NONRESIDENT TRAINING COURSE

September 2015

Blueprint Reading and Sketching

NAVEDTRA 14040A

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PREFACE

By obtaining this rate training manual, you have demonstrated a desire to improve yourself and the Navy. Remember, however, this manual is only one part of the total Navy training program. Practical experience, schools, selected reading, and your desire to succeed are also necessary to successfully round out a fully meaningful training program.

THE MANUAL: This manual is organized into subject matter areas, each containing learning objectives to help you determine what you should learn, along with text and illustrations to help you understand the information. The subject matter reflects day-to-day requirements and experiences of personnel in the rating or skill area. It also reflects guidance provided by Enlisted Community Managers (ECMs) and other senior personnel, technical references, instructions, etc., and either the occupational or naval standards that are listed in the *Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards,* NAVPERS 18068(series).

THE QUESTIONS: The questions that appear in this manual are designed to help you understand the material in the text. The answers for the end of chapter questions are located in the appendixes.

THE EVALUATION: The end of book evaluation is available on Navy Knowledge Online. The evaluation serves as proof of your knowledge of the entire contents of this NRTC. When you achieve a passing score of 70 percent, your electronic training jacket will automatically be updated.

THE INTERACTIVITY: This manual contains interactive animations and graphics. They are available throughout the course and provide additional insight to the operation of equipment and processes. For the clearest view of the images, animations, and videos embedded in this interactive rate training manual, adjust your monitor to its maximum resolution setting.

VALUE: In completing this manual, you will improve your military and professional knowledge. Importantly, it can also help you study for the Navy-wide advancement in rate examination. If you are studying and discover a reference in the text to another publication for further information, look it up.

September 2015 Edition Prepared by

LT Ervin Henley
HTC (SW) Benjamin Bates
HTC (SW) Charles Menken
Mrs. Delphine Jackson
Mrs. Debra Harrison-Youngs

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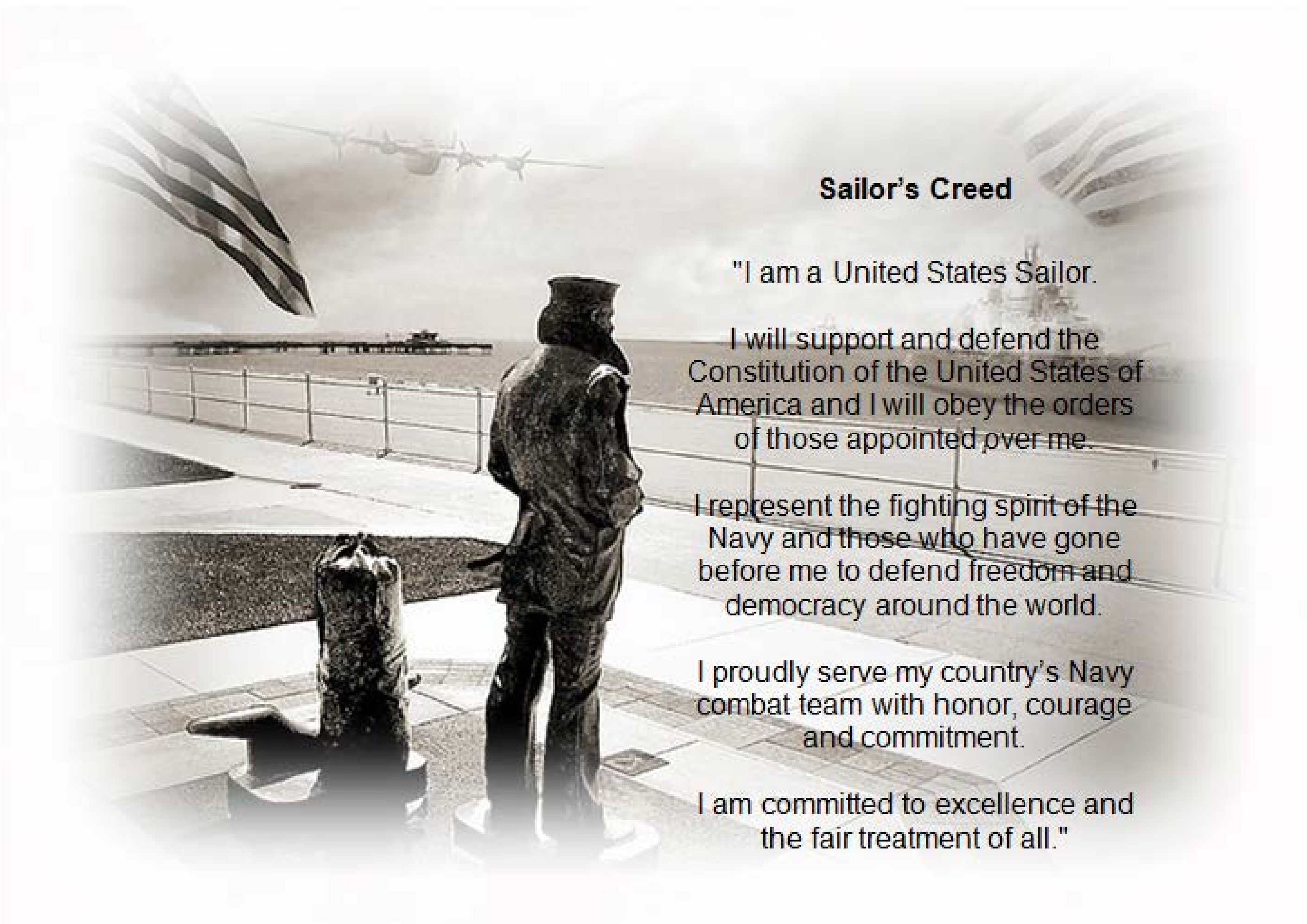
Sailor's Creed
"I am a United States Sailor.
I will support and defend the Constitution of the United States of America and I will obey the orders of those appointed over me.
I represent the fighting spirit of the Navy and those who have gone before me to defend freedom and democracy around the world.
I proudly serve my country's Navy combat team with honor, courage and commitment.
I am committed to excellence and the fair treatment of all."

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CHAPTER 1

BLUEPRINTS

Blueprints (prints) are copies of mechanical or other types of technical drawings. The term blueprint reading means interpreting ideas expressed by others on drawings, whether or not the drawings are actually blueprints. Drawing or sketching is the universal language used by engineers, technicians, and skilled craftsmen. Drawings need to convey all the necessary information to the person who will make or assemble the object in the drawing. Blueprints show the construction details of parts, machines, ships, aircraft, buildings, bridges, roads, and so forth.

LEARNING OBJECTIVES

When you have completed this chapter, you will be able to do the following:

1. Identify a blueprint.
2. Determine how blueprints are produced.
3. Identify the information contained in blueprints.
4. Explain the proper filing of blueprints.

BLUEPRINT PRODUCTION

Original drawings are drawn, or traced, directly on translucent tracing paper or cloth using black waterproof India ink, a pencil, or computer-aided drafting (CAD) systems. The original drawing is a tracing or master copy. These copies are rarely, if ever, sent to a shop or site. Instead, copies of the tracings are given to persons or offices where needed. Tracings that are properly handled and stored will last indefinitely.

The term blueprint is used loosely to describe copies of original drawings or tracings. One of the first processes developed to duplicate tracings produced white lines on a blue background; hence the term blueprint. Today, however, other methods produce prints of different colors. The colors may be brown, black, gray, or maroon. The differences are in the types of paper and developing processes used.

A patented paper identified as black and white (BW) paper produces prints with black lines on a white background. The diazo, or ammonia process, produces prints with either black, blue, or maroon lines on a white background.

Another type of duplicating process rarely used to reproduce working drawings is the photostatic process, in which a large camera reduces or enlarges a tracing or drawing. The photostat has white lines on a dark background. Businesses use this process to incorporate reduced-size drawings into reports or records.

The standards and procedures prescribed for military drawings and blueprints are stated in military standards (MIL-STDs), military handbooks (MIL-HDBKs), American National Standards Institute (ANSI) standards, American Society of Mechanical Engineers (ASME), and the Institute of Electrical and Electronics Engineers (IEEE). The acquisition streamlining and standardization information system (ASSIST) Web site lists these standards. A list containing common standards, listed by number and title, that concern engineering drawings and blueprints are illustrated in *Table 1-1*.

Table 1-1 — Common Standards

Number	Title
ASME Y14.100-2013	Engineering Drawing Practices
ANSI Y14.5M-2009	Dimensioning and Tolerancing
ANSI Y14.6-2001	Screw Thread Representation
ASME B46.1-2009	Surface Texture (Surface Roughness, Waviness, and Lay)
ASME Y14.38-2007	Abbreviations and Acronyms for use on Drawings and Related Documents
IEEE-315-1975	Graphic Symbols for Electrical and Electronic Diagrams (Including Reference Designation Letters)
ANSI Y32.9	Electrical Wiring Symbols for Architectural and Electrical Layout Drawings
ANSI Y32.16-1965	Electrical and Electronic Reference Designations
ASTM F1000-13	Standard Practice for Piping Systems Drawing Symbols
MIL-HDBK-21	Welded-Joint Designs, Armored-Tank Type
MIL-STD-22D	Welded Joint Designs
MIL-STD-25B	Ship Structural Symbols for Use on Ship Drawings

PARTS OF A BLUEPRINT

The ASME Y14.100-2013 specifies the size, format, location, and type of information that should be included in military blueprints. Included in this standard are the information blocks, finish marks, notes, specifications, legends, and symbols you may find on a blueprint. This information is discussed in the following paragraphs.

Information Blocks

The information blocks give the reader additional information about materials, specifications, and so forth that are not shown in the blueprint or that may need additional explanation. Some blocks remain blank if the information in that block is not needed. The following paragraphs contain examples of information blocks.

Title Block

The title block (*Figure 1-1*) is located in the lower right corner of all blueprints and drawings prepared according to MIL-STDs. It contains the drawing number, name of the part or assembly that it represents, and all information required to identify the part or assembly.

It also includes the name and address of the Government agency or organization preparing the drawing, the scale, the drafting record, the authentication, and the date.

A space within the title block with a diagonal or slant line drawn across it shows that the information is not required or is given elsewhere on the drawing.

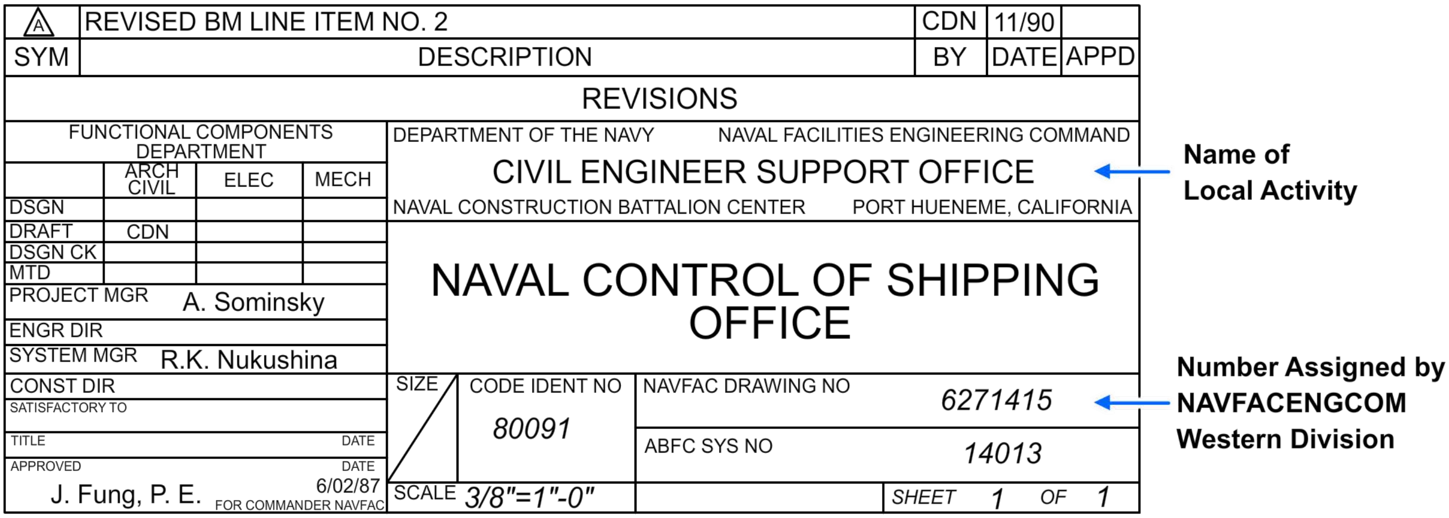


Figure 1-1 — Title block.

Revision Block

If a revision has been made, the revision block will be in the upper right corner of the blueprint, as shown in *Figure 1-2*. All revisions in this block are identified by a letter and a brief description of the revision. A revised drawing is shown by the addition of a letter to the original number, as in *Figure 1-2*. When the print is revised, the letter A in the revision block is replaced by the letter B, and so forth.

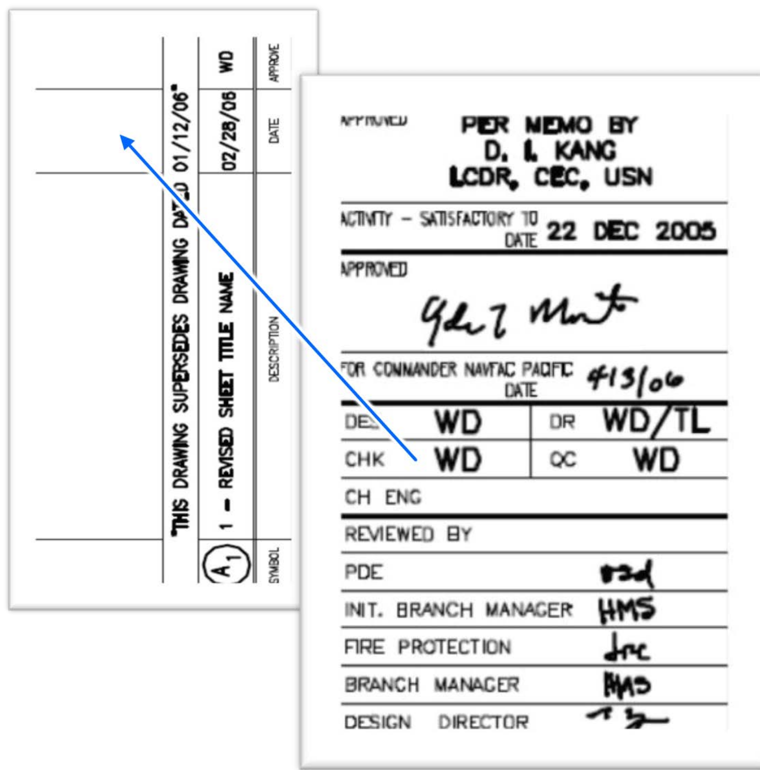


Figure 1-2 — Revision block.

Drawing Number

Each blueprint has a drawing number (*Figure 1-1*), which appears in a block in the lower right corner of the title block. The drawing number can be shown in other places, for example, near the top border line in the upper corner or on the reverse side at the other end so it will be visible when the drawing is rolled. On blueprints with more than one sheet, the information in the number block shows the sheet number and the number of sheets in the series. For example, the title blocks have SHEET 1 of 1 (*Figure 1-1*).

Reference Number

Reference numbers that appear in the title block refer to numbers of other blueprints. A dash and a number show that more than one detail is shown on a drawing. When two parts are shown in one detail drawing, the print will have the drawing number plus a dash and an individual number. An example of a reference number would be 6271415-1 in the lower right corner of the title block.

In addition to appearing in the title block, the dash and number may appear on the face of the drawings near the parts they identify. Some commercial prints use a leader line to show the drawing and dash number of the part. Others use a circle 3/8 inch in diameter around the dash number, and carry a leader line to the part.

A dash and number identify changed or improved parts and right- and left-hand parts. Many aircraft parts on the left-hand (LH) side of an aircraft are mirror images of the corresponding parts on the right-hand (RH) side. The LH part is usually shown in the drawing.

Some parts are on the LH side, and some are on the RH side. On some prints you may see a notation above the title block, such as 159674 LH shown or 159674-1 RH opposite. Both parts carry the same number. Some companies use odd numbers for RH parts and even numbers for LH parts.

Zone Number

Zone numbers serve the same purpose as the numbers and letters printed on borders of maps to help you locate a particular point or part. To find a point or part, you should mentally draw horizontal and vertical lines from these letters and numerals. These lines will intersect at the point or part you are looking for.

You will use practically the same system to help you locate parts, sections, and views on large blueprinted objects (for example, assembly drawings of aircraft). To find parts numbered in the title, look up the numbers in squares along the lower border. Read zone numbers from right to left.

Scale Block

The scale block (*Figure 1-1*) in the title block of the blueprint shows the size of the drawing compared with the actual size of the part. The scale may be shown as 1″= 2″, 1″= 12″, 1/2″= 1′, and so forth. For example, the drawing may be shown as full size, one-half size, or one-fourth size.

If the scale is shown as 1″= 2″, each line on the print is shown one-half its actual length. If a scale is shown as 3″= 1″, each line on the print is three times its actual length.

The scale is chosen to fit the object being drawn and the space available on a sheet of drawing paper.

Never measure a drawing; use dimensions. The print may have been reduced in size from the original drawing, or you might not take the scale of the drawing into consideration. Paper stretches and shrinks as the humidity changes. Read the dimensions on the drawing; they always remain the same.

Graphical scales on maps and plot plans show the number of feet or miles represented by an inch. A fraction such as 1/500 means that 1 unit on the map is equal to 500 like units on the ground. A large-scale map has a scale of 1″= 10′; a map with a scale of 1″= 1,000′ is a small-scale map. The following chapters of this manual have more information on the different types of scales used in technical drawings.

Station Number

A station on an aircraft may be described as a rib. Aircraft drawings use various systems of station markings. For example, the center line of the aircraft on one drawing may be taken as the zero station. Objects to the right or left of center along the wings or stabilizers are found by giving the number of inches between them and the center line zero station. On other drawings, the zero station may be at the nose of the fuselage, at a firewall, or at some other location, depending on the purpose of the drawing. Station numbers for a typical aircraft are illustrated in *Figure 1-3*.

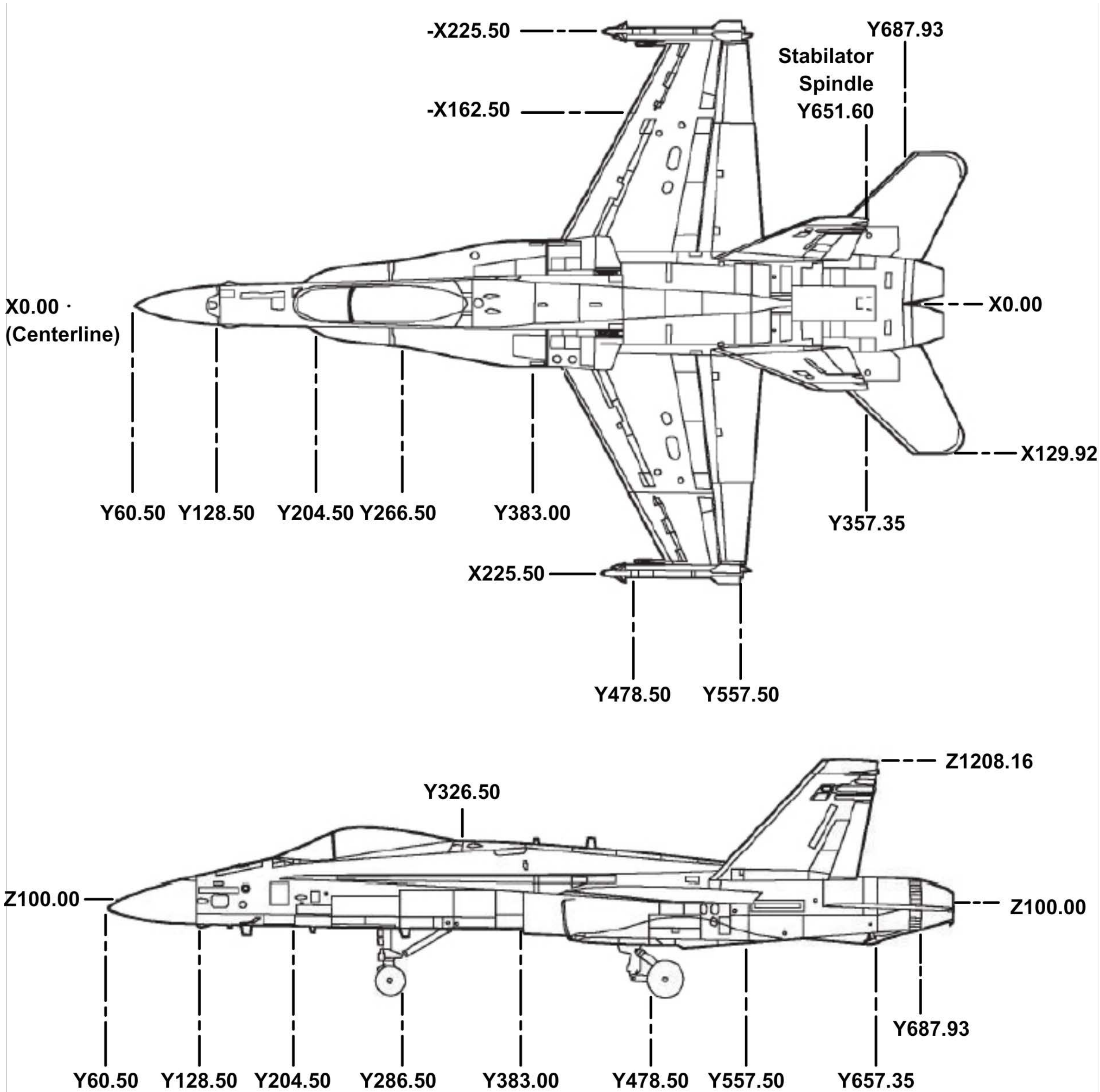


Figure 1-3 — Aircraft stations and frames.

Bill of Material

The bill of material block contains a list of the parts and/or material needed for the project. The block identifies parts and materials by stock number or another appropriate number, and lists the quantities requited.

The bill of material often contains a list of standard parts, known as a parts list or schedule. A bill of material for an electrical plan is illustrated in *Table 1-2*.

Table 1-2 — Sample of Bill of Material

BILL OF MATERIAL					
ITEM	DESCRIPTION	UNIT	ASSEMBLY OR FSN NO.	QUANTITIES	
				TROP	NORTH
3-1	LIGHTING CIRCUIT – NAVFAC DWG. NO. 203414	FT	3016	3	16
3-2	POWER BUS, 100A – NAV DWG. NO. 30413 1	FT	3047	1	20
3-3	RECEPTICAL CKT – NAV DWG. NO. 303660	EA	3019	2	1
3-4	BOX, RECEPTACLE W/CLAMP FO NONMETALLIC SHEATH WIRE	EA	5325-102-604	3	1
3-5	LAMP, ELECTRIC, MED BASE, INSTIDE FROSTED, 200 W, 120 V	EA	6240-180-314	60	6
3-6	PLUG: ATTACHMENT, 3 WIRE, 15 AMP, 125 V	HD	5936-102-309	10	1
3-7	PLATE: BRASS, DUPLEX RECEPTACLE	EA	5325-100-101	5	6
3-8	RECEPTACLE, DUPLEX, 3 WIRE, 15 AMP, 125 V	EA	5325-100-102	5	1
3-9	RCO, GROUND, 3/4″ X 10′ 0″	EA	3325-800-101	12	1
3-10	WIRE NO 2 1/C STRANDED, HARD DRAWN, BARE	EA	6143-134-200	52	1
3-11	SWITCH, SAFETY 2 P, ST 30 AMP, 250 V PLUS FUSE	EA	5930-142-401	2	1
3-12	CLAMP, GROUND ROD	EA	5009-100-101	13	13
3-13	SWITCH, SAFETY, 200 AMP, 250 V, 3 P	EA	6930-201-903	1	1
3-14	FUSE, RENEWABLE 200 AMP, 250 V	EA	6920-100-000	6	6
3-15	LINK FUSE, 200 AMP, 250 V	EA	6920-100-001	6	6
3-16	FUSE PLUG, 30 AMP, 125 V	EA	6920-100-102	12	12

Application Block

The application block on a blueprint of a part or assembly (*Table 1-3*) identifies directly or by reference the larger unit that contains the part or assembly on the drawing. The next assembly (NEXT ASS'Y) column will contain the drawing number or model number of the next larger assembly of which the smaller unit or assembly is a part. The USED ON column shows the model number or equivalent designation of the assembled unit's part.

Table 1-3 — Application Block

2A	1AB
NEXT ASS'Y	**USED ON**
APPLICATION	

Finish Marks

Finish marks (P) (*Figure 1-4*) used on machine drawings show surfaces to be finished by machining. Machining provides a better surface appearance and a better fit with closely mated parts. Machined finishes are NOT the same as finishes of paint, enamel, grease, chromium plating, or similar coatings.

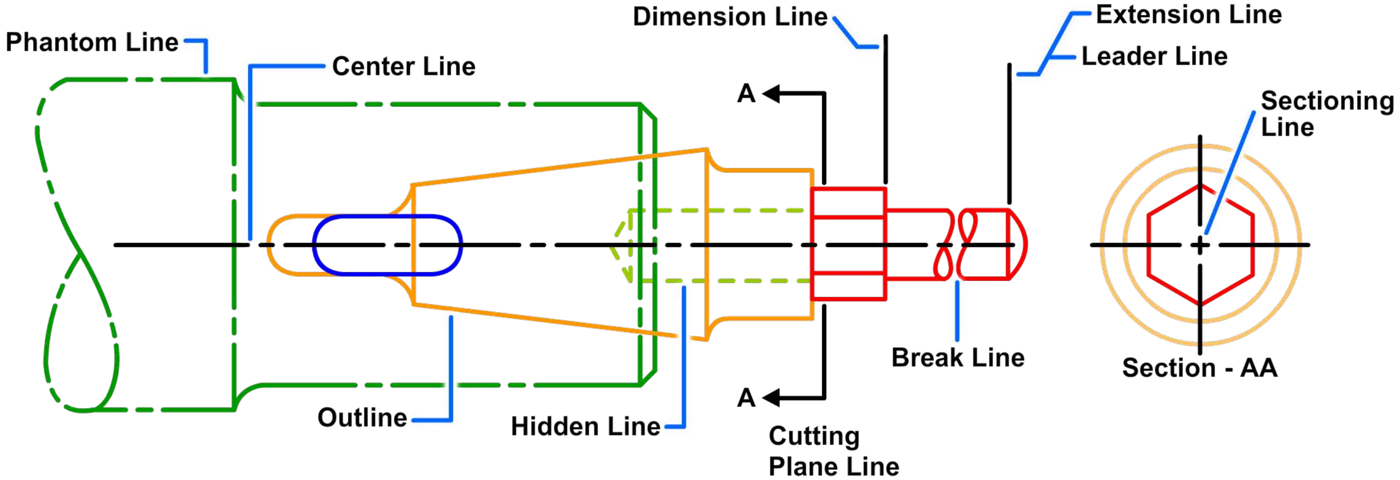


Figure 1-4 — Finish marks.

Notes and Specifications

Blueprints show all of the information about an object or part graphically. However, supervisors, contractors, manufacturers, and craftsmen need more information, and not all information is adaptable to the graphic form of presentation. Such information is shown on the drawings as notes or as a set of specifications attached to the drawings.

Notes

Notes (*Figure 1-5*) are placed on drawings to give additional information to clarify the object on the blueprint. Leader lines show the precise part notated.

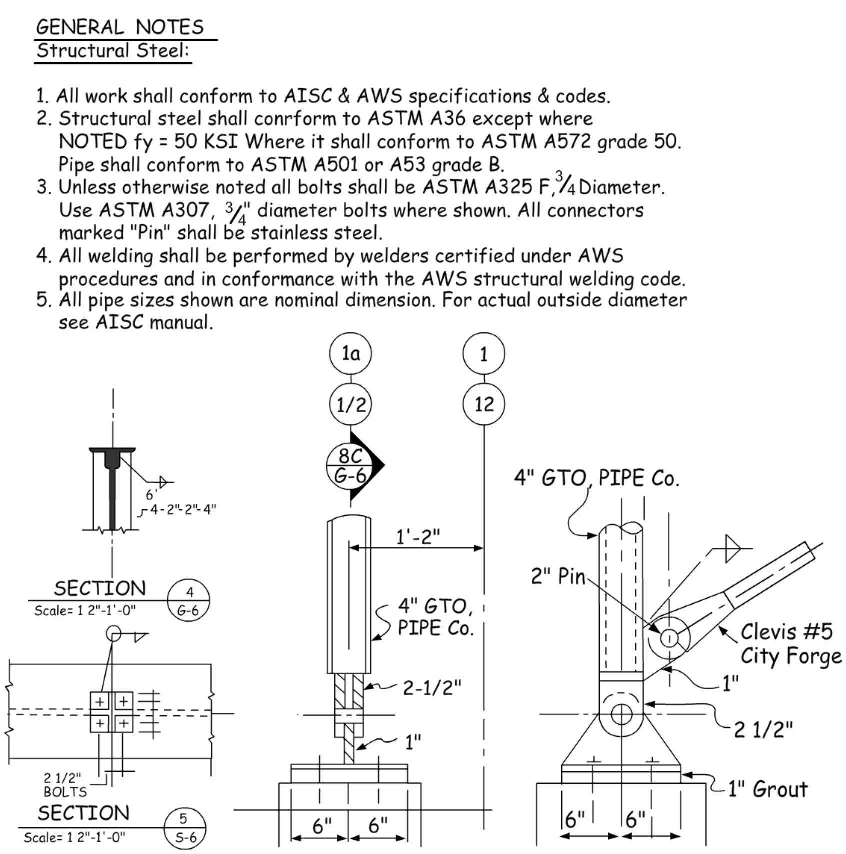


Figure 1-5 — Example of blueprint notes.

Specifications

A specification (*Figure 1-6*) is a statement or document containing a description, such as the terms of a contract or details of an object or objects not shown on a blueprint or drawing. Specifications describe items so they can be manufactured, assembled, and maintained according to their performance requirements. They furnish enough information to show that the item conforms to the description and that it can be made without the need for research, development, design engineering, or other help from the preparing organization.

Federal specifications cover the characteristics of material and supplies used jointly by the Navy and other Government departments.

Legends and Symbols

A legend, if used, is placed in the upper right corner of a blueprint below the revision block. The legend explains or defines a symbol or special mark placed on the blueprint. An example of a blueprint legend is shown in *Figure 1-7*.

LEGEND	
TB#	TACKBOARD; SEE A443
MB#	MARKERBOARD; SEE A443
TS	TACK STRIP; SEE A443
SB	SMART BOARD; SEE TELECOM
AWP	ACOUSTIC WALL PANELING
C#	CASEWORK ELEVATION; SEE A441 - A443
℄	CENTERLINE
B o	BOLLARD; SEE 7/A513
DS	DOWNSPOUT
IJ	ISOLATION JOINT
RD	ROOF DRAIN
OS	OVERFLOW SCUPPER; SEE PLUMBING
EJ	EXPANSION JOINT; SEE VARIOUS DETAILS SHEET A516
GR	GUARDRAIL; SEE 3+5/A514
LV1	LOUVER; SEE WINDOW TYPES
M.O.	MASONRY OPENING
FEC	SEMI-RECESSED FIRE EXTINGUISHER CABINET
FE	WALL BRACKET MOUNTED FIRE EXTINGUISHER
A1	WINDOW TAG; SEE WINDOW TYPES
157-A	DOOR TAG; SEE DOOR SCHEDULE
A1	WALL TAG; SEE A321 AND A322
CC	COT CURTAIN

Figure 1-7 — Blueprint legend.

SPECNOTES	
00 00 01.A2	DUMPSTER (NIC)
05 52 13.A2	DUAL 1 1/2" O.D. PIPE HANDRAILS AT 2'-4" AND 3'-0" ELEVATIONS; MOUNT TO GUARDRAIL OR WALL WITH MINIMUM 2 1/4" CLEARANCE; SEE 2+6/A514
05 52 13.A4	TYPICAL 42" GUARDRAIL; SEE 3+5/A514
10 73 13.A1	PREFINISHED ALUMINUM CANOPY SUPPORT FRAME
10 73 16.A1	DOCK BUMPERS ATTACHED TO VERTICAL WALL
22 00 60.C1	GREASE TRAP; SEE PLUMBING
23 00 50.A1	HVAC EQUIPMENT; SEE MECHANICAL
32 13 19.A1	SLIDING ALUMINUM GATE
33 00 00.A1	GAS METER (NIC)

Figure 1-6 — Example of blueprint specifications.

THE MEANING OF LINES

To read blueprints, you must understand the use of lines. The alphabet of lines is the common language of the technician and the engineer. In drawing an object, the different views are arranged in a certain way, and then different types of lines convey the information. The use of standard lines in a simple drawing is shown in *Figure 1-4*. Line characteristics, such as width, breaks in the line, and zigzags, have meaning, as shown in *Figure 1-8*.

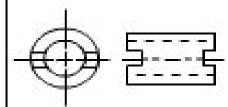
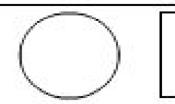
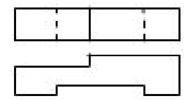
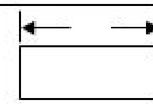
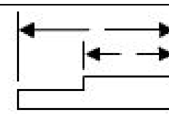
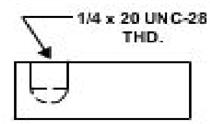
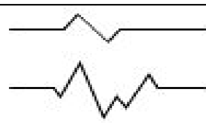
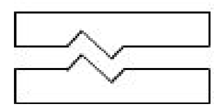
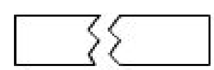
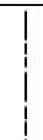
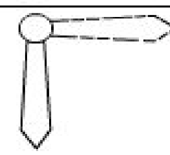
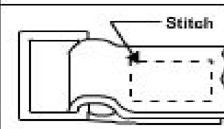
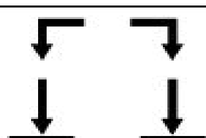
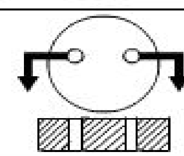
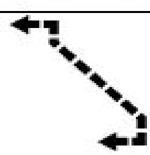
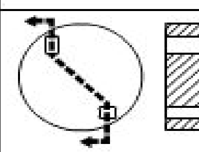
LINE STANDARDS			
Name	**Convention**	**Description and Application**	**Example**
Center Lines		Thin lines made up of long and short dashes alternately spaced and consistent in length. Used to indicate symmetry about an axis and location of centers.	
Visible Lines		Heavy unbroken lines Used to indicate visible edges of an object	
Hidden Lines		Medium lines with short evenly spaced dashes Used to indicate concealed edges	
Extension Lines		Thin unbroken lines Used to indicate extent of dimensions	
Dimension Lines		Thin lines terminated with arrow heads at each end Used to indicate distance measured	
Leader		Thin line terminated with arrowhead or dot at one end Used to indicate a part, dimension or other reference	
Break (Long)		Thin, solid ruled lines with freehand zigzags 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	
Phantom or Datum Line		Medium series of one long dash and two short dases 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 dases evenly spaced and labeled Used to indicate stitching or sewing	
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 arrowheads to show direction viewed	

Figure 1-8 — Line characteristics and conventions for MIL-STD drawings.

SHIPBOARD BLUEPRINTS

Blueprints are usually called plans. Some common types used in the construction, operation, and maintenance of Navy ships are described in the following paragraphs.

- Contract guidance plans illustrate design features of the ship subject to development.
- Contract plans illustrate mandatory design features of the ship.
- Corrected plans have been corrected to illustrate the final ship and system arrangement, fabrication, and installation.
- Onboard plans are considered necessary as reference materials in the operation of a ship. A shipbuilder furnishes a completed Navy ship with copies of all plans needed to operate and maintain the ship (onboard plans) and a ship's plan index (SPI). The SPI lists all plans that apply to the ship except those for certain miscellaneous items covered by standard or type plans. Onboard plans include only those plans Naval Ship System Command (NAVSHIPS) or the supervisor of ship building considers necessary for shipboard reference. The SPI is NOT a checklist for the sole purpose of getting a complete set of all plans.
- Preliminary plans are submitted with bids or other plans before a contract is awarded.
- Standard plans illustrate arrangement or details of equipment, systems, or parts where specific requirements are mandatory.
- Type plans illustrate the general arrangement of equipment, systems, or parts that do not require strict compliance to details as long as the work gets the required results.
- Working plans are used by the contractor to construct the ship.

When there is a need for other plans or additional copies of onboard plans, you should get them from your ship's home yard or the concerned system command. Chapter 001 of the Naval Ships' Technical Manual (NSTM) contains a guide for the selection of onboard plans.

BLUEPRINT NUMBERING PLAN

In the current system, a complete plan number has five parts: size, Federal Supply Code identification number, a two-part system command number, and a revision letter. The following list explains each part.

- The letter under the SIZE block in *Figure 1-1* shows the size of the blueprint according to a table of format sizes in ASME Y14.100-2013.
- The Federal Supply Code identification number shows the design activity. An example under the block titled CODE IDENT NO where the number 80091 (*Figure 1-1*) identifies Naval Facilities Engineering Command (NAVFAC).
- The first part of the system command number is a three-digit group number. It is assigned from the Consolidated Index of Drawings, Materials, and Services Related to Construction and Conversion, NAVSHIPS 0902-002-2000. This number identifies the equipment or system, and sometimes the type of plan.
- The second part of the system command number is the serial or file number assigned by the supervisor of shipbuilding. The number 6271415 (*Figure 1-1*) is an example under the NAVFAC DRAWING NO block.
- The revision letter was explained earlier in the chapter. It is shown under the REV block as A in *Figure 1-1*.

A current and earlier shipboard plan numbering system is illustrated in *Table 1-4*. The two systems are similar, with the major differences in the group numbers in the second block. We will explain the purpose of each block in the following paragraphs so you can compare the numbers with those used in the current system.

Table 1-4 — Shipboard Plan Numbers

CURRENT SYSTEM				
DDG 51	303	H	1844928	A
EARLIER SYSTEM				
DD 880	S3801	H	1257161	A

The first block contains the ship identification number. The examples in *Table 1-4* are DDG 51 and DD 880. Both refer to the lowest numbered ship to which the plan applies.

The second block contains the group number. In the current system, it is a three-digit number, 303, taken from NAVSHIPS 0902-002-2000, and it identifies a lighting system plan. The earlier system shows the group number system in use before adoption of the three-digit system. The earlier system used S-group numbers that identify the equipment or system concerned.

Blocks 3, 4, and 5 use the same information in the current and earlier systems. Block 3 shows the size of the plan, block 4 shows the system or file number, and block 5 shows the version of the plan.

FILING AND HANDLING BLUEPRINTS

On most ships, engineering log room personnel file and maintain plans. Tenders and repair ships may keep plan files in the technical library or the microfilm library. They are filed in cabinets in numerical sequence according to the three-digit or S-group number and the file number. When a plan is revised, the old one is removed and destroyed. The current plan is filed in its place.

The method of folding prints depends upon the type and size of the filing cabinet and the location of the identifying marks on the prints. It is best to place identifying marks at the top of prints when you file them vertically (upright), and at the bottom right corner when you file them flat. In some cases, construction prints are stored in rolls.

Blueprints are valuable permanent records. However, if you expect to keep them as permanent records, you must handle them with care. Here are a few simple rules that will help.

- Keep prints out of strong sunlight; they fade.
- Do not allow prints to become wet or smudged with oil or grease. Those substances seldom dry out completely, and the prints can become unreadable.
- Do not make pencil or crayon notations on a print without proper authority. If you are instructed to mark a print, use a proper colored pencil and make the markings a permanent part of the print. Yellow is a good color to use on a print with a blue background (blueprint).
- Keep prints stowed in their proper place. If you receive prints that are not properly folded, refold them correctly.

End of Chapter 1

Blueprints

Review Questions

1-1. What term describes interpreting ideas expressed by others on drawings?

A. Blueprint reading
B. Design
C. Diagram
D. Schematic

1-2. If tracings are handled properly, how long will they last?

A. 30 days
B. 6 months
C. 5 years
D. Indefinitely

1-3. What term describes the process in which a large camera reduces or enlarges a tracing of a drawing?

A. Carbon copy
B. Duplicate
C. Photocopy
D. Photostatic

1-4. What Web site lists military standards and American National Standards Institute standards?

A. Acquisition Streamlining and Standardization Information System
B. Commander, Naval Sea Systems Command
C. International Society of Engineers
D. Society of Electrical Engineers

1-5. What standard describes the abbreviations and acronyms for use on drawings and related documents?

A. ANSI Y32.9
B. ASME Y14.100-2013
C. ASME Y14.38-2007
D. IEEE-315-1975

1-6. What standard describes the electrical wiring symbols for architectural and electrical layout drawings?

A. ANSI Y32.9
B. ASME Y14.100-2013
C. ASME Y14.38-2007
D. IEEE-315-1975

1-7. What standard specifies the size, format, location, and type of information that should be included in military blueprints?

A. ANSI Y32.9
B. ASME Y14.100-2013
C. ASME Y14.38-2007
D. IEEE-315-1975

1-8. In what corner is the title block of all blueprints and drawings prepared according to military standards?

A. Lower left
B. Lower right
C. Upper left
D. Upper right

1-9. When a drawing is revised, what character is added to the original number?

A. A pound sign
B. A slash mark with a number
C. A dash with a number
D. A letter

1-10. What number is added to the blueprint to help locate a particular point or part?

A. Drawing
B. Reference
C. Revision
D. Zone

1-11. A station number is used in what type of drawing?

A. Aircraft
B. Building
C. Park
D. Topical

1-12. What information block on a blueprint contains a list of the parts and/or materials needed for the project?

A. Application
B. Bill of material
C. Legend
D. Title

1-13. What part of the blueprint provides additional information to clarify the object on the blueprint?

A. Finish marks
B. Note
C. Specification
D. Symbol

1-14. What type of plan is submitted with a bid or other plans before a contract is awarded?

A. Standard
B. Corrected
C. Preliminary
D. Working

1-15. What type of plan illustrates the arrangement or details of equipment, systems, or parts where specific requirements are mandatory?

A. Corrected
B. Preliminary
C. Standard
D. Working

1-16. The current blueprint number plan includes the size, Federal Supply Code identification number and what other part?

A. Reference scale
B. Revision letter
C. Title block
D. Unit identification code

1-17. The difference between the current and earlier shipboard plan number system is the group of numbers in what block?

A. 1
B. 2
C. 3
D. 4

1-18. On most ships, what personnel file and maintain the plans?

A. Supply
B. Microfilm librarian
C. Engineering log room
D. Technical librarian

1-19. What action will occur if the prints are exposed to strong sunlight?

- A. Prints will fade
- B. Prints will wrinkle
- C. Prints will become unreadable
- D. White lines will become brighter

1-20. What color is good to use on a print with blue background?

- A. Black
- B. Orange
- C. Red
- D. Yellow

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CHAPTER 2

TECHNICAL SKETCHING

The ability to make quick, accurate sketches is a valuable advantage that helps you convey technical information or ideas to others. A sketch may be of an object, an idea of something you are thinking about, or a combination of both. Most of us think of a sketch as a freehand drawing, which is not always the case. You may sketch on graph paper to take advantage of the lined squares, or you may sketch on plain paper with or without the help of drawing aids.

There is no military standard (MIL-STD) for technical sketching. You may draw pictorial sketches that look like the object, or you may make an orthographic sketch showing different views, which we will cover in following chapters.

In this chapter, we will discuss the basics of freehand sketching and lettering, drafting, and computer-aided drafting (CAD). We will also explain how CAD works with the newer computer numerical control (CNC) systems used in machining.

LEARNING OBJECTIVES

When you have completed this chapter, you will be able to do the following:

1. Identify the instruments used in technical sketching.
2. Recognize the types of lines used in technical sketching.
3. Identify basic CAD.
4. Determine CNC design techniques used in machining.

SKETCHING INSTRUMENTS

Freehand sketching requires few tools. If you have a pencil and a scrap piece of paper handy, you are ready to begin. However, technical sketching usually calls for instruments that are a little more specialized, and we will discuss some of the more common ones in the following paragraphs.

Pencils and Leads

Two types of pencils are used in drafting: wooden and mechanical. The mechanical type is actually a lead holder and may be used with leads of different hardness or softness.

There are a number of different drawing media and types of reproduction and they require different kinds of pencil leads. Pencil manufacturers market three types that are used to prepare engineering drawings; graphite, plastic, and plastic-graphite.

Graphite lead is the conventional type we have used for years. It is made of graphite, clay, and resin and it is available in a variety of grades or hardness. Drafting pencils are graded according to the relative hardness. A soft pencil is designated by the letter B, a hard pencil by the letter H. *Figure 2-1* shows 17 common grades of drafting pencils from 6B (the softest and the one that produces the thickest line) to 9H (the hardest and one that produces a thin, gray line).

You will notice that the diameters of the lead vary. This feature adds strength to the softer grades. As a result, softer grades are thicker and produce broader lines, while harder grades are smaller and produce thinner lines. Unfortunately, manufacturers of pencils have not established uniformity in grades. Hence, a 3H may vary in hardness from company to company. With experience and preference, you may select the trade name and grade of pencil that suits your needs.

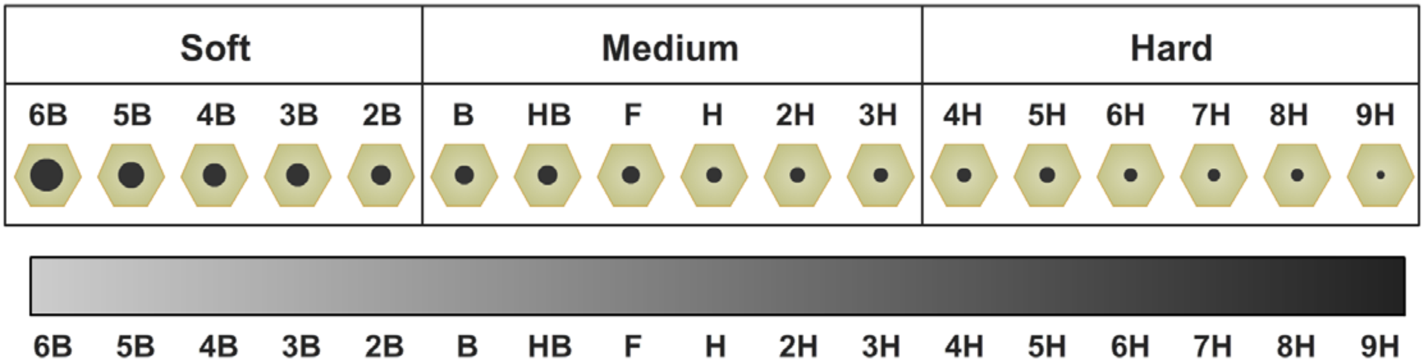


Figure 2-1 — Grades of drafting pencils.

Plastic and plastic-graphite leads were developed as a result of the introduction of film as a drawing medium, and they should be used only on film. Plastic lead has good microform reproduction characteristics, but it is seldom used since plastic-graphite lead was developed. A limited number of grades are available in these leads, and they do not correspond to the grades used for graphite lead.

Plastic-graphite lead erases well, does not smear readily, and produces a good opaque line suitable for microform reproduction. There are two types: fired and extruded. They are similar in material content to plastic lead, but they are produced differently. The main drawback with this type of lead is that it does not hold a point well.

Erasers and Erasing Accessories

You must be very careful in selecting an eraser (*Figure 2-2, frames 1 through 5*); choose one that will remove pencil or ink lines without damaging the surface of the drawing sheet.

A vinyl eraser is ideal for erasing lines drawn on tracing cloth and films. An ordinary double-beveled pencil eraser generally comes in red or pink color (sometimes called a pink pearl). A harder eraser (sometimes called a ruby red) is designed for erasing lines in ink. The art gum eraser, made of soft pliable gum, will not mar or scratch surfaces. It is ideally suited for removing pencil or finger marks and smudges.

Figure 2-2 — Common types of erasers.

Interaction Available

You can also use a kneaded eraser—the type used by artists. It is a rubber dough, kneadable in your hand, and has the advantage of leaving very little debris on the drawing sheet.

On an electric eraser, the control switch is directly under the fingertip; the body of the machine fits comfortably in the palm of the hand, and the rotating eraser can be directed as accurately as a pencil point. Refills for either ink or pencil erasing are available.

When there are many lines close together, only one of which needs removing or changing, you can protect the desired lines with an erasing shield, as shown in *Figure 2-3*.

CAUTION

Do not hold the electric eraser steadily in one spot, or you may wear a hole in, or otherwise damage, the surface of the material you are erasing.

Finely pulverized gum eraser particles are available in squeeze bottles or in dry clean pads for keeping a drawing clean while you work on it. If you sprinkle a drawing or tracing occasionally with gum eraser particles, then triangles, T-squares, scales, French curves, and other equipment tend to clean the drawing or tracing as they move over the surface, but the tools tend to stay clean themselves.

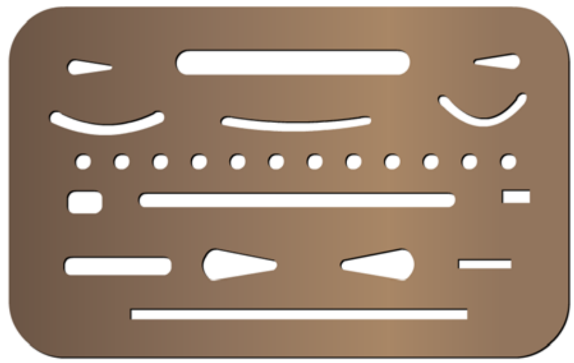


Figure 2-3 — Erasing shield.

Before inking a drawing, you usually prepared it by sprinkling on pounce (a very fine bone dust) and then rubbing in the pounce with the felt pad on the container. Pounce helps to prevent a freshly inked line from spreading. Use a dust brush for brushing dust and erasure particles off a drawing.

Pens

Two types of pens are used to produce ink lines: the ruling pen with adjustable blade and the needle-in-tube type of pen. We include the ruling pen here only for information; it has been almost totally replaced by the needle-in-tube type.

The second type and the one in common use today is a technical fountain pen (*Figure 2-4*), or needle-in-tube type of pen. Use the technical fountain pen (sometimes called a Rapidograph pen or reservoir pen) for ruling straight lines of uniform width with the aid of a T-square, triangle, or other straightedge. You may also use it for freehand lettering and drawing and with various drawing and lettering templates. One of the best features of the technical fountain pen is its ink reservoir. The reservoir, depending on the style of pen, is either built into the barrel of the pen or is a translucent plastic ink cartridge attached to the body of the pen. The large ink capacity of the reservoir saves time because you do not have to replenish the ink supply constantly. Several types of these pens now offer compass attachments that allow them to be clamped to or inserted on a standard compass leg.

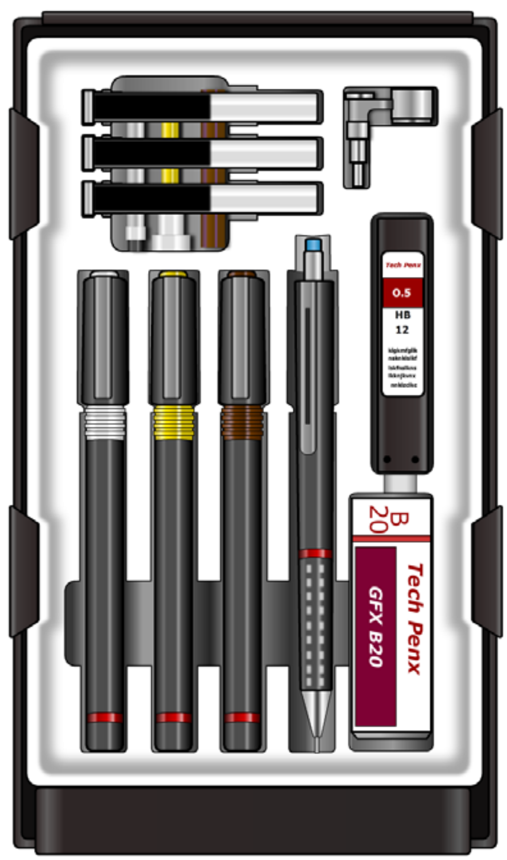


Figure 2-4 — Technical fountain pens.

Various manufacturers offer variations in pen style and line size. Some pens are labeled by the metric system according to the line weight they make. Other pens are labeled with a code that indicates line width measured in inches. For instance, a Number 2 pen draws a line 0.026 inches in width.

Most technical fountain pens are color-coded for easy identification of pen size. These pens are available either as individual fountain pen units, resembling a typical fountain pen, or as a set, having a common handle and interchangeable pen units.

