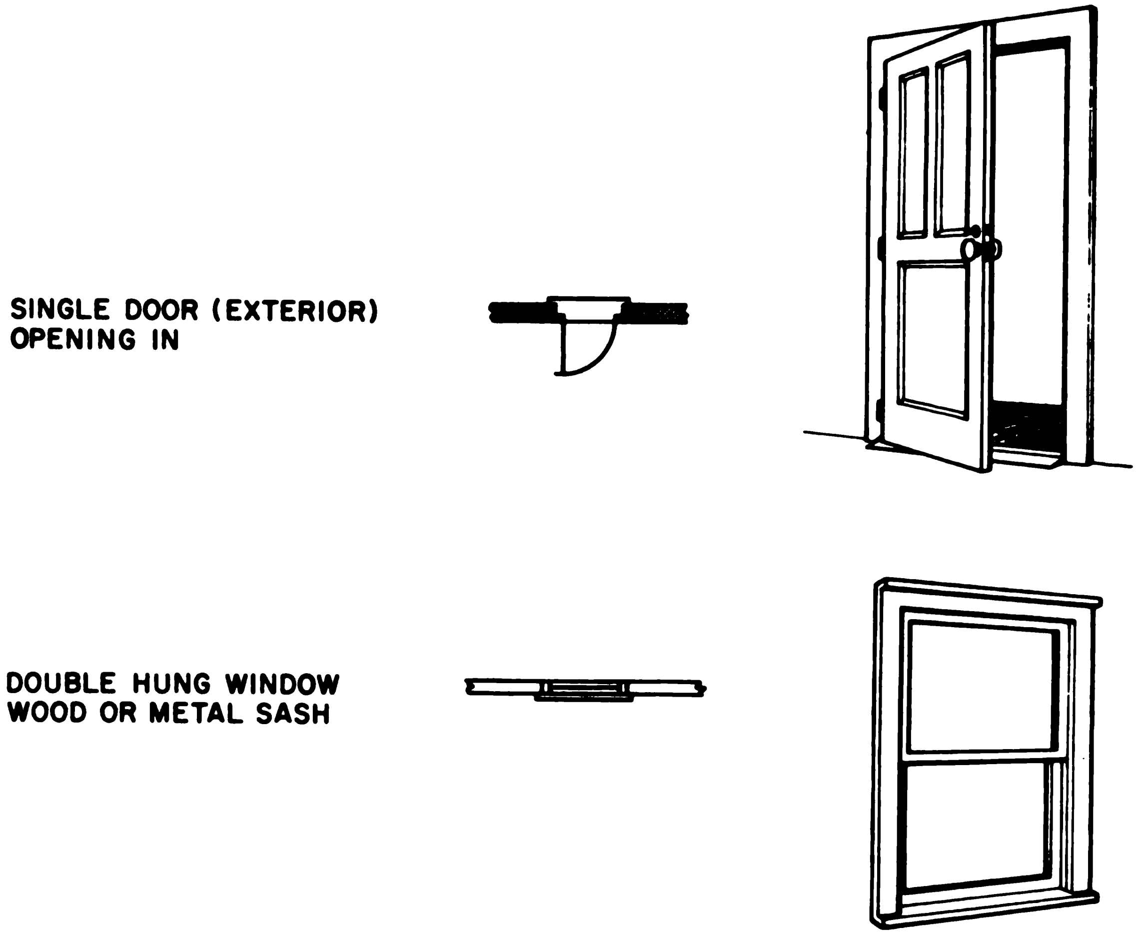


Figure 2-1. Typical architectural symbols for a door and window.

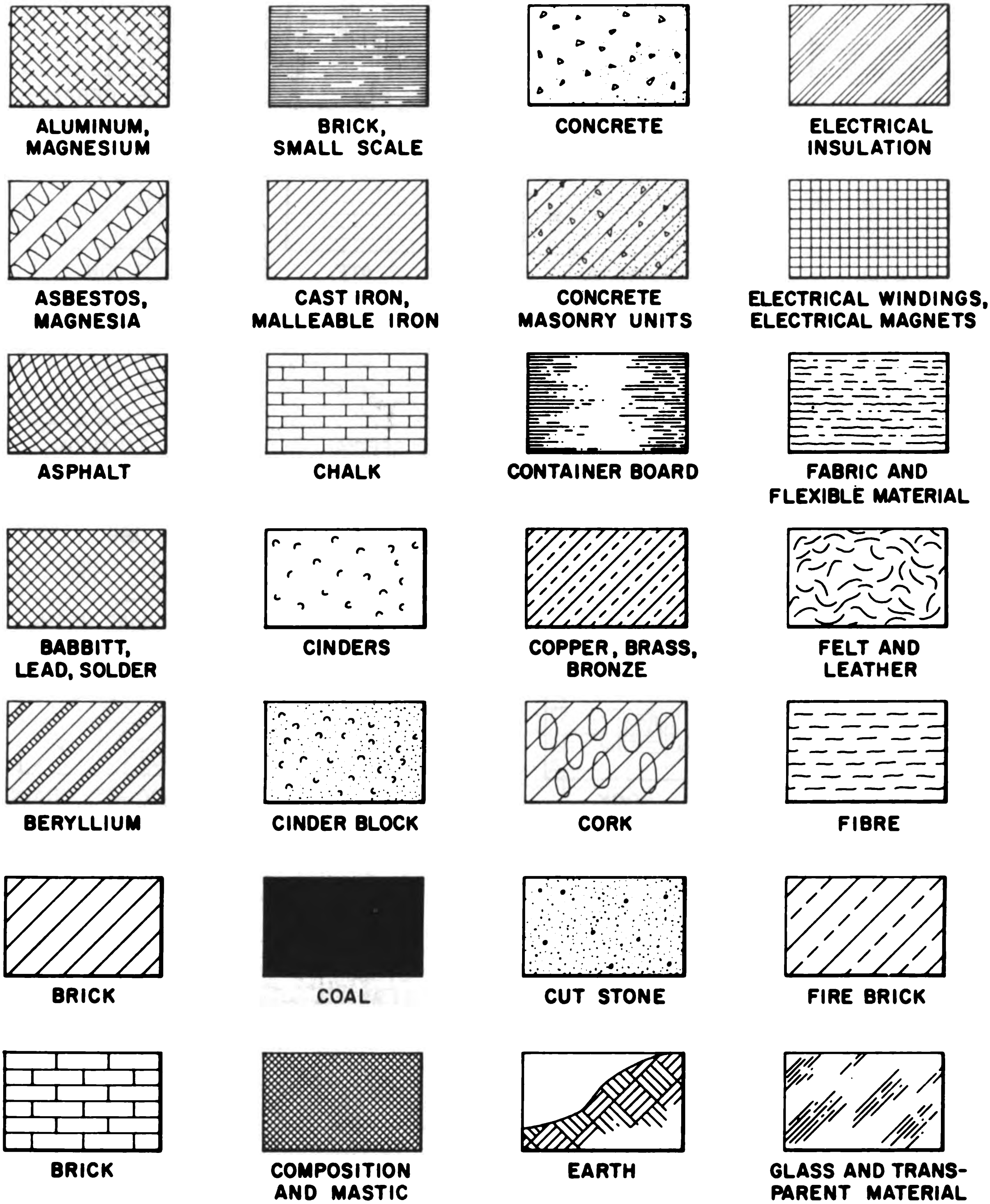
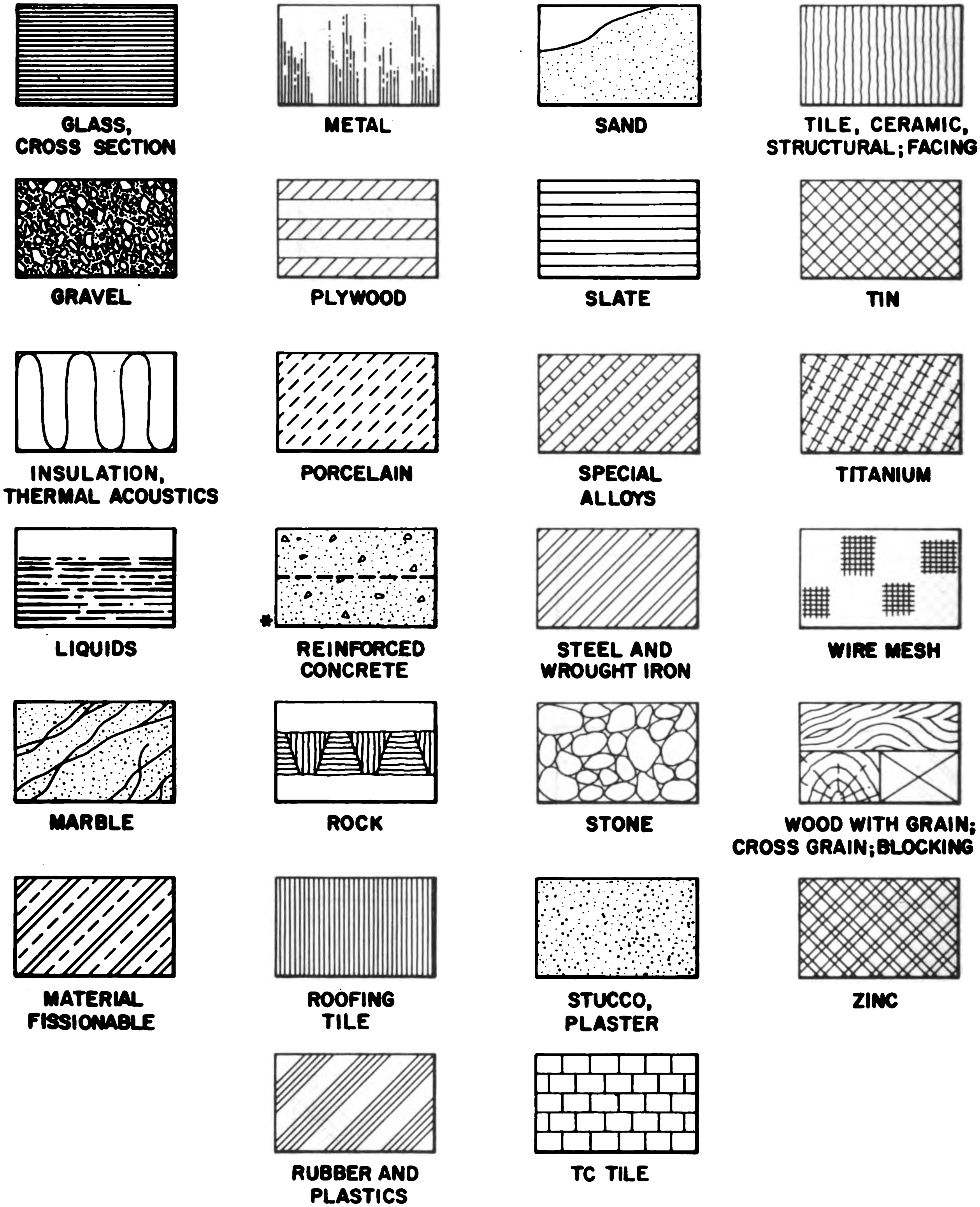
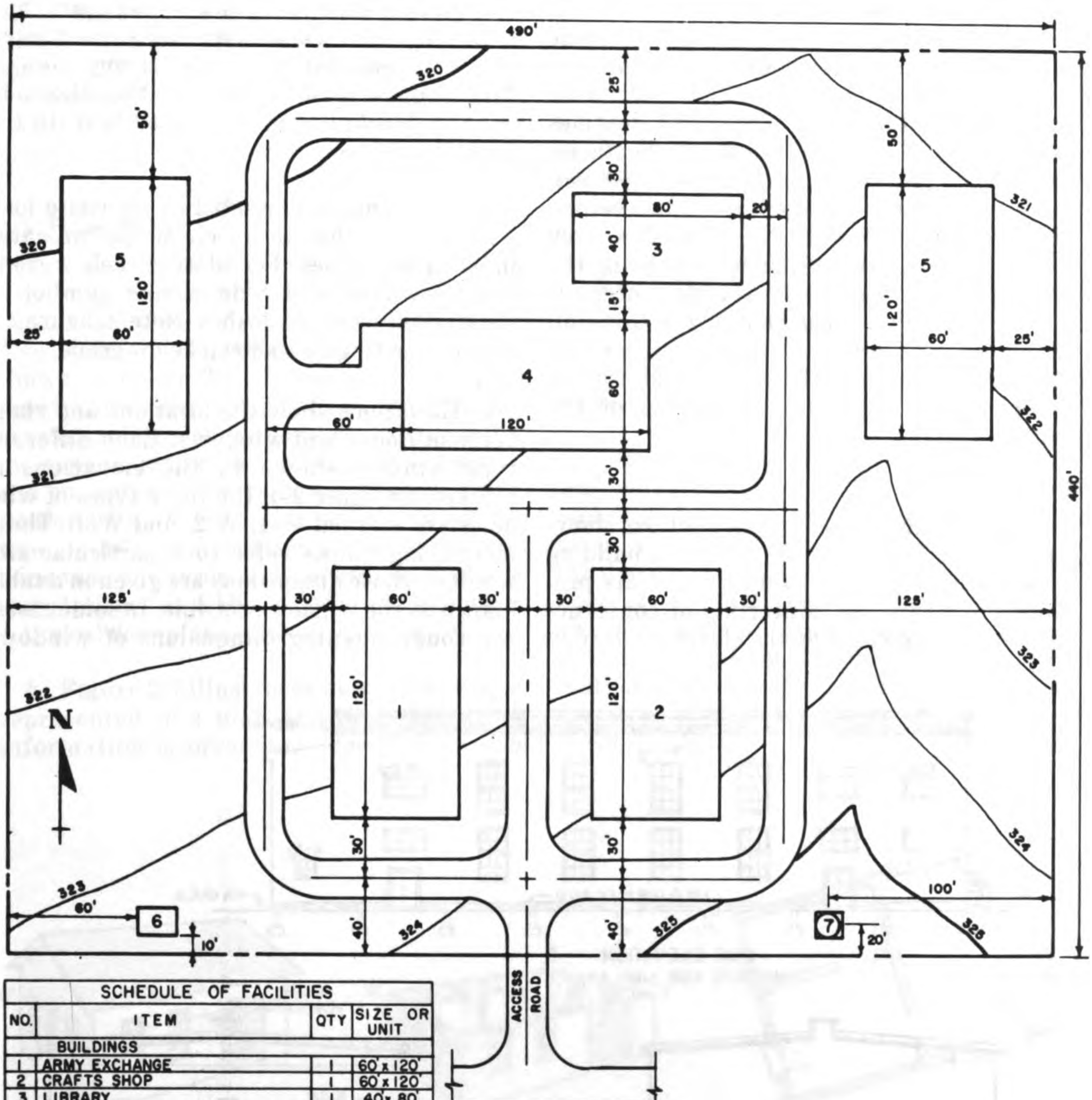


Figure 2-2. Material conventions.



* INSTEAD OF INDICATING AGGREGATE, SMUDGE ON REVERSE SIDE OF LINEN

Figure 2-2. —continued.



NO.	ITEM	QTY	SIZE OR UNIT
	BUILDINGS		
1	ARMY EXCHANGE	1	60' x 120'
2	CRAFTS SHOP	1	60' x 120'
3	LIBRARY	1	40' x 80'
4	RECREATION BUILDING	1	60' x 120'
	OTHER CONSTRUCTION		
5	ATHLETIC COURTS	2	60' x 120'
6	SUMP FIRE PROTECTION	1	10,000 Gal.
7	WATER TANK	1	10,500 Gal.
	ROAD- 22' WIDE-(2 lane) 6" MACADAM	0.5	MILE
	SITE AREA	11.2	ACRES

DEPARTMENT OF ARMY
OFFICE OF THE CHIEF OF ENGINEERS

RECREATION BUILDING—60' x 120'
SITE PLAN

Figure 2-3. Typical site plan.

b. Examine the site plan shown in figure 2-3 and note the information you are able to obtain from it. For example, note how the contour lines and elevation notations show that the ground surface of the site area slopes. See that the plan locates and identifies each facility. Note that most of the facilities are to be spaced apart by at least 60 feet, while the library (facility No. 3) and the recreation building (facility No. 4) must be only 15 feet apart. Observe that besides being the smallest of the four buildings, the library is to be closest to the road; that is, the east wall of the library is 20 feet from the centerline of the road, whereas the other buildings are 30 or 60 feet from the centerline of the road.

2-4. Elevations

a. Elevations are vertical projections showing the front, rear, or side view of a building or structure. Sample elevation views are presented in figure 2-4. Materials of construction may be indicated on the elevation. It may also show the ground level surrounding the structure, called the grade. When more than one view is shown on a drawing sheet, each view is identified by a title. If any view is drawn to a scale different from that shown in the title block, the scale is noted beneath the title of that view.

b. The centerline symbol of alternate long and short dashes in an elevation indicates finished floor lines. Foundations below grade are shown by the hidden line symbol of short, evenly spaced dashes. Note in figure 2-4 that the footings are shown below grade.

c. Elevations show the locations and character of doors and windows. Each different type window shown in the elevations is marked (in figure 2-4, the three types of windows are marked W-1, W-2, and W-3). These identifying marks refer to a particular size window whose dimensions are given in a table known as the window schedule. In some cases, the rough opening dimensions of windows

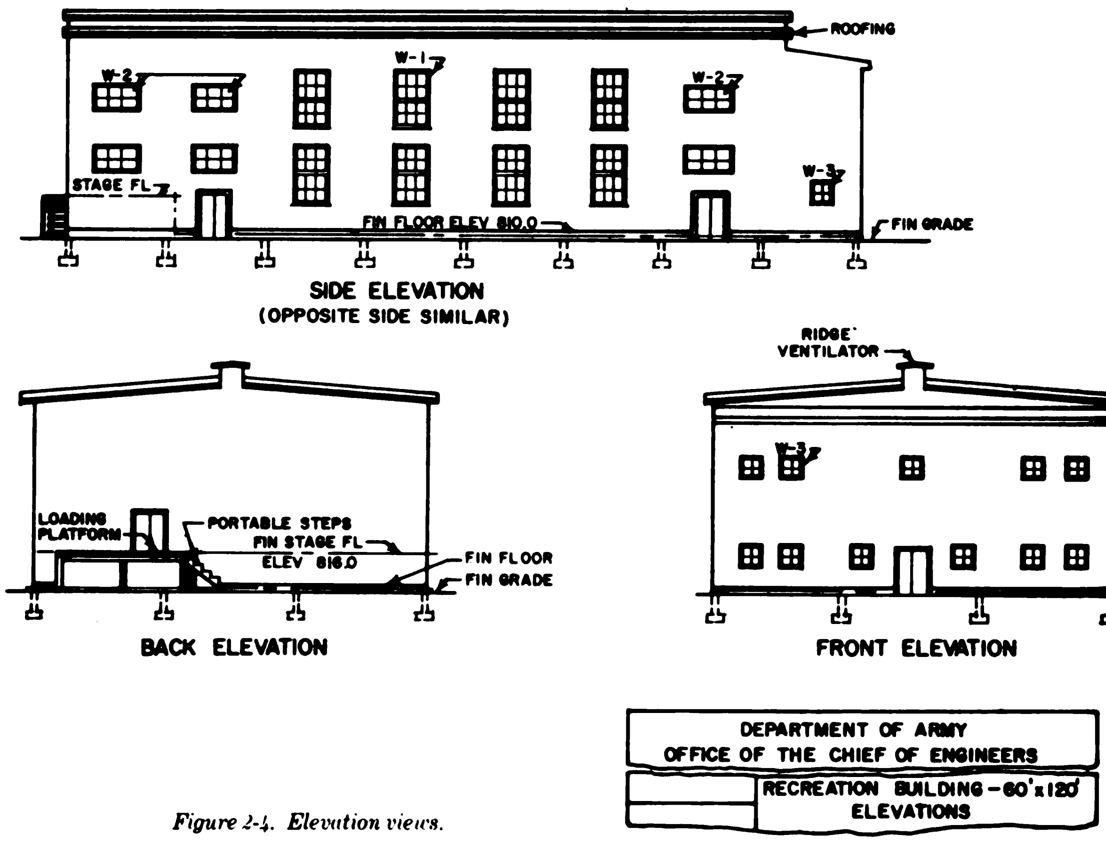


Figure 2-4. Elevation views.

are given on the drawing. Note that the recreation building shown in figure 2-4 has two double doors on each side and a double door at each end. The elevation also shows you that at the end of the building with loading platform, the door is at the level of the stage floor and all the other doors are at grade level.

2-5. Floor Plans

a. A floor plan is a cross-sectional view of a building. The horizontal cut crosses all openings, regardless of their height from the floor. The development of a floor plan is shown in figure 2-5. Note that a floor plan shows the outside shape of the building; the arrangement, size, and shape of the rooms; the type of materials; and length, thickness, and character of the building walls at a particular floor. A floor plan also includes the type, width, and location of the doors and windows; the types and locations of utility installations; and the location of stairways. A typical floor plan is shown in figure 2-6.

b. Figure 2-7 illustrates how a stairway is represented in a plan and how riser-tread information is presented. The plan symbol shows the direction of the stairs from the floor depicted in the plan and the amount of risers in the run. For example, 17 DN followed by an arrow means that there are 17 risers in the run of stairs proceeding from the floor shown on the plan to the floor below in the direction indicated by the arrow. The riser-tread diagram provides height and width information. The standard for the riser, or height from step-to-step, is from 6½ to 7½ inches. The tread width is usually such that the sum of riser and tread approximate 18 inches (a 7-inch riser and 11-inch tread is an accepted standard). On the plan, the distance between the riser lines is the width of the tread.

c. Read the floor plan shown in figure 2-6 and note the features of the recreation building. Although the location of utilities is given, you can disregard details on utilities in the discussion in this chapter. Basically, the lines with small circles show wiring for electrical outlets; appropriate symbols designate the plumbing fixtures. Complete information on reading the utility data and interpretation of the associated symbols is given in chapter 3.

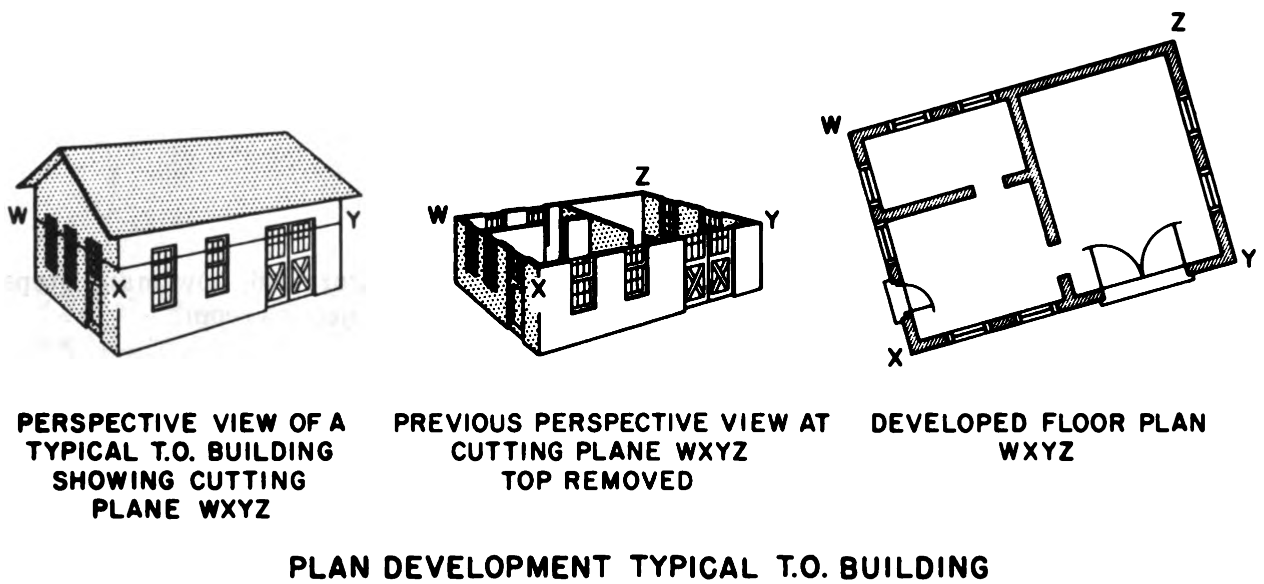


Figure 2-5. Floor plan development.

d. By examining the floor plan, you can see that the interior of the building will consist of an auditorium, a lobby with a P.X. counter, a men's toilet, a women's toilet, a projection room on a second level above the lobby, two dressing rooms, and a stage. The stage may not be apparent, but, by noting the steps adjacent to each dressing room, you can see that there is a change in elevation. The elevation view, as in figure 2-4, will indicate the stage and its elevation. The plan gives the dimensions of the areas specified. Note that all building entrances and/or exit doors are the same type (1D) and that all windows are the double-hung type. All interior single doors (2D) are the same and two double doors (3D) open into the lobby from the auditorium. The projection room will be reached via a 15-riser stairway located in a 12- by 18-foot room. Access to this room will be from the auditorium through a single door opening into the room. At the top of the stairway, a single door opens into the projection room. The wall of the projection room that faces the stage (inside wall) has three openings. Note that no windows are designated for the sides of the building where the projection room is located, but are indicated at the main level.

e. The symbols shown in figure 2-8 are typical representations of exterior walls. Note how the material conventions illustrated in figure 2-2 are used in the makeup of the symbols for masonry, brick, and concrete walls. You should become familiar with these symbols.

2-6. Self-Test

To verify your understanding of the material covered thus far, answer the following questions. Answers are given at the end of this chapter.

1. Which of the following listings are all views called elevations?
   a. Top, side, and bottom views
   b. Top, front, and rear views
   c. Rear, side, and front views
   d. Bottom, side, and rear views
2. Which of the following is not given in an elevation?
   a. Construction material
   b. Horizontal dimensions
   c. Grade
   d. Finished floor lines
3. Referring to figure 2-3, in what direction does the earth surface slope (elevation decrease)?
   a. North to south
   b. Southeast to northwest
   c. Northwest to southeast
   d. Does not slope
4. From how many directions will a vehicle be able to enter the site area?
   a. 1
   b. 2
   c. 3
   d. 4
5. Referring to figure 2-4, how many different types of windows are indicated?
   a. 2
   b. 5
   c. 4
   d. 3

3

6. Referring to figure 2-6, how many steps will go up to the projection room?
   a. 30
   b. 60
   c. 15
   d. None
7. Referring to figure 2-6, the doors marked 2D are what type?
   a. Single door, opening in
   b. Double-action single door
   c. Single door, opening out
   d. Single door, interior

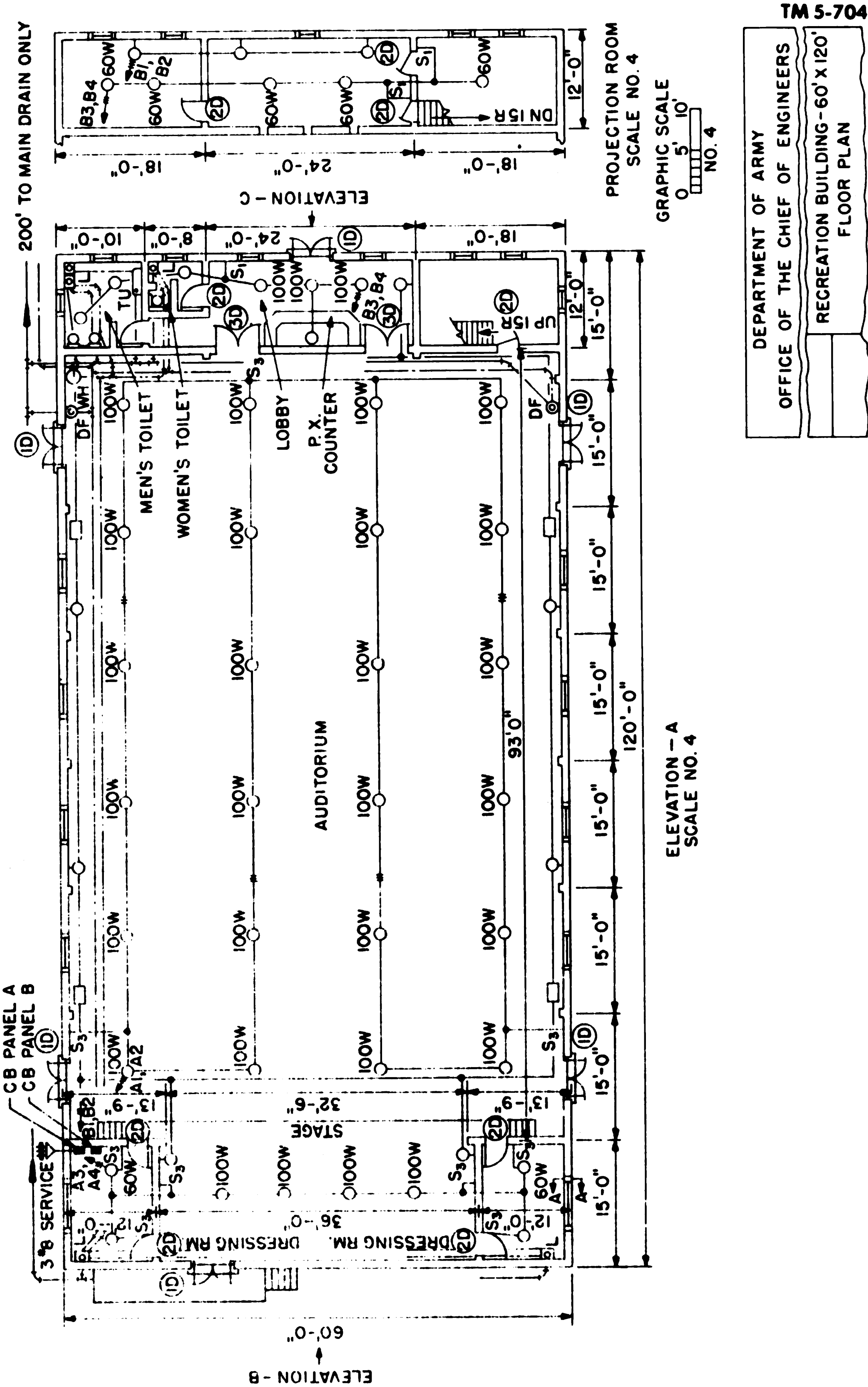


Figure 2-6. Typical floor plan.

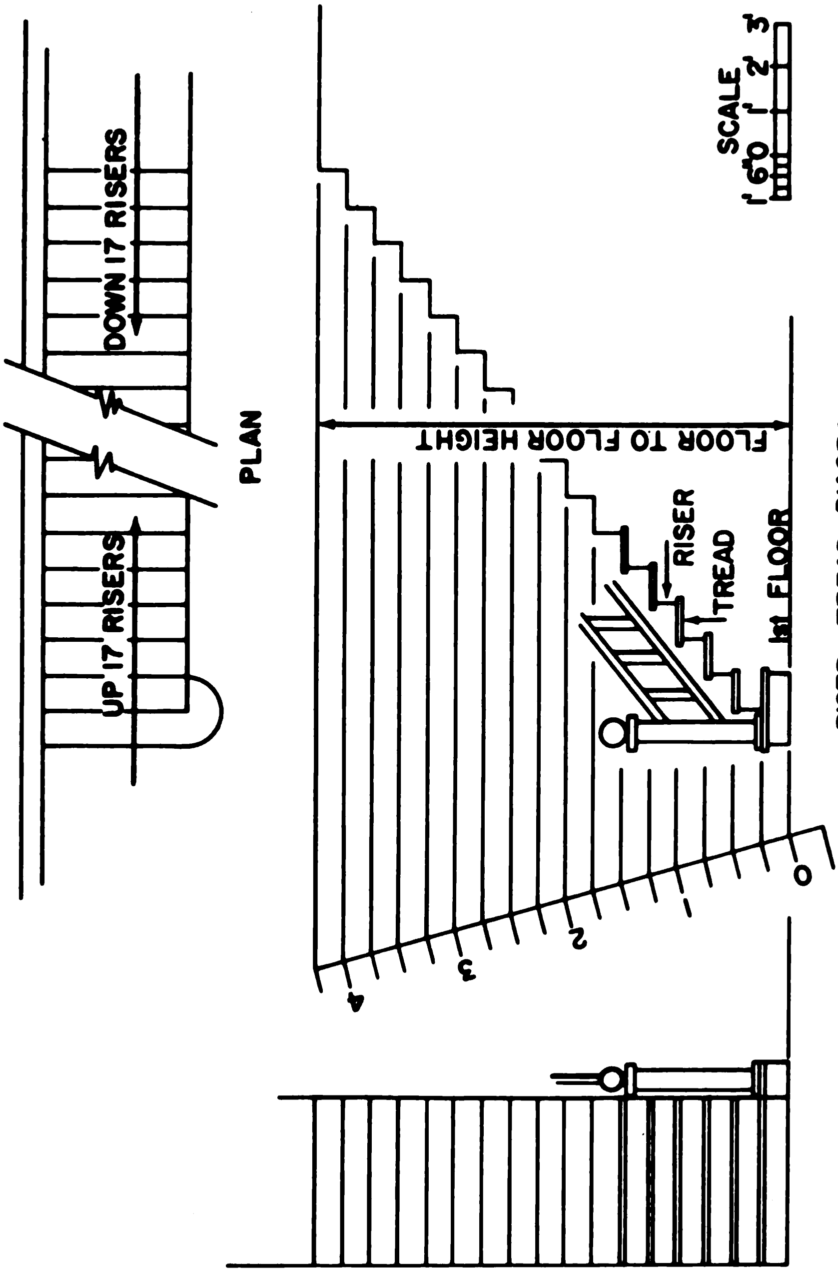


Figure 2-7. Stairway and steps.

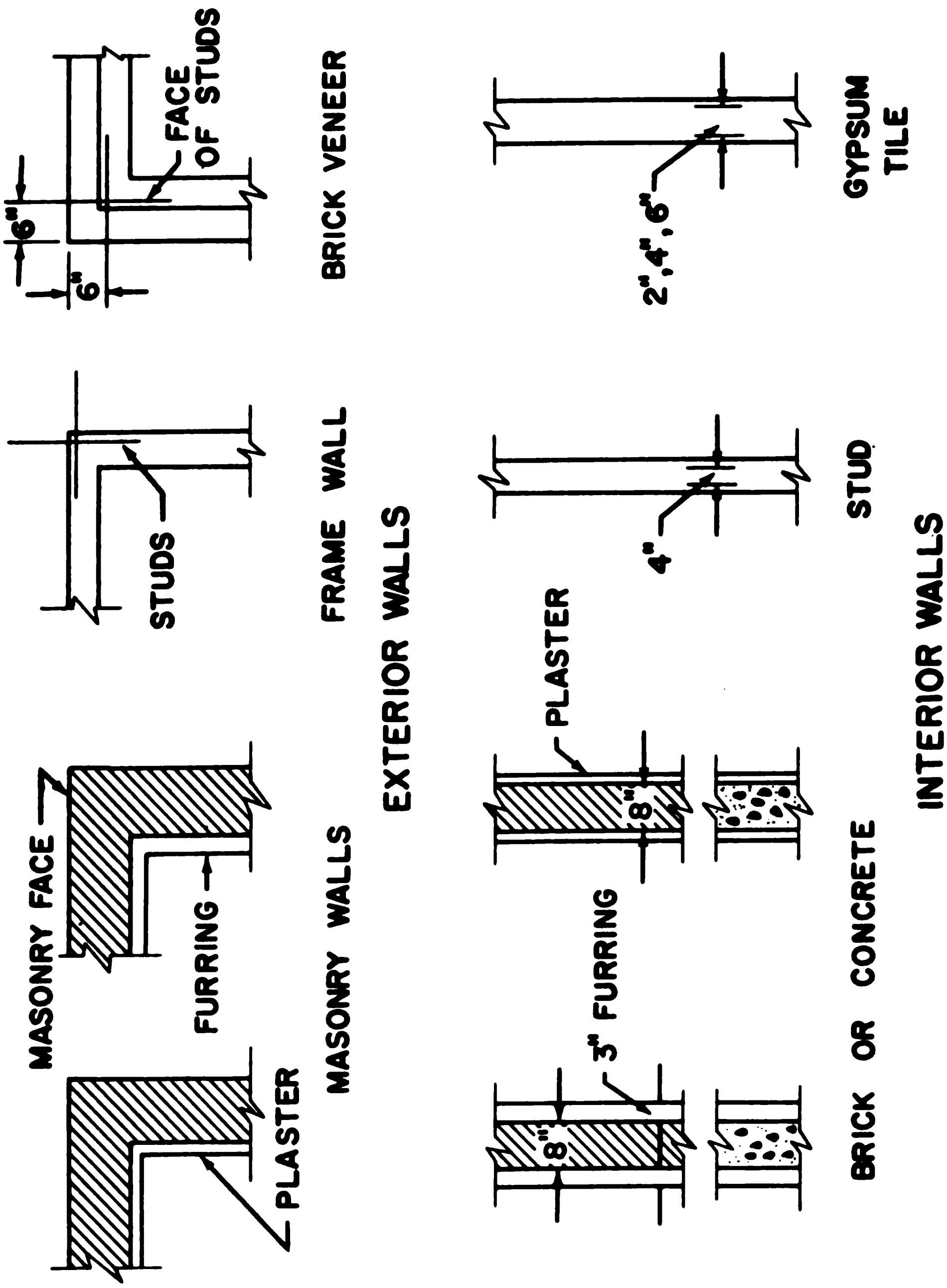


Figure 2-8. Typical wall symbols.

Section II. LIGHT AND HEAVY WOOD FRAMING

2-7. Wood Construction

Wood is a basic construction material used widely by the military, particularly in theater of operations (TO) buildings. Therefore, you should be familiar with the classification and grading of wood (lumber). The specific type and cut of lumber to be used in a construction is given in the associated specifications.

a. Species. Native species of trees are divided into two classes: hardwoods, which have broad leaves, and softwoods, which have leaves like needles or scales. No definite degree of hardness divides the species. In fact, some hardwoods actually are softer than an average softwood.

(1) Hardwoods. Some familiar native species of the hardwood or deciduous class are ash, birch, hickory, oak, beech and maple. All are broad-leaved. Lumber cut from hardwoods is not generally used for the construction of structural framing, but is employed principally for flooring, special interior paneling, trim, and doors.

(2) Softwoods. Most native species of softwood bear cones and are called coniferous woods. Some familiar softwoods are pine, spruce, fir, cedar, and redwood. These woods are worked easily and make suitable material for structural framing. Of the various softwoods, southern yellow pine and Douglas fir are the varieties used most frequently for construction.

(a) Southern yellow pine. All southern yellow pine used for structural purposes is classified as longleaf or shortleaf. The wood is dense, moderately hard, and strong. When described in a bill of material or specifications, longleaf yellow pine is abbreviated as LLYP, and shortleaf yellow pine as SLYP.

(b) Douglas fir. Douglas fir in the form of lumber and timber is one of the most desirable woods for structural purposes. It also has extensive use as poles, piling, and ties, and large quantities are cut into veneer for plywood and other purposes. Douglas fir is strong, moderately hard, and heavy. In general, however, it has a tendency to check and split and does not hold paint well.

b. Grading. Softwoods and hardwoods are graded by different standards. Only softwood grading is considered here because as explained previously, hardwoods are rarely used for structural purposes.

(1) Grading criteria. In most cases, the grade of lumber is based on the number, character, and location of features, such as knots and pitch pockets, which are commonly called defects and defined as any irregularity occuring in or on wood that may lower its strength, durability, or utility value. The best grades are practically free of these features; others, comprising the greater bulk of lumber, contain fairly numerous knots and other natural growth characteristics.

(2) Select lumber. Select lumber is the general classification for lumber of good appearance and finishing qualities. Grades A and B are suitable for natural finishes and grades C and D for paint finishes.

(3) Common lumber. Common lumber is the general classification for lumber containing the defects and blemishes described above. The grades are numbered 1 through 5. Grades No. 1 and 2 are for use without waste in framing and sheathing; No. 3 can be used for temporary construction; and No. 4 and 5 are not generally used in construction because they are of poor quality and are subject to much waste.

c. Surfacing and Working Lumber. Lumber is further classified according to the manner in which it is milled.

(1) Surfacing. Lumber is classified as rough or dressed, according to the amount of planing done in the mill.

(a) Rough. Rough lumber is as it emerges from the saw, or unplaned; the abbreviation RGH indicates rough lumber.

(b) Dressed. Dressed, or surfaced, lumber is the rough lumber after it has been run through a planer. It may have any combination of edges and sides dressed, such as S1S, surfaced on one side; S2S, surfaced on two sides; S1S1E, surfaced on one side and one edge; and S4S, surfaced on four sides.

(2) Worked lumber. Worked lumber has been run through a machine such as a matcher, shaper, or moulder. It can be matched, shiplapped, or patterned.

(a) Matched lumber. Matched lumber is cut so that it interlocks. A common type is tongue and groove (T&G), in which a groove is cut in one edge and a mating bead, or projection, is cut on the other edge. Boards are frequently dressed and matched (D&M), with the tongue and goove in the center, making the pieces center-matched.

(b) Shiplapped lumber. Shiplapped pieces are cut with a square step on either edge and the projection on one edge at the bottom and at the top of the piece on the other edge. In this way adjacent boards overlap each other to form a joint.

(c) Patterned lumber. Patterned lumber is cut in many designs and is used for trim.

d. Actual and Nominal Sizes of Lumber. Sizes of lumber are specified by nominal dimensions which differ from the actual dimensions of the milled pieces. When lumber is run through a saw and planer, its nominal size remains the same but its actual size is reduced by the amount of surfacing it undergoes. Approximately 1/4 inch is planed off each side in surfacing. Lumber is also divided into groups according to size, namely: strips, pieces less than 2 inches thick and under 8 inches wide; boards, less than 2 inches thick and more than 8 inches wide; dimensional lumber, 2 to 6 inches thick and of any width; and timber, 6 or more inches in the least dimension. Dimensions of some common sizes are given in table 2-1.

Table 2-1. Standard Sizes of Lumber (inches)

STRIPS

Nominal size	1 x 2	1 x 3	1 x 4	1 x 6
Dressed size	25/32 x 1 5/8	25/32 x 2 5/8	25/32 x 3 5/8	25/32 x 5 5/8

BOARDS

Nominal size	1 x 4	1 x 6	1 x 8	1 x 10	1 x 12
Actual size, common	25/32 x 3 5/8	25/32 x 5 5/8	25/32 x 7 1/2	25/32 x 9 1/2	25/32 x 11 1/2
Actual size, shiplap[a]	25/32 x 3 1/8	25/32 x 5 1/8	25/32 x 7 1/8	25/32 x 9 1/8	25/32 x 11 1/8
Actual size, T & G[a]	25/32 x 3 1/4	25/32 x 5 1/4	25/32 x 7 1/4	25/32 x 9 1/4	25/32 x 11 1/4

[a] Width of face

DIMENSIONED LUMBER

Nominal size	2 x 4	2 x 6	2 x 8	2 x 10
Actual size	1 5/8 x 3 5/8	1 5/8 x 5 1/2	1 5/8 x 7 1/2	1 5/8 x 9 1/2
Nominal size	4 x 4	4 x 6	4 x 8	4 x 10
Actual size	3 5/8 x 3 5/8	3 5/8 x 5 1/2	3 5/8 x 7 1/2	3 5/8 x 9 1/2
Nominal size	6 x 6	6 x 8	8 x 8	8 x 10
Actual size	5 1/2 x 5 1/2	5 1/2 x 7 1/2	7 1/2 x 7 1/2	7 1/2 x 9 1/2

2-8. Light Framing

There are three principal types of framing for light structures: western, balloon, and braced. Figure 2-9 illustrates these types of framing and specifies the nomenclature and location of the various members.

a. Western Frame. The western or platform frame (1, fig. 2-9) is used extensively in military construction. It is similar to the braced frame, but has boxed-sill construction at each floor line. Also note that cross-bridging is used between the joists and bridging is used between the studs. The western frame is preferred for one-story structures, since it permits both the bearing and nonbearing walls, which are supported by the joist, to settle uniformly. Typical components of the western frame are the following:

(1) Cross-bracing. Cross-bracing between joists is required to increase the rigidity of the structures.

(2) Joists. Joists are laid edgewise to support the floor boards.

(3) Rafter. The ribs are run from hip, or ridge, to eaves in the roof.

(4) Sheathing. Sheathing is generally applied diagonally to assist in strengthening the structure.

(5) Sill. Sills are horizontal members that either rest upon or form the foundation of the house. The sill may be a 4 x 4 or two 2 x 4 pieces spiked together.

(6) Studs. Are upright beams in the framework of a building. Studs are normally 2 x 4's set 16 inches on centers.

(7) Plates. The plate is placed across the tops of the studs. The plate, which is a 4 x 4 or two 2 x 4's spiked together, serves as a lower base for the ends of the roof rafters.

(8) Posts. Are members set on end to support a wall, girder, or other members of the structure. Corner posts are 4 x 4 inches.

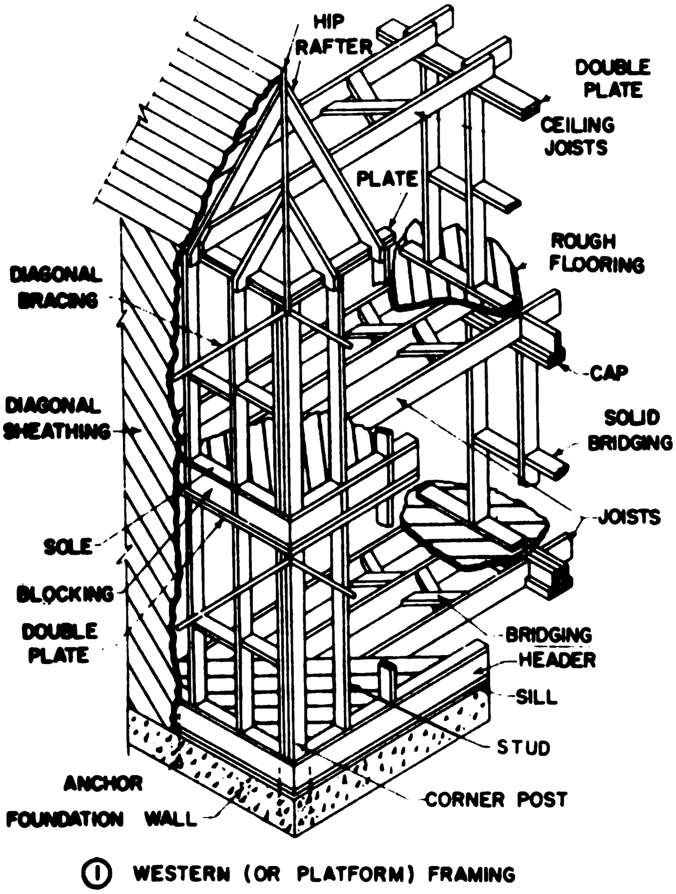
b. Balloon Frame. The balloon frame (2, fig. 2-9) is a widely used type of light framing, chiefly because it is economical. The major difference between balloon and braced framing in a multistory building is that in balloon framing the studs run the full length, from sill to rafters. It is customary for second-floor joists to rest on a 1 x 4-inch ribbon that has been set into the studs. Although a balloon frame is less rigid than a braced frame, it represents a saving in labor and material and is quite suitable for two-story structures.

c. Braced Frame. A braced frame (3, fig. 2-9) is much more rigid than a balloon frame. Exterior studs extend only between floors and are topped by girts that form a sill for the joists of the succeeding floor. Girts usually are 4 x 6 inches. With the exception of studs, braced-frame members are heavier than those in balloon framing. Sills and corner posts are customarily 4 x 6 inches. Unlike the studs, corner posts extend from sill to plate. Knee braces, usually 2 x 4 inches, are placed diagonally against each side of the corner posts. Interior studding for braced frames is the same as for balloon frame construction.

d. Light Roof Truss. The roof truss spans the area between walls. A typical light roof truss is illustrated in [1] figure 2-10. Observe that only half of the roof truss is shown and the note "trussed rafter symmetrical about this ℄" is given. This means that both halves of the truss are identical and there is no need to show both halves to present the complete picture of the truss. Note that the sizes of members and bracing details are given. For example, the knee braces for each half of the light truss are made of 2 x 4's and spaced at a maximum of 16 feet. A note on the drawing instructs you to use 16d nails except where otherwise noted. One of the exceptions for example is the nails designated for the rafter tie which are 20d nails.

2-9. Heavy Framing

a. Heavy framing, such as used in the construction of large warehouses, consists of framing members at least 6 inches in dimension (timber construction). Long, unsupported areas between walls are spanned by built-up roof trusses. A typical heavy roof truss is shown in [2], figure 2-10. Observe again that only half of the roof truss is



NOTE

STANDARD SPACING FOR STUDS SHOULD BE 16 INCHES CENTER TO CENTER TO RECEIVE STANDARD SIZE SHEETS OF PLASTERBOARD, SHEETROCK, PLYWOOD AND SO ON. JOISTS ARE ORDINARILY SPACED SIMILARILY UNLESS FURRING STRIPS OR STRAPPING ARE USED. ROUGH FLOORS WHERE LAID DIAGONALLY GIVE ADDITIONAL STRENGTH TO THE STRUCTURE BUT WHERE LAID HORIZONTALLY ECONOMY OF MATERIAL IS OBTAINED. EXTERIOR WALLS SHOULD BE BRACED WITH DIAGONAL BRACES FOR STIFFENING PURPOSES WHEN HORIZONTAL SHEATHING IS USED.

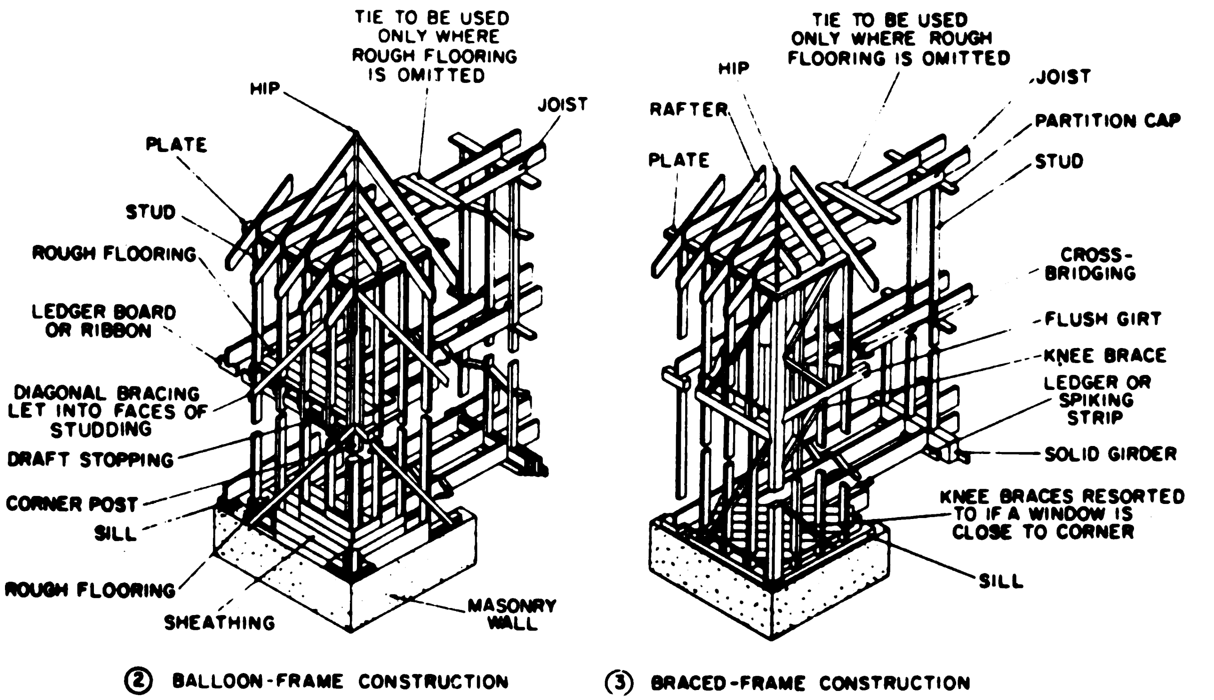
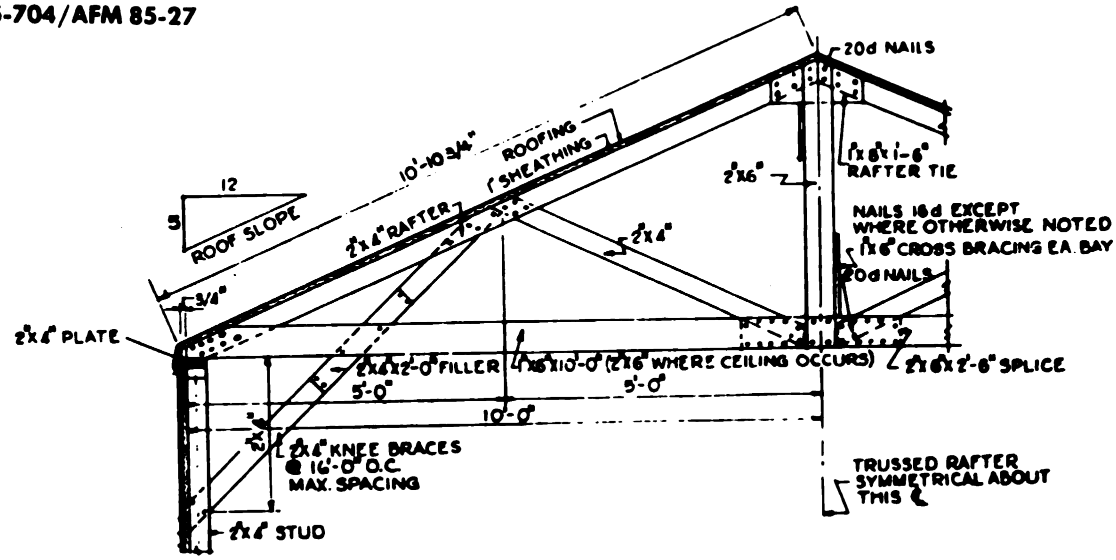
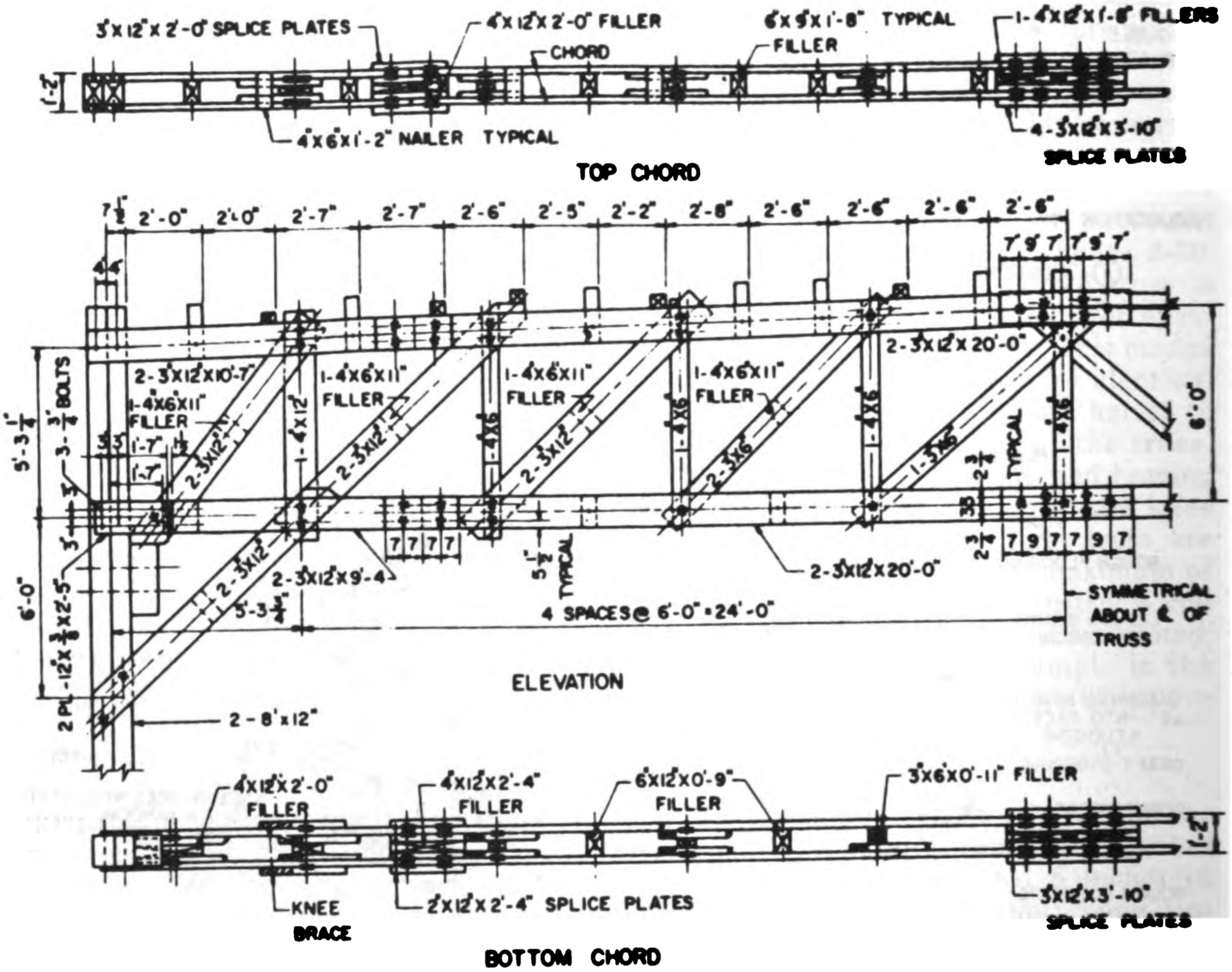


Figure 2-9. Framing for light structures.



① TYPICAL LIGHT ROOF TRUSS



② TYPICAL HEAVY ROOF TRUSS

Figure 2-10. Typical light and heavy roof trusses.

shown and the note "symmetrical about ℄ of truss" is given to indicate that both halves of the truss are identical. Also note that the size of each member is given together with the splices required, bracing details, and spacing dimensions. For example, the bottom chord for each half of the heavy truss is made up of two 3 x 12-inch x 9-foot, 4-inch long and two 3 x 12-inch x 20-foot-long members connected by 4 x 12-inch x 2-foot, 4-inch-long filler and two 2 x 12-inch x 2-foot, 4-inch splice plates secured by four bolts. The vertical and diagonal braces are connected to the top and bottom chords with the vertical brace members spaced 6 feet center-to-center; thus, the distance from the centerline of the 4 x 12-inch vertical brace to the center-line of the truss is 24 feet.

b. Members are connected with spikes, bolts, driftpins, or special timber connectors. The split ring is the most commonly used special connector. You should become familiar with all the special connectors and the identifying symbols used in military drawings that are given in figure 2-11. The specific connector to be used is specified in the bill of materials.

(1) Spikes. Spikes are used for smaller sizes of lumber, as in timber trestle construction, to connect horizontal planking to stringers.

(2) Bolts. Bolts commonly used in timber construction vary in diameter from ¼ to 1 ¼ inches. Measured from the underside of the head, lengths range from 1 inch to any length desired. Bolts are threaded, have square heads, and take square or hexagonal nuts. Bolts are placed through predrilled holes, with a washer at each end to increase the bearing area on the wood, and are fastened.

(3) Driftpins. Driftpins are large size spikes from ½ to 1 ¼ inch in diameter and from 8 to 24 inches long. They are driven into predrilled holes of the same diameter or slightly smaller than the pin diameter.

(4) Split rings. Split rings are available in 2 ½-, 4-, and 6-inch diameter sizes and are used for making wood-to-wood connections with medium and heavy loads. A hole must be drilled for the bolt and a groove made for the ring. If columns are built up of several pieces (for example, three 2 x 12-inch pieces to make a 6 x 12-inch column), the various pieces are normally fastened together with 4-inch split ring connectors. A ¾-inch bolt is used in combination with a 4-inch split ring after a high-strength, threaded rod assembly has forced the split ring to penetrate the wood.

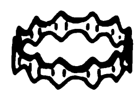
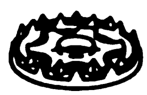
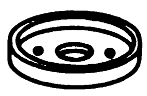
2-10. Foundation Plans

A foundation plan is a top view of the foundation walls or footings showing their area and location. Foundation walls are dimensioned to their corners and all openings in foundation walls are shown. Footings are located by distances between centerlines and distances from reference to boundary lines. Figure 2-12 shows a typical foundation plan when footings are used; the conditions for 20- and 60-foot spans are shown. You can see that the spacing of the footings along the 120-foot span is the same for both conditions. The footing details noted in A2 and B2 on figure 2-12 are shown in figure 2-13. Note that the footing details indicate the size of the various members. (In some cases, the lengths are given, while in others the bill of materials accompanying the print specifies the required lengths of the various members.) Detail A2 shows the type of footing used for the 60-foot span and detail B2 the type of footing for the 20-foot span (both cases to be 120 feet long). You can see that the heavier footing construction includes diagonal bracing (detail A2, side elevation), whereas the footing shown in detail B2 uses scabs only. Note that the height of the footing is marked "varies," which means that the height depends upon the ground elevation.

2-11. Framing Drawings

Framing drawings show the arrangement, number, and dimensions of the structural members constituting the building framework. These drawings include floor and roof framing plans and wall framing details.

a. Floor Framing Plan. Framing plans for floors are basically plan views of the girders and joists. The size and spacing of the joists, the size and number of girders, and

DESCRIPTION	SYMBOL	ILLUSTRATED USE	PICTORIAL
SPLIT RING	SR	2½ SR	
TOOTHED RING	TR	2TR	
CLAW PLATE, MALE	CPM	2⅝CPM	
CLAW PLATE, FEMALE	CPF	3⅛CPF	
SHEAR PLATE	SP	4SP	
BULLDOG, ROUND	BR	3¾BR	
BULLDOG, SQUARE	BS	5BS	

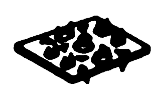
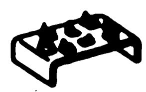
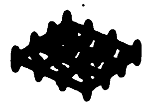
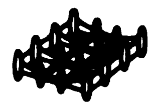
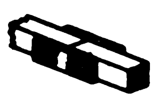
DESCRIPTION	SYMBOL	ILLUSTRATED USE	PICTORIAL
CIRCULAR SPIKE	CS	3⅛CS	
CLAMPING PLATE, PLAIN	CPP	5x5CPP	
CLAMPING PLATE, FLANGED	CPFL	5x8CPFL	
SPIKE GRID, FLAT	SGF	4⅛x4⅛SGF	
SPIKE GRID, SINGLE CURVE	SGSC	4⅛x4⅛SGSC	
SPIKE GRID, DOUBLE CURVE	SGDC	4⅛x4⅛SGDC	
WOOD SPLICE PLATES			

Figure 2-11. Timber construction symbols and connectors.

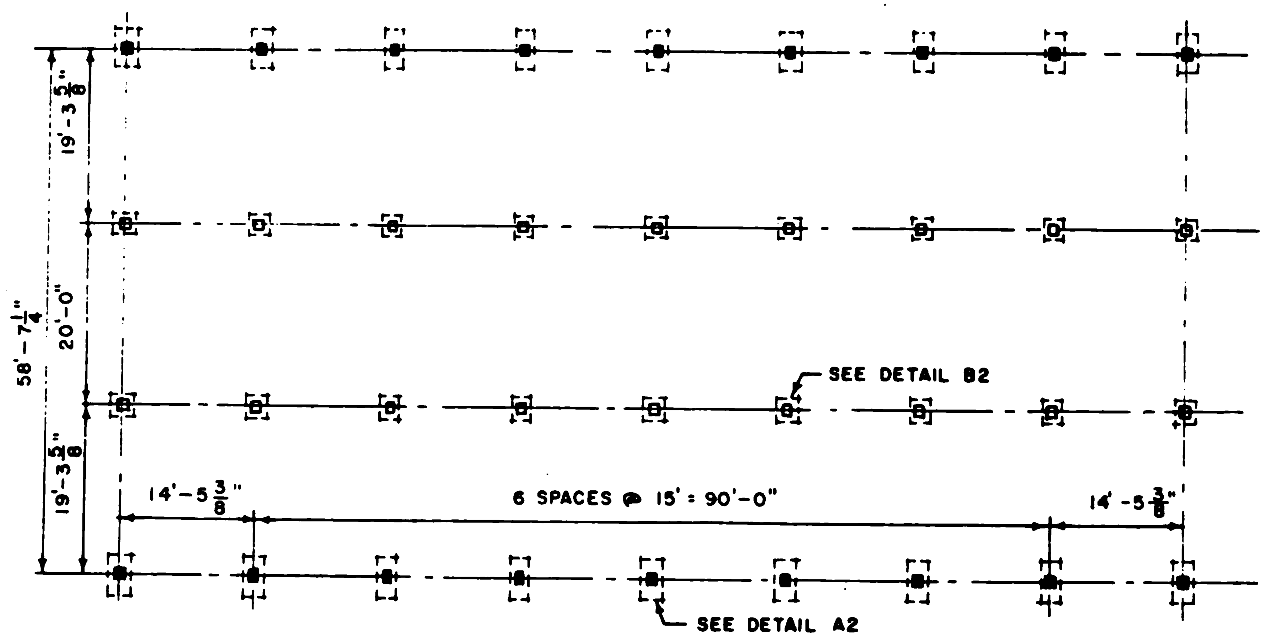


Figure 2-12. Foundation plan.

the bridging are noted on the plan. A typical floor framing plan is shown in figure 2-14. In reading the floor framing plan, you learn that the girders will be made up of three 2 x 6's (or three 2 x 8's for 20-foot spans). The joists will be made up of 2 x 6's and are to be spaced at intervals of 3 feet (2" x 6" @ 3'-0" O.C.) with bridging. The joist lengths are joined at the footings with 1½ x 2-foot splices. Note that there are two types of footings indicated. The construction of the footings would be as depicted in figure 2-13.

b. Roof Framing Plans. Framing plans for roofs are similar to floor framing plans and impart the same type of information. The size and arrangement of the rafters, ridge pieces, purlins, and other structural members in the roof are noted on the plan.

c. Wall Framing Details. Wall framing details (also called wall framing plans) present information on the studs, plates, corner posts, bracing, sills, and girts. Door and window framing is shown in wall framing details. The types of doors and windows are identified by notes.

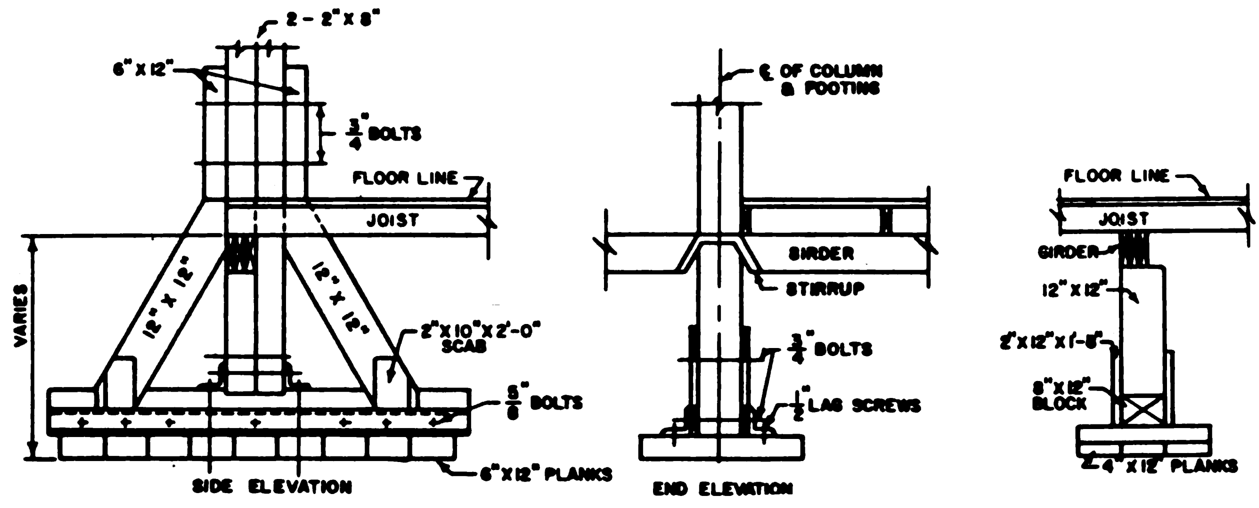
2-12. Sections

a. A section shows how a structure looks when cut vertically by a cutting plane. It is drawn to a large scale showing details of a particular construction feature that cannot be given in the general drawing. The section provides information on height, materials, fastening and support systems, and concealed features.

b. Of primary importance to construction supervisors and to the craftsmen who do the actual building are the wall sections. The wall section shows the construction of the wall as well as the way in which structural members and other features are joined to it. Wall sections extend vertically from the foundation bed to the roof. A typical wall section with the parts identified by name and/or size is illustrated in figure 2-15.

2-13. Details

a. Details are large scale drawings which show features that do not appear (or appear on too small a scale) on the plans, elevations, and sections. Details do not have a cutting-plane indication, but are simply noted by a code. The construction at doors, windows, and eaves is usually shown in detail drawings. Figure 2-16 shows some typical door and window wood framing details and an eave detail for a simple type of cornice. Other details which are customarily shown are of sills, girder and joist connections, and stairways.



DETAIL A2

DETAIL B2

Figure 2-13. Footing details.

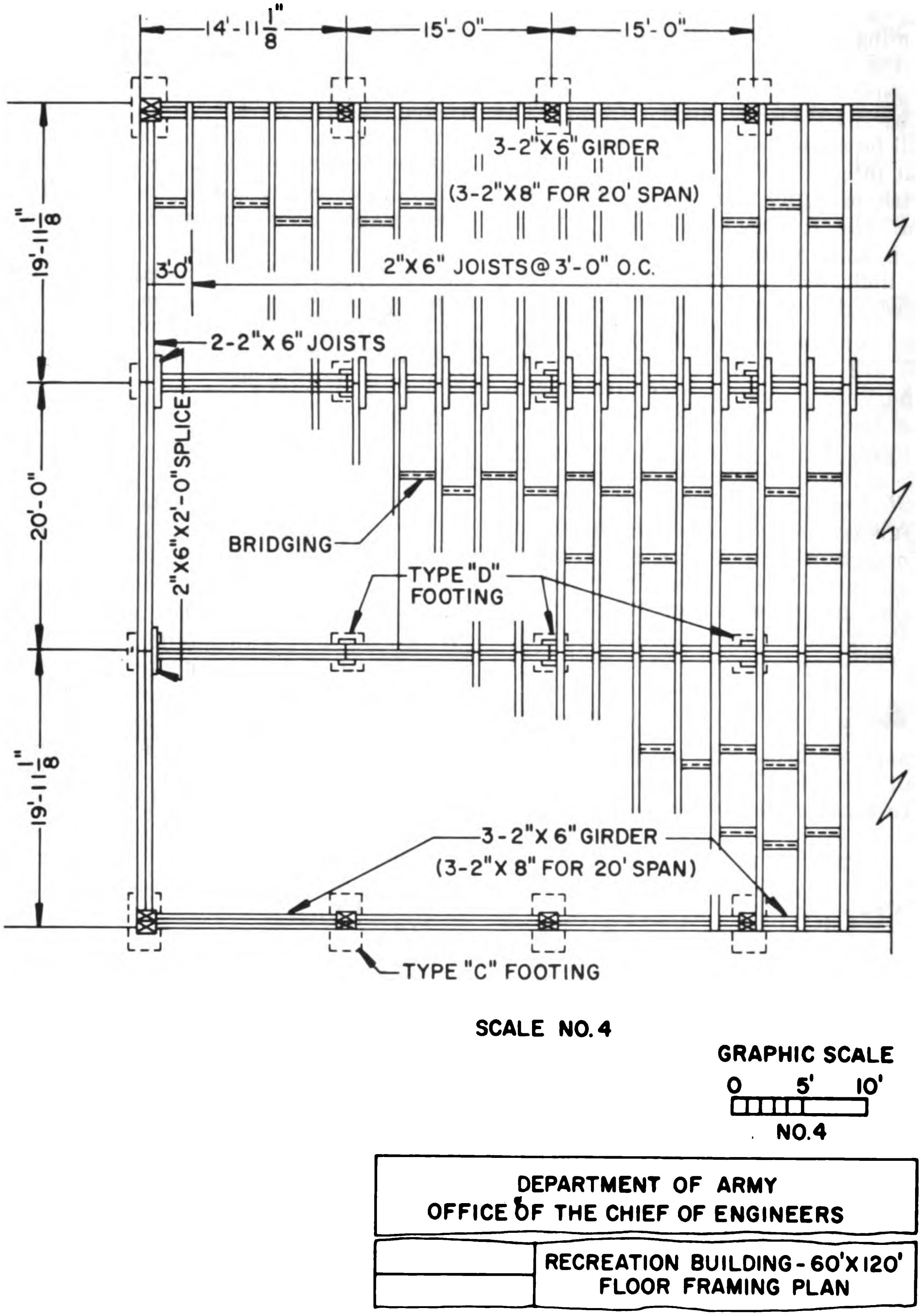


Figure 2-14. Floor framing plan.

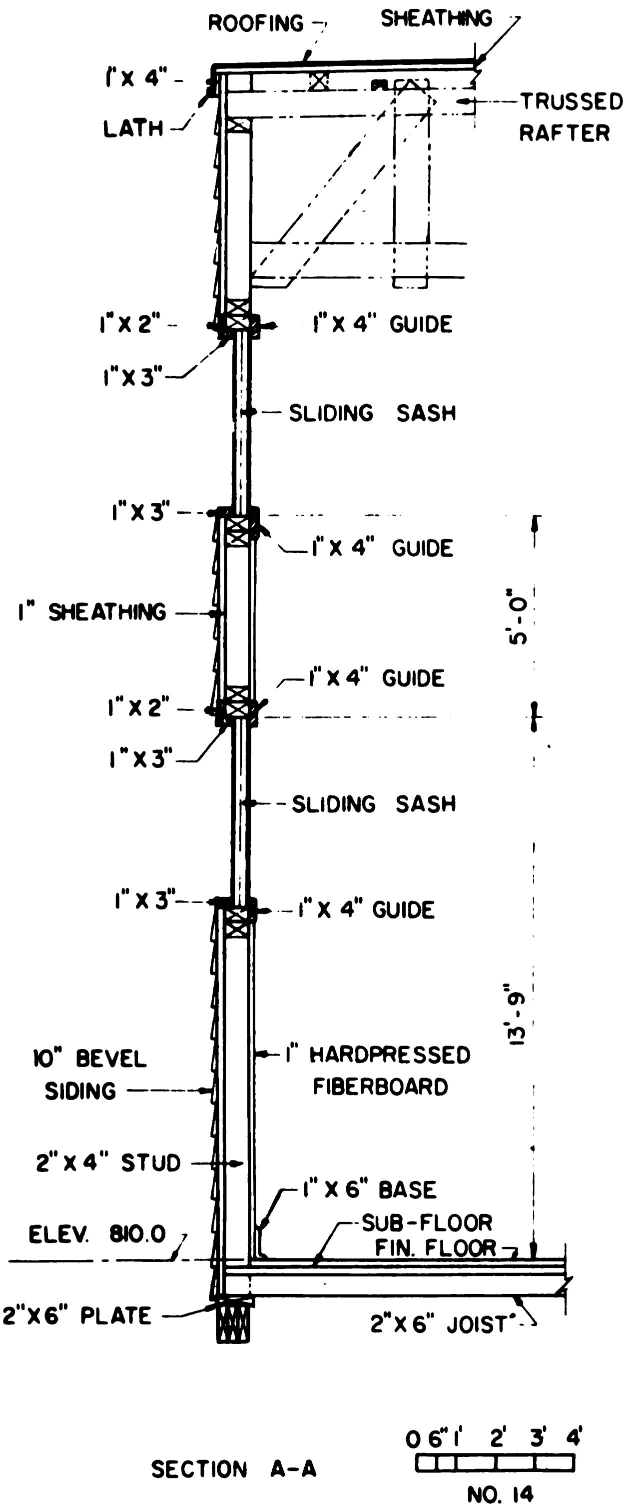


Figure 2-15. Typical wall section.

b. The sill, or soleplate, is the horizontal member on which the studs (vertical members) rest. Do not confuse this member with the sills shown in door and window details. Typical variations of details surrounding sills are illustrated in figure 2-17.

c. Joists are connected to sills and girders by several methods. In modern construction, the method that requires the least time and labor and yet gives the maximum efficiency is used. The same rule is followed in the theater of operations. Figure 2-18 shows three constructions for girders and methods of supporting the inside ends of floor joists; outside ends of floor joists are supported as shown in figure 2-17.

2-14. Self-Test

To verify your understanding of the previous material, answer the following questions. Answers are given at the end of this chapter.

1. Which of the following wood species is classified as hardwood?
   a. Cedar
   b. Oak
   c. Pine
   d. Fir
2. Which of the following members in a wood framework construction is a vertical members?
   a. Sills
   b. Joists
   c. Rafters
   d. Studs
3. In vertical views, how are heights of stairway runs designated?
   a. By specific notes
   b. From finished floor lines
   c. By general notes
   d. In proportion to fixture heights
4. Referring to figure 2-10, what size timber is to be used for the top and bottom chords on the heavy roof truss?
   a. 4 x 6
   b. 2 x 4
   c. 3 x 12
   d. 6 x 9

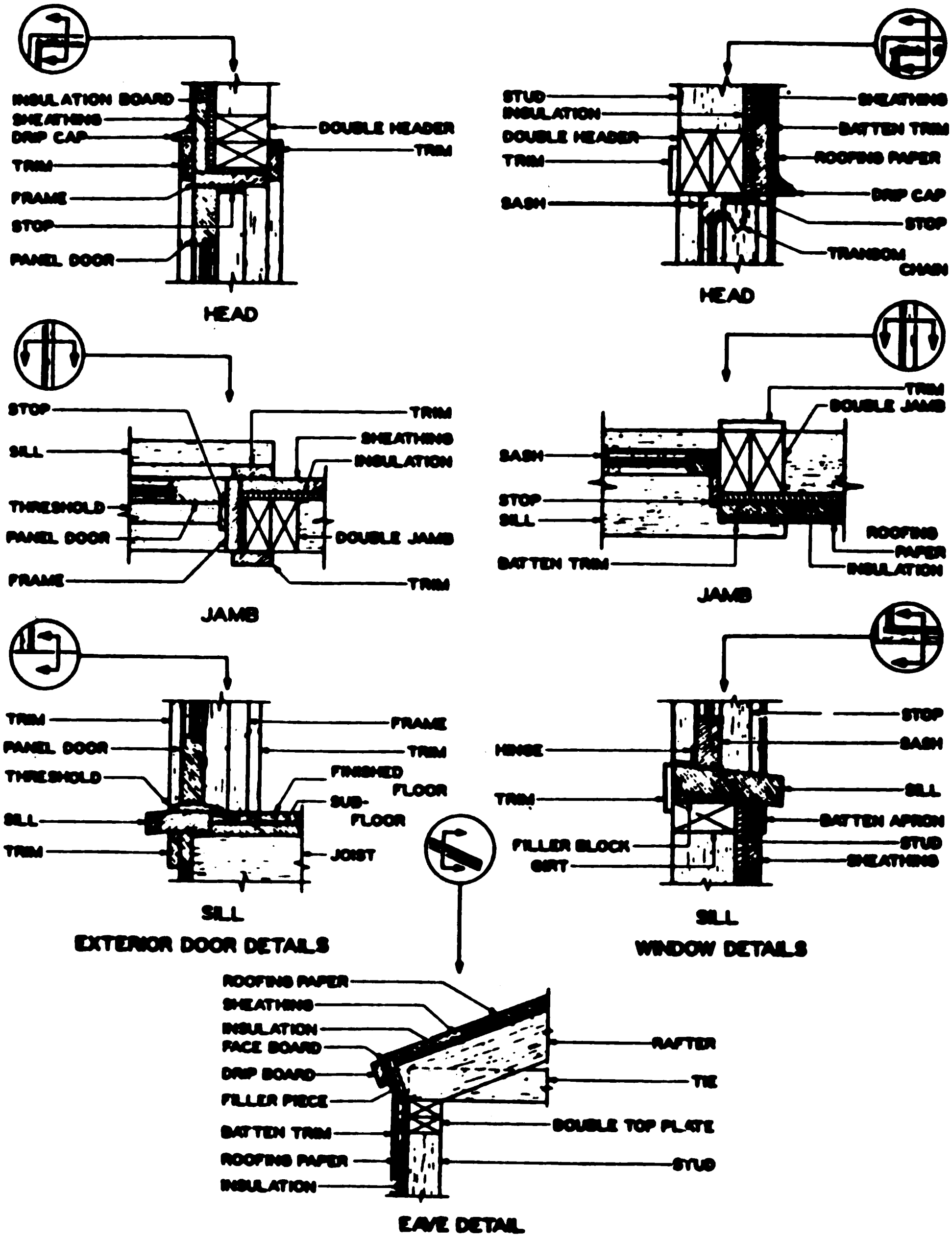


Figure 2-16. Typical door, window, and eave details.