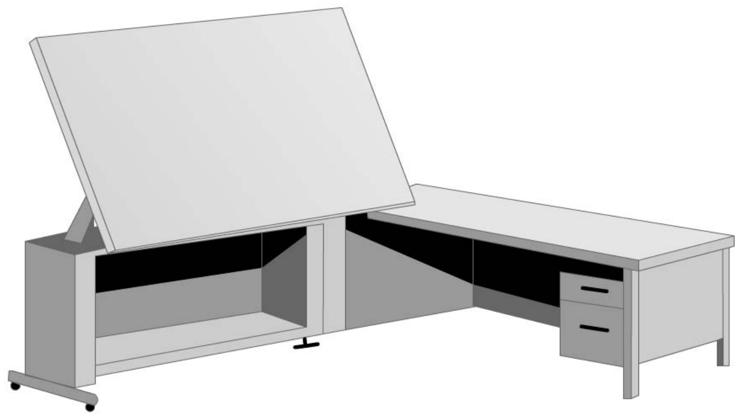
DRAWING AIDS

Some of the most common drawing aids are drafting tables with boards, triangles, protractors, and French curves.

Drafting Tables with Boards

The table (*Figure 2-5, frames 1 through 4*) should be high enough for you to work in a standing position without stooping or holding your arms in a raised position. The drawing board has hinged attachments for adjusting the incline; your line of sight should be approximately perpendicular to the drafting surface. Your drafting stool should be high enough in relation to the table for you to see the whole drafting board but not so high that you are seated uncomfortably.

You should consider only the left-hand vertical edge as a working edge for the T-square if you are right-handed (the right-hand edge if you are left-handed). You should never use the T-square with the head set against the upper or lower edge of the board, as the drafting board may not be perfectly square.



The L-Shaped desk features a drafting table and computer desk combination. The drawing board is adjustable to any angle.

Figure 2-5 — Drafting tables with boards.

Interaction Available

The drafting board should be covered. A variety of good drafting board cover materials are available. Available cover materials are cellulose acetate-coated paper, vinyl, and Mylar® film. Vinyl drafting board covers have the added advantage of being able to close up small holes or cuts, such as those made by drafting compasses or dividers. In general, drafting board covers protect the drafting board surface by preventing the drafting pencil from following the wood grain, by reducing lighting glare, and by providing an excellent drafting surface.

Since you will be constantly using your eyes, your working area must be well lighted. Natural light is best, if available and ample; although in the majority of cases acceptable natural light will be the exception rather than the rule. Drafting rooms are usually lighted with overhead fluorescent fixtures.

Ordinarily, these fixtures are inadequate in quality and intensity of light. Adjustable lamps will improve the lighting conditions. The most popular type of adjustable lamp is the floating-arm fluorescent fixture that clamps onto the table. Arrange your lighting to come from the left front, if you are right-handed; from the right front, if you are left-handed. This arrangement minimizes shadows cast by drawing instruments and your hands.

Never place your drafting board so that you will be subject to the glare of direct sunlight. North windows are best for admitting daylight in the Northern Hemisphere. Conservation of vision is of the utmost importance. You must make every possible effort to eliminate eyestrain.

T-Squares

The T-square (*Figure 2-6*) gets its name from its shape. It consists of a long, straight strip, called the blade, which is mounted at right angles on a short strip called the head. The head is mounted under the blade so that it will fit against the edge of the drawing board while the blade rests on the surface. T-squares vary in size from 15 to 72 inches in length, with 36 inches the most common size.

Figure 2-6 — Drafting board with T-square and drafting paper in place.

The head is made of hardwood, the blade usually of maple with a natural or mahogany finish. The edges of the blade are normally transparent plastic strips glued into grooves on both edges of the blade. This feature allows the edge of the T-square to ride above the drawing as the blade is moved up or down the board. This arrangement is a great advantage when you are drawing with ink. Since the tip of the ruling pen does not come in contact with the blade, but is below it, ink cannot be drawn under the blade to blot the drawing. The T-square is used for drawing horizontal lines only. Always draw lines along the upper edge of the blade. The T-square also serves as a base for drawing the vertical and inclined lines of a triangle. Some T-squares have adjustable heads to allow angular adjustments of the blade.

Handle your T-square carefully. If dropped, it may be knocked out of true and become useless. Additionally, to prevent warping, hang the T-square by the hole in the end of the blade or lay it on a flat surface so that the blade rests flat.

Before beginning a new job, check the top edge of your T-square for warp or nicks by drawing a sharp line along the top of the blade. Turn the T-square over and redraw the line with the same edge. If the blade is warped, the lines will not coincide. If the blade swings when the head is held firmly against the edge of the drawing board, the blade may be loose where it is joined to the head, or the edge of the T-square head may be warped. You can usually tighten a loose blade by adjusting the screws that connect it to the head, but if it is out of square, warped, or in bad condition, select a new T-square.

Triangles

Triangles are used in combination with the T-square or straightedge to draw vertical and inclined lines. They are usually made of transparent plastic, which allows you to see your work underneath the triangle. Triangles are referred to by the size of their acute angles. Two basic drafting triangles are illustrated in *Figure 2-7*: the 45 degree (each acute angle measures 45 degrees), and the 30/60 degree (one acute angle measures 30 degrees; the other, 60 degrees). The size of a 45 degree triangle is designated by the length of the sides that form the right angle (the sides are equal). The size of a 30/60 degree triangle is designated by the length of the longest side that forms the right angle. Sizes of both types of triangles range from 4 inches through 18 inches in 2 inch increments.

Figure 2-7 — 45 degree and 30/60 degree drafting triangles.

Like all other drafting equipment, triangles must be kept in good condition. If you drop a plastic triangle, you may damage its tip. Also, triangles may warp so that they do not lie flat on the drawing surface, or the edge may deviate from true straightness. To prevent warping or chipping, always lay them flat or hang them up when you are not using them. Since there is seldom enough drawing space available to permit laying triangles flat, develop the habit of hanging them up. If the tips are bent, use a sharp knife to cut off the damaged part. If the triangle is warped, you may be able to bend it back by hand. If bending does not straighten it, leave the triangle lying on a flat surface with weights on it or hold the triangle to the opposite curvature with weights. If the triangle becomes permanently warped, so that the drawing edges are curved or the angles are no longer true, throw it away and get another. To test the straightness of a triangle, place it against the T-square and draw a vertical line, as shown in *Figure 2-8*. Then reverse the triangle and draw another line along the same edge. If the triangle is straight, the two lines will coincide; if they do not, the error is half the resulting space.

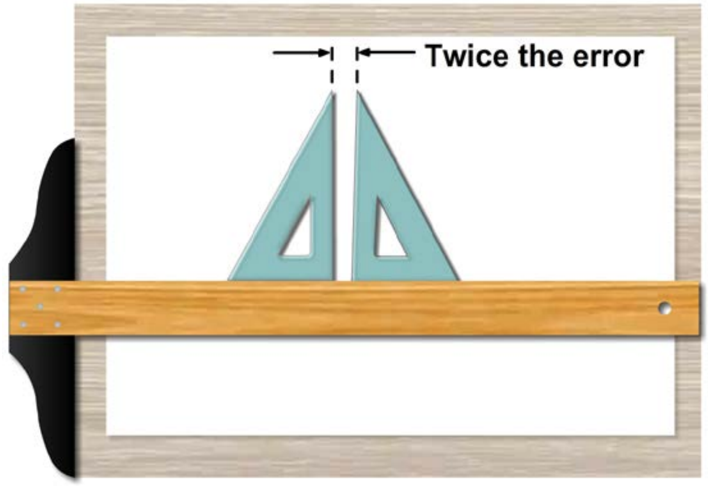


Figure 2-8 — Testing a triangle for straightness.

Adjustable Triangles

The adjustable triangle, shown in *Figure 2-9*, combines the functions of the triangle and the protractor. When it is used as a right triangle, you can set and lock the hypotenuse at any desired angle to one of the bases. The transparent protractor portion is equivalent to a protractor graduated in 1/2-degree increments. The upper row of numbers indicates angles from 0 to 45 degrees to the longer base; the lower row indicates angles from 45 to 90 degrees to the shorter base. By holding either base against a T-square or straightedge, you can measure or draw any angle between 0 and 90 degrees.

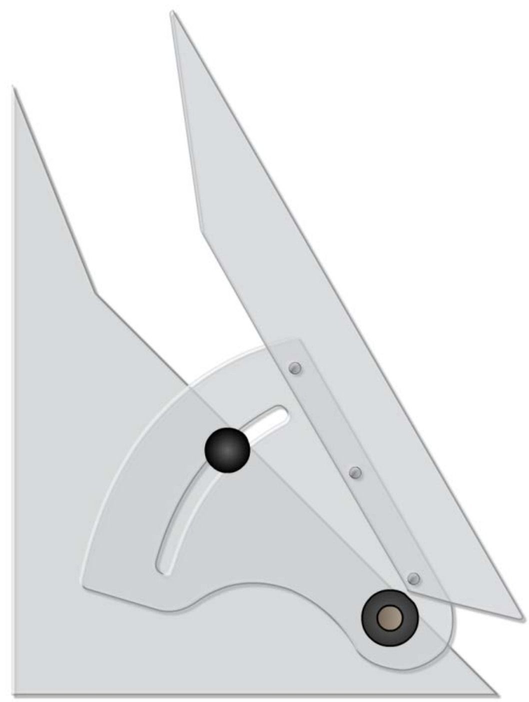


Figure 2-9 — Adjustable triangle.

The adjustable triangle is especially helpful in drawing building roof pitches. It also allows you to transfer parallel inclined lines by sliding the base along the T-square or straightedge.

Protractors

Protractors (*Figure 2-10*) are used for measuring and laying out angles other than those drawn with the triangle or a combination of triangles. Most of the work you will do with a protractor will involve plotting information obtained from field surveys. Like the triangle, most protractors are made of transparent plastic. They are available in 6-, 8-, and 10-inch sizes and are either circular or semicircular in shape.

Protractors are usually graduated in increments of half of a degree. By careful estimation, you may obtain angles of 1/4 degree. Protractor numbering arrangement varies. Semicircular protractors are generally labeled from 0 to 180 degrees in both directions. Circular protractors may be labeled from 0 to 360 degrees (both clockwise and counterclockwise), or they may be labeled from 0 to 90 degrees in four quadrants. Stow and care for protractors in the same manner as triangles.

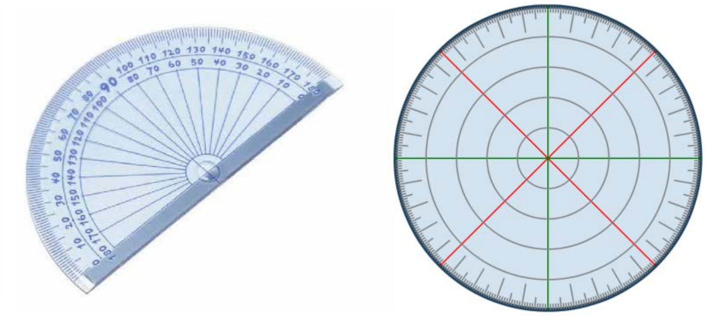


Figure 2-10 — Types of protractors.

French Curves

French curves (called irregular curves) are used for drawing smooth curved lines other than arcs or circles, lines such as ellipses, parabolas, and spirals. Transparent plastic French curves come in a variety of shapes and sizes.

An assortment of French curves are illustrated in *Figure 2-11*. In such an assortment, you can find edge segments you can fit to any curved line you need to draw. Stow and care for French curves in the same manner as triangles.

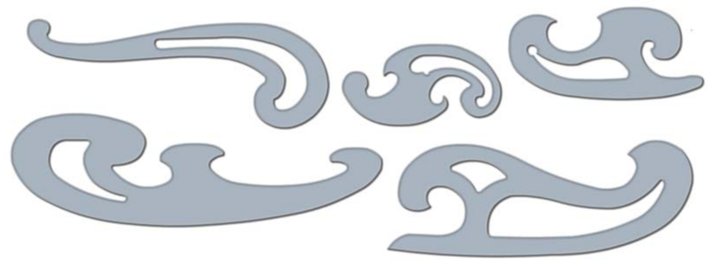


Figure 2-11 — French curves.

Drawing Instrument Sets

So far we have discussed only those instruments and materials you will need for drawing straight lines (with the exception of French curves). Many drawings you prepare will require circles and circular arcs. Use instruments contained in a drawing instrument set (*Figure 2-12*) for this purpose.

Many types of drawing instrument sets are available; however, it is sometimes difficult to judge the quality of drafting instruments by appearance alone. Often their characteristics become evident only after use.

The following sections describe these instruments as well as some special-purpose instruments not found in the set. These special-purpose instruments may be purchased separately or found in other instrument sets.

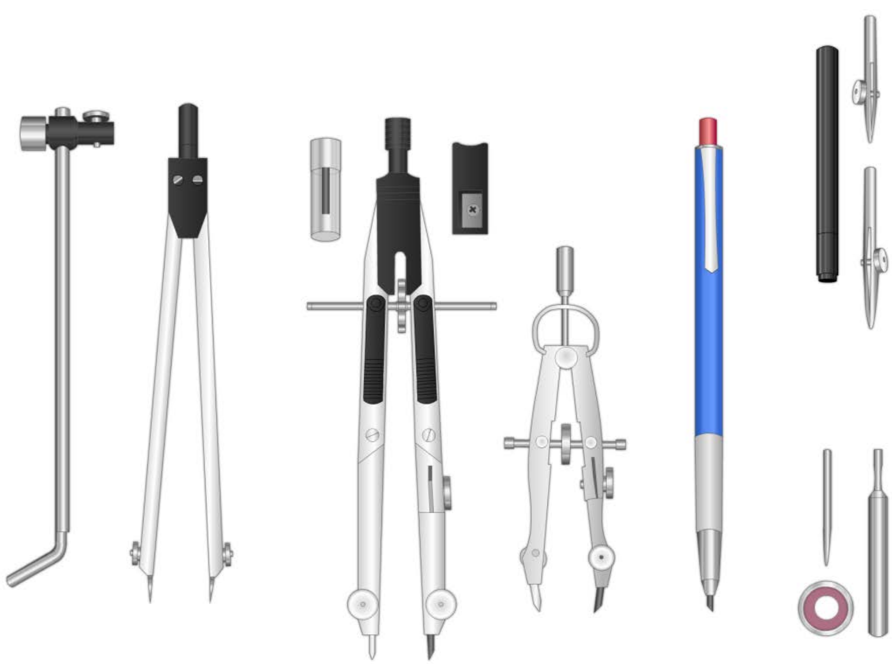


Figure 2-12 — Drawing instrument set.

Compasses

Circles and circular curves of relatively short radius are drawn with a compass. The large pivot joint compass is satisfactory for drawing circles of 1-inch to about 12-inch diameter without an extension bar.

The pivot joint provides enough friction to hold the legs of the compass in a set position. One of the legs has a setscrew for mounting a pen or pencil attachment on the compass. You can insert an extension bar to increase the radius of the circle drawn. The other type of compass in the drawing instrument set is the bow compass. The bow compasses are the preferred drawing instrument over the pivot joint compass. The bow compass is much sturdier and is capable of taking the heavy pressure necessary to produce opaque pencil lines without losing the radius setting.

There are two types of bow compasses. The location of the adjustment screw determines the type. In *Figure 2-13*, the bow pen/pencil is the center adjustment type, whereas the bow drop pen is the side adjustment type. Each type comes in two sizes: large and small. Large bow compasses are usually of the center adjustment type, although the side adjustment type is available. The large bow compasses are usually about 6 inches long, the small compasses approximately 4 inches long. Extension bars are available for large bow compasses. Bow compasses are available as separate instruments, or as combination instruments with pen and pencil attachments.

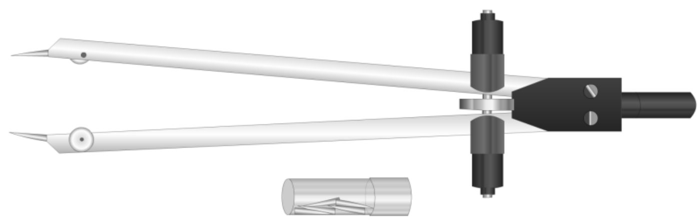


Figure 2-13 — Bow instruments.

Most compasses have interchangeable needlepoints. Use the conical or plain needlepoint when you use the compass as dividers. Use the shoulder-end needlepoint with pen or pencil attachments. When you draw many circles using the same center, the compass needle may bore an oversized hole in the drawing. To prevent these holes, use a device called a horn center or center disk. Place this disk over the center point. Then place the point of the compass needle into the hole in its center.

Dividers

Dividers are similar to compasses, except that both legs have needlepoints. The instrument set (*Figure 2-12*) contains two different types and sizes of dividers: large 6-inch hairspring dividers and small center adjustment bow dividers. You can also use the large speed compass *(Figure 2-13)* as a divider. As with compasses, dividers are available in large and small sizes, and in pivot joint, center adjustment bow (*Figure 2-14*), and side adjustment bow types. Use pivot joint dividers for measurements of approximately 1 inch or more. For measurements of less than 1 inch, use bow dividers. You can also use dividers to transfer measurements, step off a series of equal distances, and divide lines into a number of equal parts.

Figure 2-14 — Bow divider.

Drop Bow Pen

The drop bow pen (*Figure 2-15*) is not one of the standard instruments, but it is essential for some jobs. Use it to ink small circles with diameters of less than 1/4 inch. As the name indicates, the pen assembly is free to move up and down and to rotate around the main shaft. When using this instrument, hold the pen in the raised position, adjust the setscrew to give the desired radius, and then gently lower the pen to the paper surface and draw the circle by rotating the pen around the shaft.

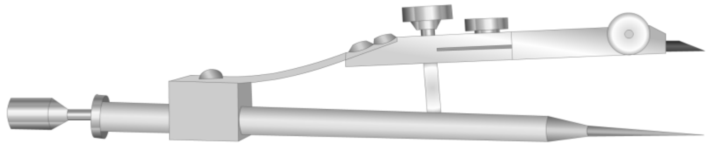


Figure 2-15 — Drop bow pen.

Maintenance of Compasses and Dividers

There are three shapes in which compasses and dividers are made: round, flat, and bevel (*Figure 2-16*). When you select compasses and dividers, test them for alignment by bending the joints and bringing the points together. New instruments are factory adjusted for correct friction setting. They rarely require adjustment. Use a small jeweler's screwdriver or the screwdriver found in some instrument sets for adjusting most pivot joint instruments. Skilled instrument repairmen should adjust instruments that require a special tool.

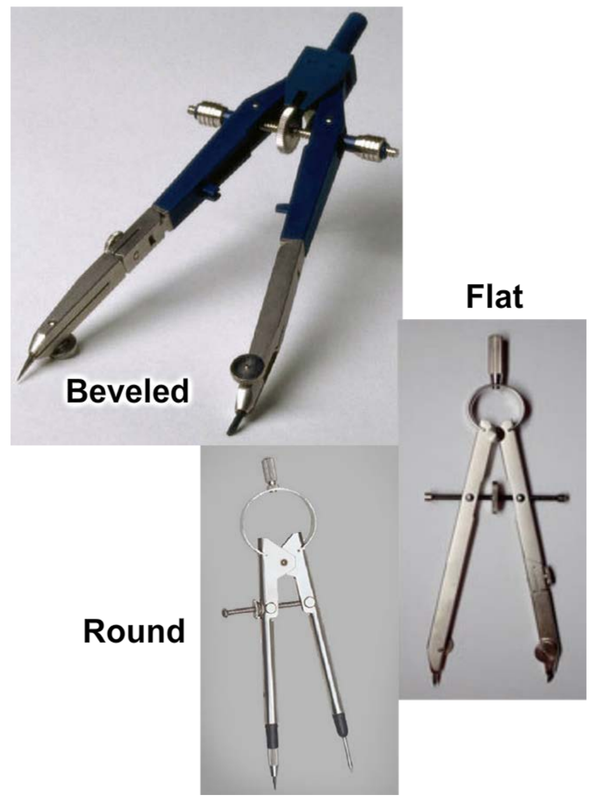


Figure 2-16 — Shapes of compasses and dividers.

Adjust pivot joint compasses and dividers so that they can be set without undue friction. They should not be so rigid that their manipulation is difficult, nor so loose that they will not retain their setting. Divider points should be straight and free from burrs. When the dividers are not in use, protect the points by sticking them into a small piece of soft rubber eraser or cork. When points become dull or minutely uneven in length, make them even by holding the dividers vertically, placing the legs together, and grinding them lightly back and forth against a whetstone as shown in *Figure 2-17, view A*. Then hold the dividers horizontally and sharpen each point by whetting the outside of it back and forth on the stone, while rolling it from side to side with your fingers (*Figure 2-17, view B*). The inside of the leg should remain flat and not be ground on the stone. Do not grind the outside of the point so that a flat surface results. In shaping the point, be careful to avoid shortening the leg. Keep

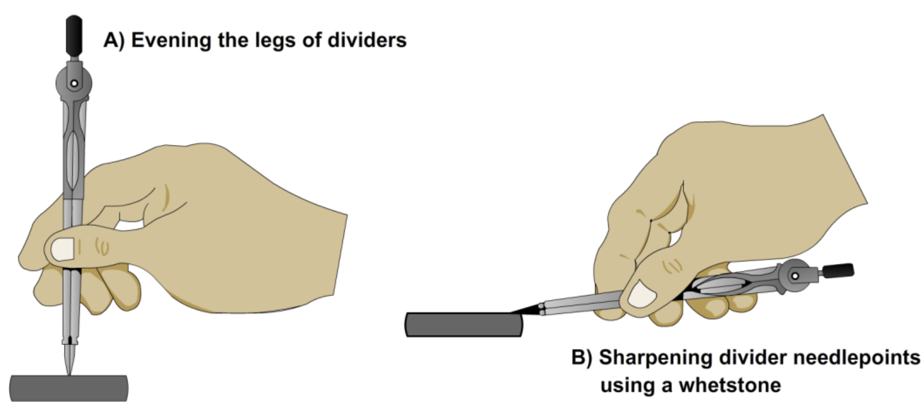


Figure 2-17 — Divider maintenance.

needles on compasses and dividers sharpened to a fine taper. When pushed into the drawing, they should leave a small, round hole in the paper no larger than a pinhole.

Since the same center is often used for both the compasses and dividers, it is best that needles on both be the same size. If the compass needle is noticeably larger, grind it until it is the correct size.

To make a compass needle smaller, wet one side of the whetstone and place the needle with its shoulder against this edge. Then grind it against the whetstone, twirling it between your thumb and forefinger (*Figure 2-18*). Test it for size by inserting it in a hole made by another needle of the correct size. When pushed as far as the shoulder, it should not enlarge the hole. The screw threads on bow instruments are delicate; take care never to force the adjusting nut. Threads must be kept free from rust or dirt. If possible, keep drawing instruments in a case, since the case protects them from damage by falls or unnecessary pressures. Also, the lining of the case is usually treated with a chemical that helps prevent the instruments from tarnishing or corroding.

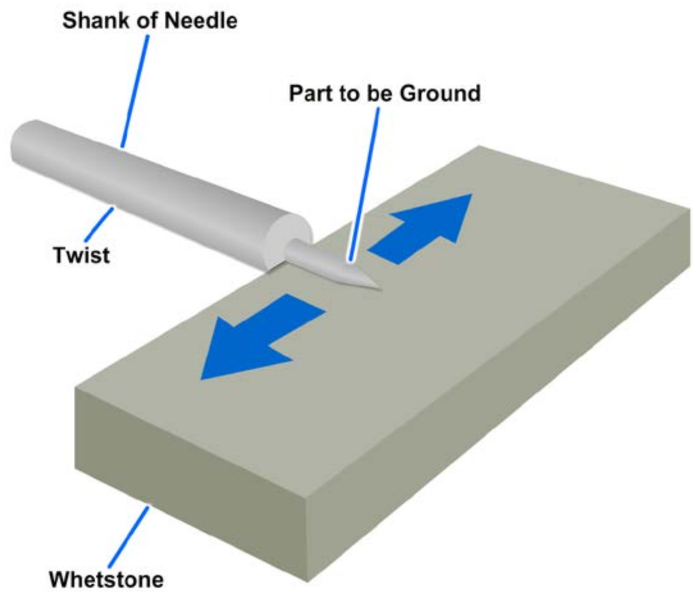


Figure 2-18 — Shaping a compass needle.

To protect instruments from rust when they are not in use, clean them frequently with a soft cloth and apply a light film of oil to their surface with a rag. Do not oil joints on compasses and dividers. When the surface finish of instruments becomes worn or scarred, it is subject to corrosion; therefore, never use a knife edge or an abrasive to clean drafting instruments.

Beam Compass

The beam compass (*Figure 2-19*) is used for drawing circles with radii larger than can be set on a pivot joint or bow compass. Both the needlepoint attachment and the pen or pencil attachment on a beam compass are slide-mounted on a metal bar called a beam.

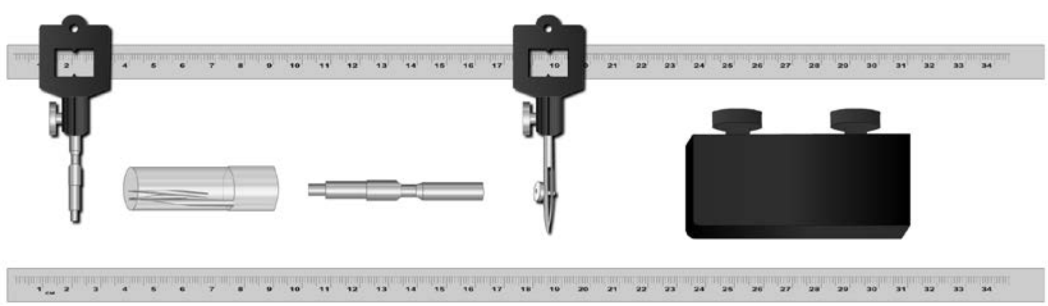


Figure 2-19 — Beam compass.

You can lock the slide-mounted attachments in any desired position on the beam. Thus, a beam compass can draw circles of any radius up to the length of the beam. With one or more beam extensions, the length of the radius of a beam compass ranges from about 18 inches to 70 inches.

Proportional Dividers

Proportional dividers (*Figure 2-20*) are used for transferring measurements from one scale to another. This capability is necessary to make drawings to a larger or smaller scale. Proportional dividers can divide lines or circles into equal parts. Proportional dividers consist of two legs of equal length, pointed at each end, and held together by a movable pivot. By varying the position of the pivot, you can adjust the lengths of the legs on opposite sides of the pivot so that the ratio between them is equal to the ratio between two scales. Therefore, a distance spanned by the points of one set of legs has the same relation to the distance spanned by the points of the other set as one scale has to the other. On the proportional dividers, a thumb nut moves the pivot in a rack-and-gear arrangement. When you reach the desired setting, a thumb-nut clamp on the opposite side of the instrument locks the pivot in place. A scale and vernier on one leg facilitate accurate setting.

Figure 2-20 — Proportional dividers.

On less expensive models, the movable pivot is not on a rack and gear, and there is no vernier. Set the dividers by reference to the table of settings that comes with each pair; they will accommodate varying ranges of scales from 1:1 to 1:10. However, do not depend entirely on the table of settings. You can check the adjustment by drawing lines representing the desired proportionate lengths, and then applying the points of the instrument to each of them in turn until, by trial and error, you reach the correct adjustment.

To divide a line into equal parts, set the divider to a ratio of 1 to the number of parts desired on the scale marked “Lines.” For instance, to divide a line into three parts, set the scale at 3. Measure off the length with points of the longer end. The span of the points at the opposite ends will be equal to one-third the measured length. To use proportional dividers to transfer measurements from feet to meters, draw a line 1 unit long and another line 3.28 units long and set the dividers by trial and error accordingly.

Some proportional dividers have an extra scale for use in getting circular proportions. The scale marked “Circle” indicates the setting for dividing the circumference into equal parts. The points of the dividers are of hardened steel, and if you handle them carefully, these points will retain their sharpness during long use. If they are damaged, you may sharpen them and the table of settings will still be usable, but the scale on the instrument will no longer be accurate.

TYPES OF LINES

When you are preparing drawings, you will use different types of lines to convey information. Line characteristics (*Figure 2-21*), such as widths, breaks in the line, and zigzags, have definite meanings.

The widths of the various lines on a drawing are very important in interpreting the drawing. Department of Defense Standard-100C (DOD-STD-100C) specifies that three widths of line should be used: thin, medium, and thick. As a general rule, on ink drawings, these three line widths are proportioned 1:2:4, respectively. However, the actual width of each type of line should be governed by the size and type of drawing.

The width of lines in format features (that is, title blocks and revision blocks) should be a minimum of 0.015 inch (thin lines) and 0.030 inch (thick lines). To provide contrasting divisions between elements of the format, use thick lines for borderlines, outline of principal blocks, and main divisions of blocks. Use thin lines for minor divisions of title and revision blocks and bill of materials. Use medium line widths for letters and numbers.

You cannot control the width of lines drawn with a pencil as well as the width of lines drawn with pen and ink. However, pencil lines should be opaque and of uniform width throughout their length. Cutting plane and viewing plane lines should be the thickest lines on the drawing. Lines used for outlines and other visible lines should be differentiated from hidden, extension, dimension, or center lines.

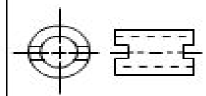
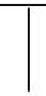
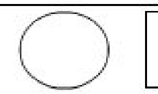
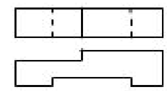
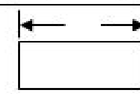
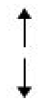
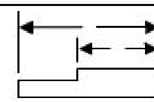
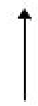
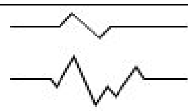
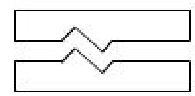
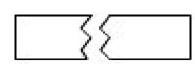
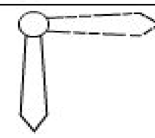
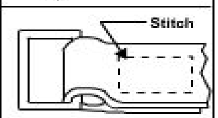
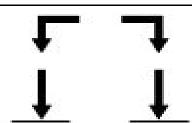
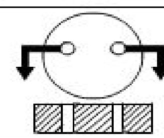
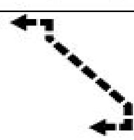
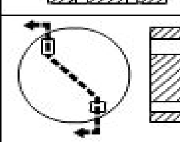
LINE STANDARDS			
Name	**Convention**	**Description and Application**	**Example**
Center Lines		Thin lines made up of long and short dashes alternately spaced and consistent in length. Used to indicate symmetry about an axis and location of centers.	
Visible Lines		Heavy unbroken lines Used to indicate visible edges of an object	
Hidden Lines		Medium lines with short evenly spaced dashes Used to indicate concealed edges	
Extension Lines		Thin unbroken lines Used to indicate extent of dimensions	
Dimension Lines		Thin lines terminated with arrow heads at each end Used to indicate distance measured	
Leader		Thin line terminated with arrowhead or dot at one end Used to indicate a part, dimension or other reference	
Break (Long)		Thin, solid ruled lines with freehand zigzags 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	
Phantom or Datum Line		Medium series of one long dash and two short dases 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 dases evenly spaced and labeled Used to indicate stitching or sewing	
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 arrowheads to show direction viewed	

Figure 2-21 — Line characteristics and conventions.

Construction Lines

Usually the first lines that you will draw are construction lines. Use these same lines to lay out your drafting sheet; you will also use them to lay out the rest of your drawing. Line weight for construction lines is not important since they will not appear on your finished drawing. Construction lines should be heavy enough to see, but light enough to erase easily; use a 4H to 6H pencil with a sharp, conical point. With the exception of light lettering guidelines, you must erase or darken all construction lines before a drawing is reproduced.

Center Lines

Use center lines (*Figure 2-22*) to indicate the center of a circle, arc, or any symmetrical object. Compose center lines with long and short dashes, alternately and evenly spaced, with a long dash at each end. Extend center lines at least 1/4 inch outside the object. At intersecting points, draw center lines as short dashes.

You may draw a very short center line as a single dash if there is no possibility of confusing it with other lines. You can also use center lines to indicate the travel of a moving center.

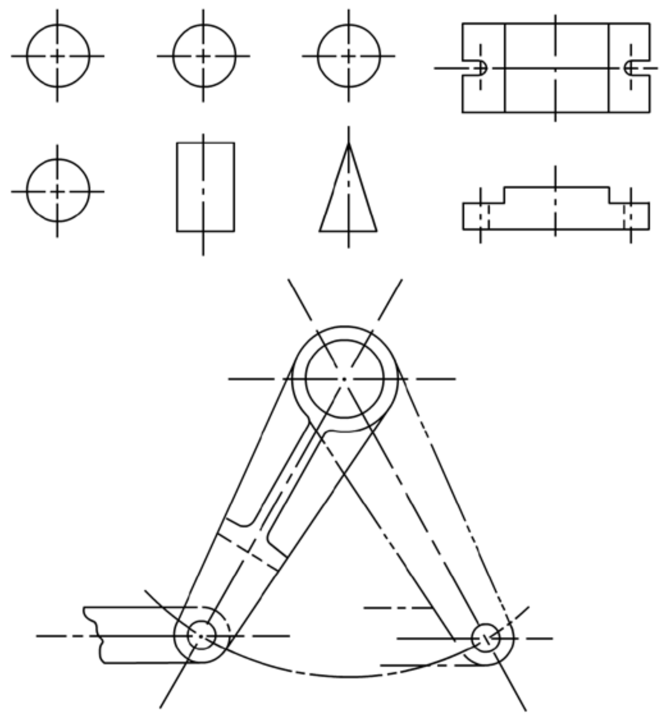


Figure 2-22 — Use of center lines.

Visible Lines

Draw the visible edge lines (*Figure 2-23*) of the view as solid, thick lines. The visible edge lines include not only the outlines of the view, but lines defining edges that are visible within the view.

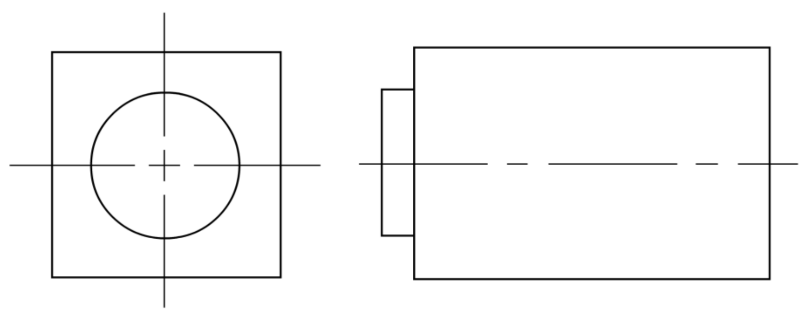


Figure 2-23 — Use of visible edge lines.

Hidden Lines

Draw hidden edge lines (*Figure 2-24*) with short dashes and use them to show hidden features of an object. Begin a hidden line with a dash in contact with the line from which it starts, except when it is the continuation of an unbroken line.

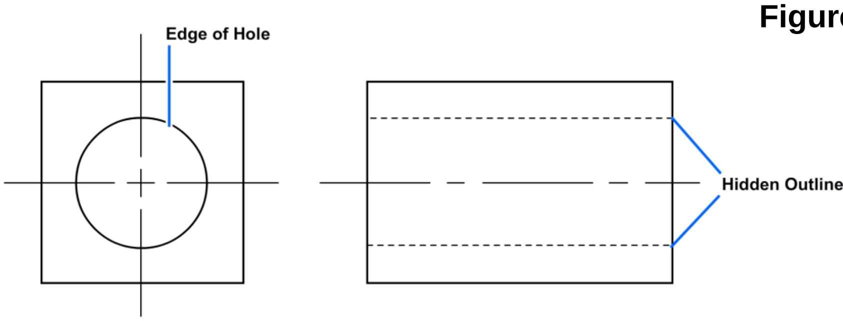


Figure 2-24 — Use of hidden edge lines.

To prevent confusion in the interpretation of hidden edge lines, you must apply certain standard techniques in drawing these lines. A hidden edge line that is supposed to join a visible or another hidden line must actually contact the line, as shown in the upper views of *Figure 2-25*; the lower views show the incorrect procedure.

An intersection between a hidden edge line and a visible edge line is illustrated in *Figure 2-26*. Obviously, on the object itself the hidden edge line must be below the visible edge line. Indicate this face by drawing the hidden edge line as shown in the left view of *Figure 2-26*. If you drew it as indicated in the right view, the hidden edge line would appear to be above, rather than beneath, the visible edge line.

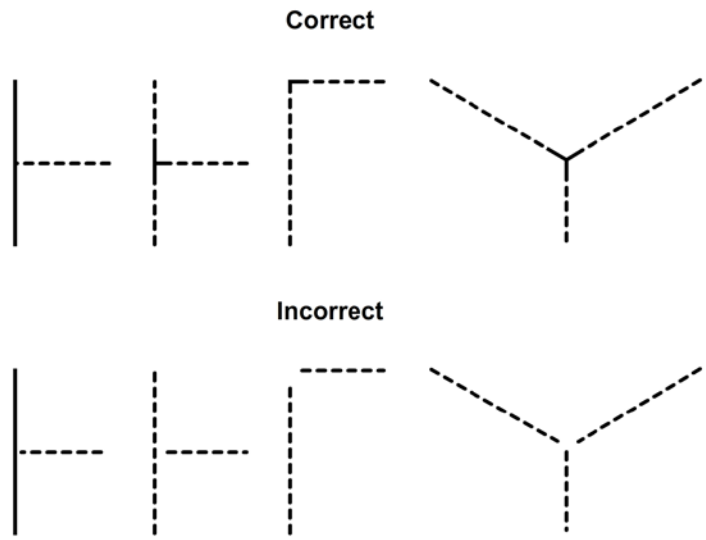


Figure 2-25 — Correct and incorrect procedures for drawing adjoining lines.

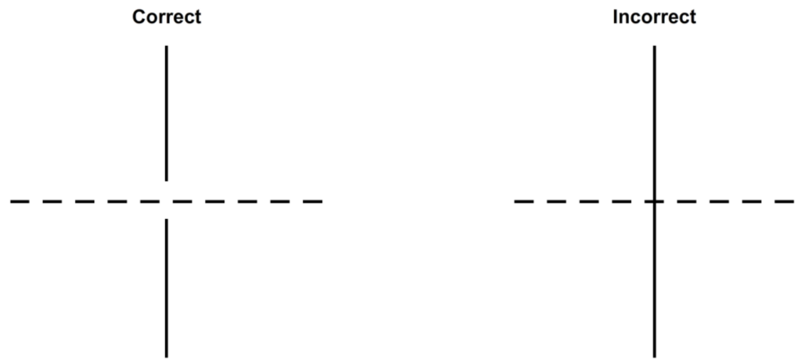


Figure 2-26 — Correct and incorrect procedures for drawing a hidden edge line that intersects a visible edge line.

An intersection between two hidden edge lines is shown in *Figure 2-27*, one of which is beneath the other on the object itself. Indicate this fact by drawing the lines as indicated in the left view of *Figure 2-27*. If you drew them as indicated in the right view, the wrong line would appear to be uppermost.

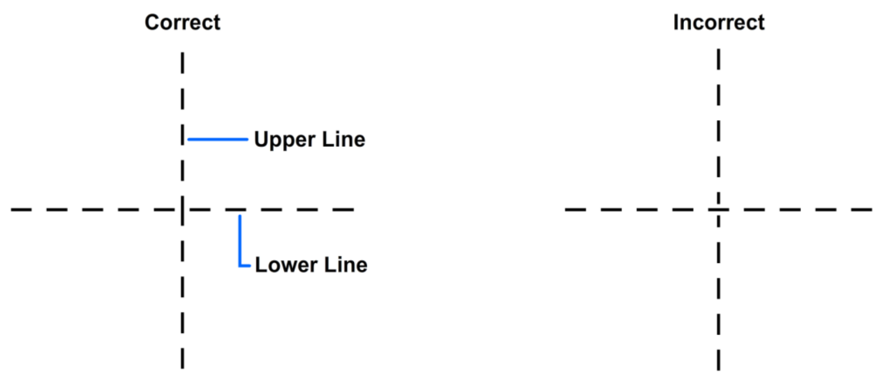


Figure 2-27 — Correct and incorrect procedures for drawing intersecting hidden edge lines that are on different levels.

Extension Lines

Use extension lines (*Figure 2-28*) to extend dimensions beyond the outline of a view so that they can be read easily. Start these thin, unbroken lines about 1/16 inch from the outline of the object and extend them about 1/8 inch beyond the outermost dimension line. Draw extension lines parallel to each other and perpendicular to the distance you are showing. In unusual cases, you may draw the extension lines at other angles as long as their meaning is clear.

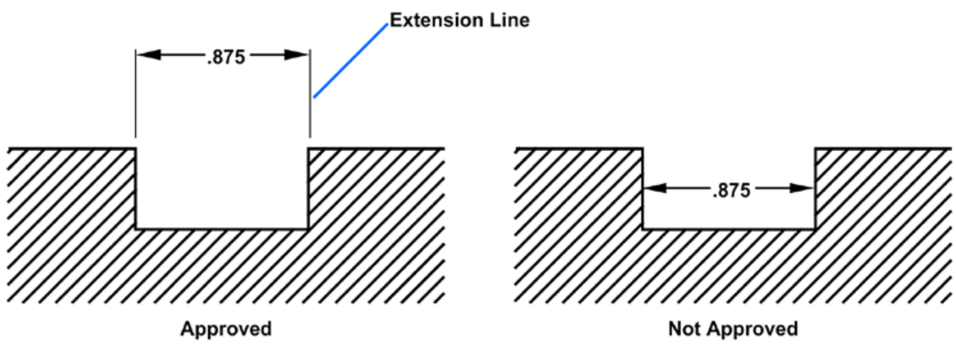


Figure 2-28 — Use of extension lines.

As far as practical, avoid drawing extension lines directly to the outline of an object. When extension lines must cross each other, break them as shown in *Figure 2-29*.

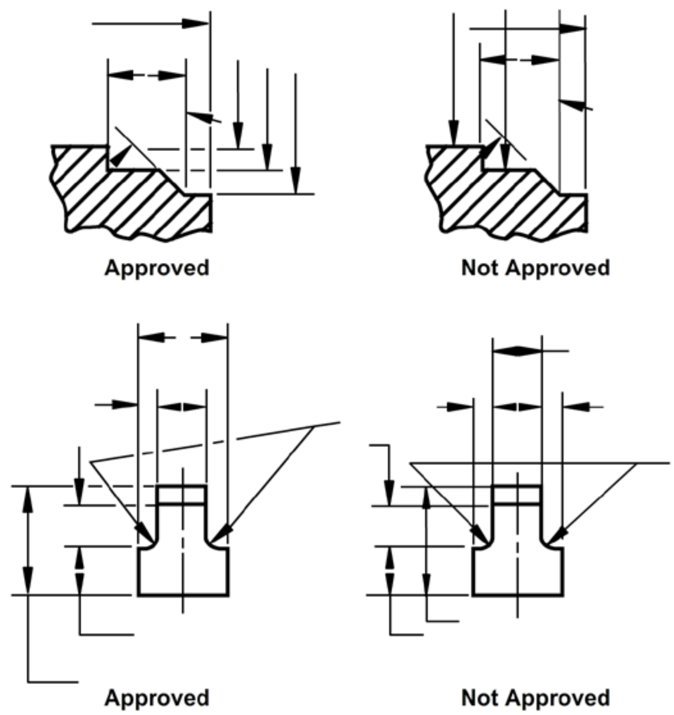


Figure 2-29 — Breaking extension lines and leaders at points of intersections.

Dimension Lines

Insert a dimension line, terminating at either end in a long, pointed arrowhead (*Figure 2-30*), between each pair of extension lines. You will draw a dimension line as a thin line with a break to provide a space for the dimension numerals (except in architectural and structural drafting).

Occasionally, when you need to indicate the radius of an arc, you will draw an arrow only the end of the line that touches the arc. The other end, without an arrow, terminates at the point used as the center in drawing the arc. The arrowhead on a dimension or leader line is an important detail of a drawing. If you draw these arrowheads sloppily and varied in size, your drawing will not look finished and professional. The size of the arrowhead used on a drawing may vary with the size of the drawing, but all arrowheads on a single drawing should be the same size, except occasionally when space is very restricted. The arrowheads you will use on Navy drawings are usually solid, or filled in, and are between 1/8 and 1/4 inch long, with the length about three times the spread.

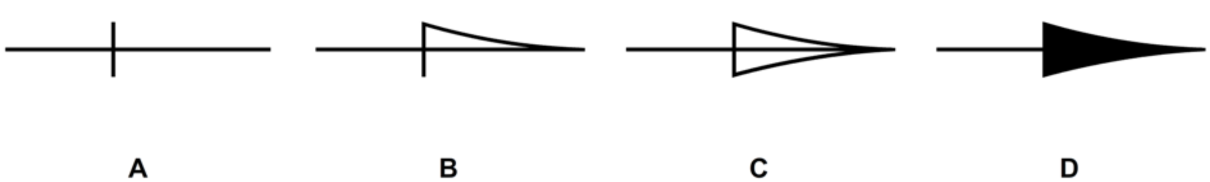


Figure 2-30 — Method of drawing an arrowhead.

With a little practice, you can learn to make good arrowheads freehand. Referring to *Figure 2-30*, first define the length of the arrowhead with a short stroke as shown at A. Then draw the sides of the arrowhead as indicated at B and C. Finally, fill in the area enclosed by the lines, as shown at D.

Leaders

Use leaders to connect numbers, references, or notes to the appropriate surfaces or lines on the drawing (*Figure 2-31*). From any suitable portion of the reference, note, or number, draw a short line parallel to the lettering. From this line, draw the remainder of the leader at an angle (dog leg) to an arrowhead or dot. In this way, the leader will not be confused with other lines of the drawing. If the reference is to a line, always terminate the leader at this line with an arrowhead. However, a reference to a surface terminates with a dot within the outline of that surface.

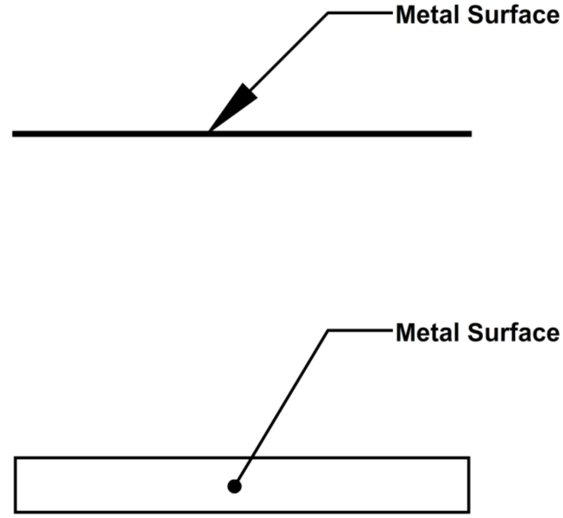


Figure 2-31 — Use of a leader.

Break Lines

You may reduce the size of an object's graphic representation (usually for the purpose of economizing on paper space) by using a device called a break. Suppose, for example, you wanted to make a drawing of a rectangle 1 foot wide by 100 feet long to the scale of 1/12, or 1 inch = 1 foot. If you drew the full length of the rectangle, you would need a sheet of paper 100 inches long. By using a break, you can reduce the length of the figure to a feasible length, as shown in *Figure 2-32*.

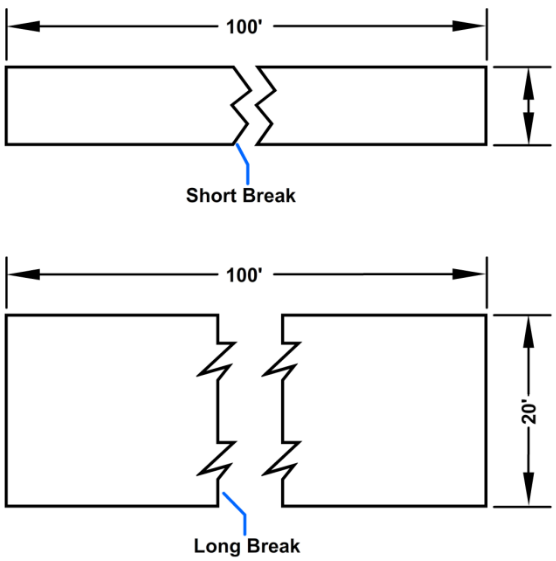


Figure 2-32 — Use of breaks.

On the original object, the ratio of width to length is 1:100. You can see that on the drawing, the ratio is much larger (roughly 1:8). However, the break tells you that a considerable amount of the central part of the figure is presumed to be removed. Use thick, wavy lines for a short break. You will usually indicate a short break for rectangular sections with solid, freehand lines. For wooden rectangular sections, you will make the breaks sharper, with a serrated appearance, rather than wavy. For long breaks, you will use full, ruled lines with freehand zigzags. For wider objects, a long break might have more than one pair of zigzag lines.

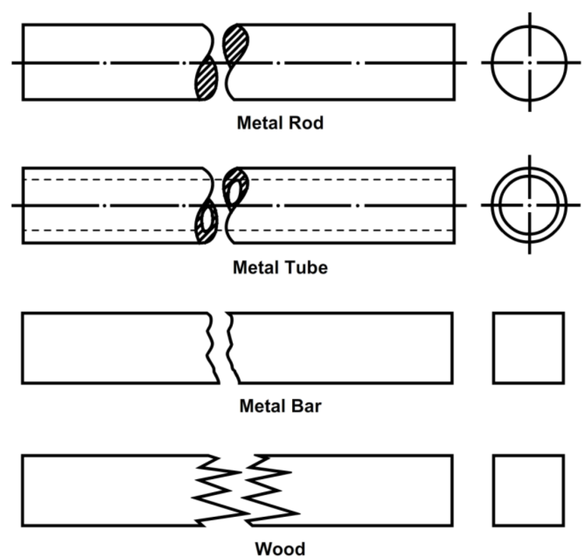


Figure 2-33 — Use of special breaks.

For drawings made to a large scale, use special conventions that apply to drawing breaks in such things as metal rods, tubes, or bars. A method of drawing these breaks is illustrated in *Figure 2-33*.

Phantom Lines

You will use phantom lines most frequently to indicate a moving part's alternate position, as shown in the left-hand view of *Figure 2-34*. Draw the part in one position in full lines and in the alternate position in phantom lines. You will also use phantom lines to indicate a break when the nature of the object makes the use of the conventional type of break unfeasible. The right hand view of *Figure 2-34* shows an example of using of phantom lines.

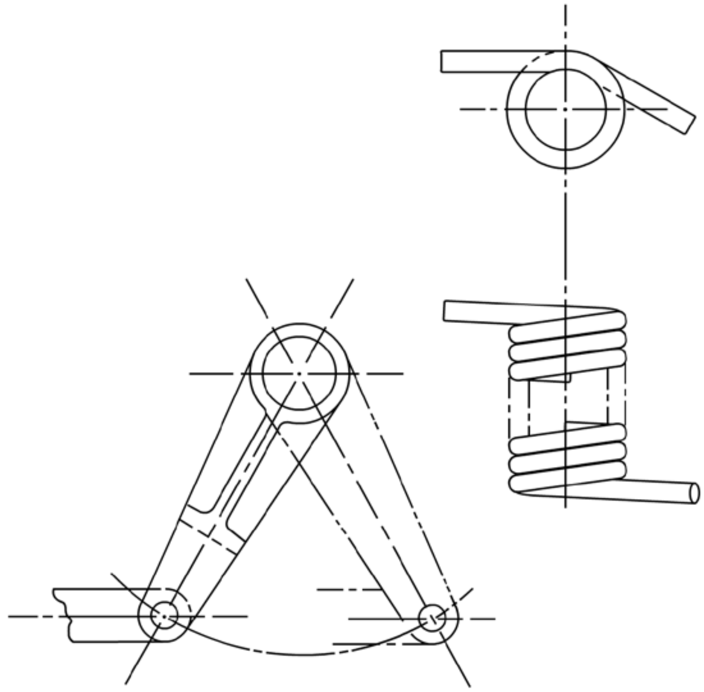


Figure 2-34 — Use of phantom lines.

Datum Lines

Use a datum line to indicate a line or plane of reference, such as the plane from which an elevation is measured. Datum lines consist of one long dash and two short dashes equally spaced. Datum lines differ from phantom lines only in the way they are used.

Stitch Lines

Use stitch lines to indicate the stitching or sewing lines on an article. Stitch lines consist of a series of very short dashes (medium thickness), approximately half the length of the dash of hidden lines, evenly spaced. You can indicate long lines of stitching by a series of stitch lines connected by phantom lines.

Viewing or Cutting Plane Lines

Use viewing plane lines to indicate the plane or planes from which a surface or several surfaces are viewed.

Cutting plane lines indicate a plane or planes in which a sectional view is taken. Section views give a clearer view of interior or hidden features of an object that cannot be clearly observed in conventional outside views.

Obtain a section view by cutting away part of an object to show the shape and construction at the cutting plane.