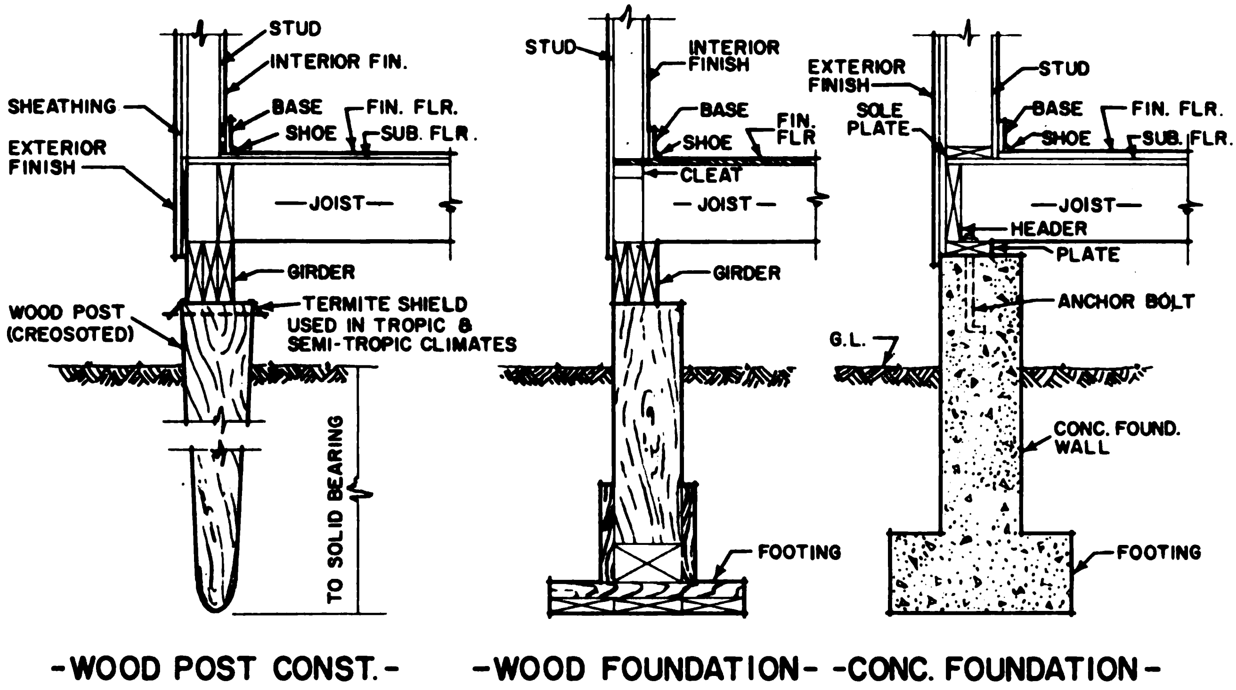


Figure 2-17. Typical sill details.

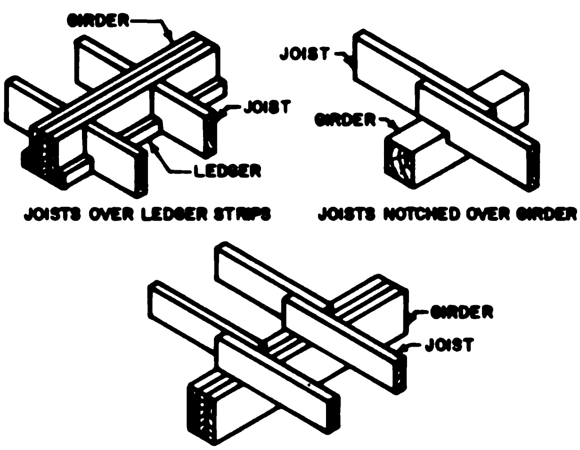


Figure 2-18. Girder and joist connectio

Section III. CONCRETE AND MASONRY

2-15. Concrete Construction

a. Concrete is a mixture of cement, water, and aggregate. Aggregate is classified as fine and coarse. Fine aggregate refers to sand and coarse aggregate to crushed stone or gravel. Mixed together in specified proportions, fine aggregate fills the voids in coarse aggregate and cement and water form a paste that hardens to bond the aggregate together in a unified mass. Concrete is poured into forms while it is still plastic. Once hard, concrete retains the shape imparted to it by the form.

b. When steel reinforcing rods are embedded in concrete, it is known as reinforced concrete. In general, bar reinforcing steel embedded in the concrete is assumed to provide for all tension and shear stresses and the concrete resists compressive stress. The bars may be round or square in cross-section, have plain or deformed surfaces, and be manufactured of mild billet or hard rail steel. Welded reinforcing mesh is normally used to prevent cracks and checks in slab or wall concrete.

(1) Plain and deformed bars. Plain bars have smooth surfaces. Deformed bars have lugs, ribs, and projections of various types on their surfaces that do not change the cross-sectional dimensions, but provide a better mechanical bond between the bars and concrete.

(2) Sizes. Table 2-2 gives the sizes, areas, and weights of plain and deformed reinforcing bars in common use.

(3) Bending and placing bars. Bars are manufactured in straight lengths and are cut and bent. Bars are bent by the steel fabricator in the shop and sent to the job ready to place without further cutting or bending. The bars are placed and wired in position before concrete is poured.

Table 2-2. Sizes, Areas, and Weights of Reinforcing Bars

Diameter (inches)	Size [a] (numbers)	Weight (pounds per foot)	Nominal Diameter (inches)	Dimensions of Round Cross-Sectional Area (square inches)	Section Perimeter (inches)
¼	2[b]	0.167	0.250	0.05	0.786
⅜	3	0.376	0.375	0.11	1.178
½	4	0.688	0.500	0.20	1.571
⅝	5	1.043	0.625	0.31	1.963
¾	6	1.502	0.750	0.44	2.356
⅞	7	2.044	0.875	0.60	2.749
1	8	2.670	1.000	0.79	3.142
1	9[b]	3.400	1.128	1.00	3.544
1⅛	10[b]	4.303	1.270	1.27	3.990
1¼	11[b]	5.313	1.410	1.56	4.430

[a] Bar numbers are based on the number of ⅛ inches included in the nominal diameter of the bar.

[b] Bar number 2 in plain rounds only. Bars numbered 9,10, and 11 are rounded bars 1-, 1⅛-, and 1¼-inch and are equivalent in weight and nominal cross-sectional area to the old type square bars.

2-16. Reinforced Concrete Details

a. Location. Location of the reinforcing steel is shown in detail drawings of the various structural members. It is not possible to show the shapes and sizes of the reinforcing bars by the usual orthographic views; therefore, a systematic method of marking is used in which bars are identified by symbols and reference numbers. Once assigned, the same reference number is used to identify the bar in any view in which it appears. Reinforcement size-and-shape details are provided in a separate reinforcement detail drawing which consists of a reinforcement schedule and diagrammatic bar-bending details.

b. Symbols. The symbols used in drawings of reinforced concrete structures include the material symbol for concrete in section and the symbols for reinforcing steel.

(1) Concrete. The symbol for concrete (fig. 2-2) indicates coarse and fine aggregate. Fine aggregate is represented by fine dots and coarse aggregate by irregularly drawn triangles.

(2) Reinforcement. Figure 2-19 presents the symbols for typical shapes of reinforcing steel. Figures 2-20 through 2-22 illustrate some applications of these symbols. Note that in addition to their symbolic representation, reinforcing bars parallel to the section are represented by heavy dashed lines; those perpendicular to the section are represented by heavy round or square dots, depending upon the cross-sectional shape of the bars. In notes, the symbols ϕ and $\not\phi$ are used to indicate round and square bars, respectively.

c. Reinforcing Schedules. Figure 2-20 shows a portion of a floor framing plan and provides examples of reinforcing schedules for slabs, bar bends, and beams located on the plan. The slab and beam schedules are keyed to marks on the plan. For example, note that D2 is a bond mark described on the second line of the slab schedule and 2B6 is a beam mark that is the first described in the beam schedule. The bending schedule is keyed to a bar type number given in the slab schedule. The bottom bars of slab band mark D2, for example, are listed in the slab schedule as type R500. The dimensions and a description of the type R500 bar bend are provided in the bending schedule. You should know the following about the data listed in the reinforcing schedules: The No. columns list the quantity requirement. Size refers to the bar diameter, length to the stretchout length, and type to the shape of the bar. Bending details pertain to the outside lengths of the straight and curved segments. The shipping mark provides the dimensions in code, with the first number giving the bar diameter in multiples of 1/8 inch and the remaining three or four numbers the overall bar length in feet and inches. Mark 5246 indicates 5/8-inch diameter and 24-feet, 6-inches long, while mark 31810 denotes 3/8-inch diameter and 18-feet, 10 inches long.

d. Bar-Bending Details. Bar-bending details resemble the diagrammatic shapes shown in figure 2-19. The manner in which bar-bending details are indicated in reinforcing schedules is illustrated in figure 2-20.

e. Section Details. Figures 2-21 and 2-22 illustrate how basic information is given in typical reinforcement section details. You can read both figures in the same manner. The principal difference between these illustrations is that figure 2-21 depicts vertical structures (column, pier, and walls), whereas figure 2-22 depicts horizontal construction items (beams and slab).

(1) Look at the reinforced concrete column in figure 2-21. What you see is a plan and elevation section of a 14 x 14-inch (1'-2" x 1'-2") reinforced concrete column with a 12-inch beam. There are four vertical, 3/4-inch diameter round bars on 10-inch centers to be set 2 inches inside the face of the concrete. Lateral ties of 1/4-inch diameter round bars are placed around the vertical bars.

(2) Read the elevation and plan sections of the reinforced concrete pier in figure 2-21. Note that the pier consists of a post that is 12 inches square on a footing measuring 2 feet, 8 inches square and 1 foot (minimum)

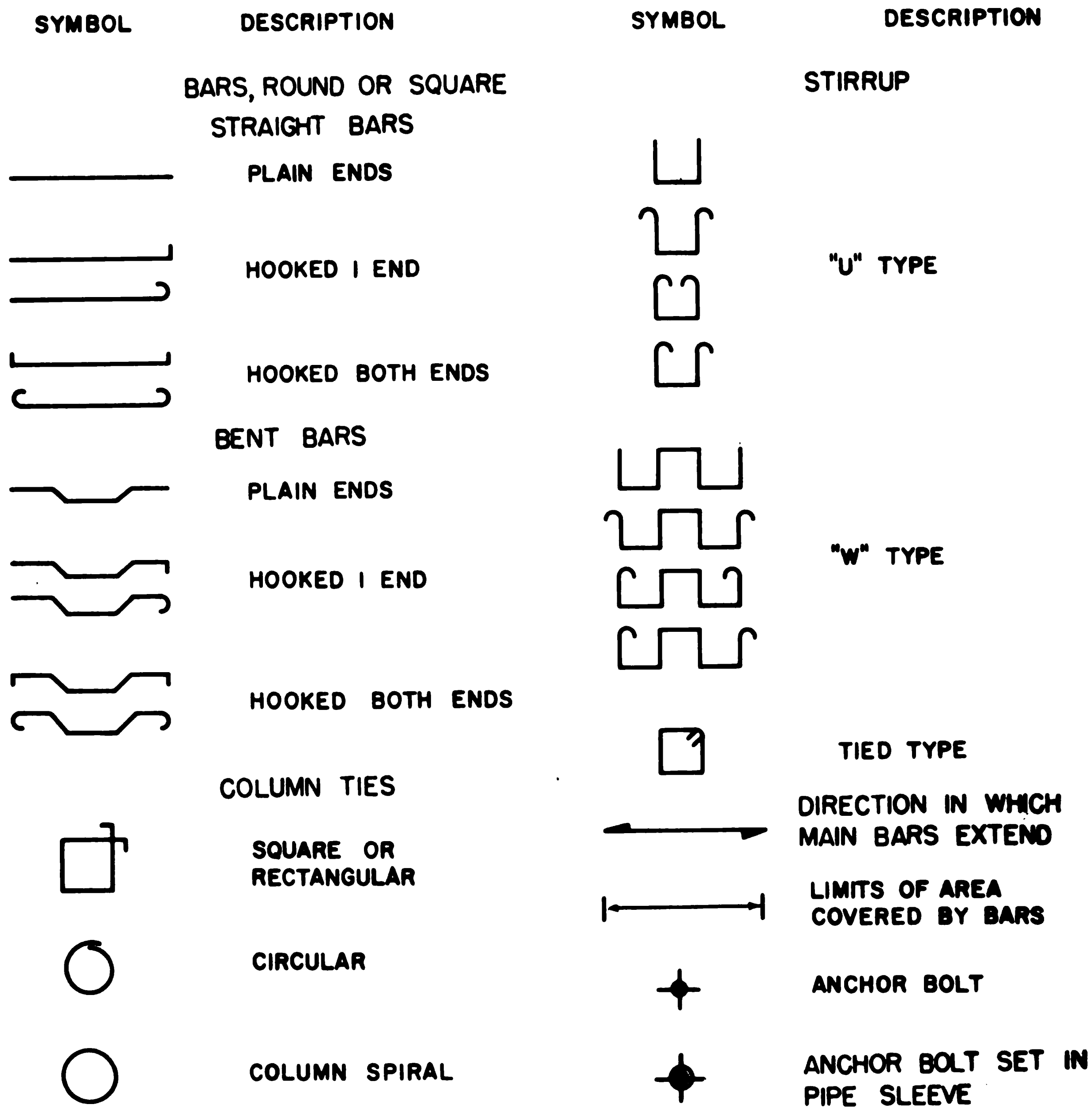
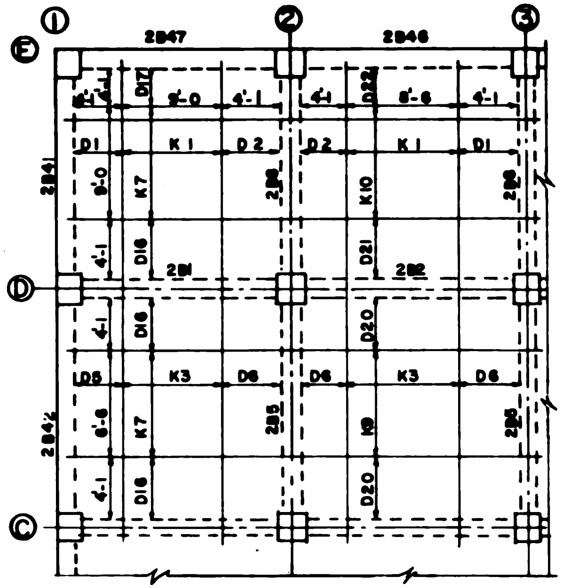


Figure 2-19. Reinforcement shapes (symbols).



SECOND FLOOR FRAMING PLAN
ALL SLABS 5" THICK

SLAB SCHEDULE

	No. of Bands	Band Mark	Bar Spacing	BOTTOM BARS No.	Length	Type	Sketch	Shipping Mark	TRUSS BARS No.	Length	Type	Sketch	Shipping Mark	7/8 SLAB BOLSTERS No.	Length	CONTINUOUS HIGH CHAIRS No.	Length	Height
Lower Layer	2	D1	8 3/4	2	19'-6	R500		5196	3	24'-6	R501		5246					
	2	D2	11	2	19'-6	R500		5196	2	24'-6	R501		5246					
	2	K1	8 3/4	5	18'-6	R503		5186	8	29'-11	R502		52911	4	16'-0	4	18'-3	4 1/4
Upper Layer	3	D16	11	2	17'-3	R506		5173	2	24'-6	R511		5246					
	1	D17	8 3/4	2	17'-9	R507		5179	3	24'-6	R511		5246					
	2	K7	8 3/4	5	19'-6	R500		5196	8	24'-6	R511		5246			2	12'-0	4 3/4

BENDING SCHEDULE

Type	Hk		Length	Type	Hk		S1		S2		H	J	Length
R500	6	19'-0	19'-6	R501	6	2'-9	6 1/2	11'-6	6 1/2	6'-8	4 1/2		24'-6
R504	6	20'-3	20'-9	R502		8'-2	6 1/2	9'-10	6 1/2	6'-2	4 1/2		23'-3

Note: All slab bars are 5/8 φ
All bending detail dimensions are out to out

BEAM SCHEDULE

No. of Beams	Beam Mark	SIZE Width	Depth	STRAIGHT BARS No.	Size	Length	Remarks	Shipping Mark	HOOK BARS No.	Size	Length	Hook		Hook	Shipping Mark	TRUSS BARS No.	Size	Length	Hook		S1		S2		Hook	H	LOCATION	℄ of support Remarks	Shipping Mark	STIRRUPS No.	Size	Length	B x C	Type	Spacing each end	2" Beam Bolsters
2	2B6	14	20	1	7/8	20'-6		7206	2	7/8	17'-10	9	16'-6		71710	2		28'-7	1'-1	2'-4	1'-11	11'-0	1'-10	7'-7		1'-4			8267	14	1/2	5'-6	11x17	S1	2-3,3-6, 5-9	4 at 1'-1
2	2B7	14	20	2	7/8	18'-6		7186								2		28'-1												14	1/2	5'-6	11x17	S1	do	4 at 1'-1

Figure 2-20. Typical reinforcing plan.

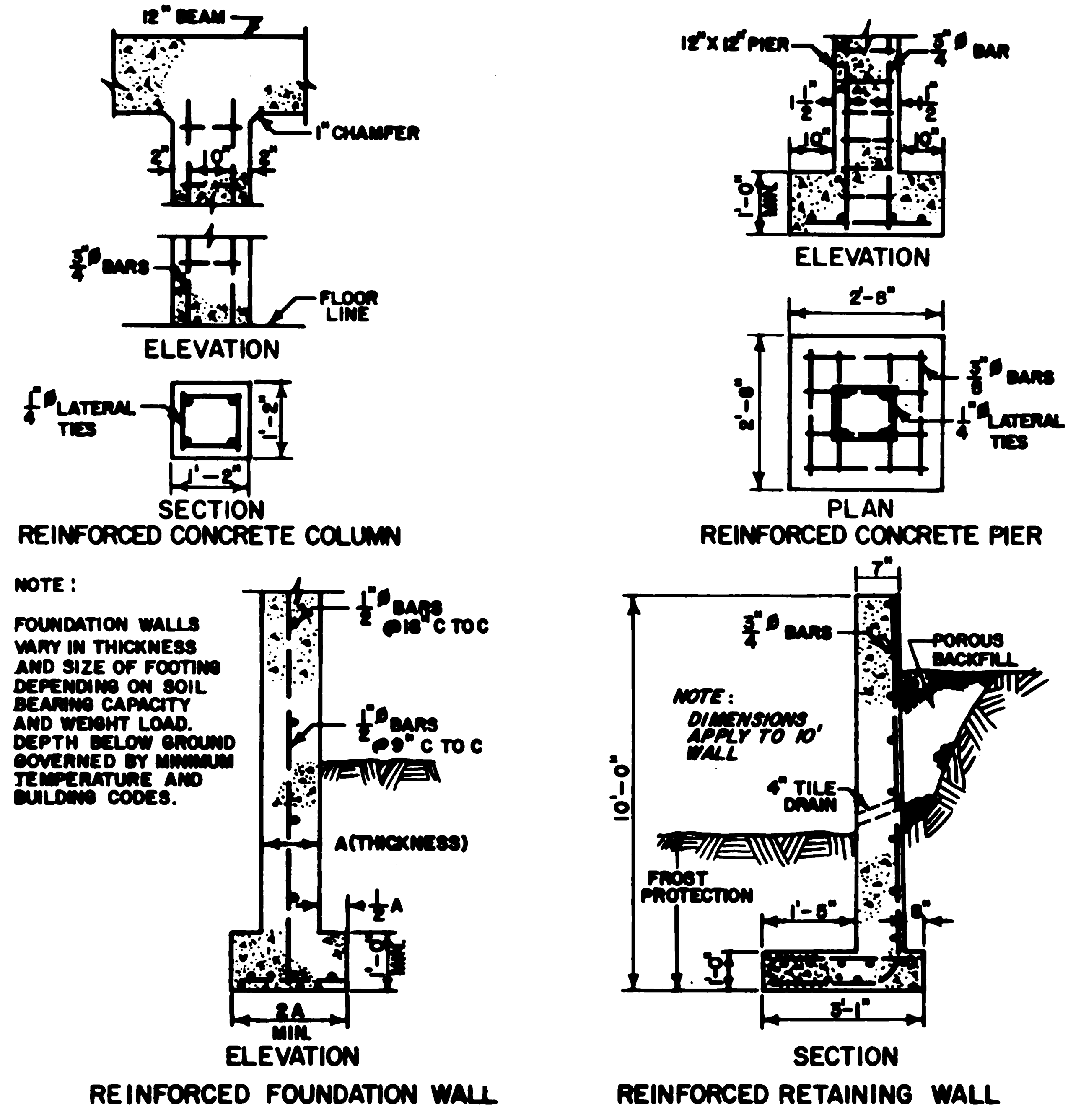


Figure 2-21. Common reinforced concrete sections.

in depth. The post reinforcement consists of four vertical, 3/4-inch diameter round bars on 9-inch centers, with 1/4-inch diameter round bar hoops at specified intervals (designated on the print or in the reinforcing schedule). The footing reinforcement consists of eight 3/8-inch diameter round bars arranged as a mat.

(3) The elevation section of a reinforced foundation wall (fig. 2-21) shows vertical, horizontal, and longitudinal bars. Note that the wall thickness is designated by the letter "A" minimum. An explanatory note on figure 2-21 advises that the thickness of the wall and the size of the footing depends upon the soil bearing capacity and weight load. This note also reveals that minimum temperature and building codes determine the depth below ground of a reinforced foundation wall. The vertical bars are 1/2-inch diameter round bars spaced at 9 inches center-to-center and the longitudinal bars are ½-inch diameter round bars spaced at 18 inches center-to-center. The horizontal bars in the footing are not specified in figure 2-21, but will be found elsewhere in associated plans.

(4) In viewing the section of a reinforced retaining wall shown in figure 2-21, you will find the thickness and height of the wall and the height and width of the footing. You will also learn that the backfill of the wall is porous, a 4-inch tile drain is provided, and the longitudinal reinforcement bars are to be ¾-inch round. Note that the wall thickness increases from a thickness of 7 inches at the top to 1 foot at the bottom. Data not given in this section, such as bar lengths and degree of bends, as well as radius of hoops and spacing, is supplied in the plans and schedules of the structure.

(5) An inspection of figure 2-22 will show you the shapes and locations of the steel bars in portions of a continuous rectangular beam, a continuous T-beam, and a span of oneway reinforced concrete slab floor. For example, you can see that the continuous rectangular beam will be reinforced with 4-½-inch diameter truss bars, 2¾-inch diameter straight rods, and ½-inch diameter stirrups. You should also note that the cross-section size of the beam is 6 x 12 inches. Beam length is given in the associated schedule.

2-17. Joints and Connections

The manner in which structural members and construction materials are connected to each other is shown in detail drawings.

a. Foundation Walls. Foundation walls are bonded to footings with vertical reinforcing bars called dowels, which are placed in footings and extend upward 3 to 4 feet into the wall (fig. 2-21). A wedge-shaped trough, called a key, is built into spread footings to strengthen the bond between footings and walls that are poured later.

b. Construction Joints. Construction joints are divisions between concrete work performed at periods far enough apart to allow partial hardening. For horizontal work, such

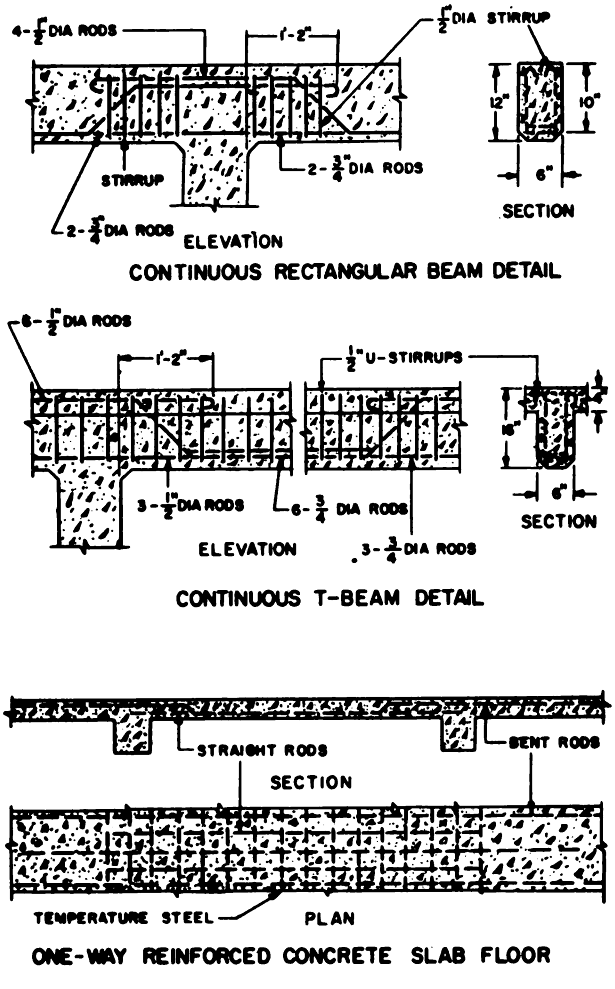


Figure 2-22. Reinforcement details for beam and slab floors.

as floor slabs, construction joints should be in a vertical plane. For vertical work, such as columns, the joints should lie in a horizontal plane. Although construction joints have no permanent function but to represent a convenient stopping place, they affect the strength of the structure. Their location is indicated in a drawing with a heavy, unbroken line and the note "permissible construction joint" or "construction joint."

c. *Contraction and Expansion Joints.* Concrete usually contracts while hardening and expands after it has hardened because of changes in atmospheric temperature. To provide for the changes in volume that occur at these times, it is necessary to supply joints at frequent intervals.

(1) *Contraction joints.* Various designs of contraction joints are used. In all cases, however, they represent a clean break between the two sections. No reinforcing extends across the break, which should be filled with an elastic joint filler or protected in some other way. Joint details are shown in a detail drawing.

(2) *Expansion joints.* Expansion joints are required wherever expansion might cause a concrete slab to buckle. Mastic joints are commonly used to separate sections from each other, thus allowing room for expansion.

d. *Masonry Units.* Masonry units, such as brick, structural tile, and cinder block, are bonded to foundation walls with mortar. Metal ties may be added to increase the strength of the bond.

e. *Grout.* Grout is a mixture of cement, sand, and water. Grouting is the process of adding a layer of concrete to concrete that has been poured previously. It is frequently used to bring bearing surfaces, such as column footings and foundation walls, to the exact grade desired. Grout is not indicated symbolically on drawings, but its thickness is noted.

f. *Bearing Plates.* When heavily loaded beams or columns bear on masonry or concrete supporting members, metal plates are used to distribute the load and prevent crushing the surface of the supporting member. The plates are made of steel or cast iron and may be held in place by grout, dowels, anchor bolts, or the weight of the supported member.

(1) *Beam supports.* Bearing plates are used to distribute the loads of horizontal members bearing on masonry walls. Usually these plates are of a simple rectangular shape.

(2) *Column supports.* Base plates are used to distribute the loads of columns bearing on concrete or masonry piers and footings and may be plain or ribbed. Base plates for pipe columns may have a vertical projection or dowel to fit inside the column to hold the column in place.

g. *Anchor Bolts.* Anchor bolts are the most frequently used means of connecting wood and steel to concrete (fig. 2-17). The end embedded in the concrete is hooked to provide a stronger bond. Anchor bolt dimensions are given in specific notes and state diameter and length. For example, the note "½ x 1' —2" anchor bolts @4' —8" OC" means that the bolts are ½ inch in diameter; 1 foot, 2 inches long, and are spaced at intervals of 4 feet, 8 inches measured on centers around the perimeter of the foundation wall.

2-18. Masonry Construction

Bricks, hollow clay tiles, concrete or cinder blocks, concrete tiles, and stone are used in various combinations in masonry construction. The sizes, shapes, and characteristics of masonry units determine their applicability and use in construction. The specified type and placement of masonry units are shown in plans of masonry structures.

a. *Brick Types.* Brick types are determined by size, shape, and usage. Figure 2-23 shows the various brick cuts and masonry joints.

(1) *Whole.* A whole brick is a standard 2¼ x 3¾ x 8-inch brick.

(2) *Split.* A split brick or soap is a flat half-brick that has been split lengthwise.

(3) *Quarter or closer.* A quarter or closer is a quarter segment of a brick broken across the narrow section at quarter length.

(4) *Three-quarter.* A three-quarter brick is the remainder of a brick with the quarter removed.

(5) *Soldier.* A soldier is a whole brick laid vertically with the narrow face showing in the wall.

(6) *Queen closer.* A queen closer is a brick split lengthwise through its short axis.

(7) *Stretcher.* A stretcher is a whole brick laid flat longitudinally with the wall.

(8) *King closer.* A king closer is a whole brick with a corner clipped off.

(9) *Half or bat.* A half or bat is half a brick.

(10) *Header.* A header is a whole brick laid flat across the wall with one end showing in the wallface.

(11) *Rowlock.* A rowlock is a brick laid on its edge across two rows of flat brick with one end showing in the wall.

b. *Brick Joints.* Joints in brick masonry (2, fig. 2-23) are formed by the mortar which bonds the masonry together. The type of joint to be used is included in the notes of the plan or is included in the brickwork specification. To finish the joints and make a waterproof bond between brick and mortar in the exterior faces of brickwork, the joints are struck, or ironed, with various shapes of jointers or a pointing trowel. Two typical joints are: the flush or plain joint, in which the mortar joint is struck flush with the exterior of the masonry wall; and the raked joint, in which some of the mortar is removed with the point of the trowel to make the brickwork stand out. Other joints are the struck, weathered, stripped, V, or concave joints, all of which are made with the proper use of the trowel.

c. *Brick Bond.* Bond is an arrangement of built-up bricks or other units laid so that their overlapping thoroughly ties the units together. This is not to be confused with the term "bond" as applied to a bonding material, such as mortar. The specifications or notes in the plans will specify the type of bond required. There are many types of brick bonds. A few typical bonds are shown in figure 2-24. The type bond generally used in military construction is the common bond (1, fig. 2-24). Details on masonry construction can be found in TM 5-742, Concrete and Masonry.

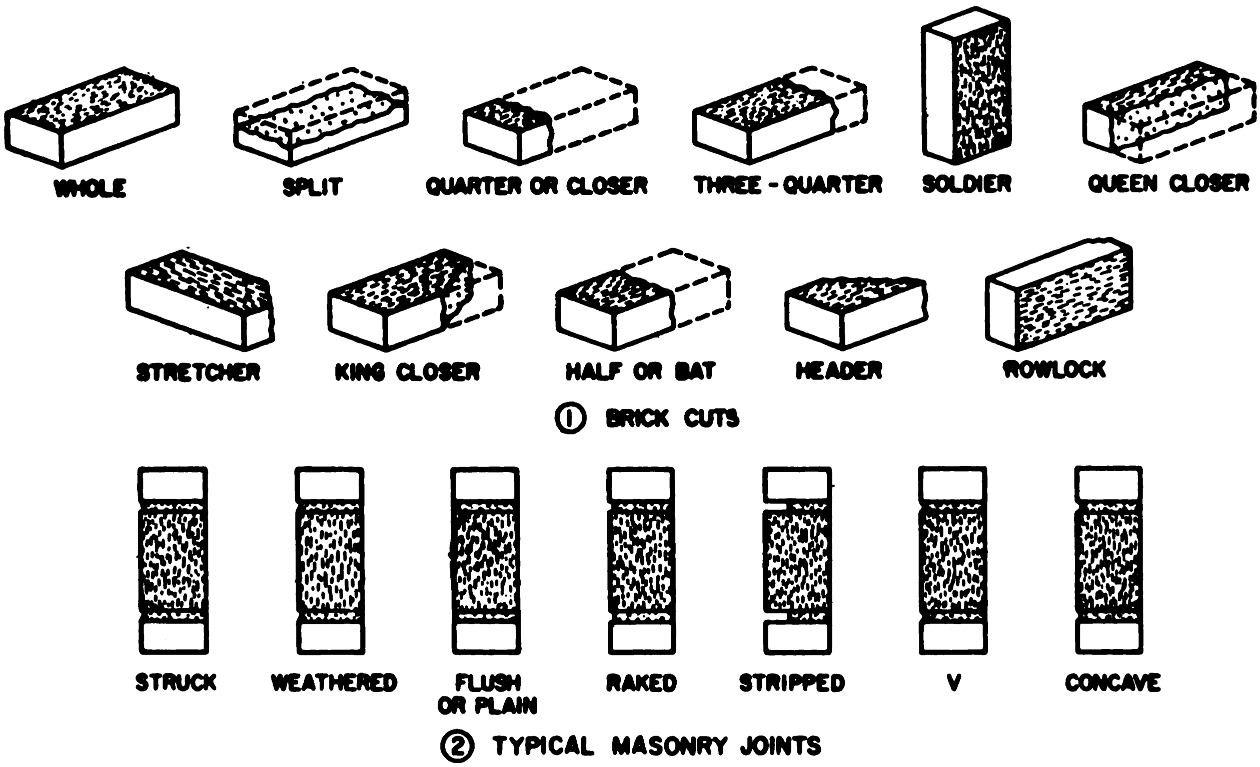


Figure 2-23. Brick cuts and typical masonry joints.

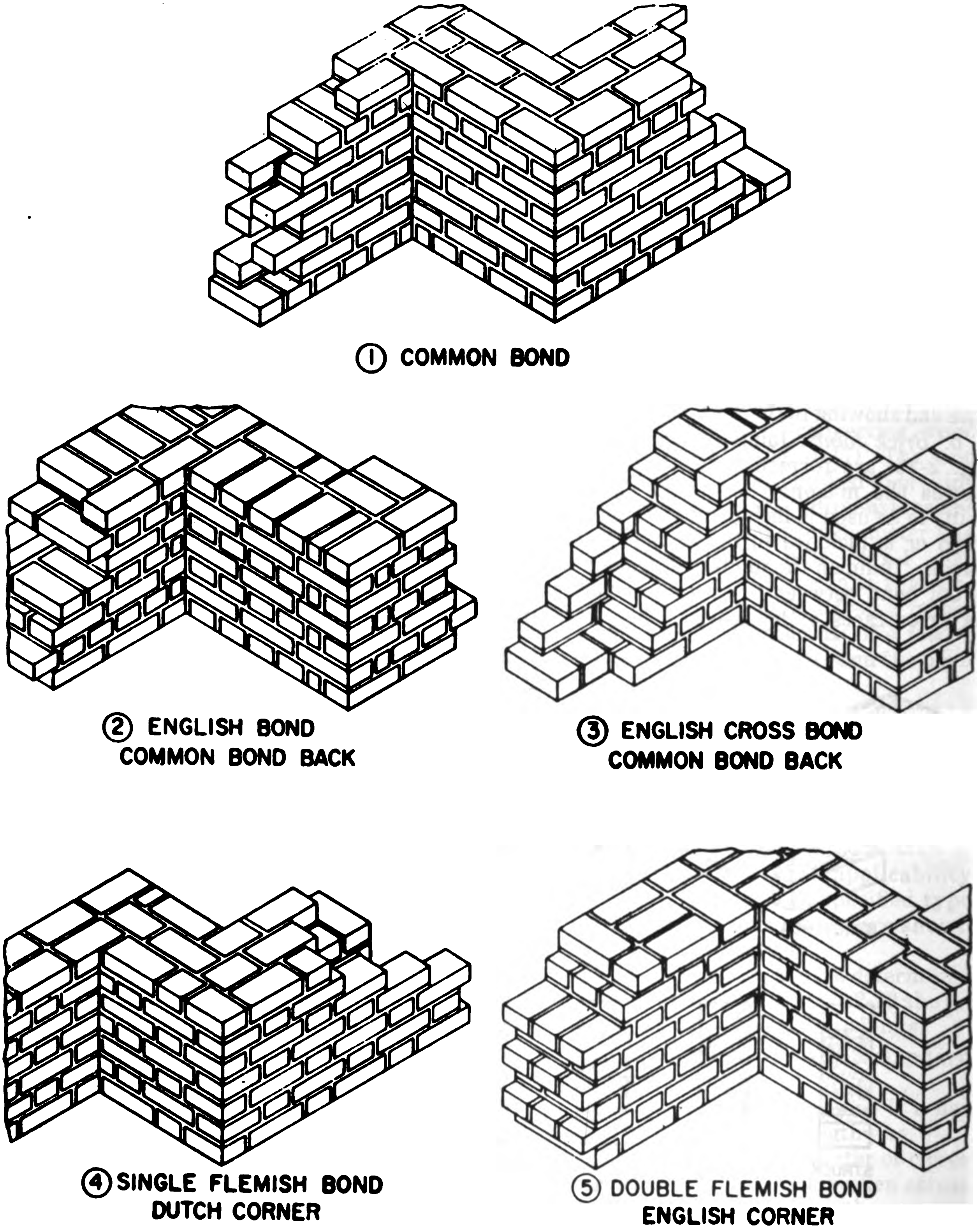


Figure 2-24. Common types of brick bonds.

d. Hollow Clay Tiles. Hollow clay tiles are units of burned clay constructed with hollow cores and laid in cement mortar. Their use may be indicated in the plans or the specifications for the construction of partitions, furring, and outside walls faced either with stucco or brick tied to the tile by headers or metal ties. Plans of small military buildings of hollow clay will normally show the exterior walls to be tile without brick facing. Some common types and sizes of hollow clay tiles with which you should become familiar are illustrated in figure 2-25.

e. Concrete Blocks and Tiles and Cinder Blocks. Concrete blocks and tiles are solid or hollow molded units of portland cement and fine aggregates and are laid in cement mortar. Cinder blocks are lightweight units of cinders with portland cement and sand made to the same forms and dimensions as concrete blocks. These masonry units usually are made in standard sizes of various thicknesses, with the most common being 8 x 8 x 16-inch nominal size. The nominal size allows for the mortar joint. Note the typical concrete masonry units shown in figure 2-26. Concrete blocks and tiles and cinder blocks are used for walls, partitions, and foundations and can be used for low retaining walls. The required types of blocks or tiles and their designated use in construction are given in notes or specifications; the units themselves are not shown in the plans.

f. Stone. When used as found in the field or quarry, stone is called rubble. When cut and shaped into fairly regular forms, it is called squared stone or ashlar. When cut into rectangular blocks, it is known as cut stone. Stone masonry is composed of either solid stone or stone backed with other types of masonry and is laid in mortar to a specified type of pattern consistent with the type of stone available in military construction. In theater of operations construction, stone masonry is normally used only in foundation walls, retaining walls, piers, and drainage structures. In the building of military structures, stone as a building unit is seldom used unless other materials are difficult to obtain.

2-19. Masonry Construction Drawings

The most common use of masonry is in wall construction.

a. Types of Masonry Walls. The principal types of masonry walls are bearing, curtain, veneer, and hollow walls.

(1) *Bearing walls.* A bearing wall is one that supports a vertical load other than its own weight; its thickness is regulated by its height. The minimum thickness of a brick bearing wall for a dwelling is 8 inches; for buildings such as warehouses, which carry heavy loads, the minimum thickness is 12 inches.

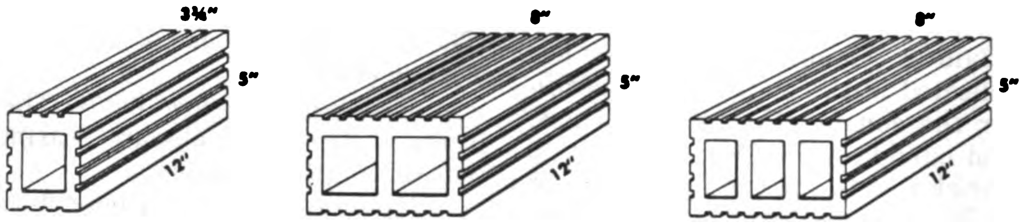
(2) *Curtain walls.* A curtain wall is a masonry wall enclosing a framework of steel or reinforced concrete; it is not a bearing wall. The curtain wall may support its own weight or may be supported at intervals on the frame of a building. The minimum thickness of a brick curtain wall is 8 inches.

(3) *Veneer.* Veneer implies a masonry facing over an exterior bearing wall. The veneer is not self-supporting and is fastened to the frame of the building with metal clips spaced at specified intervals. Some examples of masonry veneer are stone on a wood frame, brick on a wood frame, or brick on cement tile.

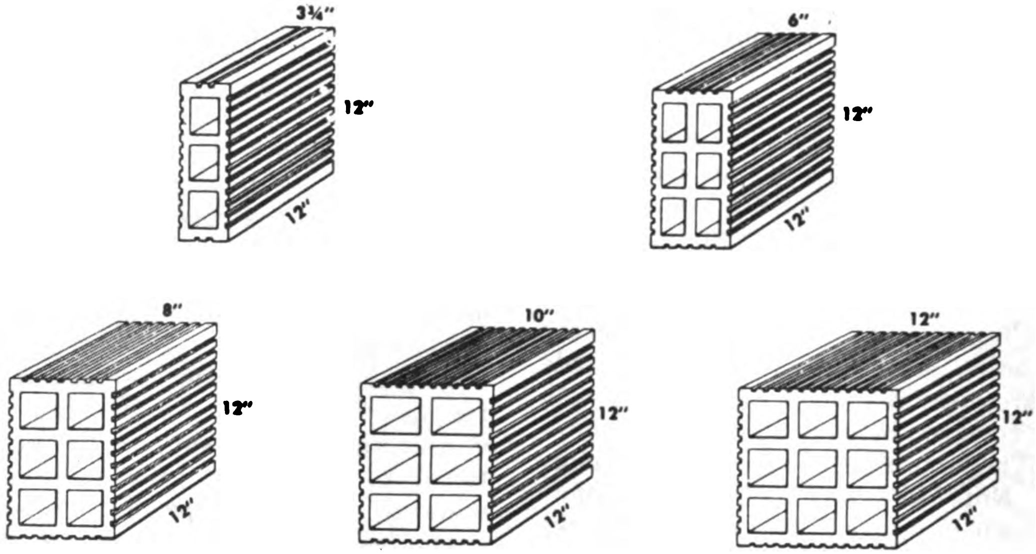
(4) *Hollow walls.* Buildings with masonry walls are occasionally constructed with parallel walls separated by an air-space. Hollow-wall or cavity construction permits plaster to be placed directly on the interior wall without first building a backing-out from the wall.

b. Plans. Symbols, dimensions, and notes are used in a plan view to show location, thickness, and types of masonry walls. Dimensions give the overall length and width as well as the location and width of all doors and window openings. The double-line wall symbol is drawn to scale and the appropriate section symbol is used to indicate the masonry material graphically. Brick walls are dimensioned to the outside corner in plan views.

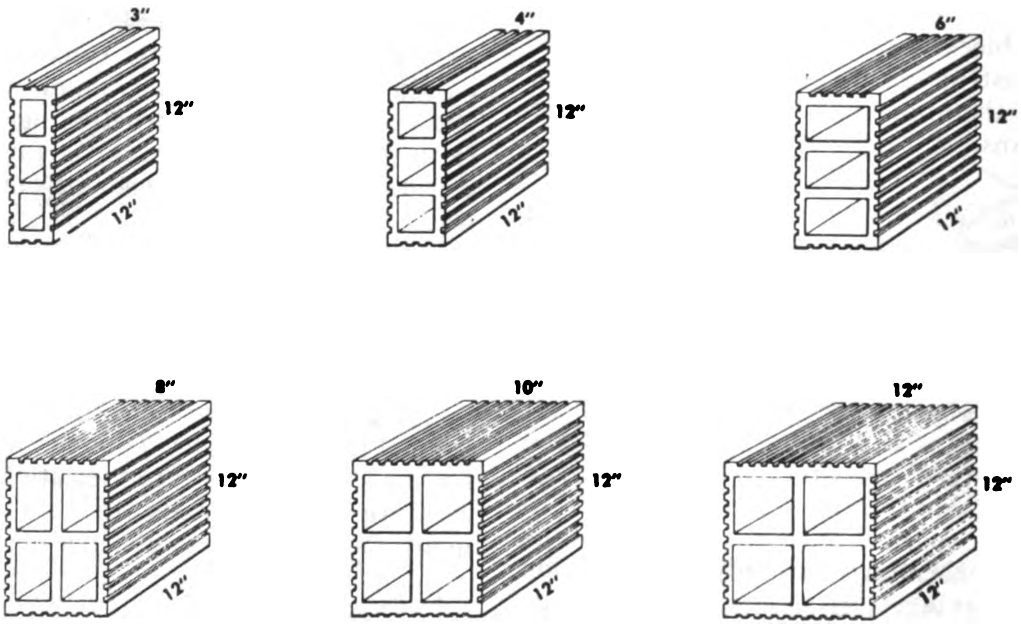
c. Elevation. Door and window openings are drawn to scale. Wall material is indicated by a few courses of brick, block, stone, or tile, as required. The number and dimensions



1 Standard tile for side construction



2 Standard tile for end construction



3 Standard tile for partitions

Figure 2-25. Types of hollow clay construction tile.

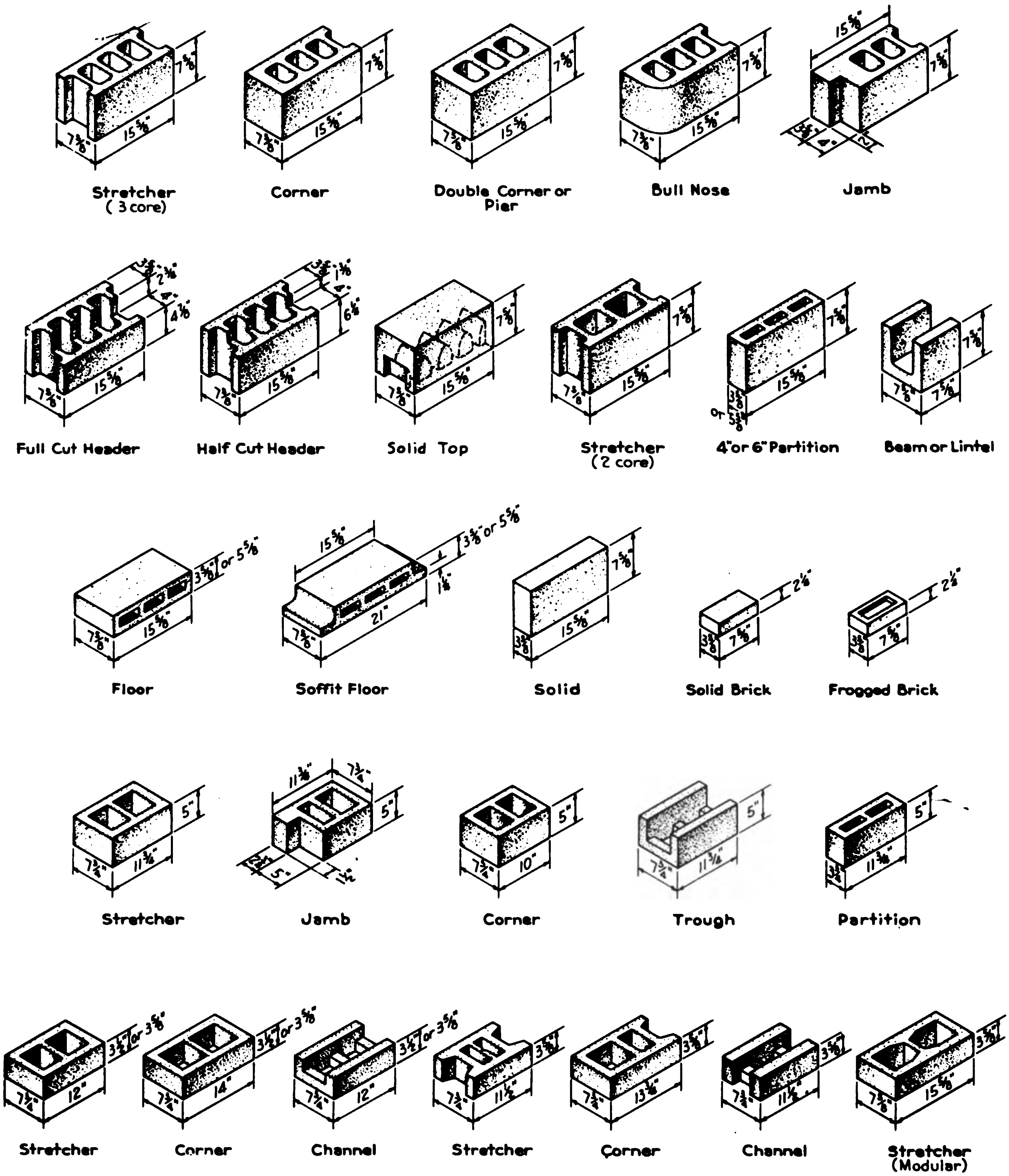


Figure 2-26. Standard types of building blocks.

of courses are shown in elevations between finished floor lines, from finished floor line to the bottom of a window opening, and to the other vertical construction points from datum lines as required. Bricks above doors and windows are in rowlock bond. Lintels may be used in lieu of rowlock bonded bricks above doors and windows (fig. 2-26.1).

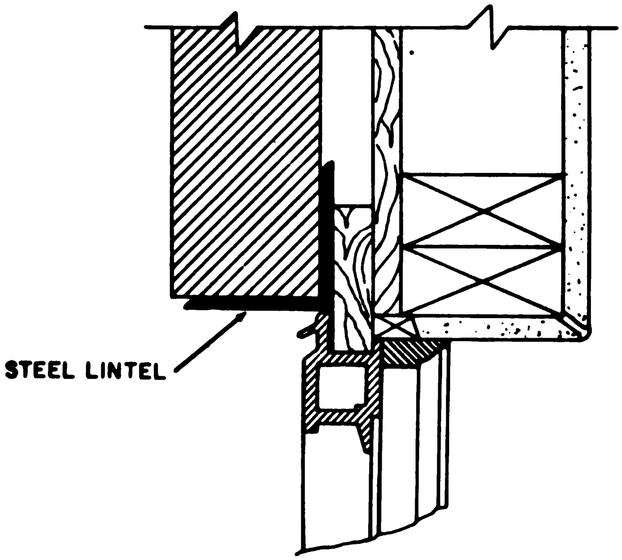


Figure 2-26.1. Typical steel lintel detail.

d. Sections. The details of masonry construction are indicated in wall sections (fig. 2-27) drawn to large scale (¾ inch = 1 foot or 1½ inches = 1 foot). Construction details are shown at the building sill, head, jamb, sills of doors and windows, and at the eaves. Additional sections are shown when there are departures from the typical, such as variations of roof and floor framing into the masonry wall. Large-scale wall sections show the actual sizes of masonry units to represent joints by a space to scale between unit outlines, and to show all other items exactly to scale in order that mechanics will have a clear picture. Joint dimension, masonry material, and any details of construction requiring explanation are explained by specific notes or dimensions.

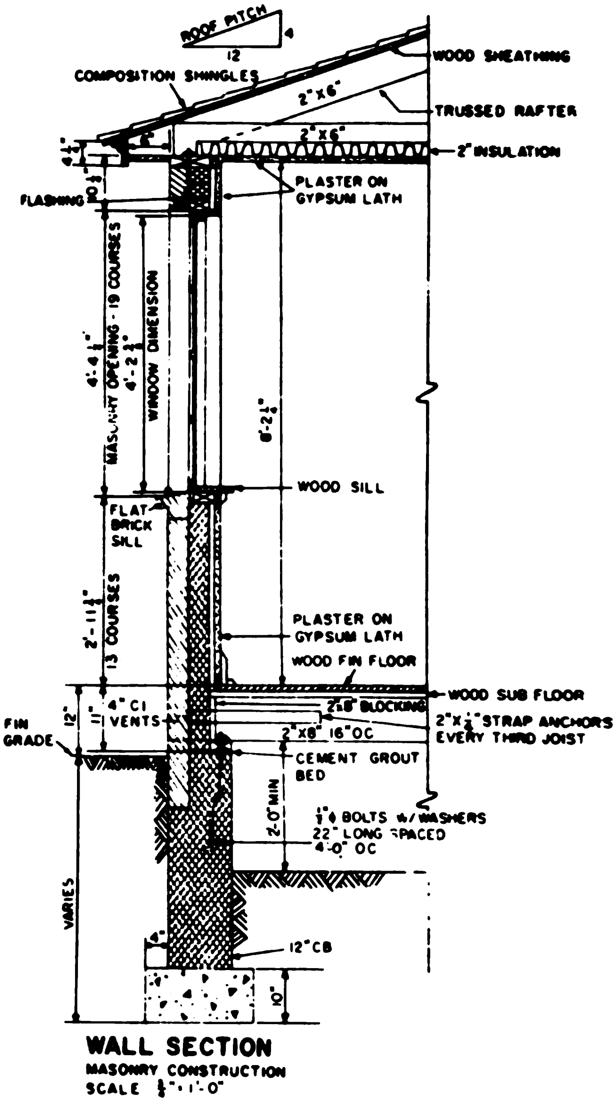


Figure 2-27. Masonry construction wall section.

2-20. Self-Test

To check your knowledge of the material covered in this section, answer the following questions. Answers are given at the end of this chapter.

1. What are the dimensions of a reinforcing bar that has shipping mark 52911?
   a. 5-inch diameter and 29 feet, 11 inches long
   b. ½-inch diameter and 2 feet, 9 inches long
   c. 5/8-inch diameter and 29 feet, 11 inches long
   d. 5/8-inch diameter and 9 feet, 11 inches long
2. On section views, reinforcing bars perpendicular to the section are represented by
   a. Heavy dash lines
   b. The symbol for steel
   c. Typical shapes
   d. Round or square dots.
3. The Length column of a reinforcement schedule lists the:
   a. Stretchout length
   b. Details to outside lengths
   c. Overall length
   d. Segment length
4. Which of the following items is used to connect wood or steel to concrete?
   a. Plaster
   b. Mortar
   c. Anchor bolts
   d. Grout
5. Which type of drawing will show the location of contraction and expansion joints?
   a. Reinforcement details
   b. Wall section
   c. Plain
   d. Reinforcement schedule

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2-21. Structural Steel

Structural members are normally cut and fitted in special fabricating shops and transported to the building site for final assembly and erection. Steel structures are composed of rolled-steel shapes used either singly or built up to form members. In the field, members are erected in their relative positions, fastened temporarily with bolts and drift-pins, and permanently connected with rivets, bolts or by welding.

a. Structural Shapes and Symbols. Structural steel drawings show the shapes and sizes of the steel used and the details of assembly of the parts. Note the sections of common rolled-steel shapes shown in figure 2-28. The symbols used to identify the shapes in notes, dimensions, and bills of meterial are shown in parenthesis.

(1) Angles (L). The angle is a standard structural shape whose cross-section resembles the letter L. Angles are used singly or in combinations of two or four angles to form main members. They are also used to connect two main members or parts of members together. Angles are identified by the dimensions of their legs, measured in inches along the outside or backs of the legs. The sequence in which dimensions of angles is noted is: symbol followed by dimension of wider leg first and thickness of the legs third (both legs always have equal thickness). Thus, L 7 x 4 x ½ indicates that the steel section is an angle whose legs are 7 inches and 4 inches wide and ½ inch thick.

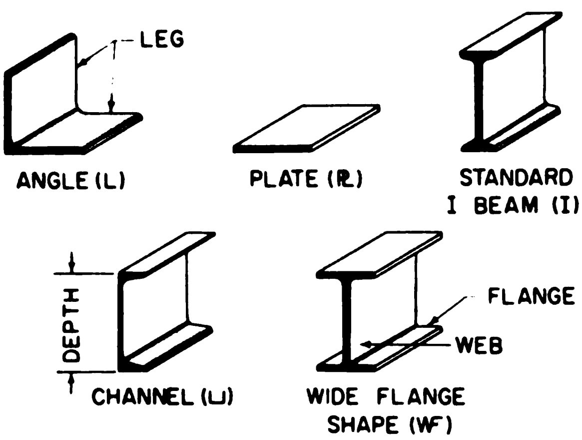


Figure 2-28. Common rolled-steel shapes and symbols.

(2) Plates (PL). Plates are noted by width, thickness, and length. Thus, 1 PL 11 x 3/8 x 2'-7 indicates that the item is a single plate whose dimensions are 11 inches at its widest point, 3/8 inches thick, and 2 feet, 7 inches at its longest point.

(3) Standard I-Beam **(I).** The **I**-beam is a standard structural shape whose cross-section is in the form of the letter **I**. **I**-beams are used as beams, columns, truss members, and any other application where their shape makes their use desirable. An **I**-beam is identified by its nominal depth in inches and weight in pounds per foot of length. For example, the notation 15 **I** 42.9 designates an **I**-beam that has a nominal depth of 15 inches and weighs 42.9 pounds per linear foot.

(4) Wide-flange shapes (WF). The wide-flange shape is a standard structural shape whose cross-section is in the form of the letter H. Wide-flange shapes have the same general use as **I**-beams; however, wide-flange shapes have greater strength and adaptability than **I**-beams. Identification of a wide-flange shape is by its nominal depth and weight per foot. For example, 24 WF 76 designates a wide-flange section that is 24 inches deep and weighs 76 pounds per linear foot.

(5) Channels (⊔). The channel is structural shape whose cross-section is similar to a squared letter C. Channels are principally used in locations where a single flat face without outstanding flanges on one side is required. The channel is not very efficicient as a beam or column when used alone, but efficient built-up members may be constructed of channels assembled together with other structural shapes and connected by rivets or welds. Channels are identified by their depth and weight per foot. For example, the notation 9 ⊔ 13.4 indicates that the channel has a nominal depth of 9 inches and weighs 13.4 pounds per linear foot.

b. Actual Size and Weight versus Nominal Size Classification. It is important to note that the process for rolling structural-steel shapes permits a wide range of actual sizes and weights within a single nominal size classification. Examples of actual dimensions for the various weights of typical American Standard channels, beams, and wide-flange shapes are given in table 2-3, 2-4, and 2-5, respectively. It may be necessary to refer to tables such as these for additional information about specific situations.

Table 2-3. Detail Dimensions of Typical American Standard Channels

Depth of Section (inches)	Weight per Foot (pounds)	Flange		Web
		Width (inches)	Mean Thickness (inches)	Thickness
	13.0	2⅛	⅜	7/16
	10.5	2	⅜	5/16
	8.2	1⅞	⅜	3/16

Table 2-4. Retail Dimensions of Typical American Standard Beams (I-Beams)

Depth of Section (inches)	Weight per Foot (pounds)	Flange		Web
		Width (inches)	Mean Thickness (inches)	Thickness (inches)
10	35.0	5	½	⅝
	25.4	4⅝	½	5/16

Table 2-5. Detail Dimensions of Typical Wide-Flange Shapes

Nominal Size (inches)	Weight per Foot (pounds)	Depth (inches)	Flange		Web
			Width (inches)	Thickness (inches)	Thickness (inches)
16 x 11½	96	16⅜	11½	⅞	9/16
	88	16⅛	11½	13/16	½
16 x 8½	78	16⅜	8⅝	⅞	9/16
	71	16⅛	8½	13/16	½
	64	16	8½	11/16	7/16
	58	15⅞	8½	⅝	7/16
16 x 7	50	16¼	7⅛	⅝	⅜
	45	16⅛	7	9/16	⅜
	40	16	7	½	5/16
	36	15⅞	7	7/16	5/16

2-22. Connections

The building of any structure consists of joining component parts. The parts are connected with bolts and nuts or by welding.

a. Bolts and Nuts. In general, data concerning bolt dimensions is obtained from standard tables. However, bolts and nuts are seldon shown on detail drawings. Bolt and nut connection is the primary type used in the field. Bolt and nut are used because they require less skill and less tools. On assembly drawings, where bolts and nuts are encountered most frequently, approximate dimensions are adequate. Thread specifications are given in a note. The format or order of the specification note is in accordance with accepted standards. Figure 2-29 indicates the order of the specification note for a typical American standard thread and explains its interpretation. Referring to figure 2-29, you will see that the first number of the note (¾) denotes the nominal size of the major diameter and the number following the first dash (10) indicates that there are 10 threads per inch. Also apparent is that the letters NC indicate the thread series (National Coarse) and the last number (2) the class of fit (class of thread and tolerance). The letters LH following the last number designate left-hand threads, while notes without LH designate right-hand threads. The most widely used thread series are the American Standard National Coarse (NC) and National Fine (NF). The NF series have more threads per inch than the NC series as shown in table 2-6.

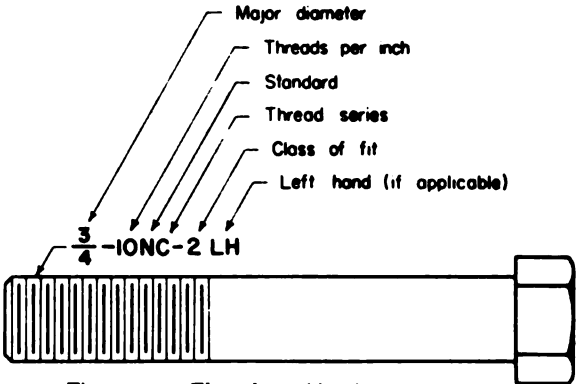


Figure 2-29. Thread specification note.

Table 2-6. American National Coarse (NC) and National Fine (NF) Series

(Number of Threads per Inch)

Size of Major Diameter	NC Series	NF Series	Size of Major Diameter	NC Series	NF Series
0	—	80	¾	10	16
1	64	72	⅞	9	14
2	56	64	1	8	14
3	48	56	1⅛	7	12
4	40	48	1¼	7	12
5	40	44	1⅜	6	12
6	32	40	1½	6	12
8	32	36	1¾	5	
10	24	32	2	4½	
12	24	28	2¼	4½	
¼	20	28	2½	4	
5/16	18	24	2¾	4	
⅜	16	24	3	4	
7/16	14	20	3¼	4	
½	13	20	3½	4	
9/16	12	18	3¾	4	
⅝	11	18	4	4	

Note: Number 13 size NF series is not given.

b. Rivets. Rivets are rarely used as connectors in the field. Some members may be fabricated in the shop with rivet connectors and then brought to the field for bolt and nut or weld connecting. All holes for rivets are punched or drilled in the fabricating shop whether the rivets are to be driven in the shop or in the field. Rivets that will be placed and driven in the shop to connect structural members are indicated on the print by a shop rivet symbol (O). Structural members to be connected at the job site are indicated on the print by a field rivet symbol (●). Conventional shop and field rivet symbols are shown in figure 2-30. Note that the rivet head diameter is used to represent shop rivets and the rivet shank diameter to represent field rivets. The symbol for field rivets indicates a hole in which rivets are to be placed. The intersection of pitch and gage lines, represented by centerlines on detail drawing made to small scale, shows the placement of the rivets. Standard forms of rivet heads are shown in figure 2-31.

c. Welding. Welding is used in the rear area as a method permanent joint between two metal parts. Welding requires a great amount of equipment and therefore, has only limited use in the front areas. Welding has its own language of symbols for use on drawings. The welding symbol is a composite of symbols and data indicating the requirements of a given weld. As you can see in figure 2-32, the basic welding symbol is simply a reference line and an arrow. This basic welding symbol serves as the base on which all symbol information is placed in standard locations. Symbols used to indicate the type of weld (called basic weld symbols) and supplementary weld symbols are shown in figure 2-33. The weld symbols is their respective positions on the reference line and arrow, together with dimensions and other data, form the welding symbol. The assembled welding symbol consists of the eight elements listed below, or such of these elements as are necessary. The elements of the welding symbol have standard locations with respect to each other as shown in figure 2-34.

(1) *Reference line.* This is the base for all data and symbols comprising the welding symbol.

(2) *Arrow.* The arrow points to the location of the weld.

(3) *Basic weld symbol.* This symbol designates the type of weld. Its location on the reference line indicates the side of the object to be welded; that is, arrow side, other side, or both sides.

(4) *Dimensions and other data.* The information provided by this element of the welding symbol is given on figure 2-34, identified by the symbols S, R, and (N).

(5) *Supplementary symbols.* This shows the supplementary weld symbols (fig. 2-33). The supplementary symbols on figure 2-34 indicate a field weld, to weld all around, and contour of weld is to be flush, respectively.

(6) *Finish.* The finish symbols indicate the method of finishing (C = chipping, M = matching, G = grinding, R = rolling, H = hammering) and not the degree of finish.

(7) *Tail.* The tail is only used to set off the notation that designates a definite process or specification or other references considered as element (8) of the welding symbol. When no notation is required, the tail may be omitted from the welding symbol.

(8) *Specification, process, or other references.* This is a notation that indicates a definite process or certain specifications or other references. When the use of a definite process is required, the process may be indicated by one or more of the letter designations listed in tables 2-7 and 2-8.

d. Application of Welding Symbols. Applications of the welding symbol are shown in figure 2-35. Note how the location of the weld symbol designates arrow side, other side, or both sides to be welded.

Shop Rivets, Two Full Heads

Shop Rivets, Countersunk and Chipped, Near Side

Shop Rivets, Countersunk and Chipped, Far Side

Shop Rivets, Countersunk and Chipped, Both Sides

Shop Rivets, Countersunk but Not Chipped, Max. ⅛ in. High — Near Side

Shop Rivets, Countersunk but Not Chipped, Max. ⅛ in. High — Far Side

Shop Rivets, Countersunk but Not Chipped, Max. ⅛ in. High — Both Sides

Shop Rivets, Flattened to ¼ in. High for ½ in. and ⅝ in. Rivets — Near Side

Shop Rivets, Flattened to ¼ in. High for ½ in. and ⅝ in. Rivets — Far Side

Shop Rivets, Flattened to ¼ in. High for ½ in. and ⅝ in. Rivets — Both Sides

Shop Rivets, Flattened to ⅜ in. High for ¾, ⅞, and 1 in. Rivets — Near Side

Shop Rivets, Flattened to ⅜ in. High for ¾, ⅞, and 1 in. Rivets — Far Side

Shop Rivets, Flattened to ⅜ in. High for ¾, ⅞, and 1 in. Rivets — Both Sides

Field Rivets, Two Full Heads

Field Rivets, Countersunk and Chipped, Near Side

Field Rivets, Countersunk and Chipped, Far Side

Field Rivets, Countersunk and Chipped, Both Sides

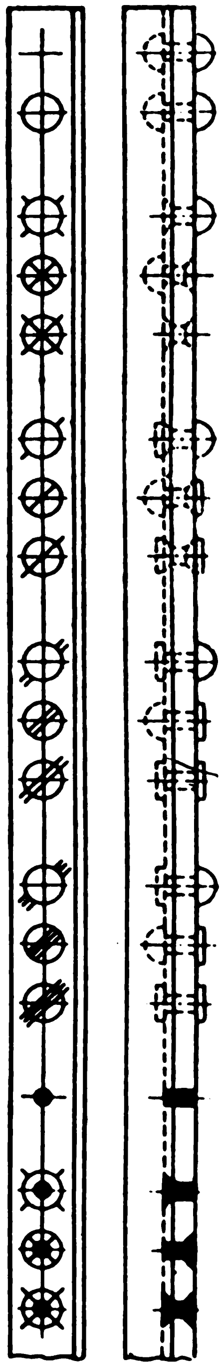


Figure 2-30. Rivet conventions.

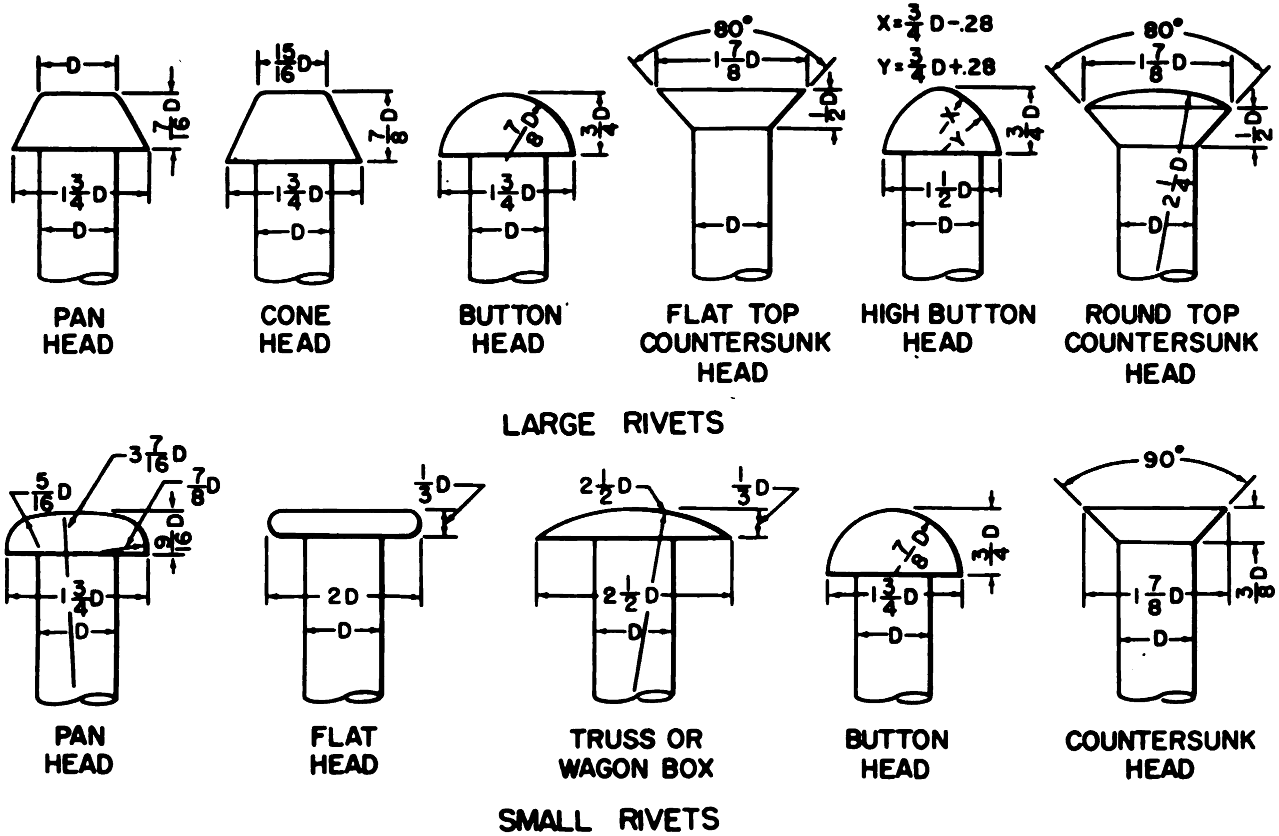


Figure 2-31. Forms of rivet heads.

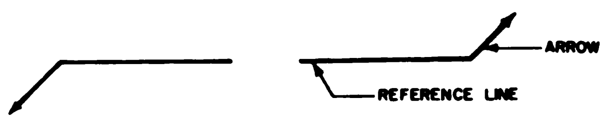
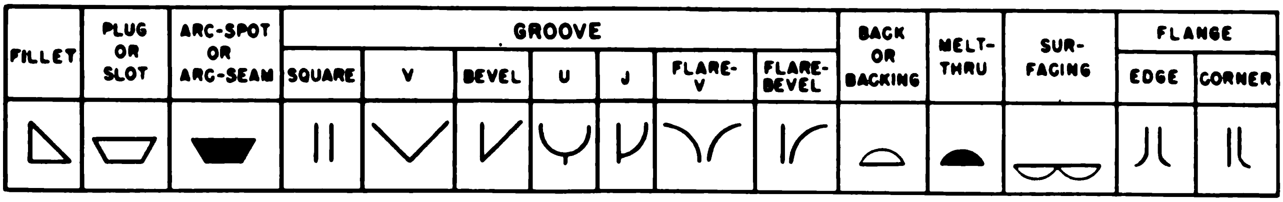
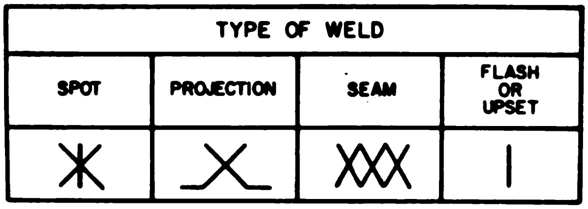


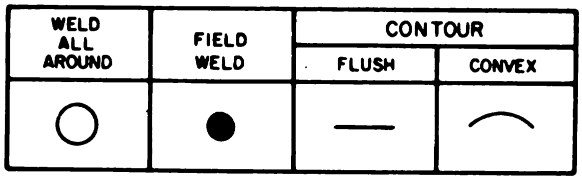
Figure 2-32. Basic welding symbol.



BASIC ARC AND GAS WELD SYMBOLS



BASIC RESISTANCE WELD SYMBOLS



SUPPLEMENTARY SYMBOLS

Figure 2-33. Basic and supplementary weld symbols.

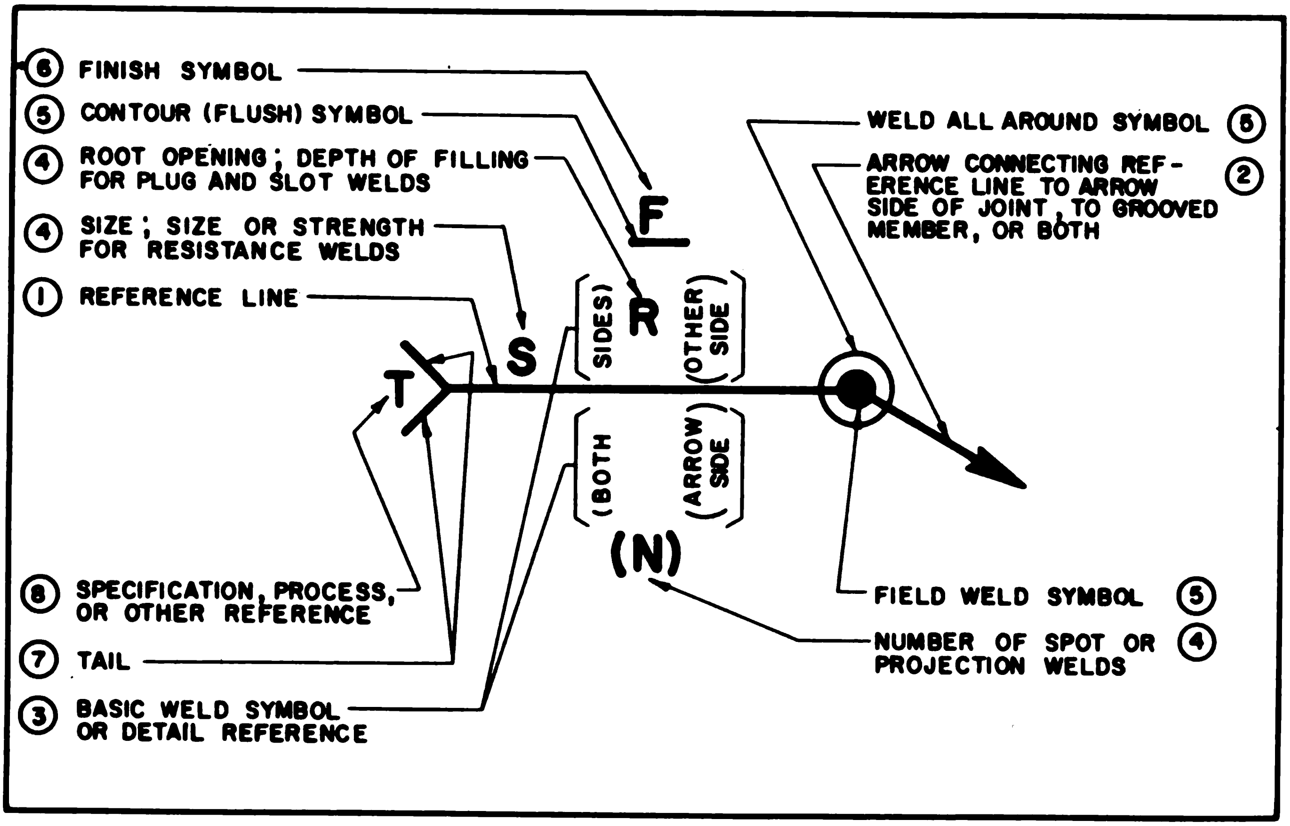


Figure 2-34. Standard location of elements of a welding symbol.

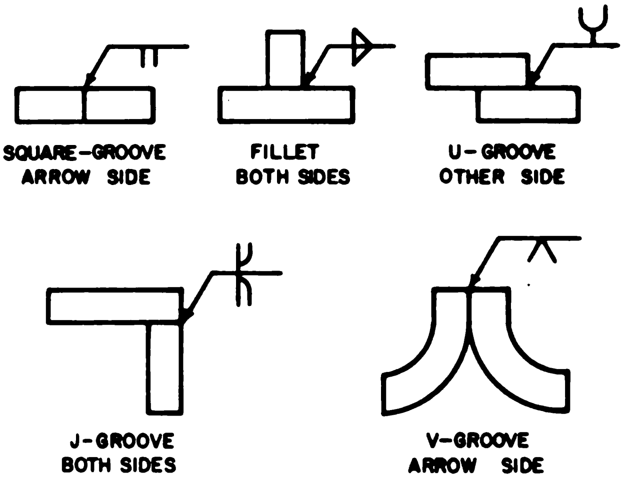


Figure 2-35. Applications of the welding symbol.

Table 2-7. Designation of Welding Processes by Letters[a]

Type of Weld	Welding Process	Letter Designation
Brazing	Torch Brazing	TB
	Twin-Carbon-Arc Brazing	TCAB
	Furnace Brazing	FB
	Induction Brazing	IB
	Resistance Brazing	RB
	Dip Brazing	DB
	Block Brazing	BB
	Flow Brazing	FLB
Flow Welding	Flow Welding	FLOW
Resistance Welding	Flash Welding	FW
	Upset Welding	UW
	Percussion Welding	PEW
Induction Welding	Induction Welding	IW
Arc Welding	Bare Metal-Arc Welding	BMAW
	Stud Welding	SW
	Gas-Shielded Stub Welding	GSSW
	Submerged Arc Welding	SAW
	Gas Tungsten-Arc Welding	GTAW
	Gas Metal-Arc Welding	GMAW
	Atomic Hydrogen Welding	AHW
	Shielding Metal Arc Welding	SMAW
	Twin-Carbon-Arc Welding	TCAW
	Carbon-Arc Welding	CAW
	Gas Carbon-Arc Welding	GCAW
	Shielded Carbon-Arc Welding	SCAW

[a] The following suffixes may be used to indicate the method of applying the avove processes:

Automatic Welding	-- AU
Machine Welding	-- ME
Manual Welding	-- MA
Semi-Automatic Welding	-- SA.

Table 2-7. Designation of Welding Processes by Letters(Cont)

Type of Weld	Welding Process	Letter Designation
Thermit Welding	Nonpressure Thermit Welding	NTW
	Pressure Thermit Welding	PTW
Gas Welding	Pressure Gas Welding	PGW
	Oxygen-Hydrogen Welding	OHW
	Oxygen-Acetylene Welding	OAW
	Air-Acetylene Welding	AAW
Forge Welding	Roll Welding	RW
	Die Welding	DW
	Hammer Welding	HW

Note: Letter designations have not been assigned to arc-spot, resistance-spot, arc-seam and resistance-seam welding or to projection welding since the weld symbols used are adequate.

[a]The following suffixes may be used to indicate the method of applying the above processes:

Automatic Welding	-- AU
Machine Welding	-- ME
Manual Welding	-- MA
Semi-Automatic Welding	-- SA

Table 2-8. Designation of Cutting Processes by Letters [a]

Cutting Process	Letter Designation
Arc Cutting	AC
Air-Carbon-Arc Cutting	ACAC
Carbon-Arc Cutting	CAC
Metal-Arc Cutting	MAC
Oxygen Cutting	OC
Chemical Flux Cutting	FOC
Metal Powder Cutting	POC
Oxygen-Arc Cutting	AOC

[a]The following suffixes may be used to indicate the methods of applying the above processes:

Automatic Cutting	-- AU
Machine Cutting	-- ME
Manual Cutting	-- MA
Semi-Automatic Cutting	-- SA

2-23. Structural Drawings

Structural drawings usually consist of some or all of the elements described in the following paragraphs.

a. Shop Drawings. Shop drawings show the details of the fabrication of parts and methods of assembly of the structural members that are prepared in special fabricating shops. Figure 2-36 illustrates structural members (a beam and a column) fabricated from a combination of rolled steel shapes. Figure 2-37 illustrates structural members of a welded steel truss.

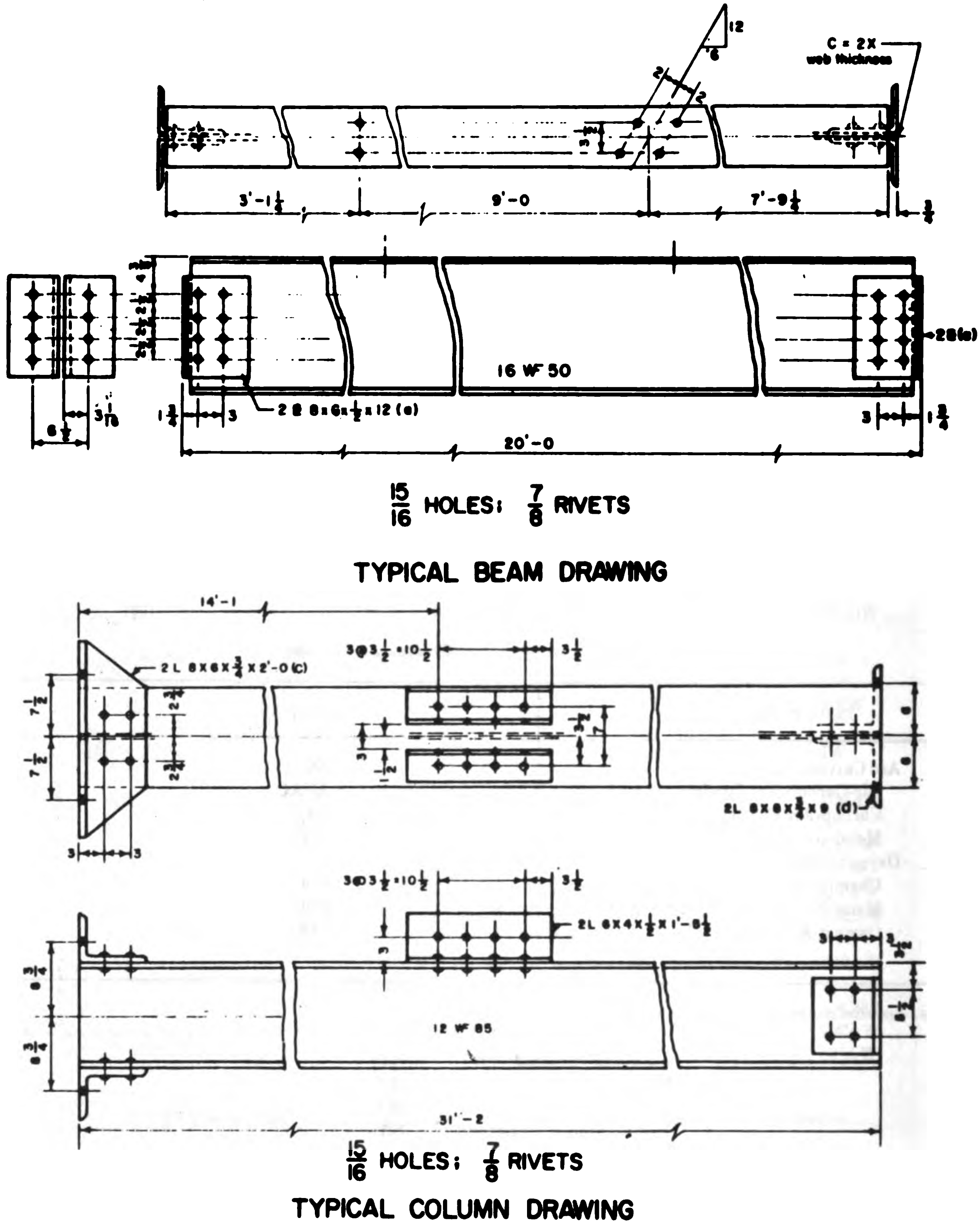


Figure 2-36. Shop drawing of a beam and a column.