Notice the cutting plane line AA in *Figure 2-35, view A*; it shows where the imaginary cut has been made. The single view in *Figure 2-35, view B*, helps you to visualize the cutting plane. The arrows point in the direction in which you are to look at the sectional view.

In *Figure 2-35, view C,* a front view shows how the object looks when cut it in half. The orthographic section view of *Figure 2-35, view D* should be used on the drawing instead of the confusing front view in *Figure 2-35, view A*. Notice how much easier it is to read and understand.

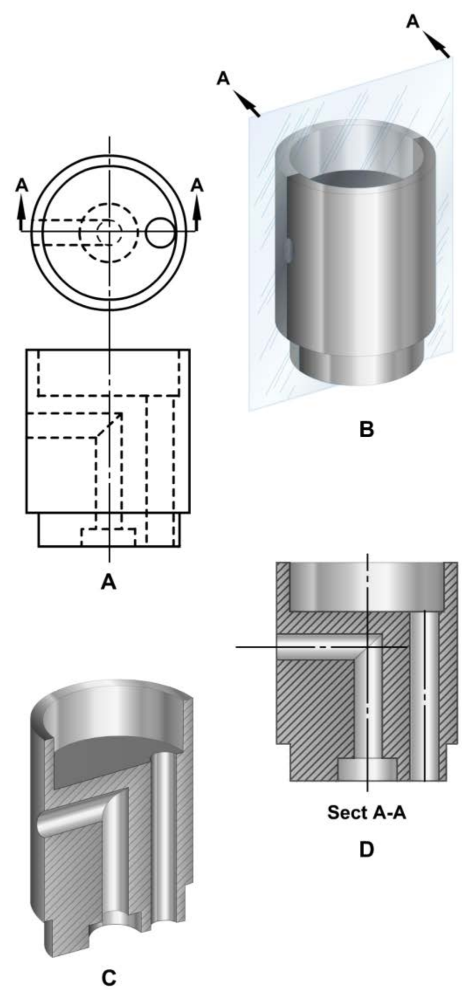


Figure 2-35 — Action of a cutting plane.

Note that hidden lines behind the plane of projection are omitted in the sectional view. These lines are omitted by general custom, because the elimination of hidden lines is the basic reason for making a sectional view. However, lines that would be visible behind the plane projection must be included in the section view.

Cutting plane lines, together with arrows and letters, make up the cutting plane indications. Placing arrows at the end of the cutting plane lines indicates the direction to view the sections. The cutting plane may be a single continuous plane, or it may be offset if the detail can be shown to better advantage. On simple views, indicate the cutting plane as shown in *Figure 2-35, view A*. On large, complex views or when the cutting planes are offset, indicate them as shown in *Figure 2-36.*

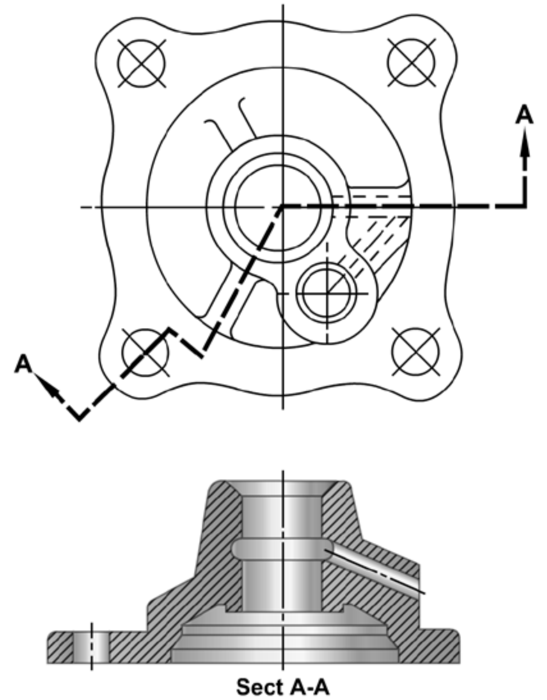


Figure 2-36 — Use of an offset section.

Identify all cutting plane indications with reference letters placed at the arrowhead points. When a change in direction of the cutting plane is not clear, you should place reference letters at each change of direction. When more than one sectional view appears on a drawing, alphabetically letter the cutting plane indications.

Include the letters that are part of the cutting plane indication as part of the title; for example, section A-A, section B-B, if the single alphabet is exhausted, multiples of letters may be used. You may abbreviate the word section, if desired. Place the title directly under the section drawing.

Section Lines

Sometimes you can best convey the technical information in a drawing by a view that represents the object as it would look if part of it were cut away. A view of this kind is called a section. The upper view of *Figure 2-37* shows a plan view of a pipe sleeve. The lower view is a section, showing the pipe sleeve as it would look, viewed from one side, if you cut it exactly in half vertically. The surface of the imaginary cut is crosshatched with lines called section lines. According to the DOD-STD-100C, section lining shall be composed of uniformly spaced lines at an angle of 45 degrees to the baseline of the section. On adjacent parts, the lines shall be drawn in opposite directions. On a third part, adjacent to two other parts, the section lining shall be drawn at an angle of 30 to 60 degrees.

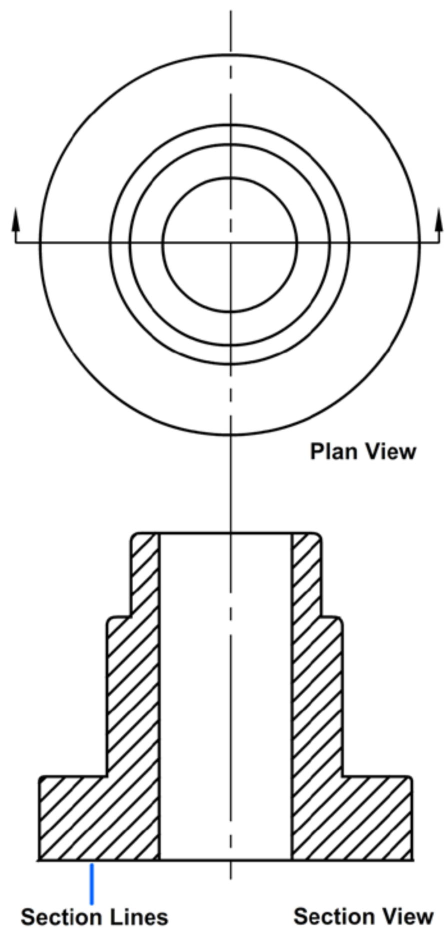


Figure 2-37 — Drawing of a plan view and a full section.

You can use the cross-hatching shown in *Figure 2-37* on any drawing of parts made of only one material (like machine parts, for example, which are generally made of metal). The cross-hatching is the symbol for metals and may be used for a section drawing of any type of material.

A section like the one shown in *Figure 2-37*, which goes all the way through and divides the object into halves, is called a full section. If the section showed the sleeve as it would look if cut vertically into unequal parts, or cut only part way through, it would be a partial section. If the cut followed one vertical line part of the way down and then was offset to a different line, it would be an offset section.

Match Lines

Use match lines when an object is too large to fit on a single drawing sheet and must be continued on another sheet. Identify the points where the object stops on one sheet and continues on the next sheet with corresponding match lines.

Match lines are medium weight lines labeled with the words match line and referenced to the sheet that has the corresponding match line. Examples of construction drawings that may require match lines are maps and road plans where the length is much greater than the width and reducing the size of the drawing to fit a single sheet is impractical.

BASIC CAD

The process of preparing engineering drawings on a computer is known as CAD, and it is the most significant development to occur in the field of drafting. It has revolutionized the way we prepare drawings. This section is a brief overview of CAD. For further detailed information, review the CAD system manuals for operation.

The drafting part of a project is often a bottleneck because it takes so much time. Approximately two-thirds of the time is “laying lead”. But in CAD, you can make design changes faster, resulting in a quicker turn-around time.

The CAD system can relieve you from many tedious chores such as redrawing. Once you have made a drawing you can save it. You may then call it up at any time and change it quickly and easily. An advantage of using a CAD system is the ability to create three-dimensional images for visual representation of the final product. After review of the product, you can print the final product or save it for later use.

It may not be practical to handle all of the drafting workload in a CAD system. While you can do most design and drafting work more quickly on CAD, you may still need to use traditional methods for some tasks. For example, you can design certain electronics and construction projects more quickly on a drafting table.

A CAD system by itself cannot create; it is only an additional and more efficient tool. You must use the system to make the drawing; therefore, you must have a good background in design and drafting.

In manual drawing, you must have the skill to draw lines and letters and use equipment such as drafting tables and machines, and drawing aids such as compasses, protractors, triangles, parallel edges, scales, and templates. In CAD, however, you don’t need those items. A display monitor, a central processing unit, a digitizer, and a plotter replace them. Some of these items at a computer work station are illustrated in *Figure 2-38*. These items will be discussed in this section.

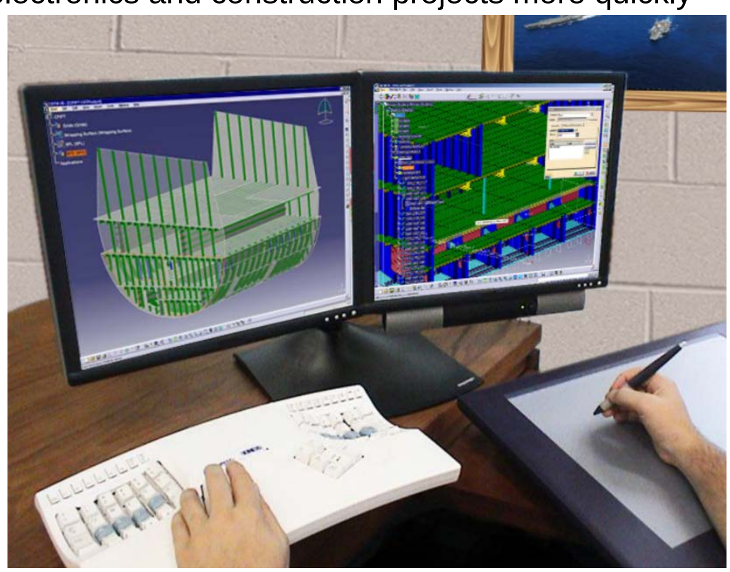


Figure 2-38 — Computer work station.

Generating Drawings in CAD

A CAD computer contains a drafting program that is a set of detailed instructions for the computer. When you open the program, the monitor displays each function or instruction you must follow to make a drawing. The program includes templates that can get you started drawing quickly. When working in the program, you can create a customized template where settings, size, and units of measurement can be set and used for multiple projects.

The CAD programs available to you contain all of the symbols used in mechanical, electrical, or architectural drawing. You will use the keyboard and/or mouse to call up the drafting symbols you need. Examples are characters, grid patterns, and types of lines. When you select the symbols you want on the monitor, you will order the computer to size, rotate, enlarge, or reduce them, and position them on the monitor to produce the image you want.

The computer also serves as a filing system for any drawing symbols or completed drawings stored electronically. You can call up this information any time and copy it or revise it to produce a different symbol or drawing.

In the following paragraphs, we will discuss the other parts of a CAD system; the digitizer, plotter, and printer.

The Digitizer

The digitizer tablet (*Figure 2-39*) is used in conjunction with a CAD program; it allows the operator to change from command to command with ease. As an example, you can move from the line draw function to an arc function without using the function keys or menu bar to change modes of operation.

Figure 2-39 — Basic digitizer tablet.

The Plotter

A plotter (*Figure 2-40*) is used mainly to transfer an image or drawing from the computer monitor to some form of drawing media. When you have finished producing the drawing in CAD, you will order the computer to send the information to the plotter, which will then reproduce the drawing from the computer monitor. A line-type digital plotter is an electromechanical graphic output device capable of two-dimensional movement between a pen and drawing media. Because of the digital technology, a plotter is considered a vector device.

Different types of plotters are available. You will usually use the plotter to produce a permanent copy of a drawing. Some common types are pen, laser, and inkjet plotters, and they may be single or multiple colors. These plotters will draw on various types of media such as vellum and Mylar®. The drawings are high quality, uniform, precise, and expensive.

Figure 2-40 — Typical plotter.

The Printer

Figure 2-41 — Inkjet printer.

A printer is a computer output device that duplicates the monitor display quickly and conveniently. Speed is the primary advantage; it is much faster than plotting. You can copy complex graphic monitor displays that include any combination of graphic and nongraphic (text and characters) symbols. The printer, however, is limited by the size of paper that it may print on. Large scale drawing may be reduced to fit on the smaller paper size. The printer may not have as much necessary detail as drawings printed on the plotters.

Several types of printers are available. The two common types of printers in use are inkjet (*Figure 2-41*) and laser jet (*Figure 2-42*). The laser printer offers the better quality and is generally more expensive.

Figure 2-42 — Laser printer.

COMPUTER-AIDED DESIGN/COMPUTER-AIDED MANUFACTURING

Using computer technology to make blueprints was discussed previously. A machinist may also use computer graphics to lay out the geometry of a part; the computer on the machine uses the design to guide the machine as it makes the part. A brief overview of numerical control (NC) in the field of machining is discussed in the following sections.

NC is a process by which machines are controlled by input media to produce machined parts (*Figure 2-43*). In the past, the most common input media used were magnetic tape, punched cards, and punched tape. Today, most of the new machines, including all of those at Navy intermediate maintenance activities, are controlled by computers and known as computer numerical control (CNC) systems.

Figure 2-43 — NC operated lathe.

The NC machines have many advantages. The greatest is the unerring and rapid positioning movements that are possible. An NC machine does not stop at the end of a cut to plan its next move. It does not get tired and it is capable of uninterrupted machining, error free, hour after hour. In the past, NC machines were only used for mass production because small orders were too costly. But CNC allows a qualified machinist to program and produce a single part economically.

In CNC, the machinist begins with a blueprint, other drawing, or sample of the part to be made. Then he or she uses a keyboard, mouse, digitizer, and/or light pen to define the geometry of the part to the computer. The image appears on the computer monitor where the machinist edits and proofs the design. When satisfied, the machinist instructs the computer to analyze the geometry of the part and calculate the tool paths that will be required to machine the part. Each command determines a machine axis movement that the machine needs to produce the part.

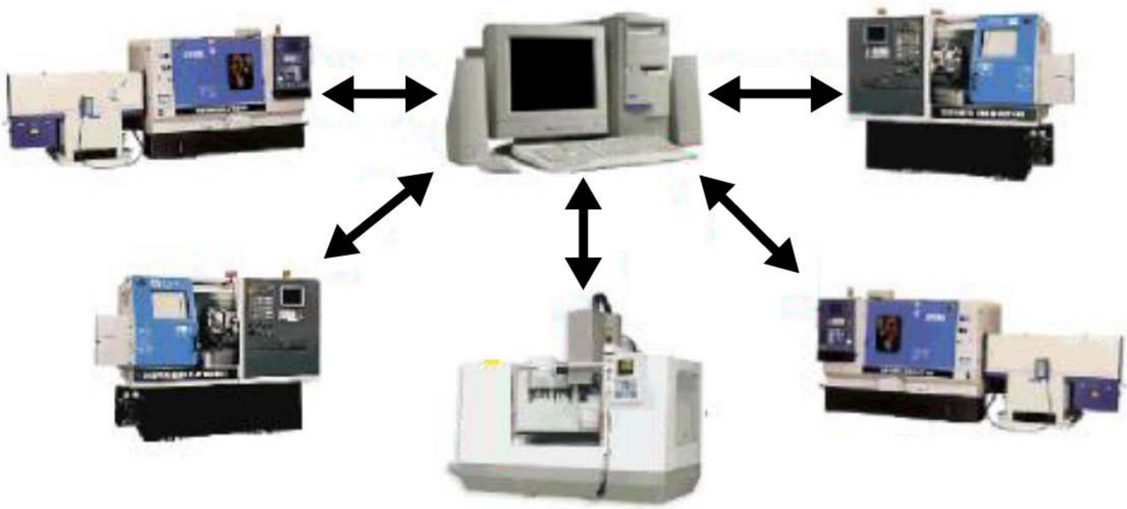


Figure 2-44 — Direct numerical control station.

The computer-generated instructions can be stored electronically, for direct transfer to one or more CNC machine tools that will make the parts, known as direct numerical control (DNC) station (*Figure 2-44*). A direct numerical controller is shown in *Figure 2-45*.

The system that makes all this possible is known as computer-aided design/computer-aided manufacturing (CAD/CAM). There are several CAD/CAM software programs and they are constantly being upgraded and made more user friendly.

To state it simply, CAD is used to draw the part and to define the tool path, and CAM is used to convert the tool path into codes that the computer on the machine can understand.

We want to emphasize that this information is a brief overview of CNC. It is a complicated subject and many books have been written about it. Before you can work with CNC, you will need both formal and on-the-job training. This training will become more available as the Navy expands its use of CNC.

Figure 2-45 — Direct numerical controller.

End of Chapter 2

Technical Sketching

Review Questions

2-1. What two types of pencils are used in drafting?

A. Electric and mechanical
B. Electric and plastic
C. Wooden and electric
D. Wooden and mechanical

2-2. What three types of pencils do manufacturers market for use in engineering drawings?

A. Graphite, plastic, and plastic-graphite
B. Graphite, resin, and grease
C. Grease, carbon, and carbon-grease
D. Wax, grease, and wax-grease

2-3. What feature adds strength to the softer grades of lead?

A. Diameter
B. Extra resin
C. Heat treatment
D. Length of lead

2-4. What type of eraser is ideal for erasing lines drawn on tracing cloth and films?

A. Art gum
B. Vinyl
C. Plastic
D. Kneaded

2-5. What type of eraser is ideal for erasing lines drawn in ink?

A. Art gum
B. Kneaded
C. Ruby red
D. Pink pearl

2-6. What type of pen is commonly used in technical sketching today?

A. Fine tip Sharpie pen
B. Medium ball point
C. Quill and ink
D. Technical fountain pen

2-7. Some of the most common drawing aids are drafting tables with boards, triangles, and what other device?

A. Compass
B. French bell
C. Protractor
D. Spanish marker

2-8. The drafting table should be high enough for you to work in which of the following positions?

A. Prone
B. Standing
C. Kneeling
D. Squatting

2-9. Which of the following types of lighting is best for the working area?

A. Natural
B. Fluorescent
C. Incandescent
D. Light emitting diodes

2-10. With which of the following degree ranges are protractors generally labeled?

A. 0 to 45
B. 0 to 60
C. 0 to 90
D. 0 to 180

2-11. Which of the following drawing aids assist in drawing lines such as ellipses, parabolas, and spirals?

A. Adjustable triangle
B. Circular protractor
C. French curve
D. Semicircle protractor

2-12. Circles and circular curves of relatively short radius are drawn with what drawing instrument?

A. Compass
B. Divider
C. Proportional divider
D. Protractor

2-13. Which of the following lines include the outline and defining edges of the view?

A. Center
B. Visible
C. Dimension
D. Hidden

2-14. Which of the following lines extends the dimensions beyond the outline of the view?

A. Break
B. Dimension
C. Extension
D. Leader

2-15. Which of the following lines connects numbers, references, or notes to the appropriate surfaces or lines on the drawing?

A. Break
B. Dimension
C. Extension
D. Leader

2-16. Which of the following lines is used for the purpose of economizing paper space?

A. Break
B. Dimension
C. Extension
D. Leader

2-17. Which of the following lines is used to represent an object as if part of it was cut away?

A. Datum
B. Section
C. Match
D. Phantom

2-18. What term describes the process of preparing engineering drawings on a computer?

A. Common-assistance drafting
B. Common-assistance sketching
C. Computer-aided drafting
D. Computer-assisted drawing

2-19. An advantage of using a computer-aided drafting system is creating what type of images?

A. Animated
B. Colored
C. Three-dimensional
D. High-definition

2-20. What two types of printers are used in computer-aided design?

A. Dot matrix and laser jet
B. Dot matrix and light emitting diode
C. Inkjet and dot matrix
D. Inkjet and laser jet

2-21. What term describes the process by which machines are controlled by input media to produce machined parts?

A. Computer drafting
B. Numerical control
C. Computer-aided design
D. Dot matrix

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CHAPTER 3

PROJECTIONS AND VIEWS

This chapter deals with projection theory and methods of preparing projection drawings. By applying basic geometric construction to the various projection methods, you can illustrate a clear representation of any object or structure on paper. The methods discussed here are basic to all drawings.

Every object or structure you draw has length, width, and depth, regardless of its size. Your goal, however, is to draw the object or structure on paper, which is a flat two-dimensional plane. To show the three dimensions by lines alone, you must use either a system of related views or a single pictorial projection. You must be able to show clearly the shape of the object, give the exact size of each part, and provide necessary information for constructing the object.

In theory, projection is done by extending lines of sight (called projection lines) from the eye of the observer, through lines and points of an object being viewed, to the plane of projection.

LEARNING OBJECTIVES

When you have completed this chapter, you will be able to do the following:

1. Recognize the types of projections.
2. Recognize the types of views.

In learning to read blueprints, you must develop the ability to visualize the object to be made from the blueprint (*Figure 3-1*). You cannot read a blueprint all at once any more than you can read an entire page of print all at once. When you look at a multi-view drawing, first survey all of the views, and then select one view at a time for more careful study. Look at adjacent views to determine what each line represents.

Each line in a view represents a change in the direction of a surface, but you must look at another view to determine what the change is. A circle on one view may mean either a hole or a protruding boss (surface) as shown in the top view in *Figure 3-2*. When you look at the top view, you see two circles, and you must study the other view to understand what each represents. A glance at the front view shows that the smaller circle represents a hole (shown in dashed lines), while the larger circle represents a protruding boss. In the same way, you must look at the top view to see the shape of the hole and the protruding boss.

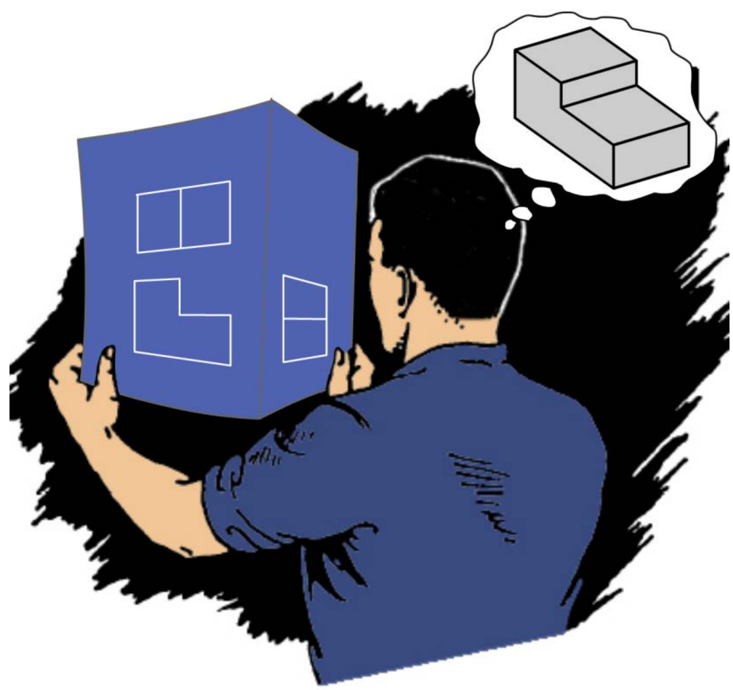


Figure 3-1 — Visualizing a blueprint.

You can see from this example that you cannot read a blueprint by looking at a single view, if more than one view is shown. Sometimes two views may not be enough to describe an object; and when there are three views, you must view all three to be sure you read the shape correctly.

PROJECTIONS

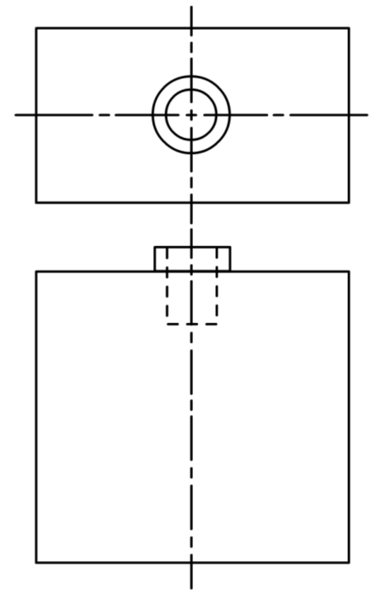


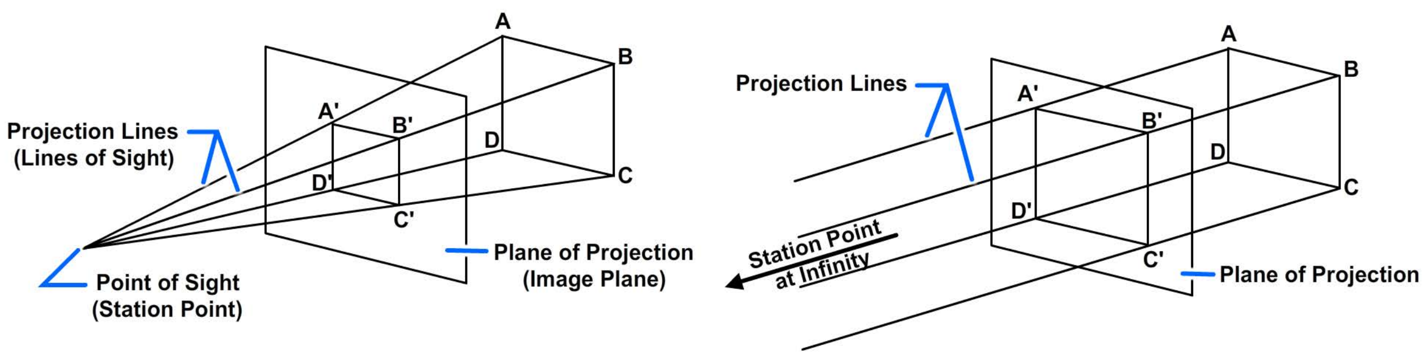
Figure 3-2 — Reading view.

In blueprint reading, a view of an object is known technically as a projection. Projection is done, in theory, by extending lines of sight called projectors from the eye of the observer through lines and points on the object to the plane of projection. This procedure will always result in the type of projection shown in *Figure 3-3, view A*. It is called central projection because the lines of sight, or projectors, meet at a central point: the eye of the observer.

You can see that the projected view of the object varies considerably in size, according to the relative positions of the objects and the plane of projection. It will also vary with the distance between the observer and the object, and between the observer and the plane of projection. For these reasons, central projection is seldom used in technical drawings.

If the observer were located a distance away from the object and its plane of projection, the projectors would not meet at a point, but would be parallel to each other. For reasons of convenience, this parallel projection is assumed for most technical drawings and is shown in *Figure 3-3, view B*. You can see that, if the projectors are perpendicular to the plane of projection, a parallel projection of an object has the same dimensions as the object. This statement is true regardless of the relative positions of the object and the plane of projection, and regardless of the distance from the observer.

Orthographic and Oblique Projection



A. Perspective Pictorial Projection **B. Parallel Projections**

Figure 3-3 — Types of projections.

An orthographic projection is a parallel projection in which the projectors are perpendicular to the plane of projection as in *Figure 3-3*. An oblique projection is one in which the projectors are other than perpendicular to the plane of projection. The same object in both orthographic and oblique projections is shown in *Figure 3-4*. The block is placed so that its front surface (the surface toward the plane of projection) is parallel to the plane of projection. You can see that the orthographic (perpendicular) projection shows only this surface of the block, which includes only two dimensions: length and width. The oblique projection, on the other hand, shows the front surface and the top surface, which includes three dimensions: length, width, and height. Therefore, an oblique projection is one way to show all three dimensions of an object in a single view. Axonometric projection is another, and we will discuss it later in this section.

Multi-View Projection

When you view an object through a plane of projection from a point at infinity, you obtain an accurate outline of the visible face of the object (*Figure 3-4*). However, the projection of one face usually will not provide an overall description of the object; you must use other planes of projection. Establishing an object's true height, width, and depth requires front, top, and side views, which are called the principal planes of projection. The three principal (or primary) planes of projection, known as the vertical, horizontal, and profile planes, are shown in *Figure 3-5*. The angles formed between the horizontal and the vertical planes are called the first, second, third, and fourth angles. Currently, however, for technical reasons, only the use of first- and third-angle projection is practical.

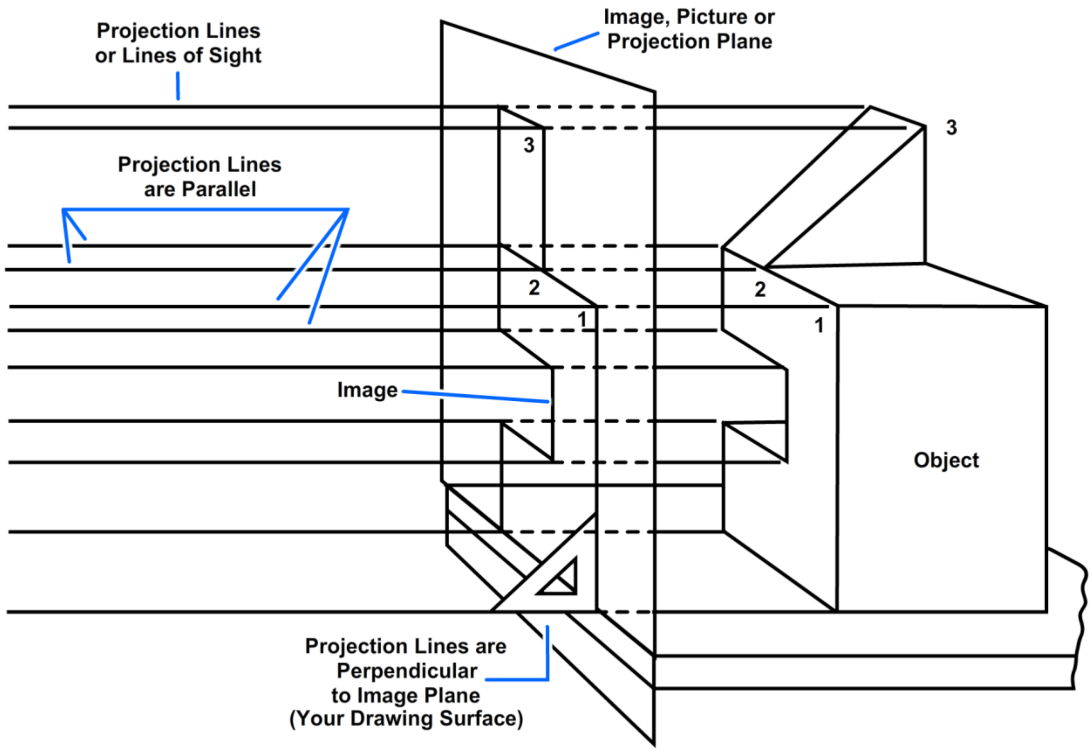


Figure 3-4 — Orthographic and oblique projections.

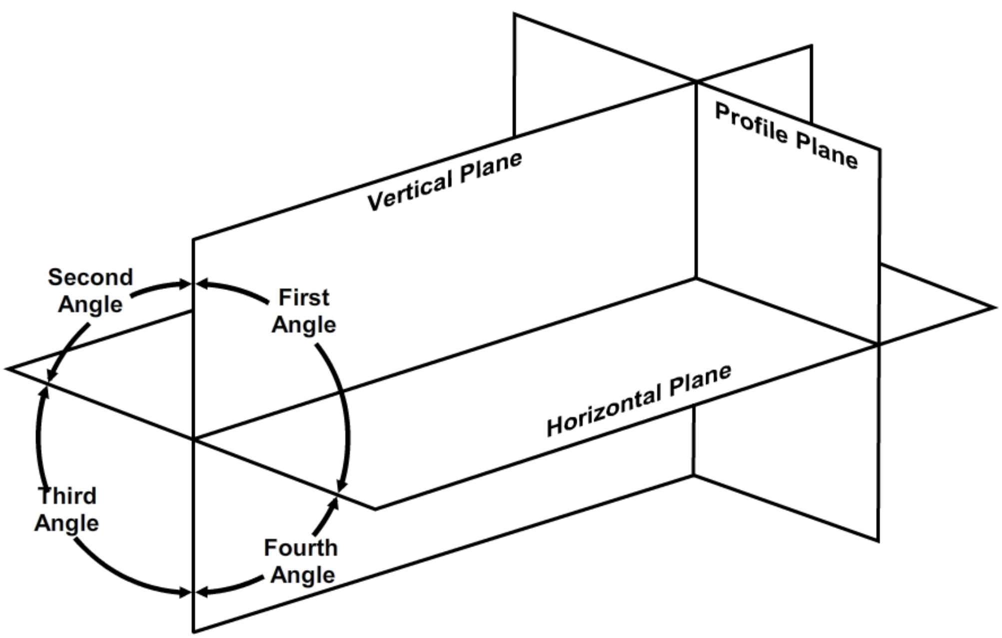


Figure 3-5 — Principal (primary) planes of projections.

First-Angle Projection

An example of first-angle projection using a cube is illustrated in *Figure 3-6*. The front of the cube is facing toward the vertical plane of projection. As you can see, you get a front view on the vertical plane, a left side view on the profile plane, and a top view on the horizontal plane.

Now, to put these views on a sheet of drafting paper, you must put them all into the same plane. Presume that the vertical plane of projection is already in the plane of the paper. To get the other two views into the same plane, rotate the profile plane counterclockwise and the horizontal plane clockwise. The projection now appears as shown in *Figure 3-7*.

In common European drafting practice, this first-angle projection arrangement of views is considered satisfactory. In the United States, it is considered illogical because the top view is below the front view; because the right side of the object, as shown in the front view, is toward the left side view of the object; and because the bottom of the object, as shown in the front view, is toward the top view of the object. For these and other reasons, first-angle projection is not commonly used in the United States.

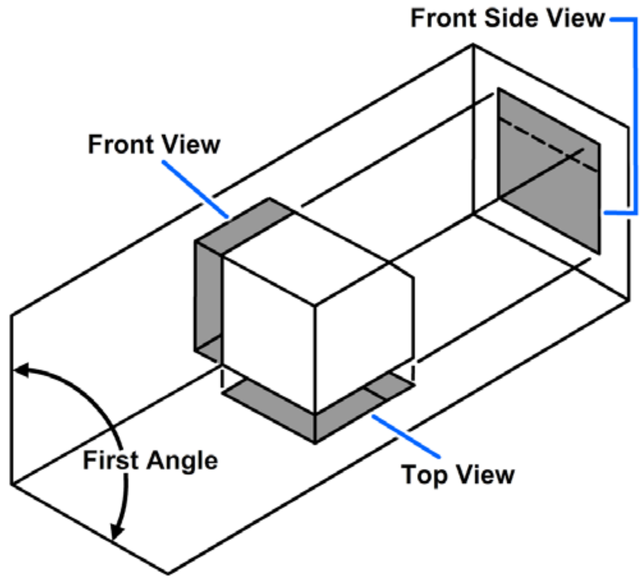


Figure 3-6 — First-angle projections.

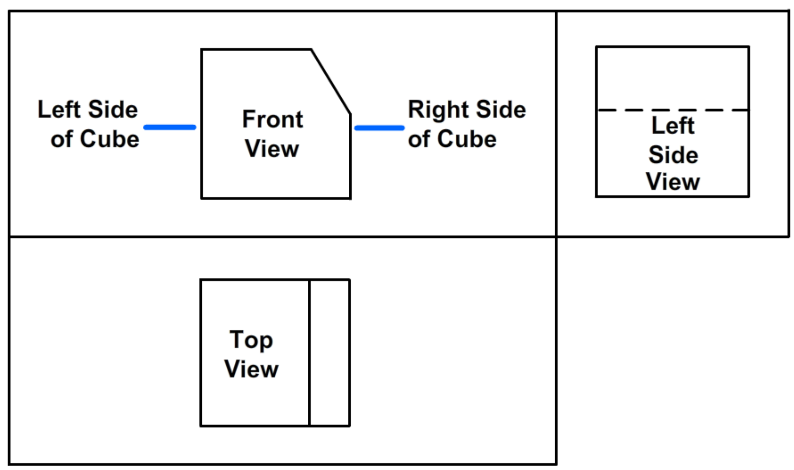


Figure 3-7 — First-angle projection brought into a single pane.

Third-Angle Projection

In a third-angle projection of a cube (*Figure 3-8*), you get a front view on the vertical plane, a right side view on the profile plane, and a top view on the horizontal plane.

The first view, the vertical plane, is already in the plane of your drawing paper. To get the other two views onto the same plane, rotate them both clockwise. A third-angle projection of an object brought into a single plane is shown in *Figure 3-9*. The top view is above the front view; the right side of the object, as shown in the front view, is toward the right side view; and the top, as shown in the front view, is toward the top view.

The following sentences describe the basic procedures of the method used to make the third-angle projection shown in *Figure 3-9*. Draw a horizontal line AB and a vertical line CD, intersecting at O (*Figure 3-10*). AB represents the joint between the

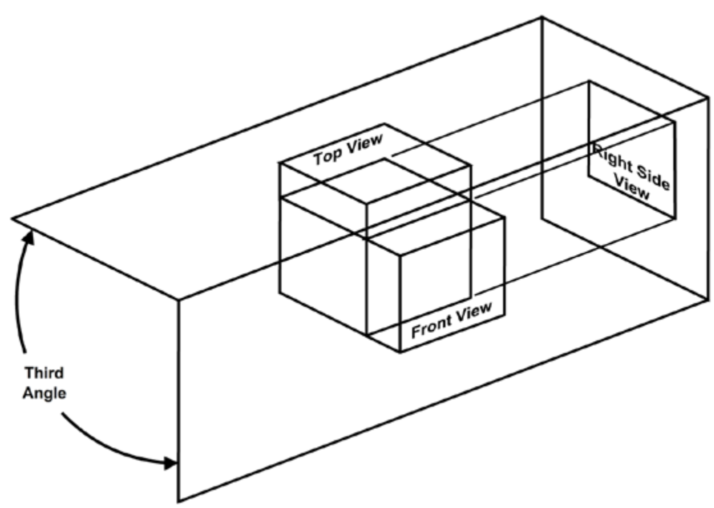


Figure 3-8 — Example of a third-angle projection.

horizontal and the vertical plane; CD represents the joint between these two and the profile plane. You could draw any of the three views first and the other two projected from it. Assume that the front view is drawn first on the basis of given dimensions of the front face. Draw the front view, and project it upward with vertical projection lines to draw the top view. Project the top view to CD with horizontal projection lines. With O as a center, use a compass to extend these projection lines to AB. Draw the right side view by extending the projection lines from AB vertically downward and by projecting the right side of the front view horizontally to the right.

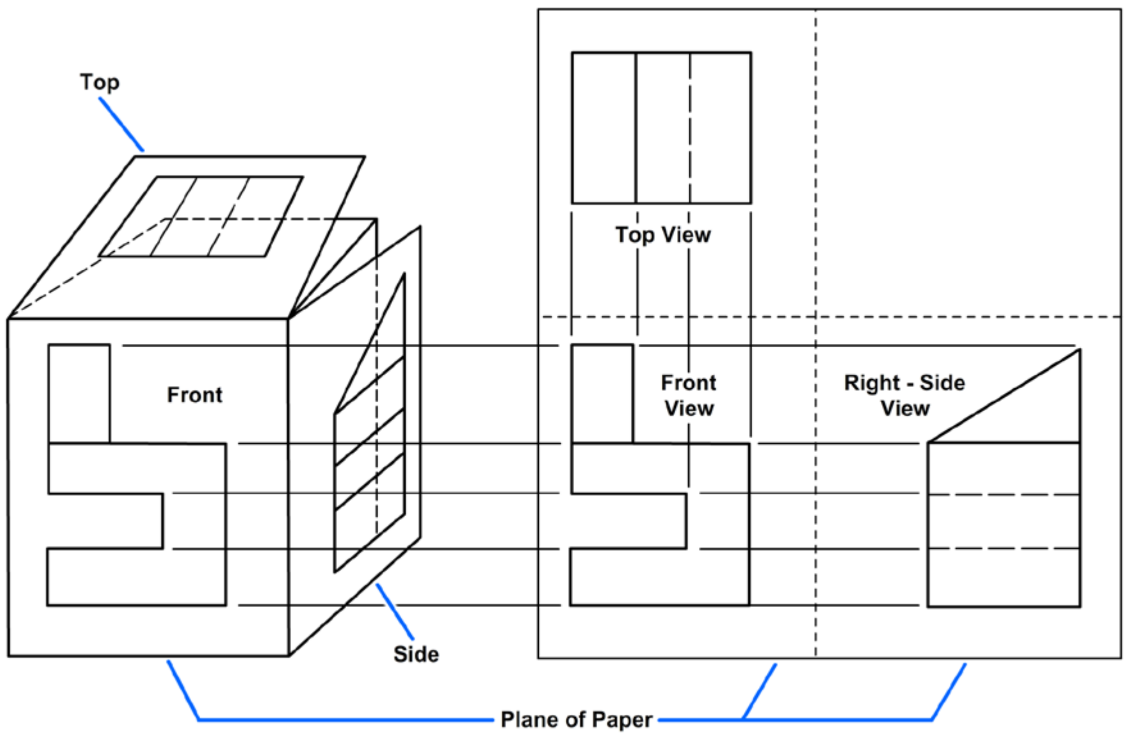


Figure 3-9 — Third-angle orthographic projection brought into a single pane.

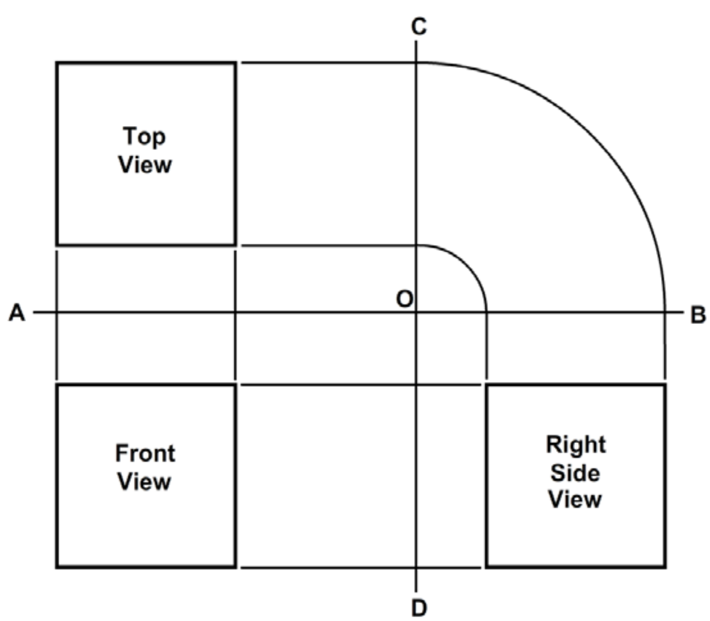


Figure 3-10 — Method of making a third-angle projection.

Use of a Miter Line

Using a miter line (*Figure 3-11*), you can lay out a third view while you are in the process of drawing two other views (*Figure 3-11, view A*). Place the miter line (*Figure 3-11, view B*) to the right of the top view at a convenient distance, keeping the appearance of a balanced drawing. Draw light projection lines from the top view to the miter line (*Figure 3-11, view C*), then vertically downward (*Figure 3-11, view D*). Using the front view, draw horizontal projection lines (*Figure 3-11, view E*) to the right, intersecting the vertical projection lines. This process results in the outline and placement of the right side view (*Figure 3-11, view F*).

Some drawings extend the top view projection lines to the right side view.

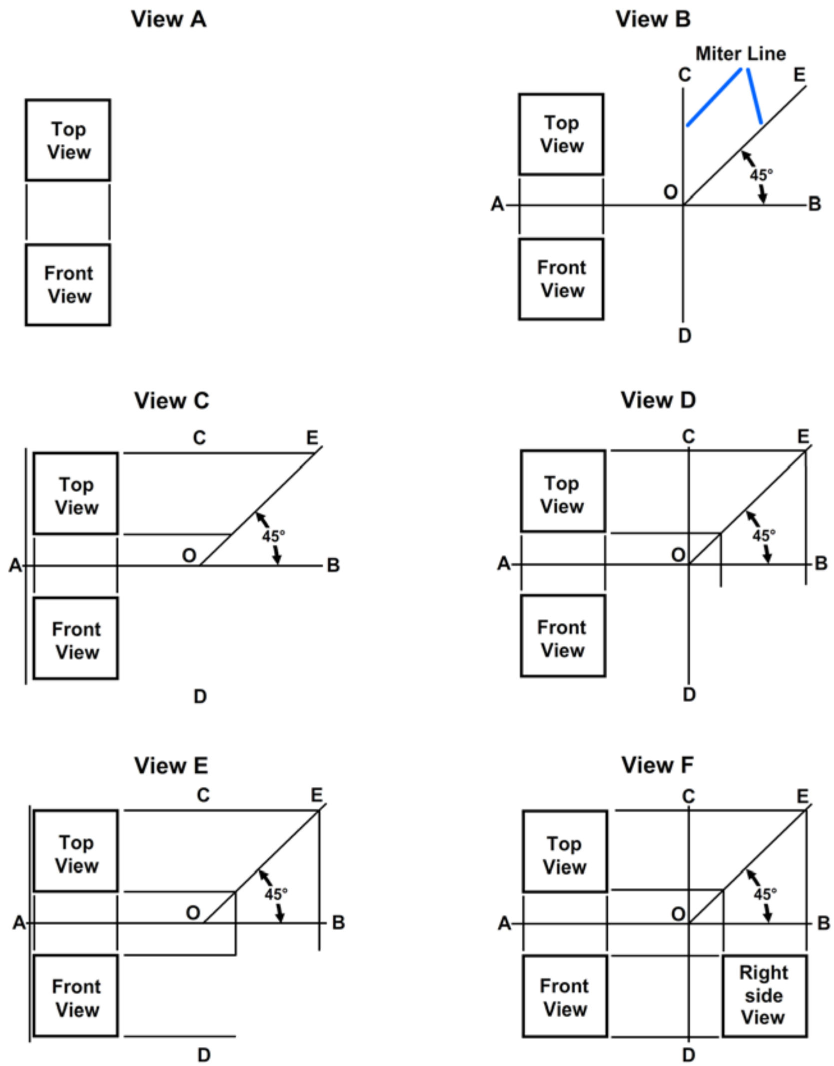


Figure 3-11 — Using a miter line.

Isometric Projection

Isometric projection is the most frequently used type of axonometric projection, which is a method used to show an object in all three dimensions in a single view. Axonometric projection is a form of orthographic projection in which the projectors are always perpendicular to the plane of projection. However, the object itself, rather than the projectors, are at an angle to the plane of projection.

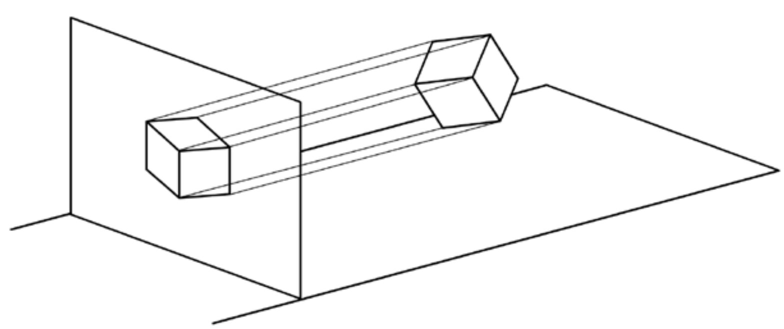


Figure 3-12 — Isometric projection of a cube.

A cube projected by isometric projection is shown in *Figure 3-12*. The cube is angled so that all of its surfaces make the same angle with the plane of projection. As a result, the length of each of the edges shown in the projection is somewhat shorter than the actual length of the edge on the object itself. This reduction is called foreshortening. Since all of the surfaces make the angle with the plane of projection, the edges foreshorten in the same ratio. Therefore, one scale can be used for the entire layout; hence, the term isometric, which literally means one-scale.

Figure 3-13 illustrates how an isometric projection would look to an observer whose line of sight was perpendicular to the plane of projection. Note that *Figure 3-13* has a central axis, formed by the lines OA, OB, and OC; this property is the origin of the term axonometric projection. In an isometric projection, each line in the axis forms a 120-degree angle with the adjacent line, as shown. A quick way to draw the axis is to draw the perpendicular OC, then use a T square and a 30-/60-degree triangle to draw OA and OB at 30 degrees to the horizontal. Since the projections of parallel lines are parallel, the projections of the other edges of the cube will be, respectively, parallel to these axes.

You can easily draw a rectangular object in isometric by the procedure known as box construction. The upper part of *Figure 3-14* shows a two-view normal multi-view projection of a rectangular block; the lower part shows an isometric drawing of the block. You can see how you build the image on the isometric axis and how you lay out the dimensions of the object on the isometric drawing. Because you lay out the identical dimensions, it is an isometric drawing rather than an isometric projection.

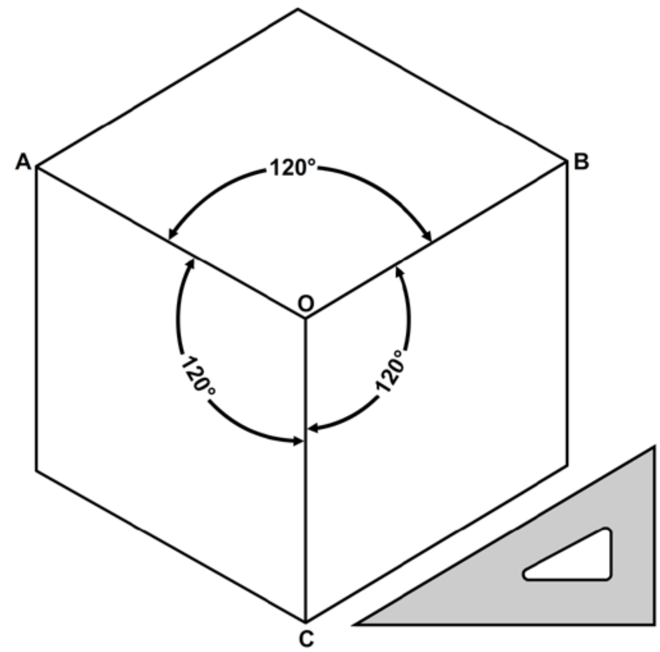


Figure 3-13 — Use of an isometric axis.

Non-Isometric Lines

Examining the isometric drawing shown in *Figure 3-14*, you will note that each line in the drawing is parallel to one or another of the legs of the isometric axis. You will also notice that each line is a normal line in the multi-view projection. Recall that a normal line, in a normal multi-view projection, is parallel to two of the planes of projection and perpendicular to the third. Thus, a non-isometric line is not parallel to any one of the three legs of the isometric axis. It is not a normal line in a normal multi-view projection of the object.

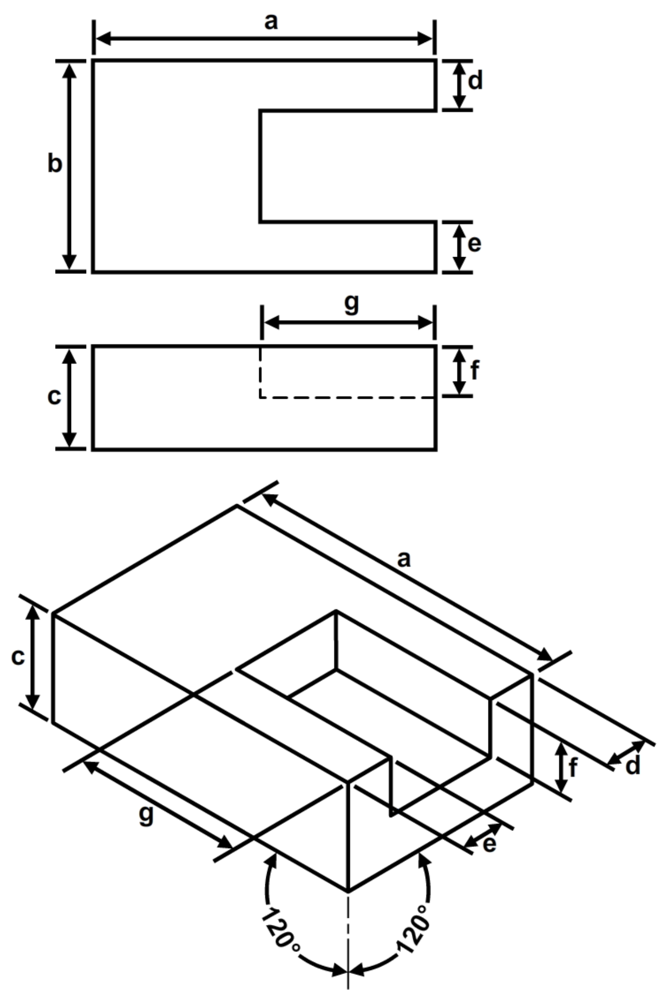


Figure 3-14 — Use of box construction in isometric drawing.

The upper part of *Figure 3-15* shows a two-view normal multi-view projection of a block.

Though the line AB is parallel to the horizontal plane of projection, it is oblique to both the vertical and the profile planes. It is therefore not a normal, but an oblique, line in the multi-view projection, and it will be a non-isometric line in an isometric projection or drawing of the same object.

The line AB appears in its true length in the top multi-view view because it is parallel to the plane of the view (the horizontal plane), but it will appear as a non-isometric line, and therefore not in its true length, in an isometric drawing, as shown in the bottom part of *Figure 3-15*. It follows that you cannot transfer AB directly from the multi-view projection to the isometric drawing. You can, however, directly transfer all the normal lines in the multi-view projection, which will be isometric lines appearing in their true lengths in the isometric drawing. When you have completed the transfer of lines, you will have constructed the entire isometric drawing, exclusive of line AB and of its counterpart on the bottom face of the block. The end points of AB and of its counterpart will be located, however, and it will only be necessary to connect them by straight lines.

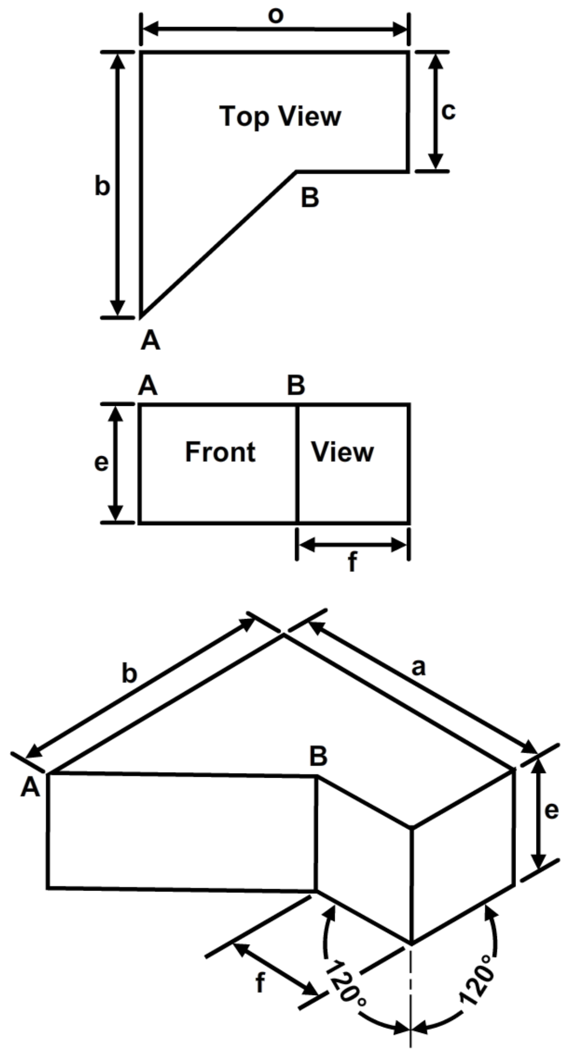


Figure 3-15 — A non-isometric line (AB) in an isometric projection.

Angles in Isometric

In a normal multi-view of an object, an angle will appear in its true size. In an isometric projection or drawing, an angle never appears in its true size. Even an angle formed by normal lines, such as each of the 90-degree corner angles of the block shown in the bottom part of *Figure 3-16*, appears distorted in isometric.

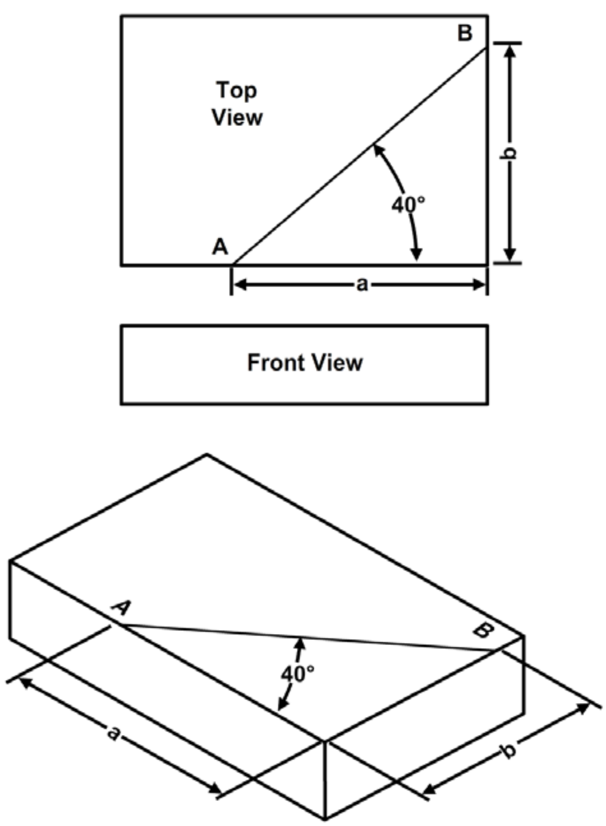


Figure 3-16 — Drawing an angle in isometric.

The same principle used in transferring a non-isometric line is used to transfer an angle in isometric. The upper part of *Figure 3-16* shows a two-view multi-view projection of a block. On the top face of the block, the line AB makes a 40-degree angle with the front edge. The line AB is an oblique (that is, not normal) line, which will appear as a non-isometric line in the isometric drawing. Locate the end points of AB on the isometric drawing by measuring distances along normal lines on the multi-view projection and laying them off along the corresponding isometric lines on the isometric drawing. The angle that measures 40 degrees on the top multi-view view measures about 32 degrees on the isometric drawing. Note, however, that it is labeled 40 degrees on the isometric drawing because it actually is a 40-degree angle as it would look on a surface plane at the isometric angle of inclination.

Circles in Isometric

A circle in a normal multi-view view will appear as an ellipse in an isometric drawing as shown in *Figure 3-17, view A*.

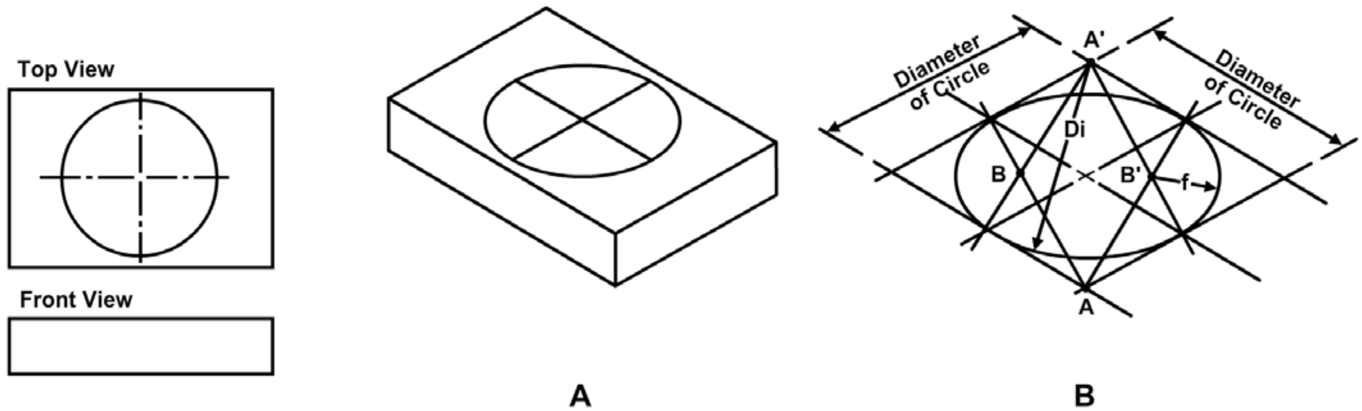


Figure 3-17 — A circle on a normal multi-view view appears as an ellipse in an isometric drawing.

A procedure that may be used to construct an isometric circle is shown in *Figure 3-17, view B*. The steps of that procedure are as follows:

1. Draw the isometric center lines of the circle. Then, using those center lines, lay off an isometric square with each side equal to the diameter of the circle.
2. From the near corners of the box, draw bisectors to the opposite intersections of the center lines and the box. The bisectors will intersect at four points (A, A', B, B'), which will be the centers of four circular arcs.
3. Draw two large arcs with radius R, using Points A and A' as centers. Draw the two smaller arcs with radius r, using Points B and B' as centers.

The above discussion should seem familiar, since it is simply an approximation of the four-point method you studied in the previous chapter. However, you can use it only when drawing isometric circles on an isometric drawing.

Noncircular Curves in Isometric

A line that appears as a noncircular curve in a normal multi-view view of an object appears as a non-isometric line in an isometric drawing. To transfer such a line to an isometric drawing, plot a series of points by measuring along normal lines in the multi-view view and transferring these measurements to corresponding isometric lines in the isometric drawing.

The upper part of *Figure 3-18* shows a two-view multi-view projection of a block with an elliptical edge. To make an isometric drawing of this block, draw the circumscribing

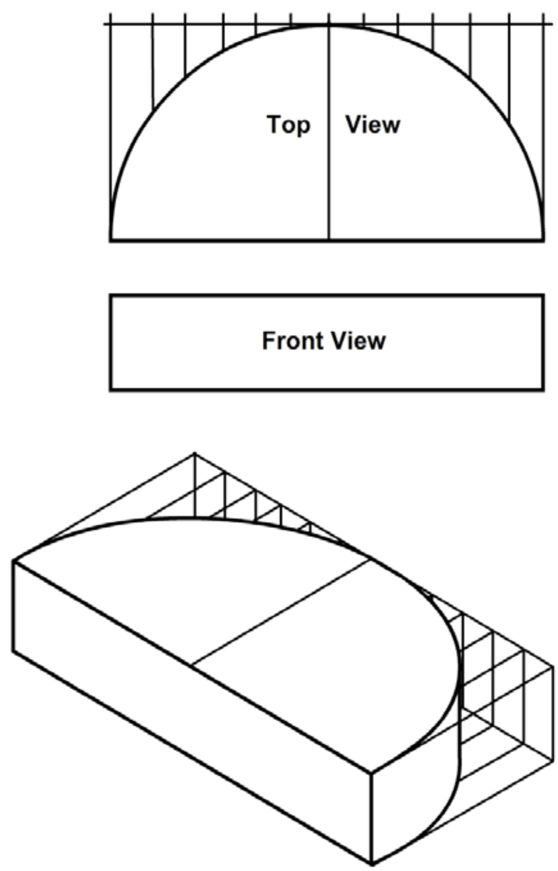


Figure 3-18 — Method of drawing a noncircular curve in isometric.

rectangle on the top multi-view view, lay off equal intervals as shown, and draw perpendiculars at these intervals from the upper horizontal edge of the rectangle to the ellipse. Then, draw the rectangle in isometric and plot a series of points along the elliptical edge by laying off the same perpendiculars shown in the top multi-view view. Draw the line of the ellipse through these points with a French curve.

Alternate Positions of Isometric Axis

Up to this point, the isometric axis has been used with the lower leg vertical. The axis may, however, be used in any position, provided the angle between adjacent legs is always 120 degrees. Varying the position of the axis varies the view of the object, as illustrated in *Figure 3-19*.

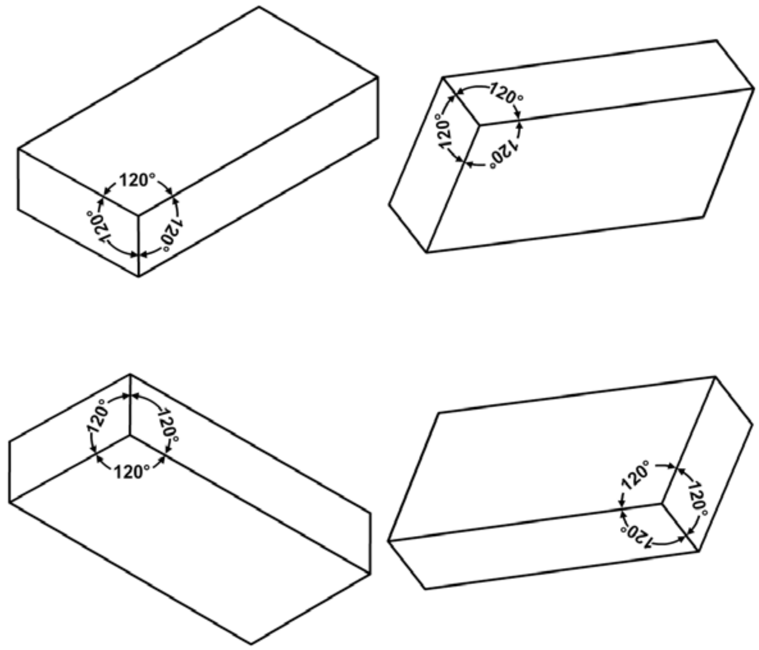


Figure 3-19 — Various positions of isometric.

Diagonal Hatching in Isometric

Diagonal hatching on a sectional surface shown in isometric should have the appearance of making a 45-degree angle with the horizontal or vertical axis of the surface. If the surface is an isometric surface (one that makes an angle of 35 degrees with the plane of projection), lines drawn at an angle of 60 degrees to the horizontal margin of the paper, as shown in *Figure 3-20*, present the required appearance. To show diagonal hatching on a non-isometric surface, you must experiment to determine the angle that presents the required appearance.

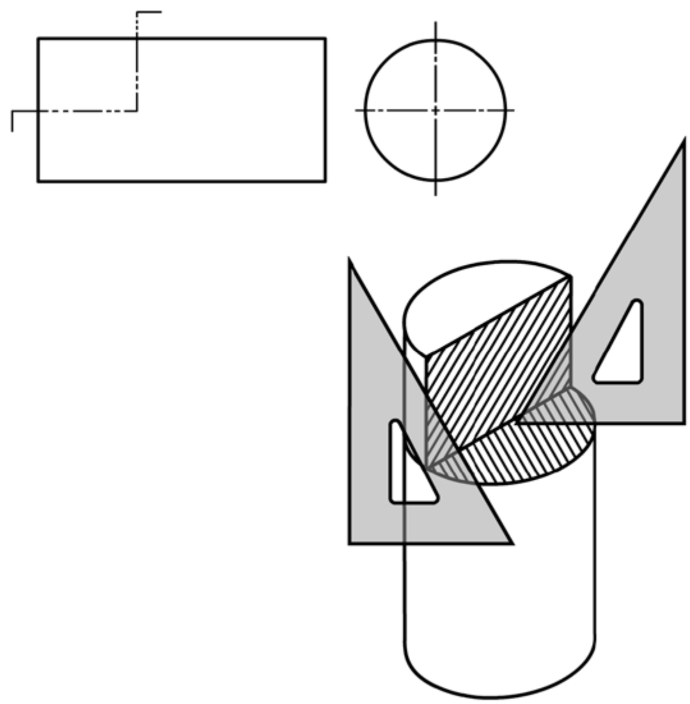


Figure 3-20 — An example of diagonal hatching in isometric.

Dimetric and Trimetric Projections

Two other sub-classifications of the axonometric projection category are dimetric and trimetric projections; however, these types are used less frequently than isometric projections and will not be discussed further in this training manual.

VIEWS

The following pages will help you understand the types of views commonly used in blueprints.

Multi-View Drawings

The complexity of the shape of a drawing governs the number of views needed to project the drawing. Complex drawings normally have six views: both of the ends, front, top, rear, and bottom. However, most drawings are less complex and are shown in three views. We will explain both in the following paragraphs.

An object placed in a transparent box hinged at the edges is shown in *Figure 3-21*. With the outlines scribed on each surface and the box opened and laid flat, the result is a six-view orthographic projection. The rear plane is hinged to the right side plane, but it could hinge to either of the side planes or to the top or bottom plane. The projections on the sides of the box are the views you will see by looking straight at the object through each side. Most drawings will be shown in three views, but occasionally you will see two-view drawings, particularly those of cylindrical objects.

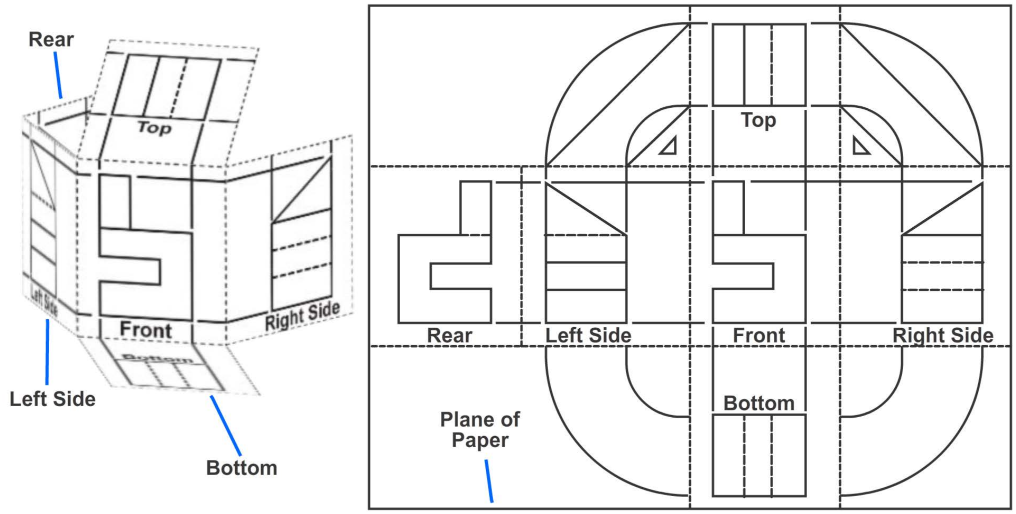


Figure 3-21 — Third-angle orthographic projection brought into a single pane.

A three-view orthographic projection drawing shows the front, top, and right sides of an object. Refer to *Figure 3-21*, and note the position of each of the six sides. If you eliminate the rear, bottom, and left sides, the drawing becomes a conventional 3-view drawing showing only the front, top, and right sides.

Study the arrangement of the three-view drawing in *Figure 3-22*. The views are always in the positions shown. The front view is always the starting point and the other two views are projected from it. You may use any view as your front view as long as you place it in the lower-left position in the three-view. This front view was selected because it shows the most characteristic feature of the object, the notch.

The right side or end view is always projected to the right of the front view. Note that all horizontal outlines of the front view are extended horizontally to make up the side view. The top view is always projected directly above the front view and the vertical outlines of the front view are extended vertically to the top view.

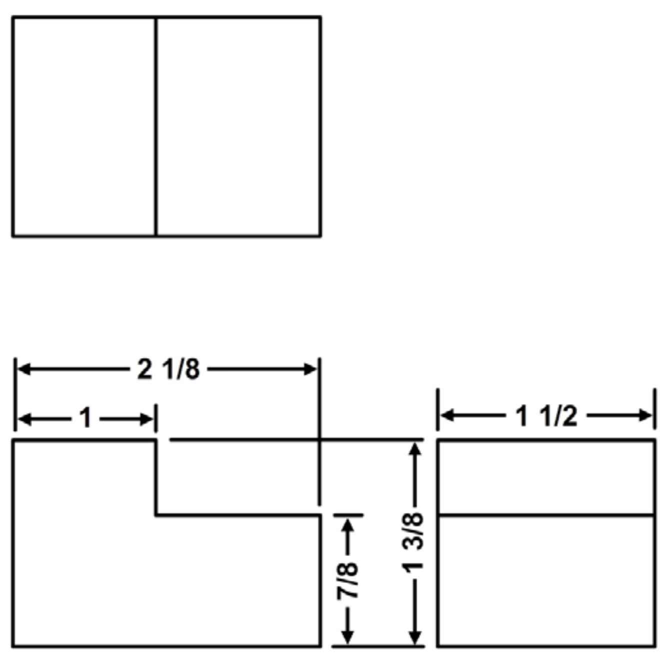


Figure 3-22 — A three-view orthographic projection.

Interaction Available

After you study each view of the object, you can see it as it is shown in the upper part of *Figure 3-23*. To clarify the three-view drawing further, think of the object as immovable and visualize yourself moving around it. Visualizing moving around the object will help you relate the blueprint views to the physical appearance of the object.

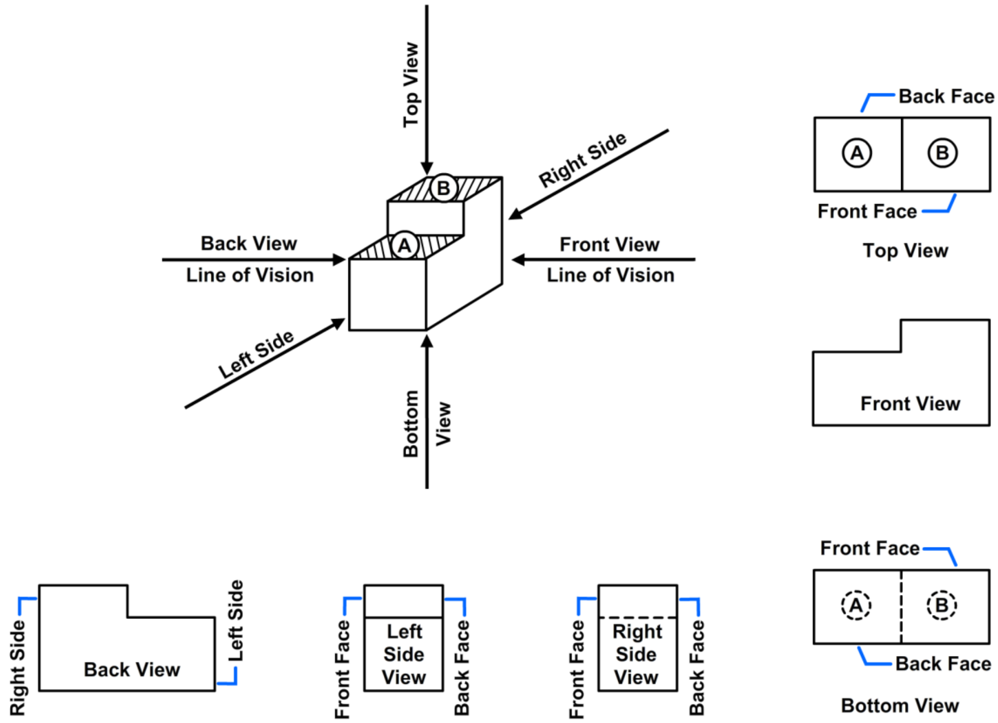


Figure 3-23 — Multi-view analysis of a third-angle orthographic projection.

Now study the three-view drawing shown in *Figure 3-24*. It is similar to that shown in *Figure 3-22* with one exception: the object in *Figure 3-24* has a hole drilled in its notched portion. The hole is visible in the top view, but not in the front and side views. Therefore, hidden (dotted) lines are used in the front and side views to show the exact location of the walls of the hole.

The three-view drawing shown in *Figure 3-24* introduces two symbols that are not shown in *Figure 3-22*. They are a hidden line that shows lines you normally cannot see on the object, and a center line that gives the location of the exact center of the drilled hole. The shape and size of the object are the same.

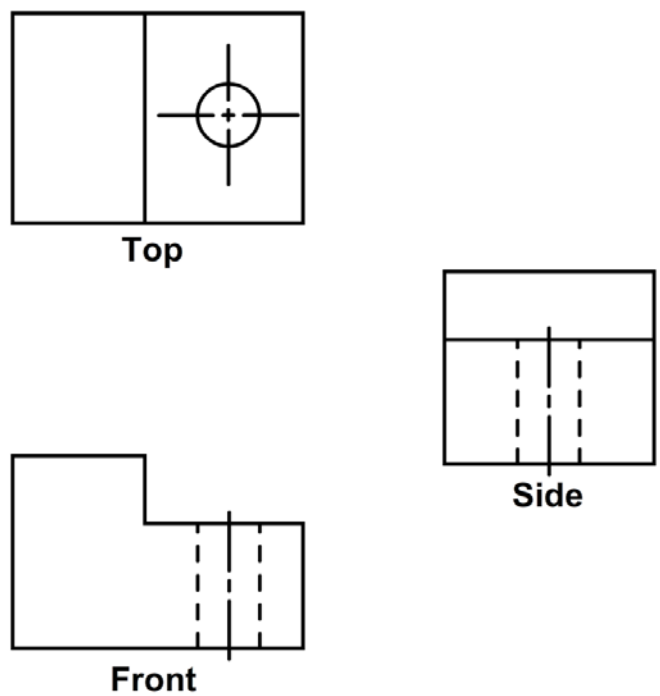


Figure 3-24 — A three-view drawing.

Perspective Projection and Perspective Drawings

A perspective drawing is the most used method of presentation used in technical illustrations in the commercial and architectural fields. Perspective projection is achieved when the projection lines converge to a point that is at a finite distance from the plane of projection. Each projection line forms a different angle with the plane of projection, giving the viewer a three-dimensional picture of the object. This type of projection, however, cannot accurately convey the structural features of a building; hence, it is not adequate for working drawings.

On the other hand, of all the three-dimensional single-plane drawings, perspective drawings are the ones that look the most natural. At the same time, they are also the ones that contain the most errors.

Lines that have the same length on the object have different lengths on the drawing. No single line or angle on the drawing has a length or size that has any known relationship to its true length or size when projected through perspective projections.

Perspective drawing (*Figure 3-25*) is used only in drawings of an illustrative nature, in which an object is deliberately made to appear the way it looks to the human eye. Most of the drawings you prepare will be drawings in which accuracy, rather than eye appearance, is the chief consideration. Consequently, you will not be concerned much with perspective drawing.

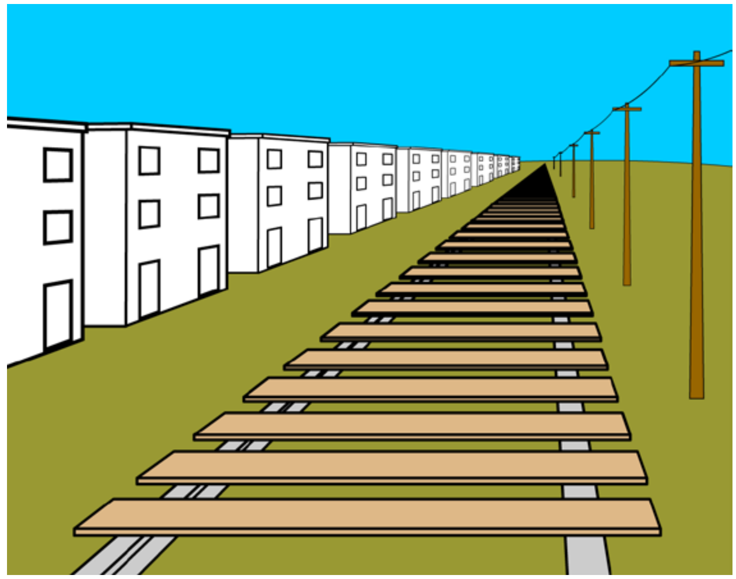


Figure 3-25 — A perspective drawing.

Special Views

In many complex objects it is often difficult to show true size and shapes orthographically. Therefore, other views provide engineers and craftsmen with a clear picture of the object to be constructed. Among these are a number of special views, some of which we will discuss in the following paragraphs.

Auxiliary Views

In theory, there are only three regular planes of projection: the vertical, the horizontal, and the profile. Actually, presume that each of these views is doubled; there is, for example, one vertical plane for a front view and another for a back view.

Assume, then, a total of six regular planes of projection. A projection on any one of the six is a regular view. A projection NOT on one of the regular six is an auxiliary view.

The basic rule of dimensioning requires that you dimension a line only in the view in which its true length is projected and that you dimension a plane with its details only in the view in which its true shape is represented. To satisfy this rule, create an imaginary plane that is parallel with the line or surface we want to project in its true shape. A plane of this kind that is not one of the regular planes is called an auxiliary plane.

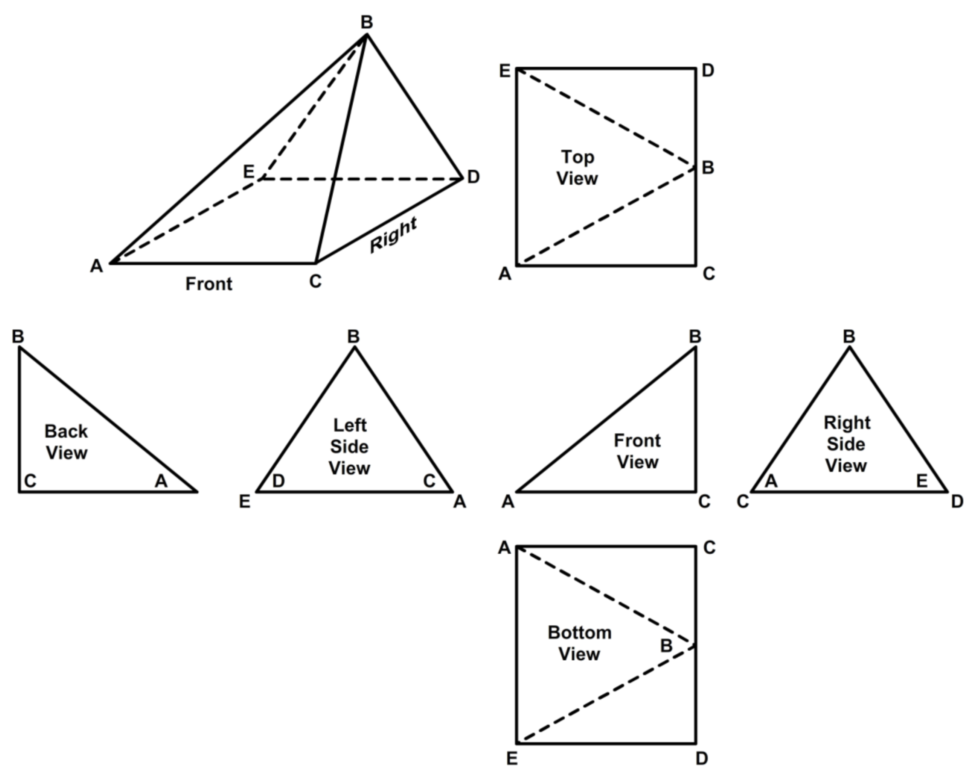


Figure 3-26 — A line oblique to all planes of projection is foreshortened in all views.

In the upper left of *Figure 3-26*, the base of the single-view projection of a triangular block is a rectangle. Presume this block is placed for multi-view projection with the right side parallel to the profile plane. Draw the block using all six views of multi-view projection.

Carefully examine *Figure 3-26*; the lines AB, AE, BD, and BC and the surfaces ABC, ABE, and BDE are oblique to three regular planes of projection. The lines are foreshortened and the surfaces are not shown in their true shape in any of the six normal views.

The first step in drawing any auxiliary view is to draw the object in normal multi-view projection, as shown in *Figure 3-27*. A minimum of two orthographic views is necessary. The space between these views is generally greater than normal. The reason for this space will become apparent. Notice in the front view of *Figure 3-27*, that A is the end point of line AE (top view) and C is the end point of CD.

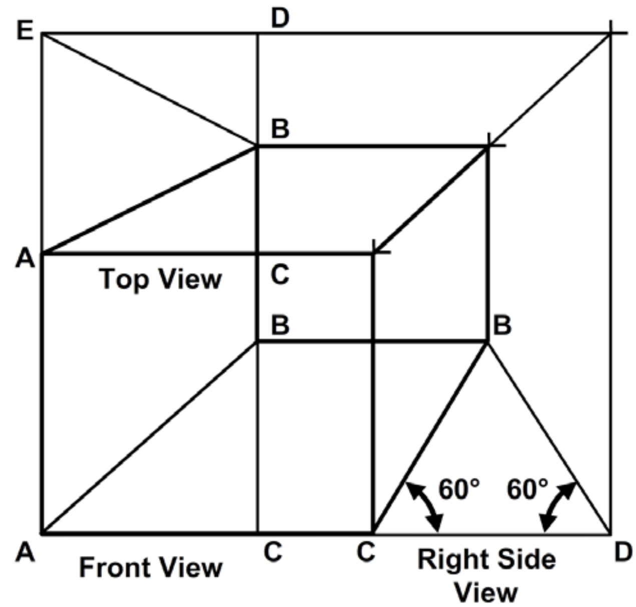


Figure 3-27 — Normal multi-view projection.

The second step is to decide which line or surface to show in an auxiliary view and which orthographic view it will be projected from. Consider the following rules when making this decision:

- Always project front or rear auxiliary views from a side view.
- Always project right or left auxiliary views from a front view.
- Always project an elevation auxiliary view from the top view.

The third step is to select the auxiliary and reference planes. The auxiliary plane is simply a plane parallel to the desired line or lines representing an edge view of the desired surface.

In *Figure 3-28*, the goal is to depict the true length of line AB and the true shape of surface ABE. You need a left side auxiliary view. Draw the auxiliary plane parallel to line AB in the front view. Line AB actually represents an edge view of surface ABE. The reference plane (top view) represents an edge view of the orthographic view (front view) from which the auxiliary view will be projected. Therefore, when you want the front, rear, or side auxiliary views, the reference plane will always be in the top view. When you draw elevation auxiliary views, the reference plane may be in any view in which the top view is represented by a straight line. The reference plane in *Figure 3-28* is the edge of the top view that represents the

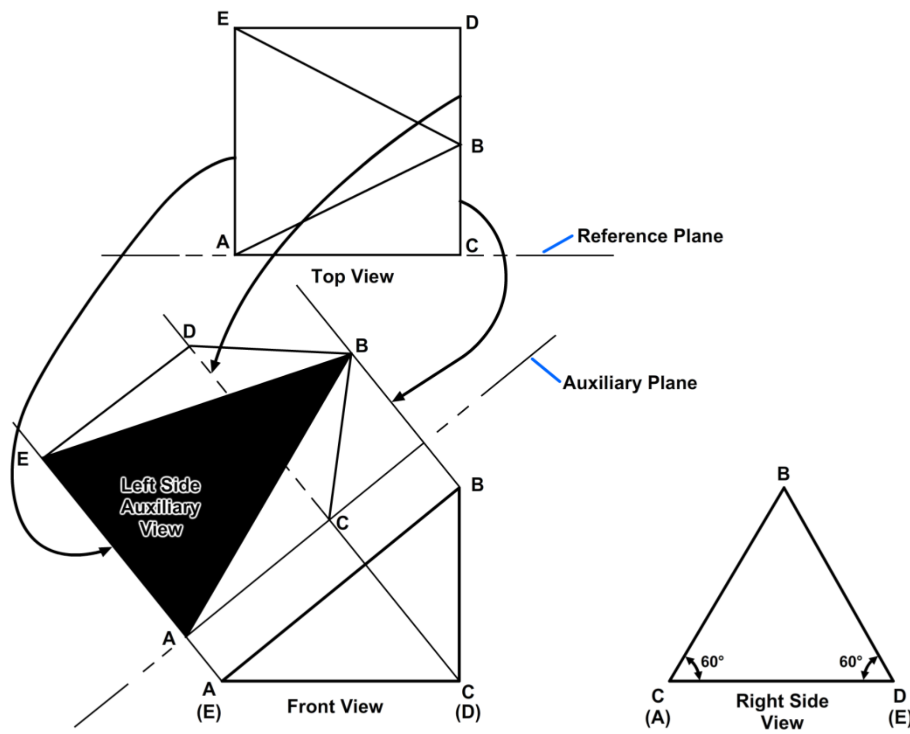


Figure 3-28 —Projection of left side auxiliary view.

front view. Remember that although these planes are represented by lines, they are actually planes running perpendicular to the views.

Step four is to project and locate the points describing the desired line or surface. Draw the projection lines from the orthographic view perpendicular to the auxiliary plane. By scaling or with a compass, take the distances from the reference plane. The distances are the perpendicular distances from the reference plane to the desired point. The projection lines drawn from points A, B, and C in the front view, perpendicular to the auxiliary plane, are illustrated in *Figure 3-28*. The projection line from point A indicates the line on which point E will also be located. The projection line from point C designates the line of both C and D, and that from B locates B only. To transfer the appropriate distances, first look for any points lying on the reference plane. These points will also lie on the auxiliary plane where their projection lines intersect it (points A and C). To locate points B, D, and E, measure their perpendicular distances from the reference plane in the top view and transfer these distances along their respective projection lines in the auxiliary view. The points are equidistant from both the reference and auxiliary planes. Therefore, any line parallel to the reference plane is also parallel to the auxiliary plane and equidistant from it.

The fifth step is to connect these points. When the total auxiliary view is drawn, it is sometimes hard to discern which lines should be indicated as hidden lines. A rule to remember is as follows:

Those points and lines lying furthest away from the auxiliary plane in the orthographic view being projected are always beneath any point or line that is closer. In *Figure 3-28*, point C (representing line CD) in the front view is further from the auxiliary plane than any line or surface it will cross in the auxiliary view. Therefore, it will appear as a hidden line.

The final step is to label and dimension the auxiliary view. The labeling must include an adequate description. The term Auxiliary must be included along with the location of the view in relation to the normal orthographic views (Left Side Auxiliary View, Rear Elevation Auxiliary View, and so forth). Dimensions are given only to those lines appearing in their true length. In *Figure 3-28*, only lines AB, AE, and BE on the auxiliary view should be dimensioned.

Sometimes you will not need the total auxiliary view. Such a view could possibly even make the drawing confusing. In this case, use a partial auxiliary view. Use only the points or lines needed to project the line or surface desired, thereby reducing the number of projection lines and greatly enhancing the clarity of the view. If you use a partial auxiliary view, label it PARTIAL to avoid confusion. In *Figure 3-28*, if you desire only the true length of line AB, project and connect the points A and B. The view would be complete after being labeled and dimensioned.

In some cases the shape of an object will be such that neither the normal orthographic view nor the auxiliary views will show the true size and shape of a surface. When this situation occurs, a secondary auxiliary view is necessary to describe the surface. The procedures for projecting and drawing a secondary auxiliary view are the same as those for a normal (or primary) auxiliary view. The reference plane for a secondary auxiliary view is located in the orthographic view from which the primary auxiliary view is projected. Usually, the primary auxiliary plane becomes the secondary reference plane. The secondary auxiliary plane is in the primary auxiliary view, and its location is determined in the same manner as the primary auxiliary plane.

Section Views

Use viewing plane lines to indicate the plane or planes from which a surface or several surfaces are viewed. Cutting plane lines indicate a plane or planes which a sectional view is taken. A section view provides a clearer view of interior or hidden features of an object that cannot be 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.

Notice the cutting plane line AA in *Figure 3-29, view A*; it shows where the imaginary cut has been made. The single view in *Figure 3-29, view B*, helps you to visualize the cutting plane. The arrows point in the direction in which you are to look at the sectional view.

A front view showing how the object looks when cut it in half is illustrated in *Figure 3-29, view C*.

The orthographic section view of *Figure 3-29, view D*, should be used on the drawing instead of the confusing front view in *Figure 3-29, view A*. Notice how much easier it is to read and understand.

Note that hidden lines behind the plane of projection are omitted in the sectional view.

These lines are omitted by general custom, because the elimination of hidden lines is the basic reason for making a sectional view. However, lines that would be visible behind the plane of projection must be included in the section view.

Cutting plane lines, together with arrows and letters, make up the cutting plane indications. Placing arrows at the end of the cutting plane lines indicates the direction to view the sections. The cutting plane may be a single continuous plane, or it may be offset if the detail can be shown to better advantage. On simple views, indicate the cutting plane as shown in *Figure 3-29, view A*. When the views are large and complex or when the cutting planes are offset, indicate them as shown in *Figure 3-30.*

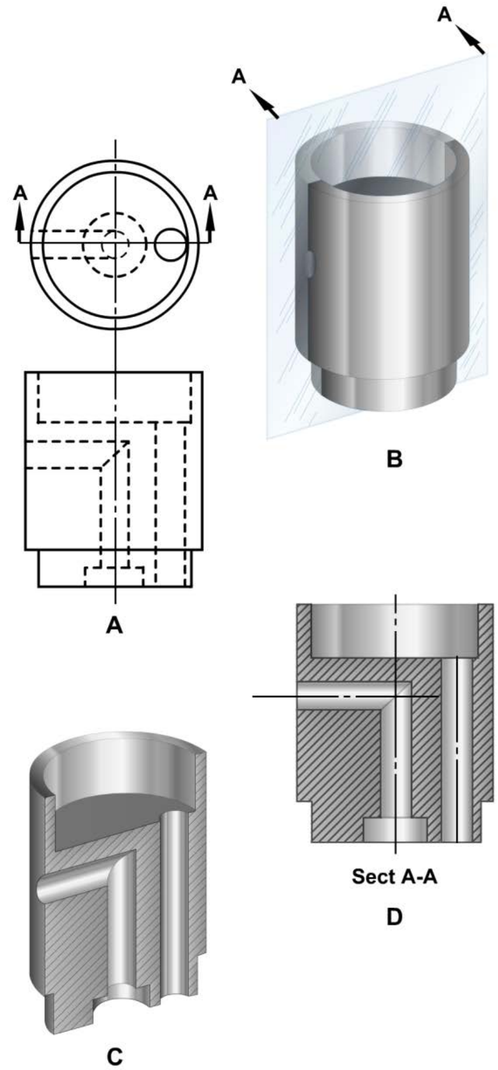


Figure 3-29 — Action of a cutting plane.

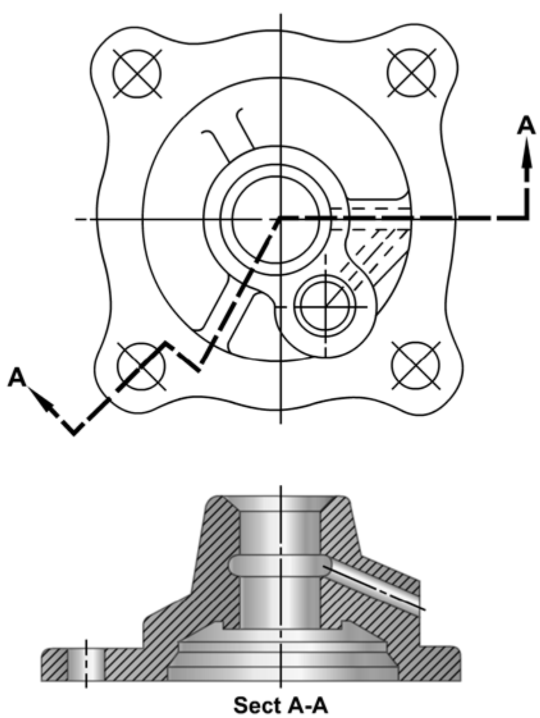


Figure 3-30 — Use of an offset section.

Identify all cutting plane indications with reference letters placed at the arrowhead points. Place reference letters at each change of direction when the change in direction of the cutting plane is not clear. When more than one sectional view appears on a drawing, add a letter to the cutting plane.

Include the letters that are part of the cutting plane indication as part of the title; for example, section A-A, section B-B. If the single alphabet is exhausted, multiples of letters may be used. You may abbreviate the word “section,” if desired. Place the title directly under the section drawing.

Half Section

The section shown in *Figure 3-30* is a full section**.** The object shown in *Figure 3-30* is a symmetrical object, meaning that the shape of one half is identical to the shape of the other. With the symmetry of the object, you could have used a half section like the one shown in *Figure 3-31*. This half section constitutes one half of the full section. Because the other half of the full section would be identical with the half shown, it need not be drawn.

Notice that a center line, rather than a visible line, is used to indicate the division between the sectioned and the un-sectioned part of the sectional view. A visible line would imply a line that is actually nonexistent on the object. Another term used in place of center line is line of symmetry.

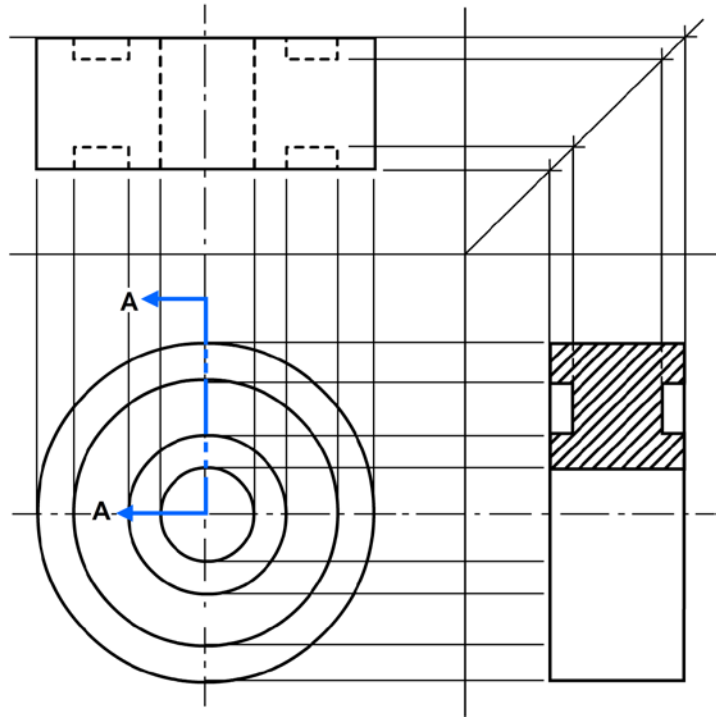


Figure 3-31 — Use of a half section.

A section consisting of less than half a section is called a partial section (*Figure 3-32*). Note that here you use a break line to indicate the division between the sectioned and un-sectioned part. For this reason, a partial section is often called a broken section.

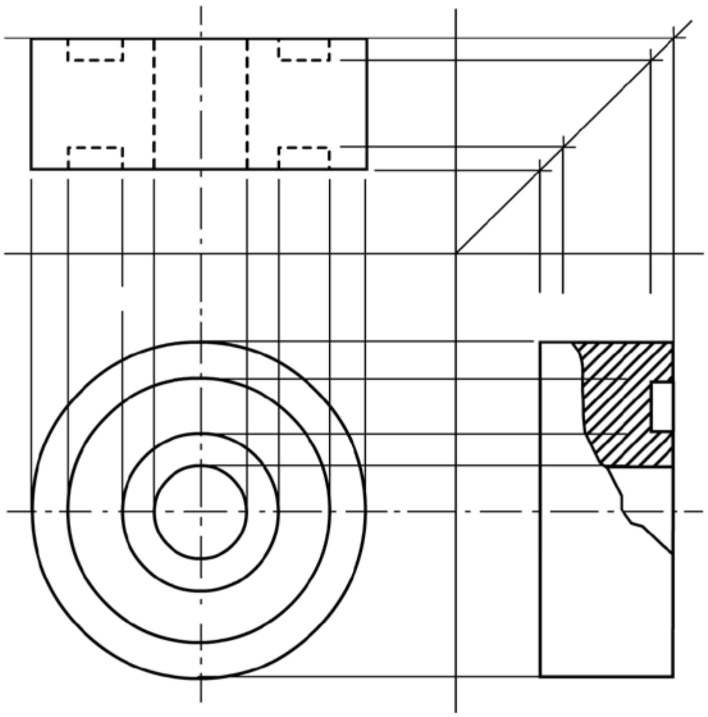


Figure 3-32 — Use of a partial or broken section.

Revolved Section

In a revolved section, you project the object on one or more of the regular planes of projection. However, instead of placing the object in a normal position, rotate it on an axis perpendicular to one of the regular planes (*Figure 3-33*). At the top of *Figure 3-33* is a single projection of a triangular block. You can show all the required information about this block in a two-view projection by including a revolved section in the front view as shown. First, assume that the block is cut by a plane perpendicular to the longitudinal axis. Then, revolve the resulting section 90 degrees on axis perpendicular to the horizontal plane of projection.

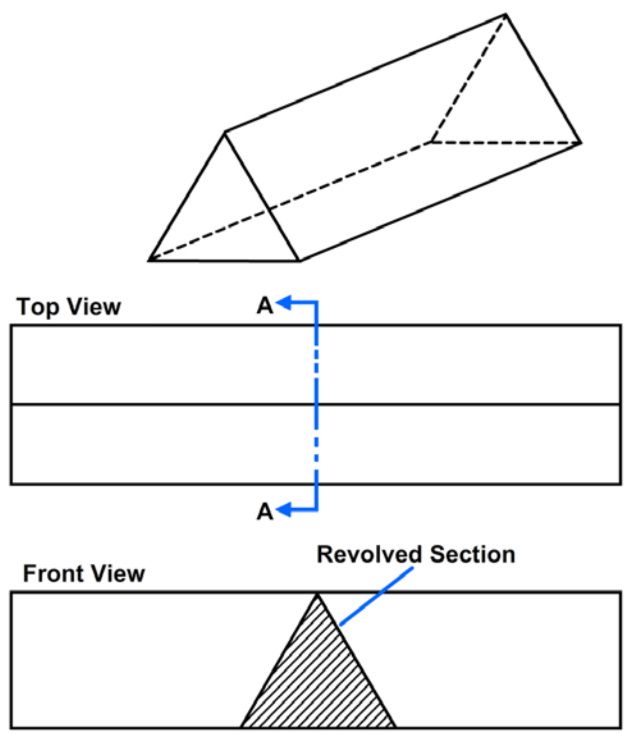


Figure 3-33 — Use of a revolved section.

Removed Section

Use this type of section to illustrate particular parts of an object. It is drawn like the revolved section, except it is placed at one side to bring out important details (*Figure 3-34*). It is often drawn to a larger scale than the view of the object from which it is removed.

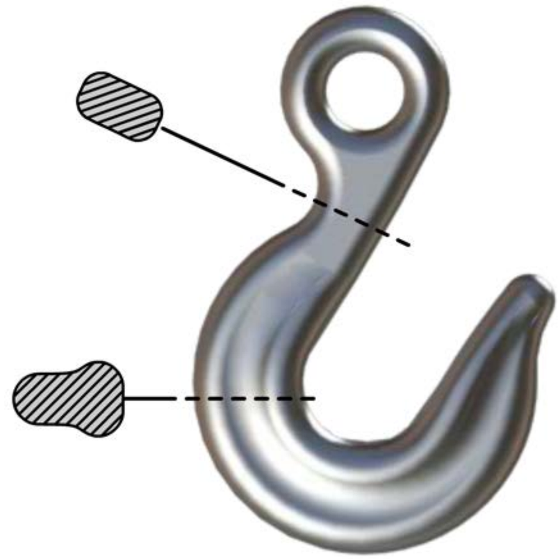


Figure 3-34 — Removed section.

Broken-Out Section

Use a broken-out section to show the inner structure of a small area by peeling back or removing the outside surface. The inside of a counterbored hole is better illustrated in *Figure 3-35* because of the broken-out section, which makes it possible for you to look inside.

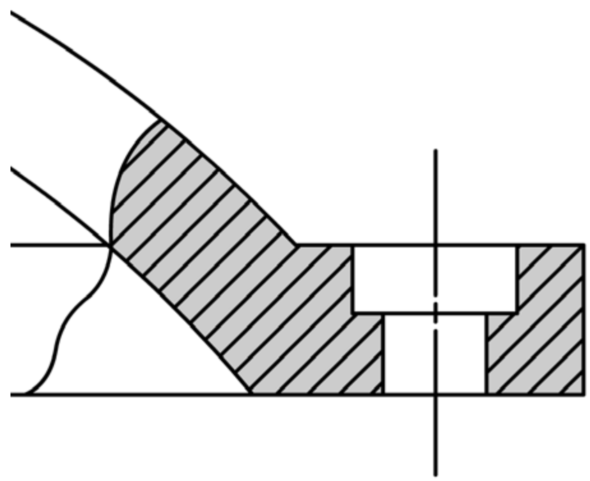


Figure 3-35 — Broken-out section through a counterbored hole.

Aligned Section

An aligned section is illustrated in *Figure 3-36*. Look at the cutting plane line AA on the front view of the handwheel. When a true sectional view might be misleading, 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 section A-A are not sectioned. If they were, the first impression might be that the wheel had a solid web rather than spokes.

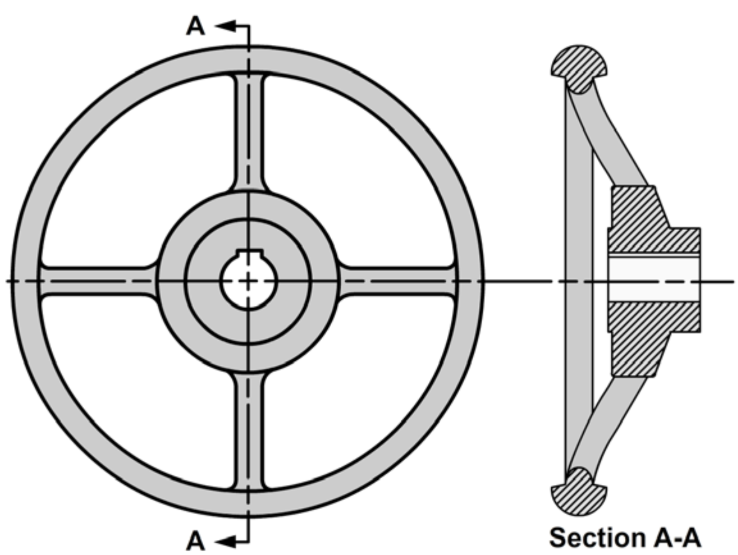


Figure 3-36 — Aligned section.