(1) Working lines and working points. Shop drawings are made about light working lines laid out first along the centerlines or rivet gage lines to form a skeleton of the assembled member. The intersections of these working lines are called working points from which all dimesnions are given. This skeleton is usually the same as, or taken from, the designer's stress diagram. Generally, the skeleton diagram is drawn to a small scale on the shop drawing (fig. 2-37).

(2) Relative position of parts. Parts to be welded or riveted together in the shop are shown in the same relative position (vertical, horizontal, or inclined, as in figure 2-37) they will occupy in their assembled position in the structure. These parts are not detailed individually, as is the practice for machine drawing. Note in figure 2-37 that due to the truss being symmetrical about each side of center, only half of the truss need be shown. In such cases, it is always the left end that is drawn.

(3) Long vertical or inclined members. Long vertical (columns) or inclined (braces) members are sometimes shown in a horizontal position on the drawing. When shown in this manner, the bottom of a vertical member appears at the left (fig. 2-36) and an inclined member is shown in the direction it would fall.

(4) Scales. Scales of shop drawings vary from 1/4 inch = 1 foot to 1 inch = 1 foot, depending upon the size of the drawing sheet as compared with the size of the structural member. Usually, two scales are used in the same view, one denoting length and the other

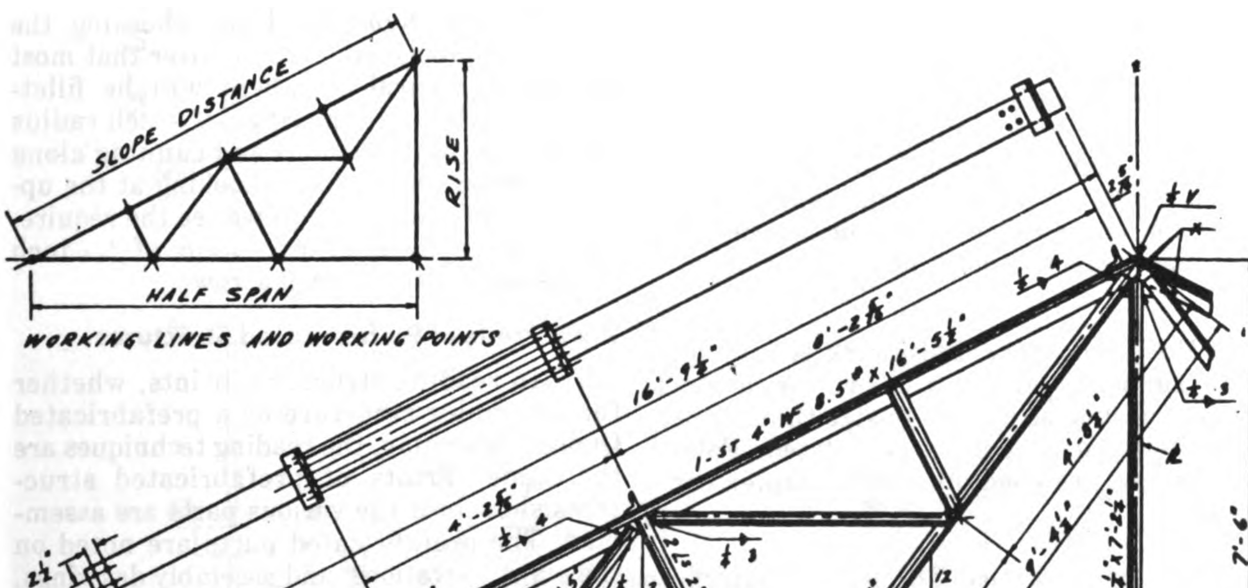


Figure 2-37. Typical welded steel truss.

showing the cross-section at a larger scale than the length.

b. General Plan. The general plan indicates the location and gives the general features of the structure and the ground upon which it is situated. It includes the necessary data for constructing both the substructure and the superstructure.

c. Stress Diagram. The stress diagram shows the main dimensions, the loadings, stresses, and sizes of the structural members.

d. Foundation Plan. The foundation or masonry plan (fig. 2-38) covers the details of the foundation, walls, piers, etc.

e. Erection Diagram. The erection diagram (fig. 2-39) shows the relative location of every part of the structure and the assembly marks for the various members. The erection diagram may also include all main dimensions, the number of pieces in the members, the packing of pins, the size and grip of pins, and any special feature or information that may assist you in the field.

f. Falsework Plan. Falsework is a temporary support, usually timber, for a steel structure such as a truss bridge that cannot be self-supporting until completed. Falsework plans are used only in a complex construction.

g. Bill of Materials. The bill of materials shows the different parts of the structure, identifying marks, and shipping weight. This also serves as a checkoff list to ensure that you have the proper materials on hand.

h. Connection List. The connection list provides the dimensions and the number of bolts, pins and rivets required in the structure.

i. List of Drawings. Since a great number of drawings are required for any sizable structure, a complete list of drawings is usually supplied with each set of drawings for the structure. This list in a logical sequence.

9-24. Reading Prints of Steel Structures

A typical welded steel truss is illustrated in figure 2-37. To read this print, the ability to interpret the structural shape notations and welding symbols is primarily all that is necessary.

a. Structural Member. The top chord is 1-ST 4 WF 8.5 x 16'-5½". This means that there is one structural tee cut from a wide flange. The tee is 4 inches deep and weighs 8.5 pounds per foot. It is 16 feet 5 1/2 inches long. The bottom chord is the same type of member and is 30 feet 6 7/8 inches long and extends across the entire width of the truss. The cross members are made from two angles 2" x 1½" x ¼.

b. Welding Symbols. Upon checking the welding symbols, you will discover that most of the structural members will be fillet-welded with a fillet having a 1/4-inch radius (thickness) on both sides and running along the member for 4 inches. Looking at the upper-right of drawing (hip) we see the requirement for a bevel-groove weld of 1/4-inch radius on the other side of arrow.

2-25. Prints of Prefabricated Structures

a. In reading structural prints, whether for a complex structure or a prefabricated Quonset assembly, the reading techniques are the same. Prints of prefabricated structures show how the various parts are assembled. The prefabricated parts are noted on the plans, elevations, and assembly drawings. Figure 2-40 illustrates an exterior elevation of a prefabricated aircraft maintenance and repair hangar. The CM notations shown in figure 2-40 mean corrugated metal panels.

b. Illustrated in figure 2-41 is an assembly drawing of a prefabricated, nailable steel frame buiding (theater of operations modular). Note that each part of the assembly is marked for identification and location. For example, C5-4 designates a wall corrugated sheet and J-20 a stringer. Figure 2-42 is a detailed drawing showing how the framework is assembled.

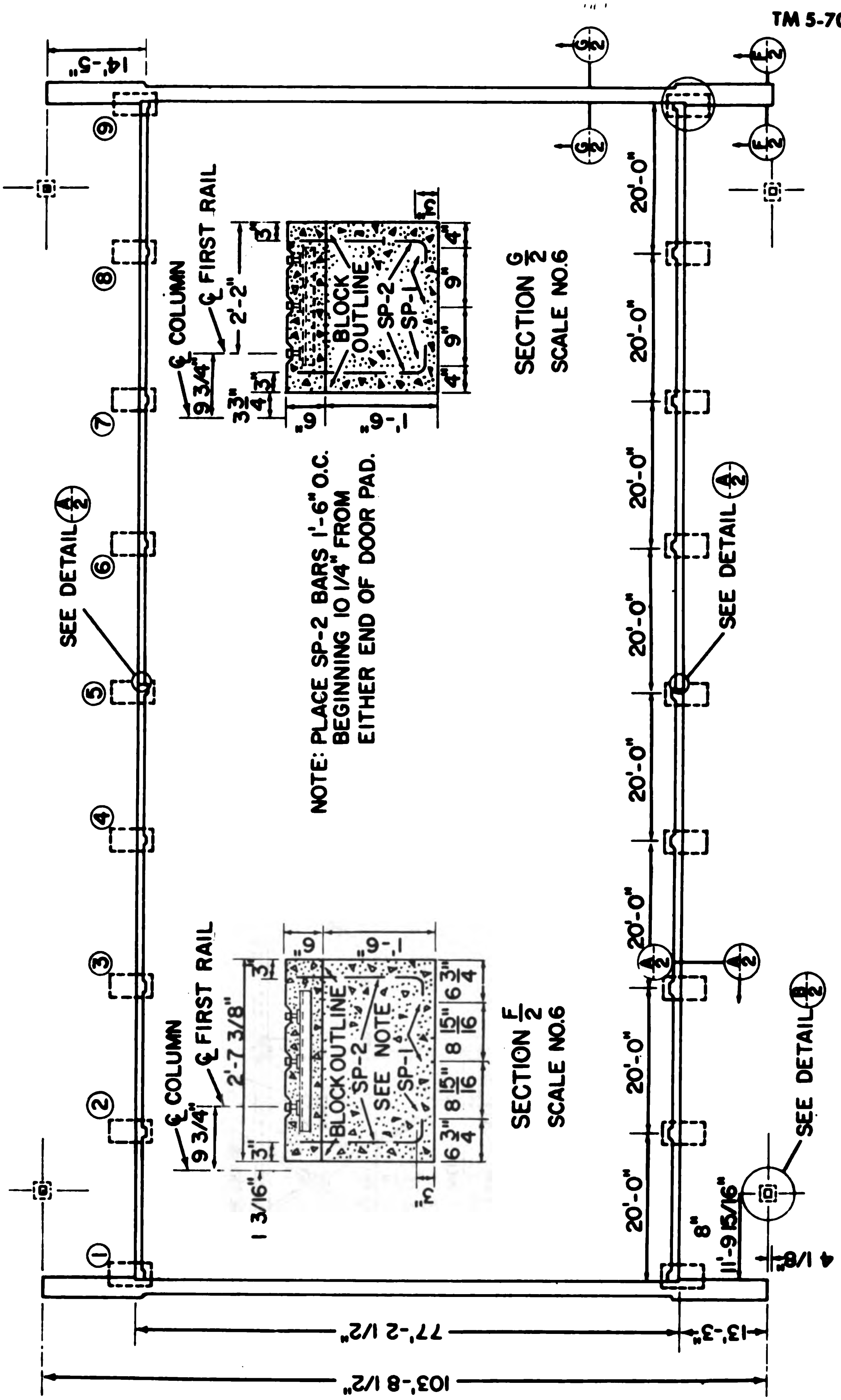


Figure 2-38. Typical foundation plan, concrete.

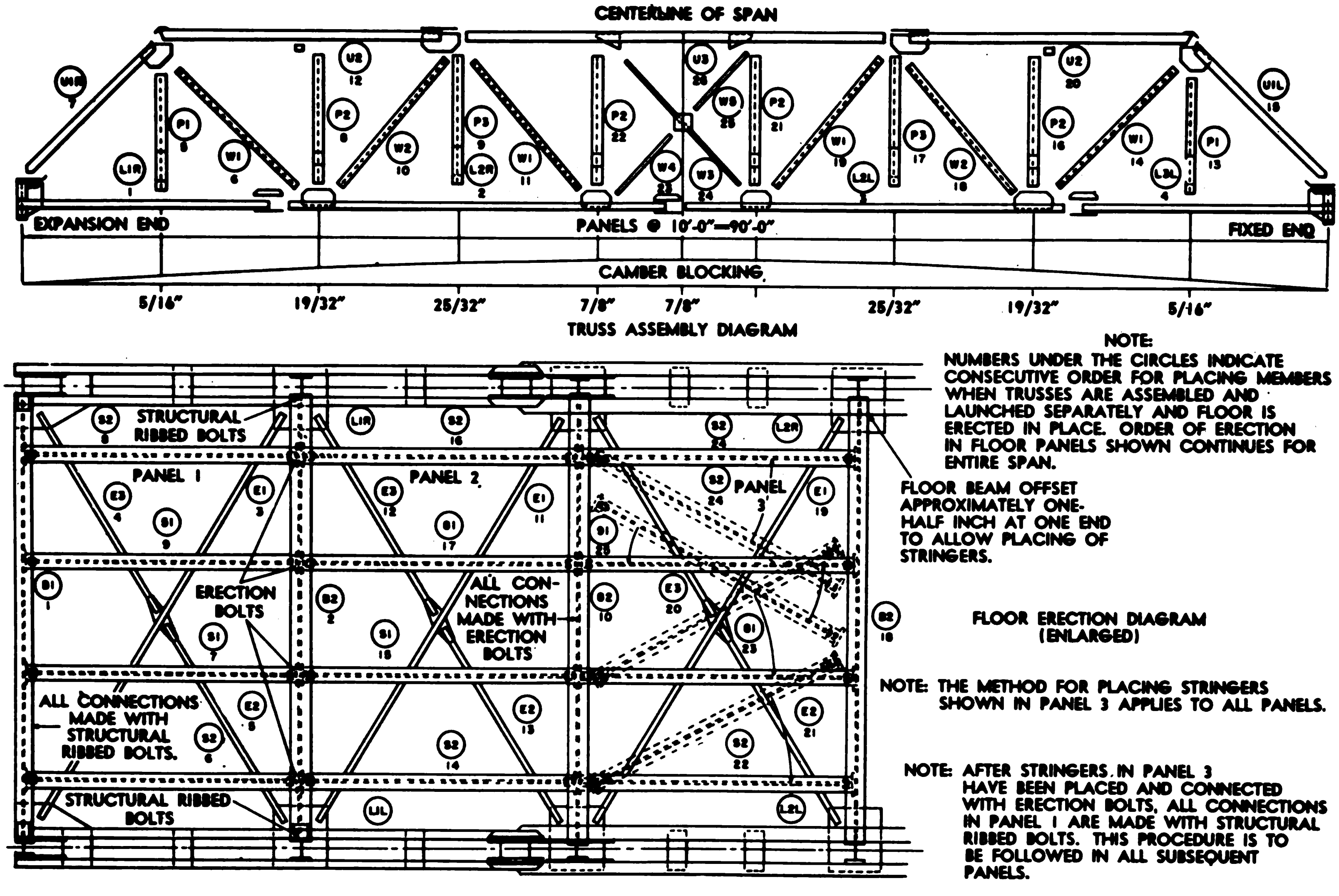


Figure 2-39. Typical erection diagram.

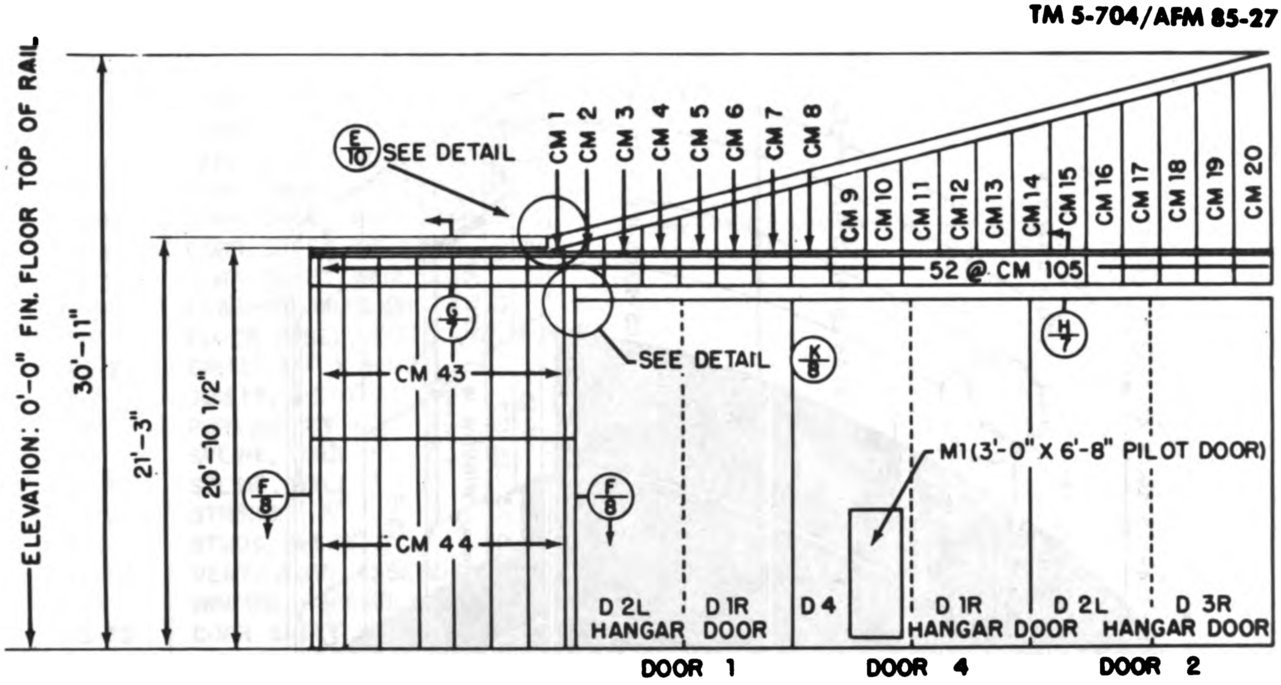


Figure 2-40. Elevation of prefabricated building.

2-26. Self-Test

To verify your understanding of the previous material, answer the following questions. Answers are given at the end of the chapter.

1. Which of the following members is designated by the notation 16 WF 50?
   a. Wide-flange, 16 inches deep, and weighing 50 pounds per linear foot.
   b. Wide-flange, 50 inches deep, and weighing 16 pounds per linear foot.
   c. I-beam, 16 inches deep, and weighing 50 pounds per linear foot.
   d. Channel, 16 inches deep, and weighing 50 pounds per linear foot.
2. Referring to figure 2-36, what are the cross-sectional descriptions of the beam and column?
3. How are the beams connected to the columns?
4. Referring to figure 2-37, what does the bottom chord consist of (shape and dimension)?
5. In figure 2-41, what is the size of the member designated PR-1?

2-27. Answers to Self-Test Questions

a. Paragraph 2-6 (working drawings)

1. c
2. b
3. b
4. a (only south end of site has access to road)
5. d
6. c
7. d

b. Paragraph 2-14 (wood framing)

1. b
2. d
3. b
4. c

c. Paragraph 2-20 (concrete and masonry)

1. c
2. d
3. a
4. c
5. c

d. Paragraph 2-26 (steel structure)

1. a
2. Beam—16 WF 50; column 12 WF 85.
3. Two angles are riveted to the ends of the beams and the other legs of the angles are riveted to the column.
4. Structural tee cut from wide-flange shape with nominal depth of 4 inches, weight of 8.5 pounds per linear foot, and length of 30 feet, 6⅞ inches.
5. PR-1 is a 2-inch purlin.

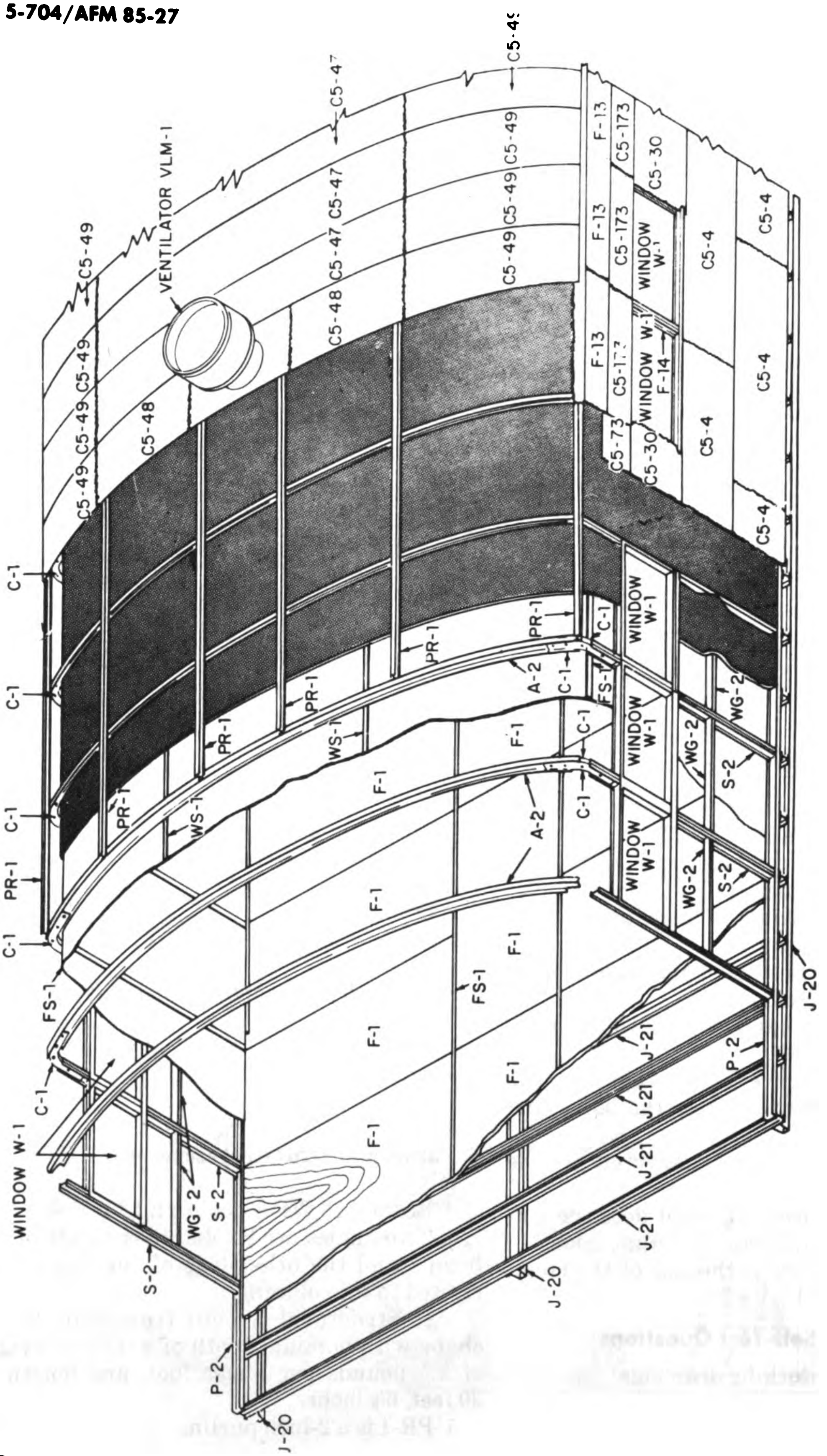


Figure 2-41. Quonset assembly.

MARK	DESCRIPTION
P-2	CHANNEL, 3-13/16"
C-1	CHANNEL SPLICE, 3-1/4" X 7/8"
C5-47	CORR. SHEET, ROOF, 27-1/2"
C5-48	CORR. SHEET, ROOF, 27-1/2"
C5-49	CORR. SHEET, ROOF, 27-1/2"
C5-4	CORR. SHEET, WALL, 26"
C5-30	CORR. SHEET, WALL, 26"
F-14	FLASHING, MULLION
F-1	FLOOR PANEL, 4'-0" X 1/2" X 8'-0"
WG-2	GIRTS, 3/4" X 3-1/2"
J-21	JOISTS, 3-5/8"
PR-1	PURLINS, 2"
FS-1	SPLINE, WALL
WS-1	SPLINE, WALL
J-20	STRINGER, 5"
S-2	STUDS, 3-5/8"
VLM-1	VENTILATOR ASSEMBLY
W-1	WINDOW ASSEMBLY
C5-73	CORR. SHEET, WALL, 13"
C5-173	CORR. SHEET, WALL, 13"
F-13	FLASHING, EAVE

Figure 2-41. Quonset assembly—continued.

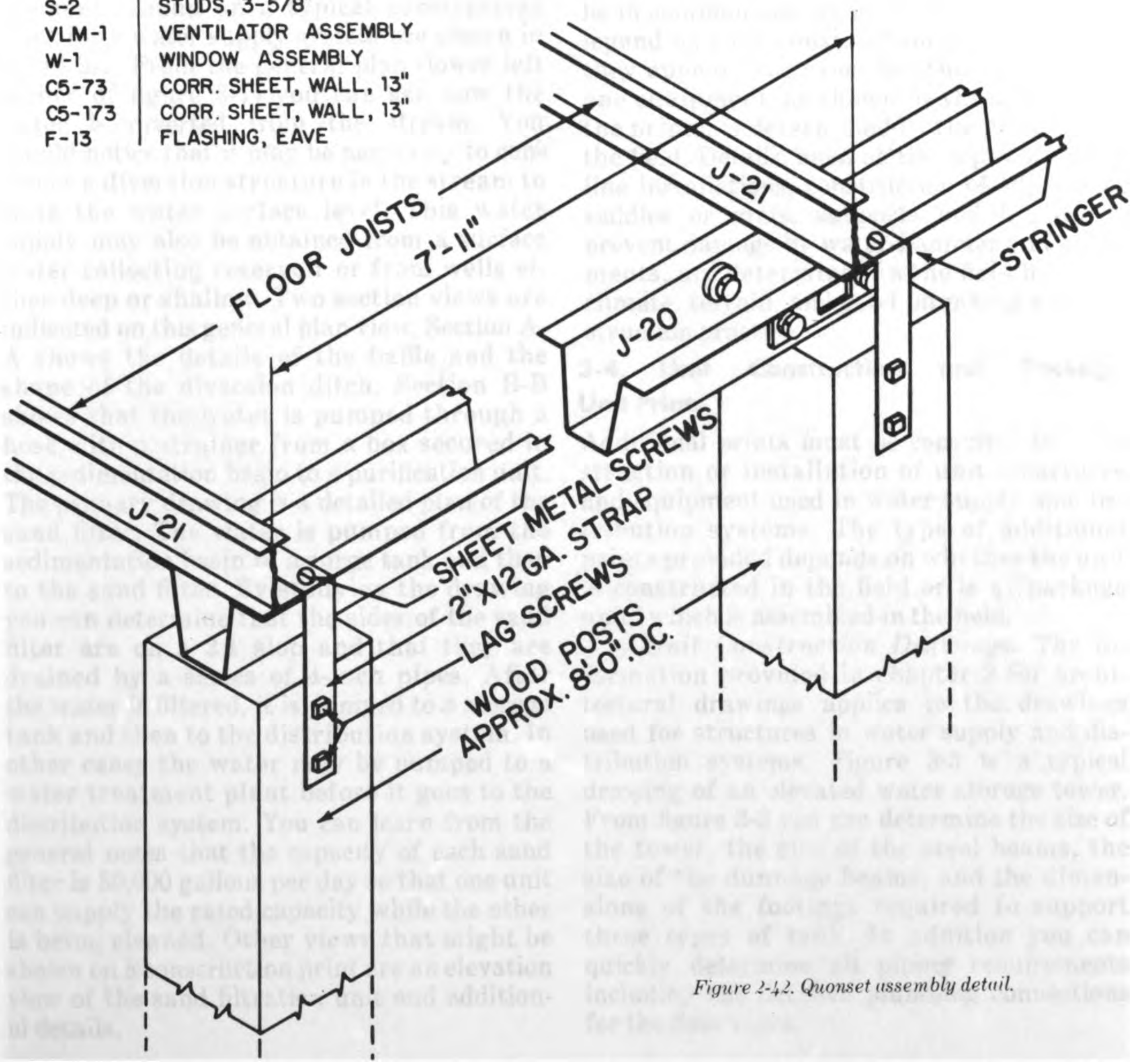


Figure 2-42. Quonset assembly detail.

CHAPTER 3
READING UTILITIES DRAWINGS

Section I. WATER SUPPLY AND DISTRIBUTION

3-1. Definition

A water supply system consists of facilities, equipment, and piping that are used to obtain, treat, and transport water for the distribution system. A distribution system is a combination of connected pipes laid out in the form of a "tree" or "gridiron" to carry the supplied water to the usage point in the system.

3-2. Water Supply System

Elements found on a typical construction print for a water supply system are shown in figure 3-1. From the general plan (lower left corner of figure 3-1) you can see how the water is diverted from the stream. You should notice that it may be necessary to construct a diversion structure in the stream to raise the water surface level. This water supply may also be obtained from a surface water collecting reservoir or from wells either deep or shallow. Two section views are indicated on this general plan view. Section A-A shows the details of the baffle and the shape of the diversion ditch. Section B-B shows that the water is pumped through a hose with a strainer from a box secured in the sedimentation basin to a purification unit. The primary drawing is a detailed plan of the sand filter. The water is pumped from the sedimentation basin to a surge tank and then to the sand filter. By studying the drawing you can determine that the sides of the sand filter are on a 2:1 slop and that they are drained by a series of 4-inch pipes. After the water is filtered, it is pumped to a storage tank and then to the distribution system. In other cases the water may be pumped to a water treatment plant before it goes to the distribution system. You can learn from the general notes that the capacity of each sand filter is 50,000 gallons per day so that one unit can supply the rated capacity while the other is being cleaned. Other views that might be shown on a construction print are an elevation view of the sand filtration unit and additional details.

3-3. Distribution System

Once the water in the water treatment plant meets certain quality specifications, it is introduced into the distribution system. Figure 3-2 shows a typical water distribution system for a hospital area. The general location and size of the pipes are shown along with the valves, sumps, water tank and other fixtures. In general, the symbols used on distribution system plans correspond to those for water plumbing. Additional symbols which may not be in common use are explained by notes or a legend on each construction print on which they appear. The exact location of pipelines and equipment, as shown by the symbols on the prints, is determined by the pipefitter in the field. Details, such as the depth of water-line installations, construction of supporting saddles or mats, supports and bracing to prevent damage by water-hammer and movements, are determined in the field based on climate, terrain, and good plumbing and construction practice.

3-4. Unit Construction and Package Unit Prints

Additional prints must be consulted for construction or installation of unit structures and equipment used in water supply and distribution systems. The type of additional prints provided depends on whether the unit is constructed in the field or is a "package unit" which is assembled in the field.

a. Unit Construction Drawings. The information provided in chapter 2 for architectural drawings applies to the drawings used for structures in water supply and distribution systems. Figure 3-3 is a typical drawing of an elevated water storage tower. From figure 3-3 you can determine the size of the tower, the size of the steel beams, the size of the dunnage beams, and the dimensions of the footings required to support three types of tank. In addition you can quickly determine all piping requirements including the detailed plumbing connections for the float valve.

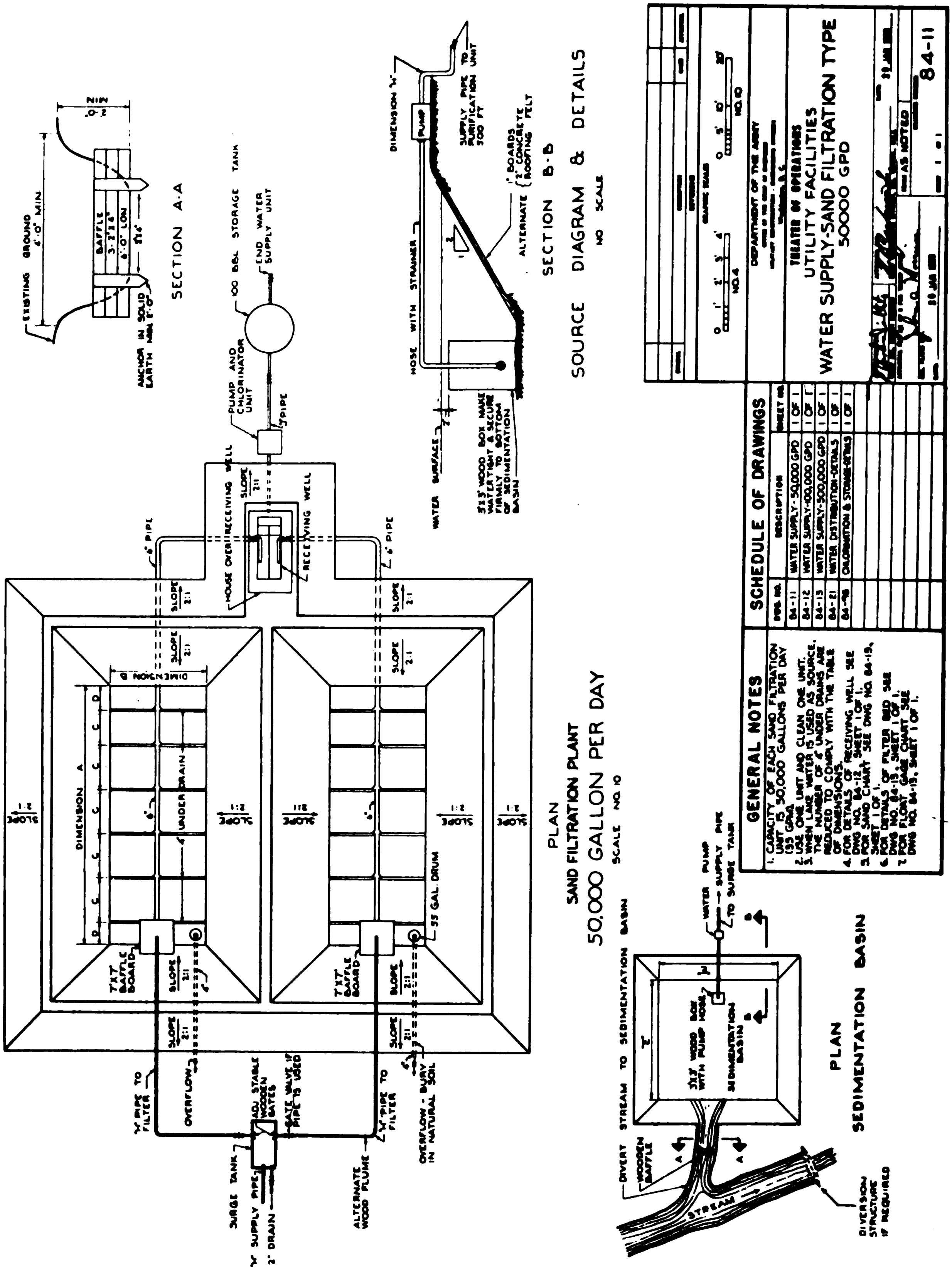
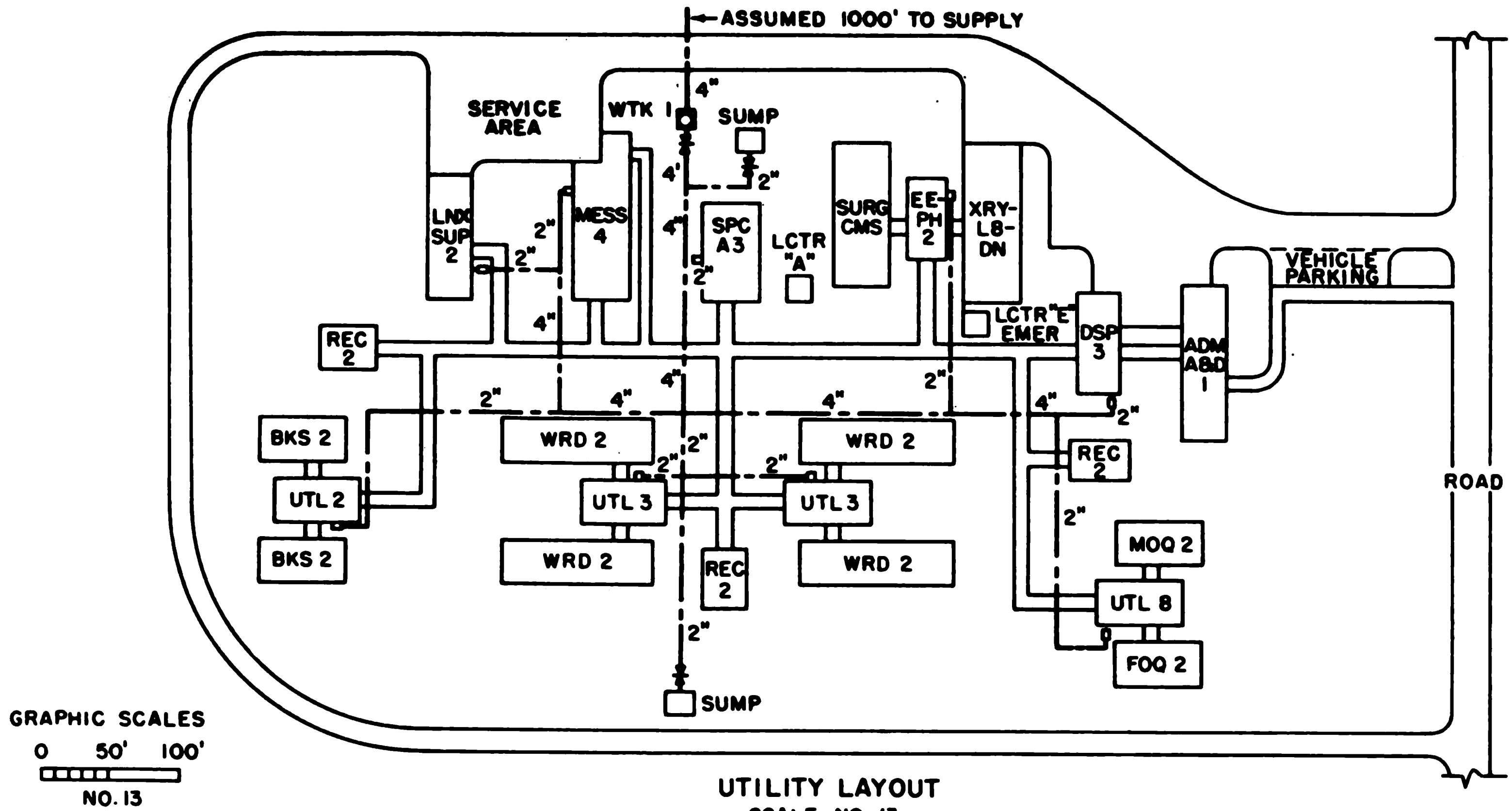


Figure 3-1. Water supply system.



UTILITY LAYOUT
SCALE NO. 13

ABBR	ITEM	QTY	SIZE OR UNIT	ABBR	ITEM	QTY	SIZE OR UNIT
	SCHEDULE OF FACILITIES						
	BUILDINGS			UTL 3	UTILITY BUILDING-3	2	30'X60'
ADM-A&D 1	ADMINISTRATION, ADMISSION & DISPOSITION-1	1	30'X 110'	UTL 8	UTILITY BUILDING-8	1	30'X60'
BKS 2	BARRACKS-2	2	30'X 60'		WALKS-COVERED	1	8'X 1435'
DSP 3	DISPENSARY-3	1	30'X 70'	WRD 2	WARD BUILDING-2-ACUTE	4	30'X 100'
EE-PH 2	EE & PHARMACY-2	1	30'X 60'	XRY-LB-DN	X-RAY-LAB-DENTAL	1	40'X 110'
LNX-SUP 2	LINEN EXCHANGE & SUPPLY-2	1	30'X 90'		OTHER CONSTRUCTION		
MESS 4	MESS BUILDING-4	1	4400 SF		ROAD-DOUBLE LANE-6" MACADAM, 1" ASPHALT	0.34	MILE
FOQ 2	OFFICERS' QUARTERS-FEMALE-2	1	30'X60'	SUMP	SUMP-FIRE PROTECTION	2	10,000 GAL
MOQ 2	OFFICERS' QUARTERS-MALE-2	1	30'X 60'		HARDSTANDS-4" MACADAM	7.1	1000 SY
REC 2	RECREATION BUILDING-2	3	30'X 40'		SITE AREA	10.1	ACRES
SPC A 3	SPECIAL SERVICES BUILDING-SPC-A3	1	40'X 70'	WTK 1	WATER TANK	1	4,000 GAL
SURG-CMS	SURGERY-CENTRALIZED MATERIEL	1	40'X 100'	LCTR	LOAD CENTER	1	---
UTL 2	UTILITY BUILDING-2	1	30'X 60'	LCTR-EMER	LOAD CENTER-EMERGENCY	1	---

Figure 3-2. Water distribution plan.

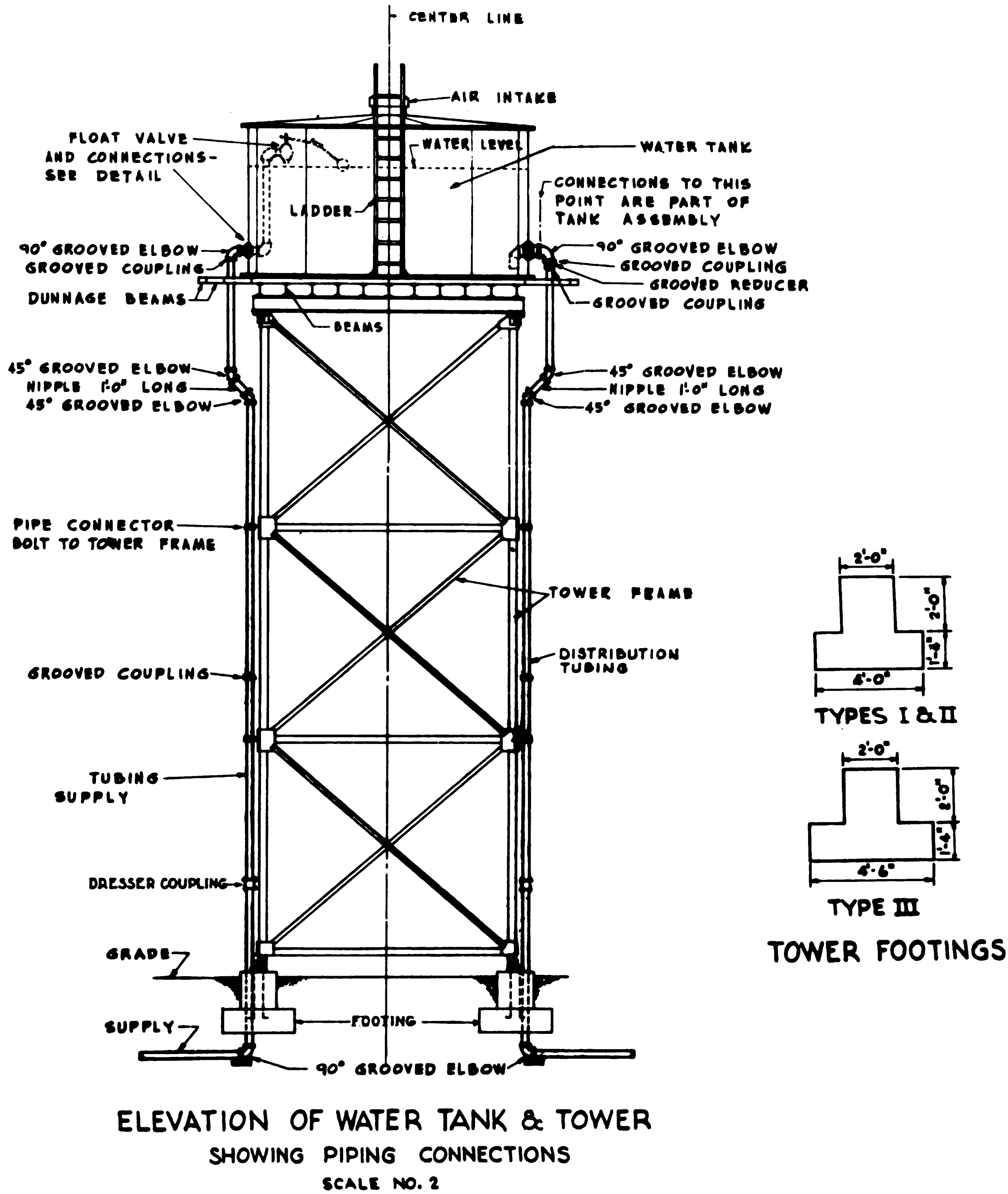
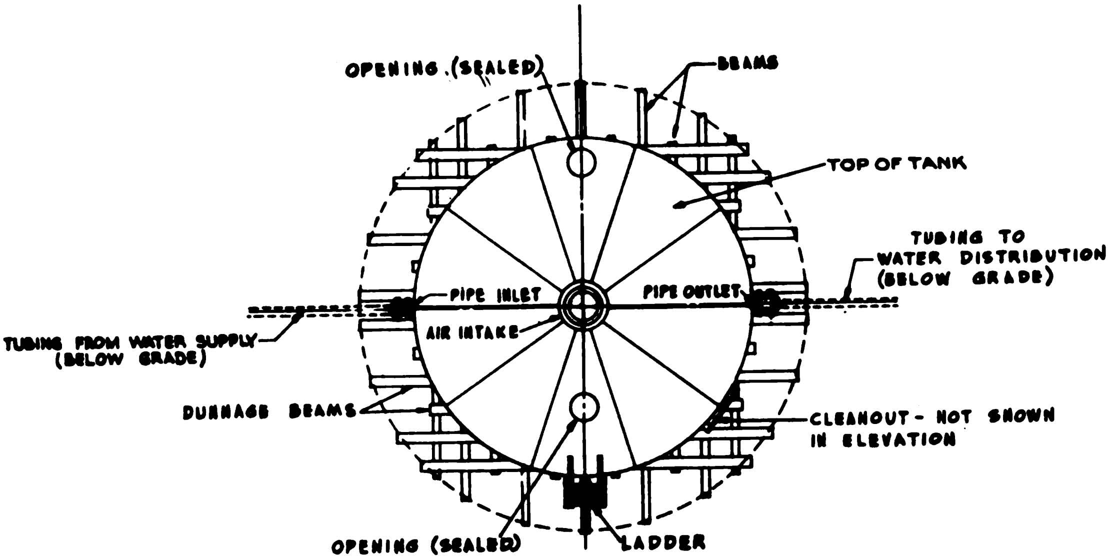
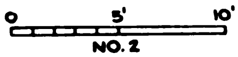


Figure 3-3. Typical water tank and tower detail plumbing diagram.



ROOF PLAN OF WATER TANK & TOWER
SHOWING PIPING CONNECTIONS
SCALE NO 2



WATER TANK & TOWER SCHEDULE

TYPE	CAPACITY				SIZE			TOWER			
	BBL.	GAL.	INLET	OUTLET	DIA.	HEIGHT	STOCK NUMBER	DUNNAGE BEAM	STEEL BEAM	HEIGHT	STOCK NUMBER
I	100	4,000	6"	4"	9'-2 ¾"	8'-0"	58-8718.041.010	4"x6"@1'-4" OC	6 B 12 @ 1'-4" O.C.	36'	58-8986.836.004
II	250	10,500	6"	4"	15'-6"	8'-0"	58-8718.041.025	4"x6"@1'-4" OC	8 B 13 @ 1'-5" O.C.	36'	58-8986.836.010
III	500	21,000	6"	4"	21'-7"	8'-0"	58-8718.041.050	4"x6"@1'-6" O.C	10 WF. 21@1'-8" O.C.	36'	58-8986.836.021

NOTE:
1- ERECTION DRAWINGS WILL BE PROVIDED WITH EACH TANK AND TOWER.
2- DETAILS ARE SHOWN FOR 4" GROOVED TYPE FITTINGS, USE 2" STANDARD THREADED FITTINGS WHEN REQUIRED.

Figure 3-3. Typical water tank and tower detail plumbing diagram - continued.

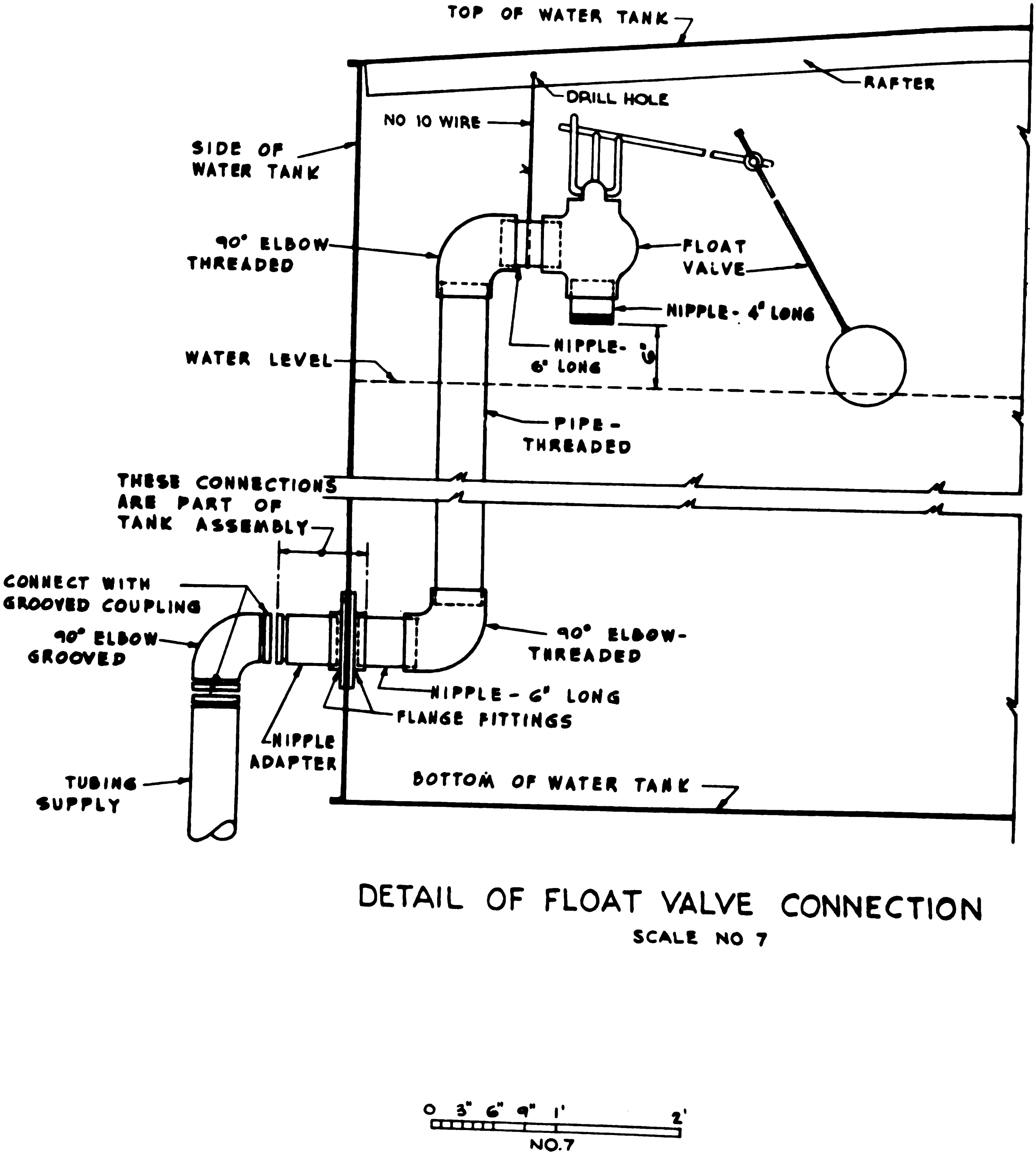


Figure 3-3. Typical water tank and tower detail plumbing diagram - continued.

b. Package Units. Package units are assembled in the field and installed in accordance with the manufacturers' instructions supplied with the unit or units. In addition to the construction drawings and specifications supplied, a drawing similar to figure 3-4 usually is supplied. You can see that several package units have to be installed and connected together to form a water treatment plant. The standard plumbing drawing would be required before you could attempt to assemble and install the package units. However, drawings similar to figure 3-4 are required to enable field personnel to visualize the completed installation. The arrows indicate the main flow path of the water and help to explain how the plant operates. The other lines are chemical feeders, drains, and filtered water return lines.

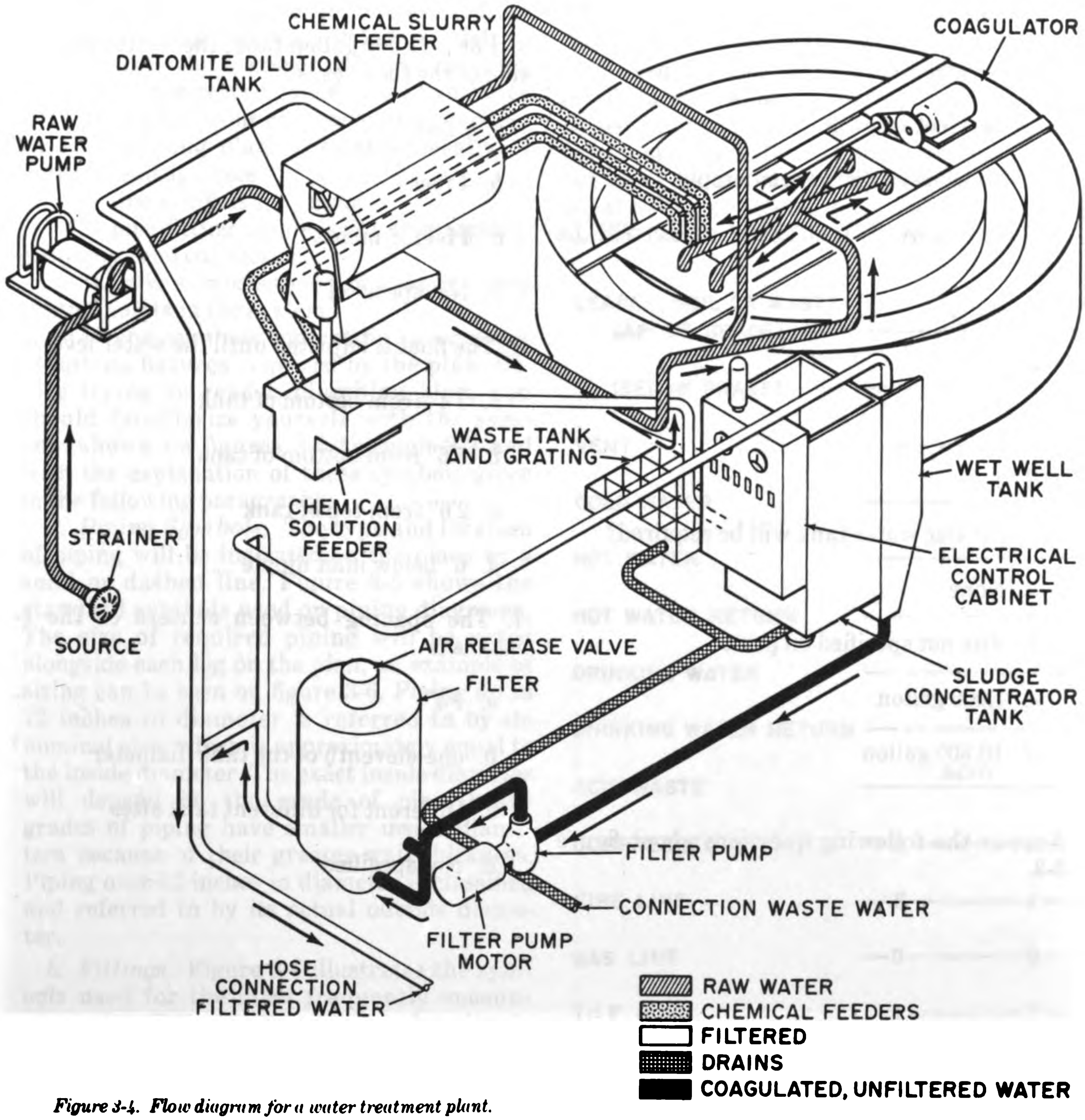


Figure 3-4. Flow diagram for a water treatment plant.

3-5. Self-Test

To check your knowledge of the material covered thus far, answer the following questions about figure 3-2. Answers are given at the end of this chapter.

1. Approximately how many feet of 2 inch pipe will be required for the distribution system?

a. 850 feet

b. 1150 feet

c. 1600 feet

d. Depends on distance to supply

2. How many 2 inch gate vales will be required?

a. None

b. 1

c. 2

d. 3

3. What size water tank will be required?

a. None

b. Size not specified on print

c. 4,000 gallon

d. 10,500 gallon

Answer the following questions about figure 3-3.

4. If the water supply comes from the north, which direction does the side of the tank with the ladder face?

a. North

b. South

c. East

d. West

5. For a 21,000 gallon tank, the widest dimension of the footings is

a. 2 feet

b. 4 feet

c. 4 feet, 6 inches

d. Not specified

6. The float is adjusted until the water level is

a. 3'4" from bottom of tank

b. 5'6" from bottom of tank

c. 2'6" from top of tank

d. 6" below inlet nipple

7. The spacing between centers of the I-beams is

a. 1'4"

b. one-eleventh of the tank diameter

c. Different for different tank sizes

d. Not specified

Section II. PLUMBING

3-6. Definition

All piping, apparatus, and fixtures for water distribution and waste disposal within a building is classified as plumbing. Piping for heating systems is called "steam fitting."

3-7. Plumbing Plans

As a rule, plumbing plans show the location of fixtures and fittings to be installed and the size and routing of piping. Details are left to the plumber who is responsible for installing a properly connected system in accordance with good plumbing and construction practices. Plumbing plans consist generally of four types of symbols;

(1) line symbols for piping;

(2) pipe-fitting symbols for pipe unions, couplings, and connections;

(3) valve symbols to indicate the required control points in the system;

(4) and symbols indicating the various plumbing fixtures required by the plan. Before trying to read a plumbing plan, you should familiarize yourself with the symbols shown on figures 3-5 through 3-8 and with the explanation of these symbols given in the following paragraphs:

a. Piping Symbols. The type and location of piping will be indicated on the plans by a solid or dashed line. Figure 3-5 shows the standard symbols used on piping diagrams. The size of required piping will be noted alongside each leg on the plan; an example of sizing can be seen on figure 3-6. Piping up to 12 inches in diameter is referred to by its nominal size, which is approximately equal to the inside diameter. The exact inside diameter will depend on the grade of pipe: heavy grades of piping have smaller inside diameters because of their greater wall thickness. Piping over 12 inches in diameter is classified and referred to by its actual outside diameter.

b. Fittings. Figure 3-6 illustrates the symbols used for the most frequently encountered pipe fittings. A more complete list is contained in appendix B. Note that the basic line symbol for a section of pipe shown at the top of figure 3-6 will actually be combined with the line symbology shown in figure 3-5. In this way, you are able to determine not only the size of pipe and method of branching and coupling, but also the use to which the pipe will be put. This is important, in that the type of material from which the pipe is made determines how the pipe should be used. This subject will be discussed in detail in later paragraphs.

c. Valves. Figure 3-7 illustrates the symbols used for the most frequently encountered valves. A more complete list is contained in appendix B. Material and sizes for valves are normally not noted on drawings, but must be assumed from the size and material of the connected pipe. However, when specified on a bill of materials or plumbing

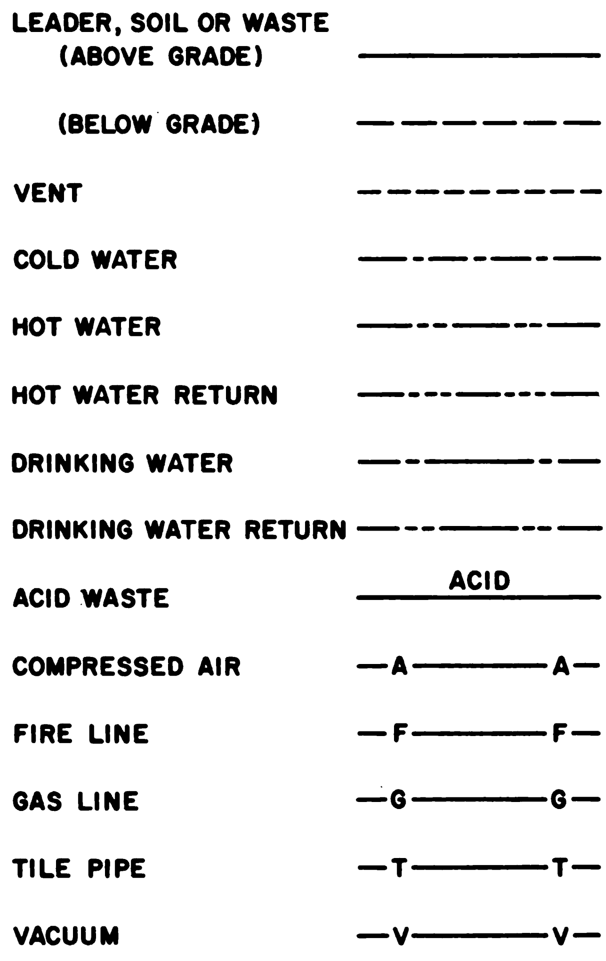


Figure 3-5. Line symbols for piping.

ITEM	SYMBOL
PIPE	SINGLE LINE IN SHAPE OF PIPE—USUALLY WITH NOMINAL SIZE NOTED
JOINT— FLANGED	DOUBLE LINE
SCREWED	SINGLE LINE
BELL AND SPIGOT	CURVED LINE
OUTLET TURNED UP	CIRCLE AND DOT
OUTLET TURNED DOWN	SEMICIRCLE
REDUCING OR ENLARGING FITTING	NOMINAL SIZE NOTED AT JOINT
REDUCER CONCENTRIC	TRIANGLE
ECCENTRIC	TRIANGLE
UNION SCREWED	LINE
FLANGED	LINE

SAMPLE APPLICATION (S) / ILLUSTRATION

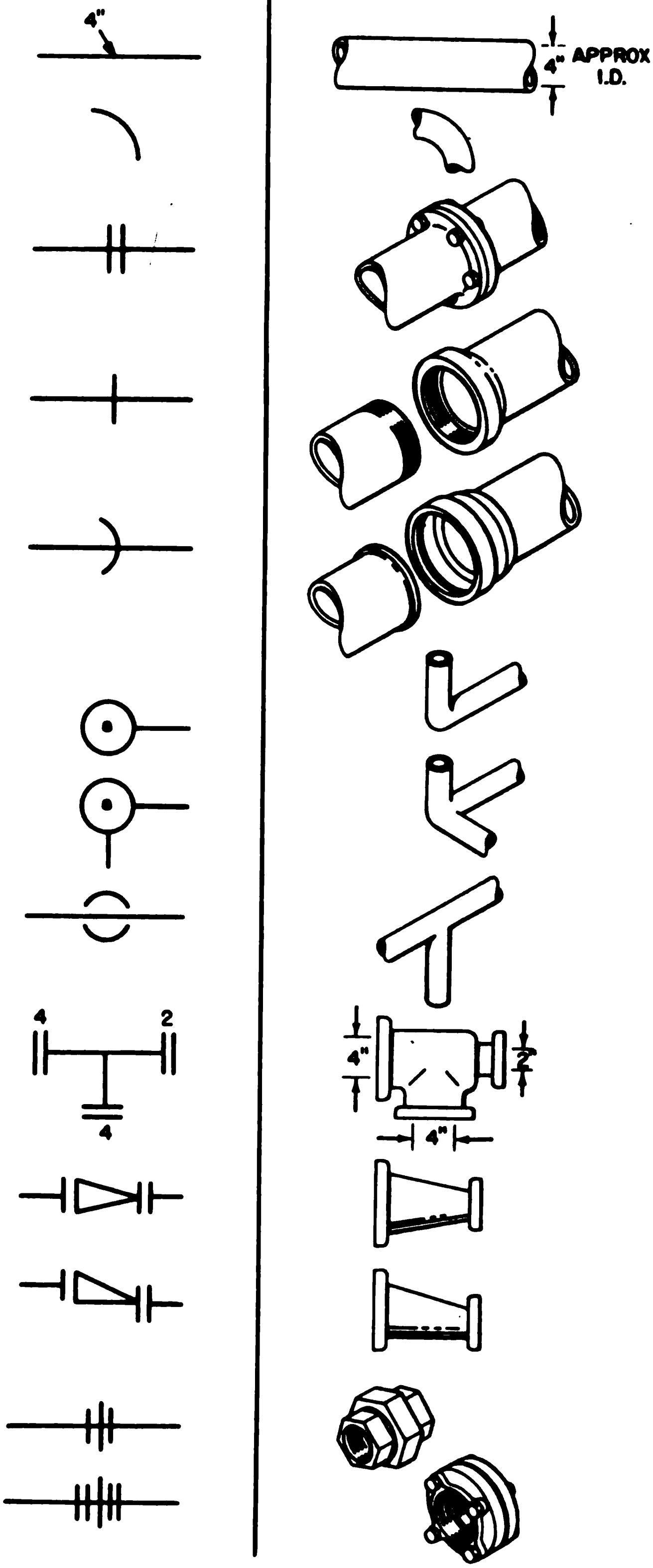
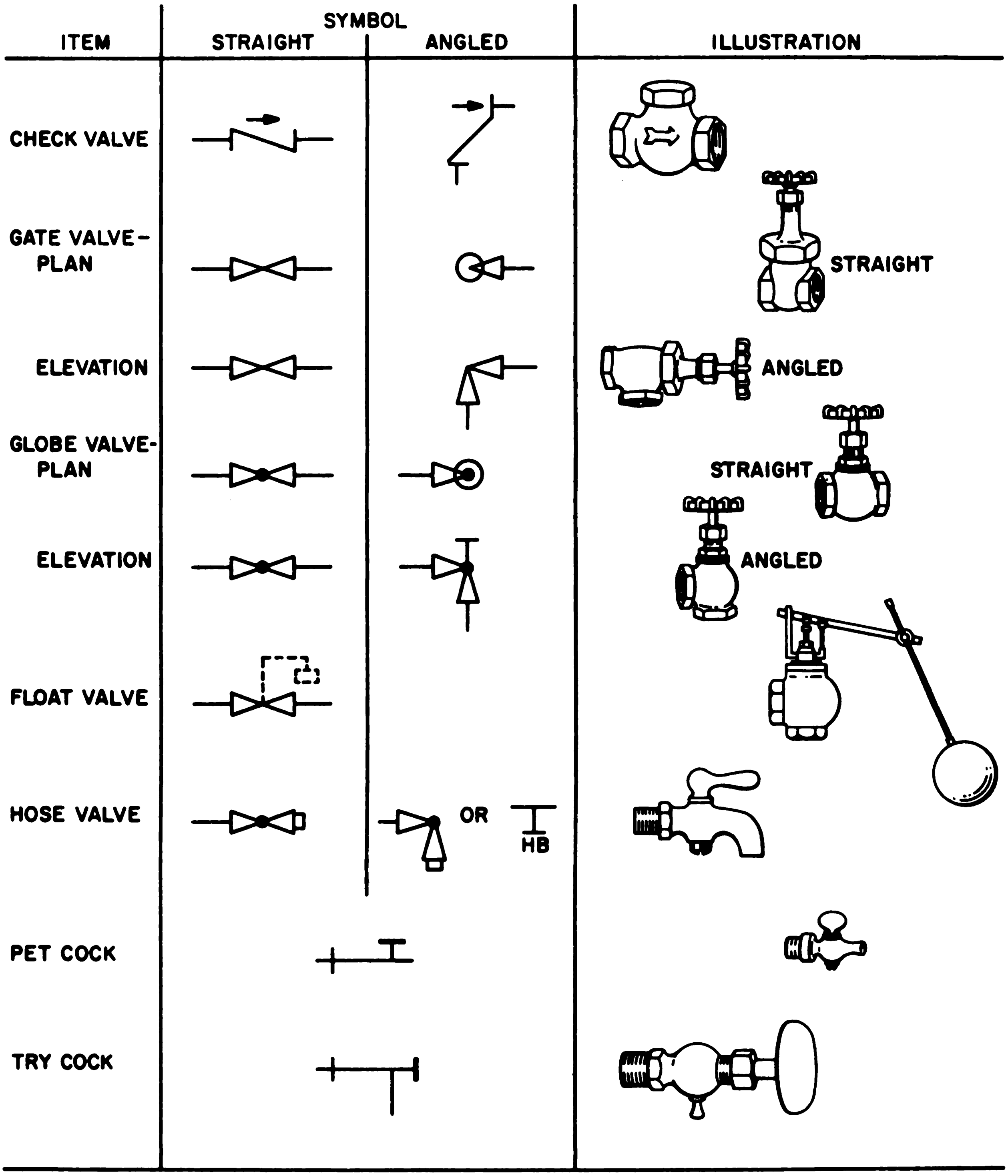
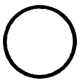
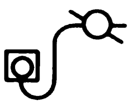
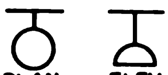
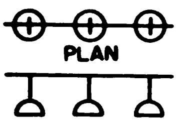


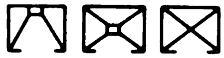
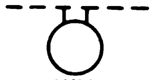
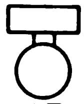
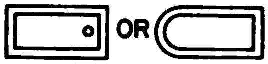
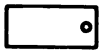
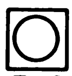
Figure 3-6. Pipe fitting symbols.



NOTE: SYMBOLS ARE SHOWN FOR SCREWED FITTINGS – SYMBOLS FOR JOINTS (FIG. 11-2) ARE ADDED FOR OTHER TYPES

Figure 3-7. Plumbing symbols for valves.

SYMBOL	ITEM	STD. ABBR
 *	DISHWASHER	DW
	DRAIN	D
	DRINKING FOUNTAIN**	DF
	FLOOR DRAIN	FD
	ROOF DRAIN	RD
	TRAP	T
	GREASE TRAP	GT
 *	BATH	B
	DISHWASHER	DW
	LAVATORY**	L
	RANGE	R
	SINK**	S
	STEAM TABLE	ST
 *	CAN WASHER	CW
	DENTAL UNIT	DU
	HOT WATER TANK	HWT
	WATER HEATER	WH
	WASH FOUNTAIN	WF
 CO	CLEANOUT	CO
 *	GAS OUTLET	G
	HOSE FAUCET	HF
	LAWN FAUCET	LF
	HOSE BIB	HB
	WALL HYDRANT	WH
	FLOOR DRAIN WITH BACKWATER VALVE	
 PLAN ELEV.	SHOWER HEAD	
 PLAN ELEVATION	SHOWER HEADS, GANG	

SYMBOL	ITEM
	SHOWER STALL
	WATER CLOSET
 WH	WATER CLOSET, WALL HUNG
 LT	WATER CLOSET, LOW TANK
	BATH
	URINAL, STALL TYPE OR AS SPECIFIED
	URINAL, CORNER TYPE
 TU	URINAL, TROUGH TYPE
	URINAL, WALL TYPE
	LAVATORY, CORNER
	LAVATORY, WALL
 EWC	ELECTRIC WATER COOLER

*STANDARD ABBREVIATION INCLUDED WITH SYMBOL

**TYPE SHOULD BE GIVEN IN SPECIFICATION OR NOTE WHEN THIS SYMBOL IS USED

Figure 3-8. Symbols for plumbing fixtures.

takeoff, valves are called out by size, type, material, and working pressure. For example: 2-inch check valve, brass, 175 pounds working pressure.

d. Fixtures. General appurtenances such as drains and sumps, plus fixtures such as sinks, water closets, and shower stalls are indicated on the plans by pictorial or block symbols. The symbols for those most frequently encountered are illustrated in figure 3-8. The extent to which the symbols are used depends on the nature of the drawing. In many cases, the fixtures will be specified on a bill of materials or other schedule keyed to the plumbing plan. When the fixtures are described on the schedule, the draftsman will often use symbols which closely approximate the shape of the actual fixtures rather than the standard block or circle and the standard abbreviation.

e. Distribution System Materials. Water distribution piping for interior installations is made of galvanized steel, wrought iron, copper, plastic, or brass. Nickel-silver or chrome-plated piping is used in locations where pipes are exposed to view. Galvanized wrought iron is the material most frequently used in theater of operations construction. Fittings normally are of the same material as the piping and are made with screw or flange connections, screw connections are normally used only for pipe up to 4 inches in diameter. Valves usually are made of brass and may or may not be plated. The material types to be used for the distribution system are designated in the specifications; sizes and special instructions are noted in the drawings.

f. Waste System Materials. Waste systems include all piping from sinks, water closets, urinals, showers, baths, and other fixtures that carry liquids and sewage outside of the building. A waste system consists of a main building drain, branch mains, and soil and vent stacks. Water, soil, and vent piping specifications include the materials of manufacture for each type of piping; cast iron, galvanized steel, wrought iron, copper, brass, lead, or acid-resistant cast-iron pipe. Fittings or traps normally are specified to be of the same material as the pipe.

(1) Galvanized steel and iron piping. Galvanized steel and iron pipes and fittings are the materials most commonly specified for waste system plumbing installations. Pipe ends have standard pipe threads and all pipes and fittings of this type are joined by standard pipe threads. Such piping is manufactured in three different weights and in diameters from 1/8-inch to 12 inches to any one of several specifications. The fittings are manufactured in all the shapes required to change or intersect flow.

(2) Vitrified clay piping and fittings. Vitrified clay piping and fittings are used for underground house drains and sewers and normally are noted in the plans as VCP or VP. VCP is sometimes used for soil and vent stacks in theater of operations construction. Pipes and fittings are made with bell-and-spigot ends. Joints are made by inserting the spigot end into the bell and caulking with cement mortar.

(3) Cast-iron pipes and fittings. Cast-iron pipes and fittings are used for building drains and for soil, waste, and vent piping. These pipes can be lain in unstable soil without danger of sagging. Pipes and fittings are made with bell-and-spigot and flanged ends. Bell-and-spigot joints are caulked with oakum and lead or a caulking compound; flanged fittings are bolted together to make a joint.

(4) Brass, lead, and copper piping. Brass, lead, or copper piping is used in high quality, or more expensive systems of waste plumbing. Brass or lead is used when excessive acids or corrosive liquids are present. Such acids or liquids are seldom present in the flow of theater of operations sewerage. Brass pipes and fittings are joined by standard pipe threads, and the fitting shapes are identical to those used for galvanized steel or wrought iron pipe. Lead pipe is very ductile, a feature that is advantageous in speed of installation, but it must be well supported because it deteriorates rapidly if permitted to sag. Copper pipe is not commonly specified for use as waste and vent piping because of the excessive cost of the larger sizes. For making connections, the pipe is cut

to the desired length and sweat-soldered to the applicable type of the several fittings available.

3-8. Utility Plans

Figure 3-9 is a typical utility plan for a bath house and latrine showing the water distribution plumbing, waste plumbing, and electrical wiring. For a small structure of this type, only a plan view as shown will normally be provided together with some additional detail drawings. You can see that the schedule of drawings lists three sources of additional information on the plumbing: a standard details drawing, a special details drawing, and a bill of materials. Standard details are indicated by a number and letter in a circle, for example (11-G). Special details are called out on the plan, "DETAIL #6" for example. An example of these standard and special details is shown on figure 3-10. Note that the method of supporting the flush tank, the method of coupling the water pipe to the flush tank, and all other necessary information that could not be shown on the plan, is clearly shown on the standard drawing for detail (11-G). Also, you can clearly see the required shower head and control valve fitting requirements in special detail #6.

a. Water Distribution. The plan shown on figure 3-9, together with the standard and special detail drawing and a bill of materials, permits the experienced plumber to install the complete water distribution system accurately and satisfactorily. Note that the hot water heater and storage tank connections would be detailed on standard detail drawing (11-L). Notice also that the point at which the incoming water supply piping would be brought up to ceiling level would be shown on the hose bib location standard detail drawing (11-X). Look carefully at the plan and note that the pipe sizes and type are clearly specified in all cases.

b. Waste System. The plan (fig. 3-9) shows the building waste system starting at the 4-inch shower drain in the shower room, out to the connection with the 4-inch fiber pipe of the sewage system. The exact piping arrangement and establishment of the correct slope are left to the plumber. Note that in the plan view, the P-traps below the drains are specified but not actually shown. However, you can see again the use of the standard detail symbols. Note that standard detail (11-Q) would give all the necessary information on the construction of the two through-the-roof 4-inch vents. When standard details are provided, it is important to remember that they are prepared to cover a large variety of applications and the plumber is expected to make minor alterations to suit particular installations. For example: Note that the 90° straight Y in the water closet detail (11-G) (fig. 3-10), is shown for flow to the left. In the installation plan (fig. 3-9), the soil pipe pitch is in the opposite direction so the Y must be installed in the opposite direction.

3-9. Building Waste System Nomenclature

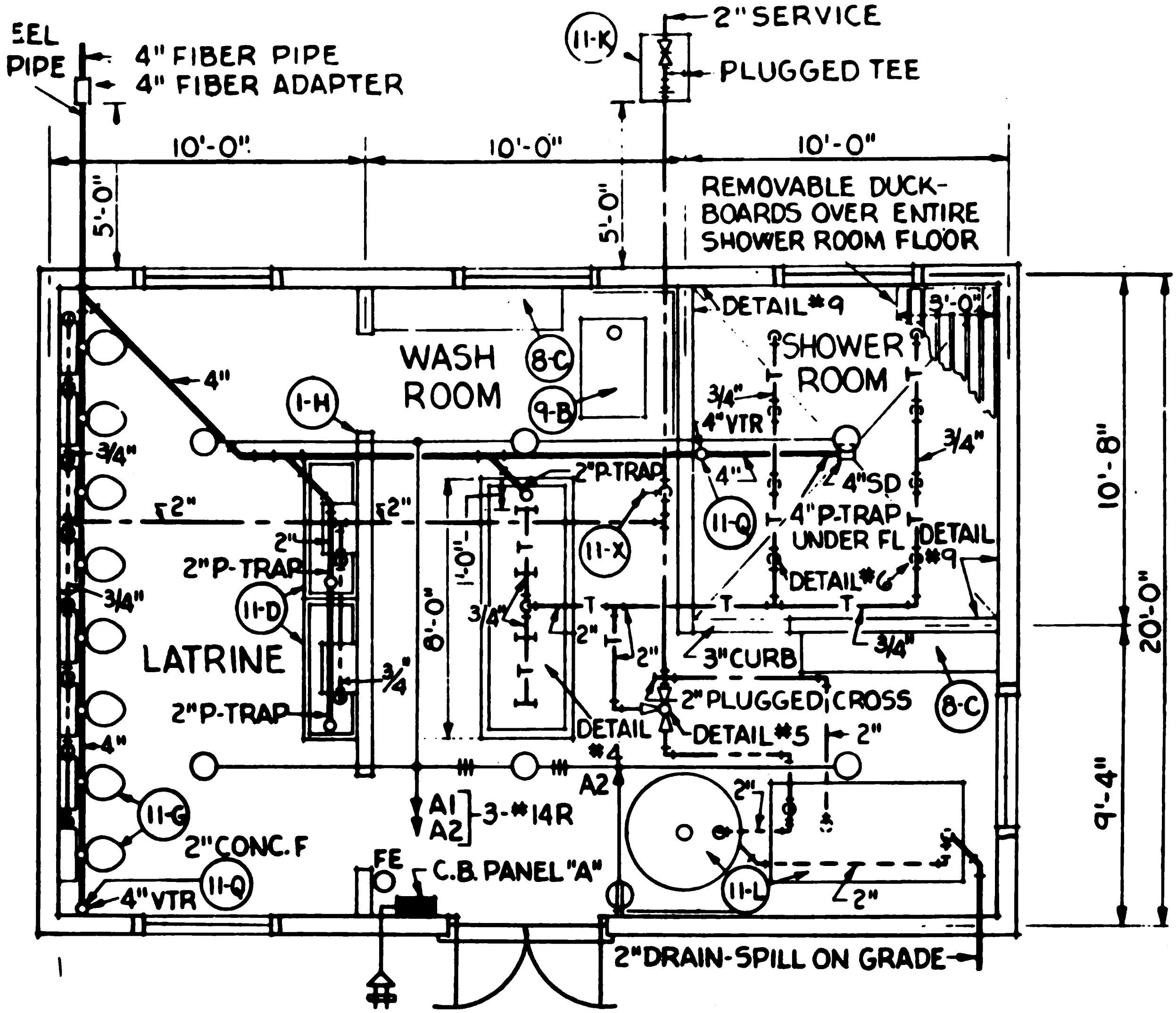
Although the waste system shown in the utility plan (fig. 3-9) is relatively simple, it does consist of four basic functional elements which are defined as follows:

a. House Sewer. The house sewer is that part of the waste plumbing system beginning just outside the foundation and terminating at a street sewerage branch or a septic tank. A typical house sewer is shown in section in figure 3-11.

b. House Drain. The house drain is that part of the waste system which receives the discharge of all soil and waste stacks within the building. It may be installed underground or suspended from the first-floor joists. The house drain system is also referred to as the "collection lines" and includes such appliances as house traps, back-flow valves, cleanouts, and area drains. In general, house drains will fall into one of four classes on any set of specific building plans.

(1) Combination system. As shown at the left on figure 3-11, a combination system receives the discharge of the sanitary wastes of the building plus the storm water from the roof and other exterior sources.

(2) Sanitary drain. A sanitary drain receives the discharge of sanitary and domestic wastes only.