Exploded View

The exploded view is another type of view that is helpful and easy to read. The exploded view (*Figure 3-37*) shows the relative location of parts, and it is particularly helpful when you must assemble complex objects. Notice how parts are spaced out in line to show clearly each part's relationship to the other parts.

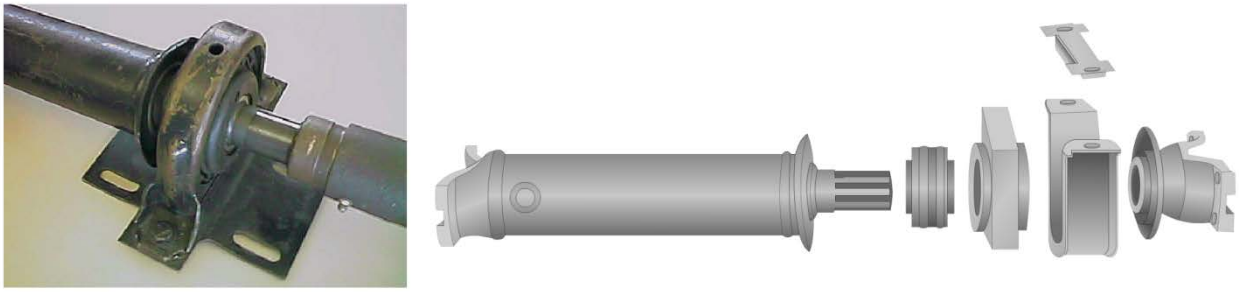


Figure 3-37 — Exploded view.

Detail Drawings

A detail drawing (*Figure 3-38*) is a print that shows a single component or part. It includes a complete and exact description of the part's shape and dimensions, and how it is made. A complete detail drawing will show in a direct and simple manner the shape, exact size, type of material, finish for each part, tolerance, necessary shop operations, number of parts required, and so forth. A detail drawing is not the same as a detail view. A detail view shows part of a drawing in the same plane and in the same arrangement, but in greater detail and to a larger scale than in the principal view.

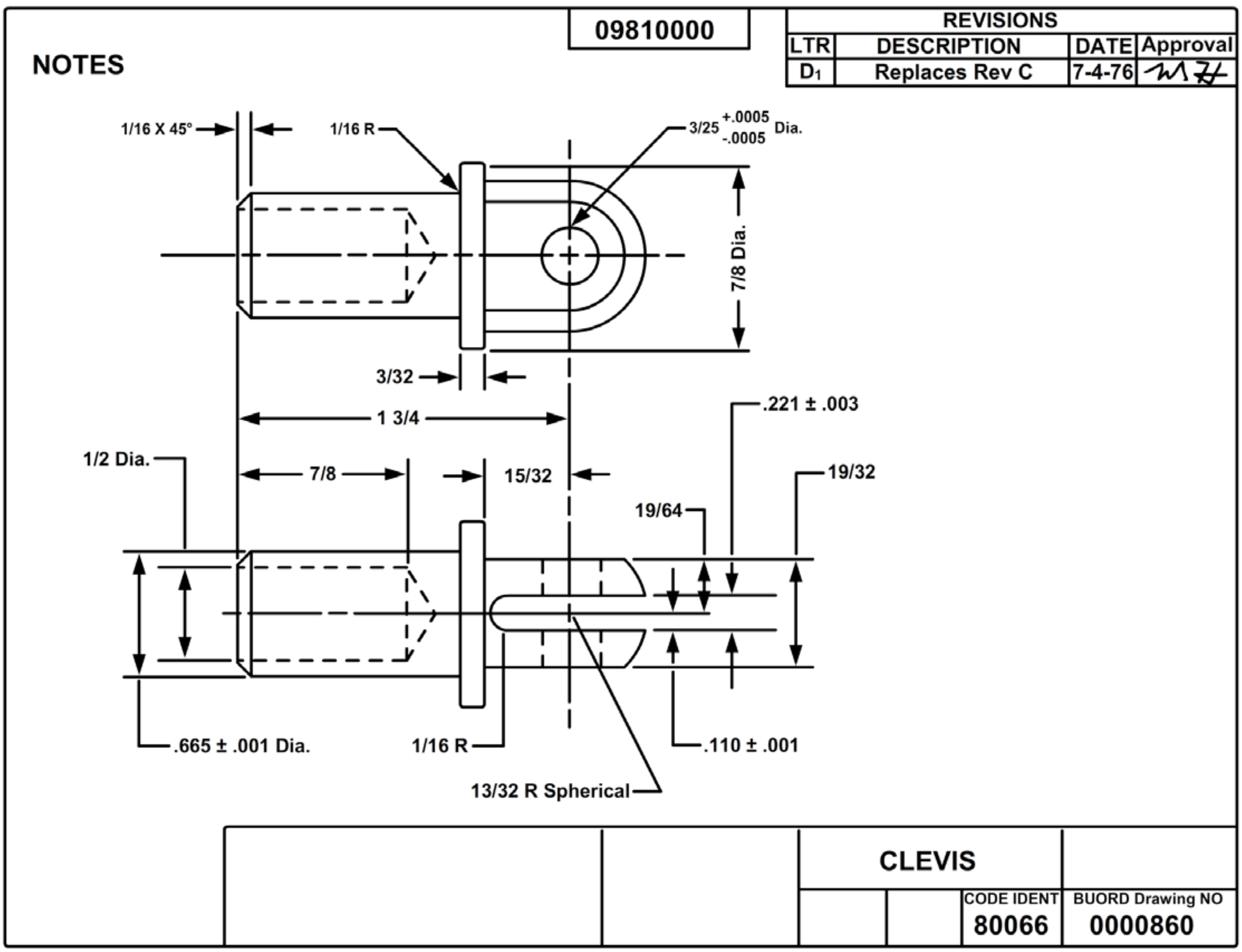


Figure 3-38 — Detail drawing of a clevis.

Study *Figure 3-38* closely and apply the principles for reading two-view orthographic drawings. The dimensions on the detail drawing in *Figure 3-38* are conventional, except for the four tolerance dimensions given. In the top view, on the right end of the part, is a hole requiring a diameter of 0.3125 +0.0005, but no minus (–). This indication means that the diameter of the hole can be no less than 0.3125, but as large as 0.3130. In the bottom view, on the left end of the part, there is a diameter of 0.665 ±0.001. This plus and minus dimension means the diameter can be a minimum of 0.664, and a maximum of 0.666. The other two tolerance dimensions given are at the left of the bottom view. An isometric view of the clevis is shown in *Figure 3-39*.

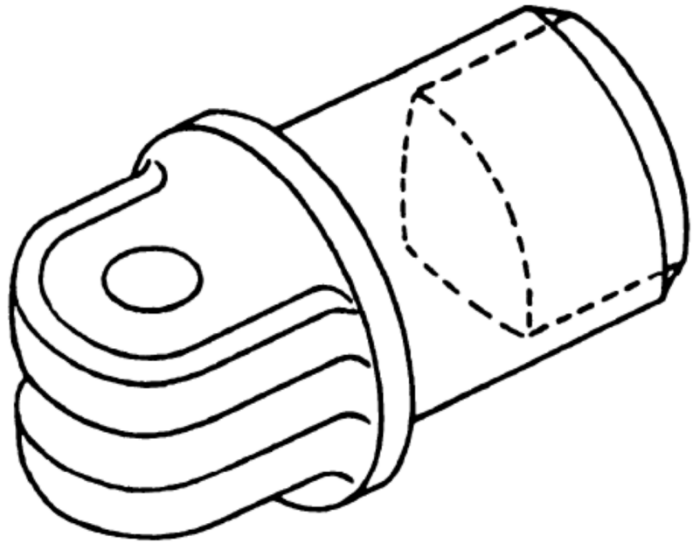


Figure 3-39 — Isometric drawing of a clevis.

An isometric drawing of the base pivot is shown in *Figure 3-40*. The base pivot is shown orthographically in *Figure 3-41*. You may think the drawing is complicated, but it really is not. It does, however, have more symbols and abbreviations than this training manual has shown you so far.

Various views and section drawings are often necessary in machine drawings because of complicated parts or components. It is almost impossible to read the multiple hidden lines necessary to show the object in a regular orthographic print. For this reason machine drawings have one more view that shows the interior of the object by cutting away a portion of the part. You can see this procedure in the upper portion of the view on the left of *Figure 3-41*.

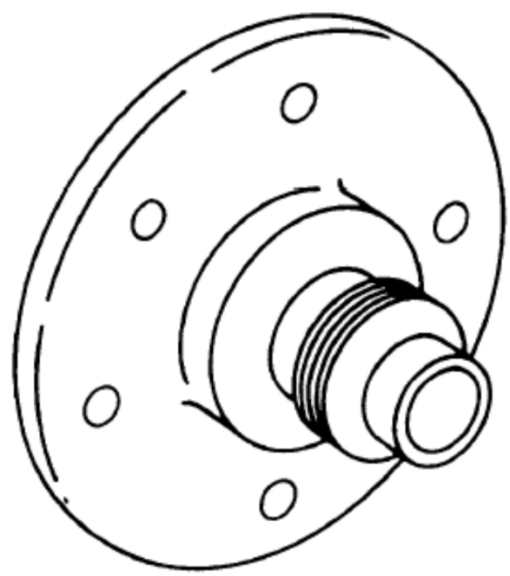


Figure 3-40 — Isometric drawing of a base pivot.

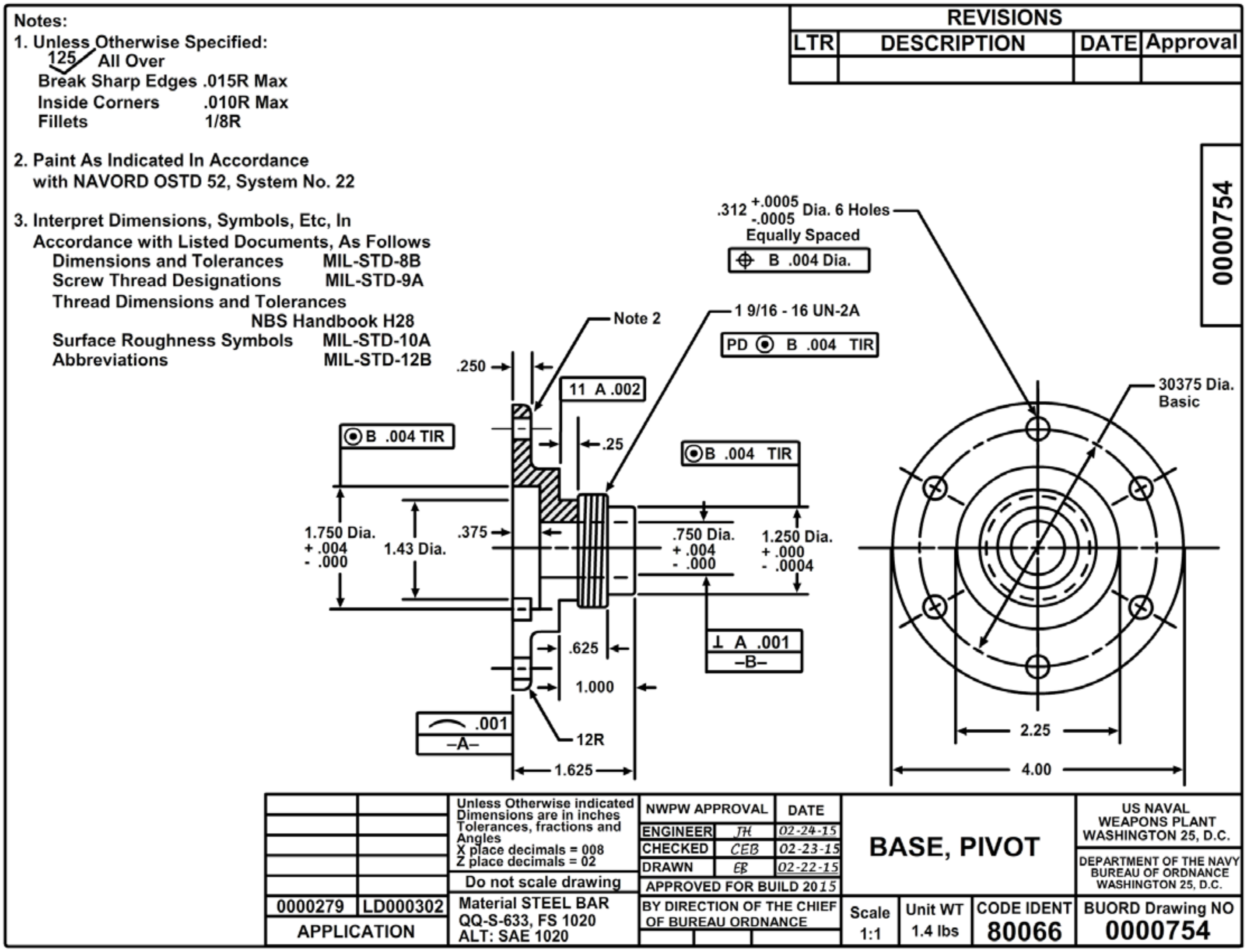


Figure 3-41 — Detail drawing of a base pivot.

End of Chapter 3

Projections and Views

Review Questions

3-1. Which of the following terms describes a view of an object?

A. Isometric
B. Projection
C. Orthographic
D. Perspective

3-2. For which of the following reasons are central projections seldom used in technical drawings?

A. Projections are distorted when not to scale
B. The projected view is drawn from one plane only
C. The projections do not meet at a central point
D. Size will vary with distance between the observer and object

3-3. An orthographic projection is a parallel projection in which the projectors are at what angle to the plane of projection?

A. Acute
B. Obtuse
C. Parallel
D. Perpendicular

3-4. The principal plane of projection includes vertical, horizontal, and what other plane?

A. Circular
B. Diagonal
C. Profile
D. Silhouette

3-5. To draw the first-angle projection on drafting paper, you must turn the profile plane in which of the following directions?

A. Clockwise and horizontal
B. Clockwise and vertical
C. Counterclockwise and horizontal
D. Counterclockwise and vertical

3-6. What term describes the method used to show an object in all three dimensions in a single view?

A. Axonometric projection
B. Diametric projection
C. Hypermetric sketching
D. Three-dimensional art

3-7. What term describes drawing a rectangular object in isometric?

A. Box construction
B. Line art
C. Rectangular projection
D. Text box

3-8. A circle will appear as what shape in an isometric drawing?

A. Crescent
B. Ellipse
C. Square
D. Triangle

3-9. Diagonal hatching should have the appearance of what angle with the horizontal and vertical axis, in degrees?

A. 15
B. 30
C. 45
D. 60

3-10. What characteristic governs the number of views needed to project the drawing?

A. Complexity of the shape
B. Military specifications
C. Number of required dimensions
D. Number of sides

3-11. What type of drawing is deliberately made to appear the way it looks to the human eye?

A. Detail
B. Isometric
C. Perspective
D. Special

3-12. What special view gives a clearer view of interior or hidden features?

A. Broken-out
B. Removed
C. Revolved
D. Section

3-13. What special view rotates the object on an axis perpendicular to one of the planes?

A. Broken-out
B. Removed
C. Revolved
D. Section

3-14. What special view is used to illustrate particular parts of an object?

A. Broken-out
B. Removed
C. Revolved
D. Section

3-15. What type of drawing shows a complete and exact description of a single component or part?

A. Detail
B. Isometric
C. Multi-view
D. Projection

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CHAPTER 4

MACHINE DRAWINGS

This chapter discusses the common terms, tools, and conventions used in the production of machine drawings.

LEARNING OBJECTIVES

When you have completed this chapter, you will be able to do the following:

1. Identify basic machine drawings terminology.
2. Identify the types of machine threads.
3. Determine gear nomenclature.
4. Determine helical spring nomenclature.
5. Recognize the use of finish marks on drawings.

COMMON TERMINOLOGY AND SYMBOLS

In learning to read machine drawings, you must first become familiar with the common terms, symbols, and conventions defined and discussed in the following paragraphs.

General Terminology

The following paragraphs cover the common terms most used in all aspects of machine drawings.

Tolerances

Engineers realize that absolute accuracy is impossible, so they calculate how much variation is permissible. This variation is known as tolerance. It is stated on a drawing as plus (+) or minus (-) a certain amount, either by a fraction or decimal. Limits are the maximum and/or minimum values prescribed for a specific dimension, while tolerance represents the total amount by which a specific dimension may vary. Tolerances may be shown on drawings by several different methods; *Figure 4-1* shows three examples. The unilateral method (*view A*) is used when variation from the design size is permissible in one direction only. In the bilateral method (*view B*), the dimension figure shows the plus or minus variation that is acceptable. In the limit dimensioning method (*view C*), the maximum and minimum measurements are both stated.

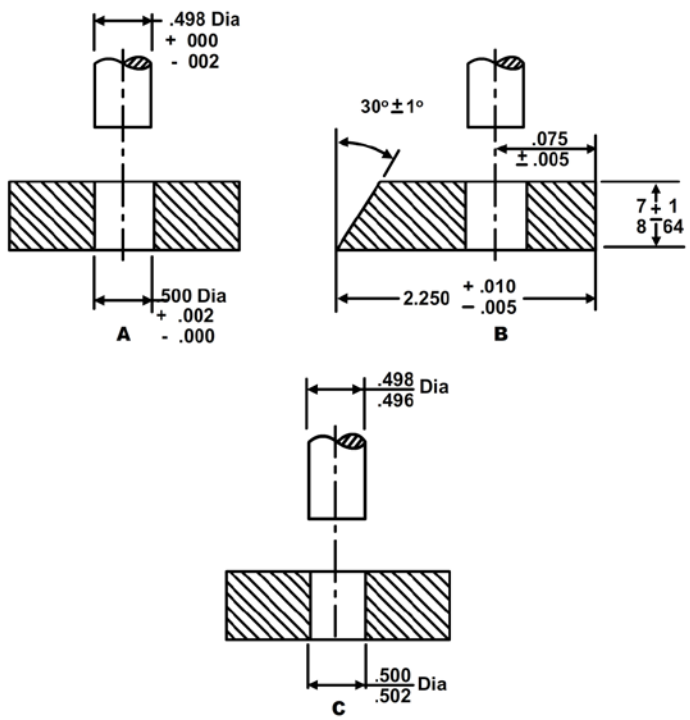

Figure 4-1 — Methods of indicating tolerances.

The surfaces being toleranced have geometrical characteristics such as roundness, or perpendicularity to another surface. Typical geometrical characteristic symbols are illustrated in *Figure 4-2*. A datum is a surface, line, or point from which a geometric position is to be determined or from which a distance is to be measured. Any letter of the alphabet except I, O, and Q may be used as a datum identifying symbol. A feature control symbol is made of geometric symbols and tolerances. A feature control symbol may include datum references (*Figure 4-3*).

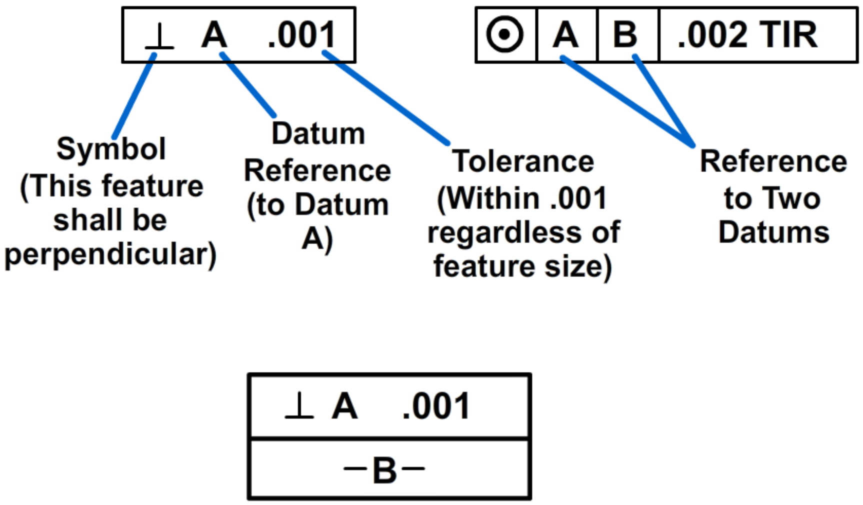

Figure 4-3 — Feature control frame indicating a datum reference.

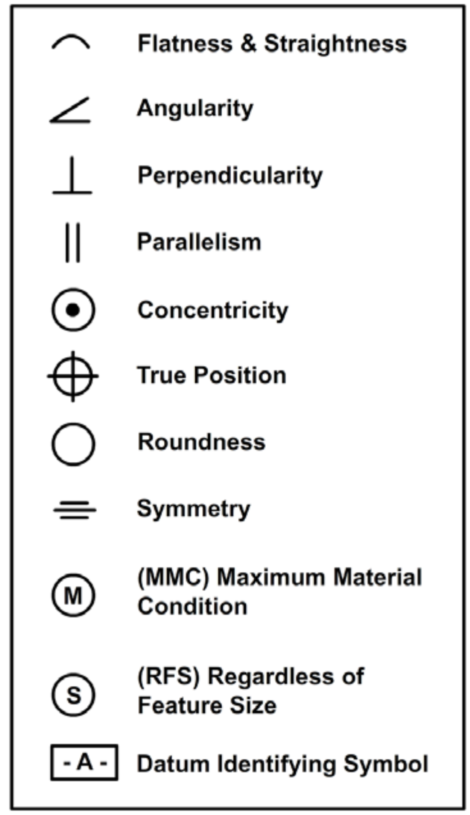

Figure 4-2 — Geometric characteristic symbols.

Fillets and Rounds

Fillets are concave metal corner (inside) surfaces. In a cast, a fillet normally increases the strength of a metal corner because a rounded corner cools more evenly than a sharp corner, thereby reducing the possibility of a break. Rounds or radii are edges or outside corners that have been rounded to prevent chipping and to avoid sharp cutting edges. Fillets and rounds are illustrated in *Figure 4-4*.

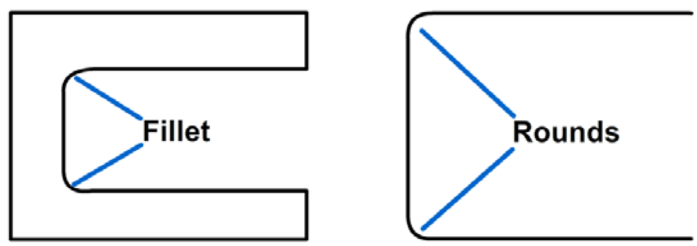

Figure 4-4 — Fillets and rounds.

Slots and Slides

Slots and slides are used to mate two specially shaped pieces of material and securely hold them together, yet allow them to move or slide. The two types, the tee slot and the dovetail slot, are shown in *Figure 4-5*. For example, a tee slot arrangement is used on a milling machine table, and a dovetail is used on the cross slide assembly of an engine lathe.

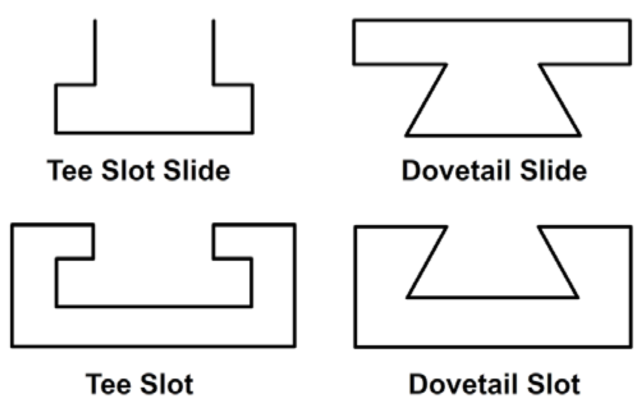

Figure 4-5 — Slots and slides.

Keys, Keyseats, and Keyways

A key is a small wedge or rectangular piece of metal inserted in a slot or groove between a shaft and a hub to prevent slippage. *Figure 4-6* shows three types of keys.

Figure 4-7 shows a keyseat and keyway. A keyseat (*view A*) is a slot or groove on the outside of a part into which the key fits. A keyway (*view B*) is a slot or groove within a cylinder, tube, or pipe. A key fitted into a keyseat will slide into the keyway and prevent movement of the parts.

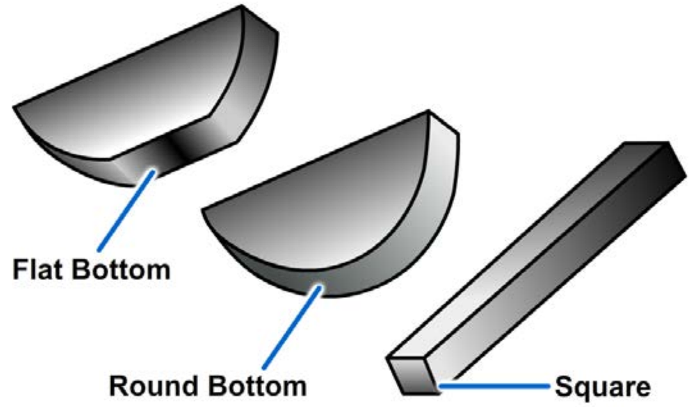

Figure 4-6 — Types of keys.

SCREW THREADS

Different methods are used to show threads on drawings. The simplified method (*Figure 4-8*) uses visible and hidden lines to represent major and minor diameters of screw threads. The schematic method (*Figure 4-9*) uses staggered lines to represent the roots and crests of visible screw threads. The detailed method (*Figure 4-10*) provides the closest representation of the appearance of the actual screw thread. The simplified, schematic, and detailed method of thread representation used for tapered pipe threads is shown in *Figure 4-11*.

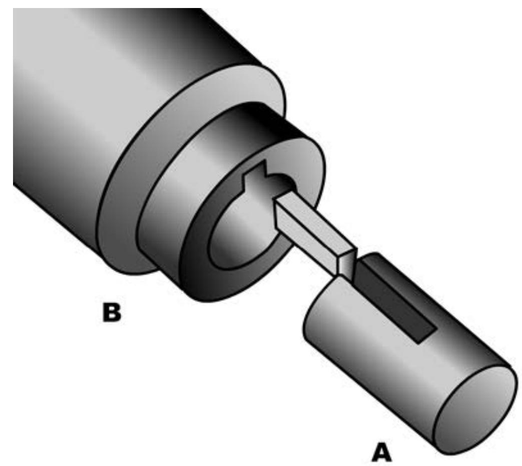

Figure 4-7 — A keyseat and keyway.

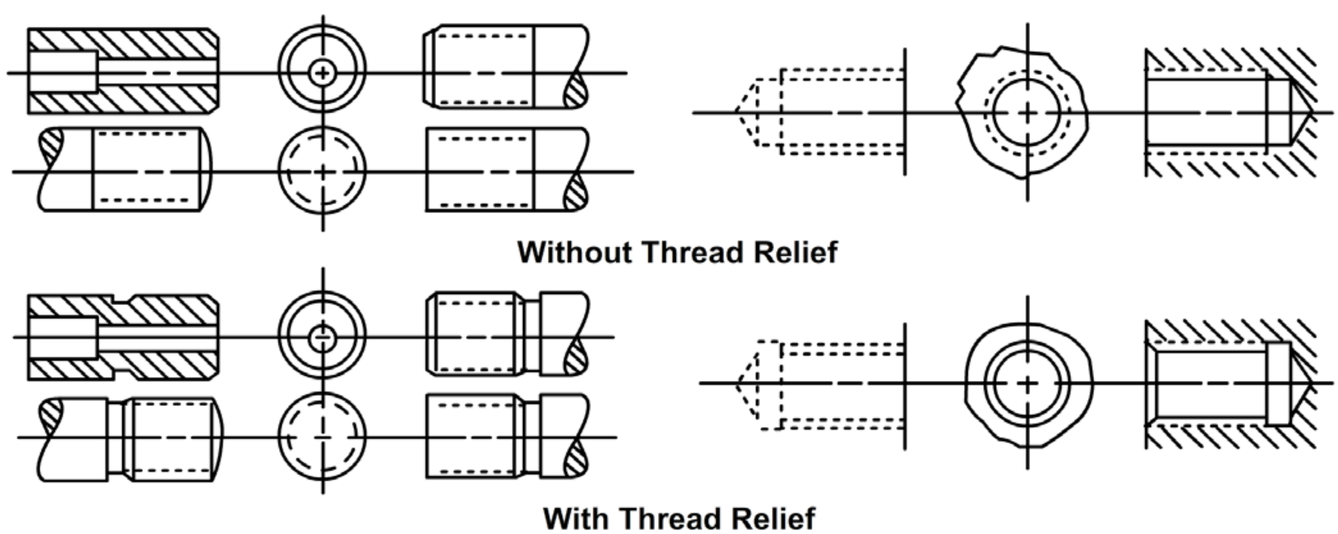

Figure 4-8 — Simplified method of thread representation.

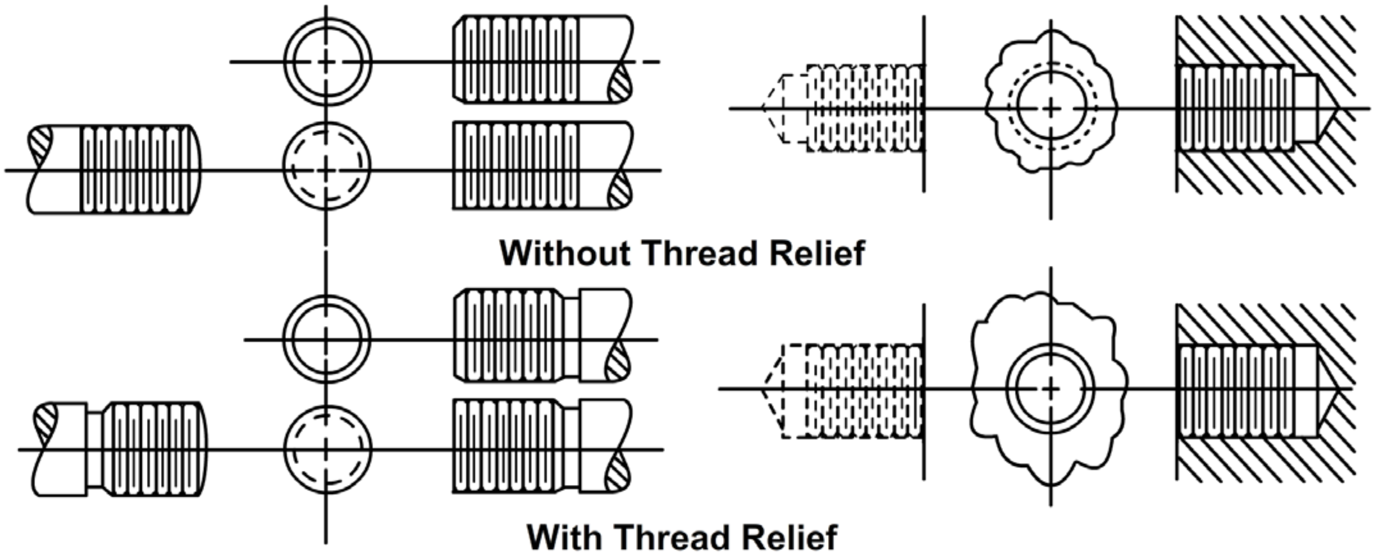

Figure 4-9 — Schematic method of thread representation.

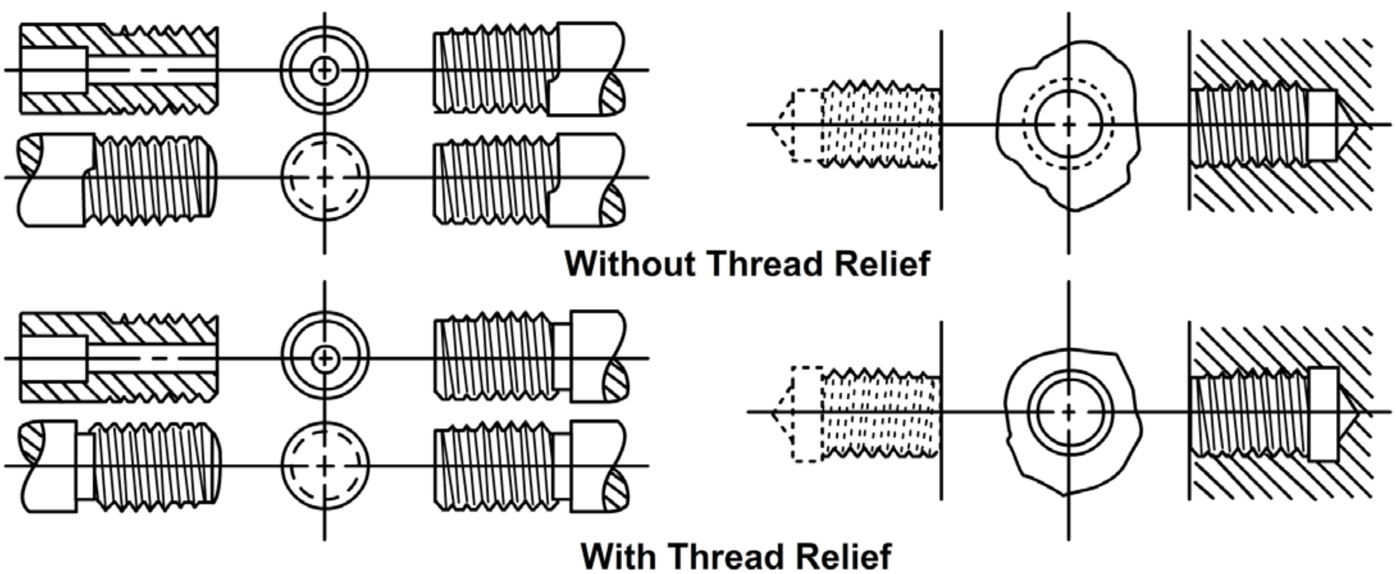

Figure 4-10 — Detailed method of thread representation.

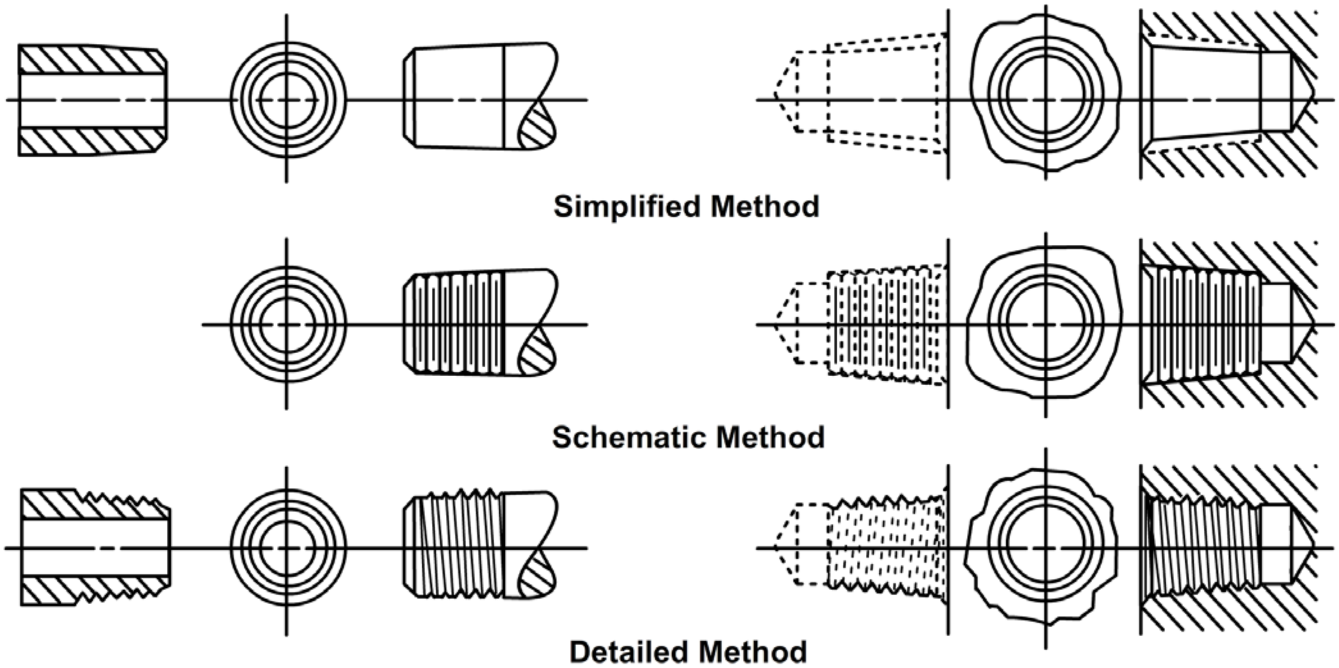

Figure 4-11 — Tapered pipe thread representation.

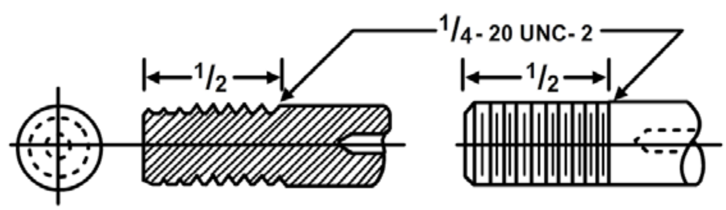

Figure 4-12 — Outside threads.

In *Figure 4-12*, the left side shows a thread profile in section and the right side shows a common method of drawing threads. To save time in a section view, symbols are used and the threads are not drawn to scale. The drawing shows the dimensions of the threaded part but other information may be placed in "notes" almost any place on the drawing but most often in the upper left corner.

However, in this example the note is directly above the drawing and shows the thread designator: 1/4-20 UNC-2. The first number of the note, 1/4, is the nominal size, which is the outside diameter. The number after the first dash, 20, means there are 20 threads per inch. The Unified National Coarse thread series is identified by the letters UNC. The last number, 2, identifies the class of thread and tolerance, commonly called the fit. If it is a left-hand thread, a dash and the letters LH will follow the class of thread. Threads without the LH are right-hand threads.

Specifications necessary for the manufacture of screws include thread diameter, number of threads per inch, thread series, and class of thread. The two most widely used screw-thread series are National Coarse (NC) and National Fine (NF) threads, which are part of the Unified or National Form Threads system. The NF threads have more threads per inch of screw length than the NC.

Classes of threads are distinguished from each other by the amount of tolerance and/or allowance specified. Class of thread was previously called class of fit; both terms are interchangeable. The term, class of thread, was established by the National Bureau of Standards in the Screw-Thread Standards for Federal Services, Handbook H-28.

Screw Threads Terminology

The terminology used to describe screw threads is illustrated in *Figure 4-13*. Each term is explained in the following paragraphs.

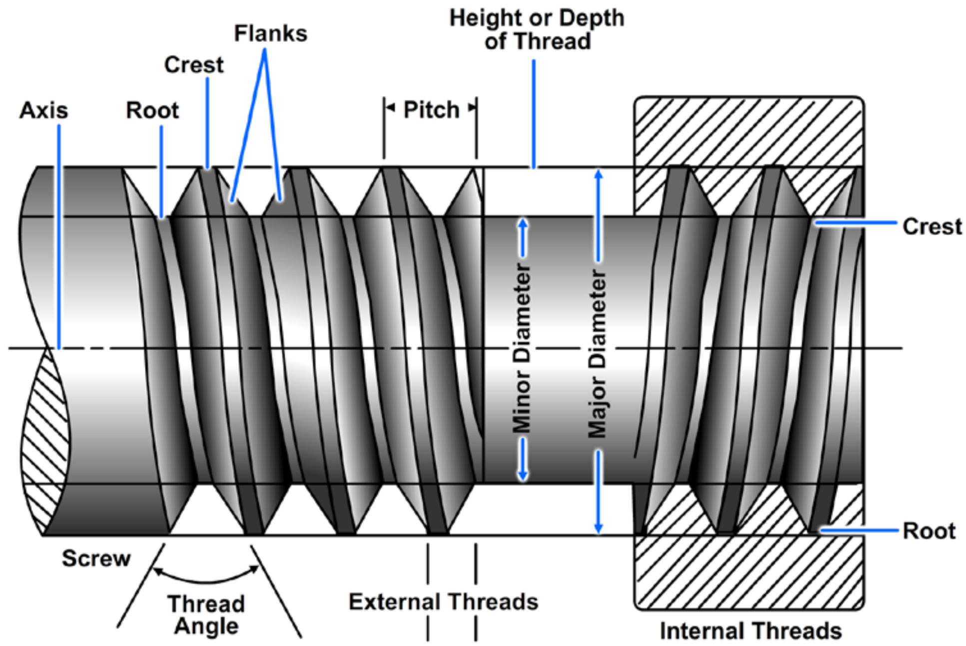

Figure 4-13 — Screw thread terminology.

Axis

The axis is the center line running lengthwise through a screw.

External Thread

These threads are on the outside of a cylinder, such as a bolt or screw.

Internal Thread

These threads are on the inside of an object, such as a nut.

Crest

The crest is located at the top edge of the thread. This area corresponds to the major diameter of an external thread and the minor diameter of an internal thread.

Root

The root is the area at the bottom of the thread. This area of the thread corresponds to the minor diameter of an external thread and the major diameter of an internal thread.

Flank

The flank is the flat surface of the screw thread between the root and crest.

Major Diameter

This diameter is the largest measurement of an external or internal thread. The external thread major diameter is the outside measurement of the crest. The internal thread major diameter is the largest measurement of the root.

Minor Diameter

This diameter is the smallest measurement of an external or internal thread. The external thread minor diameter is the measurement of the root. The internal thread minor diameter is the measurement of the crest.

Pitch

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

Lead

The distance a screw thread advances on one turn, measured parallel to the axis. On a single-thread screw the lead and the 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.

Helix

The curve formed on any cylinder by a straight line in a plane that is wrapped around the cylinder with a forward progression.

Depth

The distance from the root of a thread to the crest, measured perpendicularly to the axis.

GEARS

When sketching a gear on a machine drawing, usually only enough teeth are drawn to identify the necessary dimensions.

Gear Terminology

The terminology used to describe gears is illustrated in *Figure 4-14*. Each term is explained in the following paragraphs.

Pitch Diameter (PD)

The PD of a gear is equal to the number of teeth on the gear divided by the diametral pitch (DP).

Diametral Pitch (DP)

The DP is the ratio of the number of teeth per inch of the PD or the number of teeth on the gear divided by the PD. The DP is usually referred to as pitch.

Number of Teeth (N)

Multiply the DP by the PD (DP x PD) to find the number of teeth.

Pitch Circle

Pitch circle is an imaginary circle on a gear that divides the teeth into top and bottom lands (addendums and dedendums).

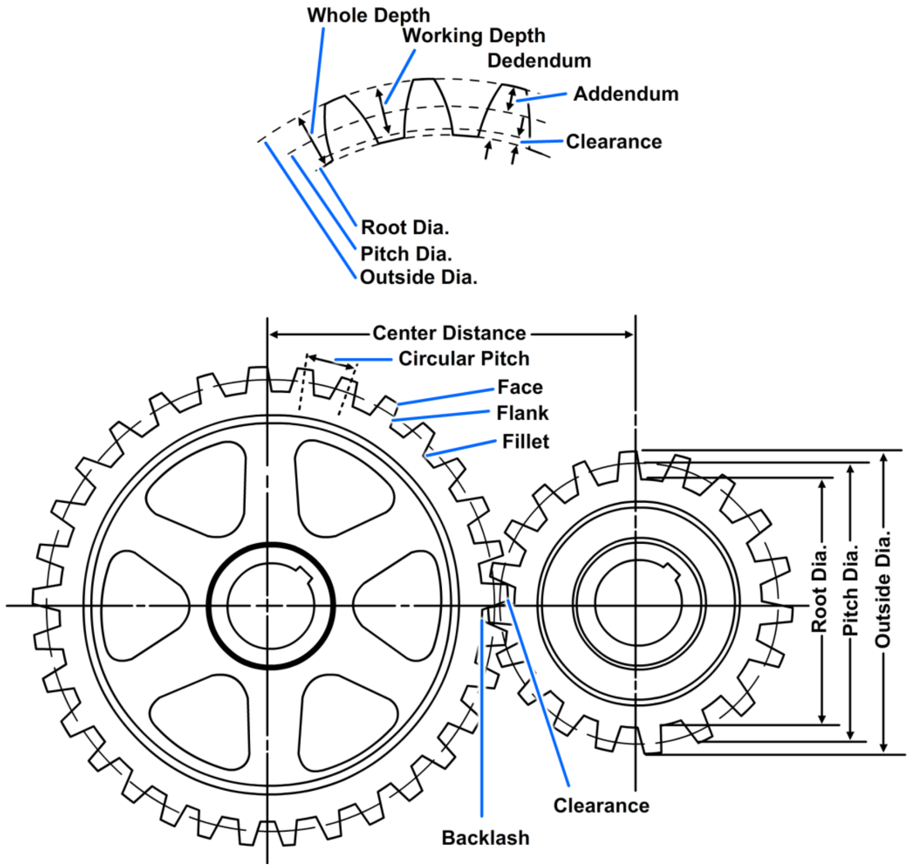

Figure 4-14 — Gear terminology.

Addendum

Addendum is the height of the tooth above the pitch circle to the top of the tooth.

Dedendum

Dedendum is the length of the portion of the tooth from the pitch circle to the base of the tooth.

Addendum Circle (AC)

The AC is an imaginary circle over the tops of the gear teeth.

Outside Diameter (OD)

The OD is the diameter of the AC that contains the tops of the teeth.

Circular Pitch (CP)

The distance between the centers of two adjacent teeth, measured along the pitch circle.

Chordal Pitch

The distance from center to center of teeth measured along a straight line or chord of the pitch circle.

Root Diameter

The diameter of the circle measured at the root of the teeth.

Clearance

Clearance is the margin of space between the top of the tooth on one gear and the bottom of the tooth of the mating gear.

Whole Depth

The whole depth is the total distance from the top of the tooth to the bottom including the clearance.

Working Depth

The working depth is the greatest depth to which a tooth of one gear extends into the tooth space of another gear.

Face

The face of the tooth is the working surface of the tooth above the pitch line.

Thickness

The thickness of the tooth is the width of the tooth, taken as a chord of the pitch circle.

Rack Teeth

The toothed cuts made in a linear or rack gear, which, when meshed with a circular gear or pinion, change circular motion into linear motion. The linear pitch of the rack teeth must equal the circular pitch of the mating gear.

HELICAL SPRINGS

There are three classifications of helical springs: compression, extension, and torsion. Drawings seldom show a true representation of the helical shape; instead, they usually show springs with straight lines. Several methods of spring representation including both helical and straight-line drawings are illustrated in *Figure 4-15*. Also, springs are sometimes shown as single-line drawings, as in *Figure 4-16*.

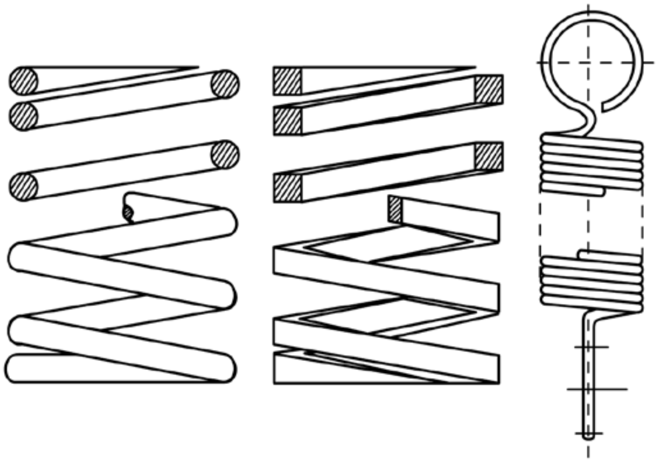

Figure 4-15 — Representation of common types of helical springs.

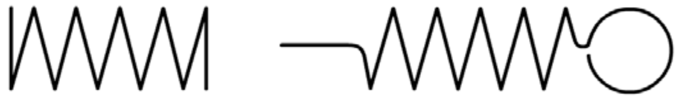

Figure 4-16 — Single line representation of

FINISH MARKS

The military standards for finish marks are set forth in American Society of Mechanical Engineers (ASME) B46.1-2009, Surface Texture (Surface Roughness, Waviness, and Lay). Many metal surfaces must be finished with machine tools for various reasons. The acceptable roughness of a surface depends upon how the part will be used. Sometimes only certain surfaces of a part need to be finished while others are not. A modified symbol (check mark) with a number or numbers above it is used to show these surfaces and to specify the degree of finish. The proportions of the surface roughness symbol are shown in Figure 4-17. On small drawings the symbol is proportionately smaller.

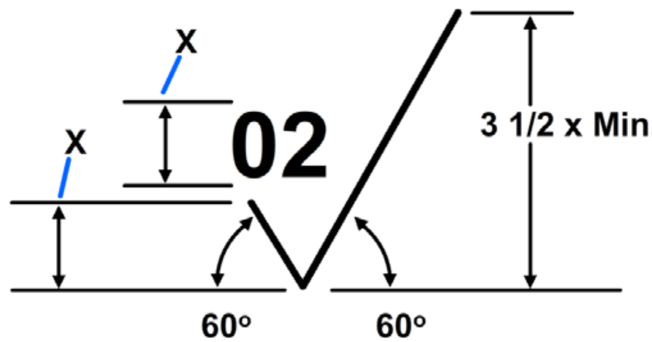

Figure 4-17 — Proportions for a basic finish symbol.

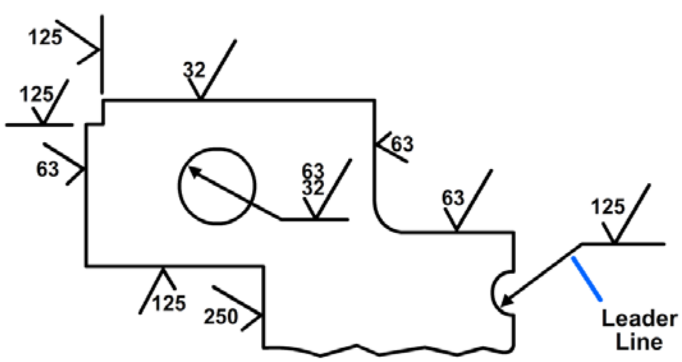

Figure 4-18 — Methods of placing surface roughness symbols.

The number in the angle of the check mark, in this case 02, tells the machinist what degree of finish the surface should have. This number is the root-mean-square value of the surface roughness height in millionths of an inch. In other words, it is a measurement of the depth of the scratches made by the machining or abrading process.

Wherever possible, the surface roughness symbol is drawn touching the line representing the surface to which it refers. If space is limited, the symbol may be placed on an extension line on that surface or on the tail of a leader with an arrow touching that surface, as shown in *Figure 4-18*.

When a part is to be finished to the same roughness all over, a note on the drawing will include the direction “finish all over” along the finish mark and the proper number. An example is FINISH ALL OVER[32]. When a part is to be finished all over but a few surfaces vary in roughness, the surface roughness symbol number or numbers are applied to the lines representing these surfaces and a note on the drawing will include the surface roughness symbol for the rest of the surfaces. For example, ALL OVER EXCEPT AS NOTED (*Figure 4-19*).

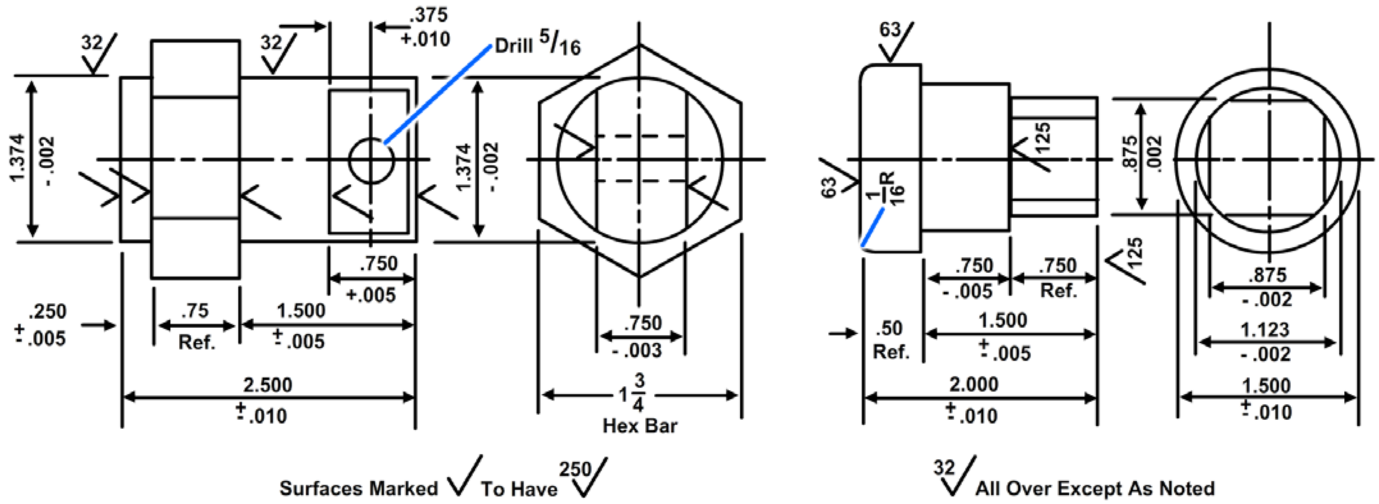

Figure 4-19 — Typical examples of the surface roughness symbol use.