SCHEDULE OF DRAWINGS

DWG. NO.	DESCRIPTION	SHEET NO.
72-32	PLANS	1 OF 1
72-31	SPECIAL DETAILS	2OF3
72-98	STANDARD DETAILS	1 THRU 8
34-91	STD FRAME BARRACKS TYPE BLDG PANEL SCHED	1 OF 2
72-99	BILL OF MATERIALS	3 OF 4

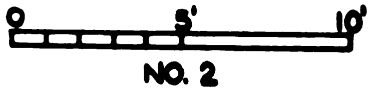
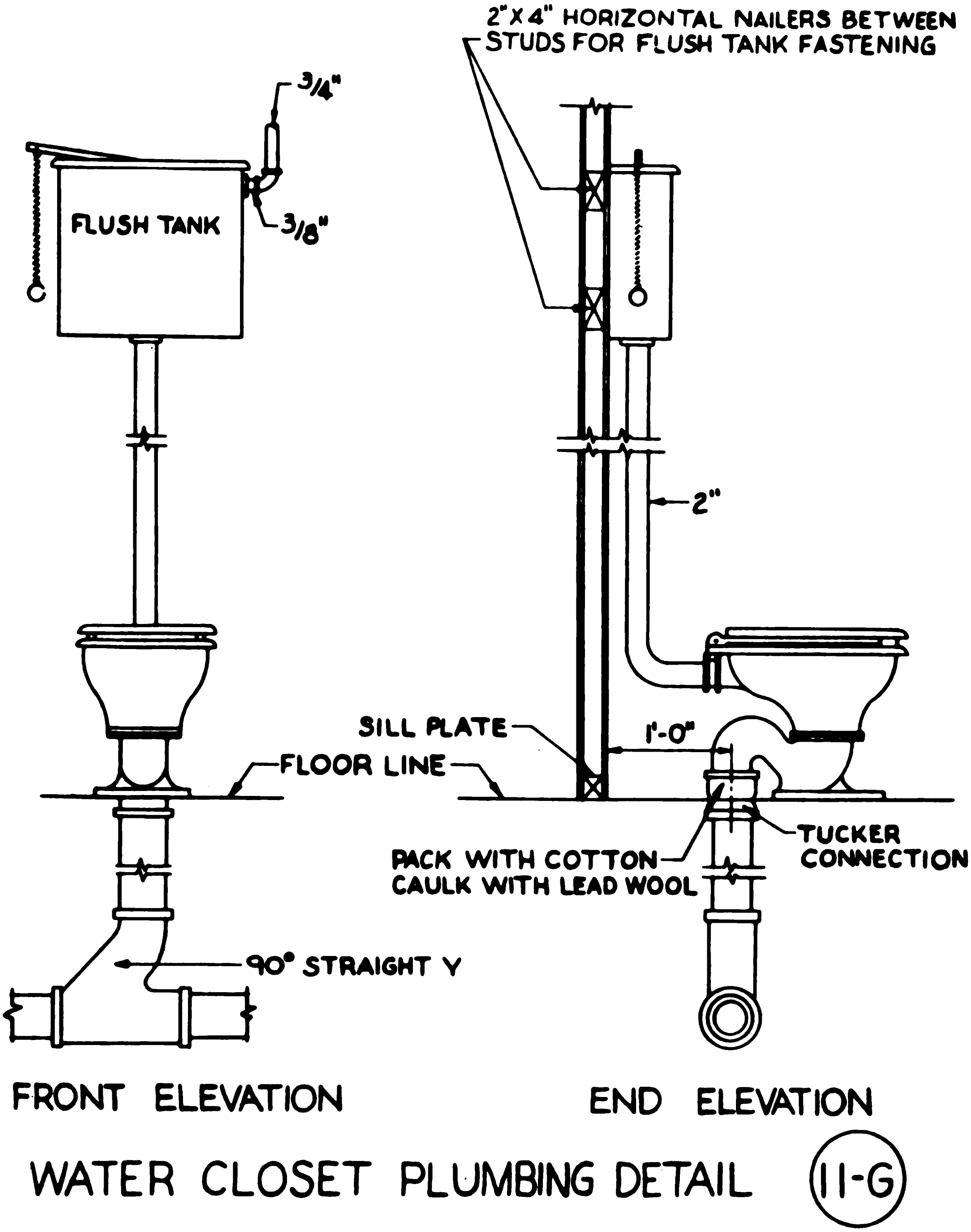


Figure 3-9. Typical utility plan for a bath house and latrine.



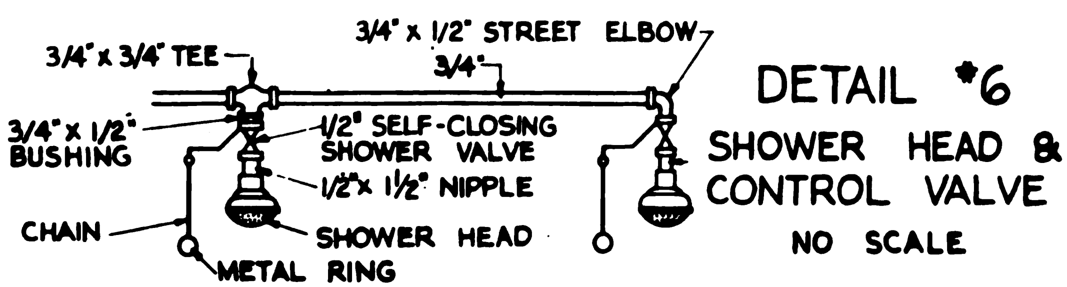


Figure 3-10. Typical plumbing details.

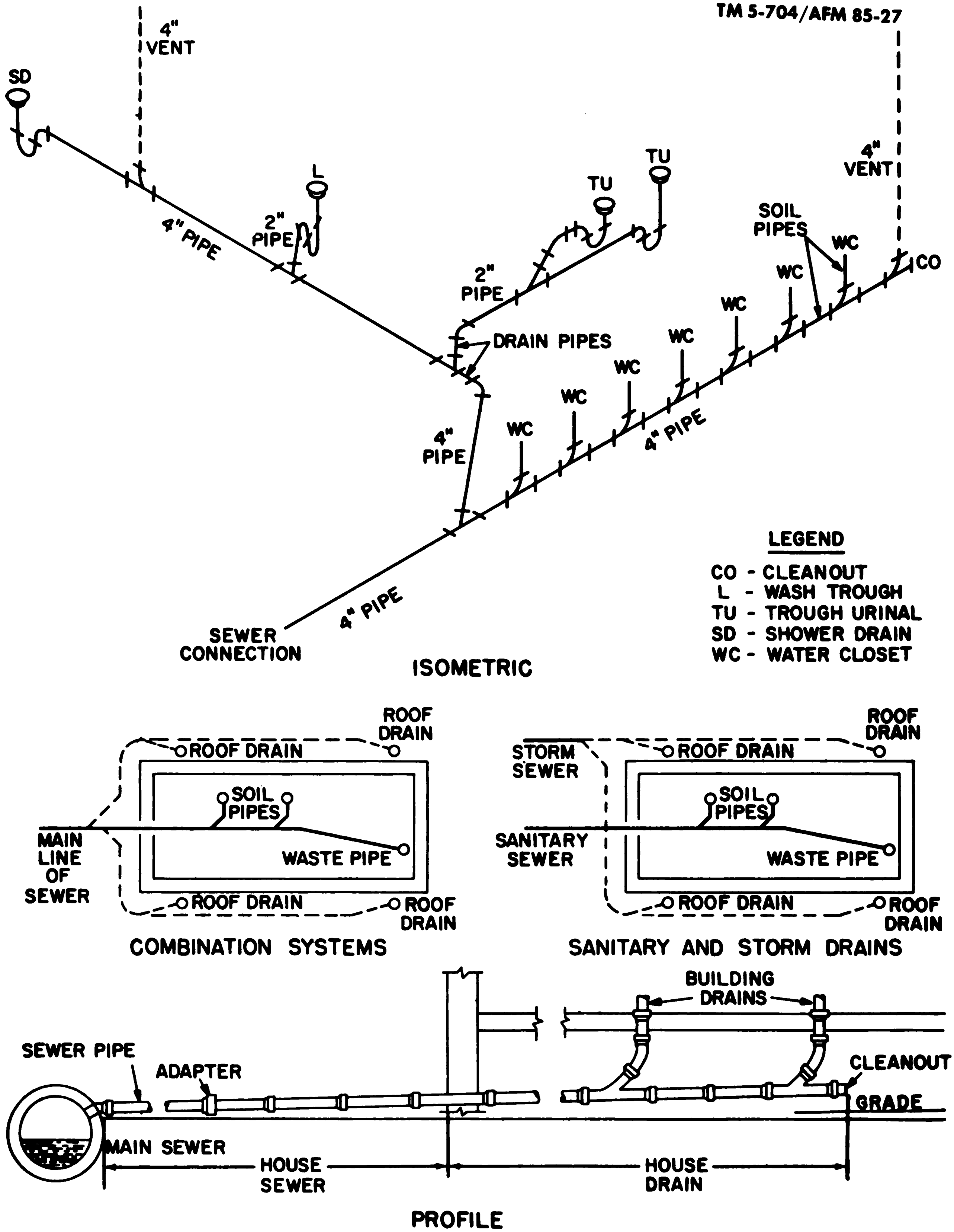


Figure 3-11. Typical building waste system arrangement.

(3) *Storm drain.* As shown at the right of figure 3-11, a storm drain receives storm, clear water, or surface-water wastes only.

(4) *Industrial drain.* An industrial drain receives liquid waste from industrial equipment or processess and consequently receives little attention in theater of operations construction.

c. *Soil Pipe.* Soil pipe is that portion of the plumbing system which receives the discharge of water closets and conveys those wastes to the house drain.

d. *Waste Pipe.* Waste pipe is that part of the drainage system which conveys the discharge of fixtures other than water closets such as sinks, lavatories, urinals, bathtubs, and similar fixtures to the soil pipe.

3-10. Self-Test

To verify your understanding of the material presented thus far, answer the following questions about the bath house and latrine plumbing shown in figures 3-9 and 3-10.

1. What size and type of pipe is used to supply water for the shower heads?

2. How many shower heads are to be installed?

3. At what point is the incoming water supply piping brought up to the ceiling level?

4. What does the dashed line running from the left side of the hot water tank to the fitting at the right side of the tank indicate?

5. Referring to figure 3-10, detail No. 6, what is used to couple the ¾-inch Tee to the ½-inch self-closing shower valve?

6. The building drain system uses 4-inch pipe throughout. (True or False)

7. Cold water is supplied to the wash trough. (True or False)

Section III. SEWERAGE SYSTEMS

3-11. Definition

a. A sewerage system is a system of pipes and associated apparatus which carry sewage from buildings to the point of discharge or disposal. A sewerage system includes the sewer pipe or conduits, manholes, flush tanks and, in some cases, storm-drain inlets. In small or medium size systems which are not served by a processing plant, the system may also include facilities for pumping, treatment, and final disposition of sewage.

b. Sewerage systems may be either combined systems or separate systems. In a combined system the conduits carry storm water as well as domestic and industrial wastes. In a separate system, the sanitary sewerage system carries the domestic and industrial wastes and a separate storm sewerage system carries storm water run-off. Because storm water requires little or no treatment before disposal, the separate system greatly reduces the load on treatment facilities.

3-12. Pipes and Fittings

The pipes and fittings for the construction of sewerage systems are well standardized by sanitary codes and general usage. Most generally used pipes and fittings are described as follows:

a. *Vitrified-Clay Tile or Concrete Sewer Pipe.* Pipe sizes of 4 inches to 36 inches in diameter are generally used for sewer system construction. Vitrified-clay tile is highly resistant to all sewage and industrial wastes and acids. Cast, spun, or vibrated concrete pipe in sizes of 12 inches to 108 inches in diameter can frequently be made available. Such concrete pipe is manufactured with or without steel reinforcing.

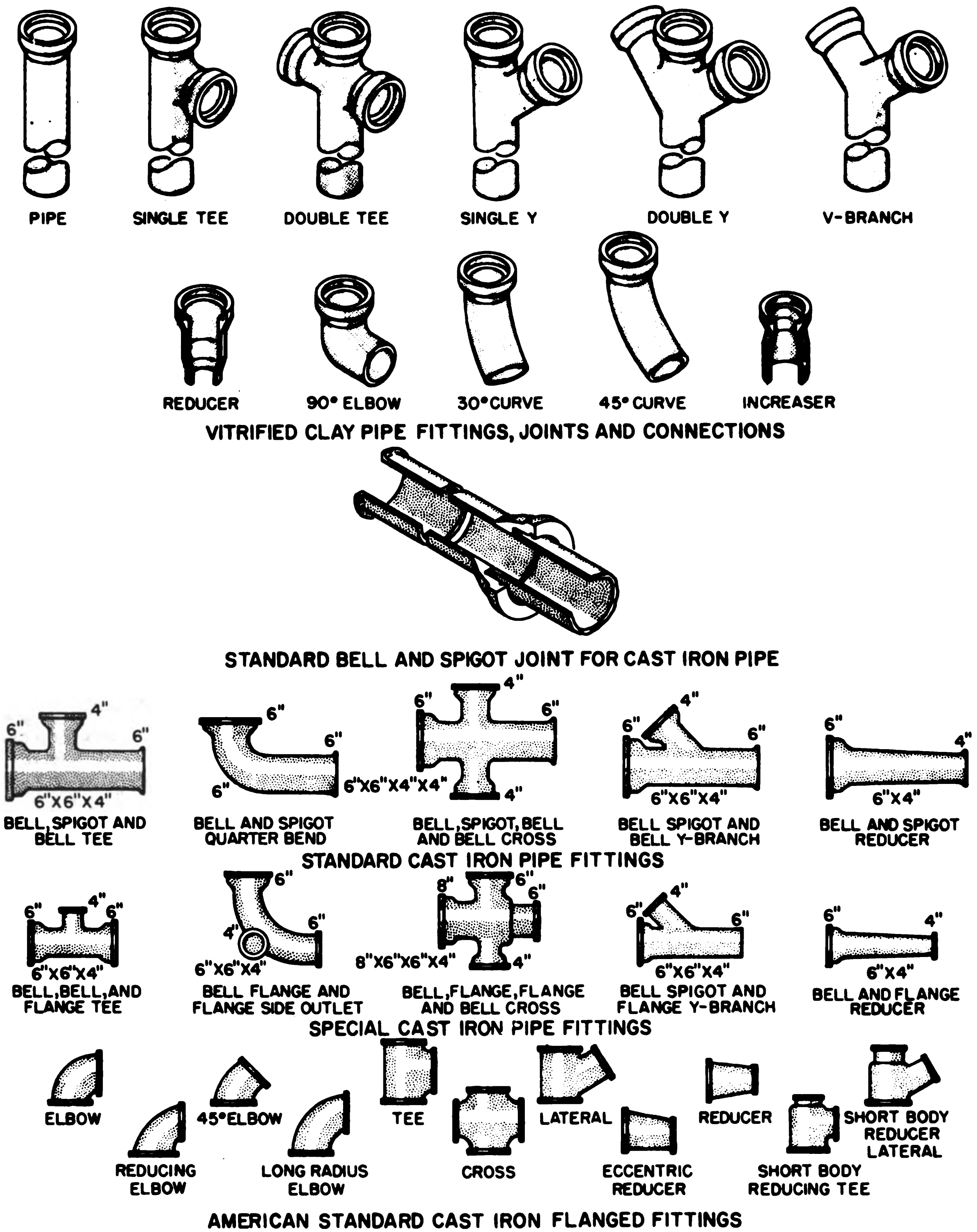


Figure 3-12. Standard vitrified-clay and cast iron pipe fittings.

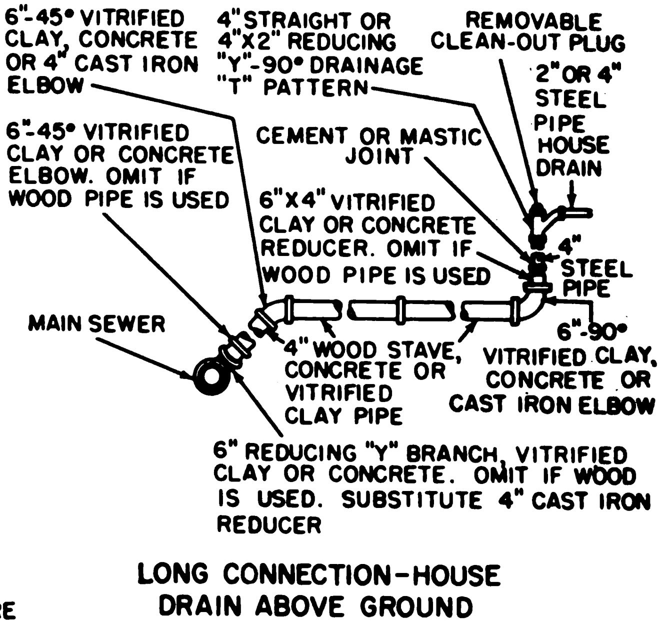
b. Cast- or Wrought-Iron Pipe. Bell-and-spigot type cast- or wrought-iron pipe with leaded joints, in sizes of 4 inches to 48 inches, can be used to make a self-supporting sewer line where relatively short sections of soft ground are encountered in the installation trench. In this situation the pipe is laid on cross-trench saddles of concrete or creosoted timbers.

c. "Cast-In-Place" Concrete Conduit. This type of conduit is frequently used where sizes greater than 60-inch diameter pipes are needed for increased capacity in main, trunk, or outfall sewers. These types of drains are not circular in section but are of several arched designs or box-section culvert reinforced-concrete construction.

d. Wood Stave Pipe. Machine-banded wood stave pipe with iron joint ends and bands is sometimes used in sizes of 4 inches to 24 inches where vitrified-clay, concrete, or cast-iron pipe is in short supply. Continuous stave pipe, built up and banded in the field, can be made in sizes of 16 inches to 16 feet.

e. Vitrified-Clay and Cast Iron Pipe Fittings. The bell-and-spigot type of joint are generally used for sewer system construction. Figure 3-12 illustrates this type of joint. Joints in clay tile are usually sealed with a hot-pour jointing compound over oakum packing. Neat-cement grout is used for joint sealing of concrete sewer pipe.

f. Conventional Symbols. When house or building connections are shown on sewerage plans, the conventions used are the same as those for plumbing plans. These symbols are covered in the preceding section. Typical building connections are shown in figure 3-13. If you study figure 3-13, you will note the amount of information supplied to the plumber. Note also the specific information given on the caulking and sealing of joints for each type of drain. These are standard detail conventions and will be found on all properly prepared sewerage plans. Figure 3-14 illustrates the conventions used in a typical sewerage system plan. You can see that this is not a simple system; however, it is typical of large-job sewerage systems. Note that reference is made to the actual building plans for the details of the house drain connections.



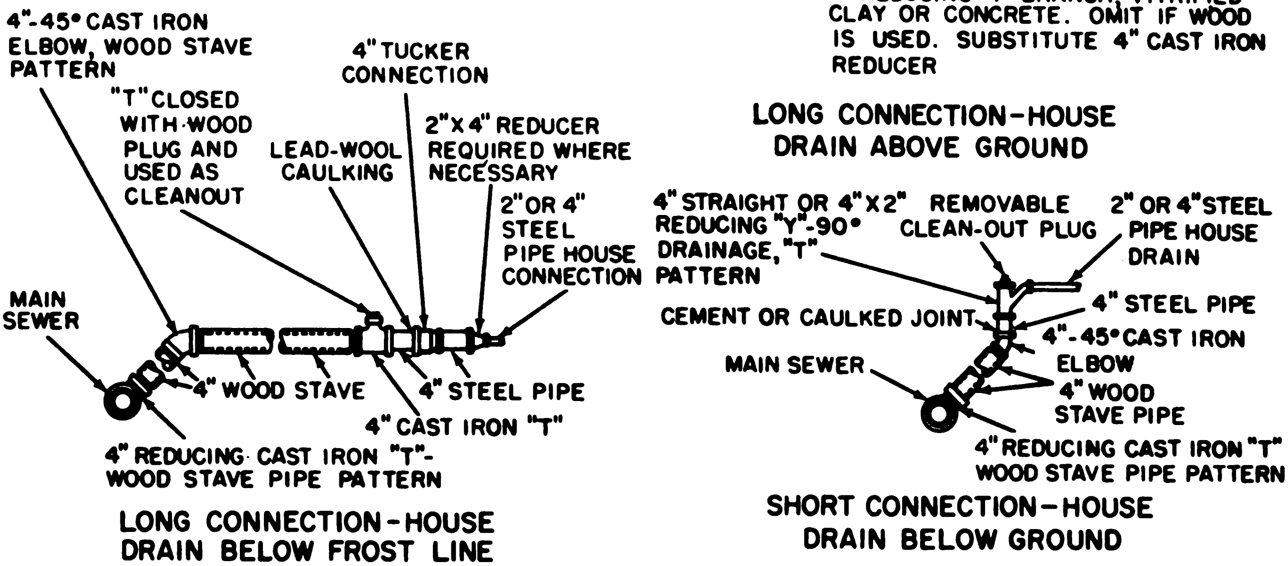


Figure 3-13. Typical building connections.

3-13. Manholes

Manholes are generally of circular cross section when made of cement-plastered brick-and-mortar walls set on a concrete base slab. The top is closed with a removable heavy lid that lays in a cast-iron top ring. Where manholes are made of wood the cross section is square or rectangular and has a removable cover set in the roofing timbers. An example of manhole construction is shown in figure 3-15. Note that the manhole depicted is made of brick or concrete and is circular. From the dimensions given, you can see that the base slab slopes. (10 inches to 9 inches). The lid is 2 feet, 4 inches in diameter and ¾-inch thick. There are three shelves around the pipes in an opening whose diameter is 3 feet, 6 inches.

3-14. Sewage Treatment

a. Grease Traps. Wooden box type grease traps are generally set in the flow line of the house or building sewer to intercept greases and fats from kitchen sinks. Baffles are placed in the boxes to collect floating grease particles but arranged so as not to restrict the flow of the effluent. Figure 3-16 shows the general design of a grease trap.

b. Septic Tanks. These are usually constructed in box-section form of lumber. Concrete, brick, or stone may be used for more permanent installations where such materials are available. Single building tanks of about 500-gallon capacity are sometimes made of steel and supplied ready for installation in the sewer system. Construction details for a small septic tank are shown in figure 3-17. A larger tank is shown in figure 3-18. An integral part of septic tanks is the dosing tank which is usually constructed of wood or concrete. When wood walls are used, a concrete slab floor is favored as giving the best foundation for installation of the intermittent syphon. Plan and elevation views of a dosage tank are shown as part of the

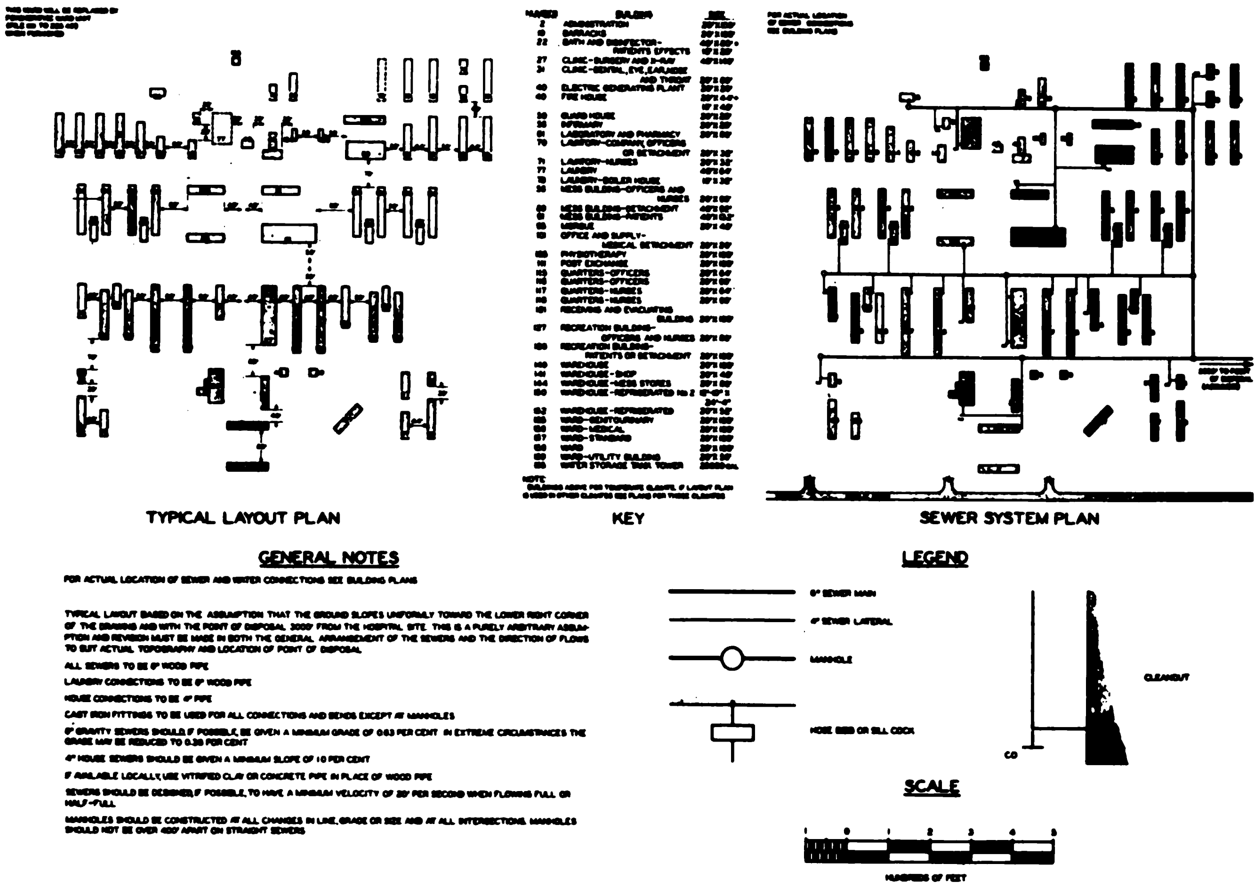


Figure 3-14. Typical sewer system plan.

septic tank details in view A-A of figure 3-18.

c. Imhoff Tank. Installations which are sufficiently complex to require a treatment plant will normally have plans prepared for a specific site, accounting for the topography and soil conditions. Where a septic tank is not adequate to handle the load, an Imhoff tank may be used. Typical construction details for a concrete Imhoff tank are shown in figure 3-19.

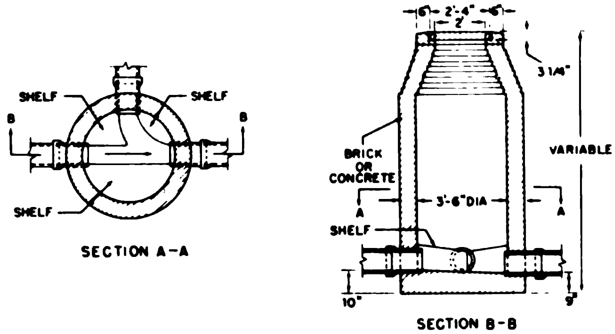


Figure 3-15. Manhole construction.

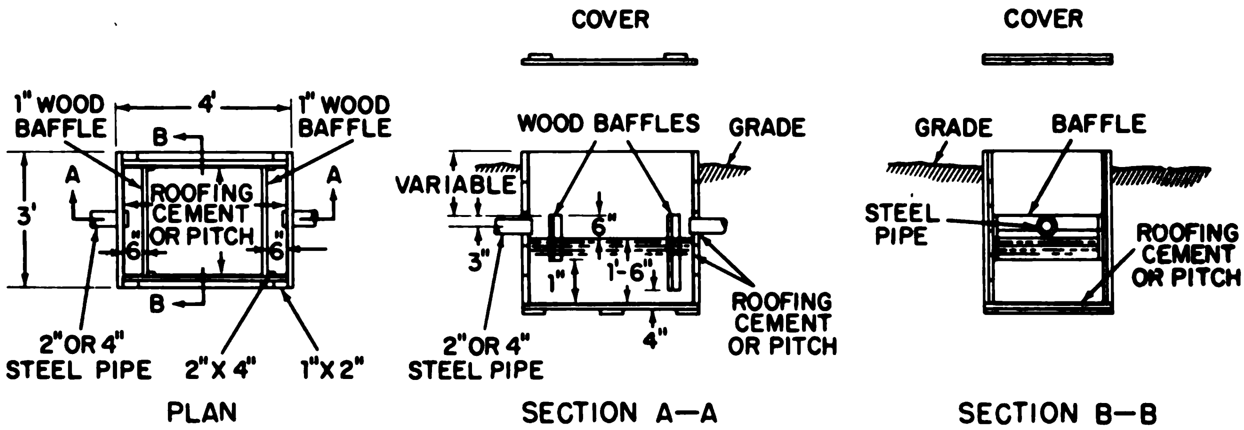


Figure 3-16. Grease trap.

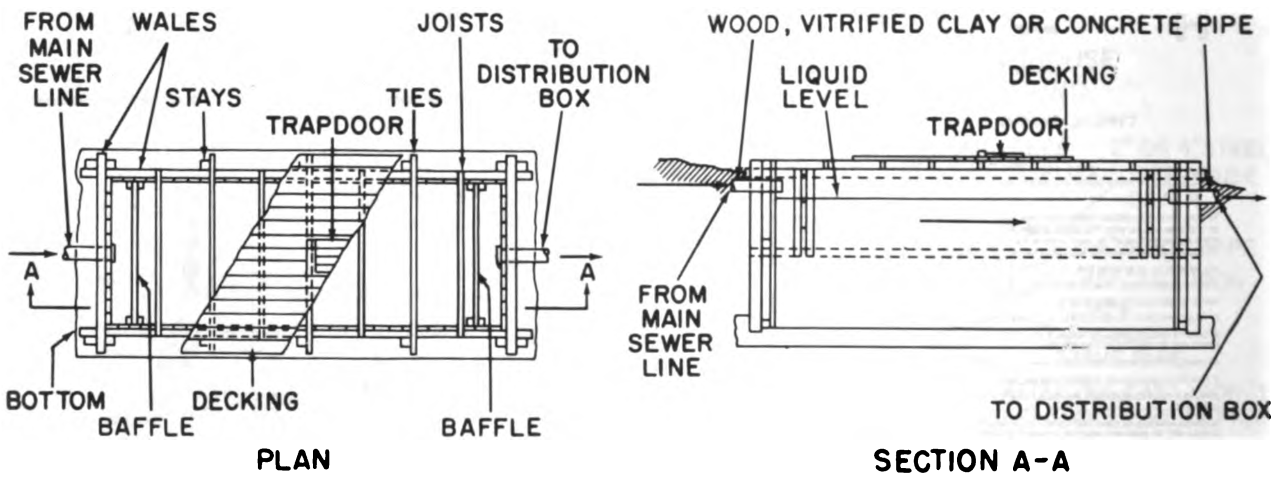


Figure 3-17. Typical small septic tank.

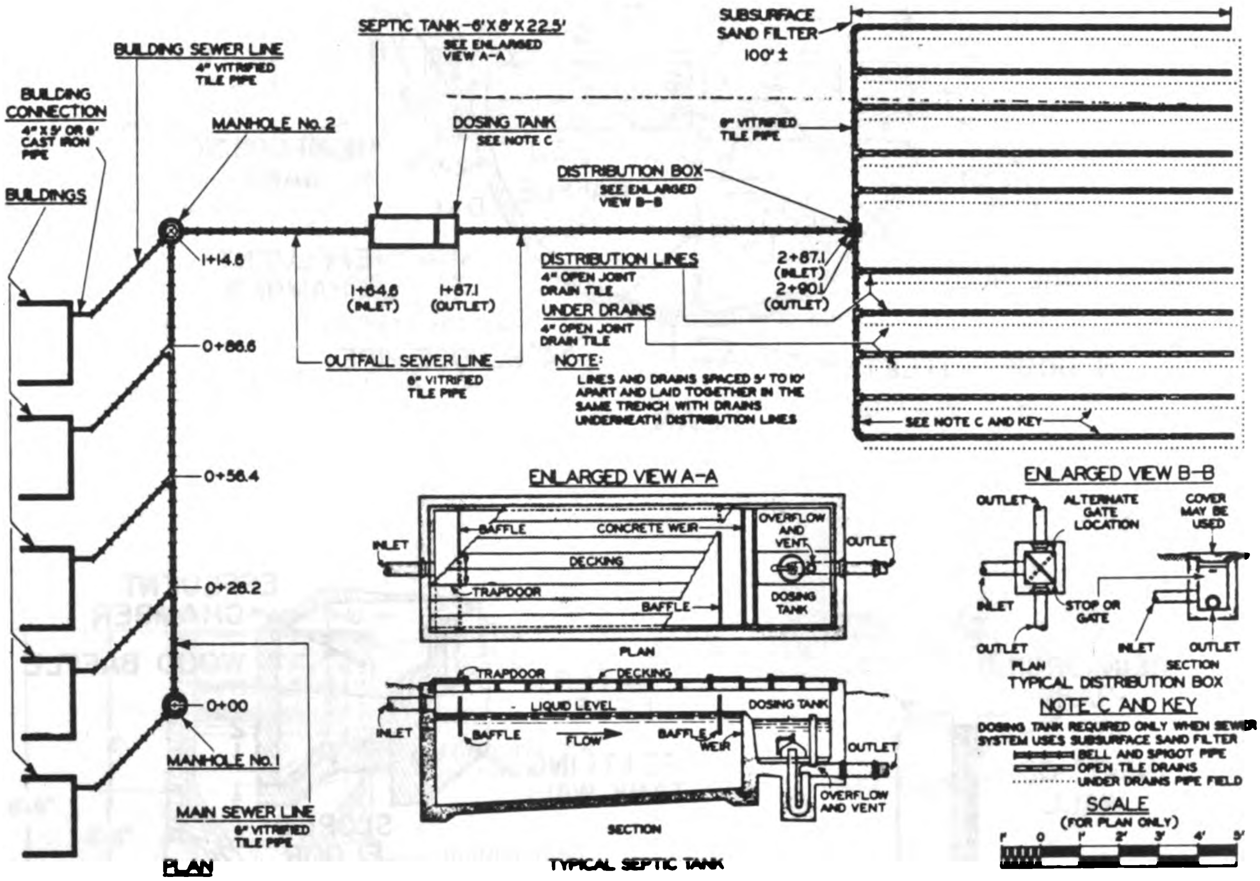
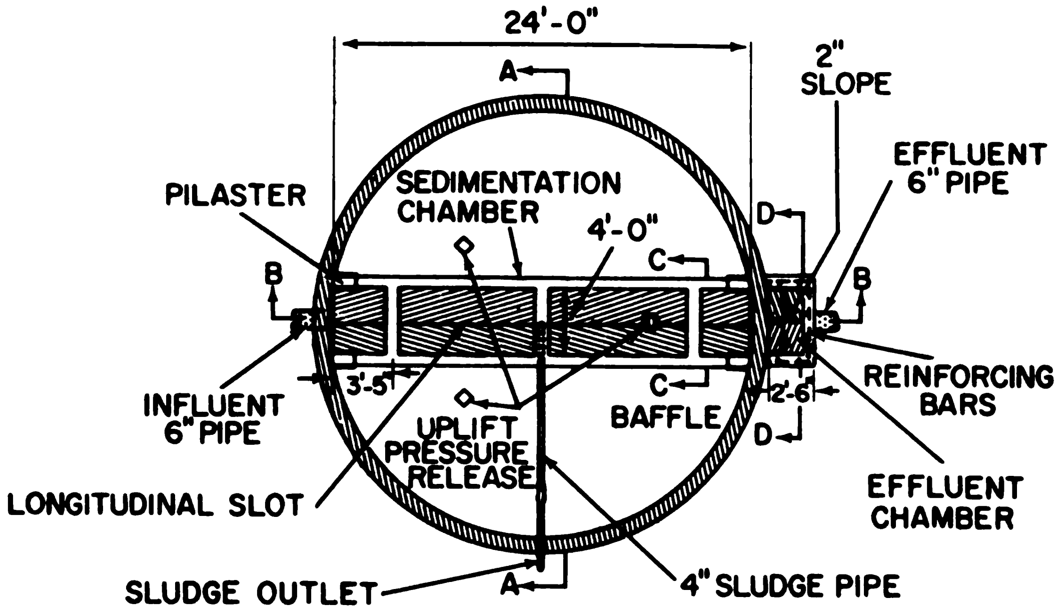
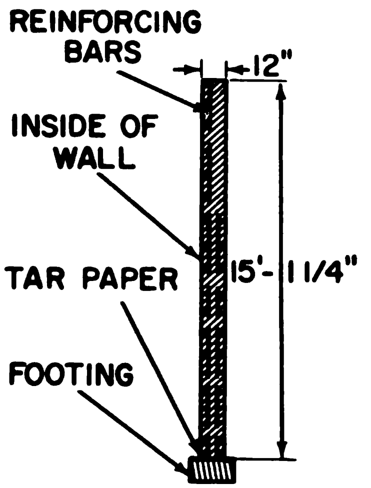


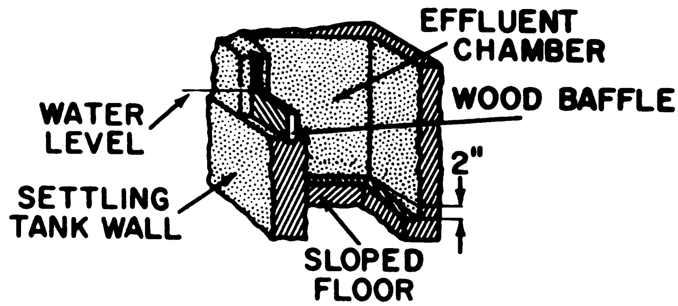
Figure 3-18. Typical small sewerage system, plan view.



PLAN



TANK WALL SECTION
DIMENSION "G"



BAFFLE DETAIL

GENERAL NOTES	
A	HORIZONTAL AND VERTICAL REINFORCEMENT BARS SHOWN BY SYMBOL
B	SLUDGE OUTLET CONNECTION CONNECTED TO SLUDGE PIPE BY 60° SCREWED "Y" BRANCH.

Figure 3-19. Imhoff tank, 25,000 gallon capacity.

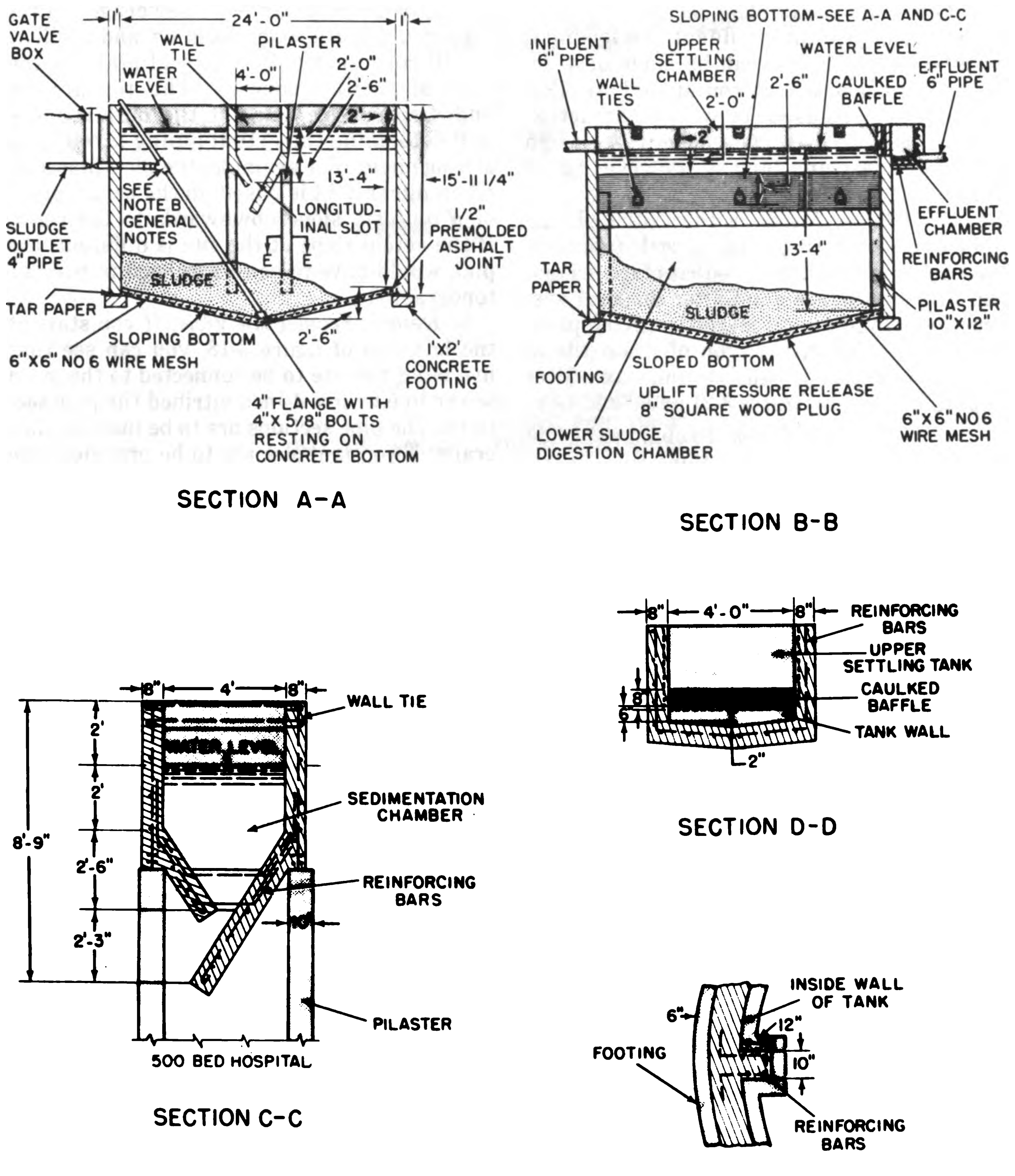


Figure 3-19. Imhoff tank, 25,000 gallon capacity—continued.

3-15. Disposal Facilities

a. Leaching Tanks. The receivers of raw sewage or septic-tank effluent are leaching tanks or cesspools and can be made of 4- by 4-inch lumber or 5-inch round timbers. Dry masonry may be used for wall construction where time and materials permit. A design for a small leaching tank is shown in figure 3-20.

b. Sand-Filter Fields. Either vitrified clay or concrete drain tile, without sealed joints is used for piping in both subsurface irrigation and subsurface sand-filter disposal systems. Approved design methods, giving plans and profiles, for installation of drain tile in the two types of irrigation and sand-filter fields are shown in figures 3-21 and 3-22.

(1) *Distribution boxes.* To change the flow of effluent to different sections of a filtration field, a distribution box is used and can be made of wood, concrete, or brick. The diversion gate is usually of wood, with a handle-slot, so that its position in the distribution box can be moved to change the sewage flow direction. See view B-B on figure 3-18 for the installation requirements of a distribution box.

(2) *Size.* Figures 3-18 and 3-23 illustrate a typical small sewerage system which uses both a septic tank and a subsurface sand filter as the final sewage disposal point. Because of the long pipe runs and the use of the sand filter, both a plan and profile view of the system are required to inform the pipe fitters of construction requirements.

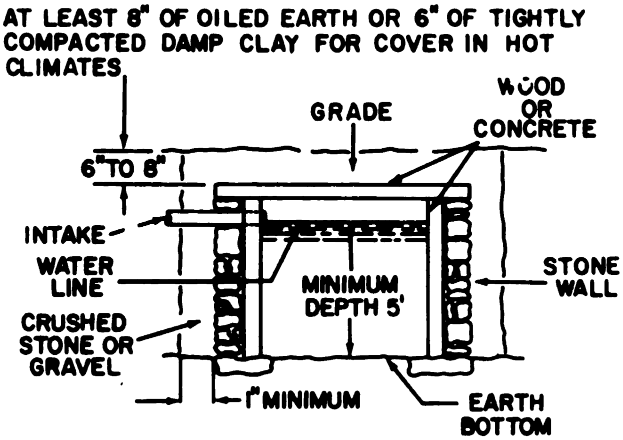
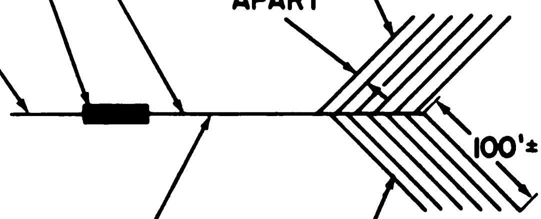


Figure 3-20. Leaching tank.

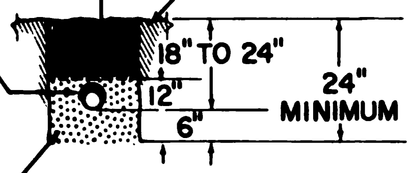
3-16. Sewerage System Plans

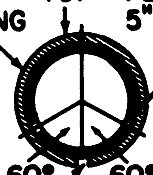
a. Topography. Unless a sewerage plan is prepared for a specific location and facility, it will represent only a typical plan for the type of facility covered. The topography and disposal facilities at the building site will determine the actual piping layout and arrangement. For example, the plan illustrated on figure 3-14 is based on the assumption of a uniform slope downwards to the right. If the actual slope at the site is different, the plan would have to be re-arranged to suit the topography.

b. Details From Plan View. If you start at the left side of figure 3-18, you can see that five buildings are to be connected to the main sewer line by five 4-inch vitrified tile pipe sections. The pipe sections are to be installed laterally. Two manholes are to be provided, one at each end of the main sewer line. The first manhole is given as the zero reference point for all other measurements. The point of connection of the first lateral is given as 0 + 28.2 feet. These numbers indicate the distance between connection points in hundreds of feet plus feet and decimal fractions of a foot. For example the symbol 0 + 28.2 reads 28.2 feet, the symbol 1 + 14.6 at manhole No. 2 indicates that this connection point is 114.6 feet from the reference point 0 + 00. You can now easily determine the distance between all the remaining connection points on the plan. Although you can read the distances between points on the plan view, you might note that you cannot determine the depth at which the pipe is to be laid in the ground from this view. Another view is required and that is the profile view. The profile view will be discussed in paragraph *c* following. Now, from figure 3-18 you can see that the main sewer line is to be connected to a septic tank whose dimensions are given as 6 feet by 8 feet by 22.5 feet. Again it would be necessary to refer to the profile view to determine at what elevation (depth below building level) the bottom of the tank is required to be placed. Note that you are directed to see enlarged view AA of the septic tank for details of the required construction Finally, the outfall of the septic tank is connected to a subsurface sand filter via a



PLAN





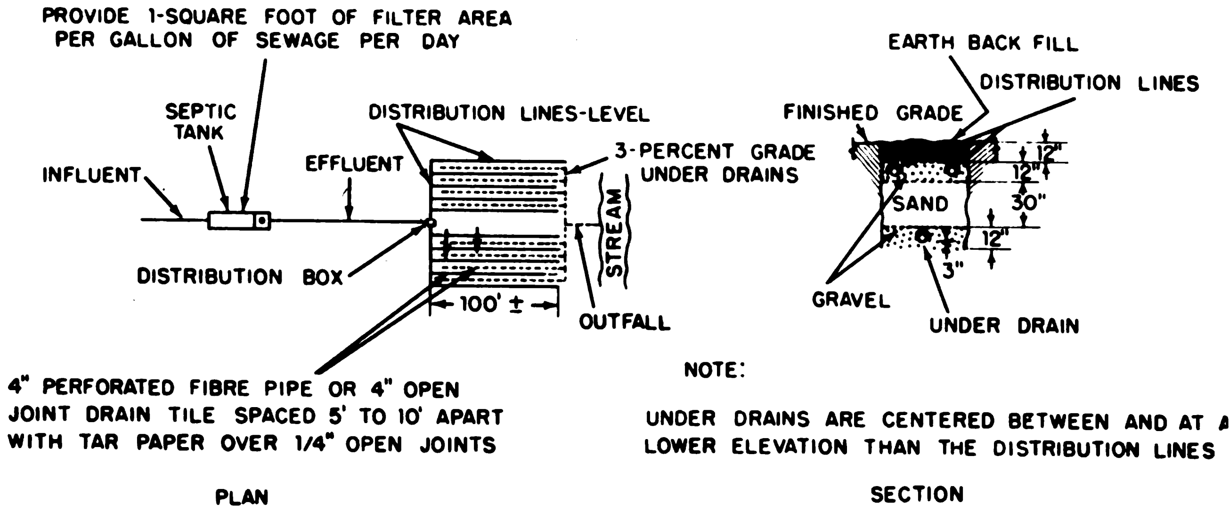
PERFORATED FIBRE PIPE SECTION

NOTE:

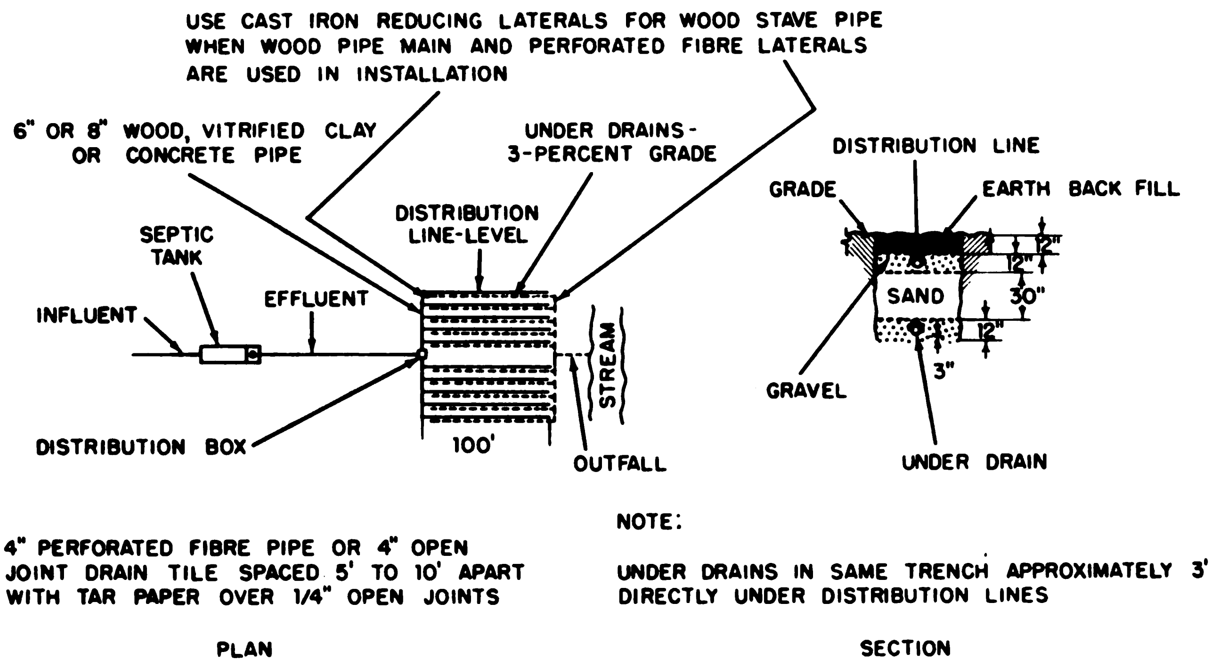
NO UNDER DRAINS PROVIDED FOR THIS LAYOUT. FOR METHODS OF DETERMINING INSTALLATION SIZE, SEE "SOIL TEST" NOTES.

TYPICAL SECTION

Figure 3-21. Typical subsurface irrigation construction.



SUBSURFACE SAND FILTER A



SUBSURFACE SAND FILTER B

Figure 3-22. Typical sand-filter fields.

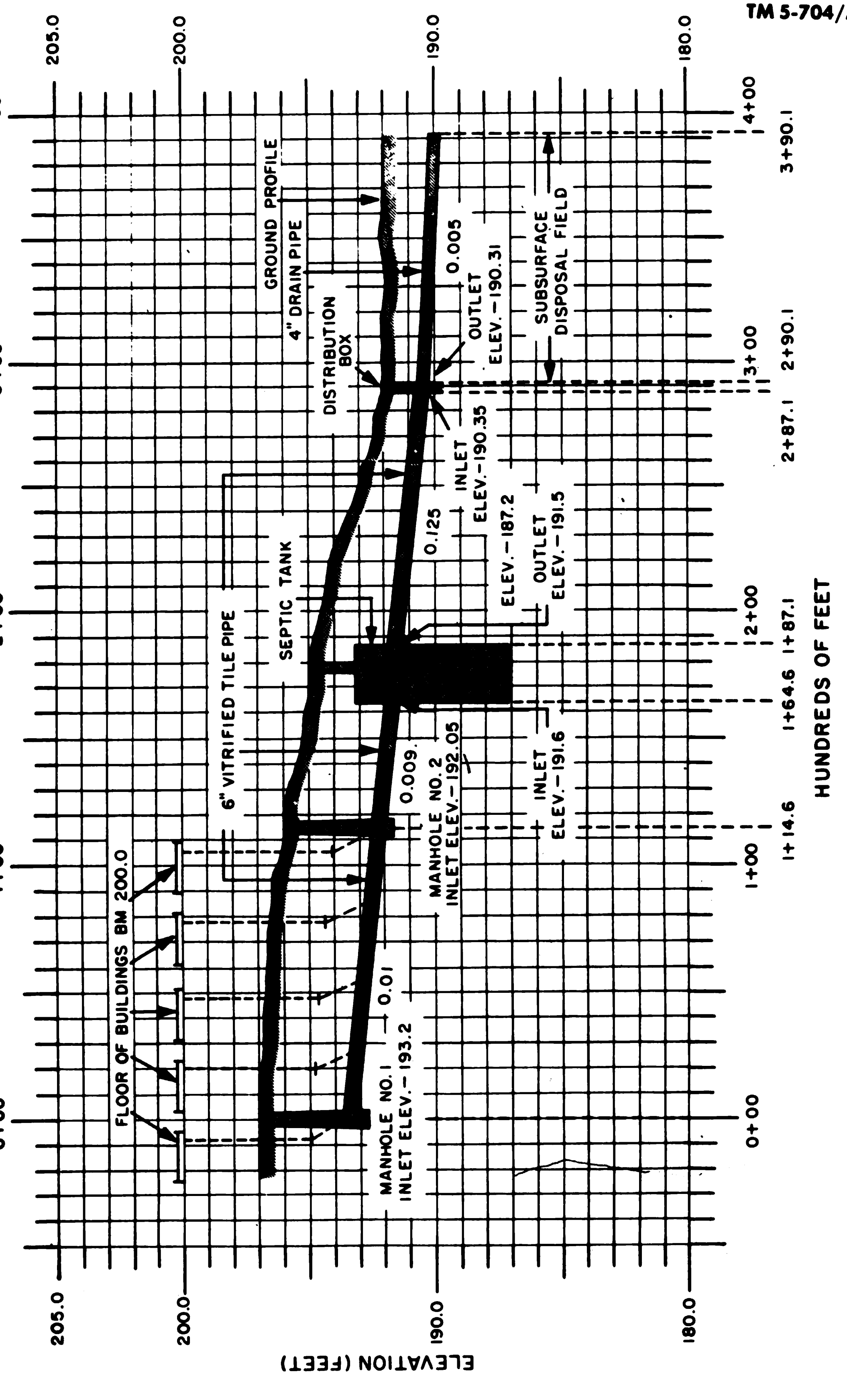


Figure 3-23. Typical small sewerage system, profile view.

distribution box. The plan tells you that the filter consists of distribution lines laid above a separate system of drain lines. Note that only the distribution lines are connected to the distribution box. The under drain lines form a separate system. Note that the extent of the subsurface sand filter is not completely specified in figure 3-18. The actual size of the filter must be determined at the site by the performance of the soil absorption test. The same test must be performed to determine the necessary percolation area when a leaching tank is used as the disposal field.

c. *Details From Profile View.* Figure 3-23 is the profile view that complements the plan of figure 3-18. The profile is taken along the path of sewage flow in the manner of an aligned section. To provide for easier reading, note that the vertical scale is expanded so that one square equals 1 foot, whereas for the horizontal scale, one square equals ten feet. Note that the floors of the buildings are shown at an elevation of 200 feet. It is common practice to assign a convenient round number to this reference point. The actual elevation might have been 196 or 207 feet, but for purposes of convenience the round number 200 is used. All elevations are then referenced to this point. Note that the laterals shown on figure 3-18 are actually dropped 6.8 feet as shown on figure 3-23 before connection is made to the main sewer line. Look carefully at each section of the main sewer and note the numbers 0.01, 0.009, 0.125, 0.005. These numbers indicate the grade of each section and are calculated as follows: From the profile, you can read the inlet elevation of manhole No. 1 as 193.2 feet and the inlet elevation at manhole No. 2 as 192.05. The distance between these two points is given as 114.6 feet. Therefore, the grade is (193.2—192.05) ÷ 114.6 = 1.15 ÷ 114.6 = 0.01, or a 1 percent grade, or a 1 foot drop in 100 feet. It was stated in paragraph *b* preceding, that although the size of the septic tank could be read from the plan view, the actual elevation of the base could not be determined from the plan view. From the profile view you can now read the required depth of the footing for the septic tank. It is shown to be at an elevation of 187.2 feet of 12.8 feet below the floor level of the buildings. One final point of major importance that cannot be completely read from either the plan or profile views is the extent, or area, of the subsurface sand filter. As was noted earlier, this must be determined by a soil absorption test which is performed as follows:

(1) *Soil absorption test procedure.* Dig test holes (at least three) 1 foot square to the proposed depth of the tile and fill them with water to a depth of 1 foot. After the water has seeped away, and while the bottom of the holes are still wet, refill the holes to a depth of 6 inches. Note the average time required for the water level to drop one inch and compute the necessary percolation area from the data in table 3-1.

Table 3-1. Soil Absorption Rates.

	ABSORPTION (GALLONS PER DAY)	
Time Required For Water Level To Fall 1 Inch* (Minutes)	Per Sq. Ft. Of Trench Bottom In Tile Field	Per Sq. Ft. Of Percolating Area In Leaching Tank
1	4.0	5.3
2	3.2	4.3
5	2.4	3.2
10	1.7	2.3
30	0.8	1.1
60	0.6	0.8

*See paragraph 3-16(k)(1) for procedure.

(2) *Example 1.* A sand filter must handle 2000 gallons per day and the average time noted in the soil absorption test is 10 minutes. From Table 3-1, this corresponds to 1.7 gallons per day per square foot.

$$\frac{2000\text{GPD}}{1.7\text{ GPD/SQ. FT.}} = 1180\text{ SQ. FT.}$$

If trenches are 18 inches wide,

$$\frac{1180\text{ SQ. FT.}}{1.5\text{ FT.}} = \text{790 ft. of trench and pipe will be required.}$$

(3) *Example 2.* A leaching tank must handle 400 gallons per day (GPD) and the average time noted in the soil test is 2 minutes. From table 3-1, this corresponds to an absorption rate of 4.3 gallons per day per square foot.

$$\frac{400 \text{ GPD}}{4.3 \text{ GPD/SQ. FT.}} = 93 \text{ SQ. FT.}$$

(4) *Capacity.* The following information in general in nature and will have been taken into consideration when the plans were made. The necessary capacity for a sewerage system is normally based on handling 25 gallons per day per man, or 50 gallons per day per bed for hospitals. A facility housing 500 troops, therefore, would require sewage disposal facilities capable of handling 12,-500 gallons per day. A 100—bed hospital would require disposal facilities capable of handling 5,000 gallons per day. Septic tanks must normally be capable of detaining sewage for 24 hours. Sewer piping is usually designed for capacities of three times the average flow in order to handle peak loads, but pipe less than 6 inches in diameter should not be used for main sewers, and the rate of flow should not be less than 2 feet per second when full or half full to prevent clogging regardless of the capacity required. The minimum velocity is usually specified as 1.5 feet per second.

3-17. Self-Test

To check your understanding of sewerage system drawings, answer the following questions. Answers are given at the end of the chapter.

1. Referring to the plan shown in figure 3-18, if the elevation of the inlet to the manhole No. 1 is 195.00 feet, and 185.50 feet at manhole No. 2 at what is the grade?
   a. 0.36 feet per hundred
   b. 0.63 feet per hundred
   c. 0.83 feet per hundred
   d. 1.05 feet per hundred

2. On the same plan, all laterals are 4-inch pipe. (True or False)

3. Approximately how many feet of 4-inch drain tile are required for the subsurface and sand filter shown in figures 3-18?
   a. 1000 feet
   b. 2000 feet
   c. 2200 feet
   d. Cannot be determined from plan

4. In figure 3-23 what is the elevation at the point where the lateral from the center building joins the main sewer line?
   a. 56.4 feet
   b. 114.6 feet
   c. 193 feet
   d. 194.8 feet
   e. Cannot be determined

5. What is the total distance from manhole No. 2 to the distribution box inlet?
   a. 73.5 feet
   b. 172.5 feet
   c. 287.1 feet
   d. 401.7 feet

SECTION IV. ELECTRICAL DISTRIBUTION SYSTEM

3-18. Definition

Electrical distribution is the delivery of power to the using premises from the power plant or substation through feeders and mains carried on poles or placed underground.

3-19. Nomenclature

The general term "power system" covers the large-capacity wiring installations and associated equipment for the delivery of electrical energy from the point of generation to the point of use. The power system is generally considered to be a combination of two sections—the transmission system and the distribution system. The difference between the two sections depends on the function of each as defined below. At times, in small power systems, the difference tends to disappear and the transmission system merges with the distribution system, and the delivery network as a whole is referred to as the "distribution system."

a. Transmission System. A transmission system usually consists of step-up and step-down transformer stations, transmission lines, and switching or substations. The system is used for the transmission of bulk power to load centers and large industrial users beyond the economical service range of the regular primary distribution lines.

b. Distribution System. A distribution system usually consists of primary distribution lines or networks, service transformer banks, and secondary lines or networks. The system is used to deliver power from generating stations or transmission substations to various points of use. While the term "distribution system" is normally used to designate the outside lines, they are frequently continued inside the buildings to power outlets for electrical equipment operation. These power outlets are distinct from the usual lighting circuits or "interior wiring."

3-20. Conventions

The conventions used on the electrical utility plans are symbols that indicate the general layout, units, related equipment and fixtures to be installed. Some common symbols you should be familiar with are shown in figures 3-24 and 3-25. You will find additional symbols which are in common use listed in Appendix B.

3-21. Materials and Fittings

The principal difference between the wiring materials for interior wiring and distribution lines is size. Larger sizes of wire are needed for greater current-carrying capacities. Spacing of wires and insulation is increased to give protection needed where high voltages are used. With the increase of wire sizes, larger conduits, outlet or junction boxes, insulators, connectors, fuses, switches, and circuit breakers are needed. Tables 3-2 through 3-5 list the dimensions and current-carrying capacity for the most frequently used wire types and sizes. Sizes are listed by American Wire Gauge (AWG) numbers. Current-carrying capacity is based on a maximum air temperature of 100%F. If the maximum air temperature is lower, add 3 percent for each 5%F; if higher, subtract 2 percent for each 5%F. You will generally find that unit electrical power devices have pertinent wiring and hook-up diagrams on the name plate or other prominent place.

Table 3-2. Characteristics of Bare Solid Copper Wire.

Size (AWG)	Diameter (inches)	Weight (pounds per 1,000 ft.)	Resistance (ohms per 1,000 feet at 20°C.)	Current-Carrying Capacity (amperes)
4/0	0.4600	639.8	0.04893	332
3/0	.4096	507.3	.06170	290
2/0	.3648	402.4	.07780	249
1/0	.3250	319.4	.09811	216
1	.2893	253.0	.1237	184
2	.2576	200.6	.1560	160
4	.2043	126.2	.2480	118
6	.1620	79.35	.3944	89
8	.1285	49.92	.6271	66

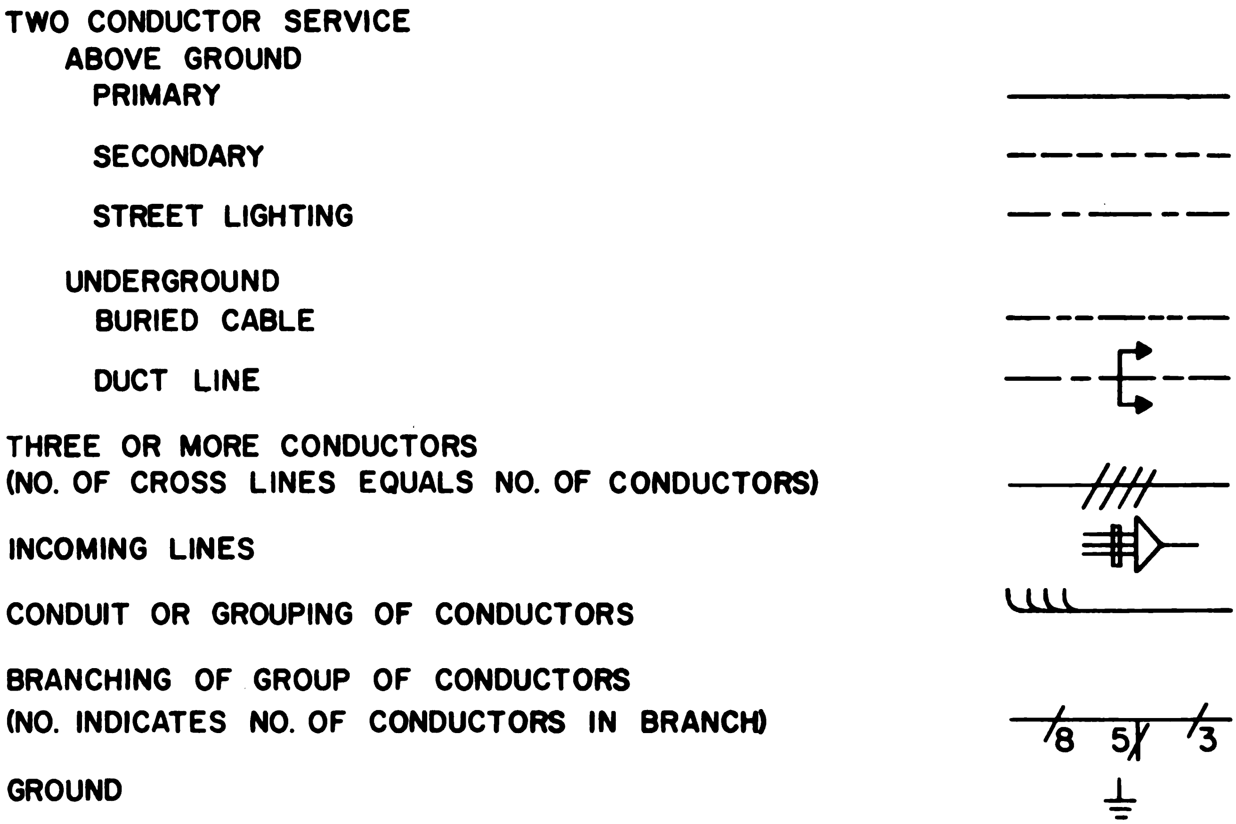


Figure 3-24. Line symbols for electric power distribution.

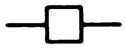
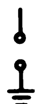
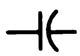
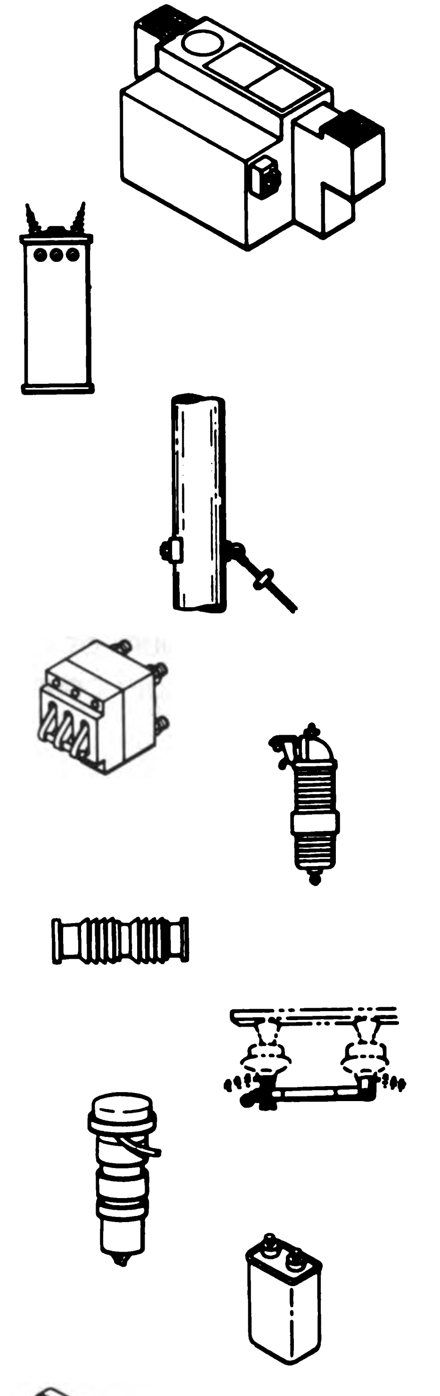
ITEM	SYMBOL
TRANSFORMER MANHOLE OR VAULT	TM
TRANSFORMER	
CONSTANT CURRENT TRANSFORMER	
POLE	
POLE WITH DOWN GUY WITH ANCHOR	
CIRCUIT BREAKER – AIR	 OR 
OIL	
FUSE	
SWITCH, MANUAL DISCONNECT	
LIGHTNING ARRESTER	
CAPACITOR (STRAIGHT LINE IS POSITIVE SIDE)	
INSTRUMENT OR METER	 OR 

ILLUSTRATION (S)



*A- AMMETER
AH- AMPERE HOUR METER
CRO- OSCILLOGRAPH
F- FREQUENCY METER
OHM- OHMMETER
OSC- OSCILLOGRAPH
PH- PHASE METER
REC- RECORDING
RD- RECORDING DEMAND METER
VAR- VARMETER
V- VOLTMETER
WH- WATT-HOUR METER
W- WATTMETER

Figure 3-25. Conventional symbols for electric distribution equipment.

Table 3-3. Characteristics of Weatherproof Solid Copper Wire.

Size (AWG)	Diameter over insulation (inches)		Weight (pounds per 1,000 ft.)		Resistance (ohms per 1,000 ft. at 20°C.	Current-carrying Capacity (amperes)
	Three-braid	Two-braid	Three-braid	Two-braid		
4/0	0.640	0.609	767	723	0.04893	368
3/0	.593	.562	629	587	.06170	318
2/0	.515	.500	502	467	.07780	274
1/0	.500	.468	407	377	.09811	237
1	.453	.422	316	294	.12370	203
2	.437	.390	260	239	.15600	176
4	.359	.328	164	151	.24800	130
6	.328	.296	112	100	.39440	98
8	.296	.250	75	66	.62710	71

Table 3-4. Characteristics of Bare Standed Copper Wire.

Size (AWG)	Diameter (inches)	Weight (pounds per 1,000 ft.)	Resistance (ohms per 1,000 ft. at 20°C.)	Wires in strand	Current Carrying Capacity (amperes)
4/0	0.5275	653.14	0.04997	19	338
3/0	.4644	512.07	.06293	7	294
2/0	.4134	406.98	.07935	7	252
1/0	.3684	322.39	.10007	7	219
1	.3279	255.45	.12617	7	186
2	.2919	202.50	.15725	7	161
4	.2316	127.40	.25000	7	119
6	.1836	80.10	.39767	7	90

Table 3-5. Characteristics of Weatherproof Stranded Copper Wire.

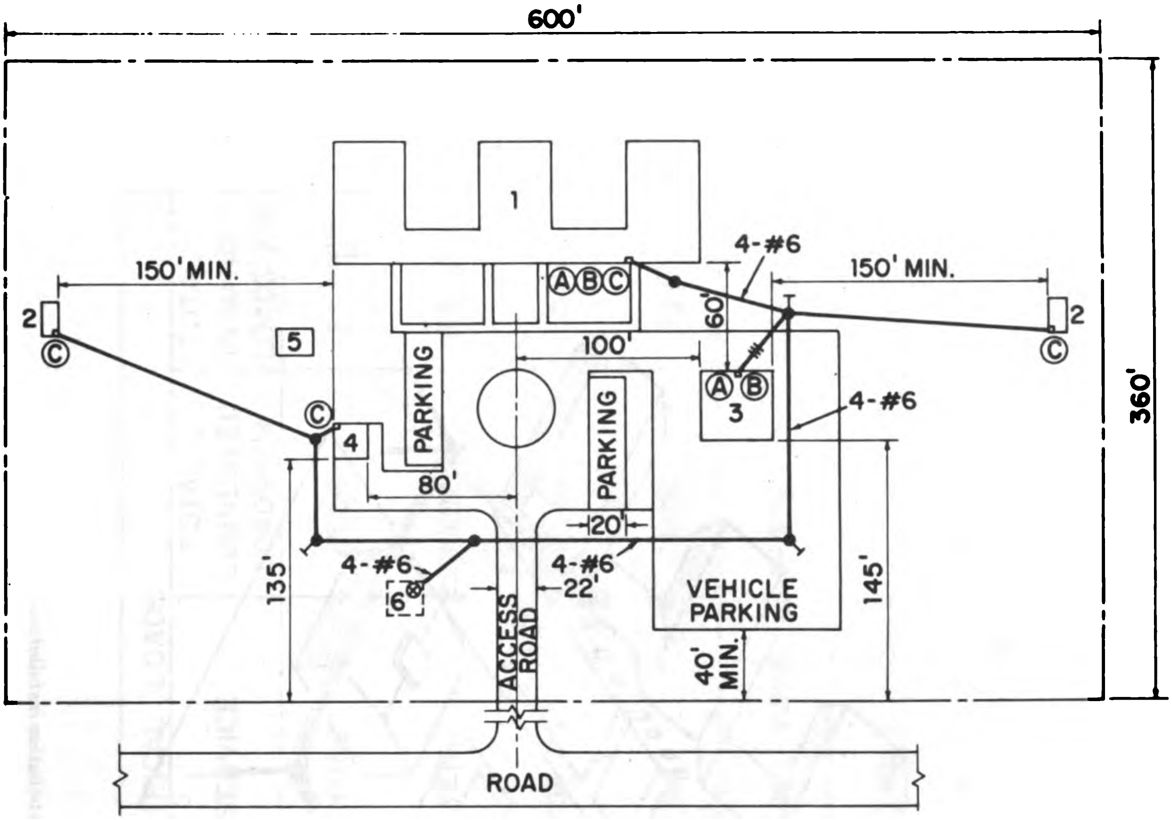
Size (AWG)	Diameter over Insulation (inches)		Weight (pounds per 1,000 ft.)		Wire in strand	Resistance (ohms per 1,000 ft. at 20° C.)	Current-Carrying Capacity (amperes)
	Three-braid	Two-braid	Three-braid	Two-braid			
4/0	0.812	0.687	800	745	19	0.04997	374
3/0	.734	.671	653	604	7	.06293	322
2/0	.687	.625	522	482	7	.07935	277
1/0	.640	.578	424	388	7	.10007	240
1	.593	.531	328	303	7	.12617	205
2	.531	.468	270	246	7	.15725	178
4	.437	.390	170	155	7	.25000	131
6	.406	.359	115	103	7	.39767	99

3-22. Electrical Distribution Plan

a. Figure 3-26 shows the electric distribution information normally provided on the utility plan for a small installation. The letter in circles at each building (Ⓐ, Ⓑ ,or Ⓒ) indicate the phase or phases to be connected to the building. Figure 3-27 is a pictorial view of the installation. You can see that only the total connected load need be listed for an installation this small. The utility layout for a larger installation would provide you with a more detailed tabulation of electrical loads for each load center as shown in figure 3-28. The tabulation shown is for the hospital layout shown in figure 3-2. The connected load is the total power requirement of all the items connected to the system. The demand load is the maximum amount of power which may be expected to be required at one time. Note that the demand load is less than the connected load for some services because not all units would be operated at one time, and the overall demand is less than the sum of the individual demand loads because the peak demand would not occur on all services at the same time.

b. In addition to the layout plans, detail drawings are used to show complex installations, standard connection methods and specifications. On figure 3-26, note that the number and size is specified for wiring on some spans (as 4-#6, for example), the number of wires is indicated by cross lines on the service drops (as to building number 3), and no specification is given on some spans (such as those to building number 4). A note on the drawing will normally specify the minimum wire size that can be used for those not specified. As shown in figure 3-24, two wires are used unless a larger number is designated. Figure 3-29 illustrates typical detail drawings for secondary power distribution connections. The first detail indicates the method of connecting service drops at a mast on a building. The lower details show pole connection for both small and large angle turns. Figure 3-30 illustrates the type of detail drawing used for complex installations. This type of drawing gives you information such as size and class of pole, dimension of cross arm, type and size of wire, height of platform, and transformer wiring.

c. The pole line installation detail (fig. 3-29) calls for a "class 5 pole." This refers to the USA Standard Institute classification which classifies poles according to the load resistance 2 feet from the top. Table 3-6 lists the characteristics of four types of poles for the various classes and sizes. When installing distribution lines you would also be responsible for proper tensioning and you would use tables which list sag for various span lengths and conditions. Tables 3-7 and 3-8 are typical of the types used for this purpose. Information of this type may be found in TM 5-765, Electrical Power Transmission and Distribution. When the stringing temperature or span length does not correspond to a value listed it will be necessary for you to interpolate between the nearest values given.



SITE & UTILITY LAYOUT
10,000 S.F. ADMINISTRATION HEADQUARTERS
SCALE NO. 13

ELECTRICAL NOTES
CONNECTED LOAD
10,000 S.F. ADMINISTRATION HQ ——11.31 KW

0 50' 100'
NO. 13

SCHEDULE OF FACILITIES			
NO.	ITEM	QTY	SIZE OR UNIT
	BUILDINGS		
1	ADMINISTRATION - HQ BUILDING - "E" SHAPE	1	10,000 S.F.
2	LATRINE - PIT TYPE	2	10'X 20'
3	SHOP - MOTOR REPAIR	1	40'X 40'
4	STOREHOUSE	1	20'X 20'
	OTHER CONSTRUCTION		
	ROAD - DBL LANE - 6" MACADAM	0.02	MILE
	ROAD - 9' SERVICE - 4" MACADAM		
5	SUMP - FIRE PROTECTION	1	10,000 GAL
	VEHICLE PARKING - (HARDSTANDS) 4" MACADAM	1	1,000 S.Y.
	SITE AREA	4.9	ACRES
6	GENERATOR BLDG. (IF REQ'D)		

Figure 3-26. Typical electric distribution plan.

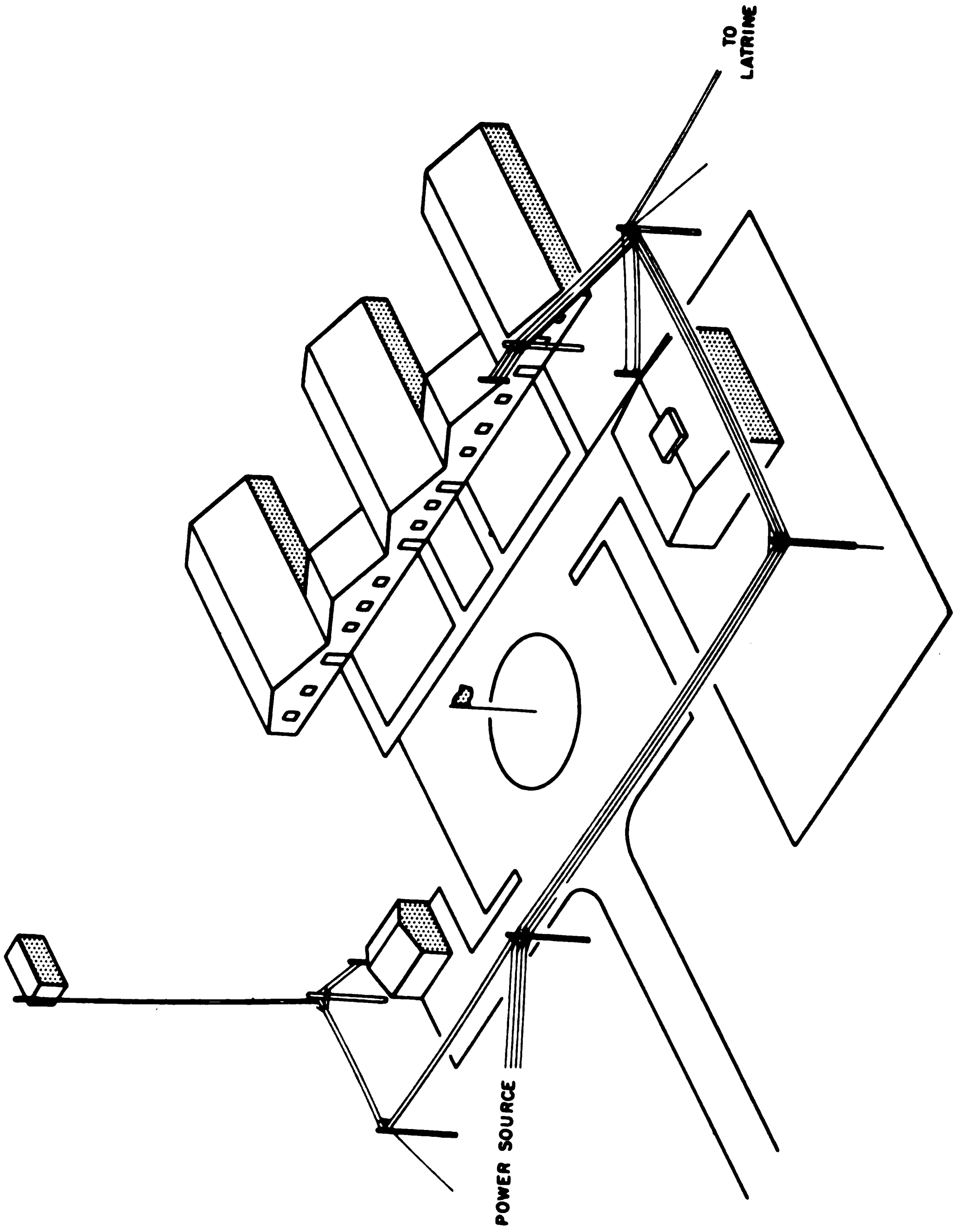
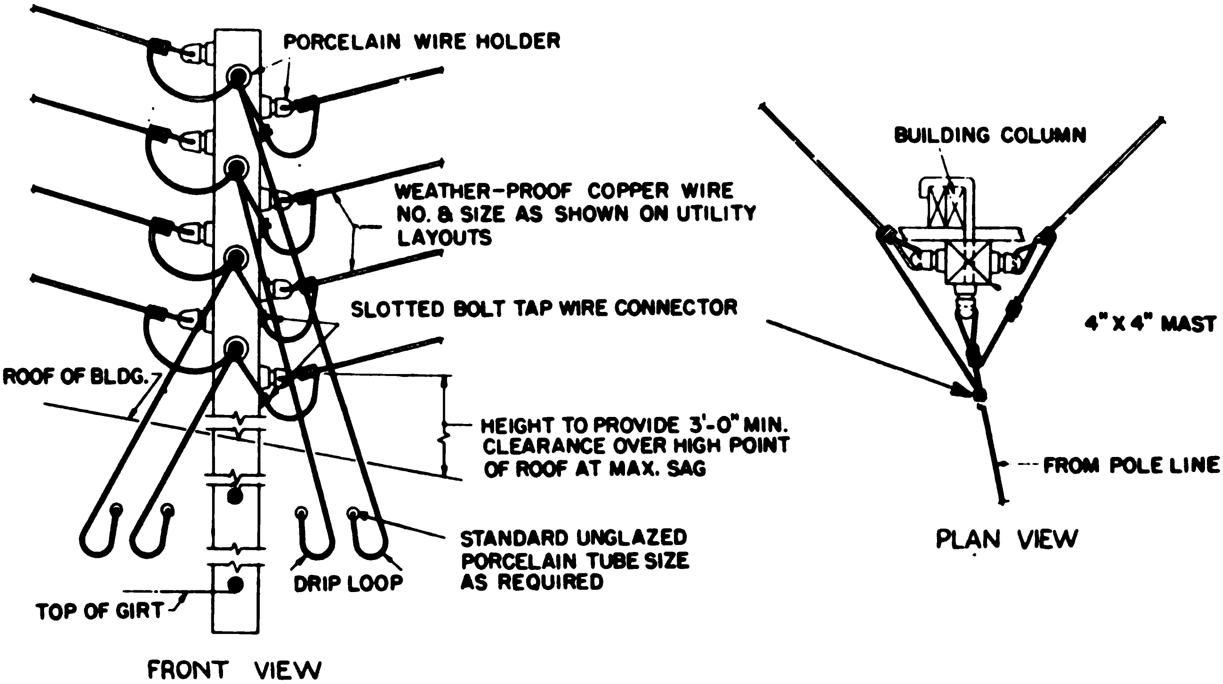


Figure 3-27. Typical electric distribution installation.