STANDARDS

American industry has adopted the standard, American National Standards Institute (ANSI) Y14.5M-2009, Dimensioning and Tolerancing. This standard is used in all blueprint production, whether the print is drawn by a human hand or by computer-aided drawing (CAD) equipment. It standardizes the production of prints from the simplest hand-made job on site to single or multiple-run items produced in a machine shop with computer-aided manufacturing (CAM). For further information, refer to ANSI Y14.5M-2009 and to Introduction to Geometrical Dimensioning and Tolerancing, Lowell W. Foster, National Tooling and Machining Association, Fort Washington, MD, 1986.

The standards listed in *Table 4-1* contain most of the information on symbols, conventions, tolerances, and abbreviations used in shop or working drawings:

Table 4-1 — Common Standards

Number	Title
ANSI Y14.5M-2009	Dimensioning and Tolerancing
ANSI Y14.6-2001	Screw Thread Representation
ASME B46.1-2009	Surface Texture (Surface Roughness, Waviness, and Lay)
ASME Y14.38-2007	Abbreviations and Acronyms for Use on Drawings and Related Documents

End of Chapter 4

Machine Drawing

Review Questions

4-1. Which of the following terms describes a variation in a machine drawing?

A. Fillet
B. Major diameter
C. Minor diameter
D. Tolerance

4-2. In what dimensioning method are the minimum and maximum measurements stated?

A. Bilateral
B. Limit
C. Metric fillet
D. Unilateral

4-3. Which of the following terms describes a surface, line, or point from which a geometric position is to be determined?

A. Datum
B. Slot
C. Switch
D. Tatum

4-4. In a cast, what feature increases the strength of a metal corner?

A. Fillet
B. Keyseat
C. Slide
D. Slot

4-5. What feature describes a slot or groove on the outside of a part into which the key fits?

A. Fillets
B. Slots and slides
C. Key
D. Keyseat

4-6. What part of a thread designator number identifies the nominal or outside diameter of a thread?

A. The first
B. The second
C. The fourth
D. The letter designator

4-7. Which of the following screw-thread series are the most widely used?

A. European Coarse and European Fine
B. European Coarse and National Standard
C. National Coarse and National Fine
D. National Metric and National Standard

4-8. Which of the following terms distinguishes threads from each other by the amount of tolerance and/or allowance specified?

A. Class of pitch
B. Class of thread
C. National Standard
D. Thread pitch

4-9. Which of the following terms describes the surface of the thread that corresponds to the minor diameter of an external thread and the major diameter of an internal thread?

A. External threads
B. Axis
C. Crest
D. Root

4-10. Which of the following terms describes the largest measurement of the external or internal thread?

A. Crest
B. Major diameter
C. Minor diameter
D. Pitch

4-11. Which of the following definitions describes the term lead?

A. The distance a screw thread advances on one turn, parallel to the axis
B. The distance the thread is cut from the crest to its root
C. The distance from the thread's pitch to its root dimension
D. The distance between external threads

4-12. Which of the following terms defines the distance from the root of the thread to the crest, when measured perpendicularly to the axis?

A. Depth
B. Helix
C. Lead
D. Pitch

4-13. When sketching gears on a machine drawing, how many teeth are drawn?

A. One quarter
B. One half
C. Enough to identify the necessary dimensions
D. All

4-14. Which of the following terms expresses the number of teeth on the gear divided by the diametral pitch?

A. Pitch diameter
B. Outside diameter
C. Number of teeth
D. Addendum circle

4-15. Which of the following terms describes the imaginary circle that divided the teeth into top and bottom lands?

A. Addendum circle
B. Chordal pitch
C. Circular pitch
D. Pitch circle

4-16. Which of the following terms describes the imaginary circle over the tops of the teeth?

A. Addendum circle
B. Chordal pitch
C. Circular pitch
D. Pitch circle

4-17. Clearance is the marginal space between the top of one tooth and what other component?

A. Adjacent tooth
B. Gear axle
C. Bottom of the tooth on the mating gear
D. Top of the tooth on the mating gear

4-18. What term identifies the working surface of the tooth above the pitch line?

A. Addendum
B. Dedendum
C. Face
D. Thickness

4-19. What term describes the tooth cuts made in linear or rack gear?

A. Pitch circle
B. Working depth
C. Rack face
D. Rack teeth

4-20. Which of the following are the three classifications of helical springs?

A. Compression, extension, and double
B. Compression, extension, and torsion
C. Single, double, and triple
D. Single, extension, and torsion

4-21. What type of line is used to show springs on a drawing?

A. Broken
B. Curved
C. Spiral
D. Straight

4-22. What standard is used for finish marks?

A. ANSI 32.9-2006
B. ASME 14.3M
C. ASME B46.1-2009
D. IEEE 3009

4-23. Which of the following symbols is used to specify the degree of surface finish?

A. Check mark
B. Parenthesis
C. Rectangle
D. Triangle

4-24. On a finish symbol, the number indicates the degree of finish to what surface height, in inches?

A. Tenths
B. Hundredths
C. Thousandths
D. Millionths

4-25. What standard has the American industry adopted for blueprint production?

A. IEEE 3009
B. ANSI 32.9-2006
C. ANSI Y14.5M-2009
D. ASME 14.3M

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CHAPTER 5

PIPING SYSTEMS

Any drawing prepared by or for the Department of Defense must be prepared following the latest military standard, Department of Defense Standard, and applicable Naval Facilities Engineering Command design manuals. Many drawings continue in use for years; occasionally, you will have to work with drawings containing obsolete symbols. Look for a legend on the drawings; it should help you identify unfamiliar symbols. If there is no legend, studying the drawing carefully should enable you to interpret the meaning of unfamiliar symbols and abbreviations. This chapter discusses the symbols and markings used in the production of piping drawings and prints.

LEARNING OBJECTIVES

When you have completed this chapter, you will be able to do the following:

1. Recognize piping blueprints.
2. Identify shipboard piping blueprints.

PIPING DRAWINGS

Water was at one time the only important fluid that was moved from one point to another in pipes. Today almost every conceivable fluid is handled in pipes during its production, processing, transportation, and use. The age of atomic energy and rocket power has added fluids such as liquid metals, oxygen, and nitrogen to the list of more common fluids such as oil, water, gases, and acids that are being carried in piping systems today. Piping is also used as a structural element in columns and handrails. For these reasons contractors, manufacturers, and engineers should become familiar with pipe drawings. Piping drawings show the size and location of pipes, fittings, and valves. A set of symbols has been developed to identify these features on drawings.

Two methods of projection used in pipe drawings are orthographic and isometric (pictorial). Orthographic projection is used to show multiple views of an object in a single plane. Isometric projection is used to show a three-dimensional view of an object in single plane.

Orthographic Pipe Drawings

Single- and double-line orthographic pipe drawings (*Figures 5-1 and 5-2*) are recommended for showing single pipes either straight or bent in one plane only. This method also may be used for more complicated piping systems.

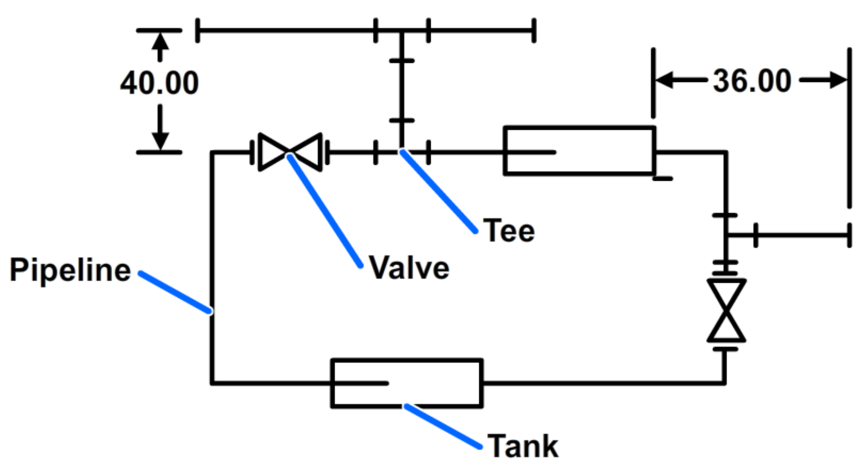


Figure 5-1 — Single-line orthographic pipe drawing.

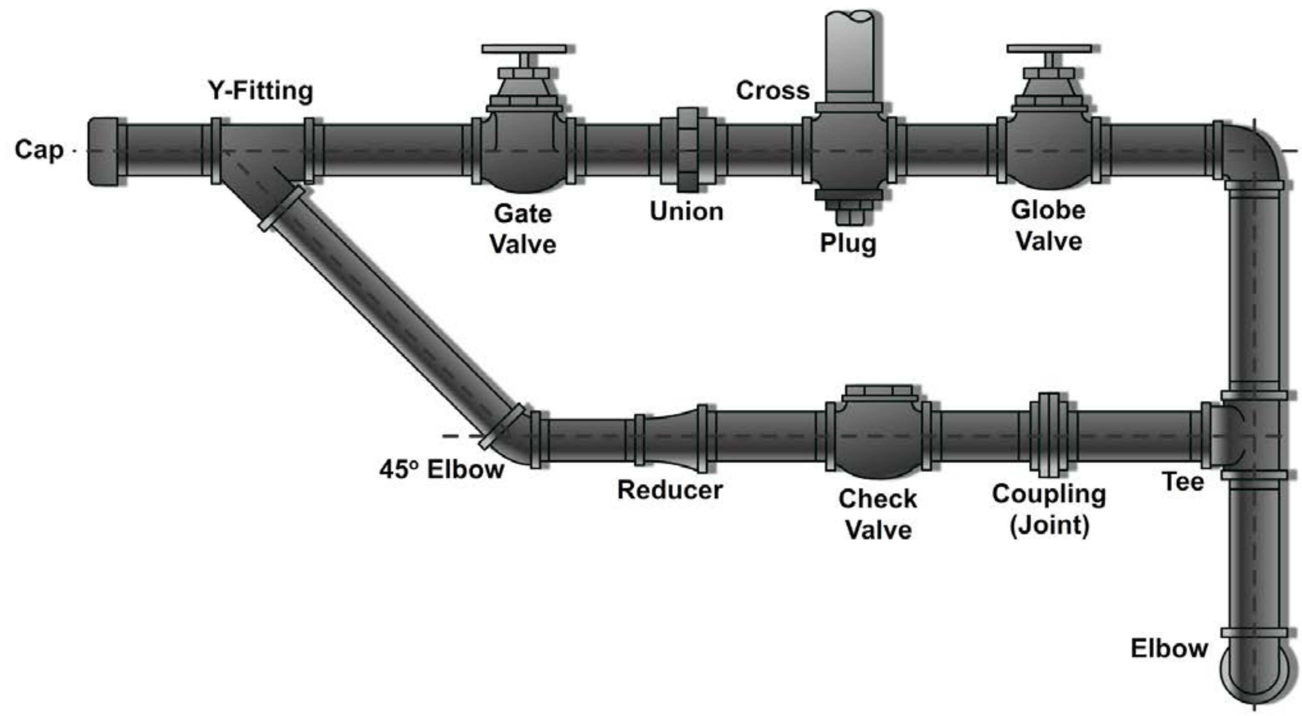


Figure 5-2 — Double-line orthographic pipe drawing.

Isometric (Pictorial) Pipe Drawings

Pictorial projection is used for all pipes bent in more than one plane, and for assembly and layout work. The finished drawing is easier to understand in the pictorial format.

Single-line drawings show the arrangement of pipes and fittings. A single-line isometric (pictorial) drawing of *Figure 5-1* is illustrated in *Figure 5-3*. The center line of the pipe is drawn as a thick line to which the valve symbols are added.

Single-line drawings take less time and show all information required to lay out and produce a piping system.

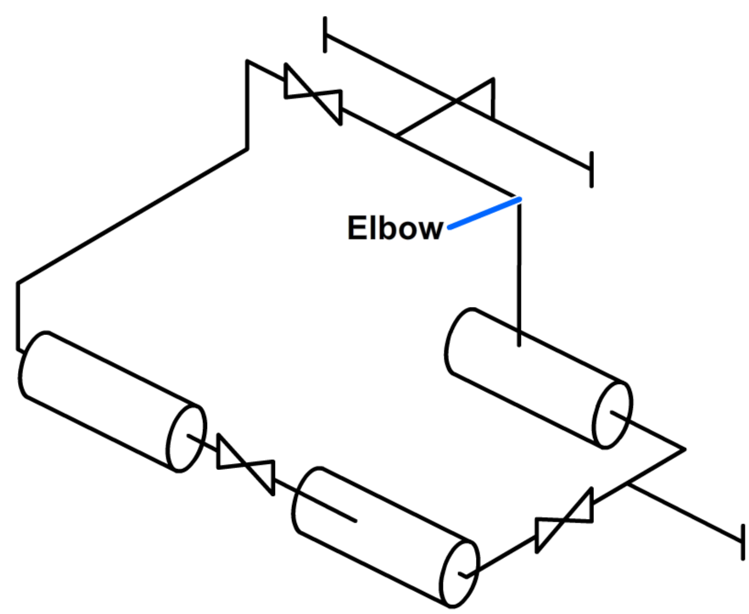


Figure 5-3 — Single-line isometric (pictorial) piping drawing.

Double-line pipe drawings require more time to draw and therefore are not recommended for production drawings. An example of a double-line pictorial pipe drawing is shown in *Figure 5-4*. They are generally used for catalogs and similar applications where visual appearance is more important than drawing time.

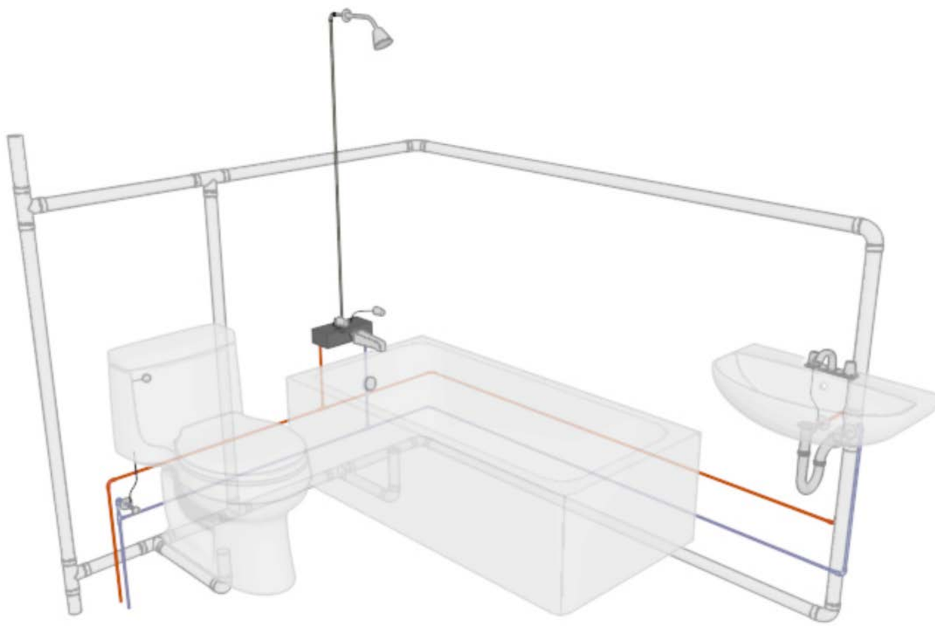


Figure 5-4 — Double-line pictorial piping drawing.

Crossings

The crossing of pipes without connections is normally shown without interrupting the line representing the hidden line (*Figure 5-5*). But when there is a need to show that one pipe must pass behind another, the line representing the pipe farthest from the viewer will be shown with a break, or interruption, where the other pipe passes in front of it, as shown in *Figure 5-5*.

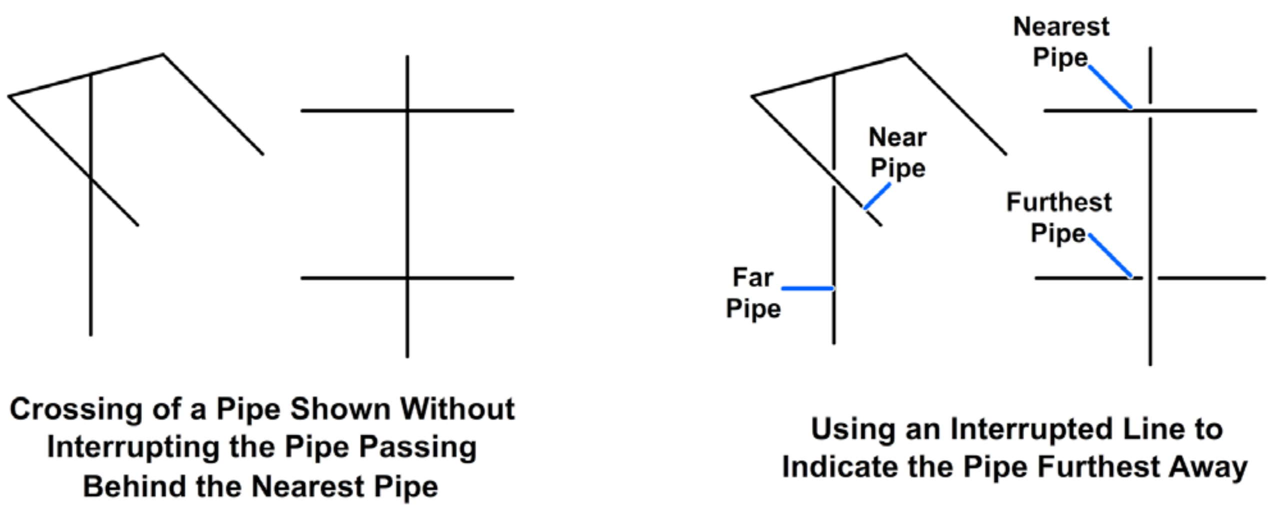


Figure 5-5 — Crossing of pipes.

Connections

Permanent connections, whether made by welding or other processes such as gluing or soldering, should be shown on the drawing by a heavy dot (*Figure 5-6*). A general note or specification is used to describe the type of connection.

Detachable connections are shown by a single thick line (*Figures 5-6 and 5-7*). The specification, a general note, or bill of material will list the types of connections such as flanges, unions, or couplings and whether the fittings are flanged or threaded.

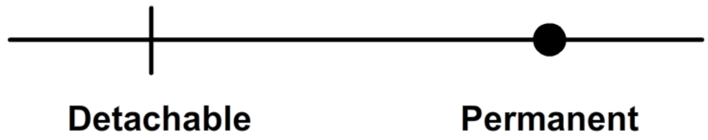


Figure 5-6 — Pipe connection.

Fittings

If standard symbols for fittings such as tees, elbows, and crossings are not shown on a drawing, they are represented by a continuous line. They define the size of the pipe, the method of branching and coupling, and the purpose of the pipe. This information is important because the purpose of the pipe determines what piping material to use. The inverse is also true; the piping material will determine how it can be used. A circular symbol for a tee or elbow may be used to indicate the piping coming toward or moving away from the viewer, as shown in *Figure 5-8*.

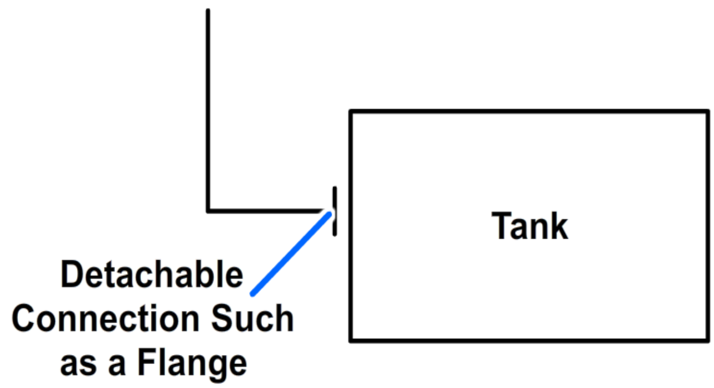


Figure 5-7 — Adjoining apparatus.

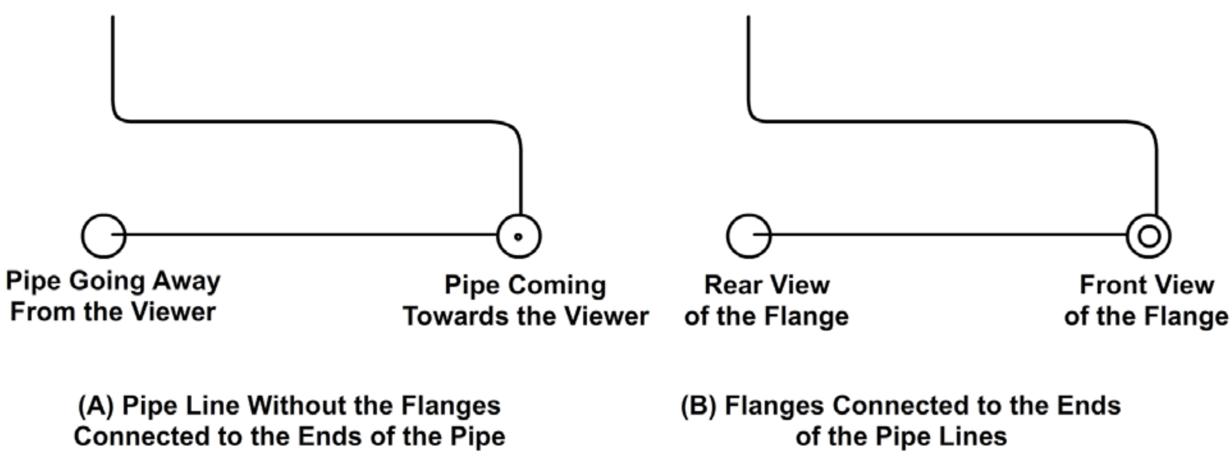


Figure 5-8 — Indicating ends of pipe and fittings.

Symbols and Markings

The American Society for Testing and Materials (ASTM) Standard F1000-13 lists mechanical symbols used on piping prints other than those for aeronautical craft, aerospacecraft, and spacecraft. Many of these symbols are listed in the Aviation Hydraulics Manual, Naval Air Systems Command (NAVAIR) 01-1A-17. Some of the common plumbing and piping symbols from the ASTM Standard F1000-13 and the Symbols, Piping Systems, Naval Sea Systems Command (NAVSEA) Standard Drawing 803-5001049 are illustrated in *Figure 5-9*.

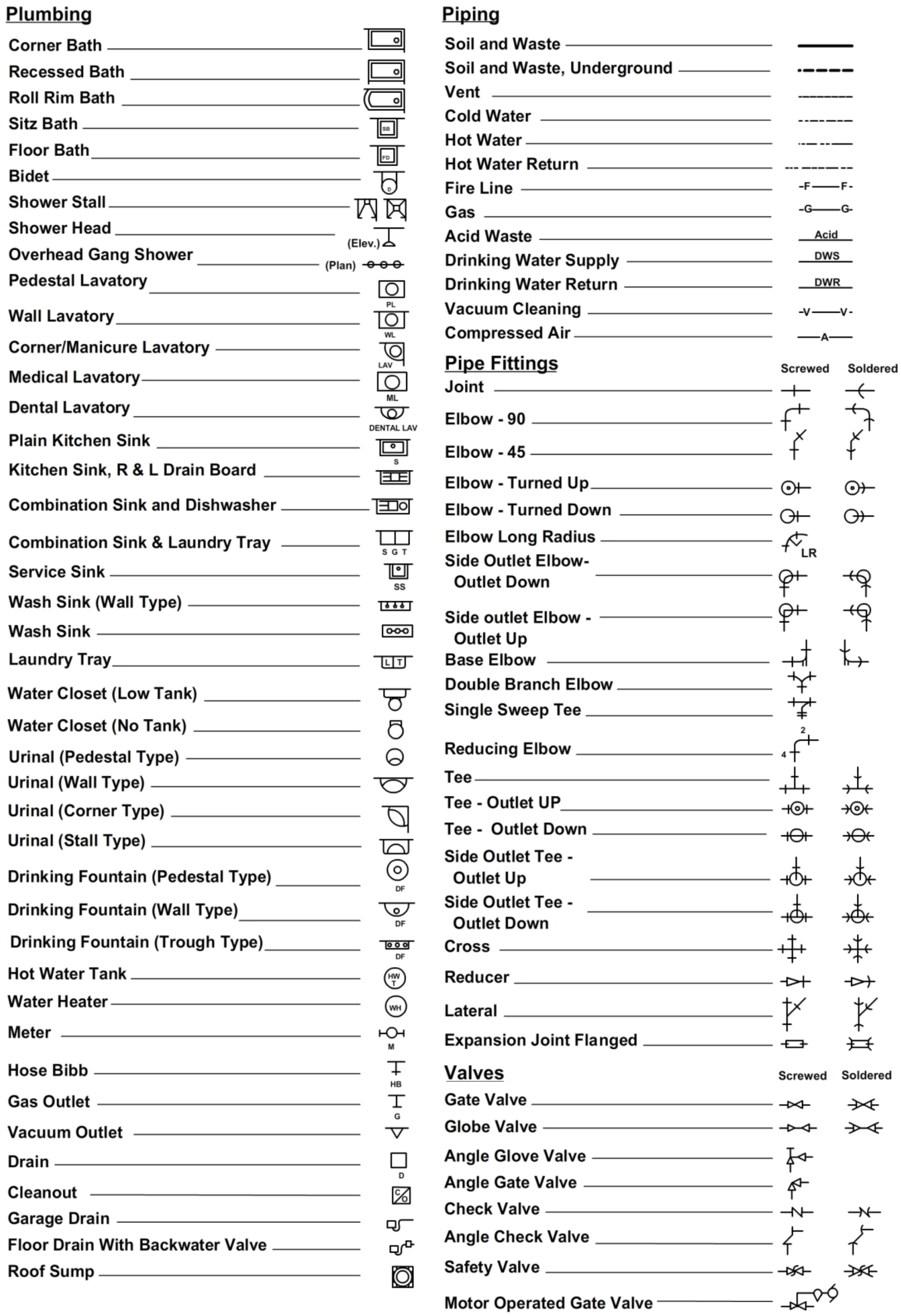


Figure 5-9 — Common plumbing and piping symbols.

Notice that the symbols may show the type of connections (screwed, flanged, welded, and so forth) and fittings, valves, gauges, and items of the equipment. When an item is not covered in the standards, the responsible activity designs a suitable symbol and provides an explanation in a note.

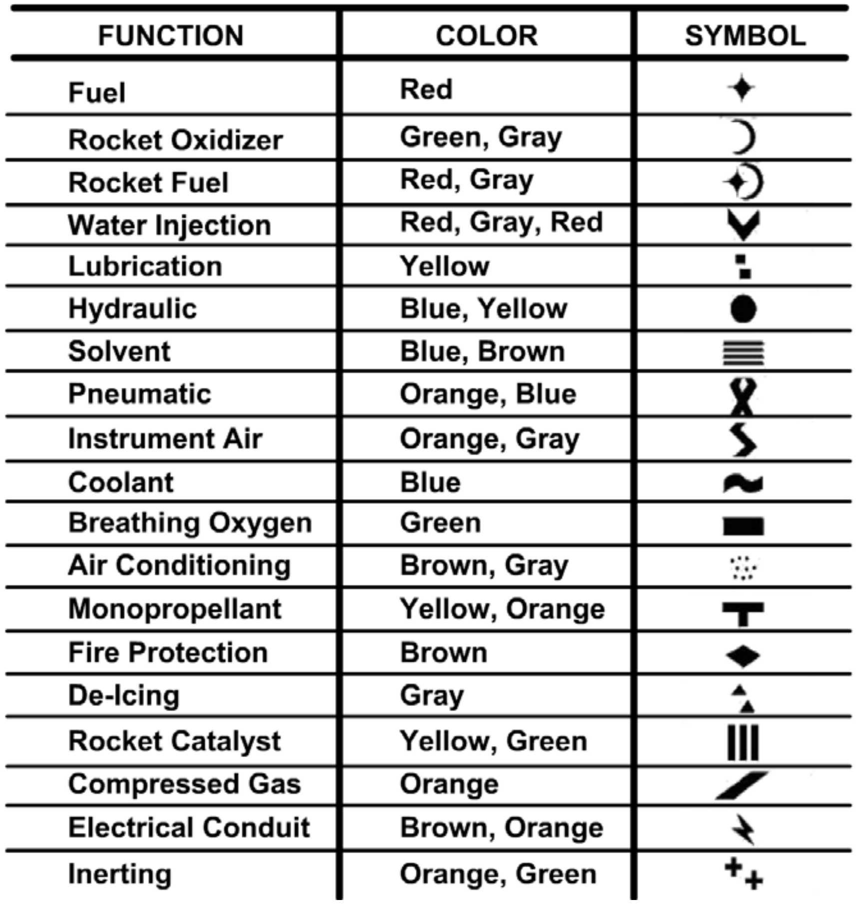
When a print shows more than one piping system of the same kind, additional letters are added to the symbols to differentiate between the systems. Notice the letters on the drinking water supply and drinking water return lines in *Figure 5-9*.

The Military Standard 101 (MIL-STD-101) establishes the color code used to identify piping carrying hazardous fluids. It applies to all piping installations in naval industrial plants and shore stations where color coding is used. While all valve wheels on hazardous fluid piping must be color coded, color coding on the piping itself is optional. The warning colors painted on valve wheels and pipe lines carrying hazardous fluids is illustrated in *Table 5-1*.

Table 5-1 — Warning Colors

Class	Standard Color	Identification Marking	Class of Material
A	**Yellow**	FLAM	**FLAMMABLE MATERIALS**. All materials known ordinarily as flammables or combustibles. Of the chromatic colors, yellow has the highest coefficient of reflection under white light and can be recognized under the poorest conditions of illumination.
B	**Brown**	TOXIC	**TOXIC AND POISONOUS MATERIALS**. All materials extremely hazardous to life or health under normal conditions as toxics or poisons.
C	**Blue**	AAHM	**ANESTHETICS AND HARMFUL MATERIALS**. All materials productive of anesthetic vapors and all liquid chemicals and compounds hazardous to life and property but not normally productive of dangerous quantities of fumes or vapors.
D	**Green**	OXYM	**OXIDIZING MATERIALS**. All materials which readily furnish oxygen for combustion, and fire producers which react explosively or with the evolution of heat in contact with many other materials.
E	**Gray**	PHDAN	**PHYSICALLY DANGEROUS MATERIALS**. All materials not dangerous in themselves, but which are asphyxiating in confined areas or which are generally handled in a dangerous physical state of pressure or temperature.
F	**Red**	FPM	**FIRE PROTECTION MATERIALS**. Materials provided in piping systems or in compressed gas cylinders for use in fire protection.

Fluid lines in aircraft are marked according to Markings, Functions, and Hazardous Designations of Hose, Pipe, and Tube Lines for Aircraft Missile, and Space Systems, Military Standard (MIL-STD) 1247D. The types of aircraft fluid lines with the associated color code and symbol for each type is illustrated in *Figure 5-10*. Aircraft fluid lines are marked with an arrow to show direction of flow and hazard marking. The following paragraphs describe the markings for the four general classes of hazards, and *Table 5-2* shows examples of the hazards in each class.



FUNCTION	COLOR	SYMBOL
Fuel	Red	
Rocket Oxidizer	Green, Gray	
Rocket Fuel	Red, Gray	
Water Injection	Red, Gray, Red	
Lubrication	Yellow	
Hydraulic	Blue, Yellow	
Solvent	Blue, Brown	
Pneumatic	Orange, Blue	
Instrument Air	Orange, Gray	
Coolant	Blue	
Breathing Oxygen	Green	
Air Conditioning	Brown, Gray	
Monopropellant	Yellow, Orange	
Fire Protection	Brown	
De-Icing	Gray	
Rocket Catalyst	Yellow, Green	
Compressed Gas	Orange	
Electrical Conduit	Brown, Orange	
Inerting	Orange, Green	

Figure 5-10 — Aircraft fluid line markings.

Table 5-2 — Hazards Associated with Various Fluids

CONTENTS	HAZARD
Air (under pressure)	PHDAN
Alcohol	FLAM
Carbon dioxide	PHDAN
Freon	PHDAN
Gaseous oxygen	PHDAN
Liquid nitrogen	PHDAN
Liquid oxygen	PHDAN
Liquid Petroleum Gas (LPG)	FLAM
Nitrogen gas	PHDAN
Oils and greases	FLAM
JP-4	FLAM
Trichloroethylene	AAHM

SHIPBOARD PIPING PRINTS

There are various types of shipboard piping systems. An example of a fuel oil service tank system is illustrated in *Figure 5-11*. Notice the drawing uses the standard symbols shown in *Figure 5-9*. Some small piping diagrams do not include a symbol list; therefore, you must be familiar with the standard symbols to interpret these diagrams.

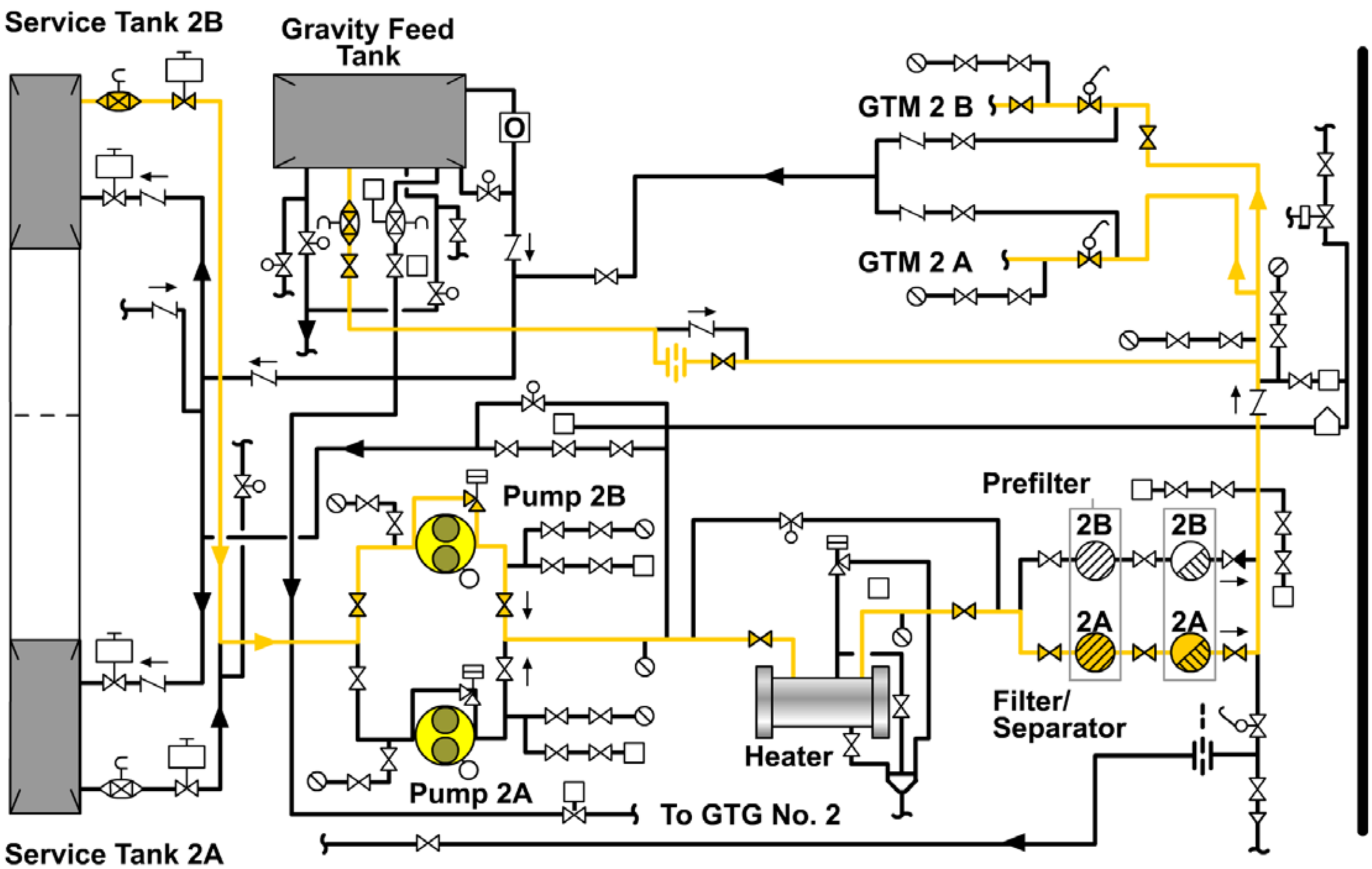


Figure 5-11 — Example of a fuel oil service tank.

Standard symbols are generally not used in drawings of shipboard piping systems found in operation and maintenance manuals. Each fitting in those systems may be drawn in detail (pictorially), as shown in *Figure 5-12*, or a block diagram arrangement (*Figure 5-13*) may be used.

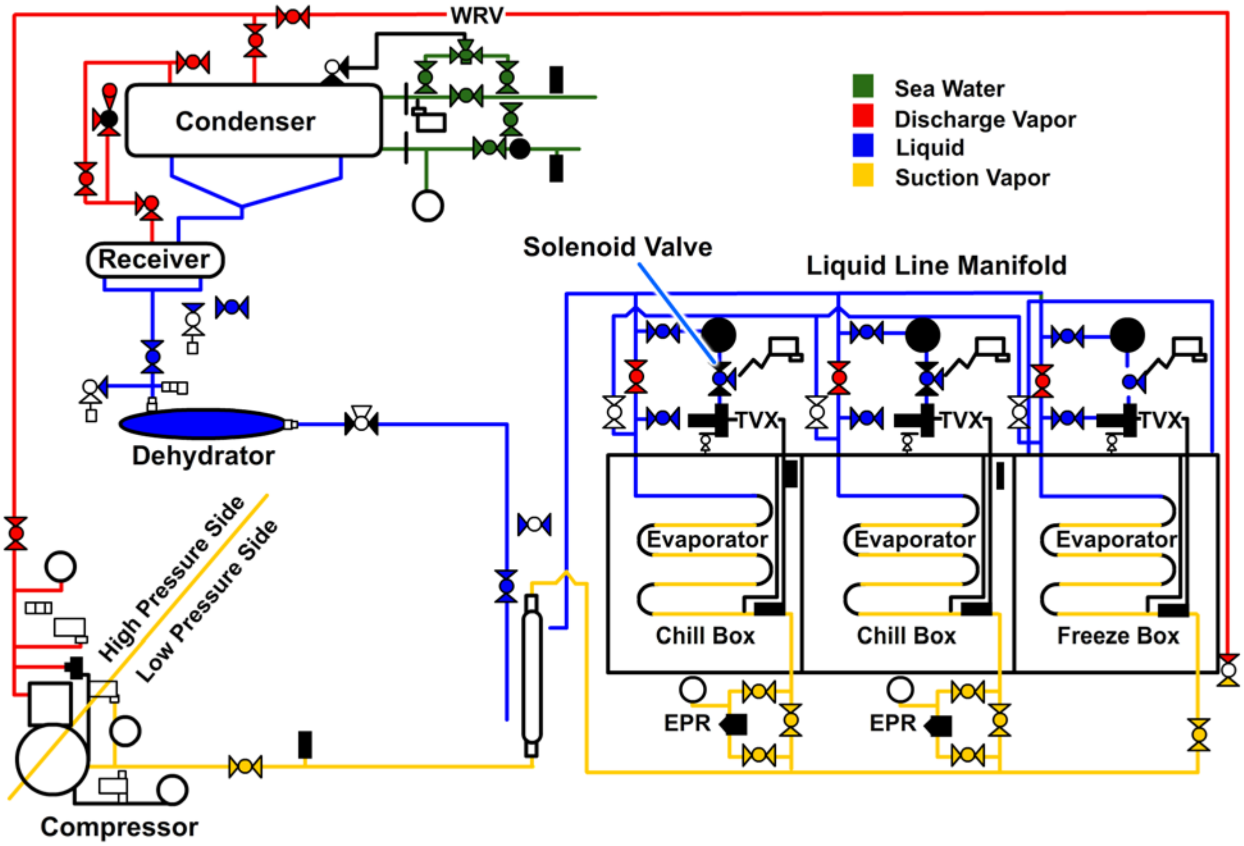


Figure 5-12 — Diagram of an R-134a refrigeration system.

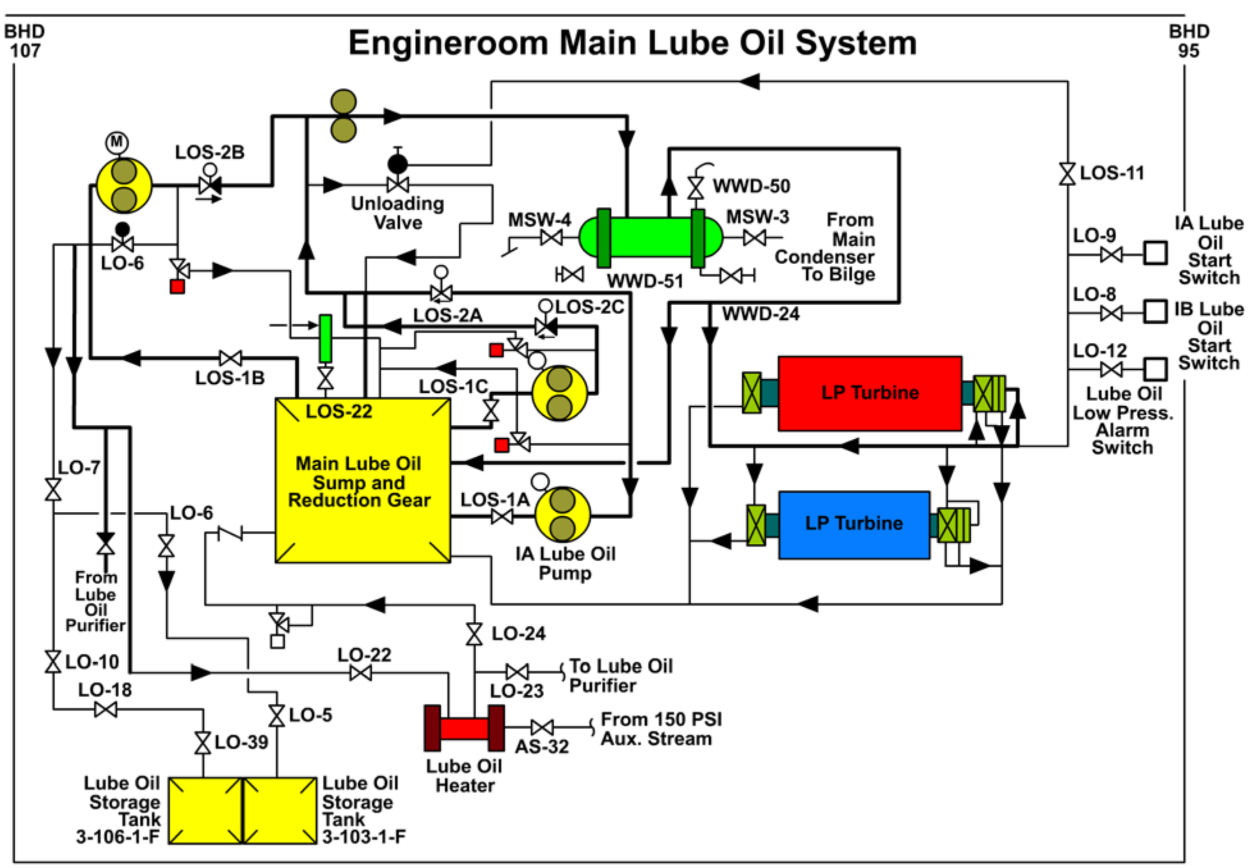


Figure 5-13 — Typical main lube oil system.

Hydraulic Prints

The Navy uses hydraulic systems, tools, and machines in various applications. Hydraulic systems are used on aircraft and aboard ship to activate weapons, navigational equipment, and remote controls of numerous mechanical devices. Shore stations use hydraulically operated shop equipment for maintenance and repair. Hydraulic systems are also used in construction, automotive, and weight-handling equipment. Basic hydraulic principles are discussed in the nonresident training course Fluid Power*,* Naval Education and Training (NAVEDTRA) 14105A.

To help you distinguish one hydraulic line from another, the lines are designated according to their function within the system. In general, hydraulic lines are designated as follows:

Supply Lines

Supply lines, also called suction lines, carry fluid from the reservoir to the pumps.

Pressure Lines

These lines carry only pressure. The pressure lines lead from the pumps to a pressure manifold and from the pressure manifold to the various selector valves, or they may lead directly from the pump to the selector valve.

Operating Lines

The operating lines, also called working lines, alternate carrying pressure to an actuating unit and returning fluid from the actuating unit. Each line is identified according to the specific function.

Return Lines

Return lines return fluid from any portion of the system to a reservoir.

Vent Lines

Vent lines carry excess fluid overboard or into another receptacle.

Hydraulic Symbols

The NAVAIR 01-1A-17, ASTM Standard F1000-13, and the NAVSEA Standard Drawing 803-5001049 list some of symbols that are used on hydraulic diagrams. *Figure 5-14* shows the outline of basic hydraulic symbols. In the actual hydraulic diagrams, the basic symbols are often improved, showing a cutaway section of the unit.

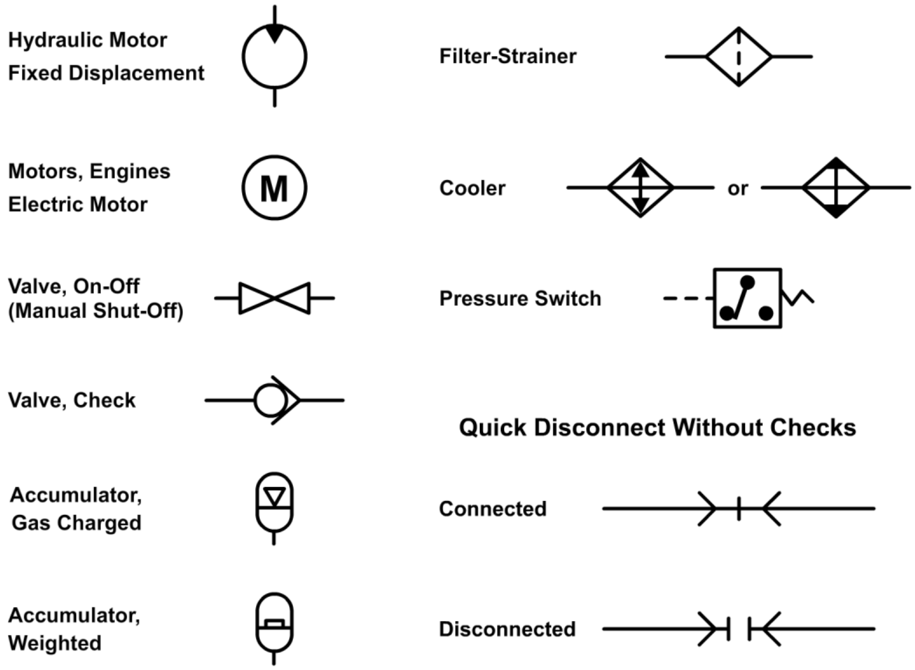


Figure 5-14 — Basic hydraulic symbols.

The lines on the hydraulic diagram shown in *Figure 5-15* are identified as to purpose, and the arrows point the direction of flow. Some additional symbols and conventions used on aircraft hydraulic and pneumatic systems and in fluid power diagrams are shown in *Figure 5-16*.

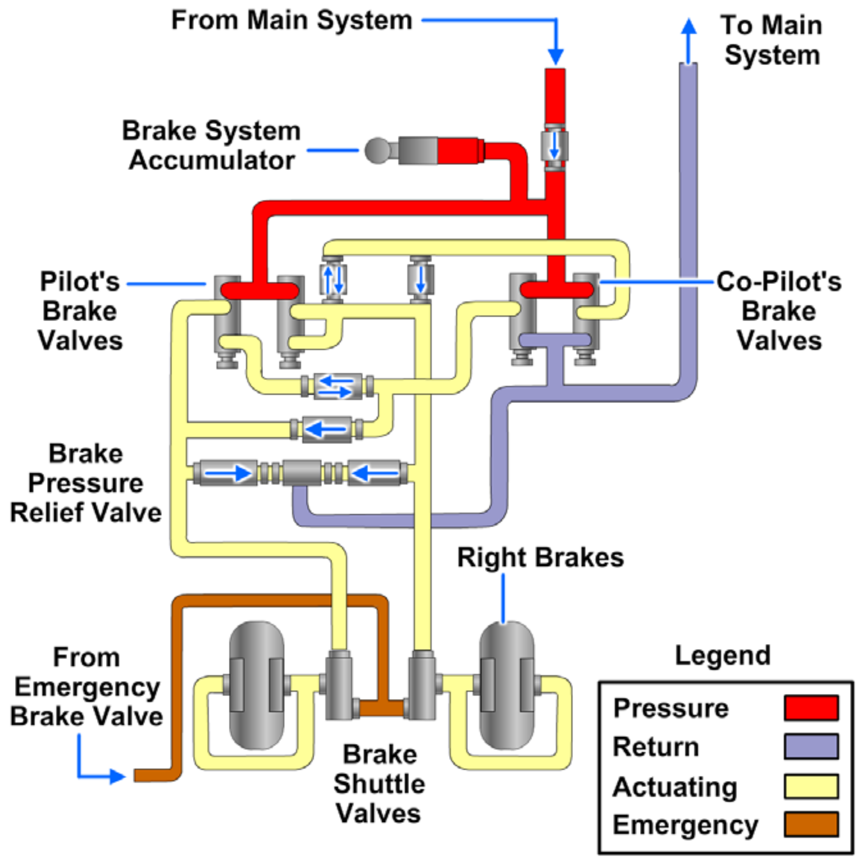


Figure 5-15 — Typical power brake control valve system.

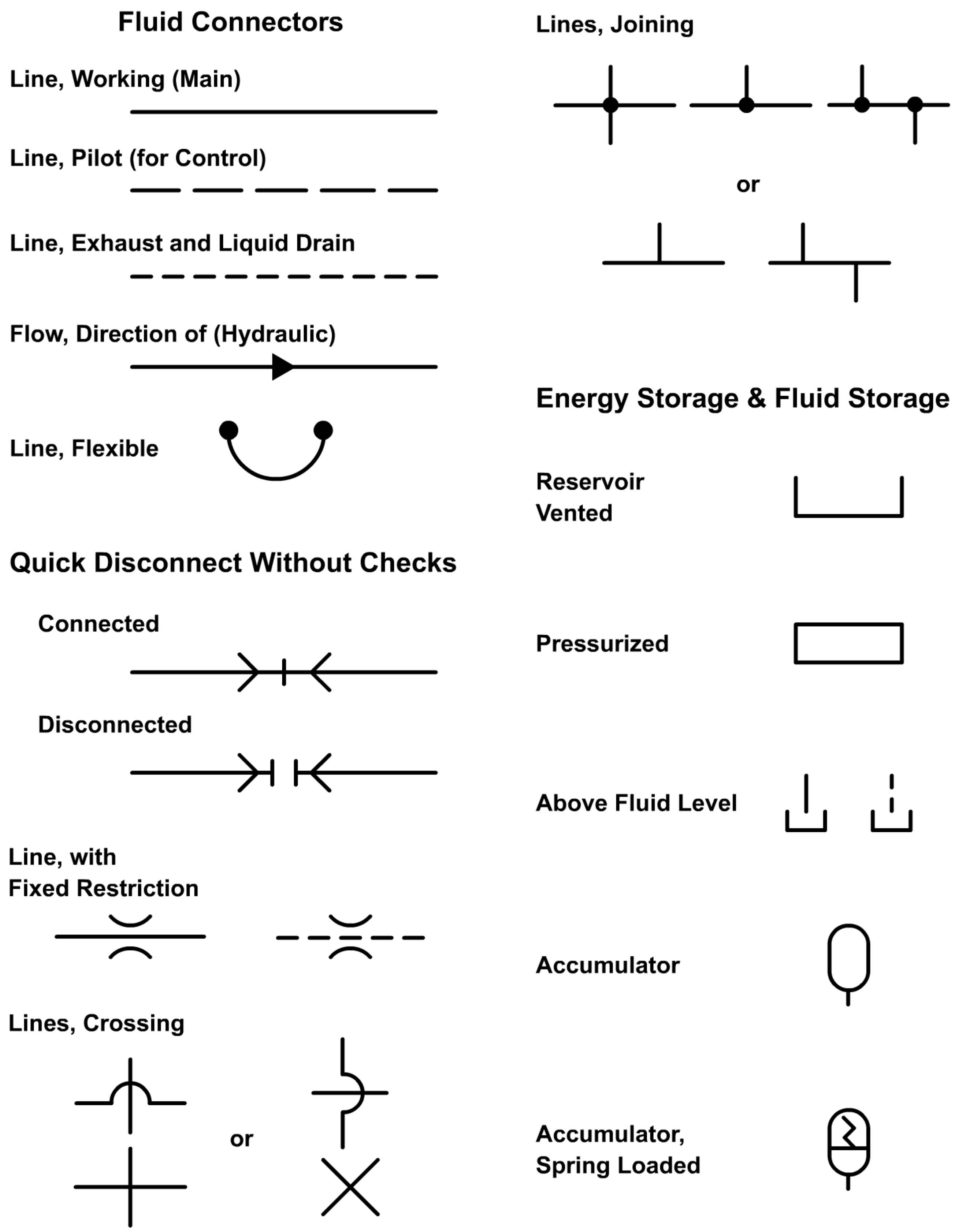


Figure 5-16 — Fluid power symbols.

Plumbing Prints

Plumbing prints use many of the standard piping symbols shown in *Figure 5-9*. The ASTM Standard F1000-13 and the NAVSEA Standard Drawing 803-5001049 list other symbols that are used in plumbing prints.

A pictorial drawing of a bathroom is shown in *Figure 5-17*. In the drawing, all that is normally placed in or under the floor has been exposed to show a complete picture of the plumbing, connections, and fixtures.

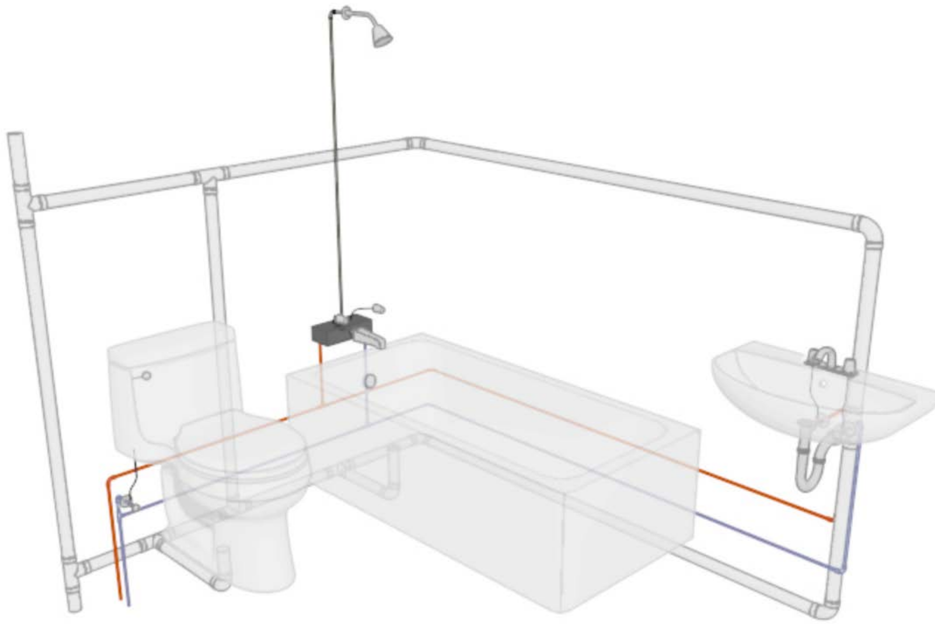


Figure 5-17 — Pictorial view of a typical bathroom.

Figure 5-18 is an isometric diagram of the piping in the bathroom shown in *Figure 5-17*. To interpret the isometric plumbing diagram shown in *Figure 5-18*, start at the lavatory (sink). You can see a symbol for a P-trap that leads to a tee connection. The portion of the tee leading upward leads to the vent and the portion leading downward leads to the drain. You can follow the drain pipe along the wall until it reaches the corner, where a 90-degree elbow is connected to bring the drain around the corner. Another section of piping is connected between the elbow and the next tee. One branch of the tee leads to the P-trap of the bathtub, and the other to the tee necessary for the vent (pipe leading upward between the tub and water closet). It then continues on to the Y-bend with a heel (a special fitting) that leads to a 4-inch main house drain. The vent pipe runs parallel to the floor drain, slightly above the lavatory.

Figure 5-18, is an isometric drawing of the water pipes, one for cold water and the other for hot water. These pipes are connected to service pipes in the wall near the soil stack, and they run parallel to the drain and vent pipes. Look back at *Figure 5-17* and you can see that the water service pipes are located above the drain pipe.

A floor plan of a small house showing the same bathroom, including the locations of fixtures and piping, is shown in *Figure 5-19*.

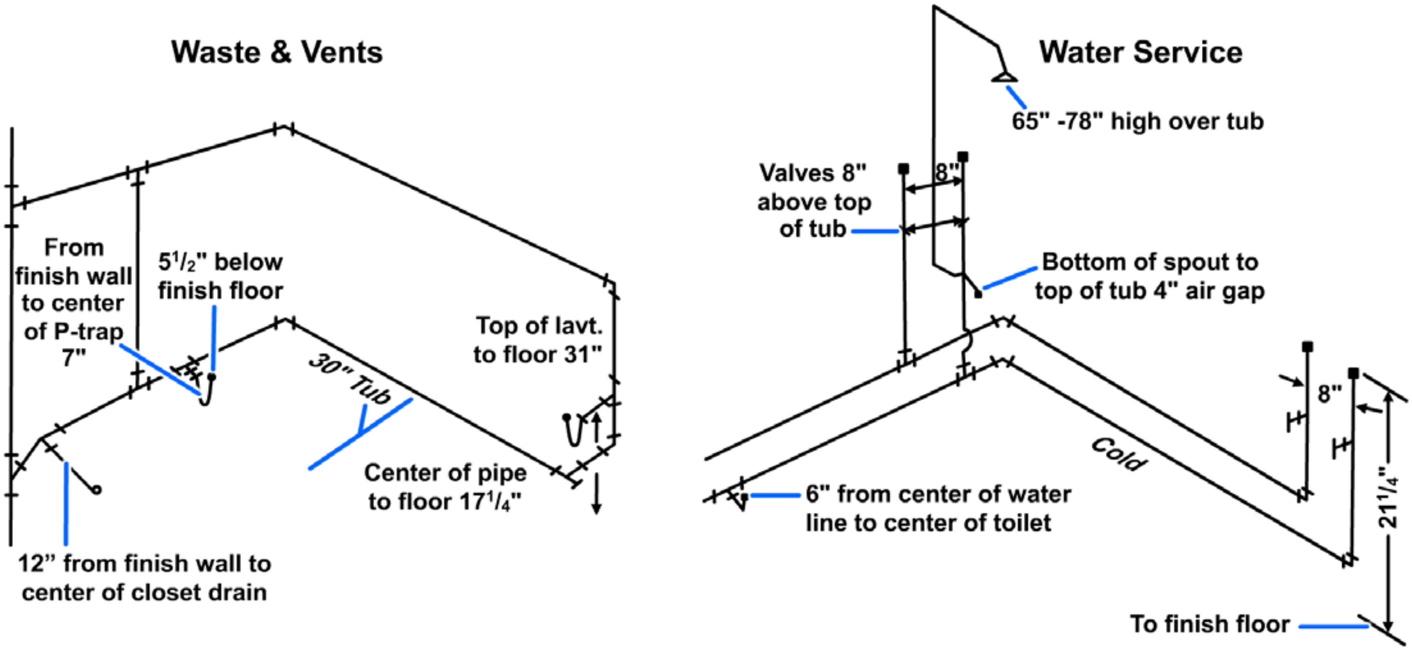


Figure 5-18 — Isometric diagram of a bathroom showing waste, vents, and water service.

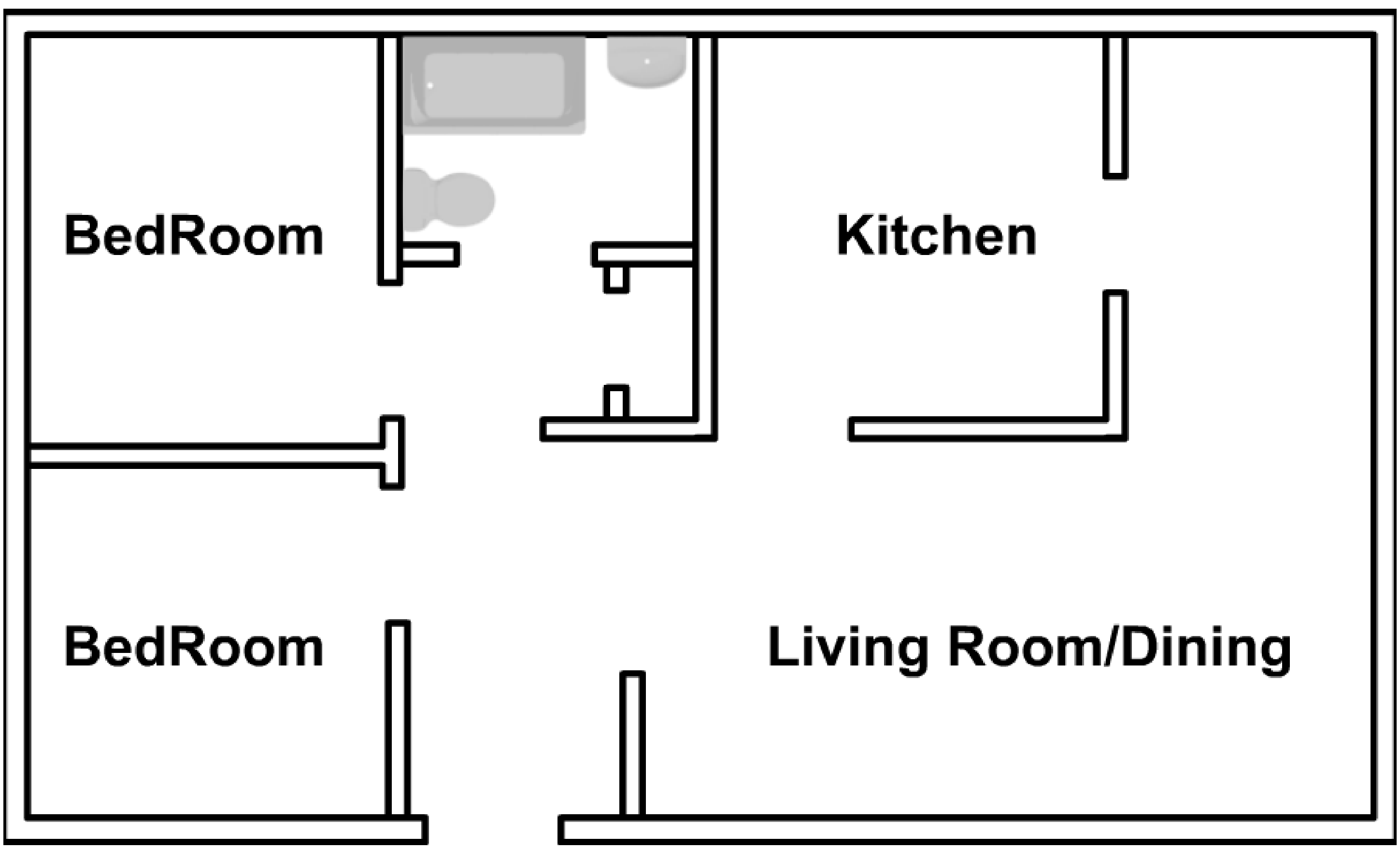


Figure 5-19 — Typical floor plan.

Reading Piping Designations

To learn how to interpret piping designations, refer to *Figure 5-20*. Each opening in a fitting is identified with a letter. For example, the fitting at the right end of the middle row shows a cross reduced on one end of the run and on one outlet. On crosses and elbows, always read the largest opening first and then follow the alphabetical order. So, if the fitting has openings sized 2½ by 1½ by 2½ by 1½ inches, you should read them in this order: A = 2½, B = 1½, C = 2½, and D = 1½ inches.

On tees, 45-degree Y-bends or laterals, and double-branch elbows, you always read the size of the largest opening of the run first, the opposite opening of the run second, and the outlet last. For example, look at the tee in the upper right corner of *Figure 5-20* and assume it is sized 3 by 2 by 2 inches. You would read the openings as A = 3, B = 2, and C = 2 inches.

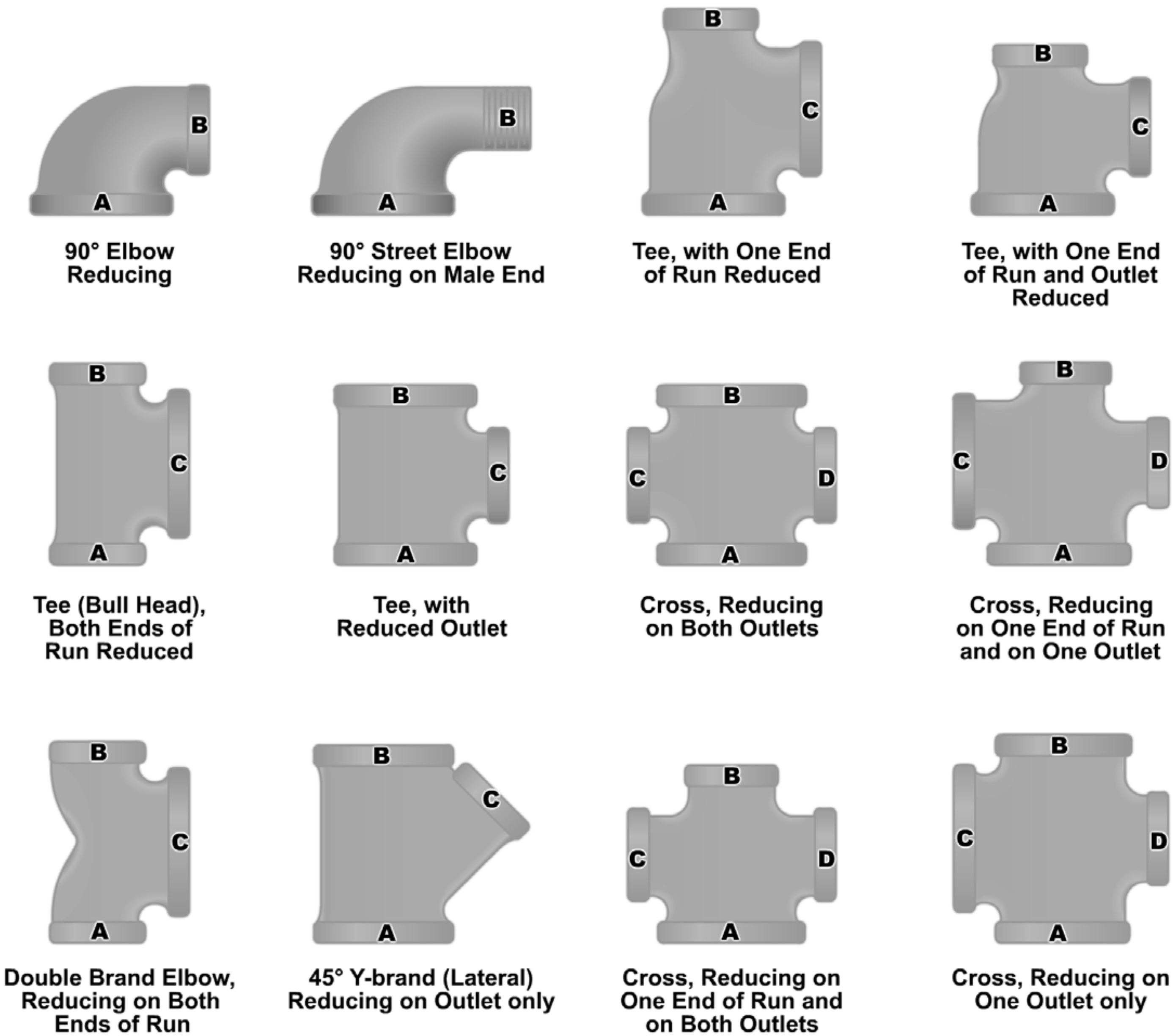


Figure 5-20 — How to read fittings.

End of Chapter 5

Piping Systems

Review Questions

5-1. Piping drawings show the size and location of pipes, fittings, and what other device?

A. Plug
B. Pump
C. Strainer
D. Valve

5-2. Which of the following methods of projection are used in pipe drawings?

A. Isometric and topographic
B. Orthographic and isometric
C. Orthographic and topographic
D. Topographic and view

5-3. What type of drawing is recommended for showing pipes either straight or bent in one plane?

A. Isometric
B. Orthographic
C. Topographic
D. View

5-4. What type of drawing is recommended for showing all pipes either straight or bent in more than one plane?

A. Isometric
B. Orthographic
C. Topographic
D. View

5-5. On a drawing that shows the crossing of pipes, what indicates the pipe farthest from the viewer where the other pipe passes in front of it?

A. Arrow
B. Break
C. Circle
D. Square

5-6. What Military Standard establishes the color code used to identify piping carrying hazardous fluids?

A. 101
B. 303
C. 505
D. 707

5-7. What warning marking identifies materials that are extremely hazardous to life or health?

A. AAHM
B. FLAM
C. PHDAN
D. TOXIC

5-8. What warning marking identifies a material that is NOT dangerous by itself, but is asphyxiating in confined areas?

A. AAHM
B. FLAM
C. PHDAN
D. TOXIC

5-9. Standard symbols are generally NOT used in drawings of shipboard systems found in which of the following types of manuals?

A. Operation and maintenance
B. Operation and supply
C. Supply and maintenance
D. Training and supply

5-10. What hydraulic line is also called a suction line?

A. Operating
B. Pressure
C. Supply
D. Vent

5-11. What hydraulic line alternately carries pressure to an actuating unit and returns fluid from the actuating unit?

A. Operating
B. Pressure
C. Supply
D. Vent

5-12. What hydraulic line carries excess fluid overboard or into another receptacle?

A. Operating
B. Pressure
C. Supply
D. Vent

5-13. What American Society for Testing and Materials Standard lists the symbols used on hydraulic diagrams?

A. 01-1A-17
B. 14105A
C. 803-50010149
D. F1000-13

5-14. On a hydraulic diagram, what markings indicate the direction of flow?

A. Arrows
B. Circles
C. Diamonds
D. Squares

5-15. When interpreting piping designations of crosses and elbows, you should read what opening first?

A. Largest
B. Smallest
C. The one facing left
D. The one facing right

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CHAPTER 6

ELECTRICAL AND ELECTRONIC PRINTS

Electrical and electronic prints identify circuits, assemblies, and systems. The chapter discusses electrical and electronic prints and symbols commonly used for electrical and electronic drawings, and describes the common types of drawings used in the installation and troubleshooting of electrical systems on ships and aircraft.

LEARNING OBJECTIVES

When you have completed this chapter, you will be able to do the following:

1. Identify shipboard electrical and electronic prints.
2. Identify aircraft electrical and electronic prints.
3. Identify basic logic diagrams on blueprints.

ELECTRICAL PRINTS

A large number of ratings may use Navy electrical prints to install, maintain, and repair equipment. In the most common examples, electrician's mates (EMs) and interior communications electricians (ICs) use them for shipboard electrical equipment and systems; construction electricians (CEs) use them for power, lighting, and communications equipment and systems ashore; and aviation electrician's mates (AEs) use them for aircraft electrical equipment and systems.

Types of Diagrams

These prints will make use of the various electrical diagrams defined in the following paragraphs.

Pictorial Diagram

Pictorial diagrams show a picture or sketch of the various components of a specific system and the wiring between these components. This simplified diagram provides the means to readily identify the components of a system by their physical appearance. This type of diagram shows the various components without regard to their physical location, how the wiring is marked, or how the wiring is routed.

Isometric Diagram

An isometric diagram is used in locating a component within a system. If it is not known where to look for a component, the isometric diagram is of considerable value. This type of diagram shows the outline of a ship, airplane, or piece of equipment. Within the outline are drawn the various components of a system in their respective locations.

Block Diagram

Block diagrams are used primarily to present a general description of a system and its functions. This type of diagram is generally used in conjunction with text material. A block diagram shows the major components of a system and the interconnections of these components. All components are shown in block form, and each block is labeled for identification purposes.

Single-Line Diagram

A single-line diagram is used basically for the same purpose as the block diagram. When used with text material, it gives a basic understanding of the functions of the components of a system. Two major differences exist between the single-line diagram and the block diagram. The first difference is that the single-line diagram uses symbols rather than labeled blocks to represent components. Second, the single-line diagram shows all components in a single line.

Schematic Diagram

A schematic diagram is a picture of a circuit that uses symbols to represent components in the circuit. Circuits that are physically large and complex can be shown on relatively small diagrams.

Wiring Diagram

A wiring diagram is a detailed diagram of each circuit installation showing all of the wiring, connectors, terminal boards, and electrical or electronic components of the circuit. It also identifies the wires by wire numbers or color coding. Wiring diagrams are necessary to troubleshoot and repair electrical or electronic circuits.

Before any blueprint can be read, the standard symbols for the type of print concerned must be familiar. To read electrical blueprints, various types of standard symbols and the methods of marking electrical connectors, cables, and equipment should be known.

Shipboard Electrical Prints

To interpret shipboard electrical prints, the graphic symbols for electrical diagrams and the electrical wiring equipment symbols for ships should be recognized. These graphic symbols are shown in Graphic Symbols for Electrical and Electronic Diagrams, Institute of Electrical and Electronic Engineers (IEEE) Standard 315A-1986 and Naval Ships' Technical Manual (NSTM) Chapter 320. In addition, the shipboard system of numbering electrical units and marking electrical cables, as described in the following paragraphs, should be familiar.

Numbering Electrical Units

All similar units in the ship comprise a group, and each group is assigned a separate series of consecutive numbers beginning with 1. Numbering begins with units in the lowest, foremost starboard compartment and continues with the next compartment to port if it contains familiar units; otherwise it continues to the next aft compartment on the same level.

Proceeding from starboard to port and from forward to aft, the numbering procedure continues until all similar units on the same level have been numbered. The numbering then continues on the next upper level and so on until all similar units on all levels have been numbered. Within each compartment, the numbering of similar units proceeds from starboard to port, forward to aft, and from a lower to a higher level.

Within a given compartment, the numbering of similar units follows the same rule; that is, lower takes precedence over upper; forward over aft; and starboard over port.

Electrical distribution panels, control panels, and so forth, are given identification numbers made up of three numbers separated by hyphens. The first number identifies the vertical level by deck or platform number at which the unit is normally accessible. Decks of Navy ships are numbered by using the main deck as the starting point as described in Basic Military Requirements, Naval Education Training Manual (NAVEDTRA) 14325. The numeral 1 is used for the main deck, and each successive deck above is numbered 01, 02, 03, and so on, and each successive deck below the main deck is numbered 2, 3, 4, and so on.

The second number identifies the longitudinal location of the unit by frame number. The third number identifies the transverse location by the assignment of consecutive odd numbers for centerline and starboard locations and consecutive even numbers for port locations. The numeral 1 identifies the lowest centerline (or centermost, starboard) component. Consecutive odd numbers are assigned components as they would be observed first as being above, and then outboard, of the preceding component. Consecutive even numbers similarly identify components on the portside. For example, a distribution panel with the identification number, 1-142-2, will be located on the main deck at frame 142, and will be the first distribution panel on the portside of the centerline at this frame on the main deck.

Main switchboards or switchgear groups supplied directly from ship's service generators are designated 1S, 2S, and so on. Switchboards supplied directly by emergency generators are designated 1E, 2E, and so on. Switchboards for special frequencies (other than the frequency of the ship's service system) have alternating current (ac) generators designated 1SF, 2SF, and so on.

Sections of a switchgear group (other than the generator section) are designated by an additional suffix letter starting with the letter A and proceeding in alphabetical order from left to right (viewing the front of the switchgear group). Some large ships are equipped with an electrical distribution system called zone distribution. In a zone distribution system, the ship is divided into areas generally coinciding with the fire zones prescribed by the ship's damage control plan. Electrical power is distributed within each zone from load center switchboards located within the zone. Load center switchboards and miscellaneous switchboards on ships with zone control distribution are given identification numbers, the first digit of which indicates the zone and the second digit the number of the switchboard within the zone as determined by the general rules for numbering electrical units.

Cable Marking

Metal tags embossed with the cable designations are used to identify all permanently installed shipboard electrical cables. These tags (*Figure 6-1*) are placed on cables as close as practical to each point of connection on both sides of decks, bulkheads, and other barriers. They identify the cables for maintenance and replacement. Navy ships use two systems of cable marking; an old color tag system and new sequential numbering system. An explanation of both systems is in the following paragraphs.

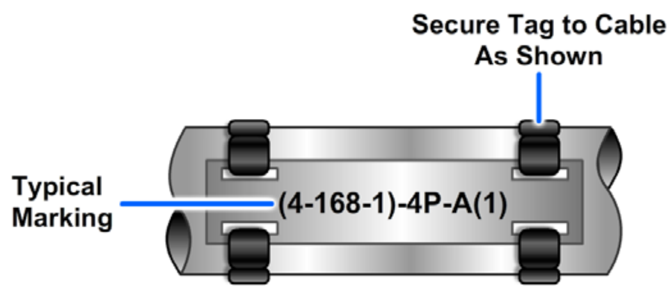


Figure 6-1 — Cable tag.

Old Cable Tag System—the color of the tag shows the cable classification: red—vital, yellow—semivital, and gray or no color—nonvital. The tags will contain the basic letters that designate power and lighting cables for the different services listed in *Table 6-1*:

Table 6-1 — Old Cable Service Identification Letters

SERVICES	DESIGNATIONS
Interior communications	C
Degaussing	D
Ship's service lighting and general power	F
Battle power	FB
Fire control	G
Minesweeping	MS

Table 6-1 — Old Cable Service Identification Letters (continued)

SERVICES	DESIGNATIONS
Electric propulsion	P
Radio and radar	R
Running, anchor, and signal lights	RL
Sonar	S
Emergency lighting and power	FE

Other letters and numbers are used with these basic letters to further identify the cable and complete the designation. Common markings of a power system for successive cables from a distribution switchboard to load would be as follows: feeders, FB-411; main, l-FB-411; submain, 1-FB-411A; branch, 1-FB-411A1; and sub-branch, l-FB-411-A1A. The feeder number 411 in these examples shows the system voltage. The feeder numbers for a 117- or 120-volt system range from 100 to 190; for a 220-volt system, from 200 to 299; and for a 450-volt system, from 400 to 499. The exact designation for each cable is shown on the ship's electrical wiring prints.

New Cable Tag System—consists of three parts in sequence. First is the service letter which identifies the particular electrical system. The second part is the circuit letter, which identifies the specific circuit within the particular system. The third part is the cable number, which identifies the individual cable in a specific circuit. These parts are separated by hyphens. The following table (*Table 6*-2) depicts the letters used to designate the different services:

Table 6-2 — New Cable Service Identification Letters

SERVICES	DESIGNATIONS
Cathodic protection	CPS
Control, power plant, and ship	K
Degaussing	D
Electronics	R
Fire control	G
Interior communications	C
Lighting, emergency	EL
Lighting, navigational	N
Lighting, ship service	L
Minesweeping	MS
Night flight lights	FL
Power, casualty	CP
Power, emergency	EP
Power, propulsion	PP
Power, ship service	P
Power, shore connections	PS
Power, special frequency	SF
Power, weapon system	WP
Power, weapon system, 400 Hz	WSF

Voltages below 100 are designated by the actual voltage; for example, 24 for a 24-volt circuit. For voltages above 100, the number 1 shows voltages between 100 and 199; the number 2, voltages between 200 and 299; the number 4, voltages between 400 and 499, and so on. For a three-wire

(120/240) direct current (dc) system or a three-wire, three-phase system, the number shows the higher voltage.

The destination of cable beyond panels and switchboards is not designated except that each circuit alternately receives a letter, a number, a letter, and a number progressively every time it is fused. The destination of power cables to power-consuming equipment is not designated except that each cable to such equipment receives a single-letter alphabetical designation beginning with the letter A.

Where two cables of the same power or lighting circuit are connected in a distribution panel or terminal box, the circuit classification is not changed. However, the cable markings have a suffix number in parentheses indicating the section. For example, *Figure 6-1* shows that (4-168-1)-4P-A(1) identifies a 450 volt power cable supplied from a power distribution panel on the fourth deck at frame 168 starboard. The letter A indicates the first cable from the panel and the (1) indicates the first section of a power main with more than one section.

The power cables between generators and switchboards are labeled according to the generator designation. When only one generator supplies a switchboard, the generator will have the same number as the switchboard plus the letter G. Thus, 1SG identifies one ship's service generator that supplies the number 1 ship's service switchboard. When more than one ship's service generator supplies a switchboard, the first generator determined according to the general rule for numbering machinery will have the letter A immediately following the designation. The second generator that supplies the same switchboard will have the letter B. This procedure is continued for all generators that supply the switchboard, and then is repeated for succeeding switchboards. Thus, 1SGA and 1SGB identify two service generators that supply ship's service switchboard 1S.

Phase and Polarity Markings

Three phase sequence are on board Navy ships, A, B, and C. Phase and polarity in the ac electrical systems are designated by a wiring color code as shown in *Table 6-3*. Neutral polarity, where it exists, is identified by the green conductor.

Table 6-3 — Color Coding on Three-Phase ac Systems

Cable Type	Phase or Polarity	Color Code
4 Conductor	A	Black
	B	White
	C	Red
	Neutral	Green
3 Conductor	A	Black
	B	White
	C	Red

Isometric Wiring Diagram

An isometric wiring diagram is supplied for each shipboard electrical system. If the system is not too large, the diagram will be on one blueprint while larger systems may require several prints. An isometric wiring diagram shows the ship's decks arranged in tiers. It shows bulkheads and compartments, a marked centerline, frame numbers usually every five frames, and the outer edge of each deck in the general outline of the ship. It shows all athwart ship lines at an angle of 30 degrees to the centerline. Cables running from one deck to another are drawn as lines at right angles to the centerline. A single line represents a cable regardless of the number of conductors. The various electrical fixtures are identified by a symbol number and their general location is shown. Therefore, the isometric wiring diagram shows a rough picture of the entire circuit layout.

All electrical fittings and fixtures shown on the isometric wiring diagram are identified by a symbol number. The symbol number is taken from the Graphic Symbols for Electrical and Electronics Diagrams, IEEE Standard 315A-1986. This publication contains a complete list of standard symbol numbers for the various standard electrical fixtures and fittings for shipboard applications.

Cables shown on the isometric wiring diagram are identified by the cable marking system. In addition, cable sizes are shown in circular mils and number of conductors. Letters show the number of conductors in a cable; S for one-, D for two-, T for three-, and F for four-conductor cables. The number following the letter denotes the wire's circular mil area in thousands. For example, a cable supplying distribution box is marked (2-38-1)-1L-C1-T-9. This marking identifies a three-conductor, 9,000-circular mil, 120-volt, ship's service submain lighting cable supplied from panel 2-38-1.

Remember, the isometric wiring diagram shows only the general location of the various cables and fixtures. Their exact location is shown on the wiring plan discussed briefly in the next paragraphs.

Wiring Deck Plan

The wiring deck plan is the actual installation diagram for the deck or decks shown and is used chiefly in ship construction. It helps the shipyard electrician lay out his or her work for a number of cables without referring to individual isometric wiring diagrams. The plan includes a bill of material that lists all materials and equipment necessary to complete installation for the deck or decks concerned. Equipment and materials, except cables, are identified by a symbol number both on the drawing and in the bill of material.

Wiring deck plans are drawn to scale (usually 1/4 inch to the foot), and they show the exact location of all fixtures. One blueprint usually shows from 150 to 200 feet of space on one deck only. Electrical wiring equipment symbols from IEEE Standard 315A-1986 are used to represent fixtures just as they do in the isometric wiring diagram.

Electrical System Diagrams

Navy ships have electrical systems that include many types of electrical devices and components. These devices and components may be located in the same section or at various locations throughout the ship. The electrical diagrams and drawings necessary to operate and maintain these systems are found in the ship's electrical blueprints and in drawings and diagrams in Naval Sea Systems Command (NAVSEA) and manufacturers' technical manuals.

Block Diagram—is a simple drawing showing the relationships of major parts of a wiring circuit or system. A block diagram of a motor control system is illustrated in *Figure 6-2*. It is easy to see how it gets its name. Sometimes the blocks are connected by only one line that may represent one or more conductors or cables. Blocks may represent major or minor components or parts. This type of diagram is often used to show something of the relationship of components in a power distribution system. The block diagram provides little help in troubleshooting.

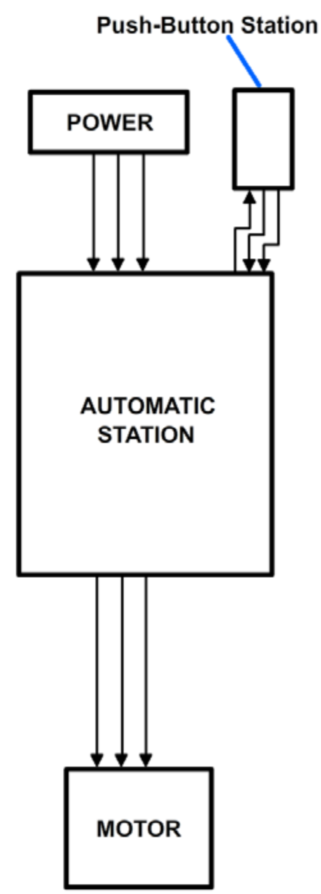


Figure 6-2 — Block diagram.

Wiring Diagram—is almost a picture drawing. It shows the wiring between components and the relative position of the components. *Figure 6-3* shows a wiring diagram of the same motor control system represented by the block diagram in *Figure 6-2*. In the wiring diagram, components are shown much as they would appear in a picture. The lines representing wires are marked with numbers or letter-number combinations.

Lines L1, L2, and L3 are incoming power leads. The diagram shows which terminals these power leads are connected to in the motor starter. Leads connected to terminals T1, T2, and T3 are the motor leads. The numbers without letters mark the control terminals of the starter. Wiring diagrams are often used along with a list of repair parts. Wiring diagrams may be of some help in troubleshooting circuit problems.

Connection Diagram—*Figure 6-4* is a combination of basic symbols (like the open-contact symbol). The controller pictured in *Figure 6-3* works internally.

The connection diagram shows all the internal and external connections. The circuitry can be traced more easily on it than on the wiring diagram. The components are still shown in their relative positions. This diagram can be used to help connect all the wiring and trace any part of the circuit. The connection diagram is a valuable troubleshooting tool. This type of diagram is often found inside the access cover of a piece of equipment.

Schematic Diagram or Elementary Diagram—is a drawing that shows the electrical connections and functions of a specific circuit arrangement. It facilitates tracing the circuit and its functions without regard to the physical size, shape, or relative position of the component device or parts. The schematic diagram (*Figure 6-5*), like the connection diagram, makes use of symbols instead of pictures. *Figure 6-5* shows, by a schematic diagram, the same motor control system shown in *Figures 6-2*, *6-3*, and *6-4*. This diagram is laid out in a way that makes the operation of the components easy to understand. This type of schematic diagram with the components laid out in a line is sometimes called a one line or single-line diagram.

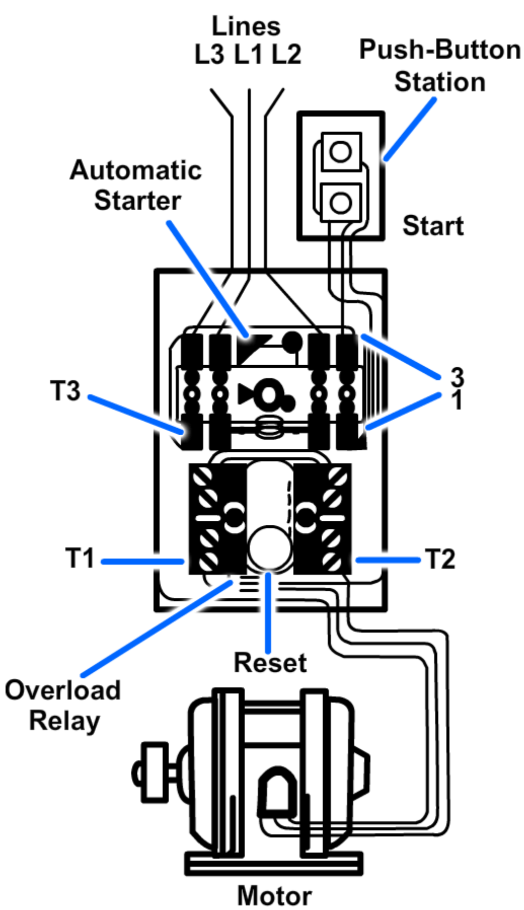


Figure 6-3 — Wiring diagram.

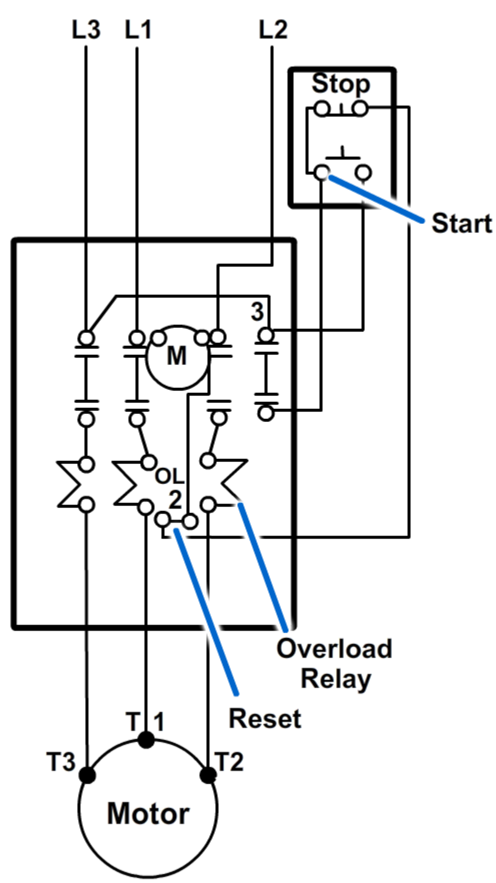


Figure 6-4 — Connection diagram.

Most schematic diagrams are more complicated than the one shown in *Figure 6-5*. The more complicated ones can be broken down into one-line diagrams, circuit by circuit A one-line diagram can be drawn (or sketched freehand) by tracing only one circuit, component by component, through a multicircuit schematic. Circuits "S" and "M" in *Figure 6-6* show only the control circuit from *Figure 6-4* laid out in one-line form. From these simple circuits, it is easy to see that as soon as the start button is pushed, the “M” coil (operating coil of the motor controller) will be energized. The operating coil is now held closed through the "M" contacts.

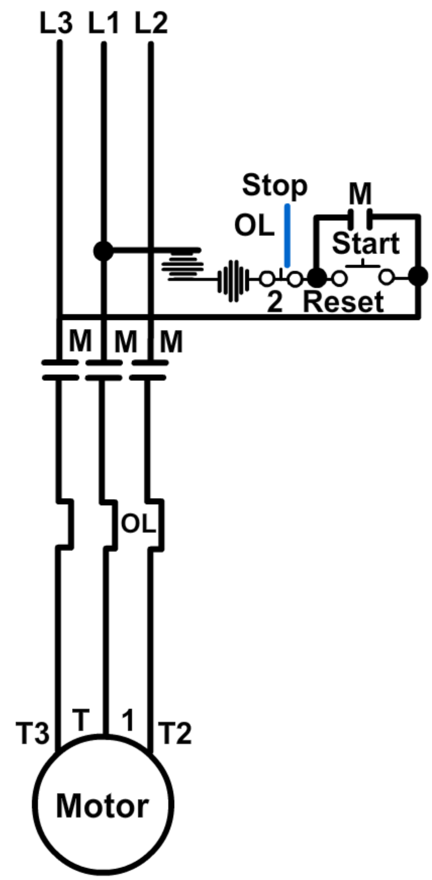


Figure 6-5 — Schematic diagram.

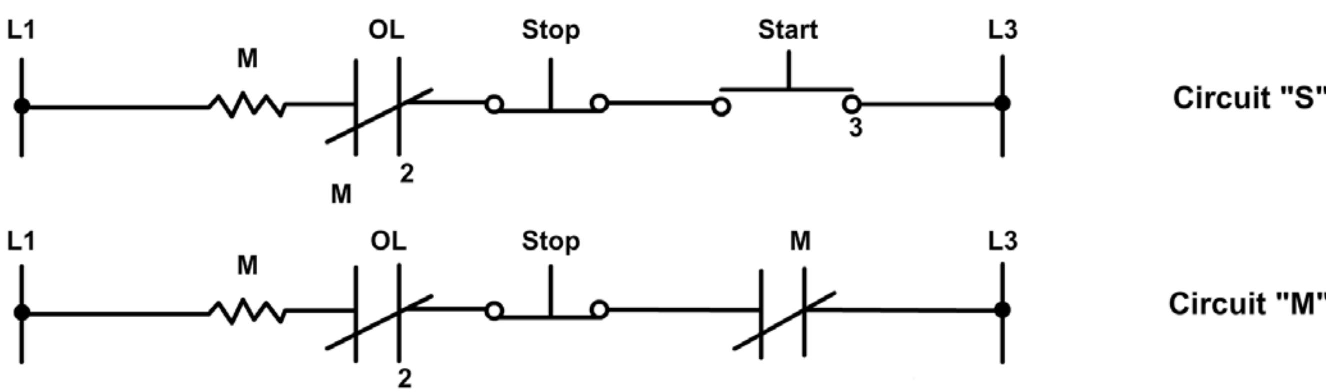


Figure 6-6 — One-line diagram of a motor control circuit.

Aircraft Electrical Prints

Aircraft electrical prints include schematic diagrams and wiring diagrams (*Figure 6-7*). Schematic diagrams show electrical operations. They are drawn in the same manner and use the same graphic symbols from IEEE Standard 315A-1986 as shipboard electrical schematics.

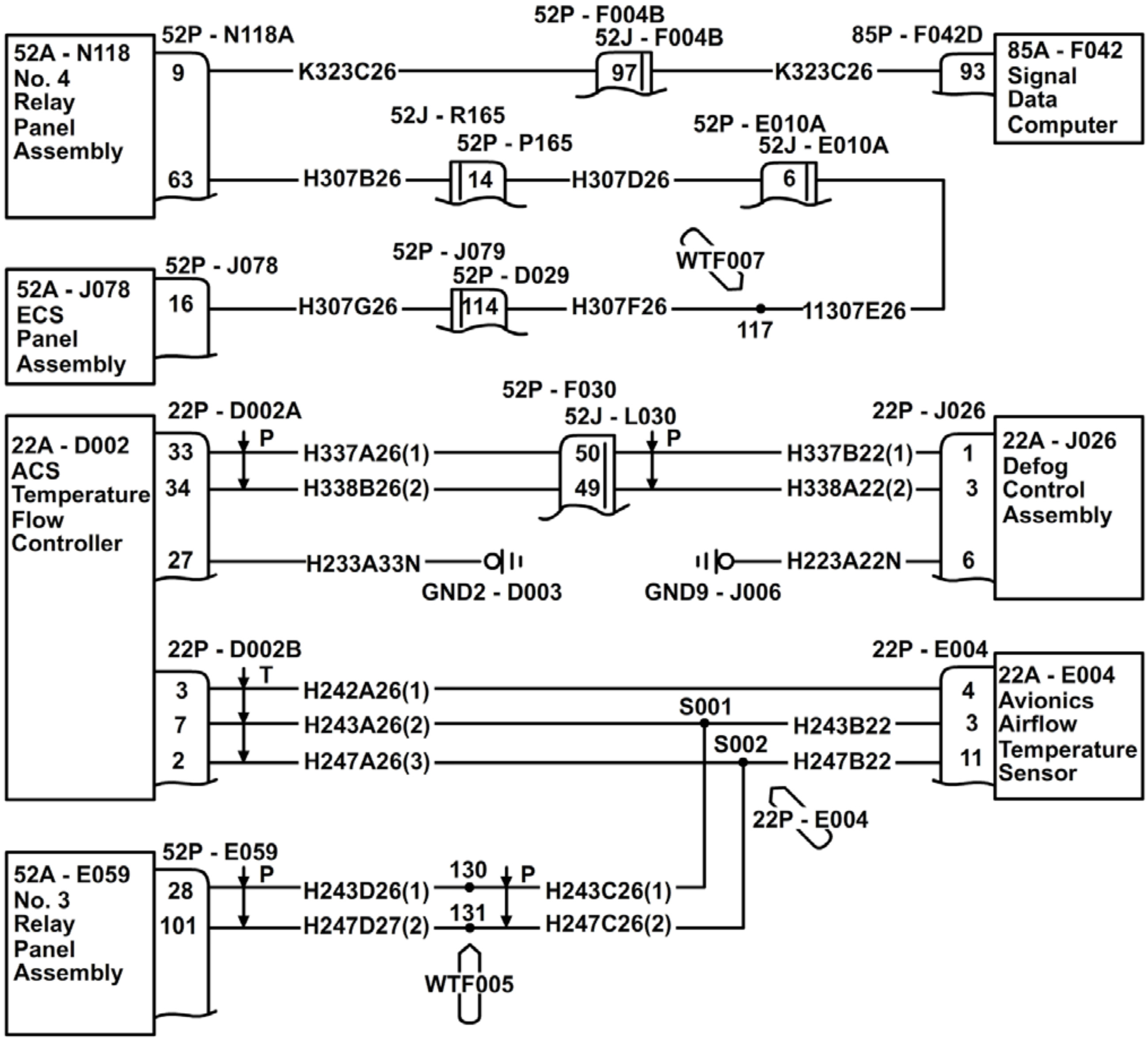


Figure 6-7 — Fighter/Attack (F/A)-18 aircraft electrical system.

Aircraft electrical wiring diagrams show detailed circuit information on all electrical systems. A master wiring diagram is a single diagram that shows all the wiring in an aircraft. In most cases these would be so large as to be impractical; therefore, they are broken down into logical sections such as the dc power system, the ac power system, and the aircraft lighting system.

Diagrams of major circuits generally include an isometric shadow outline of the aircraft showing the location of items of equipment and the routing of interconnecting cables. This diagram is similar to a shipboard isometric wiring diagram.

The simplified wiring diagram may be further broken down into various circuit wiring diagrams showing in detail how each component is connected into the system. Circuit wiring diagrams show equipment part numbers, wire numbers, and all terminal strips and plugs just as they do on shipboard wiring diagrams.

Aircraft Wire and Cable Identification

To make aircraft maintenance easier, each connecting wire or cable in an aircraft has identification marked on it. The identification is a combination of letters and numbers. The marking identifies the circuit that the wire or cable belongs to, the gauge size of the wire or cable, and the information that relates the wire or cable to a wiring diagram. This marking uses the wire or cable identification code. Details of the wire and cable identification system can be found in Military Specification: Wiring, Aerospace Vehicle, SAE-AS50881.

NOTE

For an in-depth study of aircraft wiring specifications, limitations, and repair, refer to the Naval Air Systems Command (NAVAIR) Manual 01-1A-505 and NAVEDTRA 14318 Aviation Electricity Electronics Maintenance Fundamentals.

The basic wire identification code for circuits is read from left to right (*Figure 6-8*).

The first character in the alphanumeric code is a prefix (numeral), and is referred to as the unit number. The unit number is used only in those cases where more than one unit is installed in an identical manner in the same equipment. The wiring concerned with the first unit bears the prefix 1, and corresponding wires for the second unit have exactly the same designation, except for the prefix 2. In the wire identification code shown in *Figure 6-8*, the 2 denotes that it is the second of at least two identical systems in the equipment.

The letter following the prefix number identifies the circuit function. Function letters *D, E, L, P, V,* and *X* should be the primary concern. The letter *D* denotes instruments; *E* denotes engine instruments; *L* denotes lighting; *P* denotes dc power; *V* denotes dc power and dc control for ac systems; and *X* denotes ac power. These are identified in the wiring circuit function code.

The wire number that follows the circuit function consists of one or more digits and differentiates between wires in a circuit/circuits. A different number is used for wires that do not have a common terminal or connection, such as through a circuit breaker, switching device, or load.

Wires that are segmented by the use of connectors or terminals are given different segment letters. Normally, the segment letters are in alphabetical

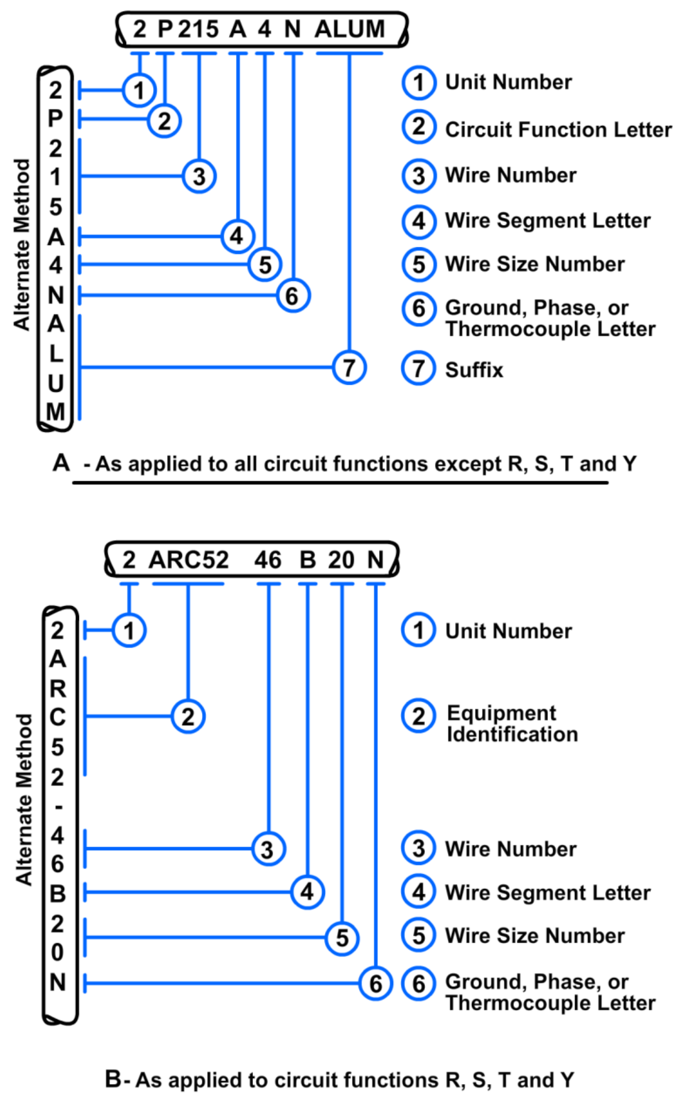


Figure 6-8 — Alphanumeric wire identification code.

sequence, beginning at the power source. The letters *I* and *O* are not used because they could be mistaken for the numerals 1 and 0. In the code shown in *Figure 6-8*, the letter *A* signifies the first segment of wire 215. The number following the segment letter identifies the size of the wire or cable.

The ground, phase, or thermocouple letter following the wire size number is used only when the segment of wire pertains to one of these items. The letters *N*, *A*, *B*, and *C* should be the primary concern. The letter *N* denotes a neutral wire; *A*, *B*, and *C* denote the three separate phases of an ac power supply or source.

The suffix letters at the end of the code are an abbreviation of the material of which the wire is made. For example, ALUM indicates the wire is made of aluminum.

Electrical circuit function letters and associated circuits are listed in *Table 6-4*.

Table 6-4 — Circuit Function Letters

Circuit Function Letter	Circuit
A	Armament
B	Photographic
C	Control surface
D	Instrument (other than flight or engine instruments)
E	Engine instrument
F	Flight instrument
G	Landing gear, wing fold
H	Heating, ventilation, and de-icing
I	To avoid confusion with the numeral one, the letter I shall not be used for circuit or cable identification
J	Ignition
K	Engine control
L	Lighting (illumination)
M	Miscellaneous (electrical)
N	Unassigned
O	To avoid confusion with the numeral zero, the letter O shall not be used for circuit or cable identification
P	Direct current (dc) power
Q	Fuel and oil
R	Radio (navigational and communication)
S	Radar (pulse technique)
T	Special electronics
U	Miscellaneous (electronic)
V	Both dc power and dc control cables for alternating current (ac) systems shall be identified by the circuit function letter V
W	Warning and emergency (except those listed under other circuit functions)
X	ac power
Y	Armament special equipment (except those listed under the circuit function A)
Z	Experimental circuits

ELECTRONIC PRINTS

Electronics prints are similar to electrical prints, but they are usually more difficult to read because they represent more complex circuitry and systems. Common types of shipboard and aircraft electronic prints and basic logic diagrams are discussed in the following sections.

Shipboard Electronics Prints

Shipboard electronics prints include isometric wiring diagrams that show the general location of electronic units and the interconnecting cable runs, and elementary wiring diagrams that show how each individual cable is connected.

Cables that supply power to electronic equipment are tagged as explained in the cable marking section. However, cables between units of electronic equipment are tagged with electronic designations. A partial listing of the electronic designations is listed in *Table 6-5*. The circuit or system designation shall be selected from the general specifications for ships of the Navy.