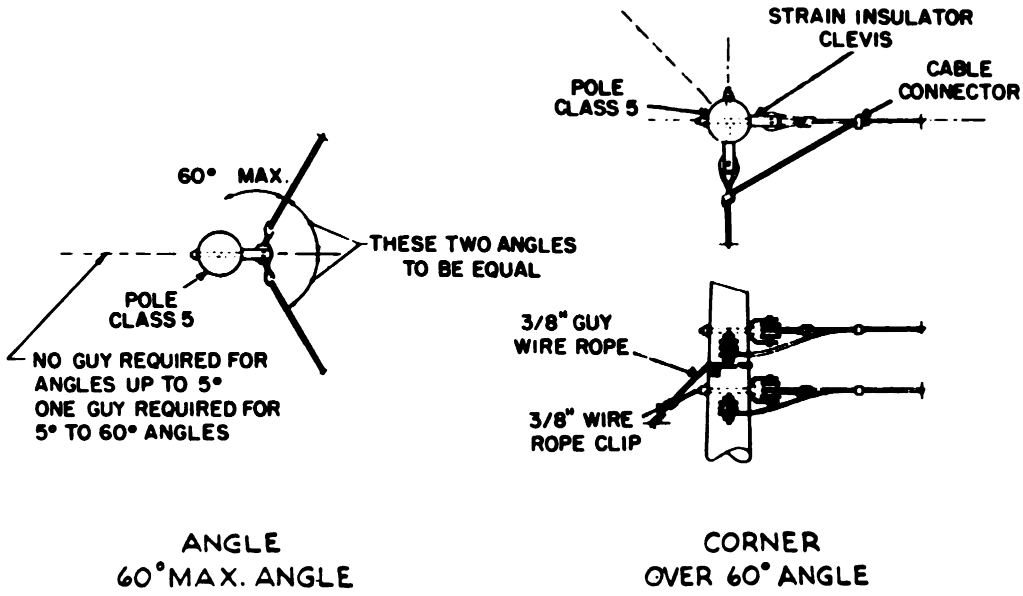
ELECTRICAL LOADS					
LOAD CTR	TYPE BUILDING	QTY	SERVICE	TOTAL CONNECTED LOADS-KW	TOTAL DEMAND LOADS-KW
	COVERED WALK	—			
	BKS 2	2	LIGHTING	25.56	25.56
	UTL 2	1			
	REC 2	3			
	LNX-SUP 2	1	POWER	88.82	88.82
	MESS 4	1			
	SPC A3	1			
	SURG-CMS	1	RECP. EST.	11.40	5.70
A	EE-PH 2	1			
	XRY-LAB-DN	1			
	DSP 3	1	X-RAY	18.00	18.00
	ADM-A&D 1	1			
	MOQ 2	1			
	UTL 8	1	GRAND TOTAL	143.78	138.08
	FOQ 2	1			
	WRD 2	4			
	UTL 3	2	OVERALL DEMAND		62.13
	SURG-CMS	1			
E	XRY-LB-DN	1	EMER. X-RAY	18.00	18.00
(EMER)	DSP 3	1	EMER. LIGHTING	1.18	1.18

Figure 3-28. Typical tabulation of electrical loads.



BUILDING MAST INSTALLATION

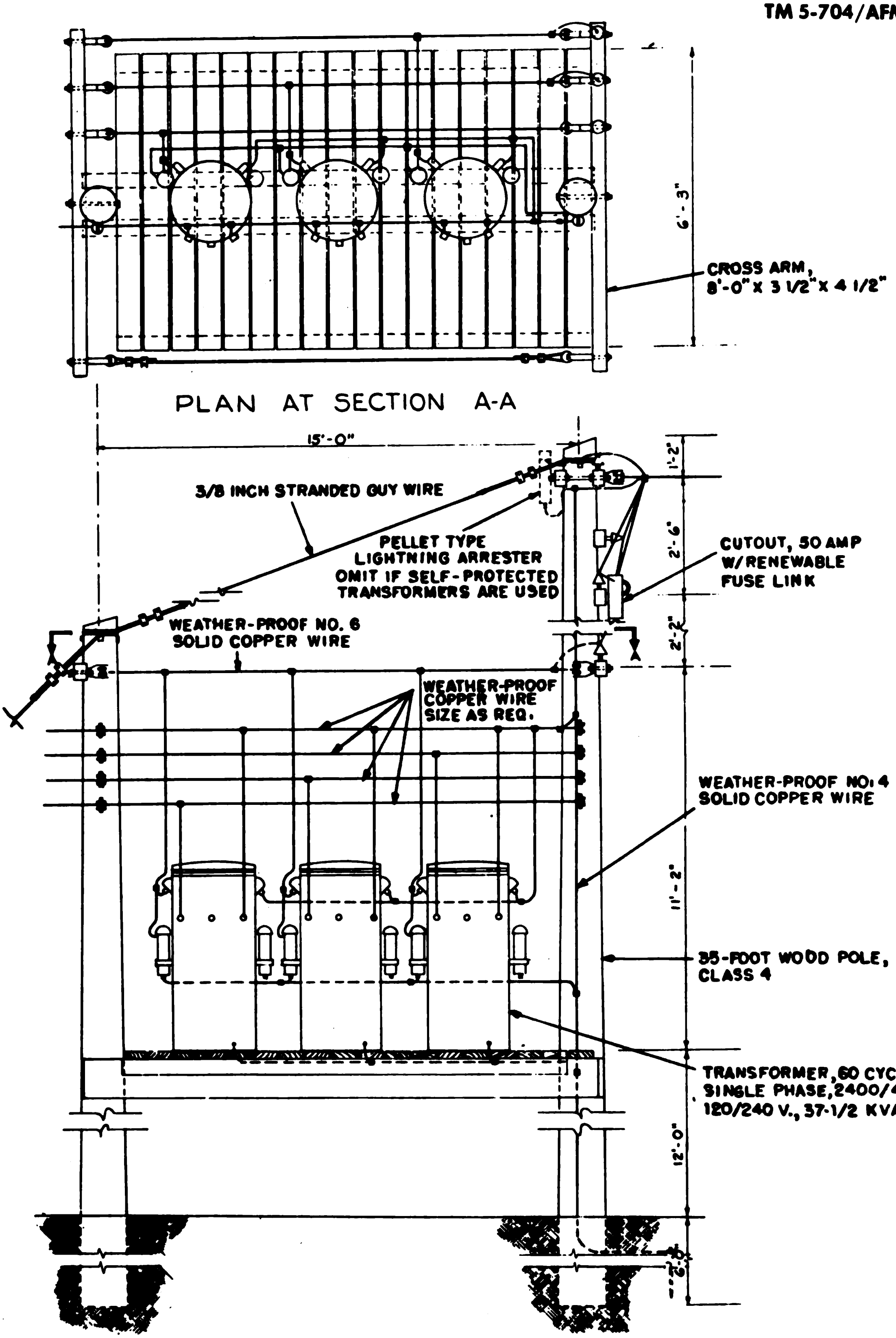
SCALE NO. 7



TYPICAL POLE LINE INSTALLATION

NO SCALE

Figure 3-29. Typical electrical secondary distribution details.



3 - 37½ KVA SINGLE PHASE TRANSFORMER INSTALLATION

Figure 3-30. Transformer installation on a platform.

Table 3-6. Classification of Wood Poles.

Pole length (feet)	USA class	Minimum circum-ference at top (inches)	Southern yellow pine: Circum. 6 ft. from butt (inches)	Southern yellow pine: Resisting moment (ft-lb)	Chestnut: Circum. 6 ft. from butt (inches)	Chestnut: Resisting moment (ft-lb)	Western red cedar: Circum. 6 ft. from butt (inches)	Western red cedar: Resisting moment (ft-lb)	Northern white cedar: Circum. 6 ft. from butt (inches)	Northern white cedar: Resisting moment (ft-lb)
25	1	27	34.5	80,200	37.0	80,200	38.0	81,000	43.5	78,200
25	2	25	32.5	67,000	34.5	65,000	35.5	66,100	41.0	65,400
25	3	23	30.0	52,700	32.5	54,300	33.0	53,100	38.0	52,100
25	4	21	28.0	42,860	30.0	42,700	30.5	41,900	35.5	42,500
25	5	19	26.0	34,320	28.0	34,720	28.5	34,200	32.5	32,660
25	6	17	24.0	26,900	25.5	26,230	26.0	25,970	30.0	25,640
25	7	15	22.0	20,800	24.0	21,870	24.5	21,730	28.0	20,840
30	1	27	37.5	102,900	40.0	101,200	41.0	101,700	47.5	101,500
30	2	25	35.0	83,700	37.5	83,500	38.5	84,300	44.5	83,700
30	3	23	32.5	67,000	35.0	67,850	35.5	66,100	41.5	67,800
30	4	21	30.0	52,700	32.5	54,300	33.0	53,100	38.5	54,800
30	5	19	28.0	42,800	30.0	42,700	30.5	41,000	35.5	42,800
30	6	17	26.0	34,320	28.0	34,720	28.5	34,200	33.0	34,100
30	7	15	24.0	26,900	26.0	27,820	26.5	27,500	30.5	26,690
35	1	27	40.0	124,900	42.5	121,400	43.5	121,800	50.5	122,300
35	2	25	37.5	102,900	40.0	101,200	41.0	101,700	47.5	101,300
35	3	23	35.0	83,700	37.5	83,500	38.0	81,000	44.0	80,900
35	4	21	32.0	64,000	34.5	65,000	35.0	63,350	41.0	65,400
35	5	19	30.0	52,700	32.0	51,900	32.5	50,700	38.0	52,100
35	6	17	27.5	40,800	30.0	42,700	30.5	41,900	35.0	40,700
35	7	15	25.5	32,380	27.5	32,920	28.0	32,410	32.5	32,800
40	1	27	42.0	144,600	45.0	144,100	46.0	143,800	53.5	145,800
40	2	25	39.5	120,300	42.5	121,400	43.5	121,600	50.0	118,700
40	3	23	37.0	98,900	39.5	97,500	40.5	98,100	46.5	95,500
40	4	21	34.0	76,700	36.5	77,600	37.5	77,900	43.5	78,200
40	5	19	31.5	60,900	34.0	62,200	34.5	60,700	40.0	60,500
40	6	17	29.0	47,600	31.5	49,400	32.0	48,400	37.0	48,100
40	7	15	27.0	38,400	29.5	40,000				
45	1.	27	44.0	166,300	47.5	169,600	48.5	168,500	56.0	166,800
45	2	25	41.5	139,400	44.5	139,300	45.5	139,100	52.5	137,400
45	3	23	38.5	111,400	41.5	113,000	42.5	113,400	49.0	111,800
45	4	21	36.0	91,100	38.5	90,300	39.5	91,000	45.5	89,500
45	5	19	33.0	70,200	36.0	73,200	36.5	71,800	42.0	70,200
45	6	17	30.5	55,400	33.0	56,800				
45	7	15	28.5	45,200	31.0	47,200				
50	1	27	46.0	190,600	49.5	191,900	50.5	190,200	58.5	190,100
50	2	25	43.0	155,200	46.5	159,000	47.5	158,300	55.0	158,000
50	3	23	40.0	124,900	43.5	130,800	44.5	130,100	51.5	129,500
50	4	21	37.5	102,900	40.0	101,200	41.0	101,700	47.5	101,800
50	5	19	34.5	80,200	37.5	83,300	38.0	81,000	44.0	80,900
50	6	17	32.0	64,000	34.5	65,000				
50	7	15	29.5	50,100	32.0	51,900				
55	1	27	47.5	209,100	51.5	216,000	52.5	213,600	61.0	215,600
55	2	25	44.5	172,000	48.5	180,500	49.5	179,100	57.5	180,500
55	3	23	41.5	139,400	45.0	144,100	46.0	143,800	53.5	145,300
55	4	21	39.0	155,800	42.0	117,200	42.5	113,400	49.5	115,300
55	5	19	36.0	91,100	39.0	94,900	39.5	91,000	48.0	92,400
55	6	17	33.5	73,400	36.0	73,800				

Table 3-7. Typical Sag Table for Primary Distribution Wiring.

Span (feet)	Sag for no. 6 AWG bare copper wire (inches) — Stringing temperature 30°F	60°F	90°F
50	2	3	3
60	3	4	5
70	4	6	7
80	6	7	9
90	8	9	11
100	9	12	14
110	12	14	17
120	14	17	20
130	16	20	23
140	18	23	26
150	21	26	30
160	24	30	34
170	27	34	39
180	31	38	44

Table 3-8. Sag Table for Secondary Distribution Wiring.

Wire size (AWG)	Stringing temp	Sag of hard or medium-drawn, covered copper wire for different span lengths (inches) — Frigid and temperate zones							Tropical zone						
		100'	125'	150'	175'	200'	250'	300'	100'	125'	150'	175'	200'	250'	300'
8	30°F	15.5	23	36	—	—	—	—	8.5	14	22.5	31	—	—	—
	60°F	18	27	40	—	—	—	—	12	18	27	36	—	—	—
	90°F	21.5	31	44	—	—	—	—	15.5	22.5	32	41	—	—	—
6	30°F	8.5	14	22	31	—	—	—	6	9	14	19.5	26	—	—
	60°F	12	18	27	36	—	—	—	8	12	18	24	32	—	—
	90°F	15.5	22.5	32	40	—	—	—	11	16	22.5	29	38	—	—
4	30°F	8.5	14	21.5	31	43	—	—	6.5	9	14	19	26	—	—
	60°F	12	18	27	36	48	—	—	8	12	18	24	32	—	—
	90°F	17	22.5	32	41	54	—	—	11.5	16	22	30	38	—	—
2	30°F	8.5	14	21.5	23.5	30	53	89	6.5	9	14	17.5	21	28	45
	60°F	12	18	27	30	36	60	96	8	12	18	22	26	34	52
	90°F	17	22.5	32	35	42	67	103	11.5	16	22	27	32	41	60
1	30°F	8.5	13.5	21	23	27	44	72	5.5	9	13.5	16.5	19	26	38
	60°F	12	18	26	29	33	52	80	8	12	18	21	24	31	45
	90°F	15.5	22.5	31	34	39	59	87	11.5	16	23	26	30	38	53
1/0	30°F	8.5	13.5	20.5	22.5	26	42	66	5.5	9	14	16.5	18	24.5	34
	60°F	12	18	26	28	32	49	72	8	12	18	21	23	30	41
	90°F	15.5	22.5	31	34	38	56	82	11.5	16.5	23	27	28	36	47
2/0	30°F	8.5	13.5	20	22.5	25	38	57	5.5	9	13.5	16	17.5	23	31
	60°F	12	18	25	28	31	46	66	8	12	18	20	22	28	37
	90°F	16	22.5	30	34	38	53	73	11.5	16	23	25	28	35	45
4/0	30°F	8.5	13.5	18.5	21	24.5	31	43	5.5	8.5	13.5	16	16.5	20.5	27
	60°F	12	18	24	27	30	38	50	8	12	18	19	21	25	32
	90°F	16	22.5	29	33	36	46	59	11.5	16	23	24.5	26	31	39

3-23. Self-Test

To verify your understanding of the previous material, answer the following questions. Answers are given at the end of the chapter.

1. Referring to figure 3-26, how many lines are to be connected to building number 3?
   a. 4
   b. 3
   c. 2
   d. 1

2. How many lines are to be connected to building number 1?
   a. 1
   b. 2
   c. 3
   d. 4

3. A 35-foot southern yellow pine pole which is 18-inches in circumference at the top and 31-inches in circumference 6-feet from the butt would be classified as:
   a. USA class 4
   b. USA class 5
   c. USA class 6
   d. USA class 7

4. Which of the following statements is true of the transformer installation shown in figure 3-30?
   a. All three transformer primaries are connected to the same supply phase.
   b. All three transformer secondary outputs are connected to the same phase.
   c. One 50-ampere fused cutout is required.

SECTION V. ELECTRICAL WIRING

3-24. Definition

The electrical wiring system in a building is the installation which distributes electrical energy. It is frequently referred to as the "interior wiring system" to distinguish it from the "electrical distribution system" which includes outside power lines and equipment for multi-building installations.

3-25. Nomenclature

The nomenclature of a building wiring system is divided into two principal parts according to function as follows:

a. Building Feeders and Subfeeders. A building feeder is a set of conductors supplying electricity to the building. A subfeeder is an extension of the feeder through a cutout, or switch, from one interior distribution center to another without branch circuits between.

b. Branches or Branch Circuits. A branch circuit is a set of conductors, feeding through an automatic cutout, or fuse, and supplying one or more energy-consuming devices such as lights or motors.

3-26. Materials and Fittings

A variety of materials and fittings are used in the installation of electrical wiring. Some common items you would use in theater of operations type construction are described in the following paragraphs.

a. Conductors. A conductor is any wire, bar, or ribbon, with or without insulation. It is usually made of copper because of the good electrical characteristics of that metal. The smallest size wire permitted for use in interior wiring systems is 14 AWG. The determination of the wire size to be used in circuits is dependent on the voltage drop coincident with each size. The size of the conductor used as a feeder to each circuit is also based on voltage drop. You would select the wire size so that the voltage drop from the branch circuit supply to the outlets will not be more than 3 percent. Table 3-9, which is based on an allowable 3 percent voltage drop, lists the wire sizes required for various distances between supply and load, at different load currents. Table 3-9 also lists the service-wire requirements and capacities. The minimum size for service-wire installation shall not be smaller than the conductors of a branch circuit and in no case smaller than No. 12. Service-wires must not only meet the voltage-drop requirements but also be inherently strong enough to support their own weight, plus any additional loading caused by nature (ice, branches, and so on). Symbols are used on electrical plans to show the routing and interconnection of wiring. The symbols that you will most frequently encounter are shown in figure 3-31. Wiring may be divided into four classes according to type of installation on the materials used.

(1) *Expedient wiring.* There are many applications where electrical wiring installations are needed for temporary use. One example is a forward area installation. A complete installation including knobs, tubes, cleats, and damage protection would require too much time and would be impractical. Consequently, expedient wiring used for temporary buildings and forward areas does not require the mounting and protective devices used in permanent installations. Generally, the wires are attached to building members with nails, and pigtail sockets are used for outlets. Soldering is omitted and friction tape is used as a protective covering on the connections. Fixture drops, preferably pigtail sockets, are installed by tapping their leads to wires and then taping the taps. The sockets are supported by the tap wires.

(2) *Open wiring.* Open wiring is the type most often used in theater of operation construction because of economy of materials and ease of making additions or alterations. Wiring is supported and separated on porcelain knobs, cleats and tubes or encased in a nonmetallic flexible casing called loom. Wiring exposed to possible mechanical damage is protected by running boards or railings. Taps or splices are supported.

Table 3-9. Minimum Wire Sizes.

Wire size for 120-volt single phase circuit															
			Wire size (AWG)												
			Distance one way from supply to load (ft.)												
Load (amps)	Minimum wire size (AWG)	Service wire size (AWG)	50	75	100	125	150	175	200	250	300	350	400	450	500
15	14	10	14	12	10	8	8	6	6	6	4	4	4		
20	14	10	12	10	8	8	6	6	6	4	4	2	2	2	2
25	12	8	10	8	8	6	6	4	4	4	2	2	2	1	1
30	12	8	10	8	6	6	4	4	4	2	2	1	1	0	0
35	12	6	8	6	6	4	4	4	2	2	1	1	0	0	2/0
40	10	6	8	6	6	4	4	2	2	2	1	0	0	2/0	2/0
45	10	6	8	6	4	4	2	2	2	1	0	0	2/0	2/0	3/0
50	10	6	8	6	4	4	2	2	2	1	0	2/0	2/0	3/0	3/0
55	8	4	6	4	4	2	2	2	1	0	2/0	2/0	3/0	3/0	4/0
60	8	4	6	4	4	2	2	1	1	0	2/0	3/0	3/0	4/0	4/0
65	8	4	6	4	4	2	2	1	0	2/0	2/0	3/0	4/0	4/0	
70	8	4	6	4	2	2	1	1	0	2/0	2/0	3/0	4/0	4/0	
75	6	4	6	4	2	2	1	0	0	2/0	3/0		4/0		
80	6	4	6	4	2	2	1	0	0	2/0	3/0	4/0	4/0		
85	6	4	4	4	2	1	1	0	2/0	3/0	3/0	4/0			
90	6	2	4	2	2	1	0	0	2/0	3/0	4/0	4/0			
95	6	2	4	2	2	1	0	2/0	2/0	3/0	4/0				
100	4	2	4	2	2	1	0	2/0	2/0	3/0	4/0				

(3) Armored cable wiring. Armored cable, commonly called BX, provides mechanical damage protection without additional protective provisions. All connections and splices are made within boxes, usually with wire nuts. Cables are run through holes in building members or supported by staples or straps. Nonmetallic sheathed cable is sometimes used for interior wiring also. Connections and supports are similar to armored cable wiring.

(4) Conduit wiring. Rigid or thin-wall conduit wiring provides the highest-quality, and most expensive installation. Rigid or thin-wall pipe is used to support and protect the conductors. Splices and taps are made at junction boxes or outlet boxes. Very little additional support or mechanical damage protection is required beyond that provided by the conduit.

b. Fixtures. The various switches and outlets, such as lighting fixtures and receptacles are shown by symbols on interior wiring plans. The most frequently encountered symbols are shown in figure 3-32.

c. Fuse Boxes and Circuit Breakers. Each branch circuit is connected to some protective device, usually at the point where electrical service enters the building. Sub-feeders and additional protective devices may be used for devices such as motors.

(1). Fuses. The device for automatically opeing a circuit when the current rises beyond the safety limit is technically called a cutout, but more commonly called a fuse. All circuits and electrical apparatus must be protected from short circuits or dangerous overcurrent conditions through correctly rated fuses. The cartridge type fuse is used for current rating above 30 amperes in interior wiring systems. The plug or screw type fuse is satisfactory for incandescent lighting or heating appliance circuits. On branch circuits, wherever motors are connected, time-lag fuses should be used instead of the standard plug or cartridge type fuse. These fuses have self-compensating elements which maintain and hold the circuit in line during a momentary heavy ampere drain, yet cut out

Table 3-9. Minimum Wire Sizes—continued.

Wire size for 220-volt three phase circuits															
	Minimum wire size (AWG)	Service wire size (AWG)	Distance one way from supply to load (ft.)												
			100	150	200	250	300	350	400	500	600	700	800	900	1000
15	14	12	14	12	10	8	8	8	6	6	6	4	4	4	2
20	14	10	12	10	8	8	6	6	6	4	4	4	2	2	2
25	12	8	10	8	8	6	6	6	4	4	2	2	2	2	1
30	12	8	10	8	6	6	6	4	4	2	2	2	1	1	0
35	12	8	10	8	6	6	4	4	4	2	2	1	1	0	0
40	10	6	8	6	6	4	4	4	2	1	1	1	0	0	2/0
45	10	6	8	6	6	4	4	2	2	2	1	0	0	2/0	2/0
50	10	6	8	6	4	4	2	2	2	1	0	0	2/0	2/0	3/0
55	8	6	8	6	4	4	2	2	2	1	0	2/0	2/0	3/0	3/0
60	8	6	6	6	4	2	2	2	1	0	0	2/0	3/0	3/0	4/0
65	8	4	6	4	4	2	2	2	1	0	2/0	2/0	3/0	3/0	4/0
70	8	4	6	4	4	2	2	1	1	0	2/0	3/0	3/0	4/0	4/0
75	6	4	6	4	2	2	2	1	0	2/0	2/0	3/0	4/0	4/0	
80	6	4	6	4	2	2	1	1	0	2/0	3/0	3/0	4/0	4/0	
85	6	4	6	4	2	2	1	0	0	2/0	3/0	4/0	4/0		
90	6	4	6	4	2	2	1	0	0	2/0	3/0	4/0	4/0		
95	6	4	6	4	2	1	1	0	2/0	3/0	3/0	4/0			
100	4	2	4	2	2	1	0	0	2/0	3/0	4/0	4/0			
125	4	2	4	2	1	0	2/0	2/0	3/0	4/0					
150	2	2	2	2	0	2/0	2/0	3/0	4/0						
175	2	1	2	1	0	2/0	3/0	4/0	4/0						
200	1	0	1	0	2/0	3/0	4/0	4/0							
225	0	0	0	0	2/0	3/0	4/0								
250	2/0	2/0	2/0	2/0	3/0	4/0									
275	3/0	3/0	3/0	3/0	3/0	4/0									
300	3/0	3/0	3/0	3/0	4/0										
325	4/0	4/0	4/0	4/0											

the circuit under short-circuit conditions. As you know, the heavy ampere demand normally occurs in motor circuits when the motor is started.

(2). *Fuse boxes.* As a general rule the fusing of circuits is concentrated at centrally located fuse or distribution panels. These panels are normally located at the service-entrance switch in small buildings or installed in several power centers in large buildings. The number of service centers or fuse boxes in the latter case would be determined by the connected power load.

(3) *Circuit breakers.* A circuit breaker is a protective switching device designed to open a current-carrying circuit under overload, high or low voltage, or short-circuit conditions and is sometimes substituted for the entrance switch in small building electrical installations. No fuses are used in the circuit breaker. The breaker is generally operated automatically although manual operation is provided for. As a rule, no detailed wiring diagram for a circuit breaker is shown on construction prints since such diagrams are to be found on the inside of the circuit breaker box cover.

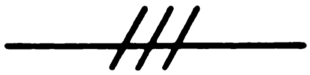
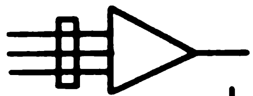
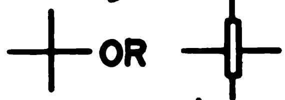
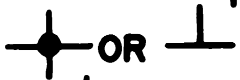
ITEM	SYMBOL
WIRING CONCEALED IN CEILING OR WALL	
WIRING CONCEALED IN FLOOR	
EXPOSED BRANCH CIRCUIT	
BRANCH CIRCUIT HOME RUN TO PANEL BOARD (NO. OF ARROWS EQUALS NO. OF CIRCUITS, DESIGNATION IDENTIFIES DESIGNATION AT PANEL)	
THREE OR MORE WIRES (NO. OF CROSS LINES EQUALS NO. OF CONDUCTORS TWO CONDUCTORS INDICATED IF NOT OTHERWISE NOTED)	
INCOMING SERVICE LINES	
CROSSED CONDUCTORS, NOT CONNECTED	
SPLICE OR SOLDERED CONNECTION	
CABLED CONNECTOR (SOLDERLESS)	
WIRE TURNED UP	
WIRE TURNED DOWN	

Figure 3-31. Line symbols for electrical wiring.

ITEM	SYMBOL	ILLUSTRATION
SWITCHES –		
SINGLE POLE SWITCH	S	
DOUBLE POLE SWITCH	S_2	
THREE WAY SWITCH	S_3	
SWITCH AND PILOT LAMP	S_P	
CEILING PULL SWITCH	(S)	
PANEL BOARDS AND RELATED EQUIPMENT		
PANEL BOARD AND CABINET		
SWITCHBOARD, CONTROL STATION OR SUBSTATION		
SERVICE SWITCH OR CIRCUIT BREAKER	OR OR	
EXTERNALLY OPERATED DISCONNECT SWITCH		
MOTOR CONTROLLER	OR MC	
MISCELLANEOUS –		
TELEPHONE		
THERMOSTAT	(T)	
MOTOR	(M)	

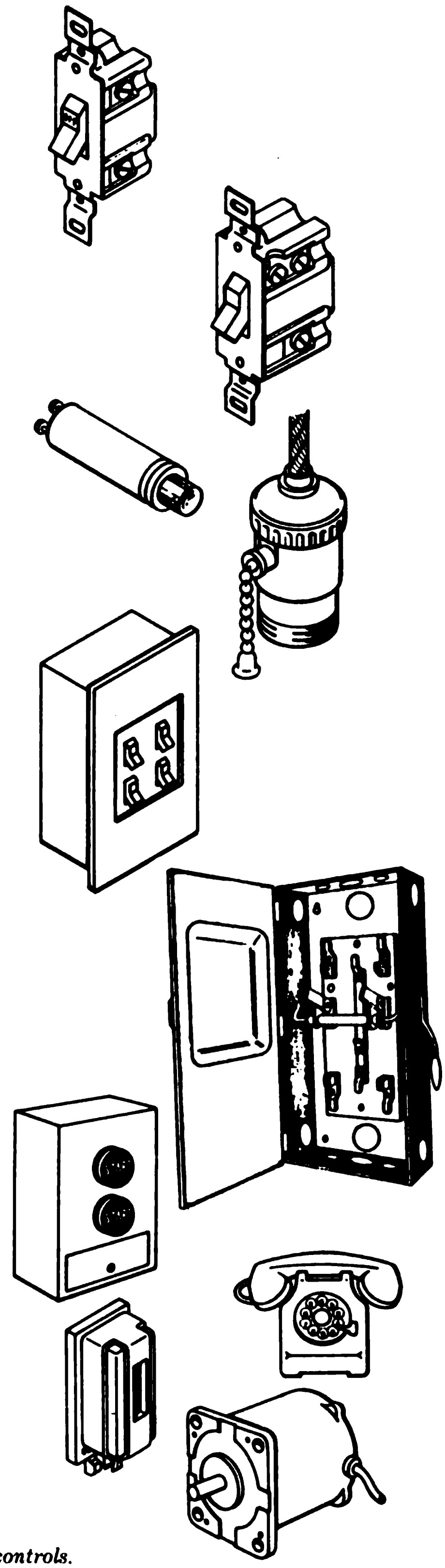
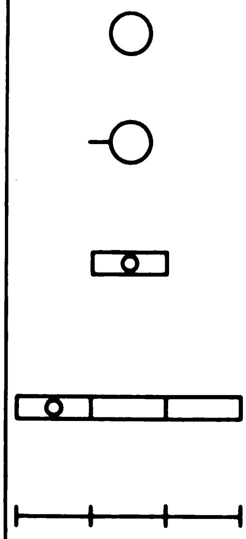
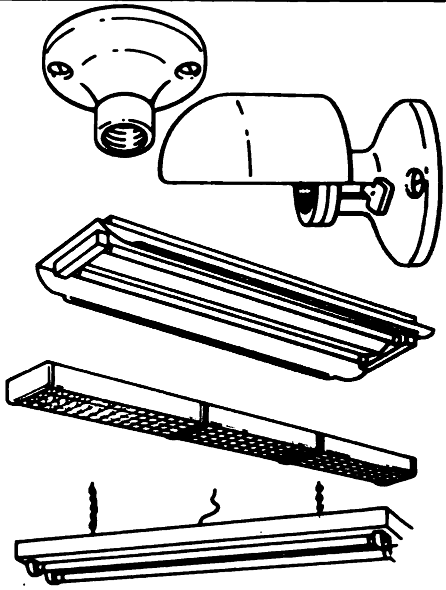


Figure 3-32. Symbols for electrical fixtures and controls.

ITEM	SYMBOL	ILLUSTRATION
LIGHTING OUTLETS*-		
CEILING		
WALL		
FLUORESCENT FIXTURE		
CONTINUOUS ROW FLUORESCENT FIXTURE		
BARE LAMP FLUORESCENT STRIP		

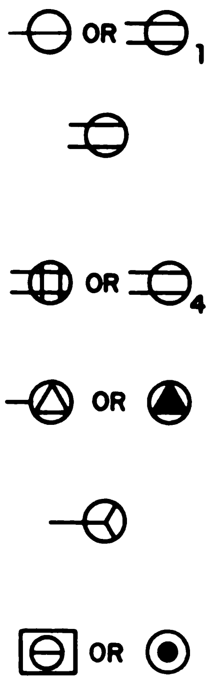


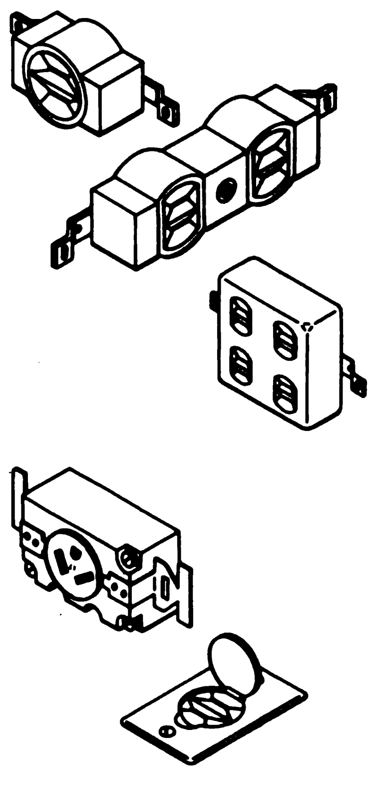


* LETTERS ADDED TO SYMBOLS INDICATE SPECIAL TYPE OR USAGE

J- JUNCTION BOX R- RECESSED
L- LOW VOLTAGE X- EXIT LIGHT

ITEM	SYMBOL	ILLUSTRATION
RECEPTACLE OUTLETS**-		
SINGLE OUTLET	OR	
DUPLEX OUTLET		
QUADRUPLEX OUTLET	OR	
SPECIAL PURPOSE OUTLET	OR	
20-AMP, 250-VOLT OUTLET		
SINGLE FLOOR OUTLET (BOX AROUND ANY OF ABOVE INDICATES FLOOR OUTLET OF SAME TYPE)	OR	





** LETTER G NEXT TO SYMBOL INDICATES GROUNDING TYPE

Figure 3-32. Symbols for electrical fixtures and controls - continued.

3-27. Electrical Plans

a. Electrical plans show what items are to be installed, their approximate location, and the circuits to which they are to be connected. A typical electrical plan for a post exchange is shown in figure 3-33. The plan shows that the incoming service consists of three No. 8 wires and that two circuit-breaker panels are to be installed. Starting at the upper left, the plan shows that nine ceiling lighting outlets and two duplex wall outlets are to be installed in the bulk storage area. The arrow designated "B2" indicates that these outlets are to be connected to circuit 2 of circuit-breaker panel B. Note that three wires are indicated from this point to the double home-run arrows designated "B1, B2". These are the hot wire from the bulk storgae area to circuit 2 of panel, B, the hot wire from the administration area to circuit 1 of panel B, and a common neutral. From the double arrowhead, these wires are run to the circuit breaker panel without additional connections. This run is shown at the left side of figure 3-34, which is typical of the ceiling wiring diagrams provided for open wiring of medium or extreme complexity. Note that the entire installation is not shown in figure 3-34. The diagram shows the splices, support and insulator arrangements used. Note that this is a physical drawing rather than symbolic one, so each line represents a single wire rather than a pair of conductors as in the plan. A note calls out a circuit breaker installation detail at the point where the wires are down to the circuit-breaker panel, and the arrowheads on the leader from the note show the direction from which the circuit breaker installation detail is drawn. The circuit breaker panel installation detail (figure 3-35) shows the installation arrangement for the circuit breakers, including grounding, splices and connections to the incoming service. Note that the circuit breaker panels are placed 5 feet, 6 inches from the floor line. You can also see that a ¾-inch pipe driven 8 feet into the ground is used for grounding the No. 8 ground wire.

b. In some installations alternate outlets are connected to different circuits so that half the lighting may be turned on at one time and only part of the service will be out if a circuit breaker is tripped. For these plans, the circuit identification (A1, B1, etc.) is noted alongside each fixture.

c. Wiring plans are not usually provided for the fixtures themselves. If the connections are not obvious, diagrams are normally supplied with the device. A three-way switch circuit, which enables the control of a single outlet from two locations, is shown in figure 3-36. On an electrical plan you will find the three-way switch is indicated by the symbol S3.

3-28. SELF-TEST

To check your understanding of electrical plans, answer the following questions about the installation shown in figures 3-33 through 3-35. Answers are given at the end of the chapter.

1. The lighting outlets in the radio repair area are connected to which circuit?

a. A1
b. A2
c. A1 or A2
d. Not specified

2. The center row of lighting outlets in the store area is connected to which circuit?

a. A5
b. A6
c. A5 or A6
d. Not specified

3. The right hand row of lighting outlets in the store area is connected to which circuit?

a. A3
b. A4
c. A3 or A4
d. Not specified

4. What is the total connected load on circuit A6?

a. 300 watts
b. 800 watts
c. 5.15 KW
d. 6.35 KW
e. Cannot be determined from plan.

5. Circuit A5 shares a common neutral wire with which circuitfl

a. A3
b. A4
c. A6
d. None

6. What is the estimated total load to be connected to the receptacle?

a. Not given
b. 15 amperes
c. 1.2 KW
d. 6.35 KW

3-29. Answers to Self-Test Questions

a. Paragraph 3-5 (water supply)

1. b
2. c
3. c
4. d
5. c
6. d
7. c

b. Paragraph 3-10 (plumbing)

1. Three-quarter inch tile pipe
2. Eight
3. At the hose bib location indicated as detail 11-X
4. A two-inch circulation pipe hidden by the tank
5. ¾-inch x ½-inch bushing.
6. False
7. False

c. Paragraph 3-17 (sewerage system)

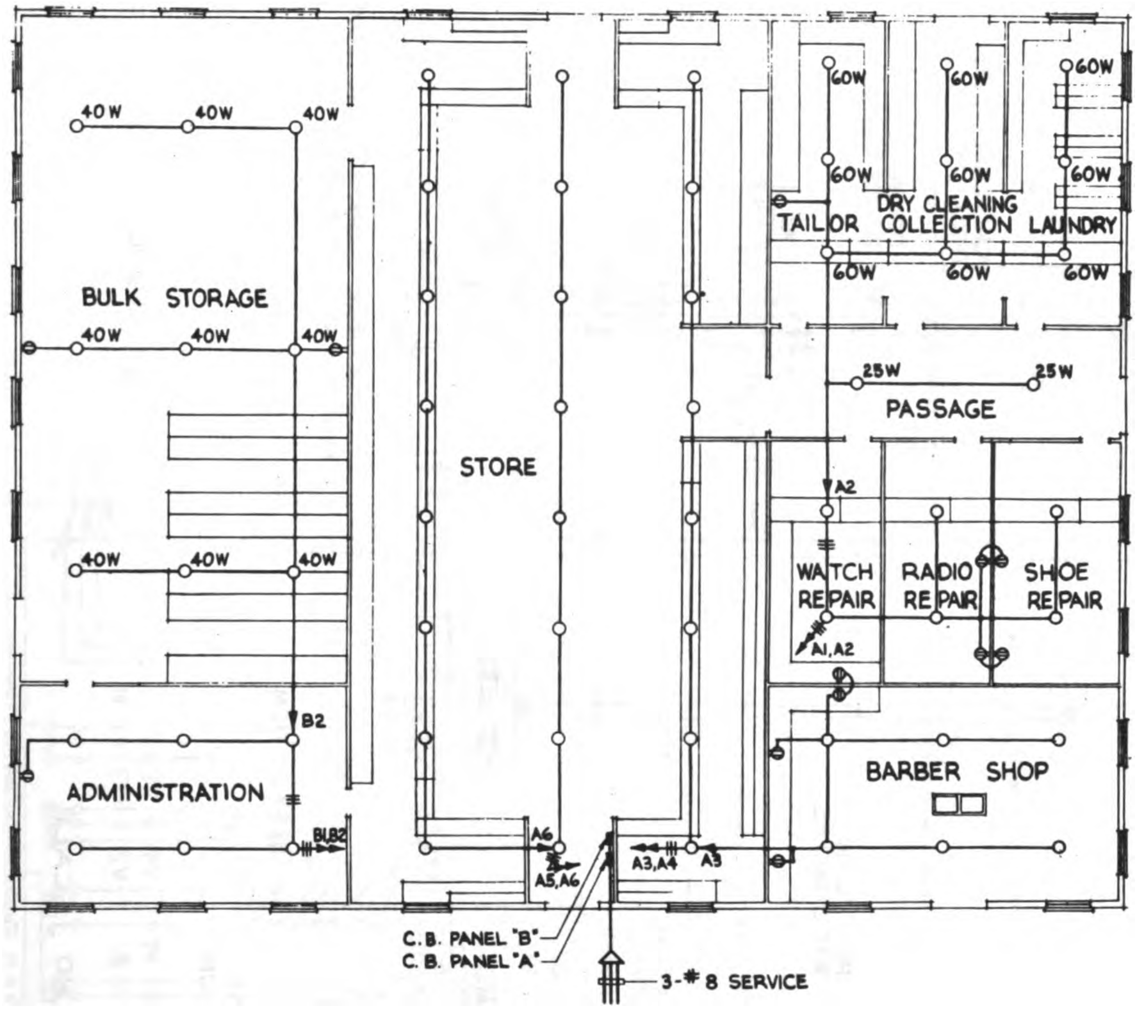
1. c
2. True
3. d
4. c
5. b

d. Paragraph 3-23 (electrical distribution system)

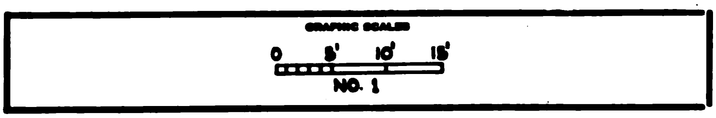
1. b
2. d
3. c
4. c

e. Paragraph 3-28 (interior wiring)

1. a
2. a
3. b
4. b
5. c
6. c



ELECTRICAL PLAN
SCALE NO. 1



ELECTRICAL NOTES

CONNECTED LOAD	
LIGHTING	5.15 KW
RECP EST	1.20 KW
TOTAL	6.35 KW

1. UNLESS OTHERWISE NOTED ON PLAN ALL LAMPS TO BE 100W.
2. ALL 40, 60 & 100W LAMPS TO HAVE 8" CONICAL SHADES.

Figure 3-33. Typical electrical plan.

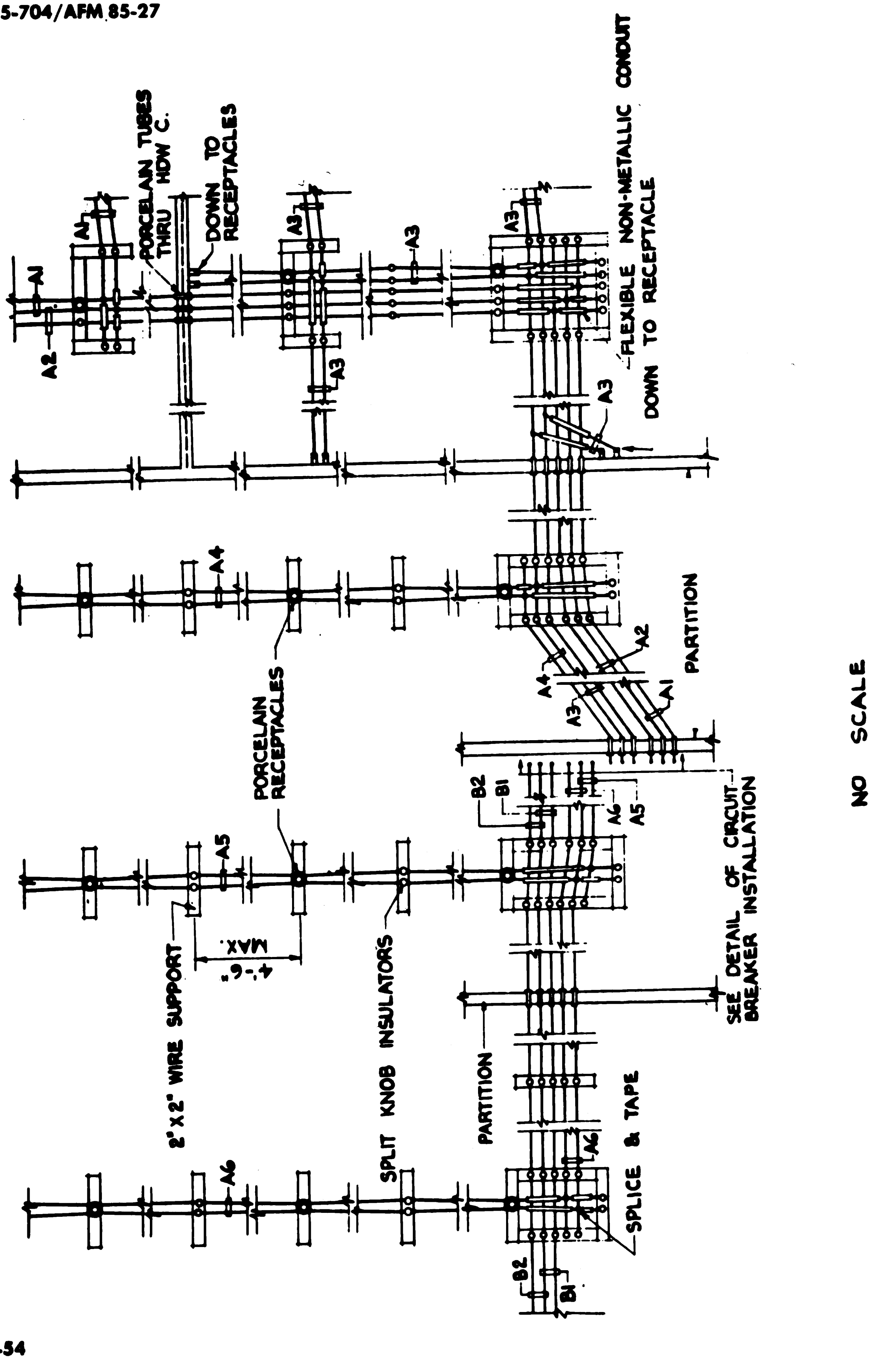


Figure 3-34. Typical ceiling wiring diagram.

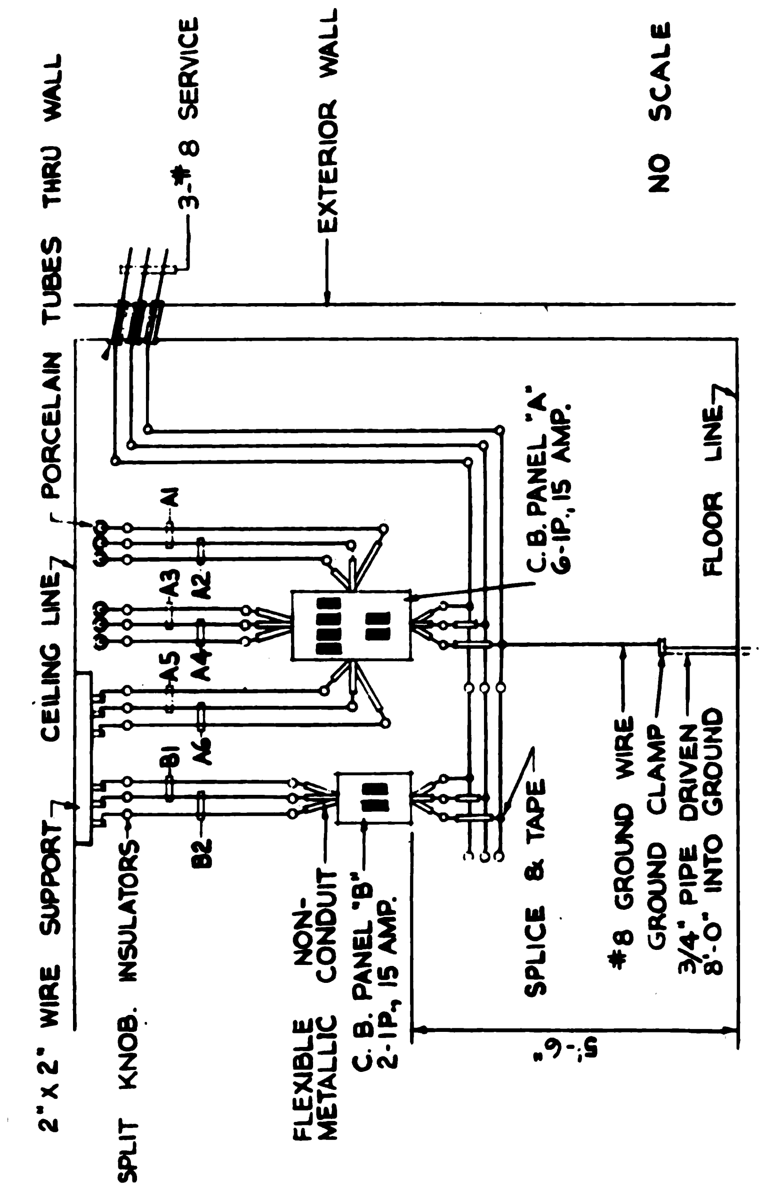


Figure 3-35. Typical circuit breaker panel installation detail.

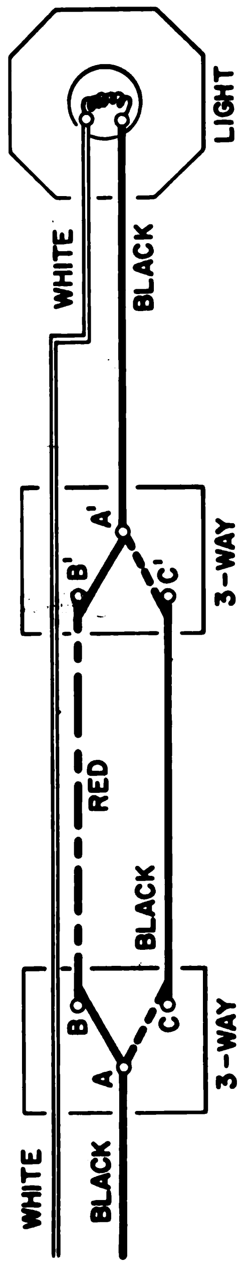


Figure 3-36. Wiring diagram for a three-way switch.

CHAPTER 4

READING HEATING, AIR-CONDITIONING AND REFRIGERATION PLANS

Section I. HEATING

4-1. Introduction

a. Heating is the operation of a system to transmit heat from a point of generation to the place or places of use. To read the plan of a heating system, you should be familiar with the basic elements of heating systems and their graphic representation. However, the design of heating installations for buildings is one of the more complex fields of construction and you will find that the variations of the basic type of heating systems are numerous.

b. Heating systems are classified according to the medium used to carry heat from the point of generation to the point of use. Steam or hot-water and warm-air systems are the classes in common use. Hot-water heating is used extensively. Warm-air heating is probably the most familiar to you because it is used in almost all semipermanent construction and most barracks.

c. Because of the variations, any discussion of heating systems must be limited. For the same reason, you will find a legend on heating prints covering the symbols used thereon. You should learn the symbols for some of the more common types of piping, fittings, traps, valves, heat-power apparatus, and fluid-power diagram symbols, Some of the symbols you should be familiar with are presented in figures 4-1 through 4-5. Additional symbols are listed in appendix B.

4-2. Hot-Water Heating Systems.

Circulation of water which has been heated at a central source through pipes to radiators or convectors and back to the heating unit describes a hot-water heating system. Usually, you will find that a pump is used to keep the water circulating, gravity systems are seldom used. There are two classes of hot water systems: the one-pipe system and the two-pipe system.

a. One-Pipe System. The one-pipe system (fig. 4-6) is the simplest type of hot water installation. Hot water circulates through a single main and through each radiator in turn. You can see that the water reaching the last radiator will be cooler than the water in the first. In order to obtain the same amount of heat from each radiator in a one-pipe system, each radiator must be larger than the one before it with the last radiator being the largest of all. It is apparent that the one-pipe system is adequate for very small installations only.

b. Two-Pipe System. You will find that the disadvantages of the one-pipe system are largely offset in a two-pipe system. Figure 4-7 shows a two-pipe hot-water heating system. You can see that the hot water from the heater unit goes directly to the five radiators via the main, tees, and elbows. The cooler water leaving the radiators goes back to the heater unit via separate return piping, elbows, and tees.

c. Hot-Water Heating System Plans. You may find a separate plan for the hot-water heating system or you may find that the plan of the heating system is incorporated with the hot and cold water and sewer lines on the plumbing plan. A plan of a hot-water heating system shows you the layout of units, piping, accessories, and connections. A typical hot-water heating system plan is illustrated in figure 4-8. (Figure 4-8 also shows electrical utility which you may disregard for this discussion.) You can see that the location of the boiler, circulating pump, and compression tank are noted. Follow the supply piping from the boiler and you can see that the one-pipe system is used; however, the hot water will flow in two directions or loops. Each loop contains two radiators. The second radiator in each loop is larger than the first. The plan also notes that the piping is 1 inch and is located in the crawl space.

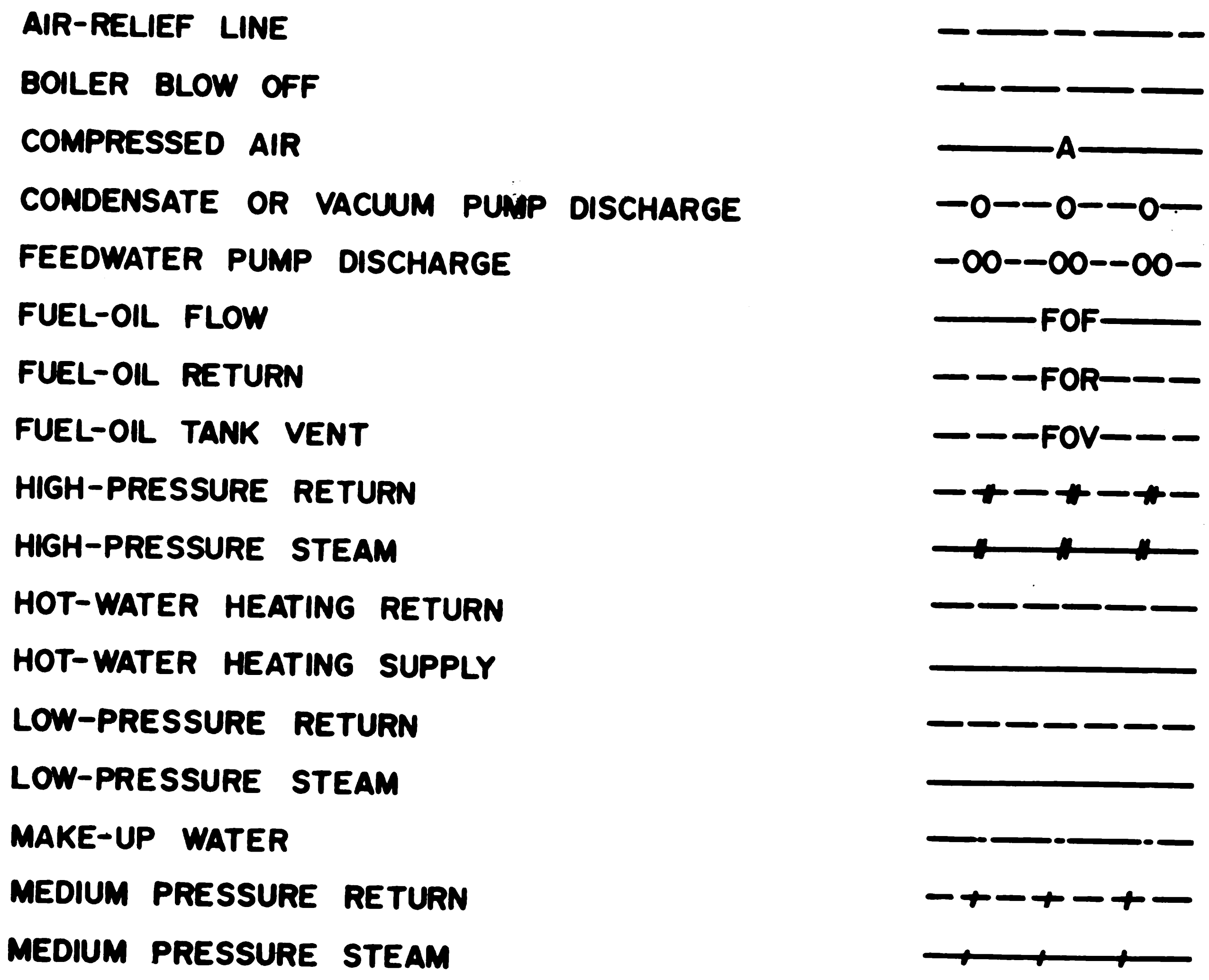


Figure 4-1. Heating piping symbols.

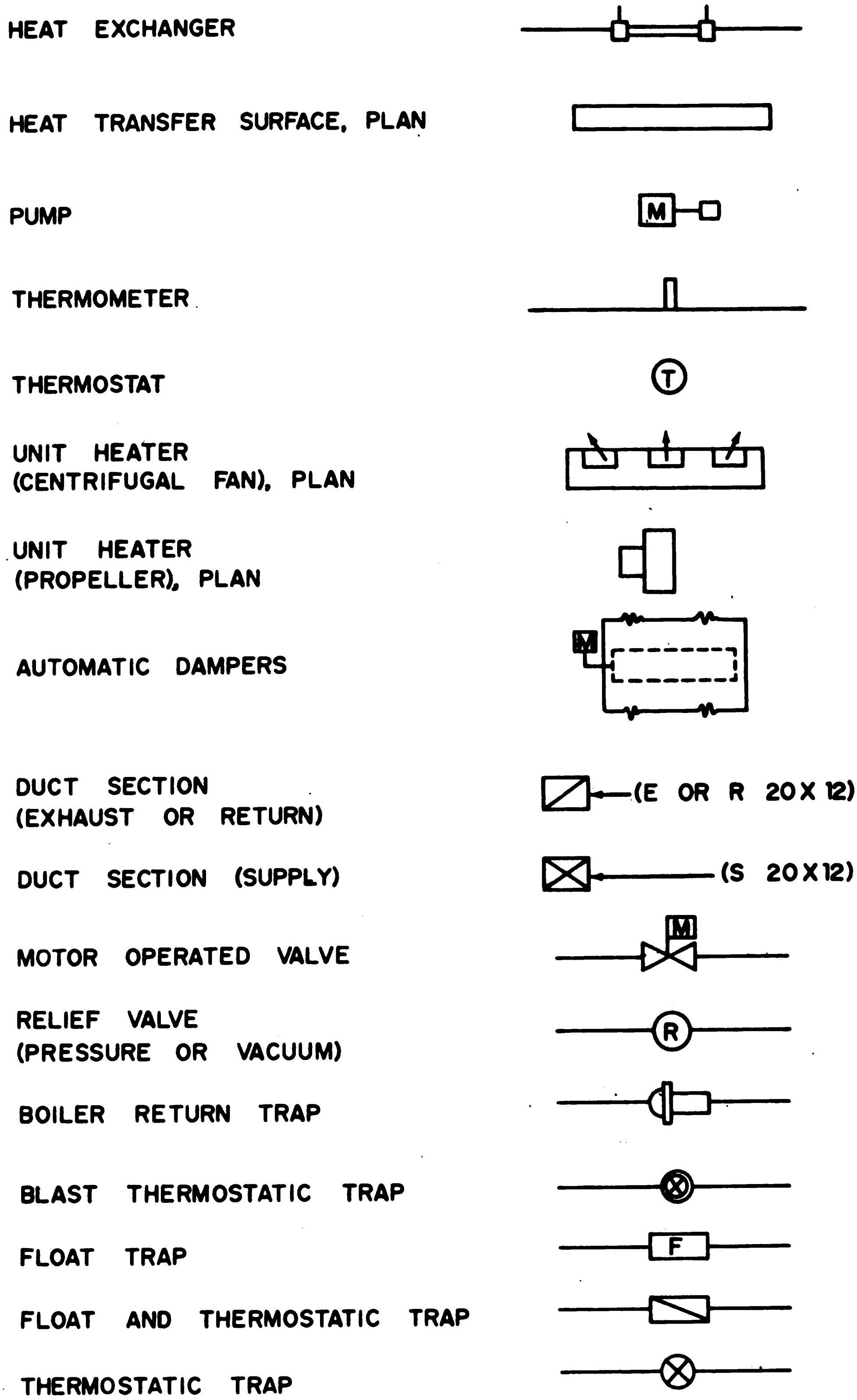


Figure 4-2. Heating symbols.

LOUVER OPENING

SUPPLY OUTLET CEILING (INDICATE TYPE)

SUPPLY OUTLET WALL (INDICATE TYPE)

VANES

VOLUME DAMPER

CAPILLARY TUBE

COMPRESSOR

CONDENSER, AIR COOLED, FINNED, FORCED AIR

CONDENSING UNIT, AIR COOLED

CONDENSING UNIT, WATER COOLED

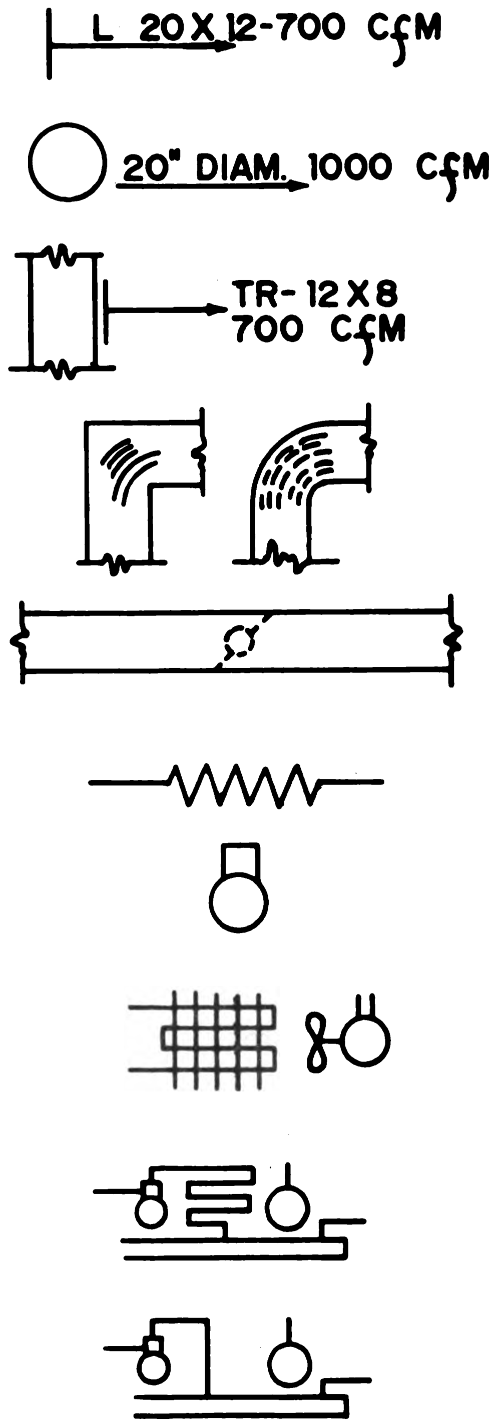
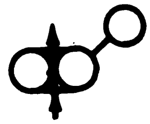
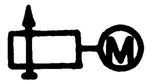


Figure 4-3. Ventilating symbols.

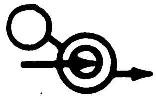
ROTARY COMPRESSOR



RECIPROCATING COMPRESSOR

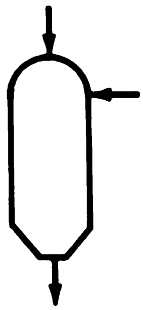


CENTRIFUGAL COMPRESSOR

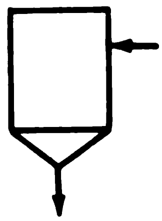


M-MOTOR
T-TURBINE

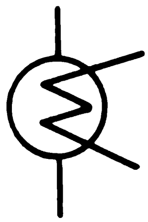
BAROMETRIC CONDENSER



JET CONDENSER



SURFACE CONDENSER



COOLER OR HEAT EXCHANGER

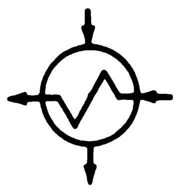


Figure 4-4. Heat-power symbols.

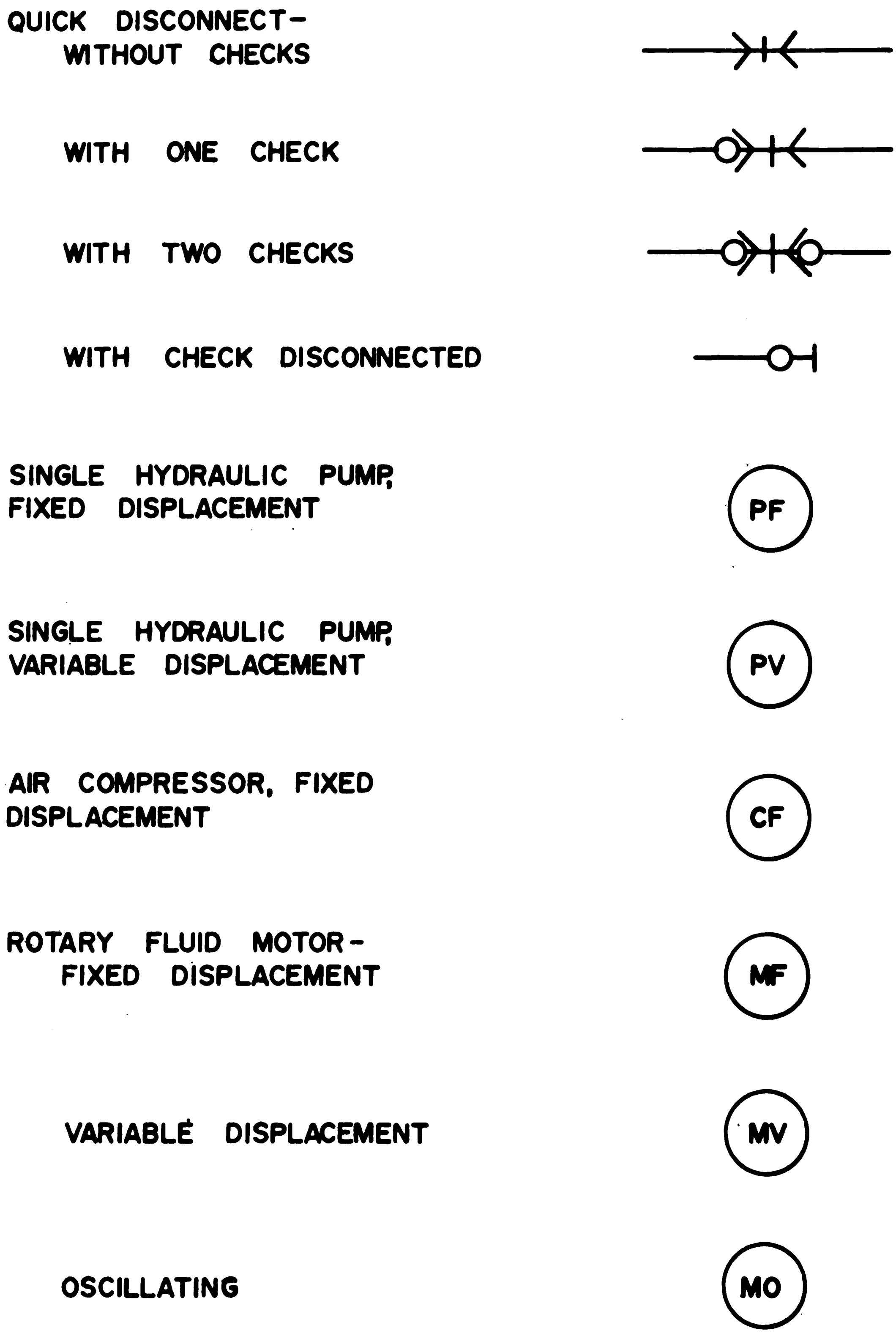


Figure 4-5. Fluid-power diagram symbols.

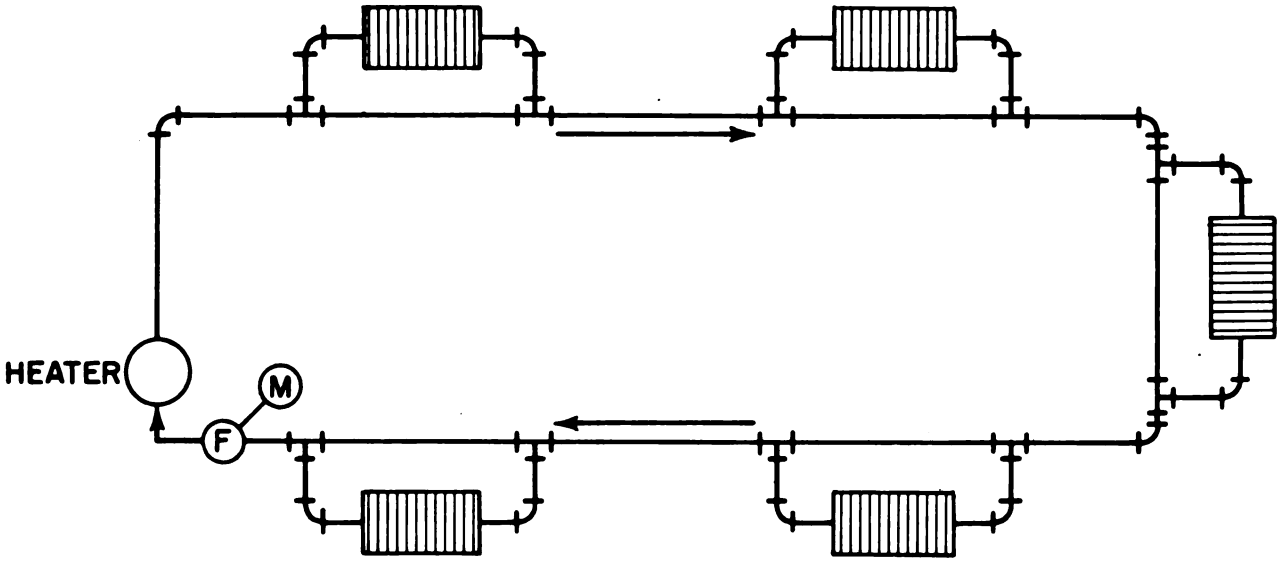


Figure 4-6. One-pipe hot-water heating system diagram.

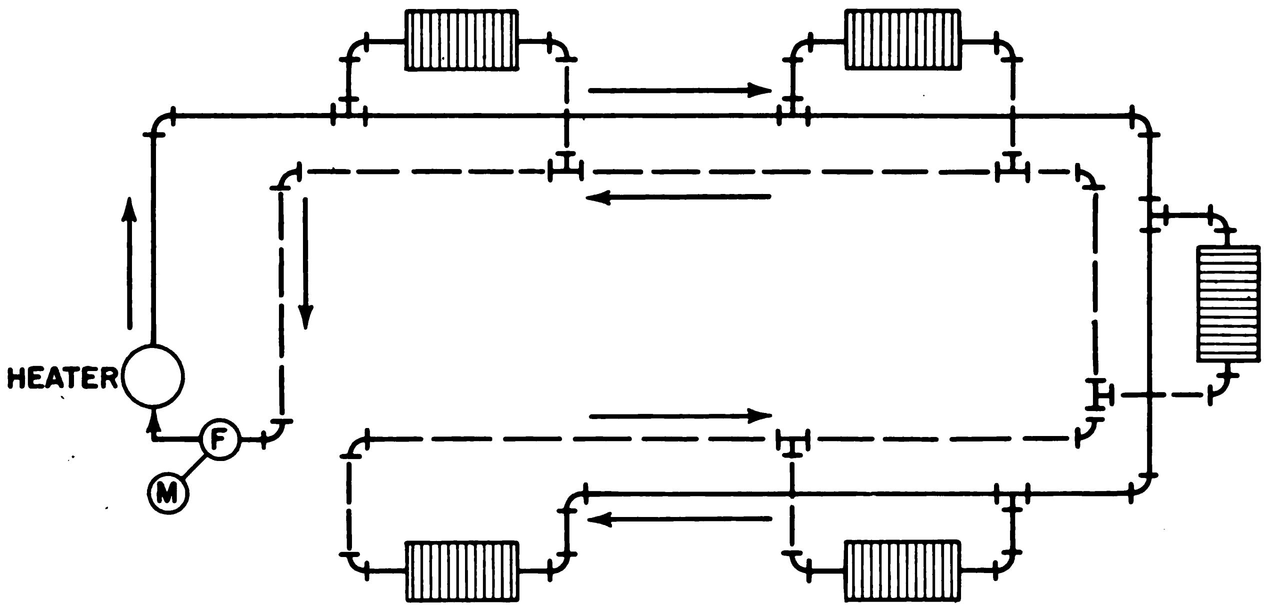


Figure 4-7. Two-pipe hot-water heating system diagram.

4-3. Warm-Air Heating Systems

Distribution of heated air through a duct system describes a warm-air heating system. Usually, gas-fired or oil-fired furnaces are used to heat the air, but you may also heat air by passing the air through steam—or water-heated coils.

a. Typical Warm-Air System. A warm-air heating system consists of a furnace, a bonnet, warm-air supply ducts and registers, return (cold) air registers and ducts, and a fan or blower for forced circulation. A warm-air heating system is shown in figure 4-9. Note the bonnet above the heat plant where the heated air is collected for distribution to the various rooms. The warm air is distributed from the bonnet through the supply ducts and discharged into the room through registers or grills. You can see that the ducts are rectangular in shape and that the warm-air register is installed in the ceiling. (Some other systems might have round ducts and warm-air registers in the wall.) The air, after circulating through the room and losing heat, is returned to the heat plant via the cold-air return registers and ducts. The return air register is placed in the wall just below the window and the return air duct is installed in the crawl space. The warm-air distribution via the branch ducts to the other rooms of the building would be the same as the examples.

b. Design Principles. The comfort zone concept is the basis for all heating design. The comfort zone is defined as the horizontal area from the top of an average man's head to his knees. It is apparent that if the air from the supply-registers were blown directly on a person, he would be very uncomfortable. To avoid this, the registers are placed either above or below the comfort zone, i.e. high on the wall or in the baseboard. Warm-air systems are laid out so that the warm air from the registers is directed at the cold exterior walls. Therefore the warm-air registers are placed on interior walls or ceilings. The registers for the cold air return are always located at baseboard height. The reason for this location is probably obvious to you. Cold air is heavy and collects at the floor of the room thus the registers located in the baseboard collect the air. The cold air is motivated through the return ducts to the furnace for reheating and recirculation. Furnace location is also important to proper warm-air heating. It is good design policy to locate the furnace room centrally in the building plan to equalize duct lengths. In addition, the main (trunk) ducts should run above a central corridor to equalize branch duct lengths to individual rooms. See figure 4-10 for illustrations of some of the common rectangular-duct connections. Illustration 1 is a typical warm-air bonnet with two main supply ducts. Two possible elbow connections are shown in [2] The split tee [3] is used to direct the flow of air on the warm side of the system. On the cold air return, the straight tee [3] may be used. Truck duct takeoffs are shown in [4] and [5] In the double branch connection, less air is present in the main duct after some of the air has been channeled into branch ducts. Therefore, the size can be reduced after the connection. The single branch connection shows two methods of reduction. The first occurs at the connection in a horizontal direction; the second is effected by a vertical reduction in depth. In both double and single branch takeoffs the branch connections form a natural air scoop to encourage airflow in the desired direction. A boot fitting from branch to stack, the stack terminating at a warm-air register is illustrated in [6] figure 4-10. Using a boot is one method of changing the shape of a duct without changing its equivalent cross section area or constricting the flow of air.

c. Warm-Air Heating System Plans. Warm-air ducts are indicated in the heating plan by solid lines. Cold-air return ducts are indicated by dashed lines. See figure 4-11. Note that all the duct sizes are given. The duct sizes are given with the horizontal or width dimension listed first. The second dimension gives the depth of the duct which is not shown. On the plan, you can locate the warm-air registers and obtain the sizes. When ceiling registers (diffusers) are used, the neck dimensions are shown on the plan (as in figure 4-11). When wall or baseboard registers are used, face dimensions are given. The height of wall registers above finished floor line would be given to you in the notes on the plan. Cold-air return registers are shown recessed into the wall. The face dimensions of the return register are noted adjacent to the symbol.

4-4. Self-Test

To verify your understanding of the previous material, answer the following questions. Answers are given at the end of the chapter.

1. What type of pipe fittings are indicated in figures 4-6 and 4-7?

2. Does figure 4-9 show a reduction in the supply duct?

3. Referring to figure 4-11, what is the size of the return duct branch from the cold-air register?

4. What is the largest size duct required in the system depicted in figure 4-11?

5. Referring to figure 4-8, how many radiators are indicated?

6. What type of radiators are designated?

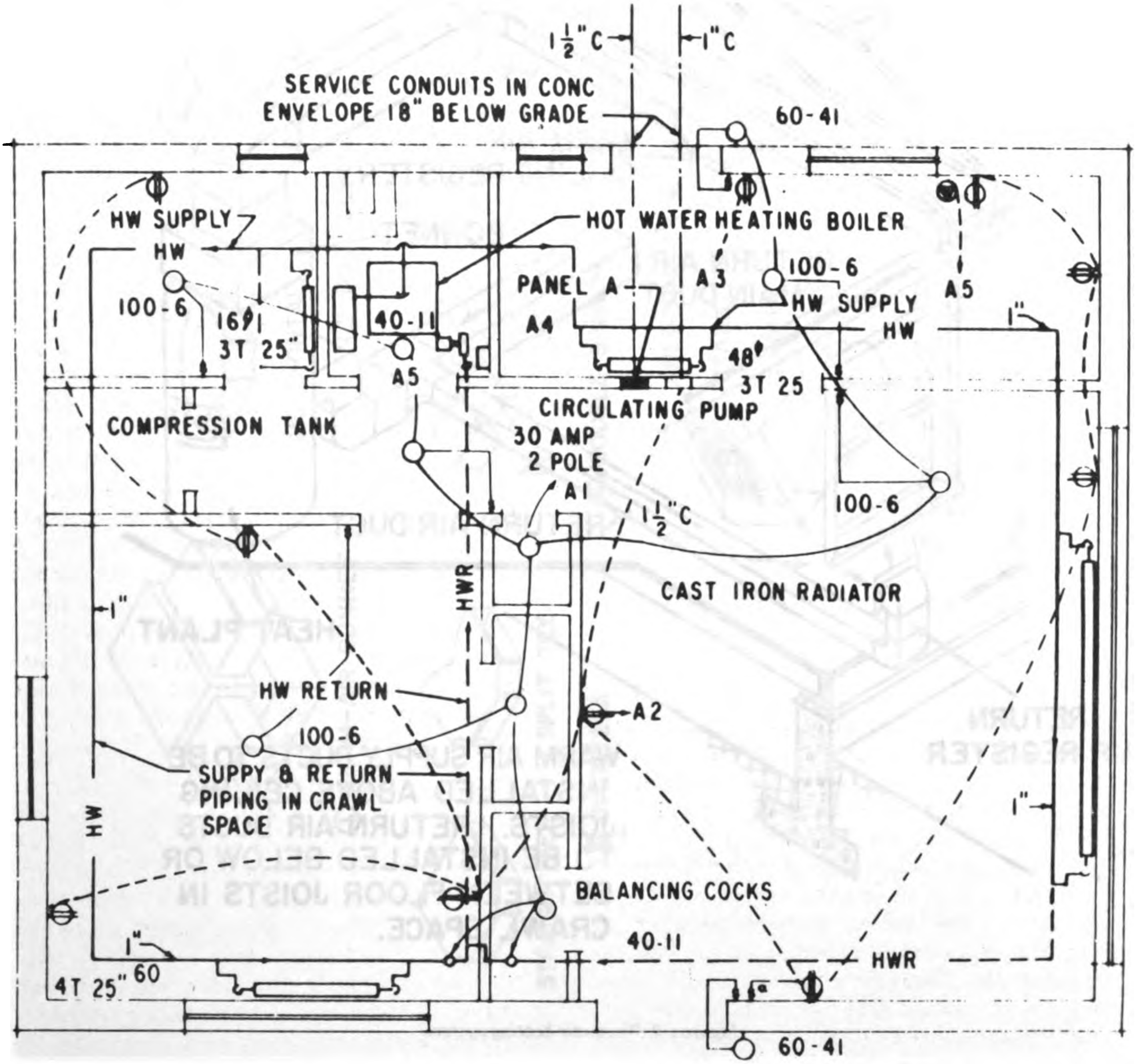


Figure 4-8. Typical hot-water heating system plan.

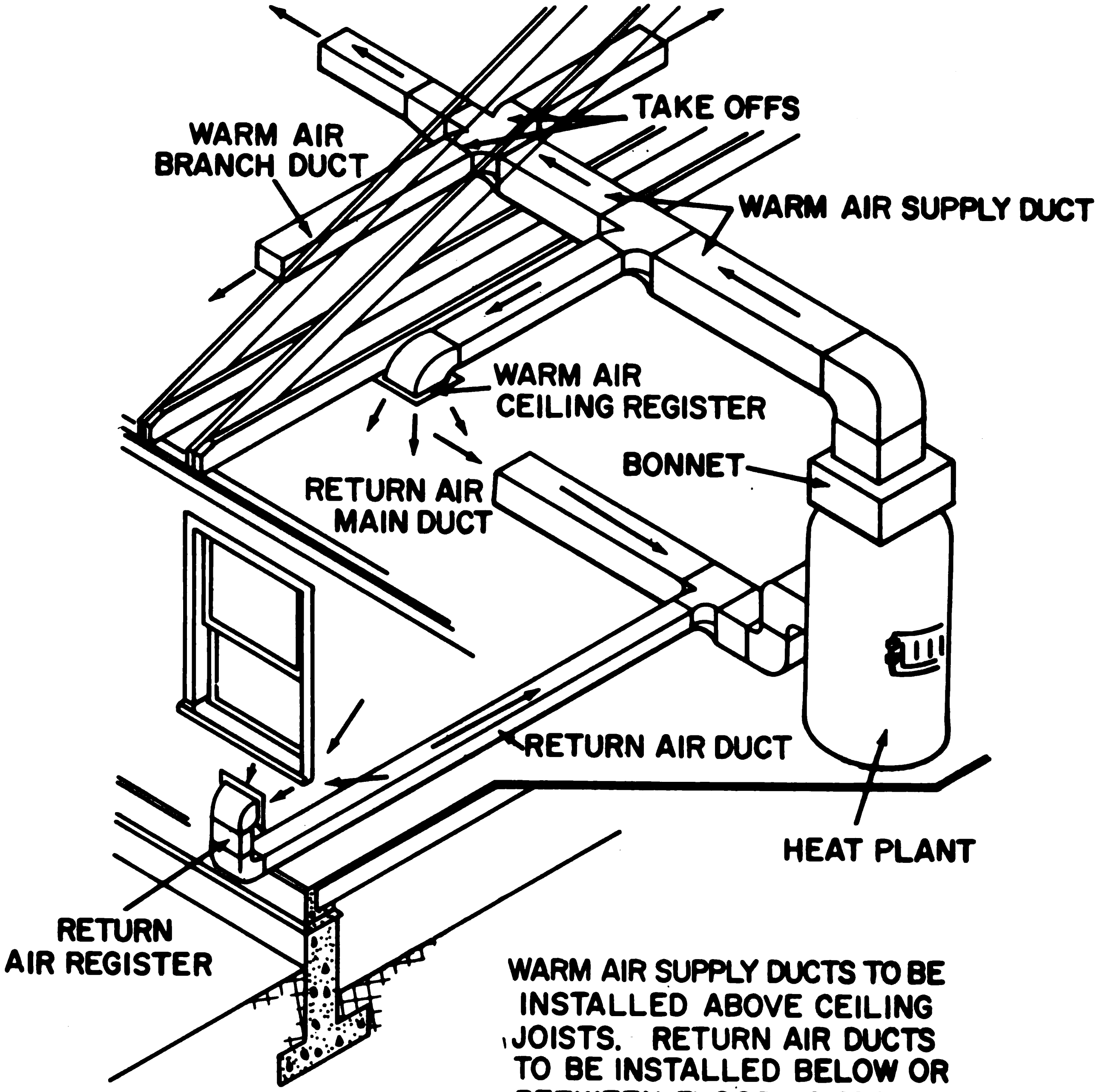


Figure 4-9. Warm-air heating system.

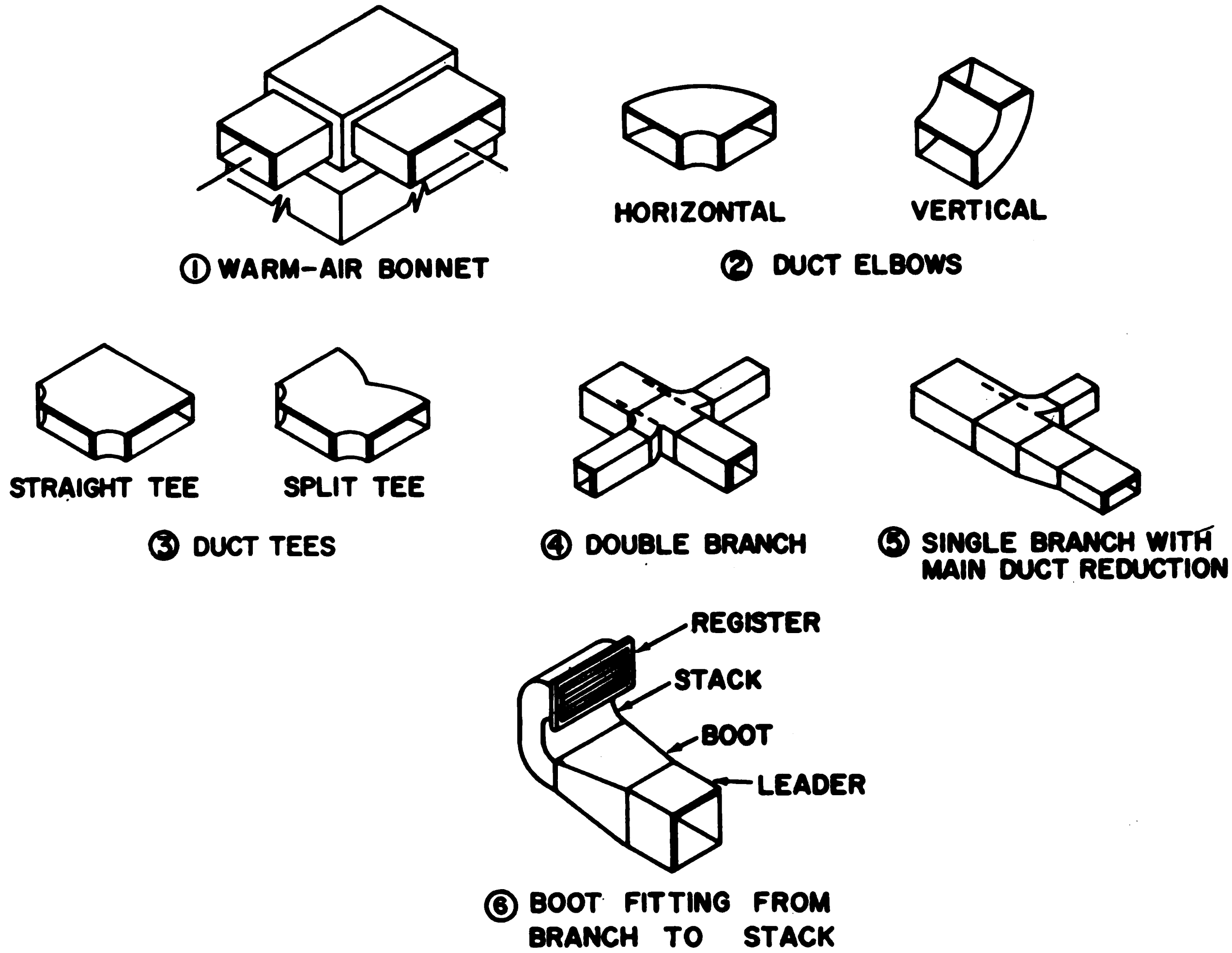


Figure 4-10. Duct connections.

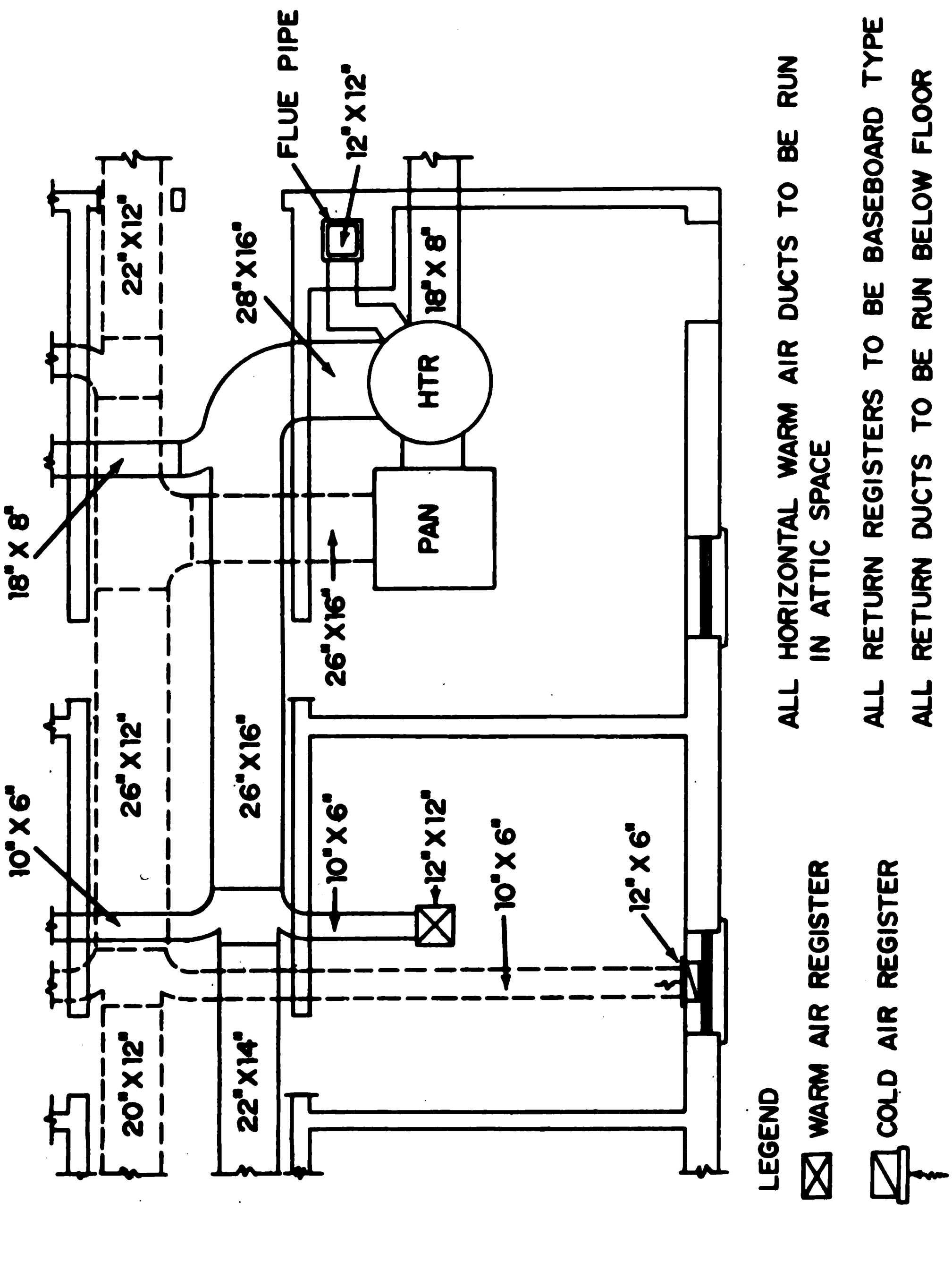


Figure 4-11. Typical warm-air heating system plan.

SECTION II. AIR CONDITIONING

4-5. Introduction

Air conditioning, as defined by the American Society of Heating and Air-Conditioning Engineers, is "the process of treating air so as to control simultaneously its temperature, humidity, cleanliness and distribution to meet the requirements of the conditioned space". You should be familiar with basic elements of an air-conditioning system and their graphic representation if you are to interpret drawings depicting air-conditioning systems. Some common symbols that you should be able to identify are shown in figures 4-12 and 4-13. The conventional symbols most commonly used on systems employed in military installations are listed in Appendix B. Symbols used to depict ductwork are the same for warm-air heating, ventilating, and air-conditioning systems. Items common to heating, air-conditioning, ventilating, and/or refrigeration (such as fan motors and temperature control devices) are depicted by the same symbols on the respective drawings. For example, the symbol for thermostat as shown in figure 4-2 also applies to air-conditioning.

4-6. Air-Conditioning System

An air-conditioning system comprises several distinctunits,each designed to perform a specific function. The system may be divided into three functional subsystems: refrigerant, control, and air path. Refrigeration is covered in Section III. The control subsystem consists of the compressor motor, fan motor, starting and running circuit, relay, pressure or temperature control switch, and thermostat. It is the air path that is of prime interest to you when reading construction prints. This includes the ductwork, grills, dampers, and screens.

4-7. Typical Air-Conditioning Plan

A plan of heating and air-conditioning systems for a hospital is shown in figure 4-14. You should disregard, for this discussion, everything on figure 4-14 that does not relate to the air-conditioning system. The plan indicates three self-contained air-conditioning units which are located in the mechanical equipment room. Note that the ductwork from the two main units is split and the size of the ducts reduced. The plan also shows you the amount of air each diffuser is to supply. For example, the supply to the lab is rated at 250 cfm while the dark room is to receive air at 100 cfm. You can see that the third air-conditioning unit supplies surgery only. The enlarged plan view of the mechanical equipment room shows you the piping connections. This piping is read in the same manner as you would read the piping on a hot water plan. For example, note the condenser water flow (c) to the three air-conditioning units.

4-8. Self-Test

To verify your understanding of the material presented, answer the following questions. Answers are given at the end of the chapter.

1. Referring to figure 4-14, what is the smallest size duct used?

2. Are typical air diffusers used to supply air to the surgery room?

3. Is any conditioned air being forced into the diet kitchen?

4. What size grille is designated for surgery room?

SECTION III. REFRIGERATION

4-9. Introduction

Refrigeration is the process of extracting heat from a specially designed building, room, or box. There are two general classes of refrigeration systems—built-up and packaged. The built-up refrigeration system is the type you erect to the manufacturer's specifications within a theater of operations special type building which keeps out heat. Package units are delivered complete with prefabrication rooms or boxes and erection diagrams. You would read the prints of either system in the same manner.

4-10. Conventions

A number of conventional symbols for depicting common refrigeration equipment and fittings on prints are shown in figures 4-15 and 4-16. Additional symbols of commonly employed refrigeration devices are listed in Appendix B. Become familiar with the common conventions so that you can more easily interpret a refrigeration print.

4-11. Materials and Fittings

You will find no difference between the material and fittings used for hook-up of refrigeration systems and standard plumbing. The standards are galvanized steel and iron, and copper tubing with sweat-soldered fittings.

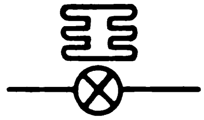
4-12. Refrigeration Plans

Refrigeration plans for theater of operations type construction generally only show the placement of the principal units in the building or room. Figure 4-17 illustrates the standard plan of a typical small refrigerated building. Plumbing and wiring details are not given; such details are left to the competent journeymen. The plan shown in figure 4-17 provides data for a 52-foot or a 100-foot refrigerated warehouse or icehouse. The refrigerated storage area would have one unit cooler in a 52-foot warehouse, whereas a 100-foot warehouse requires two units. A separate machine room is utilized to house the condenser receiver and compressors.

CIRCULATING CHILLED OR HOT-WATER FLOW	———CH———
CIRCULATING CHILLED OR HOT-WATER RETURN	- — —CHR— — —
CONDENSER WATER FLOW	———C———
CONDENSER WATER RETURN	— — —CR— — —
MAKE-UP WATER	——-——-——-——

Figure 4-12. Air-conditioning piping symbols.

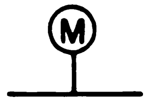
WATER VALVE



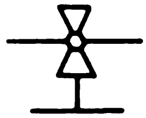
LINE VIBRATION ABSORBER

HAND EXPANSION VALVE

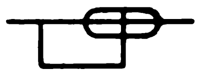
MAGNETIC STOP VALVE



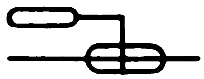
SNAP ACTION VALVE



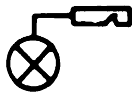
SUCTION VAPOR
REGULATING VALVE



THERMO SUCTION VALVE



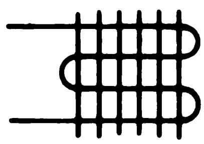
THERMOSTATIC EXPANSION VALVE



LINE FILTER

LINE FILTER & STRAINER

NATURAL CONVECTION FINNED-TYPE
COOLING UNIT



FORCED CONVECTION COOLING UNIT

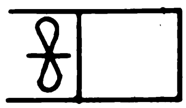


Figure 4-13. Air-conditioning symbols.

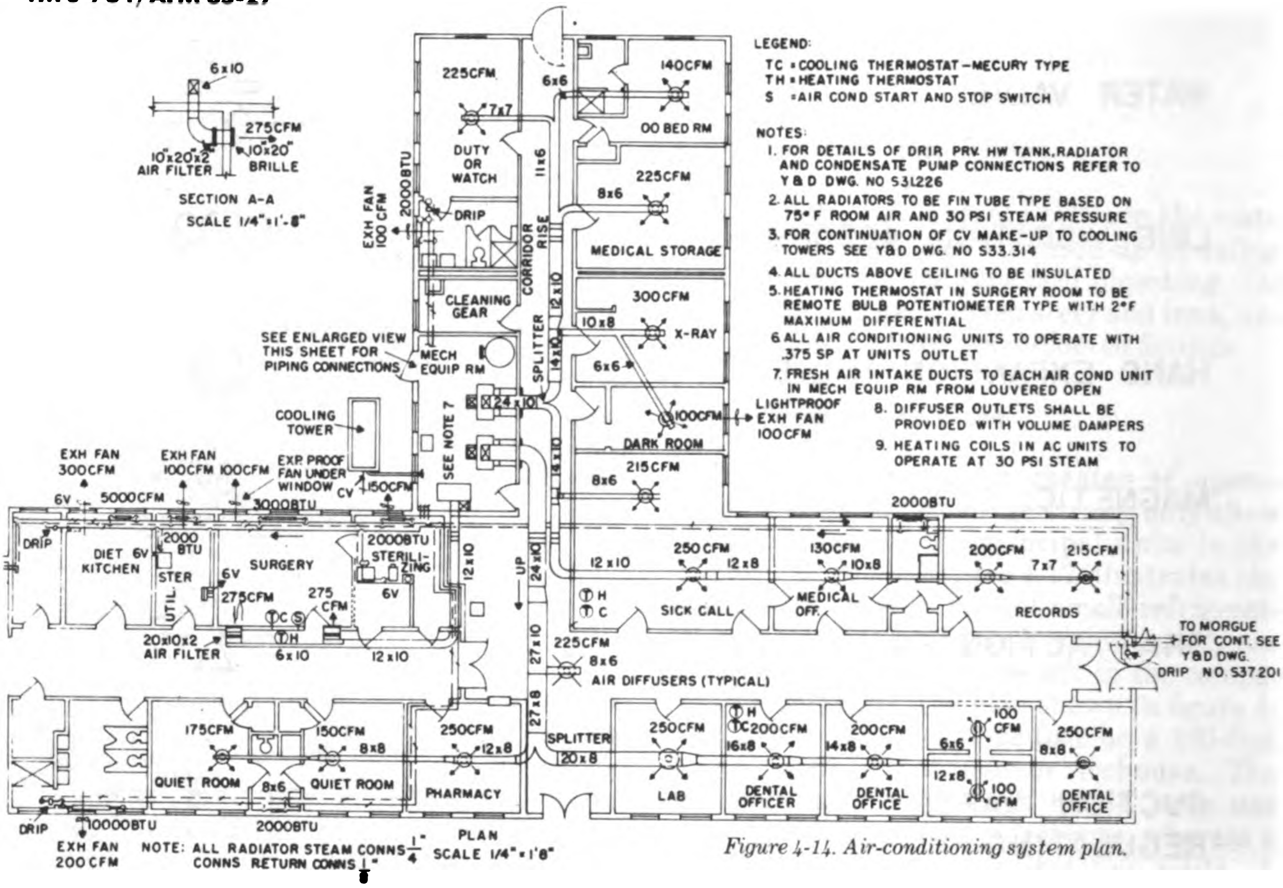


Figure 4-14. Air-conditioning system plan.

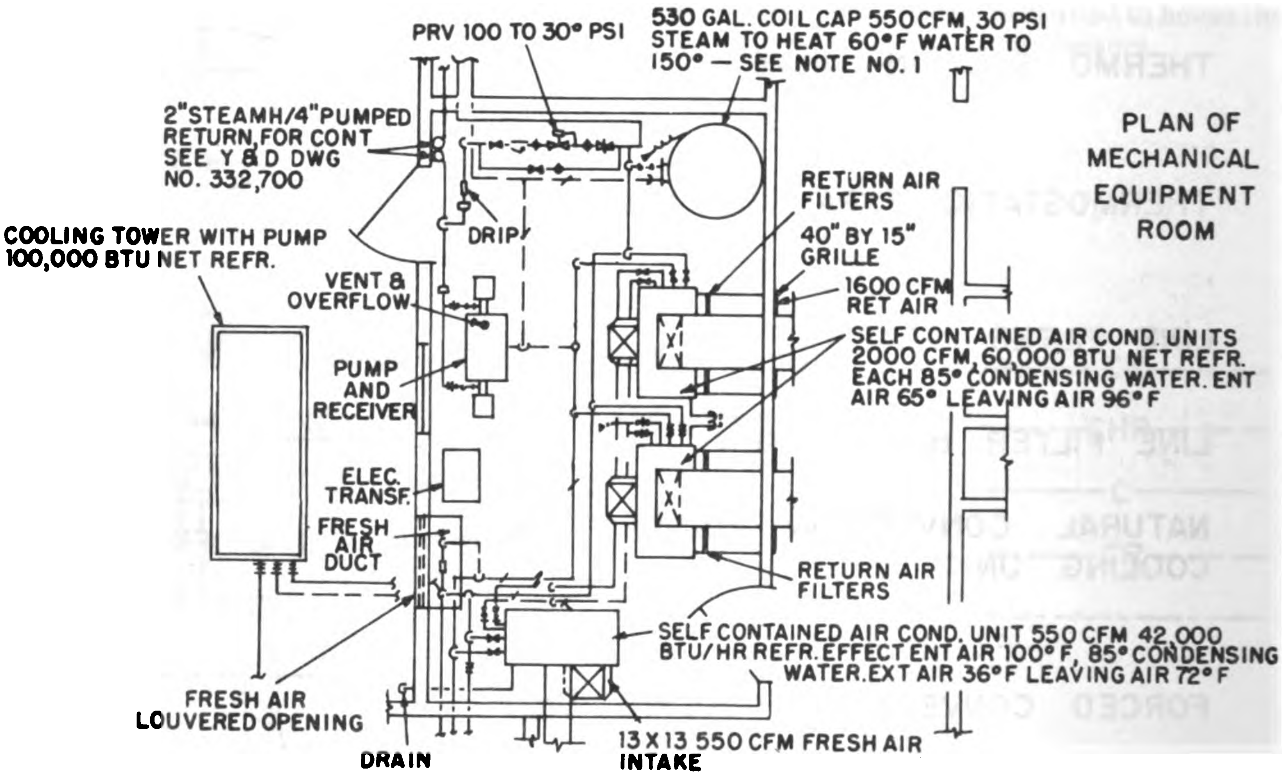
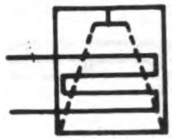
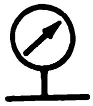


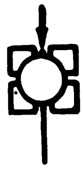
Figure 4-14. Air-conditioning system plan—continued.

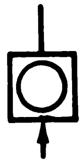
BRINE RETURN	———BR———
BRINE SUPPLY	———B———
REFRIGERANT DISCHARGE	———RD———
REFRIGERANT LIQUID	———RL———
REFRIGERANT SUCTION	———RS———

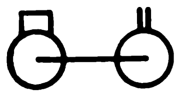
Figure 4-15. Refrigeration piping symbols.

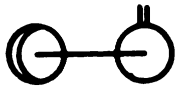
EVAPORATIVE CONDENSER 

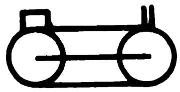
GAUGE 

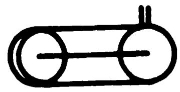
HIGH SIDE FLOAT 

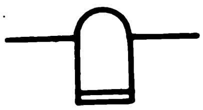
LOW SIDE FLOAT 

MOTOR-COMPRESSOR, ENCLOSED CRANKCASE, RECIPROCATING, DIRECT CONNECTED 

MOTOR-COMPRESSOR, ENCLOSED CRANKCASE, ROTARY, DIRECT CONNECTED 

MOTOR-COMPRESSOR, SEALED CRANKCASE, RECIPROCATING 

MOTOR-COMPRESSOR, SEALED CRANKCASE, ROTARY 

SCALE TRAP 

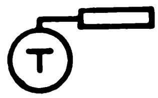
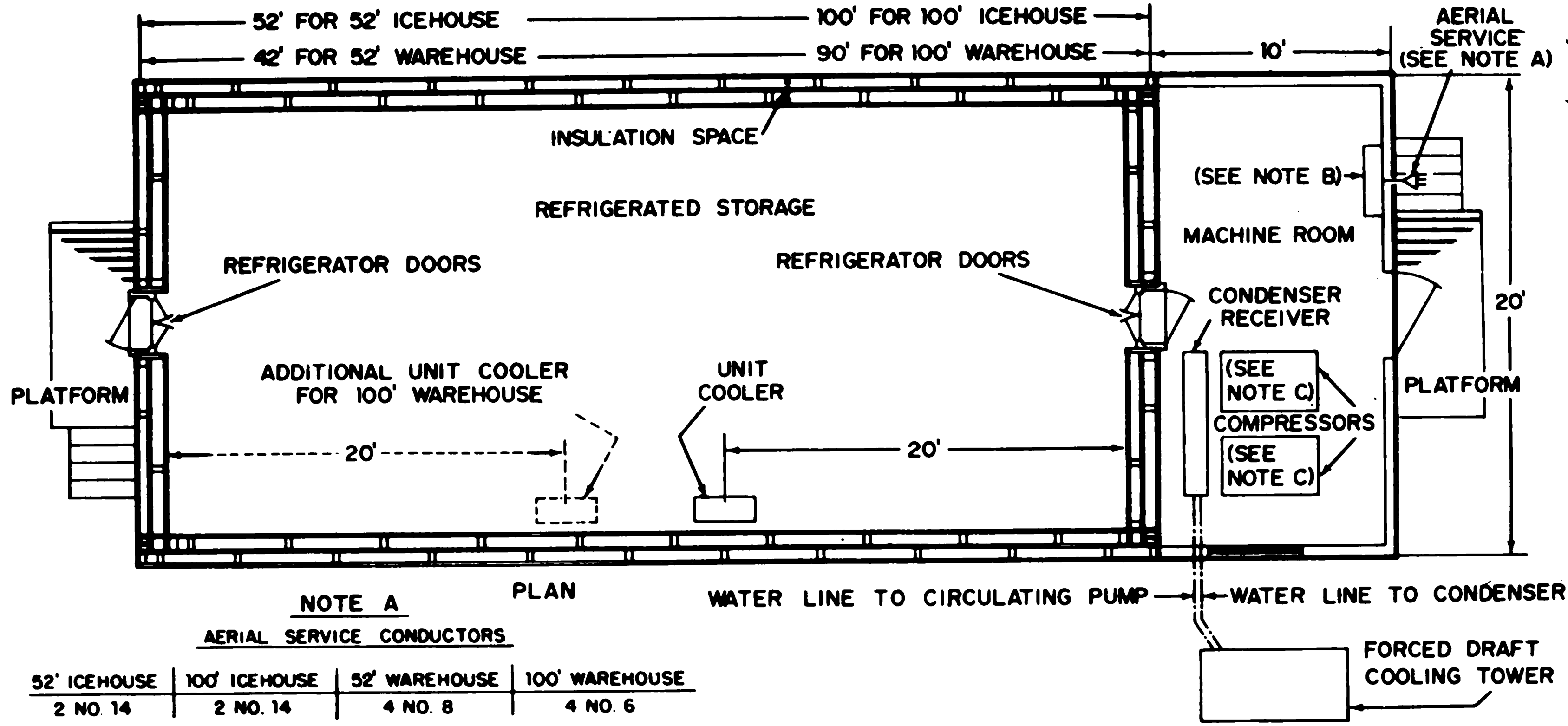
THERMOSTAT (REMOTE BULB) 

Figure 4-16. Refrigeration symbols.



NOTE A

AERIAL SERVICE CONDUCTORS

52' ICEHOUSE	100' ICEHOUSE	52' WAREHOUSE	100' WAREHOUSE
2 NO. 14	2 NO. 14	4 NO. 8	4 NO. 6

CONNECTED ELECTRICAL LOAD

BUILDING	52' ICEHOUSE	100' ICEHOUSE	52' WAREHOUSE	100' WAREHOUSE
LIGHTING	0.08	0.18	0.1	0.2 KVA
POWER (ESTIMATED)			15.23	22.65 KVA
TOTAL	0.08	0.18	15.33	22.85 KVA

GENERAL NOTES

1	IN CASE OF VARIANCE BETWEEN THIS DRAWING AND STANDARD DETAILS THIS DRAWING SHALL GOVERN
2	IN TROPICAL CLIMATE, BUILDING SHALL BE PROVIDED WITH ROOF OVERHANG AS DETAILED ON T.O. FILE NO. 11. 41A, SHEET NO. 4

NOTE B

ELECTRIC PANEL BOARD, CONTROLS AND POWER WIRING FOR REFRIGERATING EQUIPMENT ARE FURNISHED WITH THE REFRIGERATING EQUIPMENT

NOTE C

CAPACITY OF COMPRESSORS (EACH):

52' BUILDING	20,000 BTU PER HR
100' BUILDING	40,000 BTU PER HR

SCALE

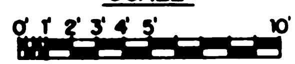


Figure 4-17. Typical small refrigerated warehouse or ice house, all climates.

4-13. Self-Test

Verify your understanding of the previous material by answering the following questions. Answers are given at the end of this chapter.

1. If you can read a print depicting the hook-up of standard plumbing fixtures, can you also read a print showing the hook-up of a regrigeration system?
2. What type of drawing would you require to install a package unit?
3. If you needed to know the placement of refrigeration units, what would you want to see?
   a. Erection diagram
   b. Piping layout
   c. Refrigeration plan
   d. Header and riser diagram
4. Referring to figure 4-17, what is the long dimension of the refrigerated storage room for a 100-foot warehouse?

4-14. Answer to Self-Test Questions

a. Paragraph 4-4 (heating)
   1. Tees and 90° elbows, screwed
   2. Yes, main duct and branch ducts
   3. 10 inches wide, 6 inches deep
   4. 28 inches by 16 inches
   5. 4
   6. Cast iron

b. Paragraph 4-8 (air-conditioning)
   1. 6 x 6 inches
   2. No. The air to surgery room must pass through 20-inch x 10-inch x 2-inch air filters.
   3. No. Only an exhaust fan is used in the diet kitchen.
   4. Grille is to be 10 inches x 20 inches as indicated in section view A-A.

c. Paragraph 4-13 (refrigeration)
   1. Yes, the connections are the same for both.
   2. An erection diagram
   3. c
   4. 90 feet

CHAPTER 5

READING MACHINE DRAWINGS

5-1. Introduction

Machine and foundry drawings probably require more description than most other working drawings because of close tolerance and finished surface requirements. This is particularly true today with the technological advancement of mechanical devices associated with the precise requirements of systems and equipment such as missiles, nuclear power, satellites, computers, etc. This chapter presents some of the common terms and symbols that you must be familiar with in order to read machine drawings. Some of the basic mechanisms which you will usually find presented in detail and assembly drawings of machines are also presented.

5-2. Common Terms and Symbols

a. Tolerance. Tolerance is stated on drawings as plus and/or minus (±) a certain amount, either by fraction ($^1/_{32}$) or decimal (0.005) and may be shown by several different methods. In the unilateral method (1, fig. 5-1), you are given the difference allowable from the design size in one direction only as a plus or minus tolerance figure. In the bilateral tolerance method (2, fig. 5-1), you are given the allowed variation from the design size in both directions as plus and minus figures. In the limit dimensioning method (3, fig. 5-1), the largest and smallest permissible dimensions are given; the tolerance is the difference between the limits.

b. Fillets and Rounds. Fillets are the rounded surfaces of internal angles. Rounds or radii are edges or external angles that are rounded to prevent chipping and to avoid sharp cutting edges. Fillets and rounds are illustrated in figure 5-2.

c. Slots and Slides. Slots and slides are shapes used for mating two pieces together so that they are free to move or slide while being held together. The tee (T) and the dovetail are two common types of slots and slides.

d. Casting. A casting is an object made by pouring molten metal into a mold (normally of sand) of the desired shape and allowing it to cool.

e. Forging. Forging is the shaping of metal while it is hot and pliable by a hammering process either by hand or machine.

f. Temper. Temper is a process of heat treatment to change the physical characteristics of steel.

g. Drill. To sink a hole with a drill (bit), usually a twist drill.

h. Bore. To enlarge a hole with a boring tool.

i. Tap. To cut threads in a hole with a threaded tool called a tap.

j. Key. A key is a small block or wedge inserted between a shaft and hub to prevent the shaft from turning independently. See figure 5-3.

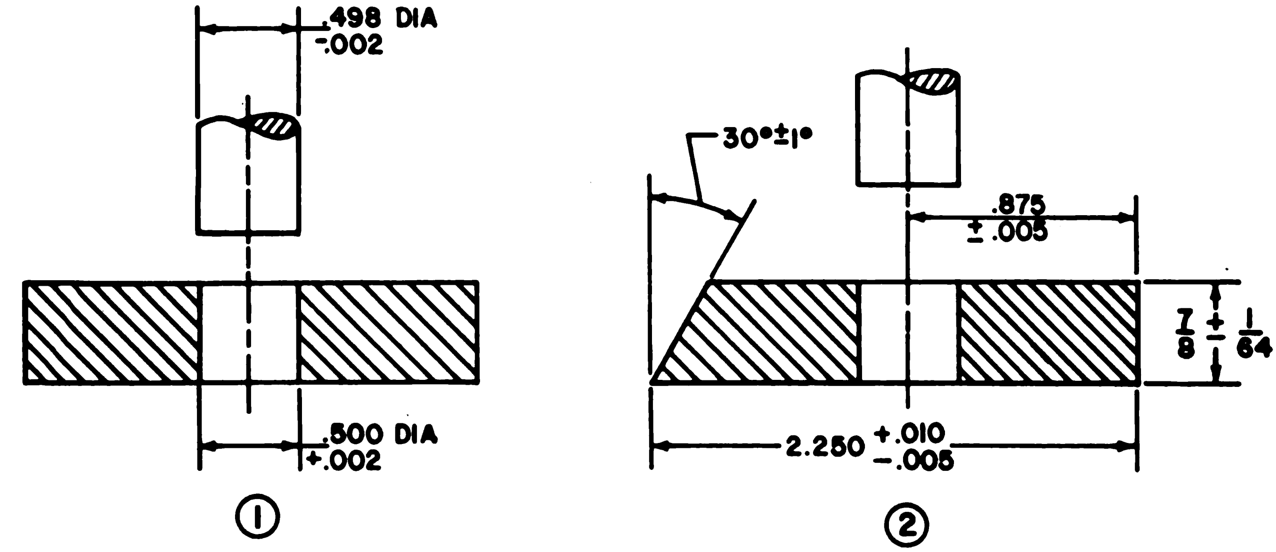
k. Key Seat. A key seat (fig. 5-3) is a slot or groove made to fit a key.

l. Keyway. A keyway (fig. 5-3) is a slot or groove in which a key fitted into a key seat will slide.

m. Common Metal Conventions. Simplified metal conventions that are the most common in foundry and machine shop drawings are illustrated in figure 5-4.

n. Finish Marks. Surfaces of a casting or forging that are to be machined are indicated by a finish mark. Figure 5-5 shows the two types of finish marks in use and illustrates how they are placed on a line. Finish marks are shown on all views in which the surface to be finished appears as a line, including a dotted line. If a part is to be finished on all surfaces, it is treated by the general note "Finish All Over".

o. Geometric Characteristic Symbols. Figure 5-6 illustrates the symbols used in lieu of, or in conjunction with notes to state the geometric characteristics being toleranced.



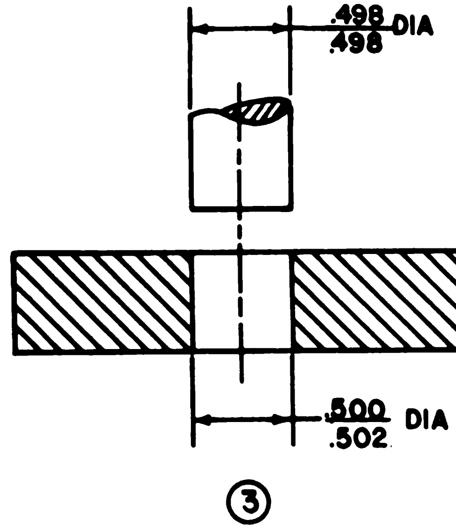


Figure 5-1. Methods of indicating tolerance.

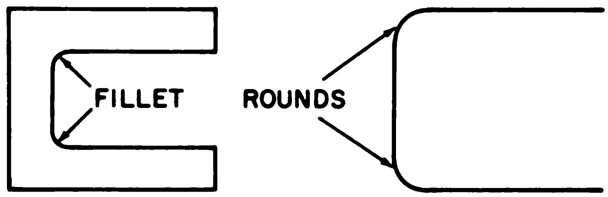


Figure 5-2. Fillets and rounds.

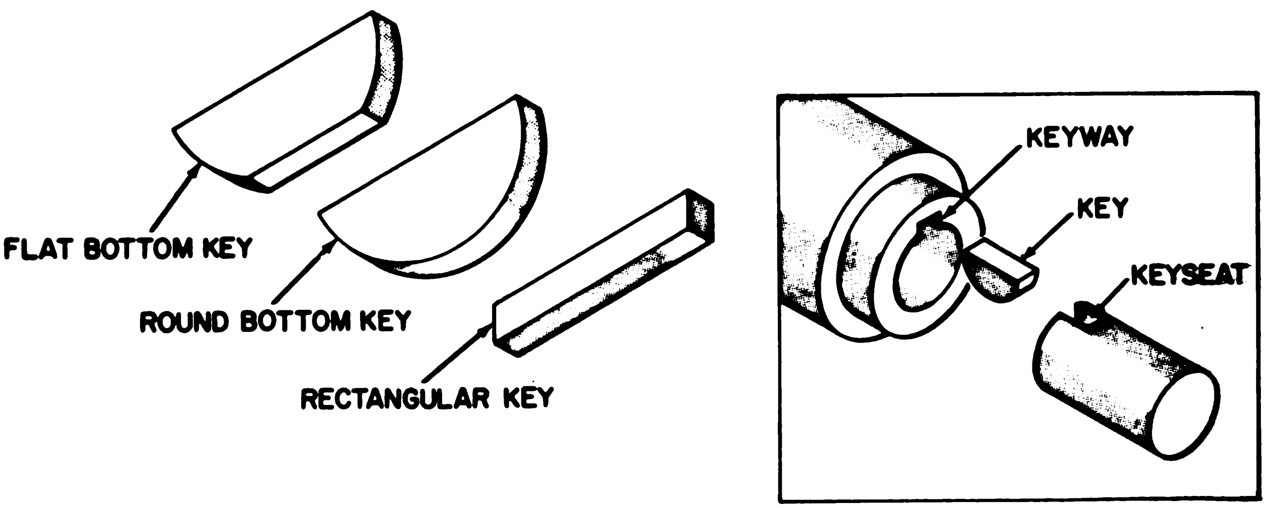


Figure 5-3. Keyseat, keyway, and types of keys.

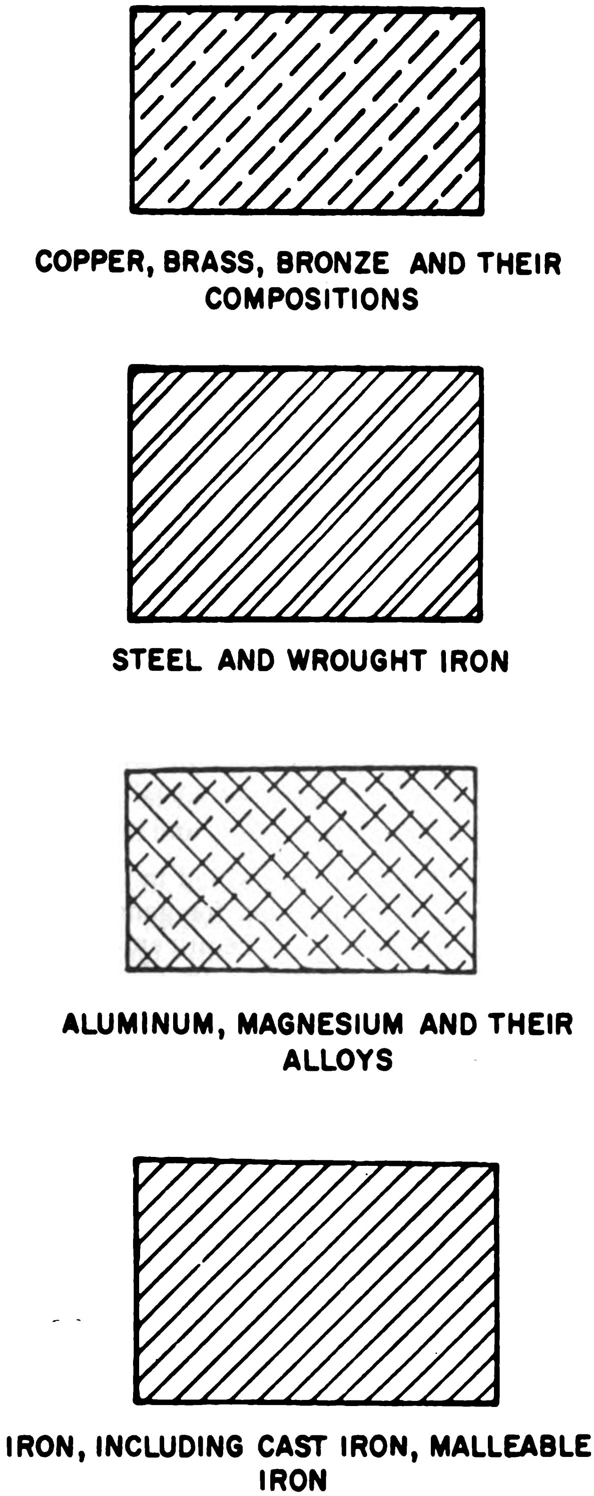


Figure 5-4. Simplified metal conventions.

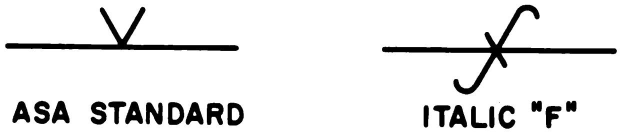


Figure 5-5. Finish marks

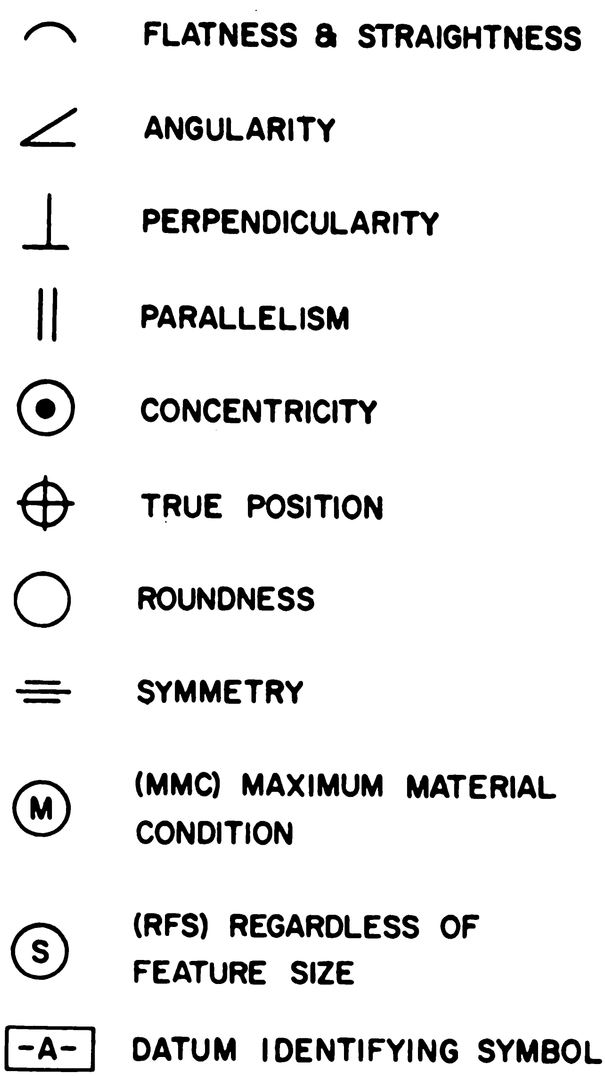


Figure 5-6. Geometric characteristic symbols.

p. Datum Identifying Symbol. The datum identifying symbol (fig. 5-6) is associated with the surface being designated as a datum. Each datum on a drawing is assigned a different identifying reference letter, and each datum identfying symbol is used only once on the drawing.

q. Feature Control Symbol. The feature control symbol comprises a geometric characteristic symbol and positional or form tolerance, and in some cases the modifier Ⓜ or Ⓢ. The symbol Ⓜ means maximum material condition (MMC); Ⓢ means regardless of feature size (RFS). A datum reference may also be incorporated in the feature control symbol as you can see in figure 5-7 which illustrates some feature control symbols. The feature control symbol is always associated with the feature being toleranced.

5-3. Screw Threads

Screw threads are used to restrict or fix the relative motion of two parts or to transmit motion from one part to another. The conventional symbols used to represent threads are shown in figure 5-8. Figure 5-9 indicates some of the terms associated with threads with which you should be familiar. Following are definitions of thread terminology.

a. Crest. The surface of the thread corresponding to the major diameter of an external thread and the minor diameter of an internal thread (top of the thread).

b. Root. The surface of the thread corresponding to the minor diameter of an external thread and the major diameter of an internal thread (bottom of the valley).

c. Major Diameter. The largest diameter of a screw thread; applies to both external and internals threads.

d. Minor Diameter. The smallest diameter of a screw thread; applies to both external and internal threads.

e. Pitch. The distance from a point on a screw thread to a corresponding point on the next thread measured parallel to the axis.

f. Pitch Diameter. The diameter of an imaginary cylinder the surface of which would pass through the threads at such points as to make equal the width of the threads and the width of the spaces cut by the surface of the cylinder.

g. Depth of Thread. The distance from the crest to the root of the thread measured perpendicular to the axis.

h. Angle of Thread. The angle made by the sides of the thread measured in an axial plane.

i. Lead. The distance a screw thread advances along the axis in one turn. On a single thread screw, the lead and pitch are identical; on a double-thread screw, the lead is twice the pitch; on a triple-thread screw, the lead is three times the pitch.

5-4. Bolts and Nuts

In general, you will obtain data concerning bolt dimensions from standard tables. On assembly drawings, bolt dimensions are usually approximate. Bolts and studs are indicated on drawings by outlines and symbols as shown in figure 5-10. You should be familiar with the following data on bolts and nuts.

a. Series. Bolts are classified in three series: *regular*—recommended for general use; *heavy*—designed to meet requirements for greater surface; and *light*—smaller across flats than the regular, they are designed to save material and weight.

b. Finish. Bolts may be unfinished, semi-finished, or finished. Unfinished bolts, except for threads, are made by forging or rolling and are not machined on any surface. On semi-finished or finished bolts, the surface under the nut or bolt head may be machine finished to provide a washer-faced bearing surface. Finished bolts are machined all over for accuracy or to improve their appearance.

c. Diameter. The shaft size.

d. Length of Bolt. The distance from under the head to the end of the bolt.

e. Thread Length. This is related to the diameter and bolt length. In general, bolts are threaded a distance of 1½ times the diameter plus ⅛ inch. Short bolts, where the formula cannot apply, are threaded full length. On the thread end, bolts are chamfered at an angle of 45° to the depth of the thread.

f. Washer Face. The diameter of the machined surface forming the washer face is equal to the distance across flats. The thickness is 1/64 inch for both both heads and nuts, and is always included in the height of the head or thickness of the nut.

g. Form. The head on unfinished, regular- and heavy-series bolts and nuts may be square or hexagonal. On all others the head form is hexagonal. The corners are chamfered to form a flat circular top having a diameter equal to the distance across flats.

h. Chamfer. The angle of chamfer with the flat top of bolts and nuts is drawn at 30° (45° for the heavy series).

i. Head Height. This is the overall height of the bolthead and for semifinished or finished bolts includes the washer-faced bearing surface (see washer face, above.).

j. Thickness of nuts. This is the overall thickness of the nut and for semifinished or finished nuts includes the washer-faced bearing surface (see washer face, above).

5-5. Basic Mechanisms

A mechanism is a subassembly of a machine which is designed to transmit force and motion from one part into the force and motion desired in another part. In simple cases, a single mechanism may comprise a machine. A mechanism of a machine may be a driver, a follower, a link or band. A driver is a mechanism which transmits its available force and motion to another mechanism called the follower. The follower of one mechanism may be the driver of another. When a driver and a follower are in direct contact it is called a direct drive mechanism. If the driver and follower are not in direct contact, the inter-

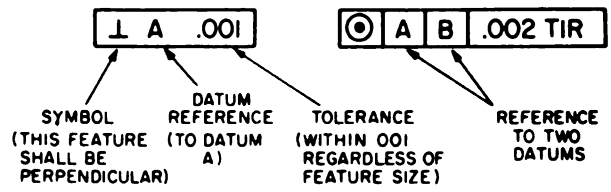


Figure 5-7. Feature control symbols.

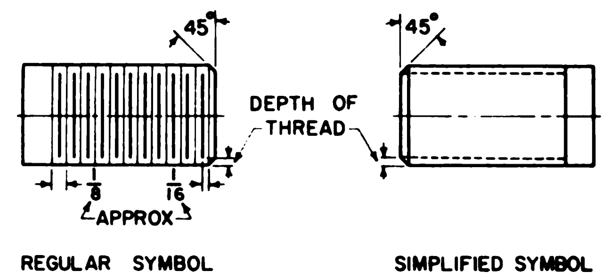


Figure 5-8. Thread conventions.

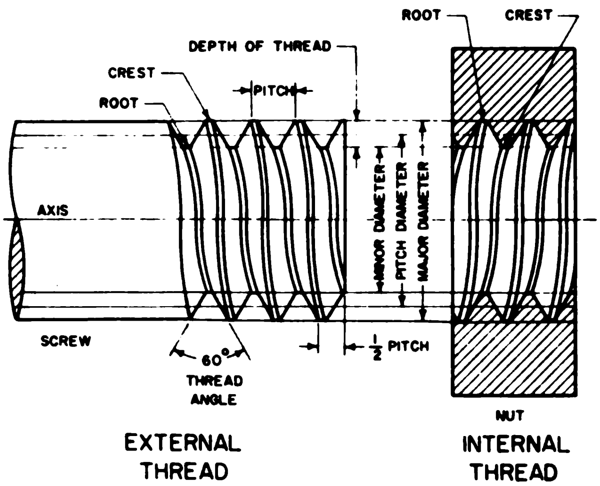


Figure 5-9. Thread nomenclature.

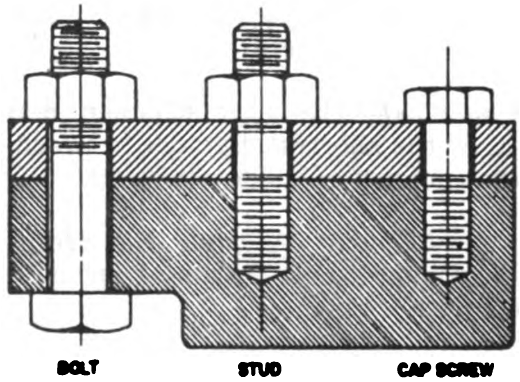


Figure 5-10. Bolt, stud, and cap screw.

mediate part is called a link or a band. A link is a rigid part capable of transmitting tension or compression forces, such as a connecting rod. A band is a flexible part which can transmit tension forces only, such as a belt or chain. Some of the basic mechanisms which are commonly presented in assembly and detail drawings of machines, and which you should recognize are discussed, in the following paragraphs.

5-6. Gears

A complete coverage of gears is beyond the scope of this manual. Only some of the terms used in connection with gears will be defined. Gear teeth generally are not shown on prints, except when a few are drawn to indicate the proper dimensions. Figure 5-11 illustrates the special terms used to indicate gear measurements; however some of these terms are shown for the purpose of discussion only. They would not be so designated on a print. Instead they would appear as notes giving the appropriate dimensions, for example:

Diametral Pitch 5

Addendum 0.1131

Dedendum 0.0992

Following are definitions of common gear terms.

a. Addendum. Height of tooth above pitch circle, or the radial distance from the pitch circle to the top of the tooth.

b. Addendum Circle. A circle coinciding with the top of the teeth.

c. Backlash. The play between mating teeth, or the shortest distance between the non-driving surfaces of adjacent teeth.

d. Pitch Circle. A circle the radius of which is equal to the distance from the gear axis to the pitch point.

e. Pitch Point. The point of tangency of the pitch circles or the point where the centerline of mating gears intersect the pitch circles.

f. Pitch Diameter. The diameter of the pitch circle.

g. Diametral Pitch. The number of teeth per inch of pitch diameter.

h. Dedendum. Depth of tooth space below pitch circle, or radial distance from the pitch circle to the bottom of a tooth space.

i. Base Circle. The circle from which an involute tooth curve is generated or developed.

j. Root Circle. A circle coinciding with the bottoms of the tooth spaces.

k. Pressure Line. That portion of the common tangent to the base circles along which contact between mating teeth occurs.

l. Face of Tooth. The tooth surface between the pitch circle and the top of the tooth.

m. Flank of Tooth. The tooth surface between the pitch circle and the root circle.

n. Circular Tooth Thickness. The thickness of a tooth measured along the arc of the pitch circle.

o. Tooth Space. The space between two teeth measured on the arc of the pitch circle.

p. Circular Pitch. Distance between corresponding points on two adjacent teeth measured along the pitch circle. The circular pitches of two meshing gears are equal.

5-7. Cams

a. A cam is a plate, cylinder, or solid piece with a curved outline or groove which rotates about an axis and transmits its rotary motion to the reciprocating (up and down) motion of the follower. The follower may have a pointed, rolling, or flat contact with the cam as shown in figure 5-12. The cam rotation, as

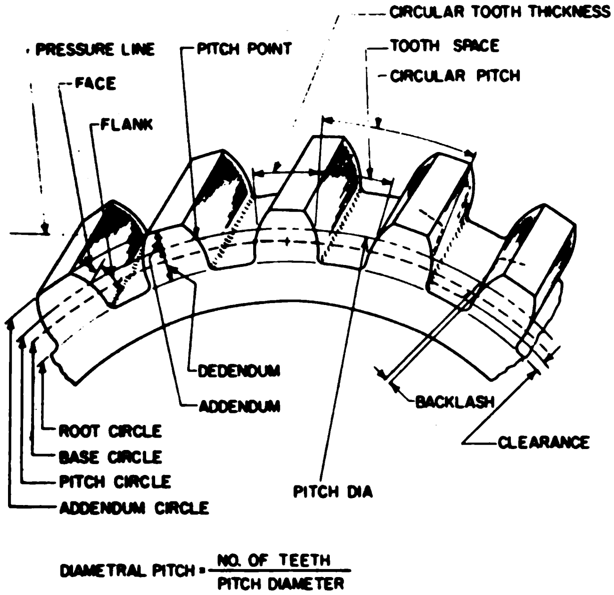


Figure 5-11. Gear terminology.

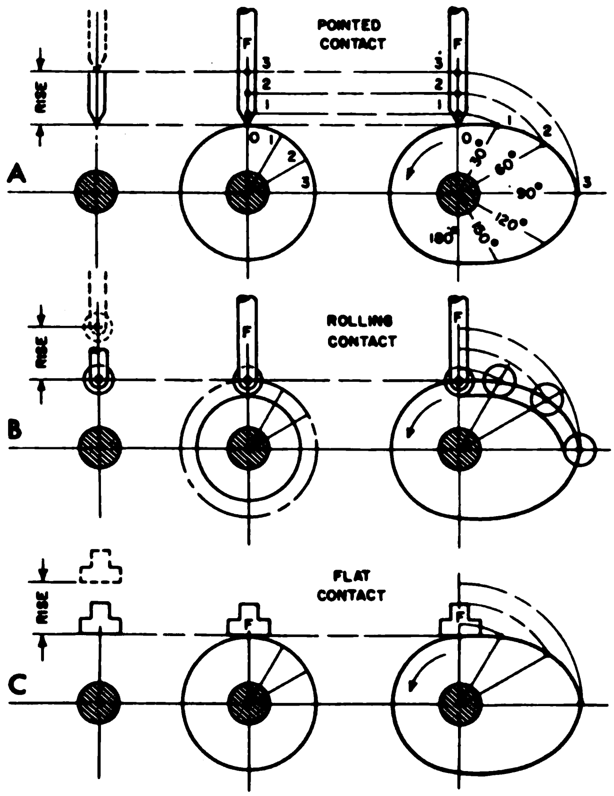


Figure 5-12. Cams and followers.

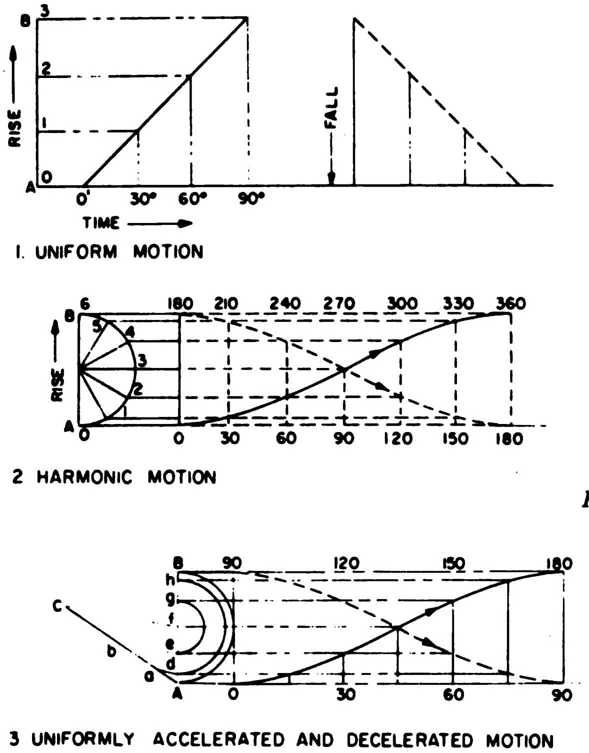


Figure 5-13. Motion diagrams.

indicated by the arrow, is counterclockwise and its largest radius is at 90° (point 3). Thus, when the cam rotates 90° (from position shown), the follower will be at its highest point as illustrated by the phantom representation.

b. The rise and fall motion of the follower may be irregular or regular. Irregular motion conforms to no definite law. Regular motion conforms to some physical law, and may be uniform, harmonic, uniformly accelerated, or uniformly retarded with reference to time. The different kinds of regular motion are illustrated by a plot of the rise and fall of the follower for each interval of time, called a motion diagram. You can see the motion diagrams by referring to figure 5-13.

(1) *Uniform motion.* When the point of a follower moves equal distances in equal periods of time, the follower has uniform motion. In diagram 1, figure 5-13, the total rise of the follower, represented by AB, is divided into three equal parts. This is to show you that the follower must rise to points 1,2, and 3 in the time it takes the cam to turn in equal intervals of time to 30°, 60°, and 90° respectively. The right side of diagram 1 shows you that the follower will have uniform fall.

(2) *Harmonic motion.* Harmonic motion of the follower is illustrated by diagram 2, figure 5-13. The line AB represents the total use of the follower. A semicircle is divided into 30-degree sectors with the intersecting points numbered from 1 to 6. The numbered points project horizontally to the ordinates which represent equal time intervals of rotation of the cam; that is, the time it takes the cam to rotate 30°. The solid curve shows the harmonic rise for 180° rotation of the cam. The dashed curve shows the harmonic fall of the follower to its original position. You would use a cam with this motion for high-speed operation.

(3) *Uniformly accelerated and decelerated motion.* Diagram 3, figure 5-13, represents uniformly accelerated and uniformly decelerated motion. Line AB represents the total rise of the follower as before. However, in this case the distances between the horizontal projections are in the ratio of 1:3:5 in the lower half and 5:3:1 in the upper half. Thus, the solid curve shows the rise of the follower by uniform acceleration to the midpoint of travel and its continued rise by uniform deceleration. The dashed line shows the fall of the follower to its midpoint of travel by uniformly accelerated motion and its continued fall by uniformly decelerated motion to its original position. Uniformly accelerated motion is the motion of a freely falling body, and it gives the easiest motion to a cam.

(4) *Reading the design of a cam.* When the design for a cam is developed it is necessary to know the initial position of the follower with respect to the camshaft, the type of contact, the motion required of the follower and the direction of rotation of the camshaft. Figure 5-14 illustrates a cam of a specified design. Can you describe the cam and the motion of the follower depicted in figure 5-14? It is a plate cam which is to turn counterclockwise. The follower will move in a vertical line above the center of the cam. In the initial position, the follower is at the lowest point (shortest distance from center of cam). The follower will have the following motions:

0°—120°, rise (1 inch) with simple harmonic motion

120°—210°, dwell or rest with no motion at 210°, drop (¼ inch) instantly

210°—360°, fall (¾ inch) with uniform motion

5-8. Helical Springs

There are three classifications of helical springs: compression, extension, and torsion. The true method of presentation, however, is seldom used and a spring is usually shown with straight lines. Figure 5-15 shows several methods of spring representation. You will also find that springs are shown as single line drawings as depicted in figure 5-16.

5-9. Machine Drawing Practices

A set of working drawings includes detail and assembly drawings. The detail drawing gives all necessary data for the manufacture of the individual items, and an assembly drawing shows the location of each item in relation to one another. In machine drawings, you will find two systems are employed for presenting the necessary data: the multiple-drawing system and the single drawing system. Both follow the practice of showing details of each piece individually. When the end item is small and consists of only a few parts, the details may be shown on the same sheet as the assembly drawing, as in figure 5-17, which shows all the parts and necessary details for assembling a truck caster. Note that each part is numbered and how the number is used to show part location and identify the detail of that part.

a. Multiple-Drawing System. Some manufacturers use the multiple-drawing system, in which different drawings are made for the pattern shop, the foundry, and machine shop. In this case, each drawing presents only that information required by the shop for which the drawing is intended. Figures 5-18 and 5-19 are multiple drawings. Figure 5-18 is for the foundry, and figure 5-19 is for the machine shop.

b. Single-Drawing System. The practice most commonly followed employs the single-drawing system, in which you will find all information necessary for the completion of the finished piece. Figure 5-20 is a single drawing to be used by both the foundry and the machine shop. The information required by each shop is given separately so that one set of dimensions and data is not dependent on the other; also the need for cross-reference is eliminated.

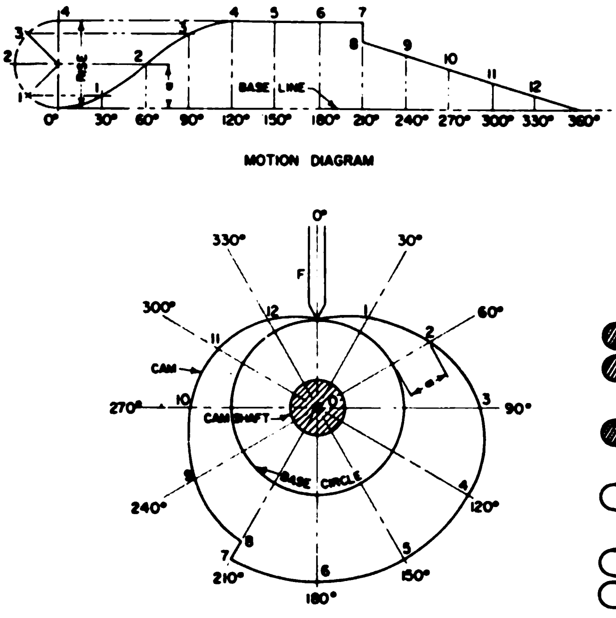


Figure 5-14. Specified cam and motion diagram.

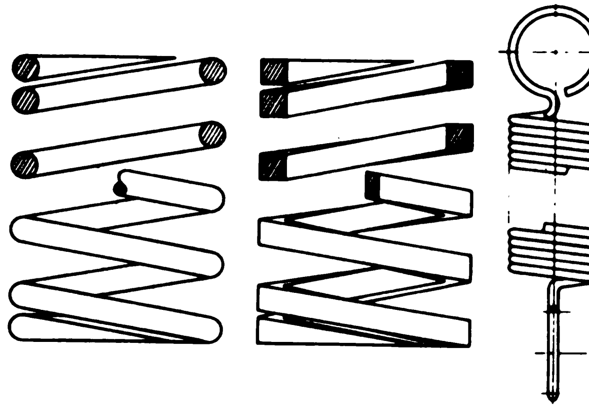


Figure 5-15. Representation of helical springs.

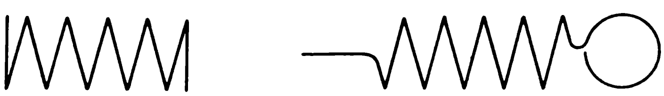


Figure 5-16. Single line representation of springs.

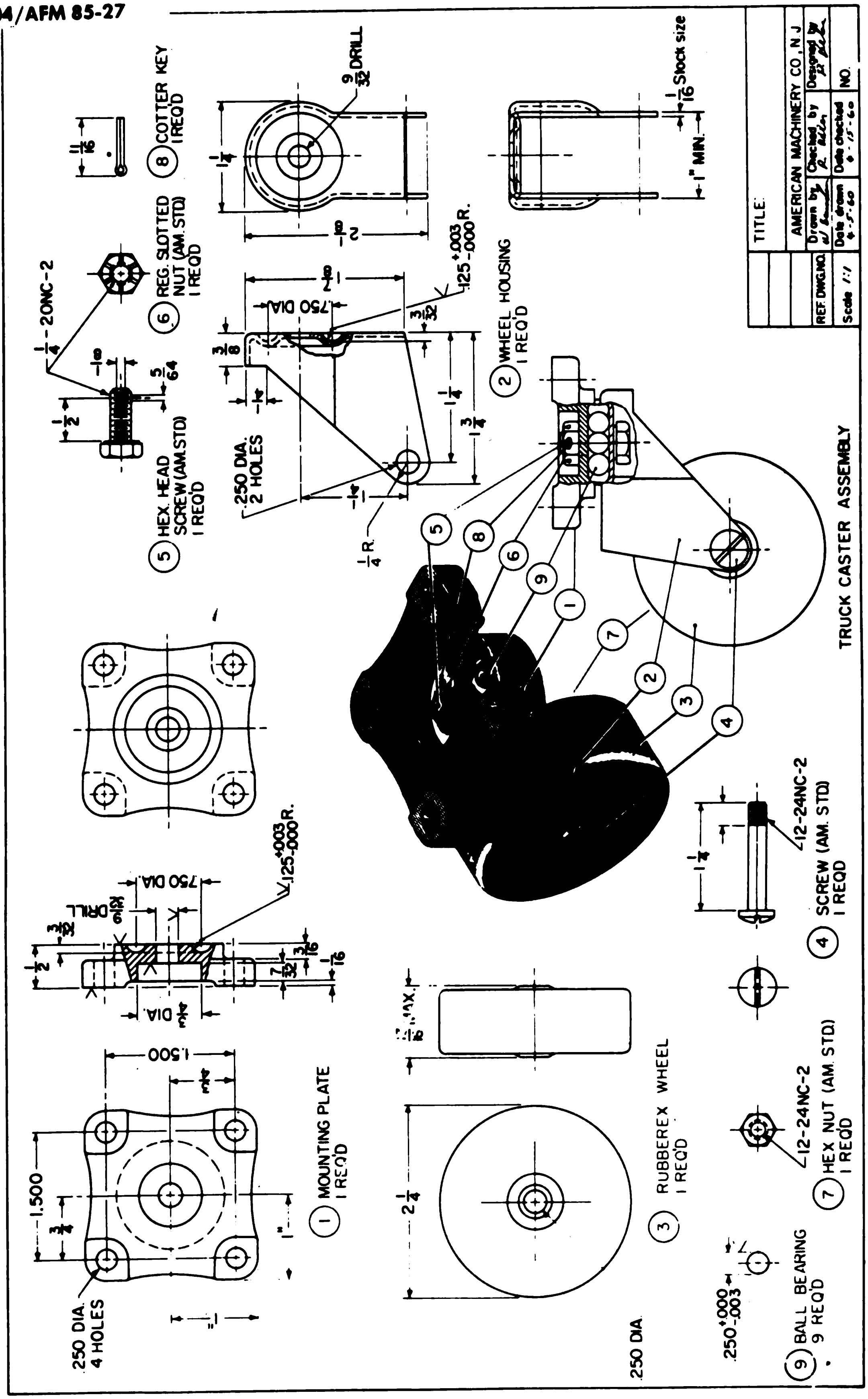


Figure 5-17. Relation of details versus assembly.

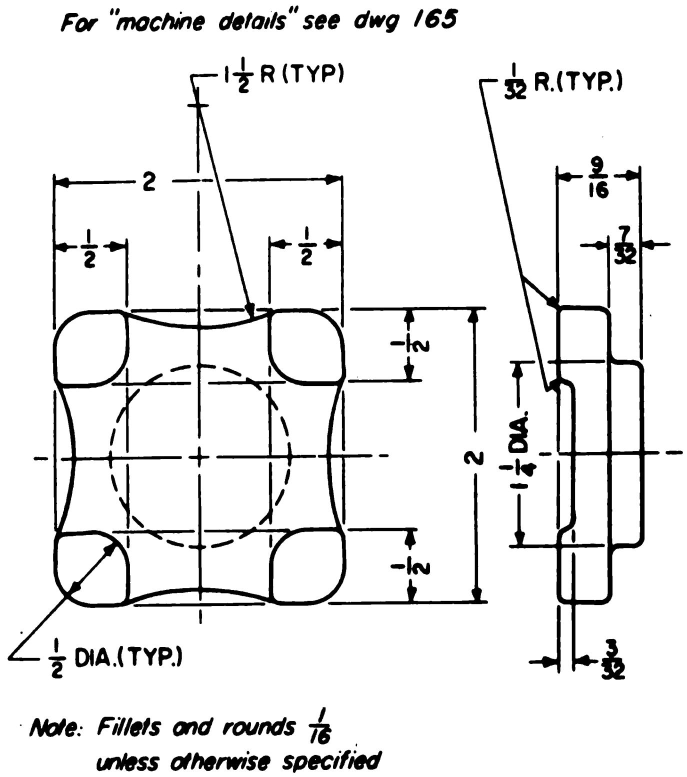


Figure 5-18. Detail of mounting plate for the foundry.

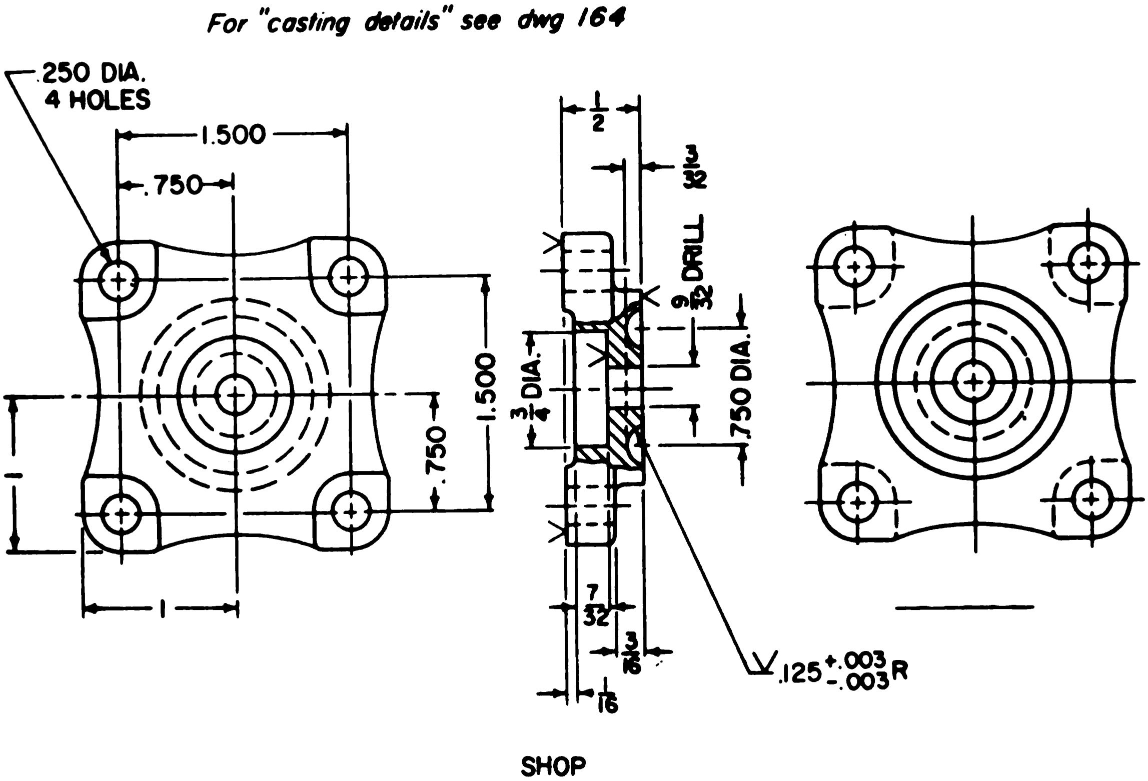


Figure 5-19. Detail of mounting plate for the machine shop.

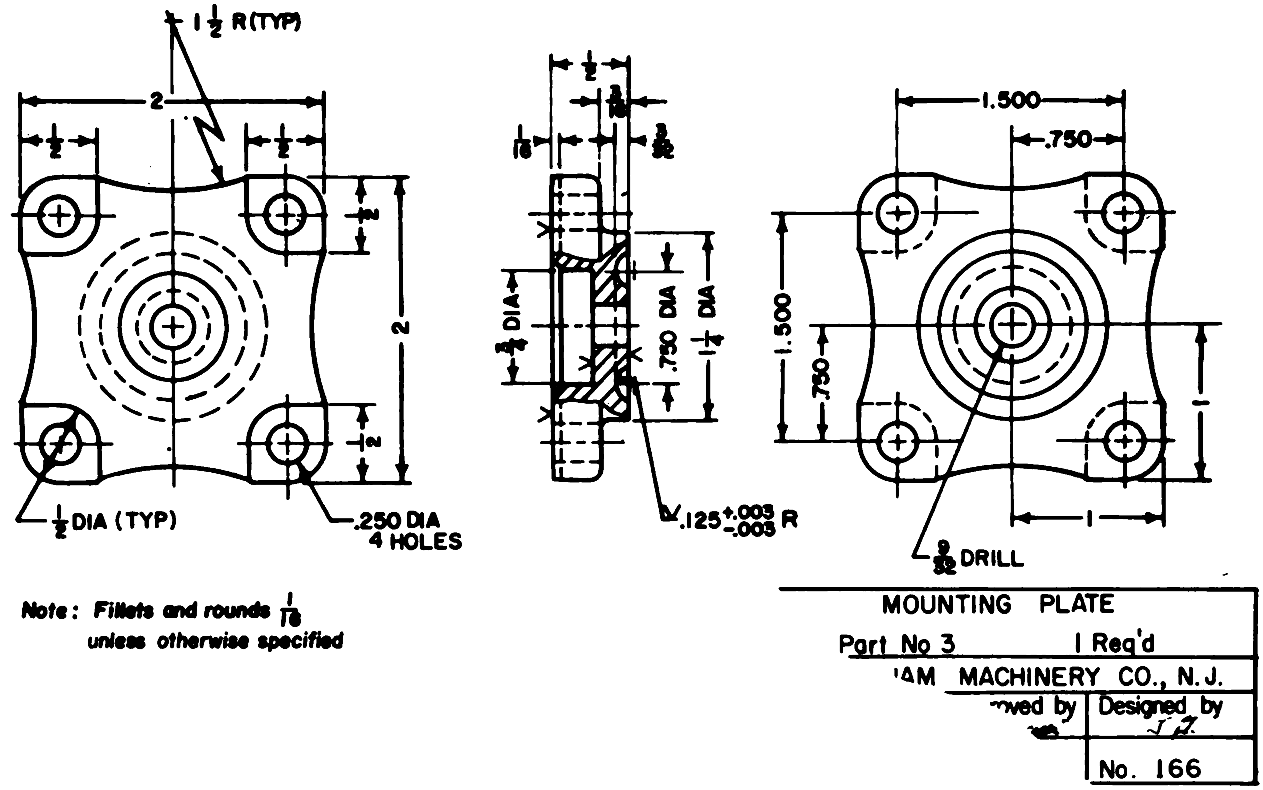


Figure 5-20. Single drawing for use by all shops.

5-10. Self-Test

To verify your understanding of the material in this chapter, answer the following questions. Answers are given in paragraph 5-11.

1. Referring to B, figure 5-1, what is the minimum allowable height?

2. Is the crest of a screw the same as the crest of a nut?

3. Where would you find dimensions of a gear depicted on a machine drawing?

4. Referring to figure 5-14, how many degrees does the cam have to rotate to move the follower to midpoint of its maximum rise?

5. What would you find noted on a detail drawing for a foundry that would not normally appear on a drawing for the machine shop (see figures 5-18 and 5-19)?

5-11. Answers to Self-Test Questions

1. 55/64
2. No. The crest of a screw is at the major diameter and the crest of a nut is at the minor diameter.
3. Appropriate dimensions of a gear would appear as notes.
4. 60°.
5. Information on fillets and rounds.

CHAPTER 6

BILLS OF MATERIALS

6-1. Definition

A bill of materials is a grouped compilation based on take-offs and estimates of all materials needed to complete a structure. The bill of materials for a given project is organized into a tabulated statement to include item number (parts and materials), name, description, unit of measure, quantity and, where called for, the stock size and number, and sometimes the weight. You may be familiar with bills of materials by some other designation such as "materials take-off sheets" or "materials estimate sheets".

6-2. Compilation

Bills of materials are usually made up by the draftsman at the time of preparation of the original drawings; you simply utilize them when ordering materials. However, where no bills of materials accompany field prints they must be compiled by the constructing or erecting forces; thus, you should understand and to be able to work with or develop bills of materials. Reasonable accuracy can best be obtained by having separate bills of materials prepared by at least two estimators. They can then be compared and one copy corrected or both consolidated into a final bill of materials.

a. Takeoff and Estimate. The takeoff usually is an actual tally and checkoff of the items shown, noted, or specified on the construction drawings and specifications. The estimated quantities are those known to be necessary but which may not have been placed on the drawings, such as nails, cement, concrete-form lumber and tie wire, temporary bracing or scaffold lumber, and so on. These are calculated from a knowledge of construction methods that will be used for field erection. You can use the information given in appendix D to help in making up an estimate.

b. Plans. Both architectural and engineering plans provide the means by which names of the various items can be listed in order to make up the bills of materials. Indicated or scaled dimensions of buildings or utilities layouts are used to determine material unit dimensions.

c. Quantities. Quantities are usually taken from the plans by extracting and listing one type of material at a time followed by a regrouping of those types by sizes commencing with the smallest and progressing to the largest.

d. Tabulation. The tabulation should include column headings for each item as follows:

(*1*) Item number. Number of the item in each section.

(*2*) Section number. The number assigned to the appropriate major groups such as: general construction, electrical, plumbing and so forth.

(*3*) Item name.

(*4*) Unit of measure.

(*5*) Quantity.

6-3. Example Bill of Materials

a. Figure 6-1 shows the floor plan and detail drawings for a 50-man barrack on a concrete floor. This set of construction drawing should be sufficient to develop a bill of materials.

b. Figure 6-2 is the bill of material for the 50-man barrack. It contains a great deal of information. To develop a detailed bill of materials, such as this, would require experience in construction print reading, construction procedures, and methods of estimating quantities.

6-4. Reading Prepared Bill of Materials

As stated previously, the bill of material is usually made up by the draftsman at the time of preparation of the original drawings. It is important that you be able to read a prepared bill of materials.

a. Heading. The headings were discussed in paragraph 6-2d. Under quantities required in

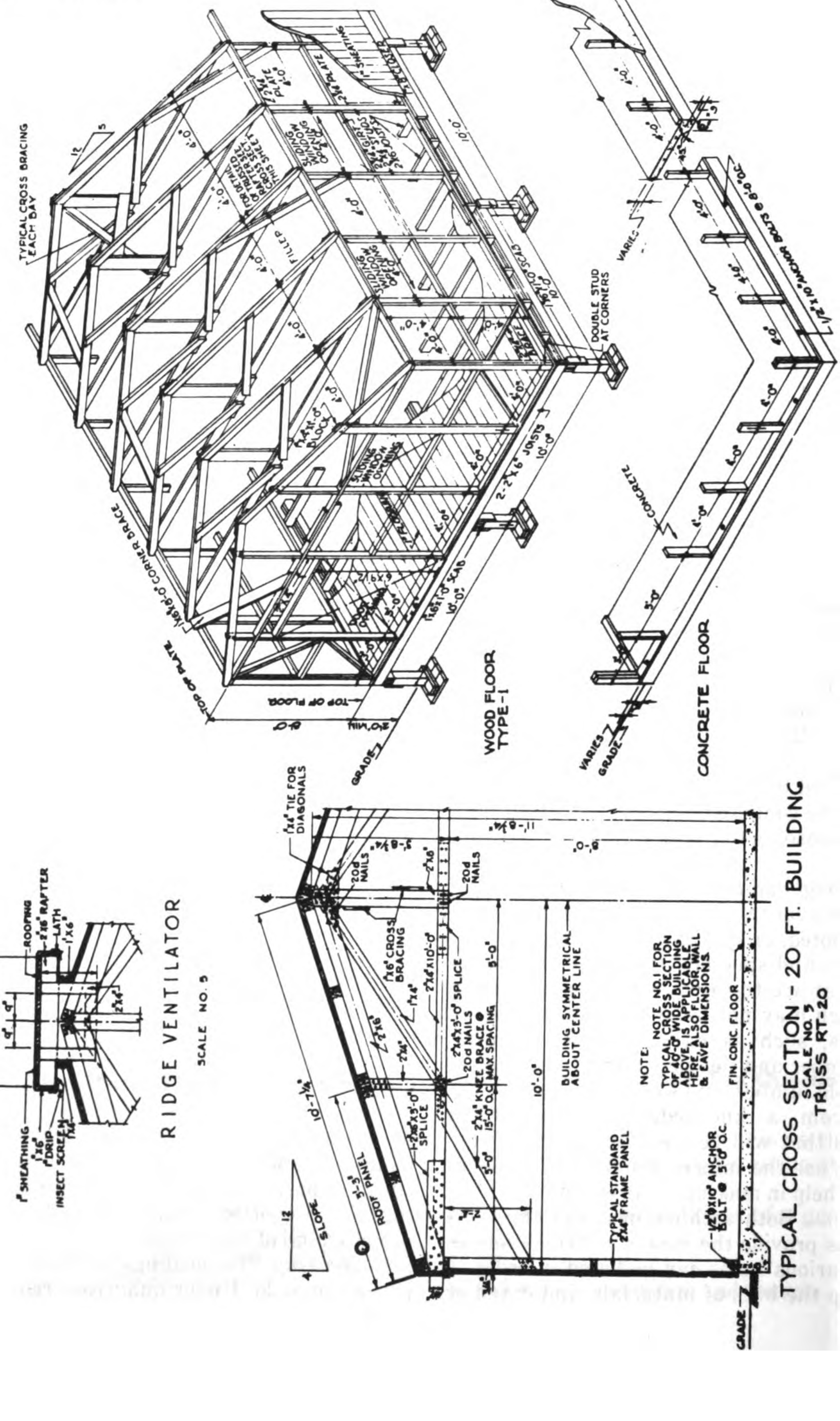


Figure 6-1. Construction drawing for 50-man barracks.

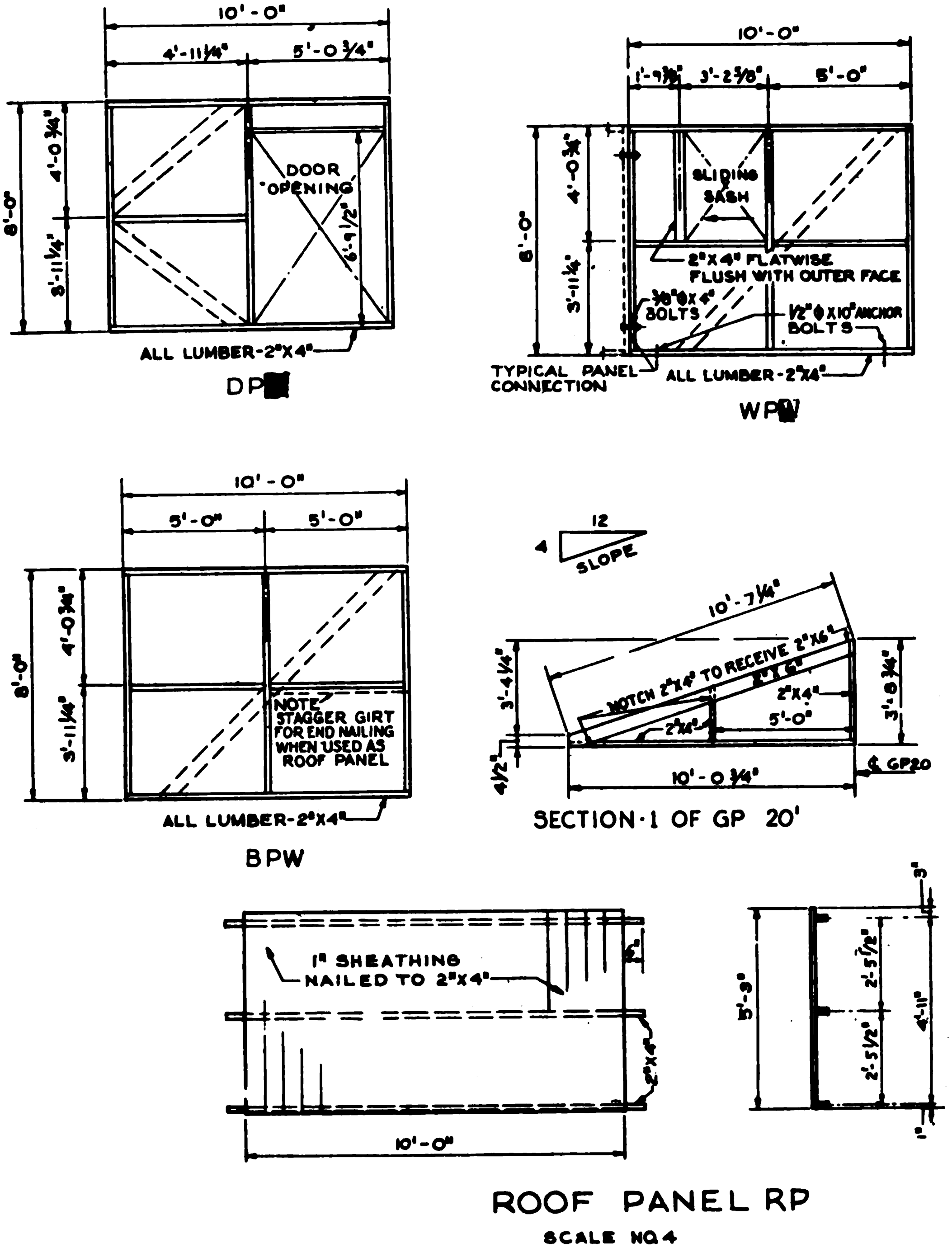


Figure 6-1. Construction drawing for 50-man barracks—continued.

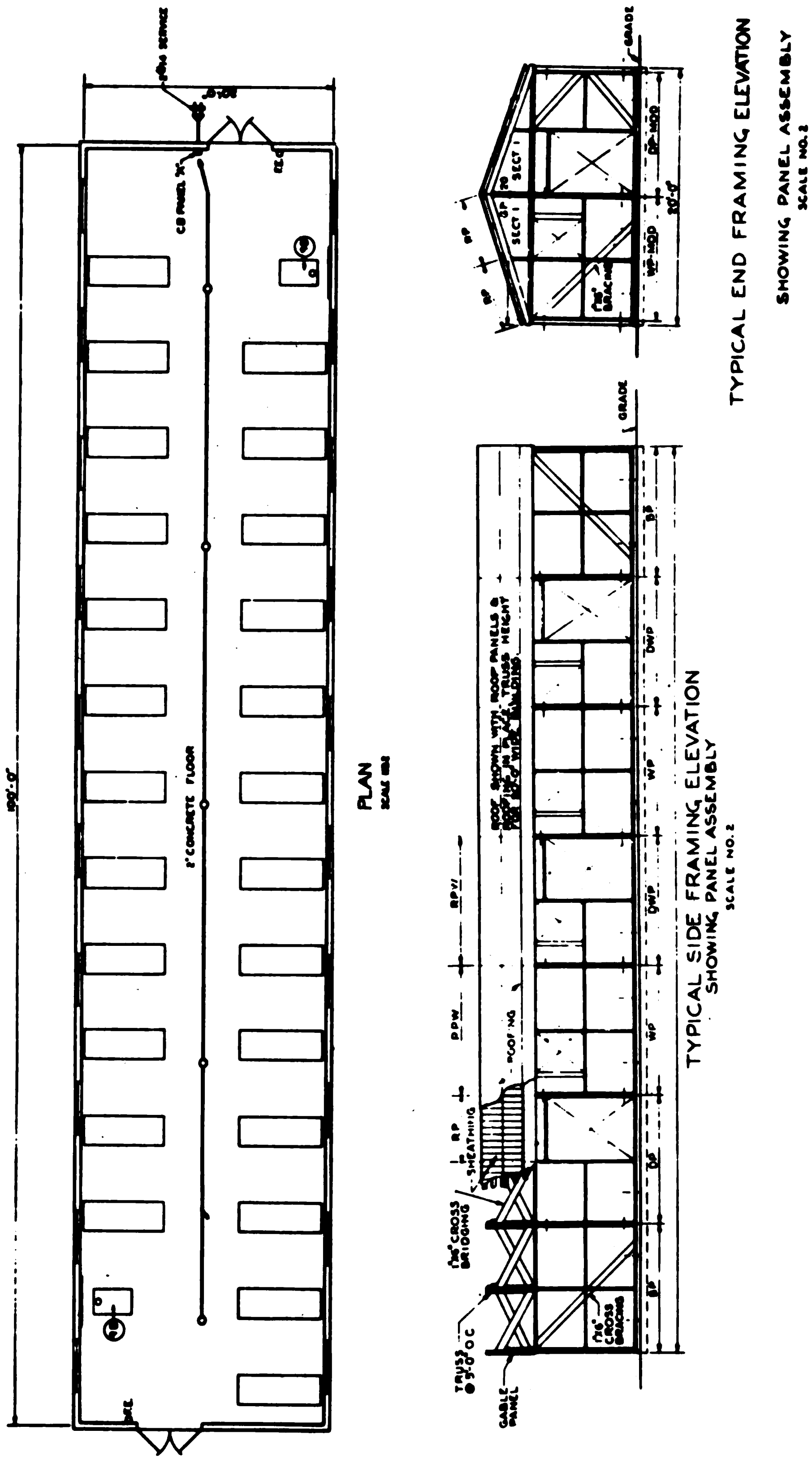


Figure 6-1. Construction drawing for 50-man barracks—continued.

ITEM NO.	SECT NO.	ITEM	UNIT	QUANTITIES REQUIRED: WALL PANELS VPW	DPW	BPW	CABLE PANELS GP-20W	ROOF RPW	ROOF TRUSS RT-20
	01	FRAME							
		Lumber							
1		2x4-8 ft	PCS	60	6	6			
2		2x4-10 ft	PCS	40	4	4	4	120	38
3		2x4-14 ft	PCS	20	2	2	2		38
4		2x6-12 ft	PCS				4		38
		Nails							
5		10D Common	LB	6	.6	.6	1.2		
6		16D Common	LB	8	.8	.8		28	57
	03	CLADDING							
		Lumber							
1		No 2 Lathwood	BD	4.4	.44	.44	.2		
2		1x3-14 ft	PCS	80	2				
3		1x4-8 ft	PCS		22				
4		1x4-14 ft	PCS	340	40	40	12	520	
5		1x6-8 ft	PCS		8				
6		1x6-12 ft	PCS	20		2			57
7		1x6-14 ft	PCS		4				19
8		1x8-8 ft	PCS		4				
9		1x8-10 ft	PCS	20	2	2			
		Nails							
10		3D Common	LB	4	.4	.4	.4		
11		8D Common	LB	40	4	4	5.6	9	
12		7/8" Roofing	LB	5	.5	.5	.4	12	
13		No 9 Double Point Tack	LB	.6					
		Miscellaneous							
14		Building Paper 15 lb,36"wide	RO	4.4	.5	.5	.28		
15		Hardware Cloth 16 mesh, 48" wide	FT	60	28				
16		Glass Substitute 14x14 mesh	RO	.8					
		Hardware							
17		Joint Fastener 5/8"	BX	10	4				
18		T Hinge 6"	PR		16				
19		Thumb Latch 2 1/2" DR	EA		2				
20		Door Spring 16 1/2"	EA		4				

ITEM NO.	SECT NO.	ITEM	UNIT	QUANTITIES REQUIRED BARRACKS 20 x 100
	05	FLOOR		
1		Cement	BG	78
	08	INTERIOR HEATING AND VENTILATING		
		Heater		
1		Conversion Coal-oil 55-gal Drum	EA	2
		Miscellaneous		
2		Split Knob Insulator #1	EA	18
3		Nails 8D Common	LB	25
4		1/2" No 8 Sheet Metal	EA	60
5		Flat Steel Sheet 28 ga,30"x120"	SH	2
6		Flat Steel Sheet 20 ga, 48"x96"	SH	1
7		Bituminous Plastic Cement	CN	10
	09	INTERIOR ELECTRICAL WORK		
		Wire		
1		WP Solid No 14	FT	260
		Fittings and Miscellaneous Materials		
2		Ground Clamp 1"	EA	1
3		Flexible Conduit 3/8"	FT	3
4		Cable Connector 6-7	EA	2
5		Split Knob Insulator #1	EA	30
6		Lamp Receptacle Keyless	EA	5
7		Porcelain Tube 3/8"x6"	EA	2
8		Lumber 2x2-14 ft	PCS	9
9		Lumber 4x4-14 ft	PCS	1
10		Nails 8D Common	LB	1
11		Machine Bolt 5/8"x16"	EA	2
12		1 1/4" [illegible] Head Wood Screws	GR	.13
13		Washer Iron 5/8"x1 3/4"	LB	.3
14		Black Steel Pipe Std 3/4"	FT	10
15		Friction Tape	RO	.25
		Circuit Breaker, Multi-breaker		
16		2-1 Pole-15 amp	EA	1
		Lamps		
17		Tungsten 60watt, 120volt	EA	5
	10	INTERIOR FIRE PROTECTION		
		Fire Extinguisher		
1		4 gal Water Pump	EA	1

Figure 6-2. Bill of materials for 50-man barracks.

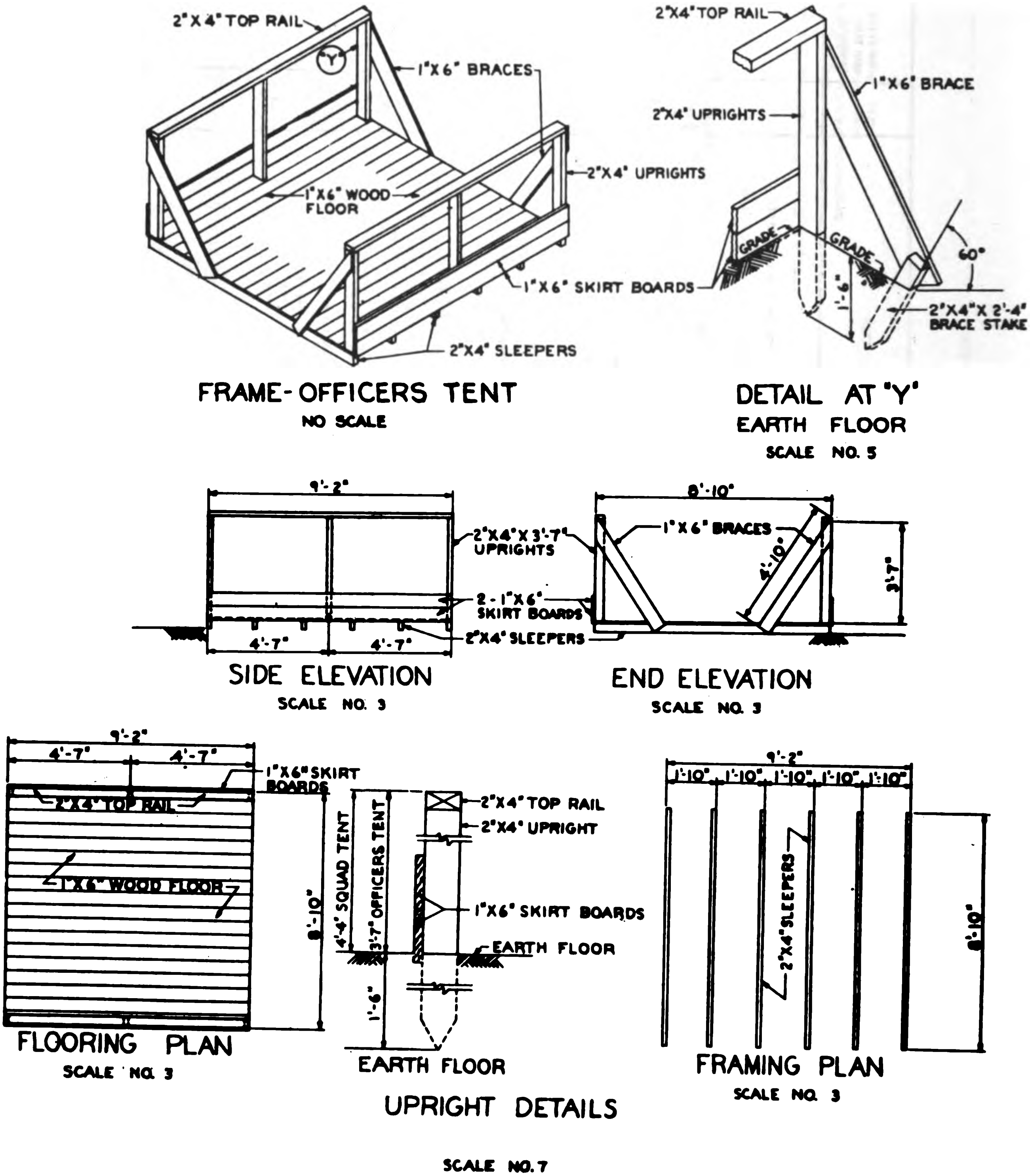


Figure 6-3. Construction drawing for frame for officer's tent.

Item No.	Sect No.	Item	Unit	Quantities required
	05	FLOOR		
		Lumber		
1		1 x 6-10 ft	PCS	22
2		2 x 4-10 ft	PCS	6
		Nails		
3		10D common	LB	2.5
	06	INTERIOR HAMMER AND SAW WORK		
		Lumber		
1		1 x 6-10 ft	PCS	6
2		2 x 4-10 ft	PCS	7
		Nails		
3		10D common	LB	1.5

Figure 6-4. Bill of materials for frame for officer's tent.

figure 6-2, the types of wall panels are: (1) WPW-window panel, (2) DPW-door panel and (3) BPW-blank panel. The final W after all the abbreviations indicates that wood cladding and felt are to be used to cover the structure.

b. Body. In the body, each of the major groups (frame, cladding, floor, etc.) have been listed separately. Each major group has been subdivided into groups of common items and under the sub-groups the individual items have been listed and described in detail. For example, the major group, FRAME, has been divided into the sub-groups, lumber and nails. Then, under lumber, each size board that is needed is listed and described. The units of measure for each item are abbreviated. You should be familiar with these abbreviations. The amounts listed under quantities required are those required for the total structure.

6-5. Self-Test

To verify your understanding of bills of materials, you should prepare one. Figure 6-3 is the construction drawing for a frame for an officer's tent. Compile a bill of materials from the drawing similiar to that in figure 6-2. After you have completed your final tabulation compare it with the bill of materials in figure 6-4.

APPENDIX A

REFERENCES

FM 5-34	Engineer Field Data
FM 21-30	Military Symbols
FM 21-31	Topographic Symbols
TM 5-230	General Drafting
TM 5-233	Construction Surveying
TM 5-302	Construction in the Theater of Operations
TM 5-460	Carpentry and Building Construction
TM 5-742	Concrete and Masonry
TM 5-744	Structural Steelwork
TM 5-745	Heating, Ventilating, and Sheet Metal Work
TM 5-760	Electrical Wiring
MIL-STD-100	Engineering Drawing Practices
MIL-STD-12B	Abbreviations for Use on Drawings and in Technical-Type P
MIL-STD-14A	Architectural Symbols
MIL-STD-15-1A	Graphic Symbols for Electrical and Electronics Diagrams
MIL-STD-15-3	Electrical Wiring Symbols for Architectural and Electrical Layout Drawings
MIL-STD-17B-1	Mechanical Symbols
MIL-STD-18A	Structural Symbols
AWS A2.0-58	Welding Symbols

APPENDIX B

STANDARD MILITARY SYMBOLS

The symbols included in this appendix are not all inclusive, but include those you are most likely to encounter in military construction. A complete listing of graphic symbols or conventions is contained in the Military Standards listed in appendix A.

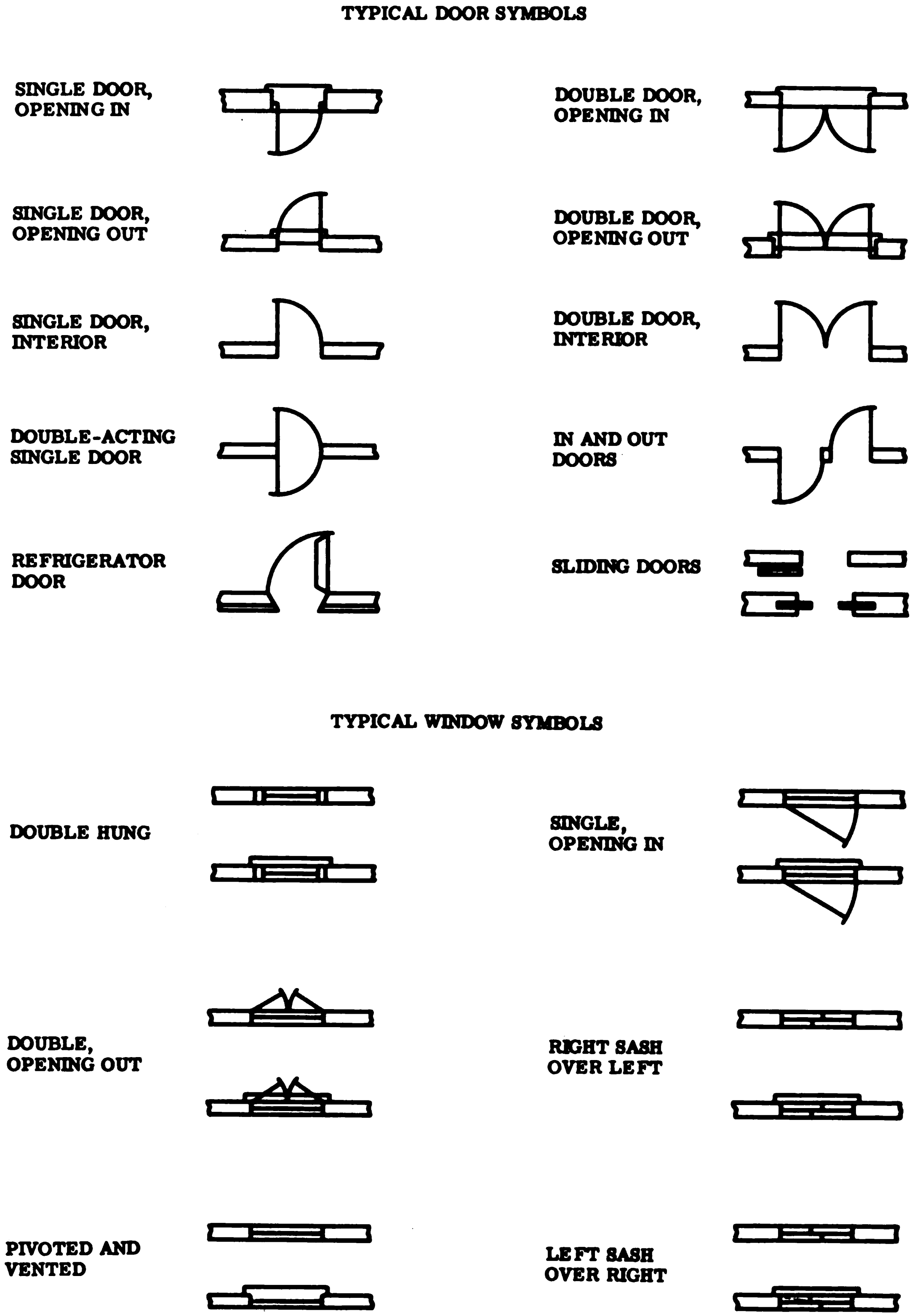
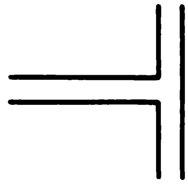


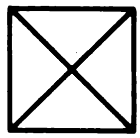
Figure B-1. Typical architectural symbols.

MISCELLANEOUS SYMBOLS

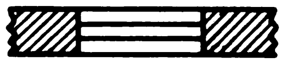
STUD PARTITION,
UNLESS OTHERWISE NOTED



ELEVATORS, HATCHWAYS,
OPENINGS IN FLOORS, DUCTS, ETC.



LOUVERED OPENING
IN MASONRY WALL



LOUVERED OPENING
IN FRAME WALL

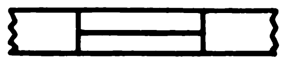


Figure B-1. Typical architectural symbols—continued.

NOTE: WHEN BOTH ALUMINUM AND STRUCTURAL STEEL SHAPES OCCUR ON THE SAME DRAWING, THE SUFFIX "AL" IS ADDED TO ALL ALUMINUM SHAPE DESIGNATIONS; FOR EXAMPLE 8 ⊔ 6.67 AL

GENERAL

GAGE	g
PITCH OF RIVETS	p
MILLED FACE	MILL

LIST OF SINGLE STRUCTURAL SHAPES

WIDE FLANGE SHAPE	WF
BEAMS	
AMERICAN STANDARD	I
LIGHT BEAMS AND JOISTS	B
STANDARD MILL	M
JUNIOR	Jr
LIGHT COLUMNS	M
CHANNELS*	
AMERICAN STANDARD	⊔
CAR AND SHIP	⊔
JUNIOR	Jr ⊔

*SYMBOLS FOR CHANNELS AND ANGLES MAY BE ORIENTED TO AGREE WITH THE POSITION OF THE MEMBER BEING DESIGNATED.

Figure B-2. Structural steel and aluminum construction symbols

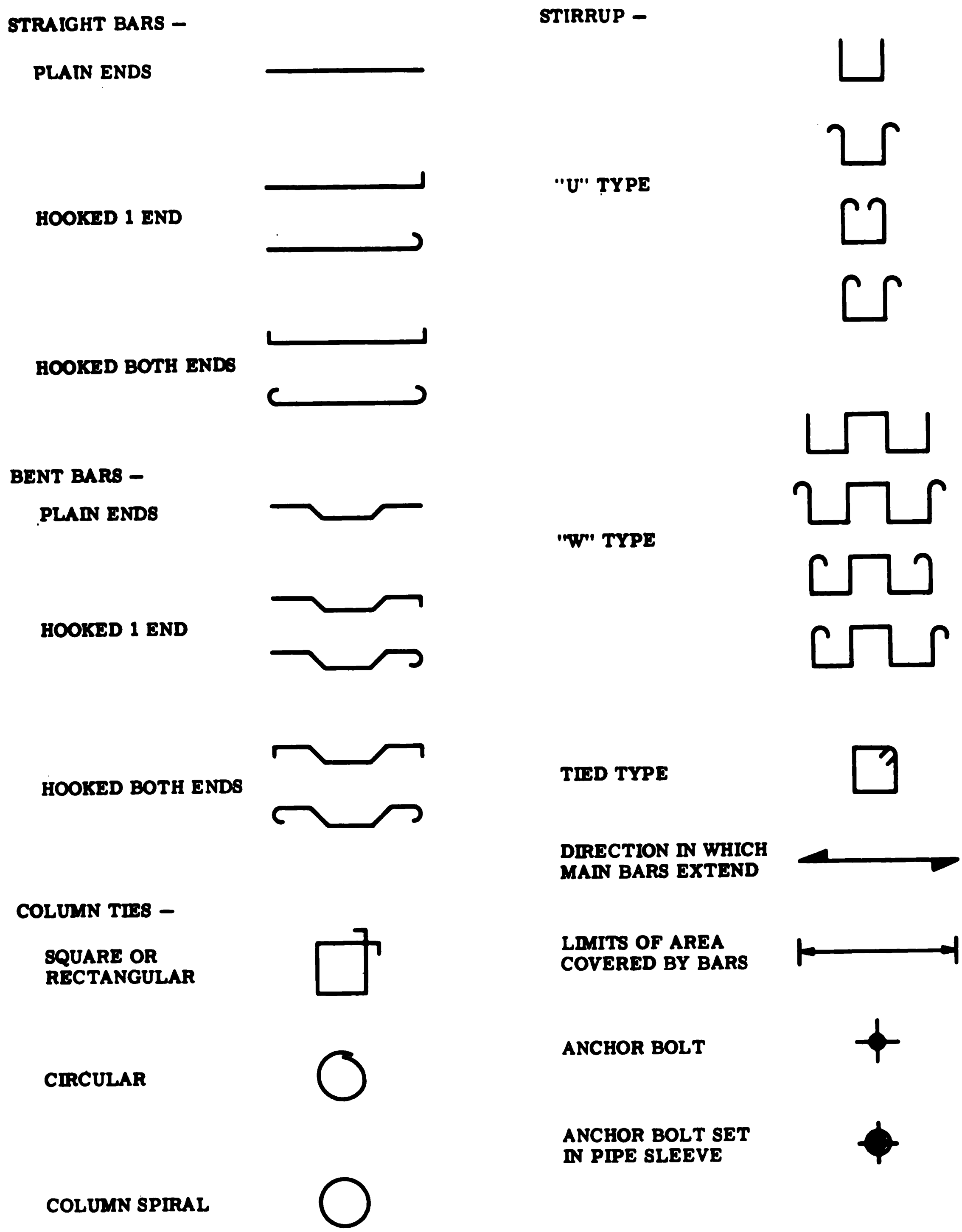


Figure B-3. Reinforced concrete construction symbols.

SHOP RIVETS, TWO FULL HEADS

SHOP RIVETS, COUNTERSUNK AND CHIPPED, NEAR SIDE

SHOP RIVETS, COUNTERSUNK AND CHIPPED, FAR SIDE

SHOP RIVETS, COUNTERSUNK AND CHIPPED, BOTH SIDES

SHOP RIVETS, COUNTERSUNK BUT NOT CHIPPED, MAX. 1/8 IN. HIGH NEAR SIDE

SHOP RIVETS, COUNTERSUNK BUT NOT CHIPPED, MAX. 1/8 IN. HIGH FAR SIDE

SHOP RIVETS, COUNTERSUNK BUT NOT CHIPPED, MAX. 1/8 IN. HIGH BOTH SIDES

SHOP RIVETS, FLATTENED TO 1/4 IN. HIGH FOR 1/2 IN. AND 5/8 IN. RIVETS NEAR SIDE

SHOP RIVETS, FLATTENED TO 1/4 IN. HIGH FOR 1/2 IN. AND 5/8 IN. RIVETS FAR SIDE

SHOP RIVETS, FLATTENED TO 1/4 IN. HIGH FOR 1/2 IN. AND 5/8 IN. RIVETS BOTH SIDES

SHOP RIVETS, FLATTENED TO 3/8 IN. HIGH FOR 3/4, 7/8, AND 1 IN. RIVETS NEAR SIDE

SHOP RIVETS, FLATTENED TO 3/8 IN. HIGH FOR 3/4, 7/8, AND 1 IN. RIVETS FAR SIDE

SHOP RIVETS, FLATTENED TO 3/8 IN. HIGH FOR 3/4, 7/8, AND 1 IN. RIVETS BOTH SIDES

FIELD RIVETS, TWO FULL HEADS

FIELD RIVETS, COUNTERSUNK AND CHIPPED, NEAR SIDE

FIELD RIVETS, COUNTERSUNK AND CHIPPED, FAR SIDE

FIELD RIVETS, COUNTERSUNK AND CHIPPED, BOTH SIDES

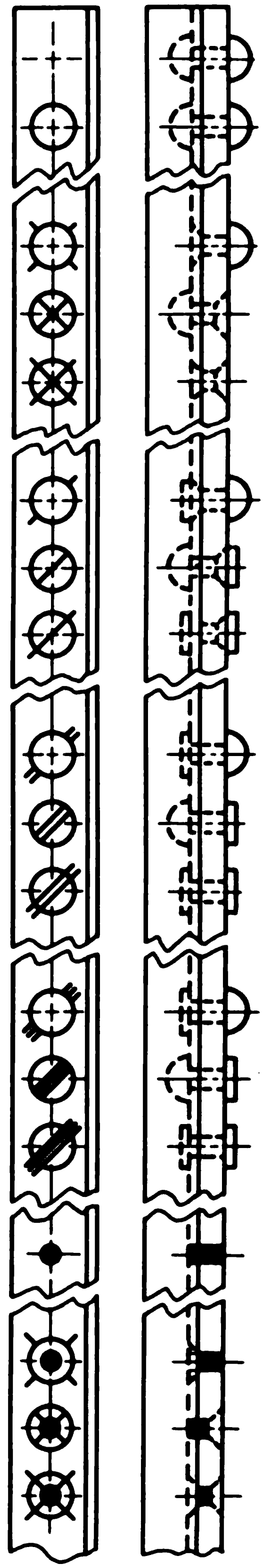


Figure B-4. Rivet conventions.

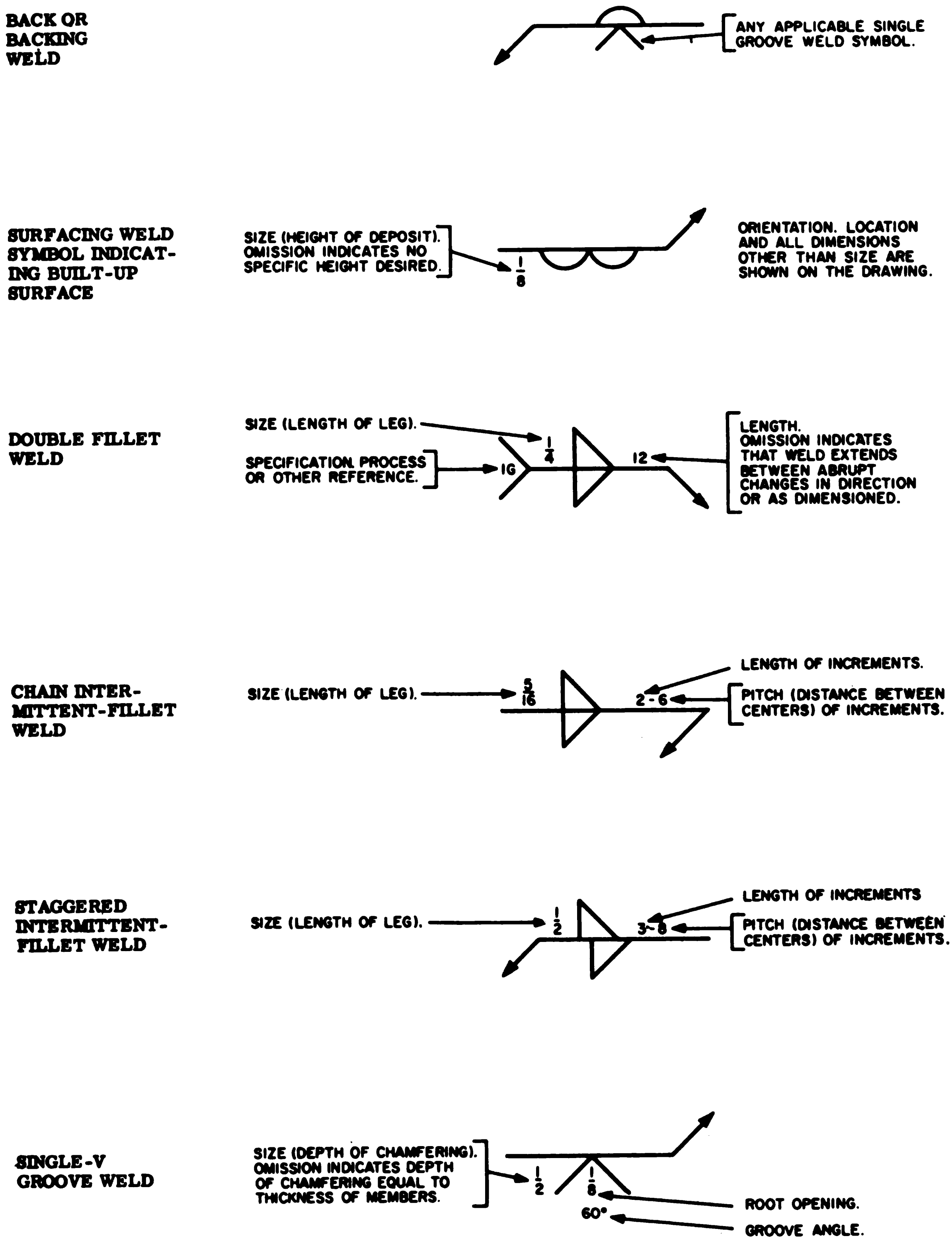


Figure B-5. Welding symbols.

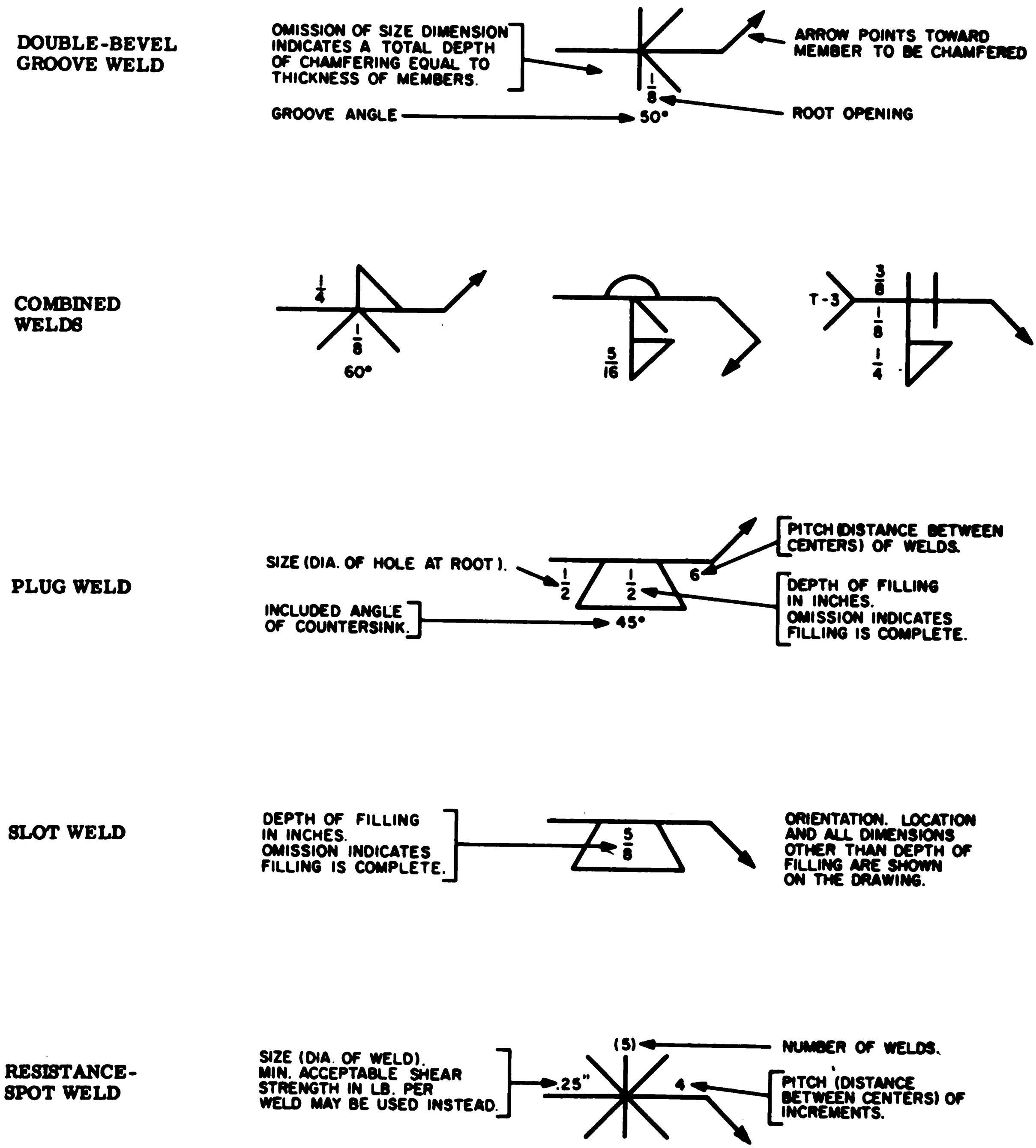


Figure B-5. Welding symbols—continued.

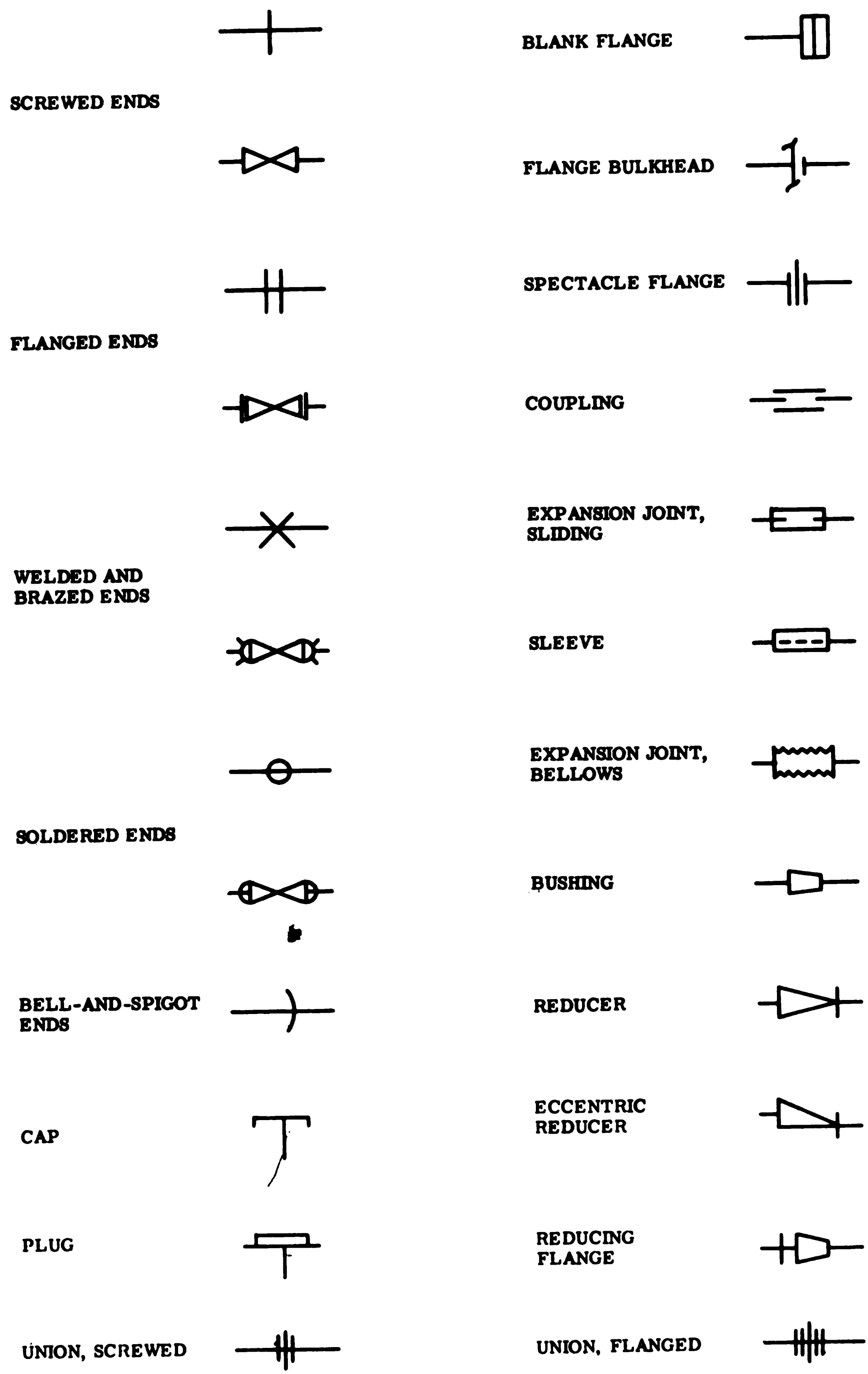


Figure B-6. Plumbing symbols.

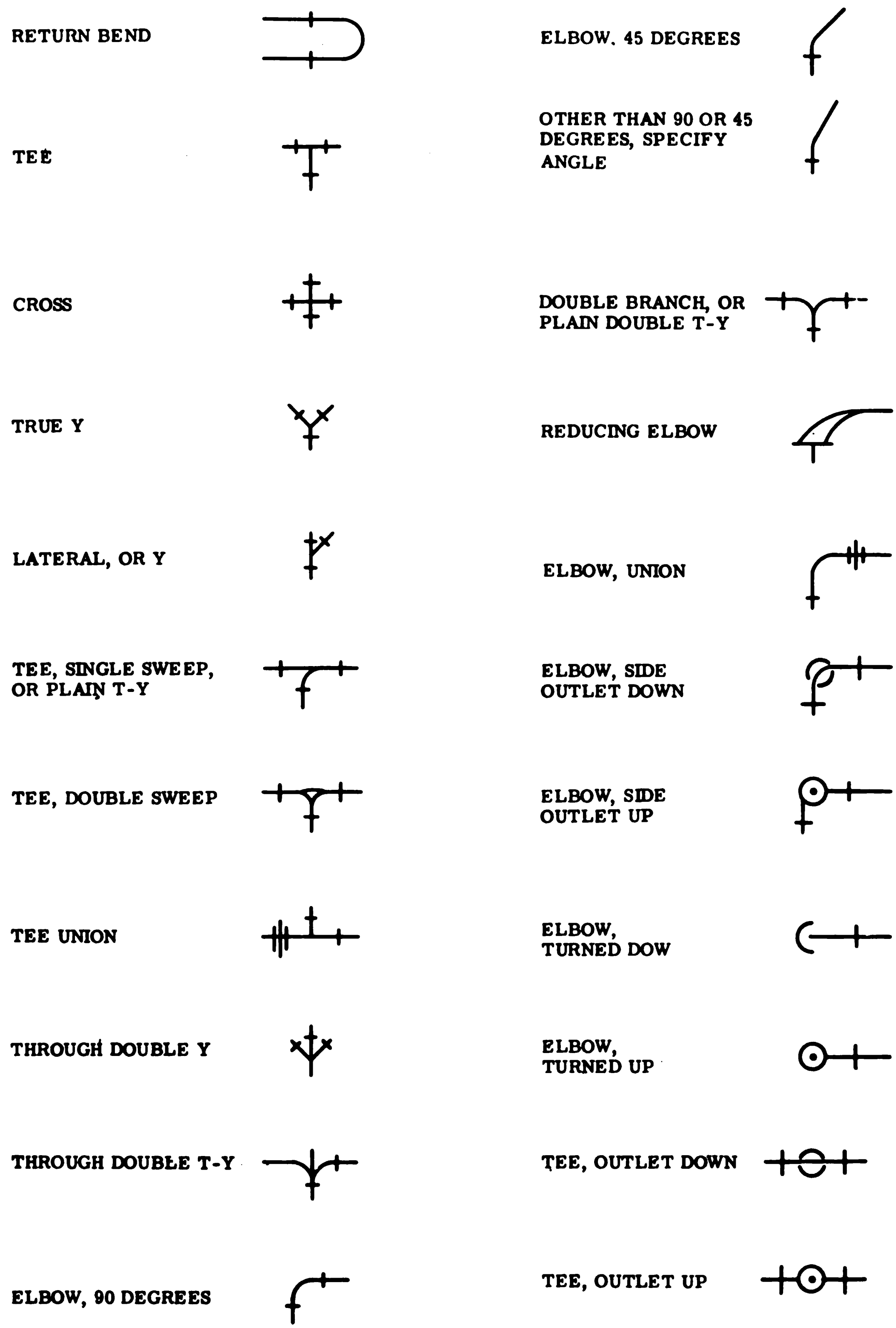


Figure B-6. Plumbing symbols - continued.

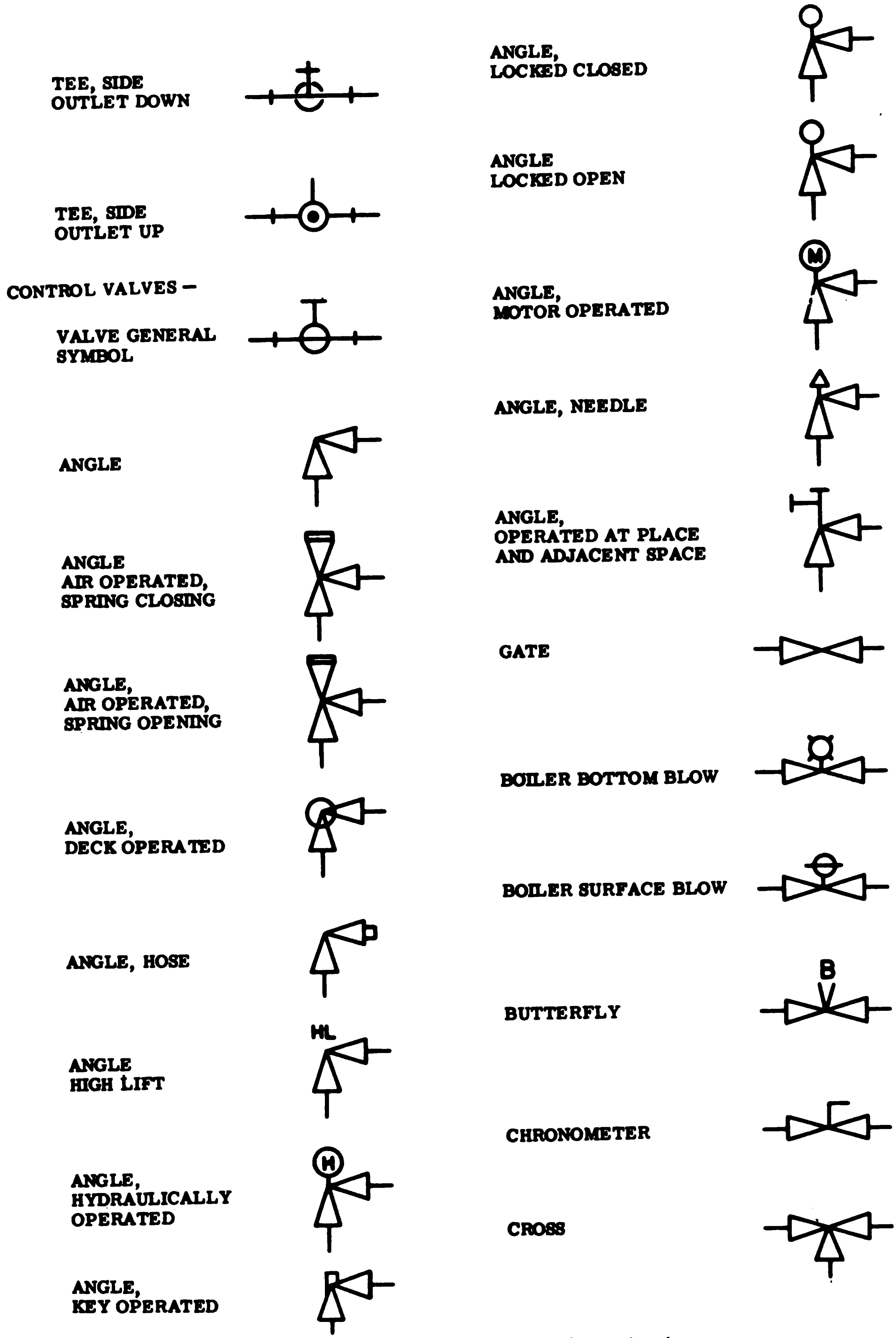


Figure B-6. Plumbing symbols - continued.

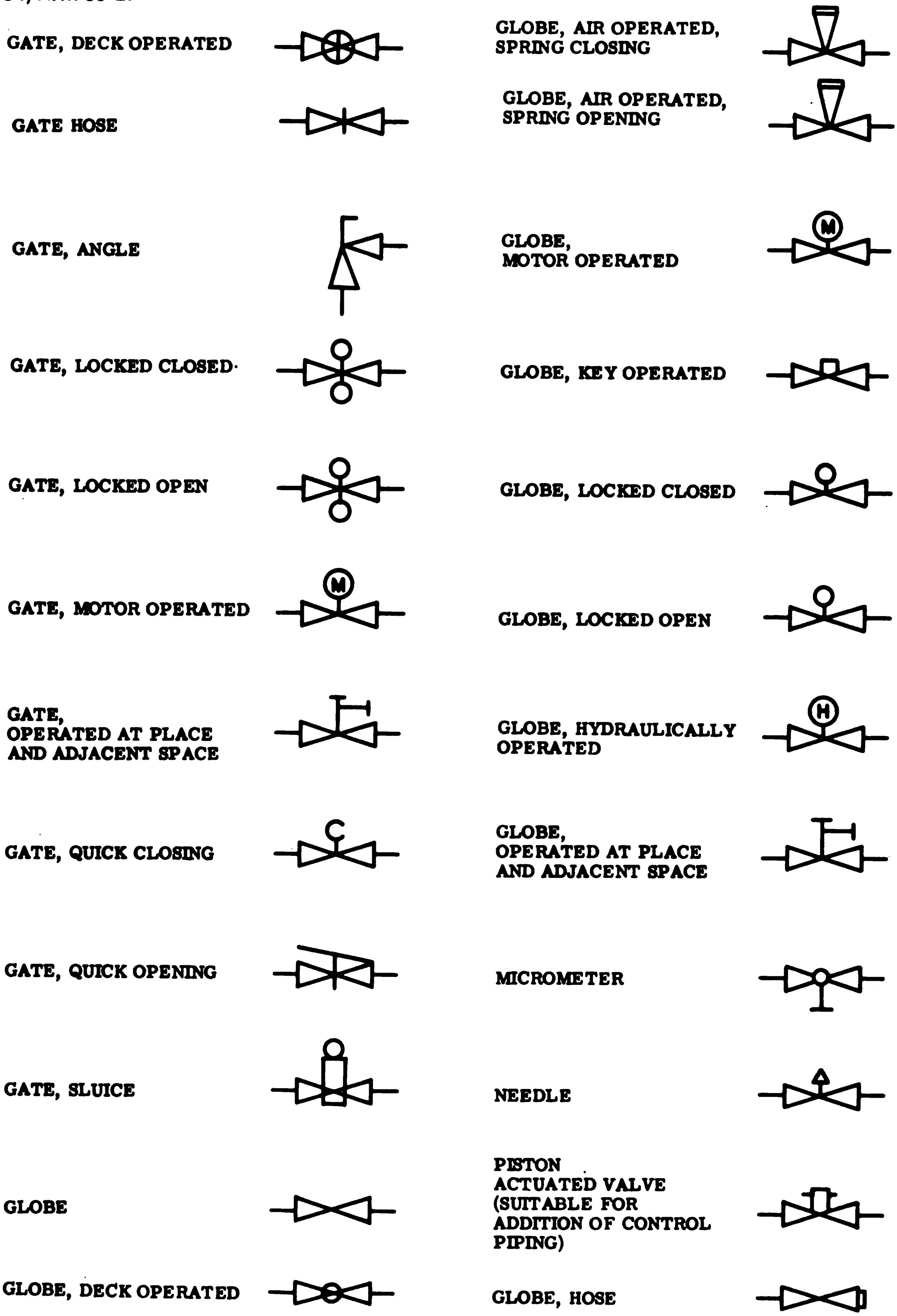


Figure B-6. Plumbing symbols - continued.

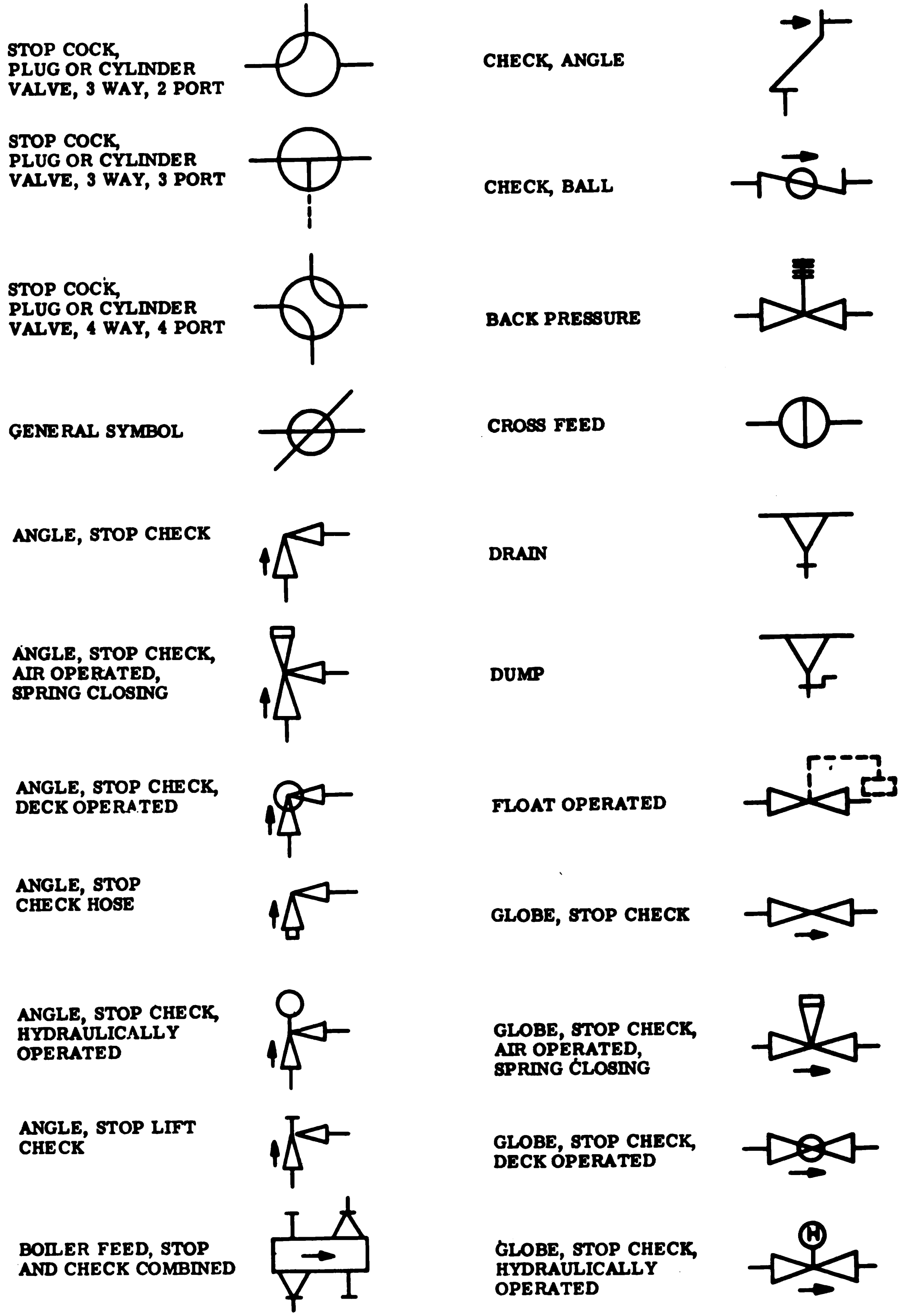


Figure B-6. Plumbing symbols - continued.

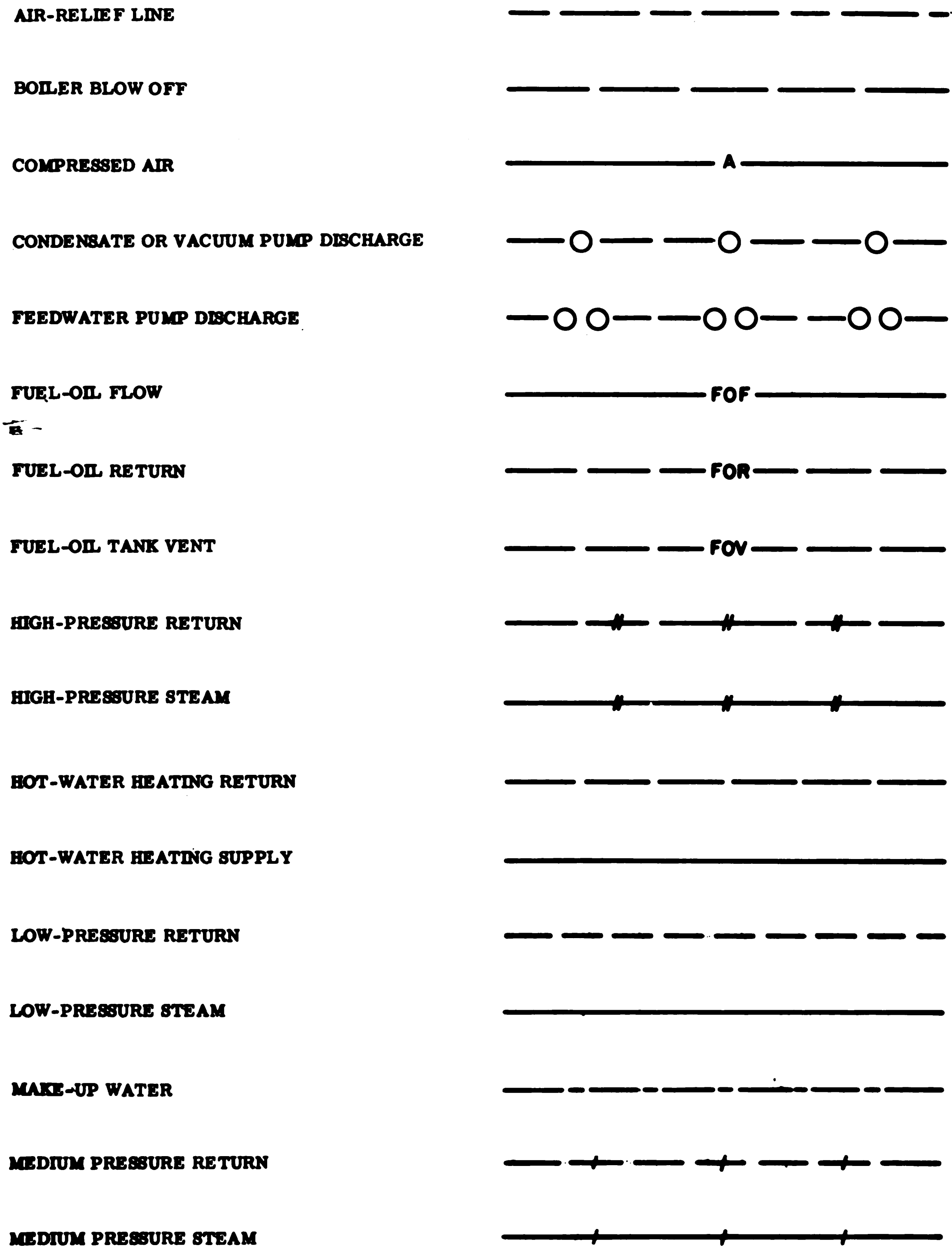


Figure B-7. Heating symbols.

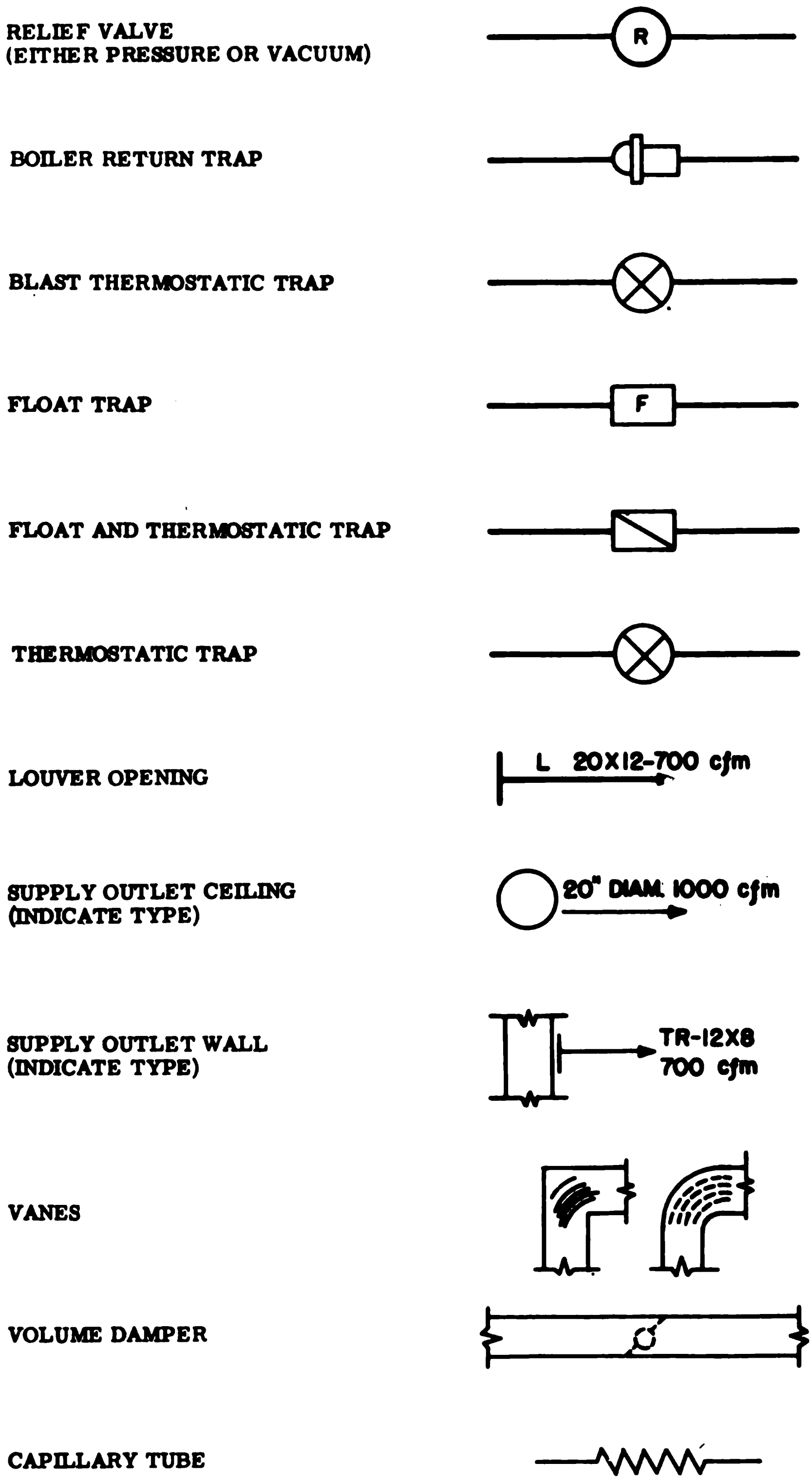


Figure B-7. Heating symbols - continued.

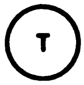
HEAT EXCHANGER

HEAT TRANSFER SURFACE,
PLAN, (WITH TYPE INDICATED
SUCH AS CONVECTOR)

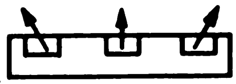
PUMP

THERMOMETER

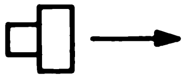
THERMOSTAT



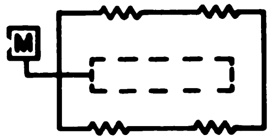
UNIT HEATER
(CENTRIFUGAL FAN),
PLAN



UNIT HEATER (PROPELLER), PLAN

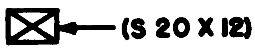


AUTOMATIC DAMPERS



DUCT SECTION (EXHAUST OR RETURN)

DUCT SECTION (SUPPLY)



MOTOR OPERATED VALVE

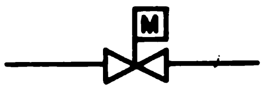


Figure B-7. Heating symbols - continued.

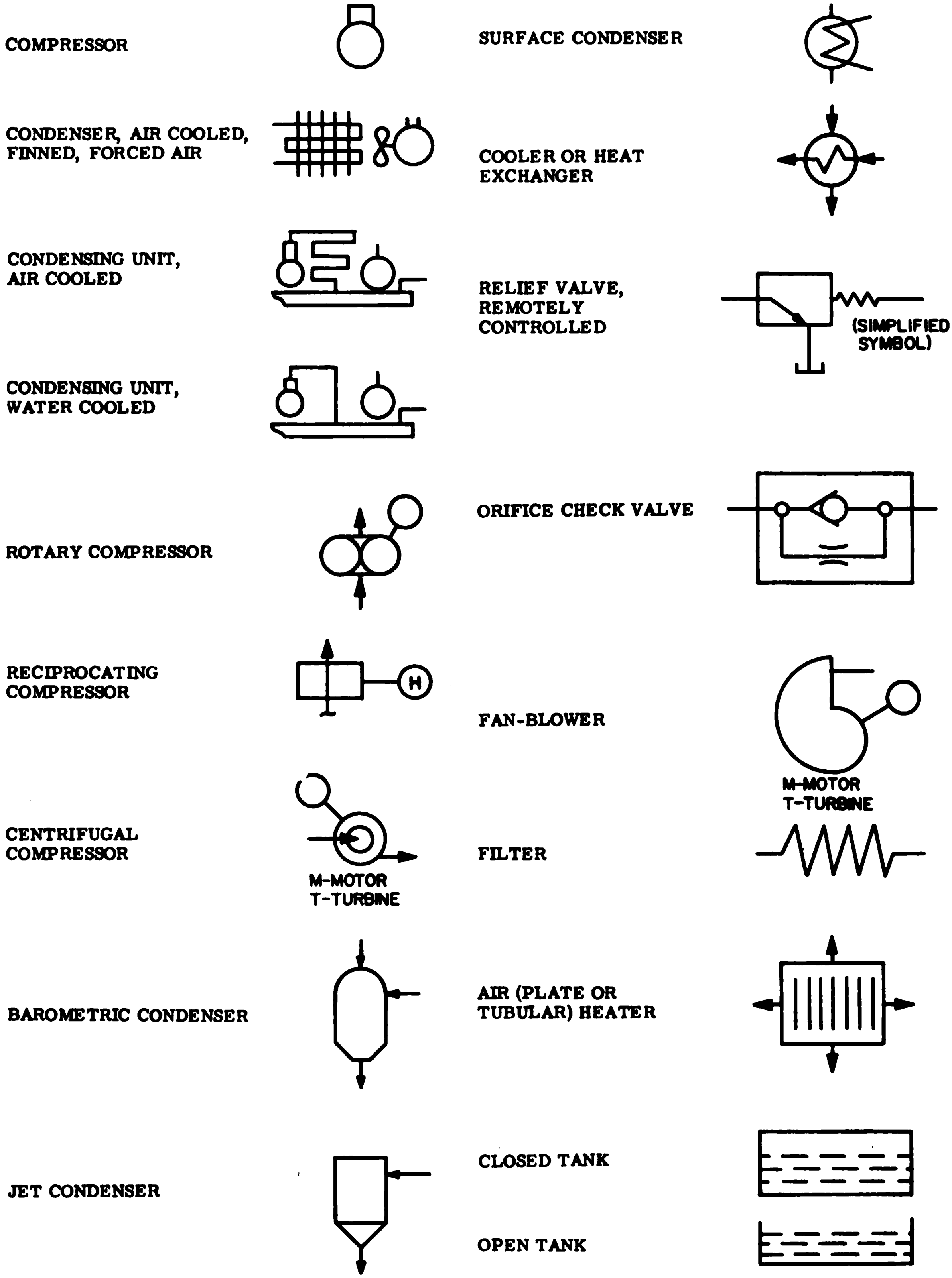
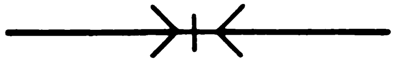


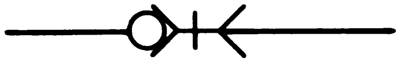
Figure B-7. Heating symbols - continued.

QUICK DISCONNECT —

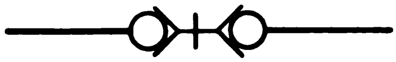
WITHOUT CHECKS



WITH ONE CHECK



WITH TWO CHECKS



WITH CHECK
DISCONNECTED

SINGLE HYDRAULIC
PUMP, FIXED
DISPLACEMENT

SINGLE HYDRAULIC
PUMP, VARIABLE
DISPLACEMENT

AIR COMPRESSOR,
FIXED DISPLACEMENT

ROTARY FLUID MOTOR —

FIXED DISPLACEMENT

VARIABLE DISPLACEMENT

OSCILLATING

Figure B-7. Heating symbols - continued.

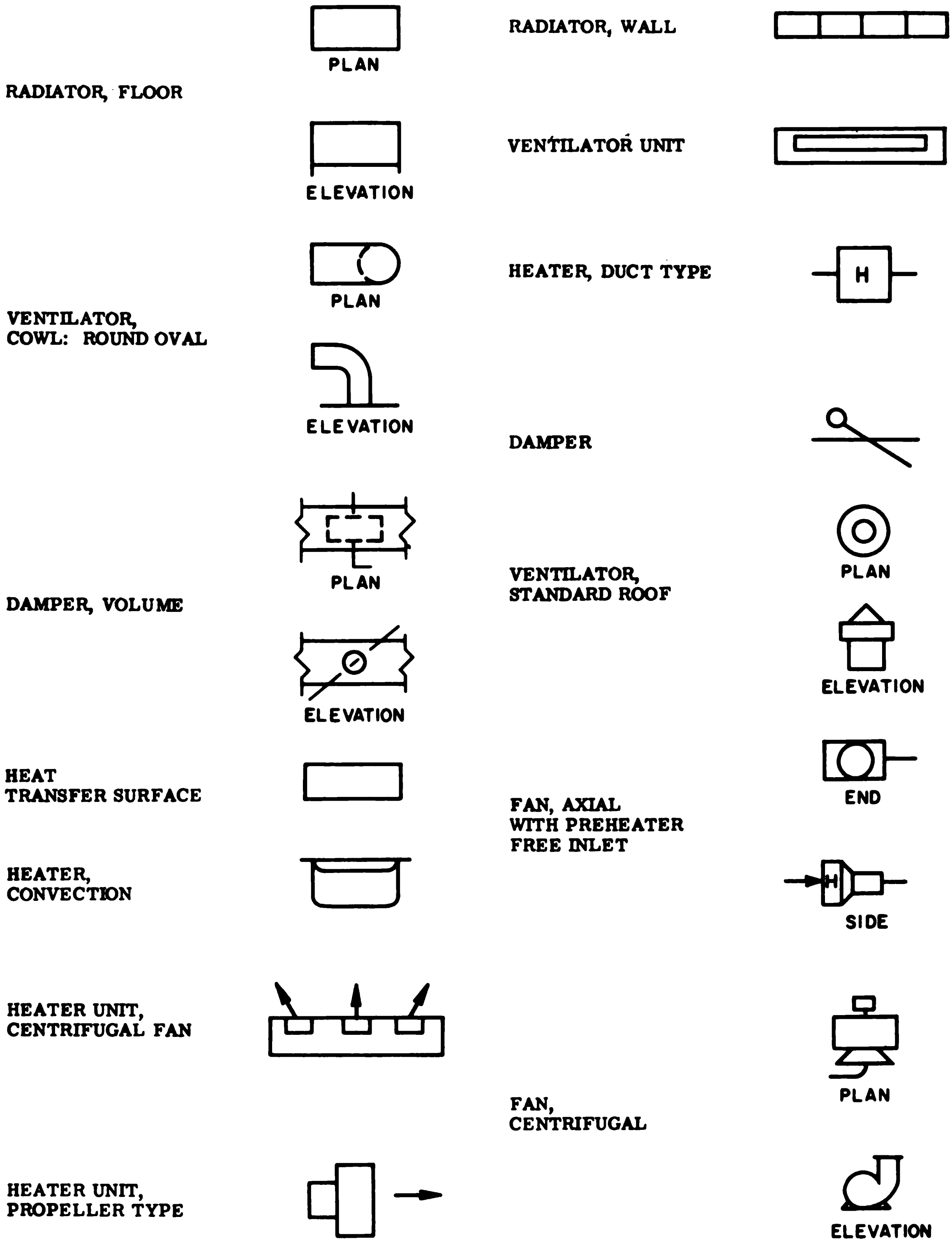


Figure B-7. Heating symbols - continued.

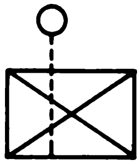
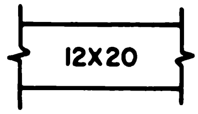
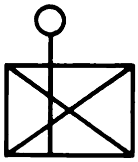
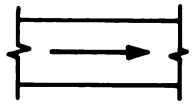
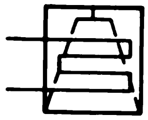
DAMPER, DEFLECTING DOWN		DUCT	
DAMPER, DEFLECTING UP		DUCT, DIRECTION OF FLOW IN	
GRILLE	G	REGISTER	R

Figure B-7. Heating symbols - continued.

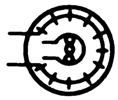
CIRCULATING CHILLED OR HOT-WATER FLOW	CH
CIRCULATING CHILLED OR HOT-WATER RETURN	CHR
CONDENSER WATER FLOW	C
CONDENSER WATER RETURN	CR
MAKE-UP WATER	
HUMIDIFICATION LINE	H
DRAIN	D
BRINE RETURN	BR
BRINE SUPPLY	B
REFRIGERANT DISCHARGE	RD
REFRIGERANT LIQUID	RL
REFRIGERANT SUCTION	RS

Figure B-8. Air conditioning and refrigeration symbols.

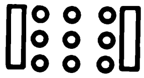
EVAPORATIVE CONDENSER



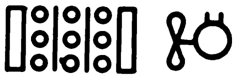
EVAPORATOR, CIRCULAR, CEILING TYPE, FINNED



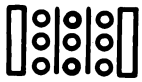
EVAPORATOR, MANIFOLDED, BARE TUBE, GRAVITY AIR



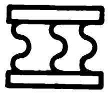
EVAPORATOR, MANIFOLDED, FINNED, FORCED AIR



EVAPORATOR, MANIFOLDED, FINNED, GRAVITY AIR



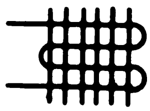
EVAPORATOR, PLATE COILS, HEADERED OR MANIFOLD



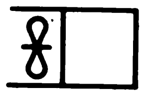
FILTER, LINE

FILTER & STRAINER, LINE

FINNED TYPE COOLING UNIT, NATURAL CONVECTION



FORCED CONVECTION COOLING UNIT

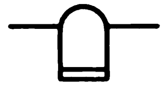


GAUGE

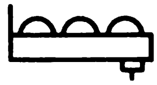
HIGH SIDE FLOAT

Figure B-8. Air conditioning and refrigeration symbols - continued.

SCALE TRAP

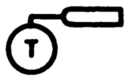


SPRAY POND



THERMAL BULB

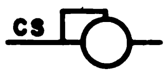
THERMOSTAT (REMOTE BULB)



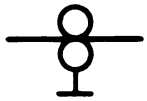
VALVES –

AUTOMATIC EXPANSION

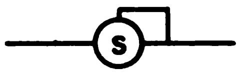
COMPRESSOR SUCTION PRESSURE LIMITING, THROTTLING TYPE (COMPRESSOR SIDE)



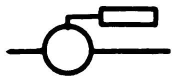
CONSTANT PRESSURE, SUCTION



EVAPORATOR PRESSURE REGULATING, SNAP ACTION



EVAPORATOR PRESSURE REGULATING, THERMOSTATIC THROTTLING TYPE



EVAPORATOR PRESSURE REGULATING, THROTTLING TYPE (EVAPORATOR SIDE)

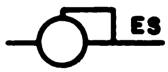
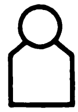
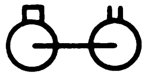
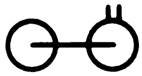


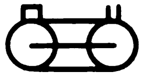
Figure B-8. Air conditioning and refrigeration symbols - continued.

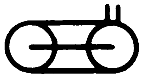
IMMERSION COOLING UNIT 

LOW SIDE FLOAT 

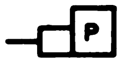
MOTOR-COMPRESSOR, ENCLOSED CRANKCASE, RECIPROCATING, DIRECT CONNECTED 

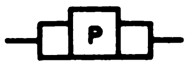
MOTOR-COMPRESSOR, ENCLOSED CRANKCASE, ROTARY, DIRECT CONNECTED 

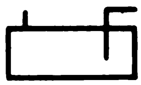
MOTOR-COMPRESSOR, SEALED CRANKCASE, RECIPROCATING 

MOTOR-COMPRESSOR, SEALED CRANKCASE, ROTARY 

PRESSURESTAT 

PRESSURE SWITCH 

PRESSURE SWITCH WITH HIGH PRESSURE CUT-OUT 

RECEIVER, HORIZONTAL 

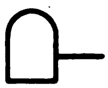
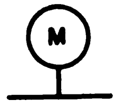
RECEIVER, VERTICAL 

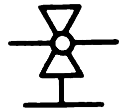
Figure B-8. Air conditioning and refrigeration symbols - continued.

HAND EXPANSION

MAGNETIC STOP

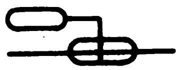


SNAP ACTION



SUCTION VAPOR REGULATING

THERMO SUCTION



THERMOSTATIC EXPANSION

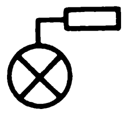


Figure B-8. Air conditioning and refrigeration symbols - continued.

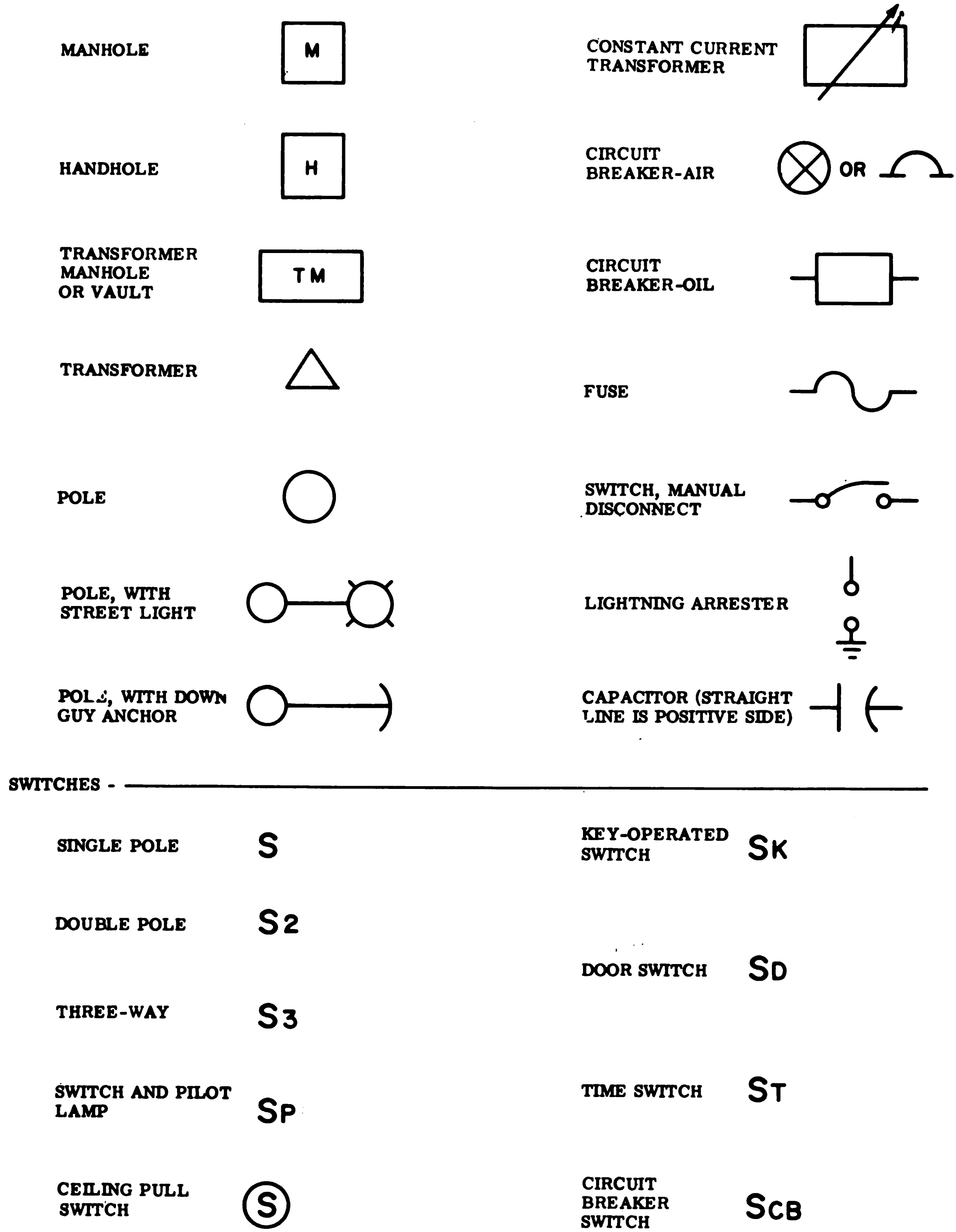
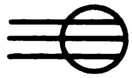
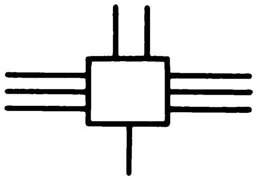


Figure B-9. Sumbols for electrical devices.

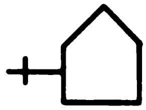
RANGE OUTLET



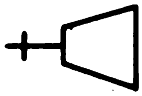
UNDERFLOOR DUCT AND JUNCTION BOX (SINGLE DOUBLE OR TRIPLE DUCT SYSTEM INDICATED BY NUMBER OF PARALLEL LINES)



WATCHMAN SYSTEM DEVICE

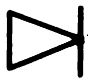


SOUND SYSTEM



BUZZER

OUTSIDE TELEPHONE



CHIME

BELL

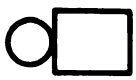


Figure B-9. Symbols for electrical devices - continued.

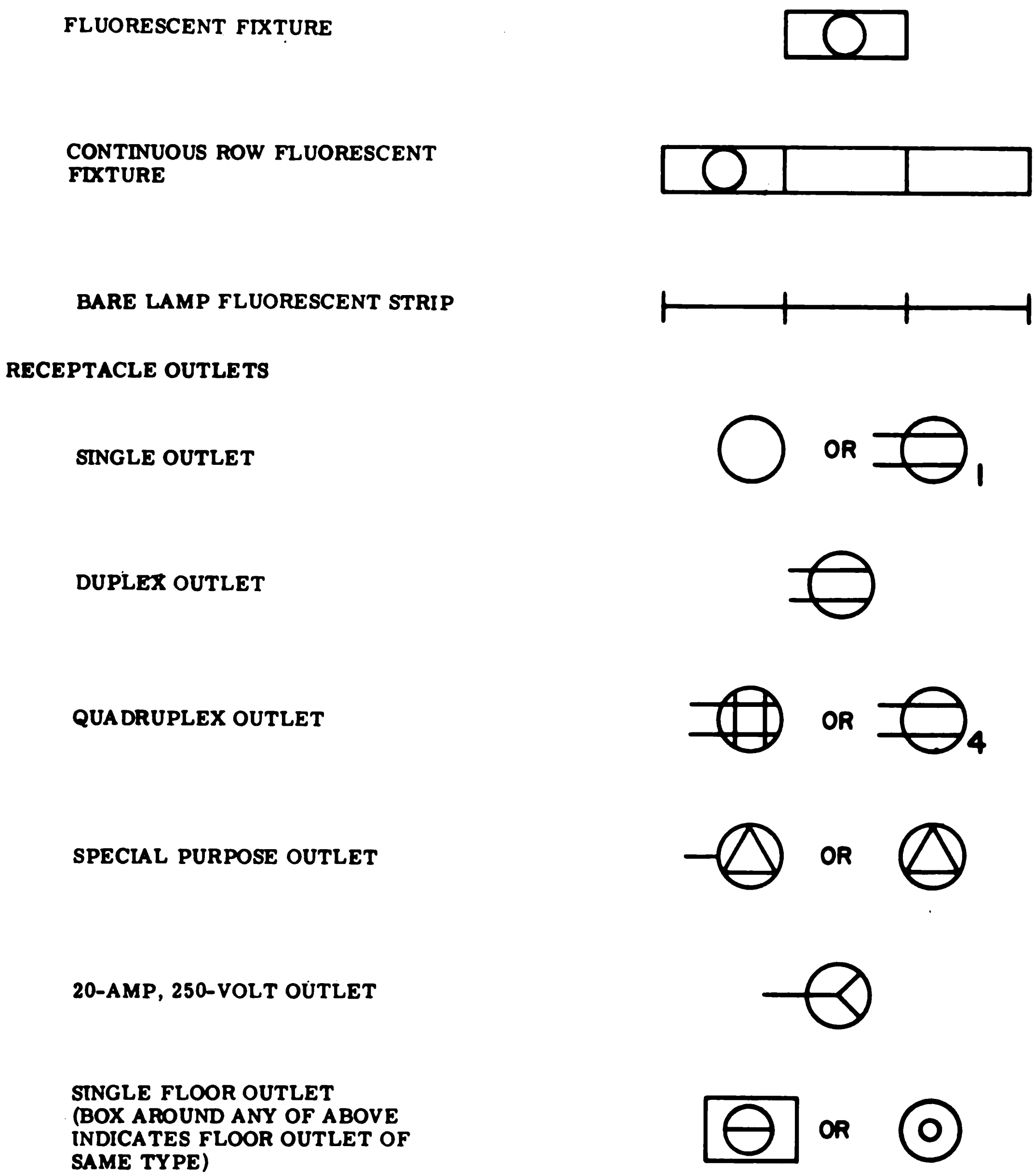


Figure B-9. Symbols for electrical devices - continued.

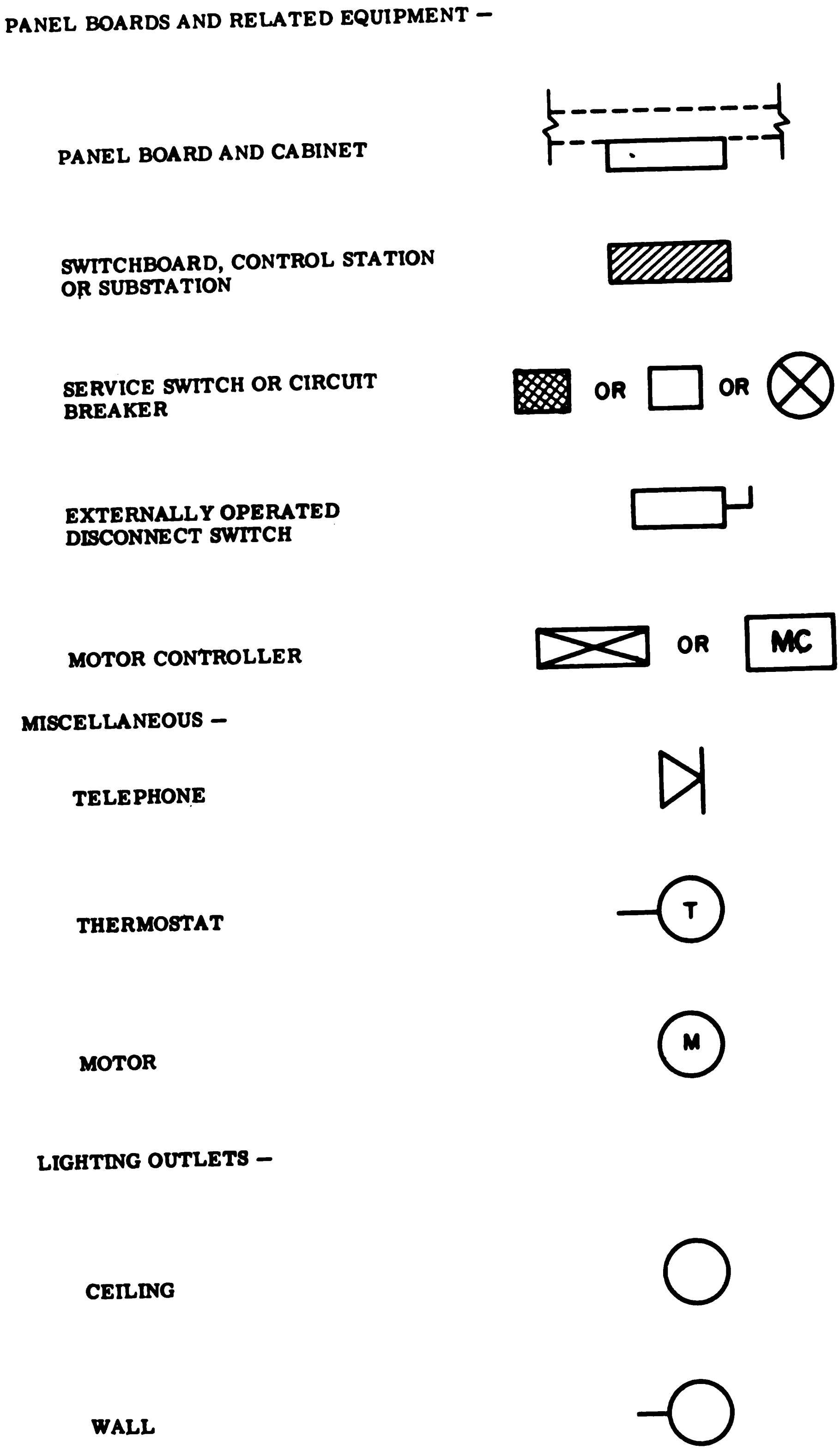


Figure B-9. Sumbols for electrical devices - continued.

WIRING CONCEALED IN CEILING OR WALL

WIRING CONCEALED IN FLOOR

EXPOSED BRANCH CIRCUIT

BRANCH CIRCUIT HOME RUN TO PANEL BOARD (NO. OF ARROWS EQUALS NO. OF CIRCUITS, DESIGNATION IDENTIFIES DESTINATION AT PANEL)

THREE OR MORE WIRES (NO. OF CROSS LINES EQUALS NO. OF CONDUCTORS TWO CONDUCTORS INDICATED IF NOT OTHERWISE NOTED)

INCOMING SERVICE LINES

CROSSED CONDUCTORS, NOT CONNECTED

SPLICE OR SOLDERED CONNECTION

CABLE CONNECTOR (SOLDERLESS)

WIRE TURNED UP

WIRE TURNED DOWN

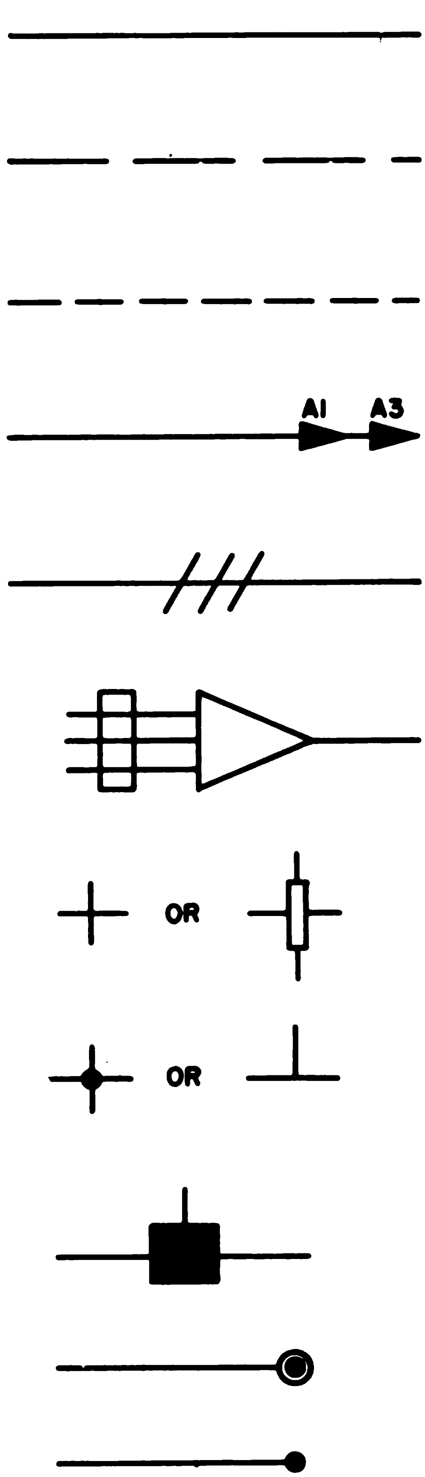


Figure B-10. Line symbols for electrical wiring.

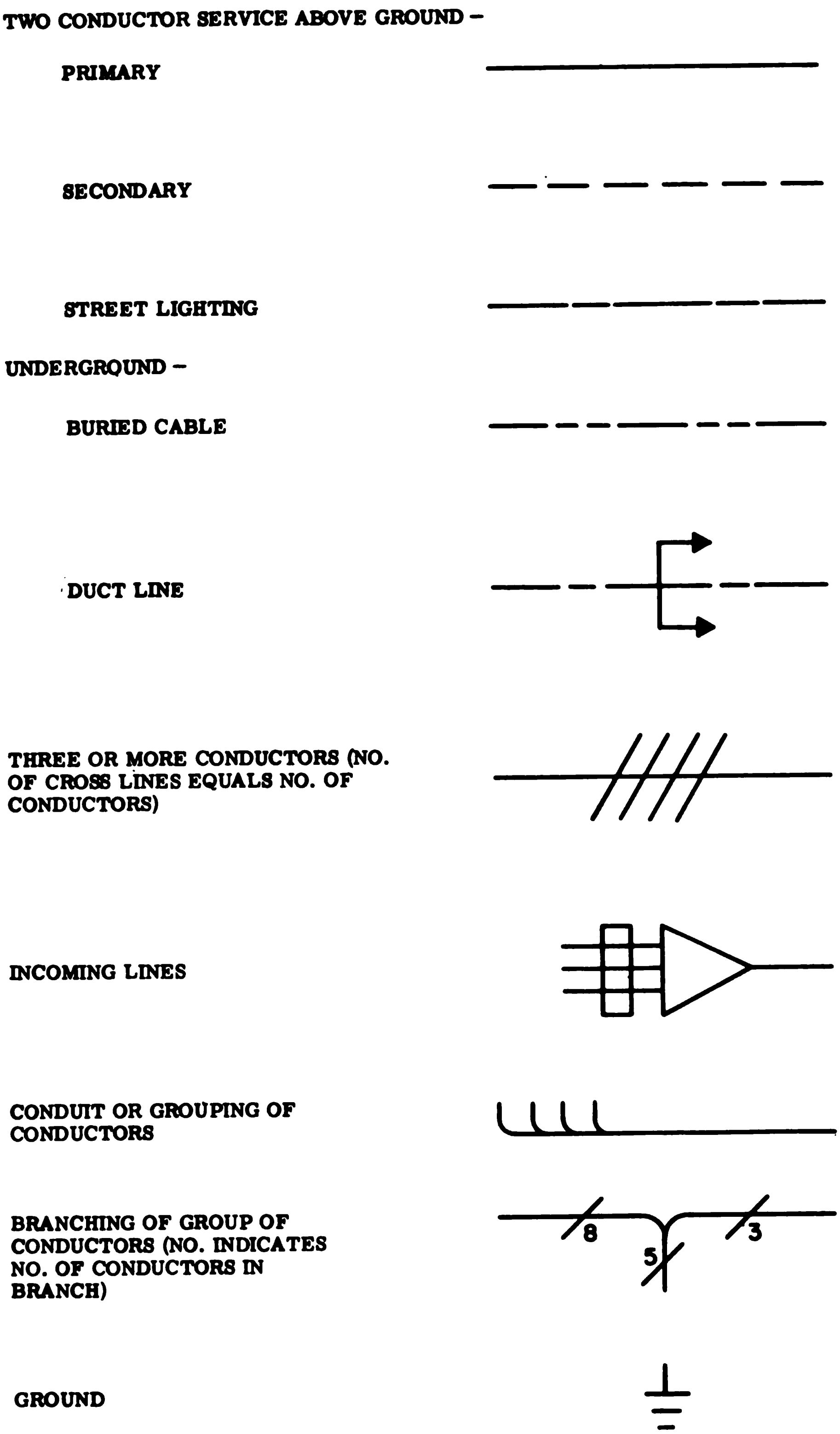


Figure B-11. Line symbols for electrical power distribution.

APPENDIX C

USEFUL FORMULAS

C-1. Formula by which to estimate the weight and volume of aggregate in cone shaped pile is:

volume = 0.2618 x height x diameter (squared)

C-2. Formula for determining current in electrical wiring:

$$\text{amperes} = \frac{\text{Total watts to be serviced}}{\text{voltage}}$$

or

$$\text{amperes} = \frac{\text{voltage}}{\text{resistance (ohms)}}$$

or

$$\text{amperes} = \frac{745.7 \times \text{Horsepower}}{\text{voltage}}$$

C-3. Formula for converting degrees Centigrade to Fahrenheit is:

$$F = \tfrac{9}{5}C + 32$$

C-4. The following formula is used in calculating specific heat problems:

British thermal units = Sp. heat x W (t_2—t_1)
where
W = weight of the substance in pounds
Sp. heat = specific heat of substance to be heated
t_2—t_1 = temperature change in degrees F.

C-5. Lengths, Areas, and Volumes of Geometric Figures:

a. Legend.

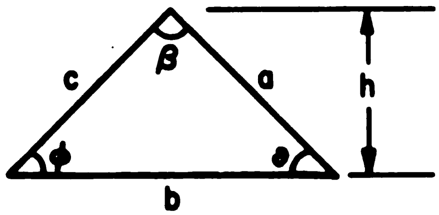
A = area
a = altitude
b = length of base
C = circumference
V = volume
r = radius
D = diameter
$\Pi = 3.1416$
L = length of arc
k = length of cord

b. Formulas.

(1) Any triangle:

$$A = \frac{1}{2} bh$$

$$\text{or } \sin y = \frac{c \sin \phi}{a}$$

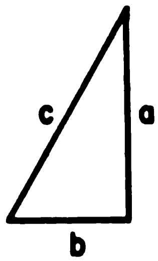


(2) Right triangle:

$$a = \sqrt{c^2 - b^2}$$

$$b = \sqrt{c^2 - a^2}$$

$$c = \sqrt{a^2 + b^2}$$

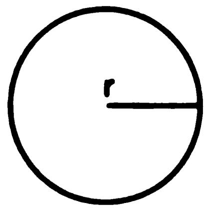


(3) Circle:

$$A = \Pi r^2$$

$$A = 0.7854 D^2$$

$$C = \Pi D$$



(4) Segment of circle:

$$A = \frac{1}{2}[r(1 - k) + ak]$$

$$L = \left(\frac{2\Pi r}{360}\right) \times a$$

$$k = \sqrt{2ar - a^2}$$

a = angle in degrees

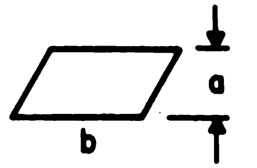
(5) Sector of circle:

$$A = \frac{ri}{2} = \frac{\Pi r^2}{360}(\text{angle in degrees})$$

(6) Regular polygons. The area of any regular polygon (all sides equal, all angles equal) is equal to the product of the square of the lengths of one side and the factors shown in table C-1. Example: Area of a regular octagon having 6-inch sides is 6 x 6 x 4.828, or 173.81 square inches. See factors in table C-1.

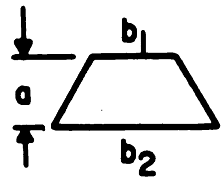
(7) Rectangle and parallelogram:

$A = ab$



(8) Trapezoid:

$A = \frac{1}{2} a(b_1 + + b_2)$



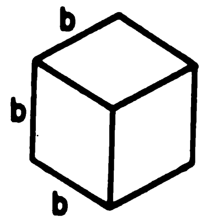
(9) Irregular figures. Measure widths at offsets regularly spaced along any straight line, and apply one of the following:

(a) Trapezoidal rule. A = one half the interval between offsets x (sum of two end widths plus twice the sum of the intermediate widths).

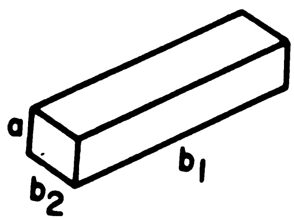
(b) Simpson's rule. (Assumes lateral boundaries are parabolic curves.) A = one third the interval between offsets x (sum of two end widths plus twice the sum of the odd widths, except first and last (3rd, 5th, 7th, etc.) plus 4 times the sum of the even widths (2d, 4th, 6th, etc.))

NOTE: The above rule required an odd number of widths. If there is an even number, compute separately the area of a trapezoid at one end.

(10) Cube:
$V = b^3$

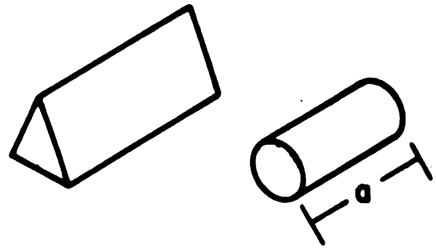


(11) Rectangular parallelepiped:
$V = a\, b_1\, b_2$



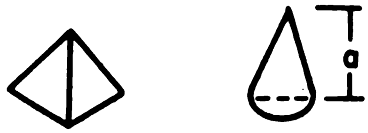
(12) Prism or cylinder:

V = a X (area of base)



(13) Pyramid or cone:

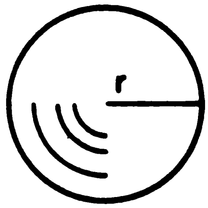
V= [⅓) a X (area of base)



(14) Spere:

$$V = (4/3)\Pi r^3 = \frac{\Pi D^3}{6}$$

$$A = 4\Pi r^2$$



(15) Prismoidal section:

V = one-sixth the length X (sum of the end areas plus 4 times the midsection area)

Table C-1. Polygon Factors

No. of Sides	Factor		No. of Sides	Factor
3	0.433		8	4.828
4	1.000		9	6.182
5	1.720		10	7.694
6	2.598		11	9.366
7	3.634		12	11.196

APPENDIX D

CONVERSION TABLES

Tables of conversion factors applicable to the U. S. (English system) measures versus the Metric system.

Conversion—English-Metric Systems

LENGTH

	km → miles	miles → kilometers	meters → yards	yards → meters	meters → feet	feet → meters	cm → inches	inches → centimeters
1	0.62	1.61	1.09	0.91	3.28	0.30	0.39	2.54
2	1.24	3.22	2.19	1.83	6.56	0.61	0.79	5.08
3	1.86	4.83	3.28	2.74	9.84	0.91	1.18	7.62
4	2.49	6.44	4.37	3.66	13.12	1.22	1.57	10.16
5	3.11	8.05	5.47	4.57	16.40	1.52	1.97	12.70
6	3.73	9.66	6.56	5.49	19.68	1.83	2.36	15.24
7	4.35	11.27	7.66	6.40	22.97	2.13	2.76	17.78
8	4.97	12.87	8.75	7.32	26.25	2.44	3.15	20.32
9	5.59	14.48	9.84	8.23	29.53	2.74	3.54	22.86
10	6.21	16.09	10.94	9.14	32.81	3.05	3.93	25.40
12	7.46	19.31	13.12	10.97	39.37	3.66	4.72	30.48
20	12.43	32.19	21.87	18.29	65.62	6.10	7.87	50.80
24	14.91	38.62	26.25	21.95	78.74	7.32	9.45	60.96
30	18.64	48.28	32.81	27.43	98.42	9.14	11.81	76.20
36	22.37	57.94	39.37	32.92	118.11	10.97	14.17	91.44
40	24.85	64.37	43.74	36.58	131.23	12.19	15.75	101.60
48	29.83	77.25	52.49	43.89	157.48	14.63	18.90	121.92
50	31.07	80.47	54.68	45.72	164.04	15.24	19.68	127.00
60	37.28	96.56	65.62	54.86	196.85	18.29	23.62	152.40
70	43.50	112.65	76.55	64.00	229.66	21.34	27.56	177.80
72	44.74	115.87	78.74	65.84	236.22	21.95	28.35	182.88
80	49.71	128.75	87.49	73.15	262.47	24.38	31.50	203.20
84	52.20	135.18	91.86	76.81	275.59	25.60	33.07	213.36
90	55.92	144.84	98.42	82.30	295.28	27.43	35.43	228.60
96	59.65	154.50	104.99	87.78	314.96	29.26	37.80	243.84
100	62.14	160.94	109.36	91.44	328.08	30.48	39.37	254.00

Example: 2 inches = 5.08 cm

Conversion—English-Metric Systems (cont)

One unit (below) ↓ Equals →	mm	cm	meters	km
mm (millimeters)	1.	0.1	0.001	0.000,001
cm (centimeters	10.	1.	0.01	0.000,01
meters	1,000.	100.	1.	0.001
km (kilometers)	1,000,000.	100,000.	1,000.	1.

One unit (below) ↓ Equals →	gm	kg	metric ton
gm(gram)	1.	0.001	0.000,001
kg(kilograms)	1,000.	1.	0.001
metric ton	1,000,000.	1,000.	1.

UNITS OF CENTIMETERS

cm	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.10
inch	0.04	0.08	0.12	0.16	0.20	0.24	0.28	0.31	0.35	0.39

FRACTIONS OF AN INCH

inch	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2
cm	0.16	0.32	0.48	0.64	0.79	0.95	1.11	1.27

inch	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1
cm	1.43	1.59	1.75	1.91	2.06	2.22	2.38	2.54

Conversion—English-Metric Systems (cont)

WEIGHT[1]

	metric ton[3] → short ton	short ton[2] → metric ton	kg → pounds	pounds → kilograms	grams → ounces	ounces → grams
1	1.10	0.91	2.20	0.45	0.04	28.4
2	2.20	1.81	4.41	0.91	0.07	56.7
3	3.31	2.72	6.61	1.36	0.11	85.0
4	4.41	3.63	8.82	1.81	0.14	113.4
5	5.51	4.54	11.02	2.67	0.18	141.8
6	6.61	5.44	13.23	2.72	0.21	170.1
7	7.72	6.35	15.43	3.18	0.25	198.4
8	8.82	7.26	17.64	3.63	0.28	226.8
9	9.92	8.16	19.84	4.08	0.32	255.2
10	11.02	9.07	22.05	4.54	0.35	283.5
16	17.63	14.51	35.27	7.25	0.56	453.6
20	22.05	18.14	44.09	9.07	0.71	567.0
30	33.07	27.22	66.14	13.61	1.06	850.5
40	44.09	36.29	88.14	18.14	1.41	1134.0
50	55.12	45.36	110.23	22.68	1.76	1417.5
60	66.14	54.43	132.28	27.22	2.12	1701.0
70	77.16	63.50	154.32	31.75	2.47	1984.5
80	88.18	72.57	176.37	36.29	2.82	2268.0
90	99.21	81.65	198.42	40.82	3.17	2551.5
100	110.20	90.72	220.46	45.36	3.53	2835.0

Example: Convert 28 pounds to kg

28 pounds = 20 pounds + 8 pounds

From the tables: 20 pounds = 9.07 kg and 8 pounds = 3.63 kg

Therefore, 28 pounds = 9.07 kg + 3.63 kg = 12.70 kg

1 The weights used for the English system are avoirdupois (common) weights.
2 The short ton is 2000. pounds.
3 The metric ton is 1000. kg.

Conversion—English-Metric Systems (cont)

VOLUME

cu. meters → cu. ft → cu. yd

cu. yd → cu. ft → cu. meters

cu. ft → cu. yd → cu. meters

	cu. ft → cu. yd	cu. ft → cu. meters	cu. yd → cu. ft	cu. yd → cu. meters	cu. meters → cu. ft	cu. meters → cu. yd
1	0.037	0.028	27.0	0.76	35.3	1.31
2	0.074	0.057	54.0	1.53	70.6	2.62
3	0.111	0.085	81.0	2.29	105.9	3.92
4	0.148	0.113	108.0	3.06	141.3	5.23
5	0.185	0.142	135.0	3.82	176.6	6.54
6	0.212	0.170	162.0	4.59	211.9	7.85
7	0.259	0.198	189.0	5.35	247.2	9.16
8	0.296	0.227	216.0	6.12	282.5	10.46
9	0.333	0.255	243.0	6.88	317.8	11.77
10	0.370	0.283	270.0	7.65	353.1	13.07
20	0.741	0.566	540.0	15.29	706.3	26.16
30	1.111	0.850	810.0	22.94	1059.4	39.24
40	1.481	1.133	1080.0	30.58	1412.6	52.32
50	1.852	1.416	1350.0	38.23	1765.7	65.40
60	2.222	.700	1620.0	45.87	2118.9	78.48
70	2.592	1.982	1890.0	53.52	2472.0	91.56
80	2.962	2.265	2160.0	61.16	2825.2	104.63
90	3.333	2.548	2430.0	68.81	3178.3	117.71
100	3.703	2.832	2700.0	76.46	3531.4	130.79

Example: 3 cu. yd = 81.0 cu. ft
Volume: The cubic meter is the only common dimension used for measuring the volume of solids in the metric system.

GLOSSARY OF ARCHITECTURAL TERMS

Arch. Any bow-like curve, structure, or object generally spanning an opening, and producing horizontal and vertical reactions.
Arch, jack. A construction in which both the underside and outside are flat.
Butten, (cleat). A strip of wood used for nailing across two other pieces to hold them together, or for covering a crack.
Cap, (lintel). A horizontal structural load-bearing member spanning an opening.
Casing. The trimming around a door or window opening, either outside or inside, or the finished lumber around a post or beam.
Cornice. The molded projection which finishes the top of the wall of a building.
Eave. The projection edges of a roof.
Flushing. The material used in the process of making watertight the roof intersections and other exposed places on the outside of a building.
Gable. Vertical triangular end of a building from the eaves to the apex of the roof.
Head. Section through top of door or window, showing construction.
Jamb. The side piece or post of an opening; usually applied to the doorframe or window frame.
Louver. A ventilating window sheltered from the weather by sloping slats.
Meeting rail. The horizontal wood or metal bar which divides the upper and lower sash of a window.
Muntin. The small member that divides the glass in a window frame.
Pane. Glass set between vertical and horizontal pieces in a sash.
Perspective drawing. A pictorial representation of an object on a plane surface as it actually appears to the eye.
Rail. The horizontal member of a door or window.
Ridge. The top of the roof where two slopes meet.
Sash. The framework which holds the glass in a window.
Sheathing. Boards nailed to studding or roofing rafters to form a foundation for the outer surface covering of the sidewalls or roof.
Siding. Lumber used for finishing the exterior walls of a building.
Sill. The horizontal timbers of a house which either rest upon the masonry foundations or, in the absence of such, form the foundations.
Stile. Vertical pieces of wood or metal, forming sides of sash.
Stucco. Plaster or cement mixture used on exterior walls of a building.
Valley. The gutter or angle formed by the meeting of two roof slopes.

GLOSSARY OF WOOD—CONSTRUCTION TERMS

Anchor. Irons of special form used to fasten together timbers or masonry.
Batter pile. Pile driven at an angle to brace a structure against lateral thrust.
Bent. A single vertical framework consisting of horizontal and vertical members supporting the deck of a bridge or pier.
Board. Thin timber less than 2 inches thick and more than 4 inches wide.
Board foot. The equivalent of a board 1 foot square and 1 inch or less in thickness.
Brace. A diagonal member used to stiffen framework.
Bridging. A horizontal or cross bracing between continuous floor joists to prevent buckling or transverse movement.
Building paper. Heavy paper used to insulate a building before the siding or roofing is put on; sometimes placed between double floors.

Built-up member. A single structural component made from several pieces fastened together.
Chamfer. A beveled surface cut upon the corner of a piece of wood.
Chock. Heavy timber fitted between fender piles along wheel guard of a pier or wharf.
Chord. The principal member of a truss on either the top or bottom.
Column. A square, rectangular, or cylindrical support for roofs, ceilings, and so forth, composed of base, shaft, and capital.
Cross brace. Bracing with two intersecting diagonals.
Decking. Heavy plank floor of a pier or bridge.
Diagonal. Inclined member of a truss or bracing system used for stiffening and wind bracing.
Fender pile. Outside row of piles that protects a pier or wharf from damage by ships.
Filler. Piece used to fill space between two surfaces.
Girt. Horizontal pieces nailed between studs.
Grade. The horizontal ground level of a building or structure.
Hanger. Vertical-tension member supporting a load.
Header. A short joist into which the common joists are framed around or over an opening.
Jamb. The side piece or post of an opening.
Knee brace. A corner brace, fastened at an angle from wall stud to rafter, stiffening a wood or steel frame to prevent angular movement.
Lintel (cap). A horizontal structural member spanning an opening, and supporting a wall load.
Member. A single piece in a structure, complete in itself.
Partition. A permanent interior wall which serves to divide a building into rooms.
Pier. *(a)* Timber, concrete, or masonry supports for girders, posts, or arches. *(b)* Intermediate supports for adjacent ends of two bridge spans. *(c)* Structure extending outward from shore into water used as a dock for ships.
Piling. Large timbers or poles driven into the ground or the bed of a stream to make a firm foundation.
Plank. A wide piece of sawed timber, usually 1½ to 4½ inches thick and 6 inches or more wide.
Plate. The top horizontal timber of a wall upon which the roof rests.
Purlins. Timbers extending between trusses, and supporting the sheathing of a roof.
Rafters. The ribs which run from hip, or ridge, to eaves in a roof.
Rake. The inclination from the horizontal, as the slope of a roof.
Ridge. The top of the roof where two slopes meet.
Scab. A short piece of lumber used to splice, or to prevent movement of two other pieces.
Splice. Joining of two similar members in a straight line.
Stringer. A long horizontal timber in a structure supporting a floor.
Stud. An upright beam in the framework of a building.
Subfloor. A wood floor which is laid over the floor joists and on which the finished floor is laid.
Tie. A piece inserted or attached to other pieces to hold them in position.
Top plate. Piece of lumber supporting ends of rafters.
Tread. The horizontal part of a step.
Wale. A horizontal beam bolted to a row of piles to receive the impact of vessels.
Wharf. A structure that provides berthing space for vessels, to facilitate loading and discharge of cargo.

GLOSSARY OF STEEL—CONSTRUCTION TERMS

Base angle. Angle piece connecting bottom of column to base plate.
Base plate. Distribution plate or steel slab upon which column rests.
Batten plate. A small plate used to hold two parts in their proper position when made up as one member.
Bay. The distance between two trusses or transverse bents.
Beam girder. Made of two or more beams fastened together either by cover plates or by bolts with separators.
Bearing. The portion of a beam, truss, and so forth, that rests on the supports.
Bearing plate. Flat steel over 6 inches wide and over 2 inches thick, used to distribute load over a large area.
Bent. A single vertical framework consisting of horizontal and vertical members, supporting the deck of a bridge or pier.
Box girder. Any built-up girder of rectangular section.
Brace. Any inclined member in a truss or frame used to stiffen the structure.
Bracket. Projecting connection, usually a plate or angle.
Buckle plate. A flat plate with dished depression pressed into it to give transverse strength.
Built-up member. A single structural member made from several pieces fastened together.
Camber. Slight upward curve given to trusses and girders to avoid effect of sag.
Cantilever. A beam, girder, or truss overhanging one or both supports.
Cap angle or plate. Angle or plate at top of a column.
Clearance. Amount of space left between members to provide for slight irregularities of workmanship or materials.
Clip angle. A small angle used for fastening various members together.
Column. A square, rectangular, or cylindrical support for roofs, ceilings, etc., composed of base, shaft, and capital.
Column base. Base plate, slab, or pedestal and connecting angles or plates of a column.
Compression member. Structural member which tends to be shortened by the loads it carries.
Cope. To cut out top or bottom of flanges and web so that one member will frame into another.
Counters. Diagonal members in a truss to provide for reversal of shear due to live loads.
Countersink. To bevel a hole in such a manner that plates, or heads of screws, rivets, or bolts, will flush with the surface.
Cover plate. A plate used in building up flanges in a built-up member to give greater strength and area, or for protection.
Crimp. To offset the end of a stiffener to fit over the leg of an angle.
Cross bracing. Bracing with two intersecting diagonals.
Cross frame. Vertical transverse cross bracing between bridge deck girders.
Dead load. Weight of the structure.
Deck bridge. Bridge with floor placed on top chord of trusses or girders.
Diagonals. Inclined members used for stiffening and wind bracing.
Diaphragm. Stiffening plate between webs of a member or from one member to another.
Eave strut. Longitudinal strut between tops of the columns of a building at the eaves.
End post. Vertical or inclined compression member at the end of a bridge truss.
Erection seat. Seat angle riveted to a supporting member to hold a member during erection.
Expansion bolt. A bolt with a split casing which acts as a wedge; used for attaching steel work to brick or concrete.

Expansion rollers. Steel rollers placed under one end of a bridge truss to allow movement caused by expansion and contraction.
Fabrication. To cut, punch, and subassemble members in the shop.
Fill plate. A plate used to take up space in riveting two members when a gusset is not used.
Grillage. A combination of beams laid transversely in the several tiers, the deepest beams being used in the top tier.
Heel plate. Gusset plate at heel or main support of a truss.
Hinged shoe. End support of a truss which has a pin or roller allowing rotation caused by deflection under heavy loads.
Knee brace. A corner brace, fastened at an angle from wall stud to rafter, stiffening a wood or steel frame, to prevent angular movement.
Lacing or lattice bars. Bars used diagonally to space and stiffen two parallel members, such as in a built-up column.
Laterals. Members used to prevent lateral deflection.
Leg. One of the two flanges or parts of an angle.
Pin plate. Reinforcing plate riveted to truss member to give greater bearing on a pin.
Plate girder. Structural member made with a web plate and flanges of angles, plates, or other shapes.
Purlins. Horizontal members extending between trusses, used as beams for supporting the roof.
Queen-post truss. A truss framed with two vertical tie members.
Ridge frame. Bent made with ridge joints between beam or girder and the supporting columns.
Rocker. Hinged shoe with pin which allows truss or girder to deflect without causing additional strain on pier or abutment.
Roller. Bearing made of hardened-steel rollers placed under one end of truss to allow movement caused by expansion and contraction.
Seat angle. Small angle riveted to one member to support end of another member.
Separator. Plate, casting, or piece of pipe on bolt placed between webs of beams to keep them a fixed distance apart.
Shoe. Part of a bridge that supports end pins of a truss.
Sole plate. Plate riveted to bottom of girder to bear upon masonry plate.
Splice. A longitudinal connection between the parts of a continuous member.
Stiffener. Angle, plate, or channel riveted to a member to prevent buckling.
Stringer. A longitudinal member used to support loads directly.
Strut. A compression member in a framework.
Tee. A steel beam whose section is like the letter T.
Tie plate. A plate attached to other members to hold them in position.
Top angle. Connection angle used at the top of a beam in conjunction with a seat angle on a column.
Truss. A ridge framework for carrying loads, formed in a series of triangles.
Web. Thin portion between flanges of a beam, channel, or other member.
Zee. A steel beam whose section is like the letter Z.

GLOSSARY OF CONCRETE AND MASONRY TERMS

Abutment. Concrete or masonry supports at end of a bridge or arch.
Anchorage hooks. Hooks bent in ends of reinforcing-steel bars for better bond in concrete.
Ashlar. Dressed stone used for the outside facing of a wall.
Backing-up. The using of bricks of a cheaper grade for the inner face of a wall.
Base course. The first course or foundation course on which the remainder rests.
Batter. The slope of the face of a wall that is out of plumb. The backward and upward slope of a retaining wall.
Bed. The horizontal surfaces on which the bricks or stone of the wall lie in courses.
Belt. A projecting band course or courses, or a course of a different kind of brick.
Blocking course. A course of stones placed on the top of a cornice crowning the walls.
Bloom. The appearance of a whitish powder on the surface of a brick or stone wall.
Bond course. A course of headers.
Bond stone. Stone running through the thickness of a wall at right angles to its face, serving to bind it together.
Breast of a window. The masonry forming the back of the recess and the parapet under the window sill.
Brick. A hardened block of clay, usually of rectangular shape, formed in a mold, dried or burned in a kiln.
Brick veneer. A facing of brick applied to a frame or other structure.
Bull header. A brick with one rounded corner usually placed with short face exposed. Laid to form the brick sill under and beyond the window frame; also used around doorways.
Bull stretcher. A bull brick laid with the long edge exposed.
Buttering. The spreading of mortar on the edges of a brick before placing it in position.
Cement. Product obtained by burning a mixture of limes and clays, and grinding to a fine powder.
Clay. A common earth, compact and brittle when dry, but plastic when wet. Used in the manufacture of bricks.
Closer. A portion of a brick used to close the end of a course.
Common brick. Brick such as is used for rough work, for filling in or backing.
Coping. The cap or top course of a wall, frequently projecting.
Corbel. One or more courses of projecting bricks to form an overhang.
Cornice. The molded projection which finishes the top of a wall of a building.
Diagonal bond. Bricks laid horizontally with ends staggered symetrically with respect to the diagonal running from corner to corner of the wall.
Extrodos. The outside curve of an arch.
Face. Front or exposed surface of a wall.
Facebrick. Exterior facing of a brick wall.
Filling in. The process of building-in the center of the wall between the face and back.
Fire clay. Clay capable of withstanding high temperatures; its quality is due to the large amount of silica and small amount of fluxing agents.
Flat arch (or jack arch). A construction in which both the soffits and extrados are flat.
Flemish garden bond. Consists of three stretchers followed by a header in each course. The headers in each course center between the stretchers in the course above and below.
Form. A temporary mold in which to cast crete.
Garden bond. Consists of three stretchers in each course followed by a header, although this bond may have from two to five stretchers between headers.
Gaging. To cut bricks or stones to make them uniform in size.
Grout. A fluid cement mixture for filling crevices.

Gutter. A bricked or paved surface in the street adjoining the curb.
Haunch. The shoulder of an arch.
Herring-bone. Masonry or brickwork when laid up in a zigzag pattern.
Herring-bone bond. A zigzag arrangement of bricks or tile, in which the end of one brick is laid at right angles against the side of a second brick.
Intrados (or soffit). The interior curve or under-surface of an arch.
Inverted arch. An arch having extrados below the axis or spring line.
Keystone. The uppermost stone of a masonry arch, and which locks the other members together.
Kneeler. A stone cut to provide a change of direction.
Mortar. A mixture of sand, slacked limes, cement, and water to form a bond between brick, stones, and so forth.
Nogging. The filling-in with brick of the spaces between studding.
Perpend. A header brick extending through the wall so that one end appears on each side of it.
Pier. A mass of masonry supporting an arch, bridge, and so forth.
Pilaster. A right-angled columnar projection from a pier or wall.
Pointing. The finishing of joints in a brick or masonry wall.
Portland cement. The building cement of common use, made by heating clay and lime substance. The vitrified product, when ground, forms a very strong hydraulic cement.
Projecting belt course. An elaboration of a plain band course of masonry or cutstone work projecting several inches beyond the face of the wall.
Pugging. A coarse mortar laid between floor joists to prevent passage of sound.
Quarry-faced masonry. Stone with face left unfinished as quarried.
Racking. In approaching a corner where two walls meet, "racking" is the making of each course shorter than the course below it, in order that the workmen on the walls may tie in their courses in the easiest manner.
Racking bond. Brick laid in an angular or zigzag fashion.
Retaining wall. A wall erected to prevent the sliding of earth or other material.
Rowlock-back wall. Wall made with the bricks of the exterior face laid flat, and the bricks of the backing laid on edge.
Rubble. Roughly broken quarry stone.
Rubble masonry. Uncut stone, used for rough work, foundations, backing, and so forth.
Rustication. Ashlar work with roughened surface and deeply sunk grooves at the joints.
Segmental arch. An arch whose curve is an arc of a circle, but less than a semicircle.
Semicircular arch. An arch whose intrados is a semicircle.
Skewback. The surface of each end of an arch upon which the first bricks are laid, and from which an arch springs.
Skintled brickwork. An irregular arrangement of bricks with respect to the normal face of the wall, the bricks being set in and out to produce an uneven effect; also the rough effect caused by mortar squeezed out of the joints.
Slab. Concrete floor or span.
Soffit. The underside of an arch, cornice, or staircase.
Spandrel. The irregular triangular space between an arch and the beam above the same, or the space between the shoulders of two adjoining arches.
Springer. The stone from which an arch springs.
Stucco. Plaster or cement used for external surfacing of walls.
T-beam. Reinforced T-shaped concrete beam and floor slab poured as a unit without joints.
Toothing. Leaving a section of brickwork toothed so that the brickwork to follow can be bonded into it. It consists of allowing alternate courses to project a sufficient distance to assure a good bond with the portion to be built later.

Vitrified brick. A very hard paving brick burned to the point of vitrification and toughened by annealing.
Voussoir. One of the wedge-shaped blocks of stone of which an arch is composed.

GLOSSARY OF WELDING TERMS

Anneal. To soften a metal piece and remove internal stresses by heating to its critical temperature and allowing to cool very slowly.

Arc welding. A non-pressure (fusion) welding process wherein the welding heat is obtained from an electric arc formed either between the base metal and an electrode, or between two electrodes.

Axis of a weld. A line through the weld parallel to the root.

Backing strip. Material (metal, asbestos, carbon, and so forth) backing up the root of the weld.

Base metal. The metal to be welded or cut.

Bead weld. Weld made by one passage of electrode or rod.

Bond. The junction of the weld metal and the base metal.

Brazing. A welding process wherein the filler metal is a nonferrous metal or alloy whose melting point is higher than 1,000° F., but is lower than that of the base metal.

Butt weld. The edges or ends of two plates joined flush; if plates are more than ¼" thick, one or both must be beveled to make a single **V** or a double **V** in order to permit complete fusion.

Composite joint. A joint wherein welding is used in conjunction with a mechanical joint.

Continuous weld. Weld which extends uninterruptedly for its entire length.

Effective length of weld. The length of the correctly proportioned cross section of a weld.

Electric brazing. A process of brazing wherein the heat is obtained from electric current.

Electrode. (1) Metal arch welding: Filler metal in the form of wire or rod, either bare or covered, through which current is conducted between the electrode holder and the arc and base metal. (2) Carbon arc: A carbon or graphite rod through which current is conducted between the electrode holder and the arc. (3) Resistance welding: A bar, wheel, or die through which the current is conducted and the pressure applied to the work.

Fillet weld. Lap joint or a connection of two pieces at right angles.

Flush weld. Weld made with a minimum reinforcement.

Intermittent weld. Weld whose continuity is broken by unwelded spaces.

Lap joint. A welded joint in which two overlapping parts are connected by means of fillet, plug, slot, projection, or seam welds.

Lap weld. Weld made on the thinned-down, overlapped edges of plates, maintaining an even thickness of material.

Penetration. Depth of fusion obtained in a welded joint.

Plug weld. The joining of two plates by welding through a hole in either one plate only or both plates.

Resistance butt welding. Process wherein the fusion occurs simultaneously over the entire contact area of the parts being joined.

Resistance welding. Process wherein the heat is obtained from the resistance to the flow of an electric current.

Seal weld. Weld used to obtain tightness, or fill in a gap.

Seam welding. Process wherein overlapping or tangent spot welds are made progressively.

Size. (1) Fillet weld: The size of a fillet weld is the leg length of the largest inscribed isosceles right triangle. (2) Groove weld: The size of a groove weld is the depth of the groove. Where depth of fusion materially exceeds the groove depth, the size of the weld is the depth of the fusion.

Slot weld. Joining of two plates by welding through a slot cut in one plate.

Spot weld. To weld in spots by means of the heat of resistance to an electric current. Not applicable to sheet copper or brass.

Tack weld. To join at the edge by welding in short intermittent sections. Used for assembly purposes only.
Types of joints. Joints made by welding are butt, corner, edge, lap, and toe.
Weld. Uniting of pieces of iron or steel by fusion accomplished by the oxyacetylene, electric, or hammering (forging) process.
Welded joint. A localized union of two parts by welding.

GLOSSARY OF PLUMBING TERMS

Aeration tank. A secondary tank in a sewage disposal plant in which the sewage is raised, by a mechanical device, from the bottom of the tank and discharged over the retained liquid. The circulation of the sewage and the consequent exposure to the atmosphere reduces the sewage to a stable effluent.

Antisiphon. A type of water seal trap in which the outlet leg is increased in diameter to contain a sufficient volume of liquid to prevent a siphoning action which would break the seal.

Area drain. A drain usually made of 4-inch or larger cast-iron pipe leading into a running trap with cleanout and into the house drain, placed in the floor of a basement areaway, a loading platform, or a cement driveway, which cannot otherwise be drained.

Back flow. Flow of water of sewage opposite to the normal direction of flow.

Backflow valve. A device inserted in the drain of a house or building to prevent a reversal of the flow of sewage.

Back pressure. Air pressure in pipes greater than atmospheric pressure.

Ball cock. A faucet opened or closed by the fall or rise of a ball floating on the surface of the water.

Bell (or hub). That portion of a pipe which, for a short distance, is sufficiently enlarged to receive the end of another pipe of the same diameter for the purpose of making a joint.

Bell-and-spigot joint. Each length of cast-iron pipe is made with an enlarged (bell) end and a plain (spigot) end. The spigot end of one length fits into the bell end of the next length and is made tight by caulking.

Bib. A spigot or faucet.

Bleeder. A small drain cock or by-pass valve.

Branch. (1) Pipe extending from a main to receive or connect drains from fixtures. (2) The outlet or inlet of a pipe fitting, set at an angle with the run.

Branch ell. An elbow having a back outlet in line with one of the outlets of the run.

Branch pipe. A general term used to designate a pipe, either cast or wrought, that is equipped with one or more branches.

Bullhead tee. A tee, the branch of which is longer than the run.

Bushing. A plug designed to be threaded into the end of a pipe. One end is bored and tapped to receive a pipe of smaller diameter than that of the pipe into which it is screwed.

By-pass. Any method by which water may pass around a fixture, appliance, connection, or length of pipe.

Catch basin. A basin, cistern, depression, or reservoir to catch and retain surface drainage.

Cesspool. A pit for the reception or detention of sewage.

Check valve. A valve which automatically closes to prevent the back flow of water or liquids.

Cleanout. Fitting with a hand hole and cover for cleaning out sediment.

Close nipple. Nipple whose length is twice as long as standard pipe thread, with no shoulder between the two sets of threads.

Cock. A plug type of valve which has an opening to permit passage of liquids or gases. A quarter turn opens or closes the valve.

Conductor (or leader). A pipe to convey rain water.

Continuous vent. A continuation of a vertical, or nearly vertical, waste pipe above the connection at which liquid wastes enter the waste pipe. The extension may or may not continue in a vertical direction.

Coupling. A fitting with inside threads only, used for connecting two pieces of pipe.

Cross. Pipe fitting with four branches arranged in pairs, each pair on one axis and the axes at right angles.

Crossover. Fitting shaped like the letter U with the ends turned out. It is used to pass the flow of one pipe past another when the pipes are in the same plane.

Crown. That part of a trap in which the direction of flow is changed from an upward to a downward direction.

Dead end. The extended portion of a pipe which is closed at one end, and to which no connections are made on the extended portion.

Downspout. A pipe or conductor for carrying rain water from a roof to the ground or to a sewer connection.

Drain. A pipe, channel, or trench through which waste water or other liquids are carried off.

Drainage. System of drains; the act or means of draining.

Drain cock. A small valve placed at a low point in a line of piping to permit draining.

Drop elbow. A small ell that is frequently used where gas is put into a building.

Drop ell. An ell lugs in the sides by means of which it can be attached to a support.

Drop tee. A small tee having the same type wings as a drop elbow.

Eccentric fitting. A fitting in which one end is offset from the center line.

Effluent. The liquid discharged from a septic tank or sewage disposal plant.

Feed pipe. A main line pipe; one which carries a supply directly to the point of use, or to secondary lines.

Flange union. A pair of flanges to be threaded onto the ends of pipes that are to be joined. The flanges are bolted together when the pipes are joined.

Float valve. A floating ball which opens or closes a valve according to the height of the water; such as used in a toilet tank.

Floor drain. A fixture used to drain water from floors into the plumbing system.

Flush valve. A valve used for flushing a fixture by using water directly from the water-supply pipes.

Fresh-air inlet. Connection made to a house drain above the house or drain pipe, leading to the outside atmosphere.

Globe valve. A type of valve in which a disk, operated by a screw and hand wheel, seats on a circular opening.

Grease trap. A device for solidifying and separating grease from domestic wastes and retaining them so that they may be removed, thus preventing the stoppage of waste pipes.

House drain. That part of the lowest horizontal piping of a plumbing system which receives the discharge from soil, waste, and other drainage pipes inside of any building and conveys the discharge to the house sewer.

House slant. A T- or Y-connection in a sewer for the purpose of receiving the connection of a house sewer.

Hydrostatic joint. Used in large water mains, in which sheet lead is forced tightly into the bell of a pipe by means of the hydrostatic pressure of a liquid.

Increaser. A coupling with one end larger than the other.

Invert. The lowest portion of the inside of any pipe or conduit which is not vertical.

Lateral. Secondary pipe line branching off a main.

Lip union. A special form of union having a lip that prevents the gasket from being squeezed into the pipe and obstructing the flow.

Loop vent. A continuation of a horizontal soil or waste pipe beyond the connection at which liquid wastes from one or more fixtures enter the waste or soil pipe. The extension is usually vertical immediately beyond its connection to the soil or waste pipe. The base of the vertical portion of the vent may be connected to the horizontal portion of the soil or waste stack between fixtures connected thereto.

Nipple. A short length of pipe threaded at both ends and less than 12-inches long.

Oakum. Hemp used for caulking.

Reducer. Any one of the various pipe connections so constructed as to permit the joining of pipes of different sizes, such as reducing ell, reducing sleeve, reducing tee, and so forth.
Return bend. A pipe bend or a fitting shaped like the letter U.
Run. That portion of a pipe or fitting continuing in a straight line in the direction of flow of the pipe to which it is connected.
Rust joint. A joint in which some oxidizing agent is employed.
Service ell. An elbow having an outside thread on one end.
Service pipe. The small pipe which conveys liquid or gas from a main pipe to its places of use.
Service tee. A tee having inside thread on one end and on the branch but outside threads on the other end of the run.
Shoulder nipple. A nipple of any length which has an unthreaded portion of pipe between the two threaded ends.
Soil pipe. Term generally applied to cast-iron pipe in 5-foot lengths used for house drainage.
Spigot. The ends of a pipe which fit into a bell. It is also another name for a faucet.
Stack. Any vertical soil, waste, or vent piping.
Standard pressure. Term applied to valves and fittings suitable for a working steam pressure of 125-pounds per square inch.
Stopcock. A type of valve which consists of a body having a tapered opening, into which is fitted a plug of corresponding taper. By turning the plug through an arc of 90°, the flow is turned on or off.
Sump. A depression in a roof, and so forth, to receive rain water and deliver it to the downspout.
Tee. A fitting for connecting pipes of unequal sizes, or for changing direction of pipe runs. A bullhead tee has an outlet larger than opening on run; straight tee has all openings of same size.
Union. A coupling or connection for pipes designed to facilitate the connecting or disconnecting of pipes.
Vent pipe. Any small ventilating pipe running from various plumbing fixtures to the vent stack.
Vent stack. The vertical pipe connecting with the vent pipes and extending through the roof.
Wye. A fitting, either cast or wrought, that has one side outlet at any other angle than 90°. The angle is usually 45° unless otherwise specified.

GLOSSARY OF SEWERAGE TERMS

Aeration tank. A secondary tank in a sewage disposal plant in which the sewage is raised, by a mechanical device, from the bottom of the tank and discharged over the retained liquid. The circulation of the sewage and the consequent exposure to the atmosphere reduces the sewage to a stable effluent.

Back flow. Flow of sewage opposite to the normal direction of flow.

Baffle. A plate made of wood or steel, used in an Imhoff tank, to deflect or retard the flow of sewage.

Catch basin. An inlet with a basin which holds sewage for a brief period to allow debris to settle.

Cesspool. A pit for the reception or detention of sewage.

Chloride of lime. A "bleaching powder" or bleaching lime obtained by treating lime with chlorine gas. Used as a disinfectant in a sewage disposal plant.

Chlorination. The principal method of sterilization for the destruction of pathogenic organisms in sewage treatment and is also used for the removal of certain tastes and odors in a water purification system.

Clog. The stoppage of flow through a pipe by the accumulation of foreign matter.

Combined sewer. A sewer carrying both sanitary and storm sewage.

Distribution box. A box or header in a subsurface disposal field for the control of flow of effluent to the subsurface irrigation pipes.

Distribution lines. Drain tile used in the disposal field of a subsurface irrigation system.

Distributor. Part of a filter for dosing effluent with a fine spray treatment of chemicals by a rotating device.

Dosing tank. A filter tank with an automatic siphon for discharging sewage into the distribution pipes when the tank is full, and cutting off when empty.

Dry well. A hole in the ground lined with stone in such a manner that liquid effluent or other sanitary wastes will leach into the surrounding soil.

Effluent. The liquid discharged from a septic tank or sewage disposal plant.

Filters. A porous bed of sand or stone, the surfaces of which, in contact with sewage, becomes coated with a gelatinous film of organic matter. In order to oxidize the sewage, the beds must be of large material with correspondingly large void spaces so that the sewage will trickle through in the presence of air or operate intermittently so that the supply of oxygen can be renewed.

Flush tanks. Masonry tanks with a siphon automatically discharging the water about once in a 24-hour period so as to supply periodic rushes of water for cleaning out obstructions in the upper ends of laterals having very flat grades.

Grease trap. A device for solidifying and separating grease from domestic wastes and retaining the same so that it may be removed and prevent the stoppage of waste pipes.

Imhoff tank. A circular or rectangular two-story septic tank having a greater efficiency than the ordinary septic tank.

Industrial waste. A liquid waste resulting from the processes employed in industrial establishments.

Infiltration. Leaching of ground water into a sewer.

Influent. Sewage of ground water into a sewer.

Inlet. An ell connected with a pipe discharging into a combined or storm sewer, the open end protected by a cast-iron frame and grating, to allow the entrance of storm water.

Inverted siphon. An arrangement where large amounts of sewage conveyed across deep depressions by one or more pressure pipes are installed to dip below the hydraulic grade line.

Joints. Concrete or vitrified-tile pipe connections.

Junctions. Intersection of two or more sewers at a manhole.
Lateral sewer. A sewer which receives no sewage from any other common sewer.
Leaching tank. A tank made of wood, concrete, or masonry used for the disposal of raw sewage from short time installations or septic tank effluent from long time installations.
Main sewer. The chief sewer in a sewerage system.
Manhole. An opening through which a workman may gain access to sewers for inspection, cleaning, and repairing.
Outfall sewer. A large sewer leading from the lower end of the collecting system to the place of disposal.
Relief sewer. A sewer build to relieve an existing sewer of inadequate capacity.
Sanitary sewer. Underground pipe or tunnel for carrying off domestic sanitary wastes.
Sedimentation. When the velocity of sewage is reduced, gravity pulls down the suspended solids.
Septic tank. Unit used for decomposing solid sewage matter and is designed to dispose of these wastes in a completely sanitary and ordorless manner by natural bacterial action which dissolves most of the solids into liquids and gases.
Sewage. Effluent carried off by a sewer.
Sewage disposal. Disposition by dilution or irrigation.
Sewage treatment. Any artificial process to which sewage is subjected in order to remove or alter its ojbectionable qualities so as to render it less dangerous or offensive.
Sewer. Pipe or tunnel for carrying away sewage or storm water for sanitary purposes.
Sewer outlet. Pipe line for discharging into water or stream from treatment plant.
Sewer pipe. Pipe used to convey sewage.
Sludge. Semiliquid mass formed by suspended solids of sewage when concentrated by sedimentation.
Sub-main sewer. Sewer having two or more tributary laterals.
Subsurface irrigation. Sewage that is applied over a field through open-jointed drain tile placed underground. Used in small installations.
Trickling filter. A unit in which the settled sewage is applied evenly as possible to the surface of the filtering medium, through which it trickles in a thin film to the underdrains at the bottom.
Underdrains. Open-joint vitrified pipe buried in gravel for removing filtered water.
Weir. Any type of bulkhead or dam over which a liquid flows.

GLOSSARY OF WATER-SUPPLY TERMS

Air gap. Vertical distance between a supply fitting and the highest possible water level in a fixture which the fitting supplies.

Asbestos-cement pipe. A nonmetallic pipe that is connected by an asbestos-cement sleeve and two rubber rings. For bends and other turns other types of pipe must be used.

Black steel pipe (threaded). Pipe used for water-supply lines using standard fittings.

Branch. Supply pipe from the building main to a fixture. Also a general term used to designate a pipe that is equipped with one or more branches.

Building main. The water-supply pipe and fittings that lead from the water main or other sources of supply to the first branch of the water distribution system in a building.

Cast-iron pipe. A pipe made of cast iron which is the most widely used material for conveying water in distribution systems.

Fittings. Parts in a piping system used to make bends in lines, branches, or connections. Also used to seal pipes and to reduce pipe diameter.

Flange pipe. Water main pipe which is provided with flanges at the ends as a means of attachment to other pipes or connections. In cast-iron pipe, the flanges are a part of the casting.

Flange union. A pair of flanges to be threaded onto the ends of pipes to be joined. The flanges are bolted together when the pipes are joined.

Floor drain. Fixture used to drain water from floors into the plumbing system.

Gravity water system. Any water system in which pressure is obtained by gravity.

Pipe coupling. A threaded sleeve used to connect two pipes.

Pipe hanger. A malleable iron, metal strap or band used to suspend pipe.

Service connections. The connection outside of a building where the building main connects to the building pipe system.

Supply system. The system of units and piping used to obtain, treat, and produce a head of water to the distribution system.

Wood pipe. A wooden pipe made with staves and with steel or cast-iron fittings, used for water-supply lines.

GLOSSARY OF ELECTRICAL—DISTRIBUTION TERMS

Adjustable-speed motor. A motor whose speed can be varied over a wide range and when once adjusted remains constant regardless of load.

Alternating-current motor. An electric motor operated by alternating current.

Alternator. An electric generator which produces alternating current.

Ammeter. The instrument used in measuring current in an electric circuit.

Ampere. Unit of measurement of electric current. A pressure of one volt will force one ampere through a resistance of one ohm.

Annunciator. A device for indicating, by visual and auditory means, a closed circuit or an activity which closes a circuit at a predetermined station or place.

Armature. The revolving member of a dynamo or motor.

Automatic circuit breaker. An automatic device for breaking the circuit when the strength of current exceeds a predetermined limit.

Automatic cutout. An electrical adjustment for automatically removing any electrical part or connection from a circuit at the proper moment.

Automatic switch. A switch opens and closes by itself at required times.

Balanced circuit. An electric circuit so adjusted with respect to nearby circuits as to escape the influence of mutual induction. A three-wire circuit having the same load on each side of the neutral wire.

Bank. A number of motors, generators, or transformers mounted on a single base. Also often used to indicate the voltage of a single generator which is about to be switched into a circuit.

Battery. A number of primary or storage cells grouped together as a single source of direct current electricity.

Booster. A generator connected in series with a circuit for the purpose of increasing the voltage of that circuit.

Brush. A device for passing electric current to and from a commutator of a motor or generator.

Capacitor. A storage device for electrical energy.

Capacity. The amount of energy a capacitor is able to store.

Carrying capacity. The greatest amount of electrical current that a conductor can safely carry, expressed in amperes.

Centrifugal switch. A switch used on the single-phase, split-phase motor to open the starting winding after the motor has almost reached synchronous speed.

Compensator. An auto transformer with a switching mechanism for starting large alternating-current induction motors.

Conduit. Pipe used as a container for electric wires.

Contactor. Electromagnetic or manually operated contacts.

Converter. Machine employing mechanical rotation in changing electrical energy from one form to another.

Crossarm. A horizontal timber mounted near the top of a pole for carrying electric wires.

Crossarm brace. A flat steel diagonal used to brace a crossarm to the pole.

Delta connection. The connection of the circuits in a three-phase system in which the terminal connections are triangular like the Greek letter delta.

Differential motor. A motor with a compound-wound field, in which the series and shunt coils oppose each other.

Double-pole switch. A switch which opens or closes two circuit wires at the same time.

Dynamotor. An electrical machine for converting mechanical energy into electrical energy.

Equalizer. Low resistance wire or bar that makes a common connection between the armature and the series field of parallel-operated compoundwound machines.

Exciter. A small D/C generator used to supply electricity for the field of an A/C generator.

Field. The area adjacent to a magnet or an electromagnet that has lines of force moving in it.

Galvanometer. An instrument for detecting small currents or difference of potential.

Hydro-electric. Relating to the production of electricity by water power.

Hysteresis. A lagging of magnetic density behind the magnetizing force, causing a loss resulting in heat.

Impedance. The total opposition in an electric circuit to the flow of an alternating current.

Induction. The production of an electric current in a conductor by the variation of the magnetic field in its vicinity.

Induction motor. An alternating-current motor which does not run exactly in step with the alternations. Currents supplied are led through the stator coils only; the rotor is rotated by currents indicated by the varying field set up by the stator coils.

Inductor. An electrical conductor in which an induced e.m.f. is produced.

Insulator. A nonconductor, usually of glass or porcelain.

Insulator pin. Wooden or metal pin used to mount an insulator on the crossarm of a pole.

Lightning arrester. A device that causes lightning to pass off to the earth and protecting electrical machines.

Line. The wires running from generating stations or substations to supply transformers or to buildings directly.

Mains. The electrical conductors from which the branch circuits are supplied.

Master switch. A main switch; a switch controlling the operation of other switches.

Multi-speed motor. A motor capable of being driven at any one of two or more different speeds independent of the load.

Nonconductor. Any substance which does not allow electricity to pass through it.

Ohm. The unit of electrical resistance.

Ohmmeter. A type of galvanometer which directly indicates the number of ohms of the resistance being measured.

Parallel connected transformer. When two or more transformers have their primary windings connected to the same source of supply in such a manner that the impressed voltage in each case is the same as that of the line.

Peak load. The heaviest load which a generator or system is called on to supply.

Phase. The time difference between relative values of two electric waves.

Polyphase. Two or more phases or circuits associated electrically with each other.

Reactor. Any device which offers opposition to the flow of alternating currents.

Rectifier. A device that changes alternating current into direct current.

Relay. A device for opening or closing a circuit under given conditions.

Rheostat. A device for regulating electrical current, in which the current is made to flow through wires having considerable resistance.

Series motor. A direct-current motor with the armature and field connected in series.

Shunt generator. A machine for generating an electric current, in which the winding for producing the magnetic field is connected in shunt (or parallel) with the armature or rotating part.

Shunt-wound motor. Used when the motor speed must be constant, irrespective of variation in load.

Single phase. A single, independent A/C circuit or winding.

Split-phase motor. A single-phase motor which is made self-starting by causing the current to lead or lag in one of its windings with respect to the other winding.

Squirrel-cage rotor. The revolving part of the ordinary induction motor.
Stator. The fixed part in an A/C motor or generator which does not rotate.
Synchronous motor. One whose speed remains constant as long as the frequency and voltage supplying power to it remains constant.
Thermocouple. An electrical generator made by the welding together, at one end, of two dissimilar metal rods or wires, which produce electricity at the free ends when the weld is heated.
Three-phase. Three A/C windings or circuits differing in phase by 120°.
Wye connection. A branching connection applied to a three-phase circuit.

GLOSSARY OF ELECTRICAL—WIRING TERMS

Anchor staple. Used to fasten armored cable to joists and studs.

Anti-short bushing. A non-conductor, usually made from plastic, to prevent edges of armor from cutting through insulation.

Cable box clamp. Two parts of steel held together by a screw, with round-edge saws, to protect weatherproof wire insulation. Used in outlet boxes in place of connectors.

Cable strap. Used to mount nonmetallic cables each time the cable changes direction and at intervals among unsupported straight lengths.

Cleat. A porcelain device used to support wires on wall in knob-and-tube systems.

Conduit pipe. A thin steel pipe used as a container for electrical wires.

Condulets. Small outlet boxes with threaded inlets to take conduit pipe.

Connector cable. Steel device used to connect and hold cable at outlet boxes.

Fluorescent tube. A glass cylinder coated inside with a phosphor and filled with an inert gas. Used with a starting switch and reactor it produces two to four times as much light per watt as an ordinary light bulb.

Fuse. An electrical safety device; the weakest thermo link in the circuit, which "blows out" when the rise of the current is greater than that for which the circuit was designed.

Fuse box. Used to connect or disconnect building wiring to power supply through protecting fuses.

Generator. A machine which is used for the transformation of mechanical energy into electrical energy.

Grounding. Intentional connection made between a circuit wire and the ground, as in the neutral wire of a three-wire system, or the bonding together electrically of electrical conduits and wire pipes.

Incandescent bulb. Electric bulb containing a thin wire or filament of infusible conducting material.

Knob. A porcelain device for holding electrical conductors in place.

Loom. A flexible nonmetallic tubing used to protect electrical conductors.

Offset hanger. Outlet boxes are recessed in the wall by using offset hangers fastened solidly to joints or studs.

Outlet box. An iron or porcelain box inserted in a conduit system, from which current is taken to supply fixtures, switches, and so forth.

Outlet-box covers. An iron or porcelain cover for outlet boxes to which fixtures, switches, and receptacles are attached.

Plug. A device with conducting projections which fit into slots and make electrical contact, usually between a portable device and a source of supply.

Push button. A device which completes an electric circuit when a small button or knob is depressed.

Receptacle. A porcelain, fiber, or composition device into which a lamp may be screwed or an attachment plug pushed, and which is fastened in place with screws.

Reflectors. Used to concentrate the light of a lamp bulb.

Service cap. Used with insulators to waterproof the service-wire conduit entrance.

Surfolet. A type or porcelain outlet used as an outlet box where exposed wiring is installed. Base is separately mounted direct on wall and cover mounted on the base.

Switch box. An iron box or case to protect the switch mechanism and to prevent accidental contact with current-carrying parts.

Tapping. The connection where a wire or conductor branches off from another wire or conductor.

Tube. A porcelain device for carrying electrical conductors through walls and studs and where one wire crosses over another.
Wire holder. An insulated anchorage for pole-to-building service lines. They are often mounted on a bracket in banks of three to hold three wires.
Vaporproof receptacle. Consists of a glass cover and base, and is used to keep moisture and vapors away from the bulb and its wiring. Is not used where lamps are exposed to explosive gases.

GLOSSARY OF HEATING TERMS

Air cleaner. Device to remove airborne dust, fumes, or smoke.

Altitude. Height of an object above its base. Vertical elevation.

Atmospheric pressure. The pressure of the atmosphere at sea level (14.7 lb. per square inch).

Baffle. A diaphragm, thin plate, or wall to deflect or retard the flow of gases.

Blowoff. A valve or drain connection on a steam or hot-water boiler so arranged that the water and steam may be drawn off with any accumulated oil, grease, and dirt.

Boiler. (1) That part of a furnace in which steam is generated for heating or for the production of power. (2) The closed container in which a supply of heated water is stored for domestic use. In general, any closed liquid-containing vessel in which heat is applied. (3) According to use and construction, boilers for heating and power purposes are classified as cast-iron sectional, steel fire tube, steel water tube, and special.

Bucket trap. A type of valve for eliminating condensation and air from radiators and pipes, without permitting steam to pass. A bucket attached to a valve actuates a discharge tube.

Bypass line. A pipe passing around a valve (operated by a special cock) allowing some fluid to flow by or out of the valve chamber although the valve is closed.

Cap. A short closed cylinder to screw on the end of a pipe.

Centrifugal. Directed or tending away from the center.

Check valve. A valve which automatically closes to prevent the back flow of water or steam.

Condensation. The change of a substance from a vapor into a liquid state due to cooling.

Condensation pump (or turbine). Device for removing the liquid condensation from steam returns.

Control. A manual or automatic device for the regulation of a machine or system.

Convection. Diffusion fo heat through a liquid or gas by motion of its parts.

Convector. A type of heating unit, for steam or hot-water heating, fitted with large extended fin surfaces which emit heat principally by convection.

Diaphragm valve. A valve closed by the pressing of a diaphram against an opening, or one in which the motion of a diaphragm under pressure controls its opening and closing.

Direct-indirect heating unit. A partially inclosed heating unit used to heat air entering from outside of the room or space to be heated.

Direct-return system. Hot-water system in which each unit has a direct return to the boiler.

Down-feed. A pipe which carries steam downward to the heating units and into which the condensation from the heating units drain.

Down-feed system. A steam-heating system in which the supply mains are above the level of the heating units which they serve.

Draw band. A split slip collar made of sheet metal with a clamp bolt used for coupling butting ducts of same diameter.

Drip line. The return pipes through which the condensation from a radiator flows back to the boiler.

Dry return. A return pipe in a steam-heating system which enters the boiler above the water line carrying condensation, water, air, and so forth.

Duct. Pipe, tube, or channel used to convey air, water, gases, or liquids.

Extended-surface heating unit. A heating unit having extended surfaces to aid convection such as a honeycomb type unit heater with fan.

Feed-water heater. A boiler in which the supply water from a steam boiler is heated, preliminary to being taken up by the pump or injector.

Float trap. A type of valve actuated by means of a hollow metal float so arranged that condensation and air may pass but steam will be held.
Floor register. Register set flush in floor.
Flue gas. The gaseous mixture found in flues.
Furnace. That part of a heating plant in which combustion of fuel takes place.
Gate valve. A valve whose action depends on the motion of a wedge-shaped gate between the inlet and outlet openings.
Globe valve. A type of valve in which a disc operated by a screw and hand wheel seats on a circular opening.
Heating surface. All surfaces of a boiler which have hot gases on one side and steam or water on the other.
Humidify To pass air for ventilating purposes through a film of water to cleanse and to add a proper amount of water.
Humidostat. An instrument for regulating the humidity in the atmosphere.
Manometer. An instrument for measuring elastic pressure, as of gases. A U-shaped tube that measures the differential pressure.
Overhead system. Any steam or hot-water system in which the supply main is above the heating units.
Pressure reducing valve. A valve for reducing steam pressure in heating system where boilers are operated, for power purposes, at high pressure.
Pyrometer. An instrument for measuring very high degrees of heat.
Radiation. The transmission of heat by wave action through space.
Radiator. A device of tubular construction through which is passed steam, hot air, or liquid for warming a building or space to be heated.
Steam trap. An automatic device to allow the escape of water or condensation from steam pipes.
Vacuum pump. A pump used to remove condensation and air from the return main of heating system in order to create a vacuum and return the condensation to the boiler or to a receiving tank.
Vapor heating. A system for warming buildings consisting of a two -pipe gravity return system of steam circulation in which provision is made to retard or prevent the passage of steam from the radiator into the return main, and in which the air from the system, as well as the condensed water, is carried back to a point near the boiler. Then the air is expelled from the mains and the water is returned to the boiler.

GLOSSARY OF AIR-CONDITIONING TERMS

Absolute humidity. Actual weight of the water vapor in a cubic foot of dry air.

Absolute pressure. That pressure measured from the true zero or no pressure. It is equal to gage pressure plus atmospheric pressure.

Absolute temperature. The sun of the temperature indicated on the Fahrenheit thermometer plus 460.

Absolute zero. The point of —460° F.

Absorbents. Liquid substances that absorb, most frequently used are ammonia, calcium chloride, and lithium chloride brines.

Absorbents. Solids that can be rejuvenated and used over and over. The most frequently used are "activated alumina", also known as aluminum oxide or alumina, and "silica gel", also known as silicon dioxide or silica.

Aspect ratio. Ratio of the width to the height of the core area of a grille or register.

Automatic cleaner. Devices using power for the automatic reconditioning of the filter medium and the maintenance of a constant resistance to air flow.

Barriers. Resistance to the elements of the atmosphere that retard their transmission from outside to inside, or vice versa.

Bimetallic thermostat. A thermostat that uses a bimetallic element, consisting of two dissimilar metals, each with a different rate of expansion; the two metals welded together. An increase in temperature causes one of the metals to expand more rapidly than the other, and this results in a distortion of the strip or element. The movement of the element, induced by a change of temperature, utilizes to make an electrical contact and to operate a switch or slide wire to control the relay or lever to the motor or solenoid.

Blowers. Centrifugal radial flow air pumps.

Brine. Water saturated or strongly impregnated with salt.

Carbon dioxide. A colorless compound gas heavier than air, neither combustible or a supporter of combustion.

Cleaning unit. Unit generally combined with a blower or fan, frequently with a silencer to reduce sound and maintain quiet within the enclosure.

Compressor. Used in refrigeration for summer air conditioning.

Condensation. The change of a substance from a vapor into a liquid state due to cooling.

Condenser. Air-or water-cooled unit used to extract and dispose heat from air.

Core area. Portion of the grille or register, inside the frame, through which air may flow.

Damper. A manual or automatic device placed in duct to control the direction, velocity, and volume of circulating air.

Dehumidification. The lessening of the moisture content of the air.

Evaporation. A rising or passing off into a vapor.

Gage pressure. The pressure exerted by a gas or fluid, above atmospheric pressure.

Humidification. Process of adding water vapor to air.

Humidifier. Unit for the adding of water vapor to air.

Humidity. Amount of water vapor in the air.

Infiltration. Inward passage of air.

Inlet. Grille or register located at the point of distribution return from a supply room, or inclosure.

Insulation. Any material used in ducts as protection against heat and cold.

Louver. Window or opening designed for ventilation.

Outlet. Grille or register located at the point of distribution supply into a space, room, or inclosure.

Oxidation. The act of uniting, or causing a substance to unite with oxygen chemically.

Precipitator. Unit that removes dust, dirt, and pollen from the air.

Refrigerant. Volatile liquids that will evaporate, compress, and condense within reasonable working temperatures and pressures.

Register. An inlet or outlet having a damper.

Spray cooling. Air to be cooled passing through a spray of cold water.

Throw. The distance over which air will carry from an outlet to a point beyond the outlet face.

Volume damper. Damper that provides for the division of air volume to various sections and connections.

GLOSSARY OF REFRIGERATION TERMS

Coil. Any cooling element made of pipe or tubing.

Compressor. A machine used to establish the necessary pressure difference between the high-pressure and low-pressure sides of a refrigeration system.

Condenser. Tubular type radiator used to remove and dissipate enough heat from compressed vapor to surrounding air or water to condense the vapor to a liquid.

Condenser blower. A supplementary device to circulate air through the tubes and fins of condenser to quicken dissipation of heat from the condenser to the atmosphere.

Dryer. By-pass connected device in the liquid line through which refrigerant liquid may be passed to absorb water which may have entered the liquid system when opened for servicing.

Evaporator. Drum and cooling coils in which evaporation of the refrigerant takes place.

Evaporator blower. A supplementing device to draw air through the cooling coils of the evaporator and blow the cold air through the diffuser to provide uniform cold-air circulation.

Liquid air. Air brought to a liquid condition by a reduction of temperature and an increase of pressure. Used as a refrigerant.

Liquid receiver. Reservoir for high-pressure refrigerant liquid, receiving liquid from the condenser and supplying it to the evaporator.

Refrigerant. Liquid chemical, or any substance which produces a refrigerating effect by its absorption of heat while expanding or vaporizing.

Refrigeration cycle. Path and process of the refrigerant through the refrigerating system.

Secondary cooler. A supplementary condenser in the line between the condenser and liquid receiver to liquefy any vapor that is only partially cooled in the primary condenser.

Superheater and heat exchanger. A supplementing device to remove heat from liquid refrigerant before it is released to the evaporator through the expansion valve.

Thermal expansion valve. A valve automatically controlling the amount of refrigerant flowing from the liquid receiver (high-pressure side) to the evaporator (low-pressure side).

Unit cooler. A unit adapted from the unit heater to cover any cooling element of condensed physical proportions and large surfaces; generally equipped with a fan.

Vapor cycle. Process of cool vapor drawn by the compressor from the evaporator through the heat exchanger, superheater, and return line to the compressor.

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NG: State AG (3); Units—Same as active Army except allowance is one (1) copy per unit.

USAR: Same as active Army except allowance is one (1) copy per unit.

For explanation of abbreviations used, see AR 320-50.

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