Cables between electronic units are tagged to show the system with which the cable is associated and the individual cable number. For example, in the cable marking R-ES4, the R identifies an electronic circuit, ES identifies the circuit as a surface search radar circuit, and 4 identifies the cable number. If a circuit has two or more cables with identical designations, a circuit differentiating number is placed before the R, such as 1R-ES4, 2R-ES4, and so on.

Table 6-5 — Electronic Circuit and System Designations

Circuit or System Designation	Circuit or System Title
R-AW	Meteorological circuits
R-BC	Radio beacons
R-BN	Radar beacons
R-CS	Sonar countermeasures system
R-DC	Radar and sonar data converters
R-DD	Data, digital
R-ED	Radar identification
R-ES	Surface search radars
R-ET	Radar trainer
R-MC	Missile control
R-MF	Drone control
R-TM	Television, monitoring
R-TV	Television, entertainment

Block Diagrams

Block diagrams describe the functional operation of an electronics system in the same way they do in electrical systems. In addition, some electronics block diagrams provide information useful in troubleshooting, which will be discussed later.

A simplified block diagram is usually shown first, followed by a more detailed block diagram. A simplified block diagram of the general announcing system, circuit 1MC, and the intership announcing system, circuit 6MC, is shown in *Figure 6-9*.

The system provides a means of transmitting general orders, information, and alarm signals to various locations simultaneously by microphones and loudspeakers connected through a central amplifier.

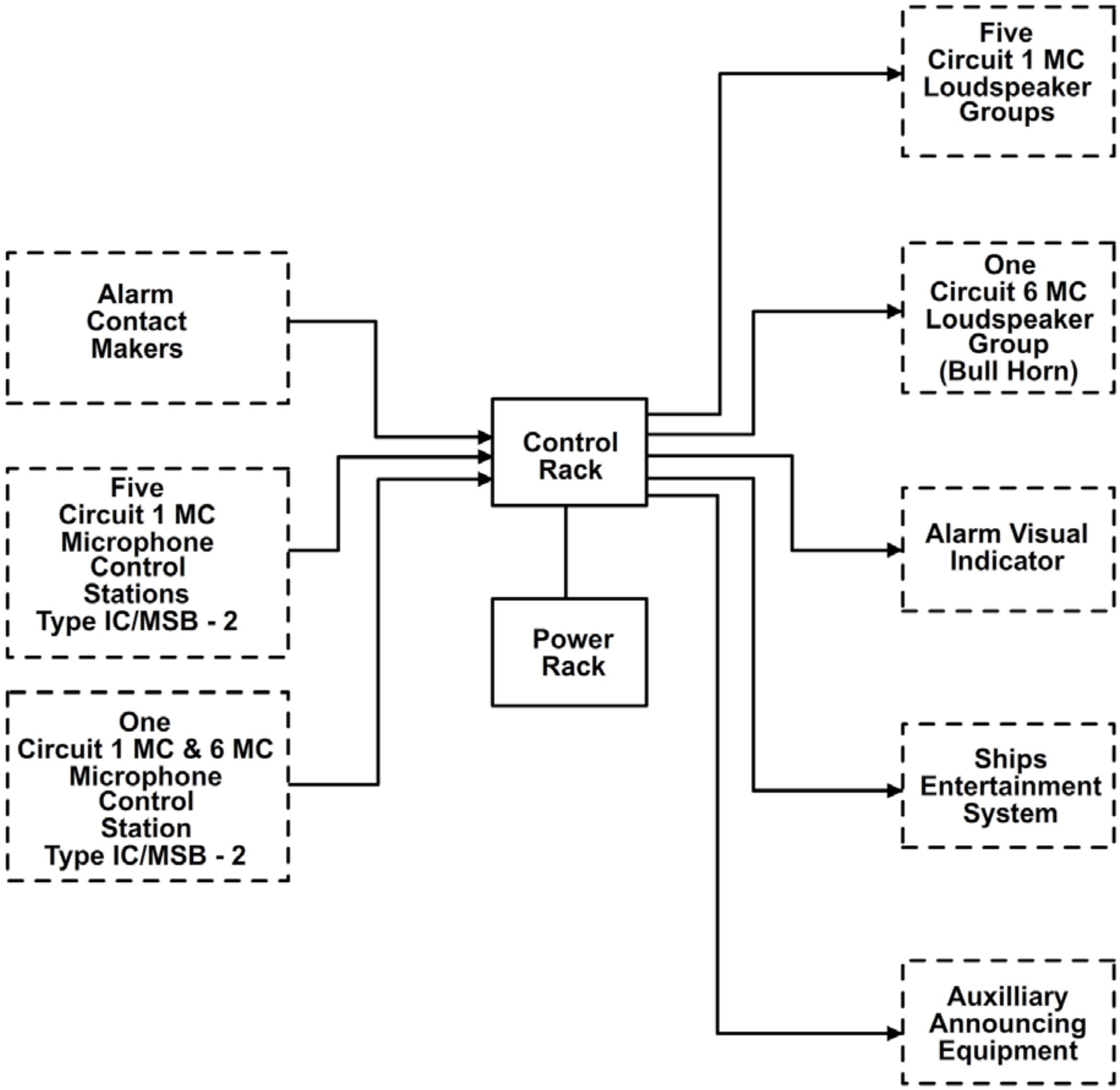


Figure 6-9 — Shipboard general and intership announcing system, simplified block diagram.

Graphic electrical and electronic symbols are frequently used in functional and detailed block diagrams of electronic systems to present a better picture of how the system functions.

Detailed block diagrams can be used to isolate a trouble to a particular assembly or subassembly. However, schematic diagrams are required to check the individual circuits and parts.

Schematic Diagrams

Electronic schematic diagrams use graphic symbols from IEEE Standard 315A-1986 for all parts, such as tubes, transistors, capacitors, and inductors. Simplified schematic diagrams are used to show how a particular circuit operates electronically. However, detailed schematic diagrams are necessary for troubleshooting.

A detailed schematic diagram of the salinity indicator system is shown in *Figure 6-10*. It shows most of the components are numbered. In an actual detailed schematic, however, all components are identified by a letter and a number and their values are given. All tubes and transistors are identified by a letter and a number and also by type.

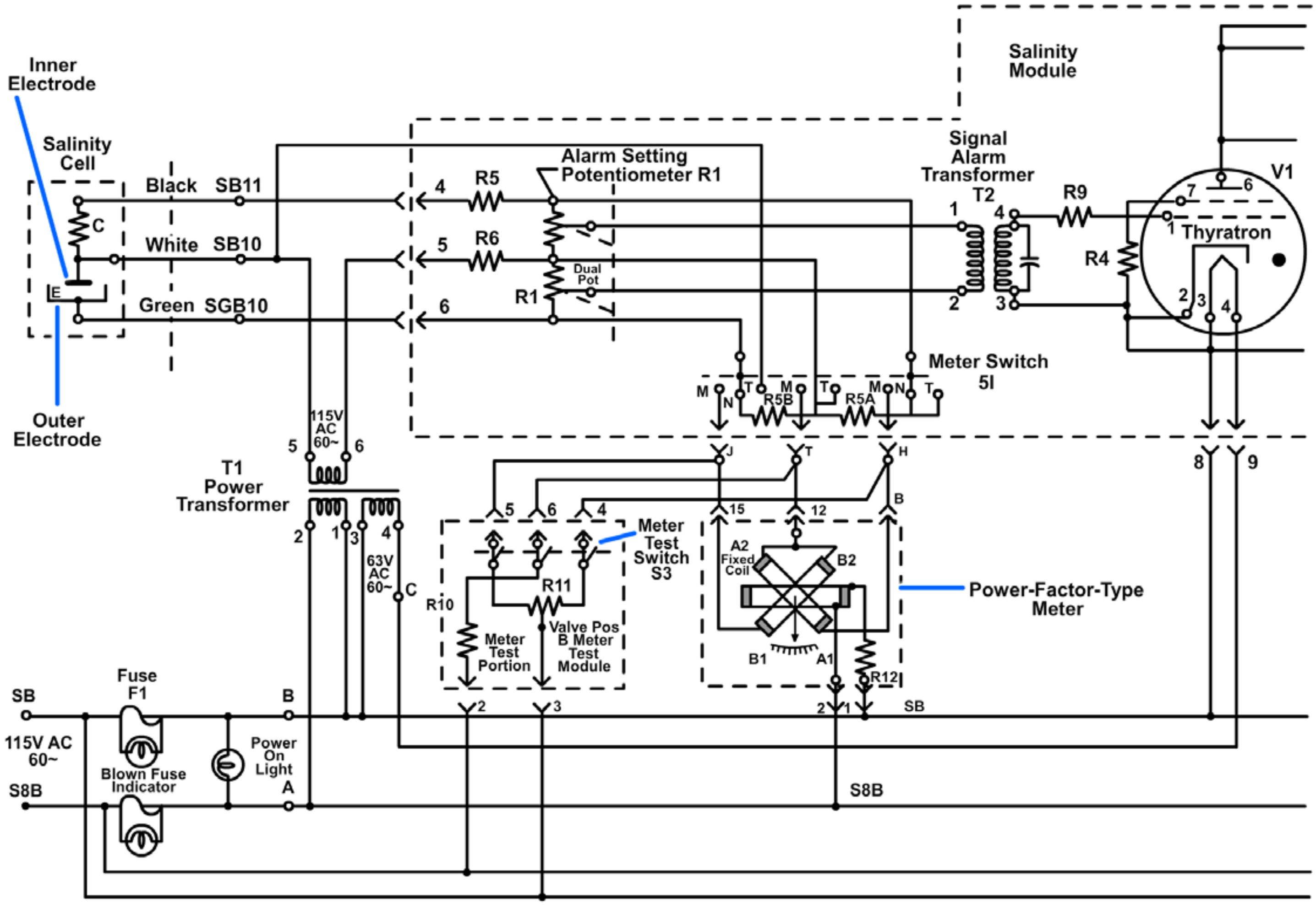


Figure 6-10 — Schematic diagram of a salinity indicator system.

Wiring Diagrams

Electronic equipment wiring diagrams show the relative positions of all equipment parts and all electrical connections. All terminals, wires, tube sockets, resistors, capacitors, and so on are shown as they appear in the actual equipment. A sample wiring diagram for three-phase distribution is illustrated in *Figure 6-11*.

The basic wiring color codes for electronics are listed in *Table 6-6*.

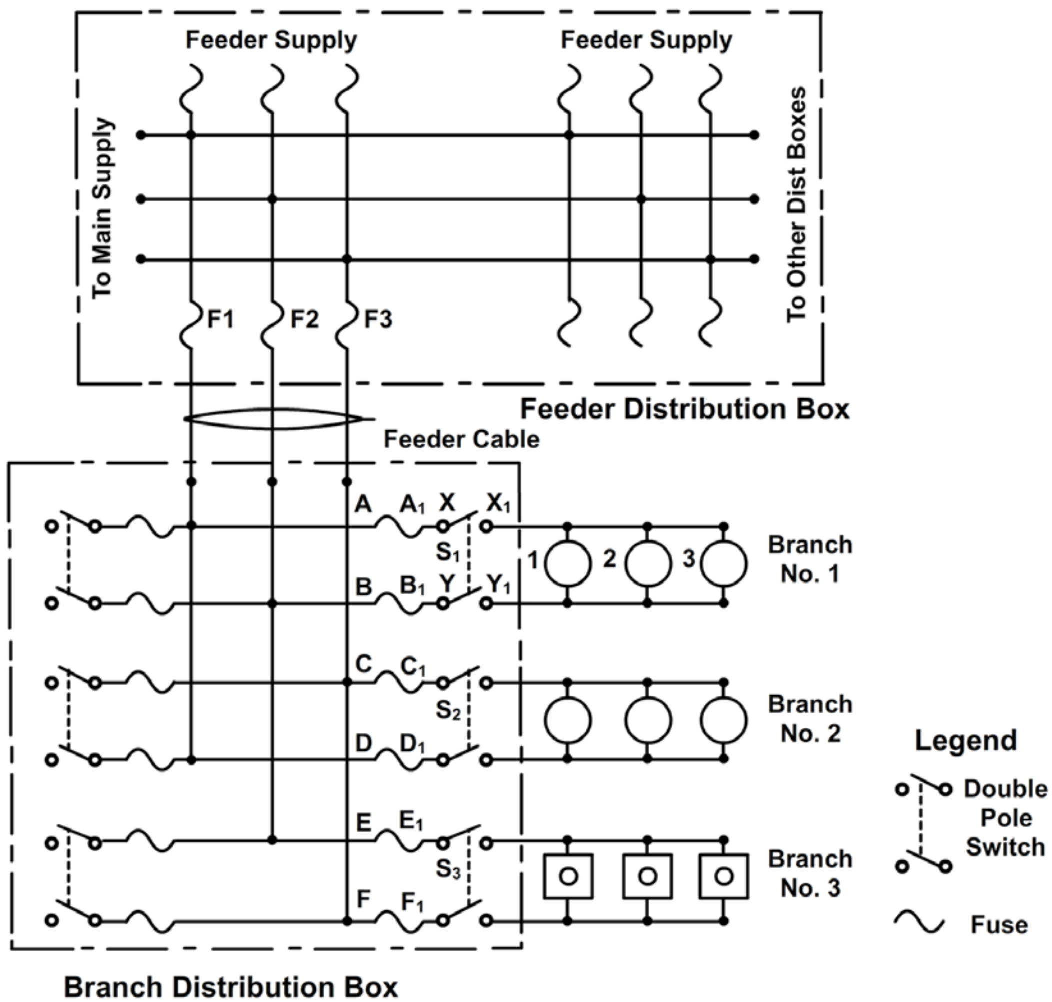


Figure 6-11 — Three-phase distribution wiring diagram.

Table 6-6 — Basic Wiring Color Codes

CIRCUIT	COLOR
Grounds, grounded elements, and returns	Black
Heaters or filaments, off ground	Brown
Power supply	Red
Screen grids	Orange
Emitters/cathodes	Yellow
Bases/control grids	Green
Collectors/plates	Blue
Power supply	Violet (purple)
Alternating current power lines	Gray
Miscellaneous, above or below ground returns, automatic volume control (AVC)	White

Reference Designations

A reference designation is a combination of letters and numbers used to identify the various parts and components on electronic drawings, diagrams, parts lists, and so on. The work prints will have one of two systems of reference designations. The old one is called a block numbering system and is no longer in use. Although, some older prints may have the old block numbering system. The current one is called a unit numbering system. Both will be discussed in the following paragraphs.

Block Numbering System—has a letter identifying the class, to which a part belongs, such as R for resistor, C for capacitor, V for electron tube, and so on. A number identifies the specific part and in which unit of the system the part is located. Parts within each class in the first unit of a system are numbered consecutively from 1 through 199; parts in the second unit from 201 through 299; and so on.

Unit Numbering System—is the currently used reference designation system. Electronic systems are broken into sets, units, assemblies, subassemblies, and parts (*Figure 6-12*). A system is defined as two or more sets and other assemblies, subassemblies, and parts necessary to perform an operational function or functions. A set is defined as one or more units and the necessary assemblies, subassemblies, and parts connected or associated together to perform an operational function.

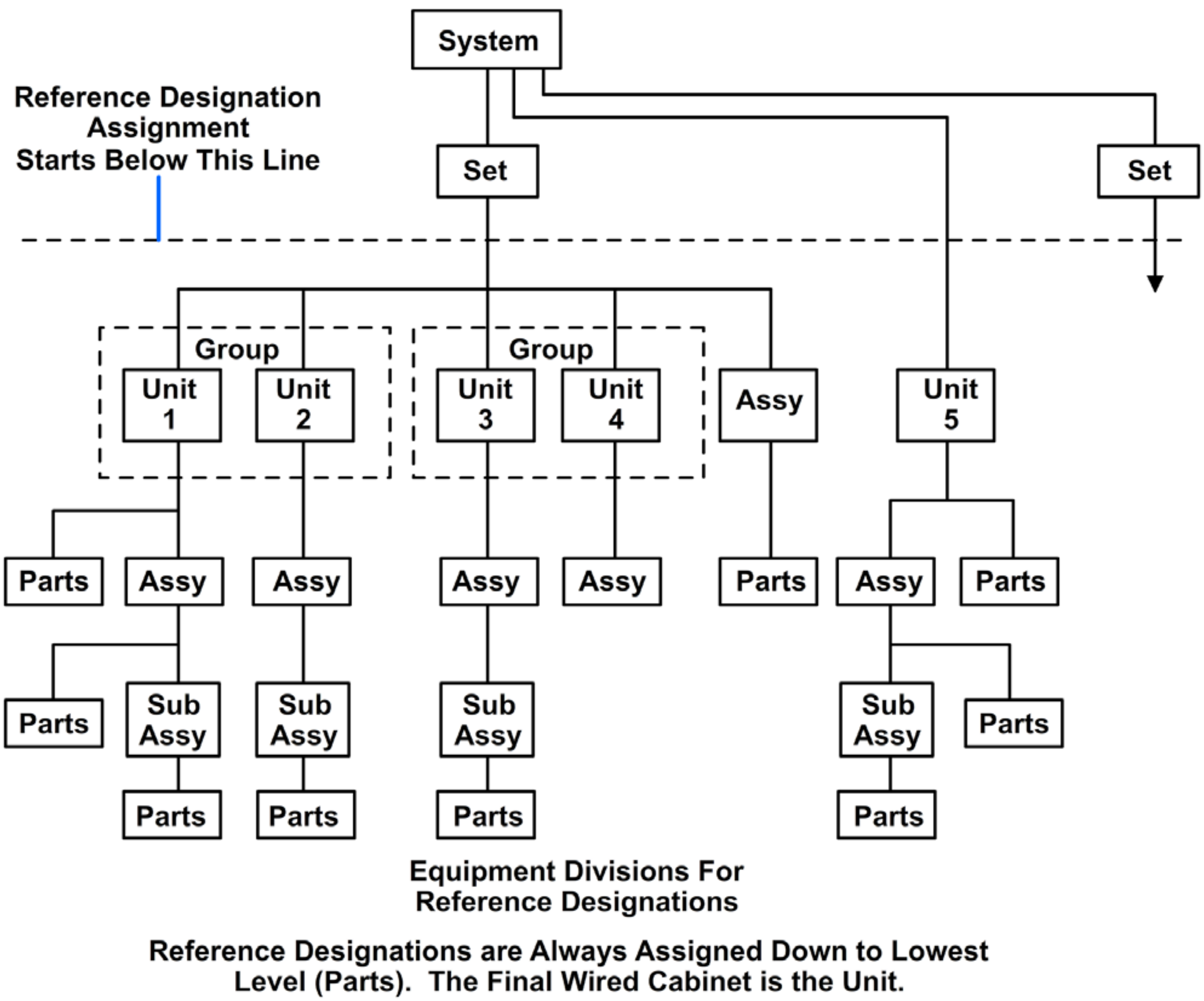


Figure 6-12 — System subdivision.

Reference designations are assigned beginning with the unit and continuing down to the lowest level (parts). Units are assigned a number beginning with 1 and continuing with consecutive numbers for all units of the set. The number is a complete reference designation for the unit. If there is only one unit, the unit number is omitted.

Assemblies and subassemblies form a portion of a unit. The assemblies and subassemblies can be replaced as a whole or individual parts are replaceable. The distinction between an assembly and a subassembly is not always exact; an assembly in one application may be a subassembly in another when it forms a portion of an assembly.

By examining the reference designator of a unit, it will be possible to determine in which group, if any, the unit is contained. A good example to break down and identify a complete reference designator for a unit is the reference designator 2A2A3C1 on *Figure 6-13*.

The first indicator, 2, is numeric and refers to unit 2. The next indicator, A2, is alphanumeric and refers to assembly A2. The next indicator, A3, is also alphanumeric and refers to subassembly A3. The last indicator, C1, like the two previous, is alphanumeric and refers to the part C1. This means capacitor C1 is on subassembly A3, which is on assembly A2, which is in unit 2 of the equipment.

Reference designations may be expanded or reduced to as many levels required to identify a particular part. In *Figure 6-13* the designator 2J1 identifies jack J1, which is mounted directly on unit 2. The designator 2A4C3 identifies capacitor C3, which is on assembly A4 in unit 2.

On electronic diagrams, the usual procedure is to use partial (abbreviated) reference designations (*Figure 6-14*). In this procedure, only the letter and number identifying the part is shown on the part

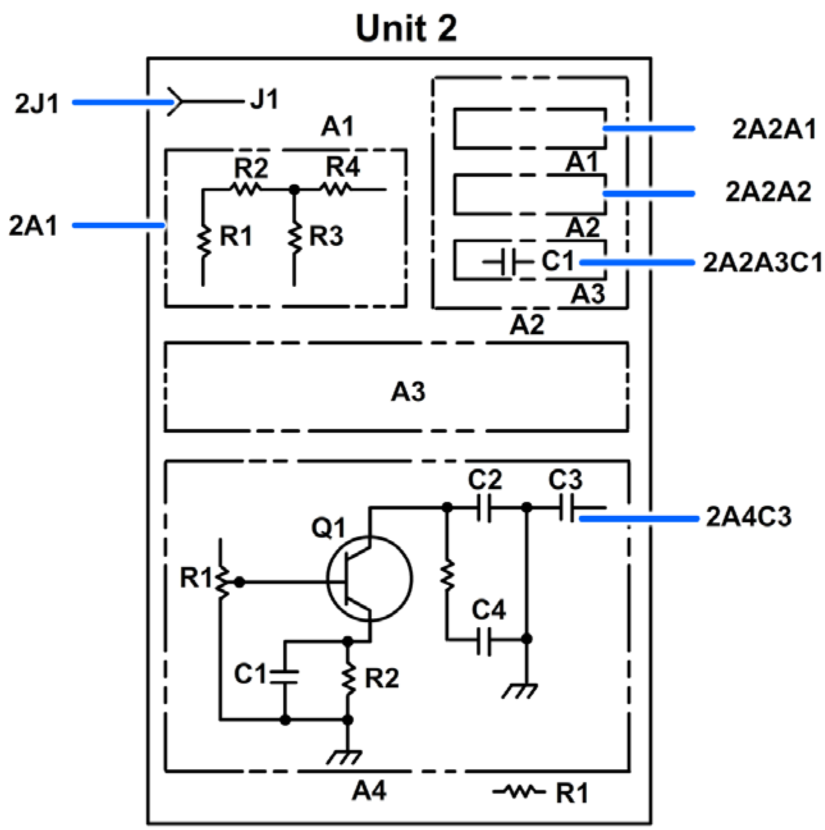


Figure 6-13 — Reference designation.

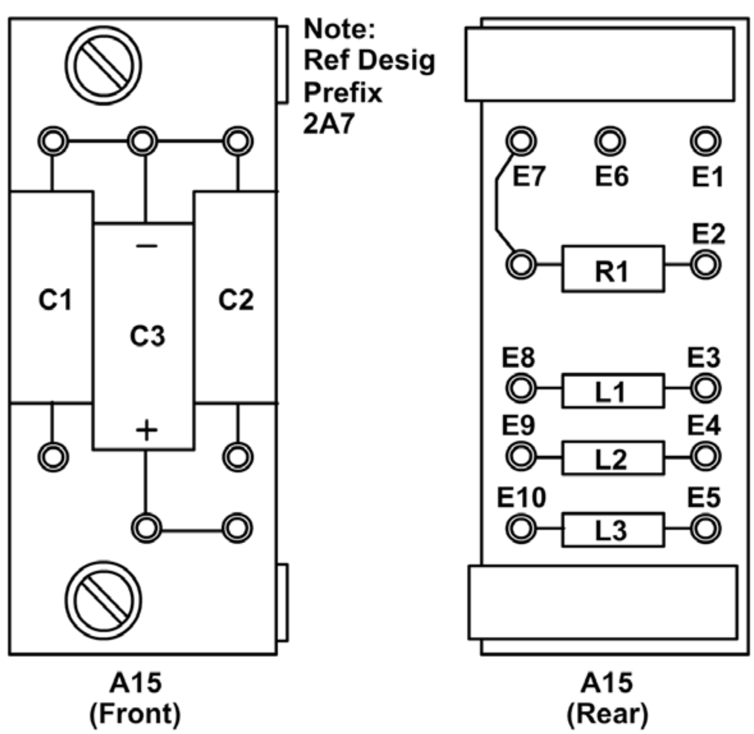


Figure 6-14 — Application of reference designations.

itself, while the reference designation prefix appears at some other place on the diagram. For the complete reference designation, the designation prefix precedes the partial designation.

Interconnection Diagrams

Interconnection diagrams show the cabling between electronic units and how the units are interconnected (*Figure 6-15*). All terminal boards are assigned reference designations according to the unit numbering method described previously. Individual terminals on the terminal boards are assigned letters and/or numbers according to the General Specifications for Overhaul (GSO) of Surface Ships, NAVSEA S9AA0-AB-GOS-010.

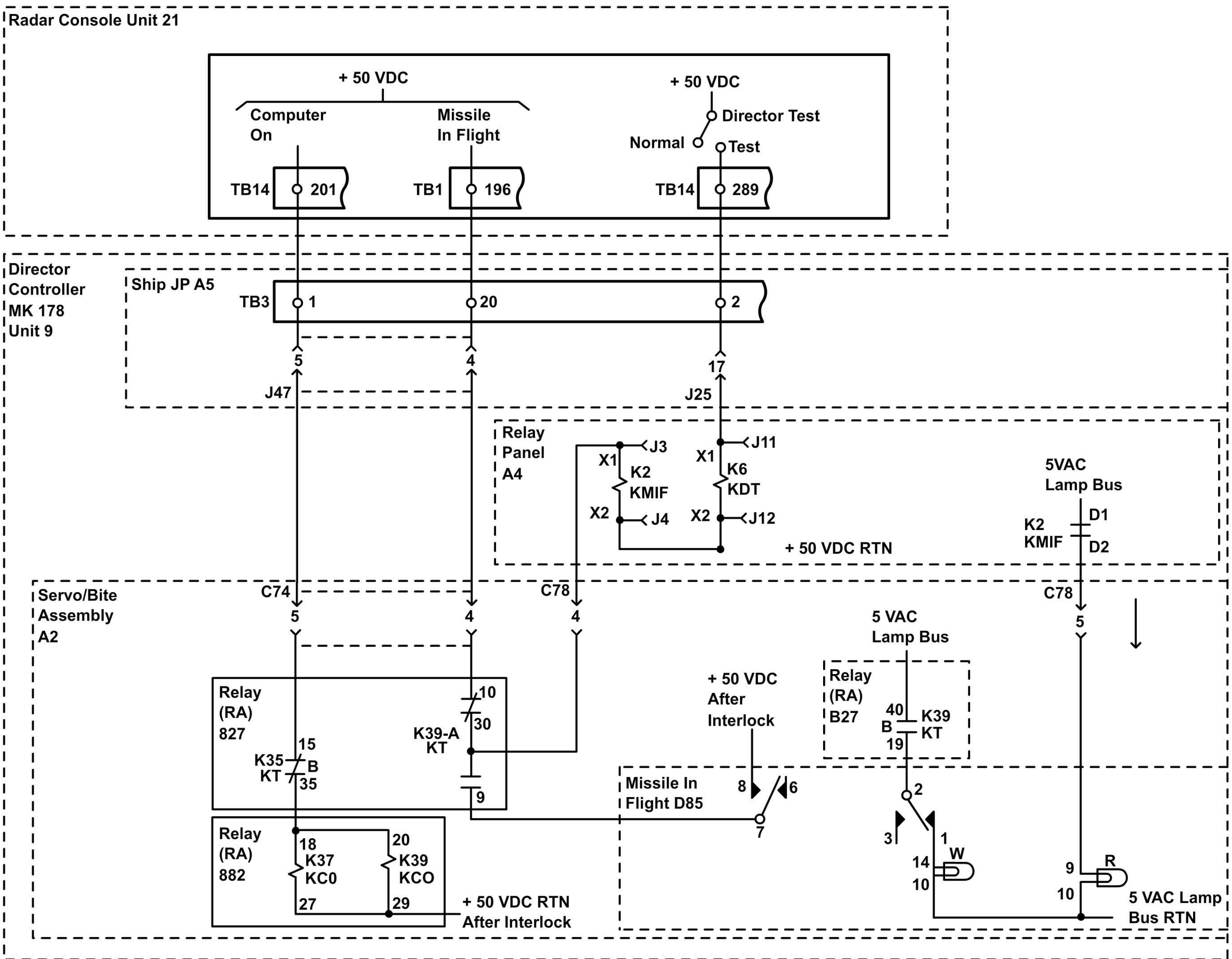


Figure 6-15 — Sample interconnection diagram.

The cables between the various units are tagged showing the circuit or system designation and the number as stated earlier. In addition, the interconnection diagram also shows the type of cable used.

Cables within equipment are usually numbered by the manufacturer. These numbers will be found in the technical manual for the equipment. If the cables connect equipment between compartments on a ship, they will be marked by the shipboard cable-numbering system previously described.

Individual conductors connecting to terminal boards are tagged with a vinyl sleeving called spaghetti that shows the terminal board and terminal to which the outer end of the conductor is connected. The sleeving is marked with identifying numbers and letters and then slid over the conductor (*Figure 6-16*). The marking on the sleeving identifies the conductor connections both "to" and "from" by giving the following information:

- The terminal "from."
- The terminal board "to."
- The terminal "to."

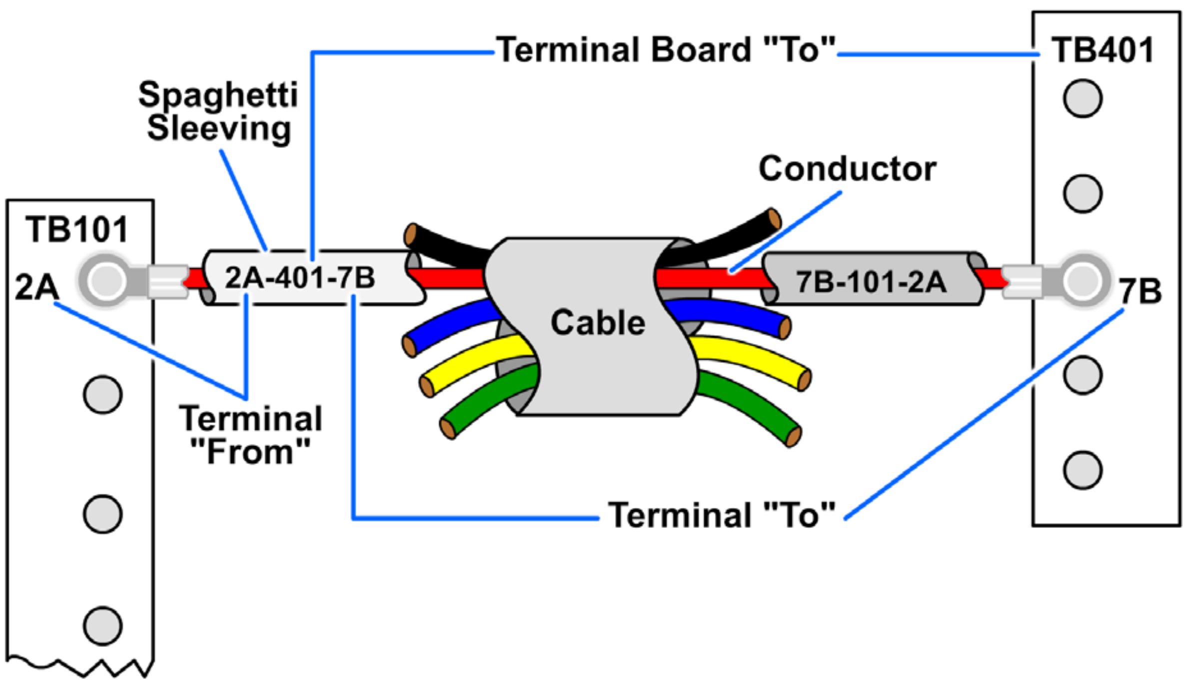


Figure 6-16 — Designating conductor marking between unlike terminals.

The designations on the sleeving are separated by a dash. The order of the markings is such that the first set of numbers and letters reading from left to right is the designation corresponding to the terminal "from" which the conductor runs. Following this number is the number of the terminal board "to" which the conductor runs. ("TB" is omitted when the sleeve is marked.) The third designation is the terminal "to" which the conductor runs.

For example, as shown in *Figure 6-16*, the conductor is attached to terminal 2A of terminal board 101 (terminal "from" 2A on the spaghetti sleeving). The next designation on the sleeving is 401, indicating it is going "to" terminal board 401. The last designation is 7B, indicating it is attached "to" terminal 7B of TB 401. The spaghetti marking on the other end of the conductor is read the same way. The conductor is going "from" terminal 7B on terminal board 401 "to" terminal 2A on terminal board 101.

Aircraft Electronics Prints

Aircraft electronics prints include isometric wiring diagrams of the electronics systems showing the locations of the units of the systems and the interconnecting wiring. Both simplified and detailed block and schematic diagrams are used. They show operation and serve as information for maintenance and repair in the same way as those in shipboard electronics systems. Detailed block diagrams of complicated systems that contain details of signal paths, wave shapes, and so on are usually called signal flow diagrams.

Wiring Diagrams

Aircraft electronic wiring diagrams fall into two basic classes: wiring diagrams and interconnecting diagrams. There are many variations of each class, depending on the application.

The diagram in *Figure 6-17* shows the wiring interconnections to other components. It does not show the actual positioning of circuit components, and it shows wire bundles as single lines with the separate wires.

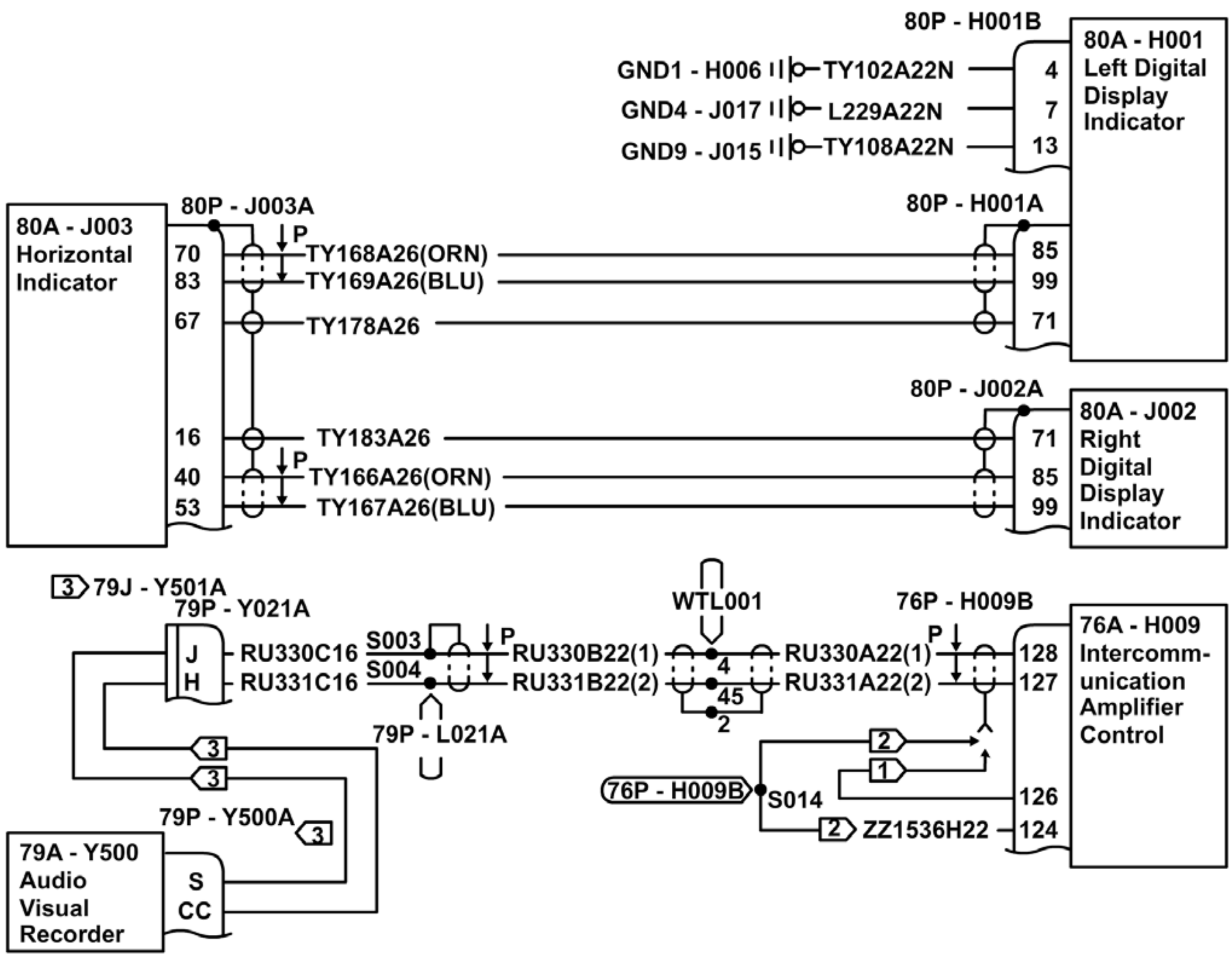


Figure 6-17 — Aircraft wiring diagram.

Each indicated part is identified by a reference designation number to help identify the circuit and to locate the illustrated parts breakdown (IPB) to determine value and other data. Wiring diagrams normally do not show the values of resistors, capacitors, or other components.

Some wiring diagrams have a wire identification code consisting of a three-part designation. The first part is a number representing the color code of the wire according to Military Specification MIL-W-76D. Many other wiring diagrams designate color coding by abbreviation of the actual colors as in *Figure 6-17*. The second part is the reference part designation number of the item to which the wire is connected, and the last part is the designation of the terminal to which connection is made.

Electromechanical Drawings

Electromechanical devices such as synchros, gyros, accelerometers, autotune systems, and analog computing elements are quite common in avionics systems. You need more than an electrical or electronic drawing to understand these systems adequately; therefore, we use a combination drawing called an electromechanical drawing. These drawings are usually simplified both electrically and mechanically, and show only those items essential to the operation. An example of one type of electromechanical drawing is shown in *Figure 6-18*.

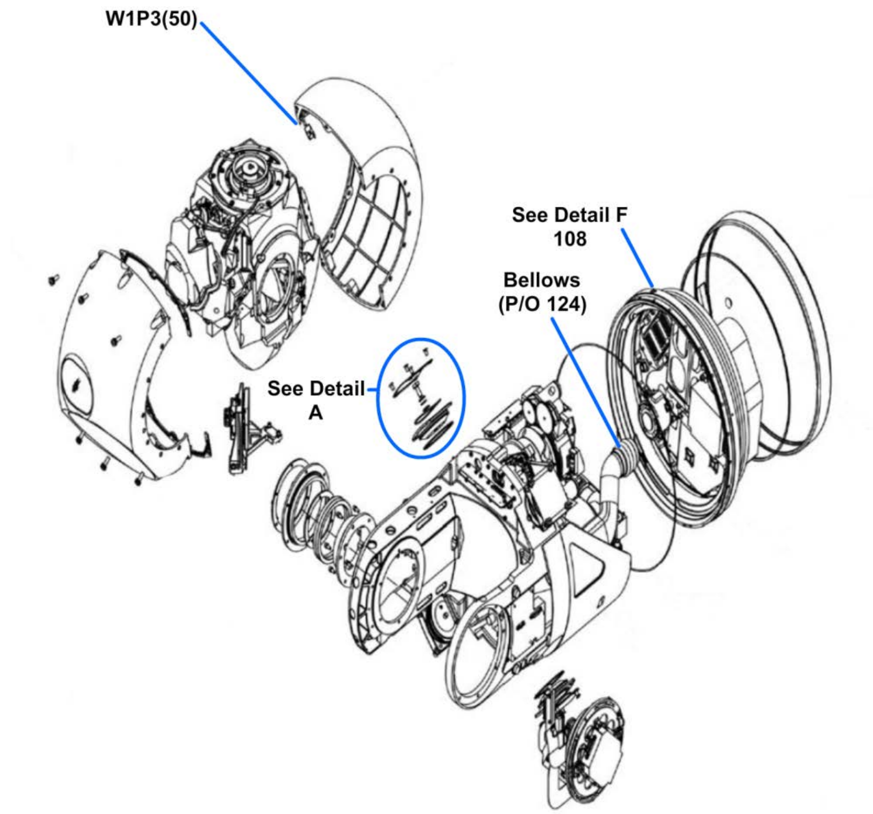


Figure 6-18 — Aircraft electro-optical sensor unit, electromechanical diagram.

Logic Diagrams

Logic diagrams are used in the operation and maintenance of digital computers. Graphic symbols from IEEE Standard 91A-1991 are used in these diagrams.

Computer Logic

Computers are used to make logical decisions about matters that can be decided logically. Some examples are when to perform an operation, what operation to perform, and which of several methods to follow. Computers never apply reason and think out an answer. They operate entirely on the principle of logic and use the true and false logic conditions of a logical statement to make a programmed decision. The rules for the equations and manipulations used by a computer often differ from the familiar rules and procedures of everyday mathematics.

People use many logical truths in everyday life without realizing it. Most of the simple logical patterns are distinguished by words such as AND, OR, NOT, IT, ELSE, and THEN. Once the verbal reasoning process has been completed and results put into statements, the basic laws of logic can be used to evaluate the process. Although simple logic operations can be performed by manipulating verbal statements, the structure of more complex relationships can be represented by symbols. Thus, the operations are expressed in what is known as symbolic logic.

The symbolic logic operations used in computers are based on the investigations of George Boole, and the resulting algebraic system is called Boolean algebra.

The objective of using Boolean algebra in digital computer study is to determine the truth value of the combination of two or more statements. Since Boolean algebra is based upon elements having two possible stable states, it is quite useful in representing switching circuits. A switching circuit can be in only one of two possible stable states at any given time; open or closed. These two states may be represented as 0 and 1 respectively. As the binary number system consists of only the symbols 0 and 1, we can see these symbols with Boolean algebra.

In familiar mathematics, there are four basic operations—addition, subtraction, multiplication, and division. Boolean algebra uses three basic operations—AND, OR, and NOT. If these words do not sound mathematical, it is only because logic began with words, and not until much later was it translated into mathematical terms. The basic operations are represented in logical equations by the symbols similar to the examples in *Table 6-7*.

The addition symbol (+) identifies the OR operation. The multiplication symbol or dot (•) identifies the AND operation, and parentheses and other multiplication signs may also be used.

Table 6-7 — Logic Symbols

OPERATION	MEANING
A • B	A and B
A + B	A or B
$\bar{A}$	A Not or Not A
(A + B) (C)	A or B, and C
AB + B	A and B, or C
$\bar{A}$ • B	Not A, and B

Logic Operations

Three basic logic operations (AND, OR, and NOT) and four of the simpler combinations of the three (NOR, NAND, INHIBIT, and EXCLUSIVE OR) are shown in *Figure 6-19*. For each operation, the figure also shows a representative switching circuit, a truth table, and a block diagram. In some instances, it shows more than one variation to illustrate some specific point in the discussion of a particular operation. In all cases, a 1 at the input means the presence of a signal corresponding to switch closed, and a 0 represents the absence of a signal, or switch open. In all outputs, a 1 represents a signal across the load, a 0 means no signal.

For the AND operation, every input line must have a signal present to produce an output. For the OR operation, an output is produced whenever a signal is present at any input. To produce a no-output condition, every input must be in a no-signal state.

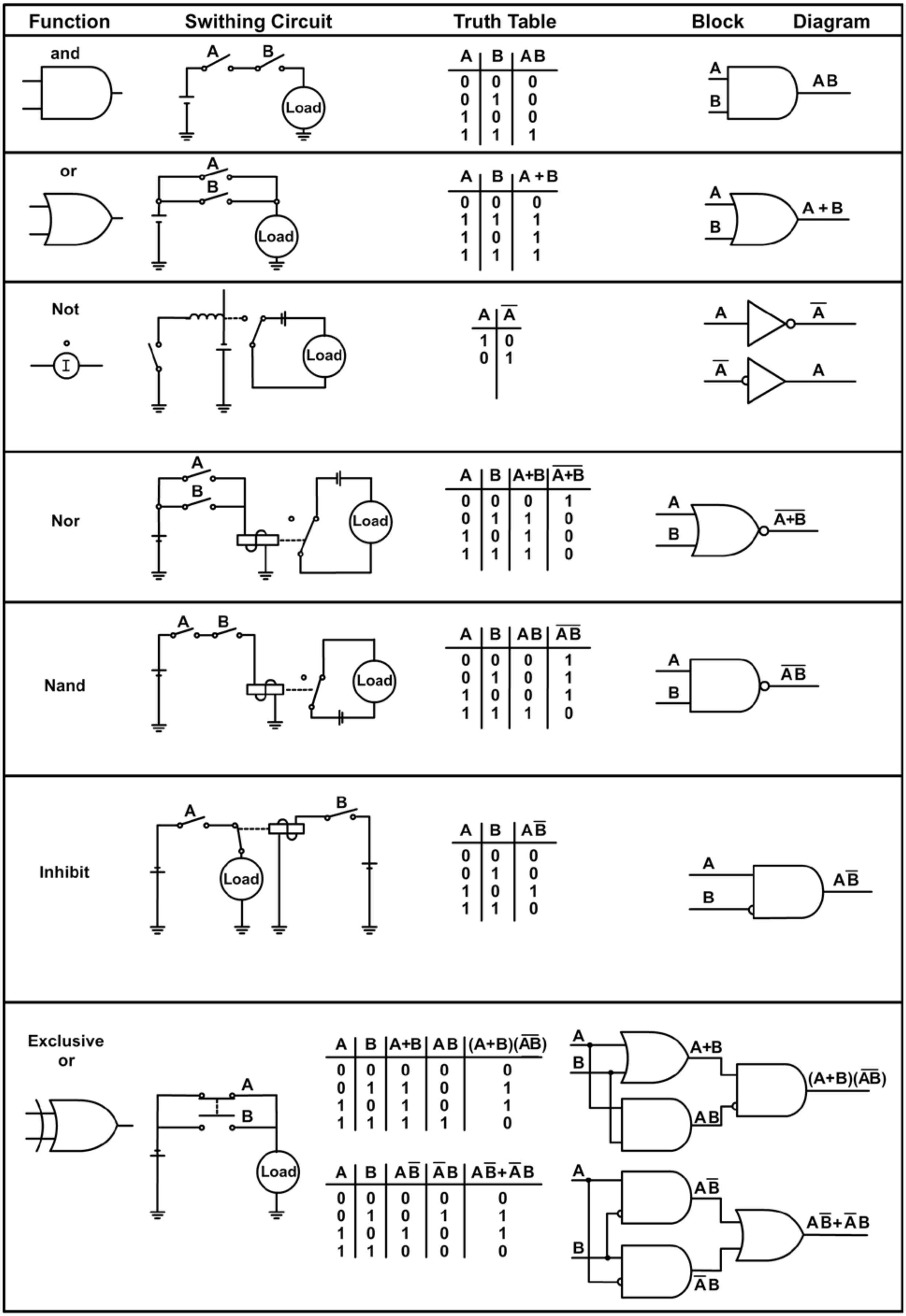
In the NOT operation, an input signal produces no output, while a no-signal input state produces an output signal. Notice the block diagrams representing the NOT circuit in *Figure 6-19*. The triangle is the symbol for an amplifier, and the small circle is the symbol for the NOT function. The circle is used to indicate the low-level side of the inversion circuit.

The NOR operation is simply a combination of an OR operation and a NOT operation. In the truth table, the OR operation output is indicated between the input and output columns. The switching circuit and the block diagram also indicate the OR operation.

The NAND operation is a combined operation, comprising an AND and a NOT operation.

The INHIBIT operation is also a combination AND and NOT operation, but the NOT operation is placed in one of the input legs. In the example shown, the inversion occurs in the B input leg; but in actual use, it could occur in any leg of the AND gate.

The EXCLUSIVE OR operation differs from the OR operation in the case where a signal is present at every input terminal. In the OR, an output is produced; in the EXCLUSIVE OR, no output is produced. In the switching circuit shown, both switches cannot be closed at the same time; but in actual computer circuitry, this action may not be the case. The accompanying truth tables and block diagrams show two possible circuit configurations. In each case the same final results are obtained, but by different methods.



A	B	AB
0	0	0
0	1	0
1	0	0
1	1	1

A	B	A + B
0	0	0
1	1	1
1	0	1
1	1	1

A	$\overline{A}$
1	0
0	1

A	B	A+B	$\overline{A+B}$
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	0

A	B	AB	$\overline{AB}$
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

A	B	$A\overline{B}$
0	0	0
0	1	0
1	0	1
1	1	0

A	B	A+B	AB	$(A+B)(\overline{AB})$
0	0	0	0	0
0	1	1	0	1
1	0	1	0	1
1	1	1	1	0

A	B	$A\overline{B}$	$\overline{A}B$	$A\overline{B}+\overline{A}B$
0	0	0	0	0
0	1	0	1	1
1	0	1	0	1
1	1	0	0	0

Figure 6-19 — Logic operations comparison chart.

Basic Logic Diagrams

Basic logic diagrams are used to show the operation of a particular unit or component. Basic logic symbols are shown in their proper relationship so as to show operation only in the most simplified form possible. A basic logic diagram for a serial subtractor is illustrated in *Figure 6-20*. The operation of the unit is described briefly in the next paragraph.

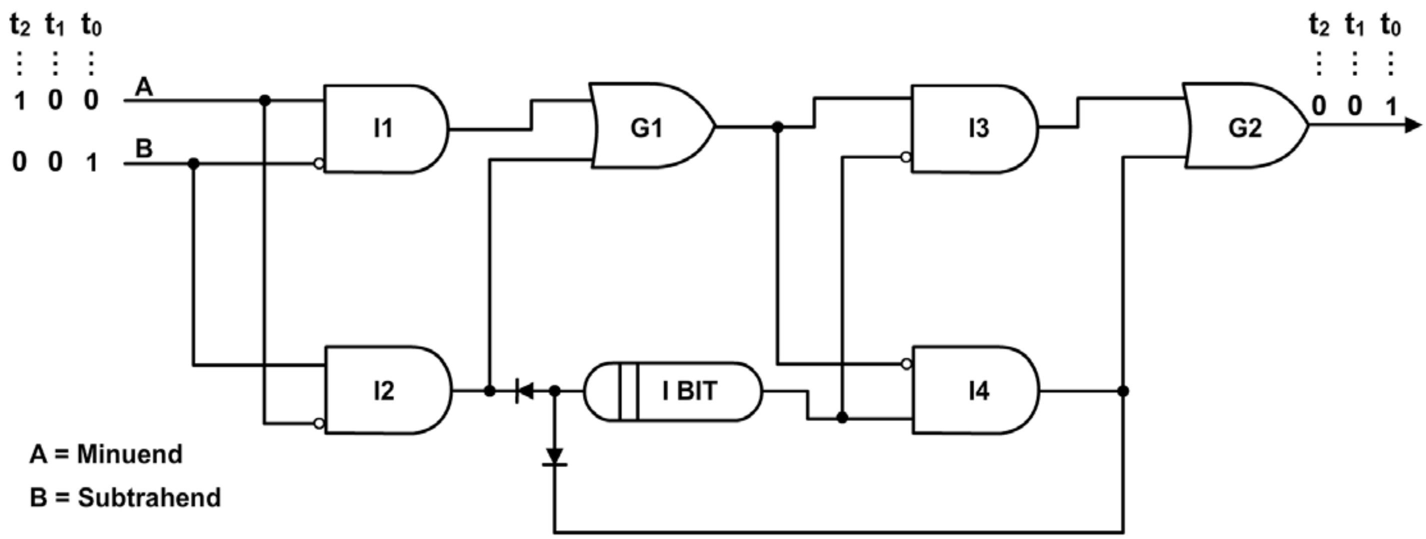


Figure 6-20 — Serial subtractor, basic logic diagrams.

As an example, in the basic subtractor, subtract binary 011 (decimal 1) from binary 100 (decimal 4).

At time t_0, the 0 input at A and 1 input at B of inhibitor I1 results in a 0 output from inhibitor I1 and a 1 output from inhibitor I2. The 0 output from I1 and the 1 output from I2 are applied to OR gate G1, producing a 1 output from G1. The 1 output from I2 is also applied to the delay line. The 1 output from G1 along with the 0 output from the delay line produces 1 output from I3. The 1 input from G1 and the 0 input from the delay line produce a 0 output from inhibitor I4. The 0 output from I4 and the 1 output from I3 are applied to OR gate G2 producing a 1 output.

At time t_1 the 0 inputs on the A and B input lines of I1 produce 0 outputs from I1 and I2. The 0 inputs on both input lines of OR gate G1 result in a 0 output from G1. The 1 input applied to the delay line at time to emerges (1 bit time delay) and is now applied to the inhibit line of I3 producing an 0 output from I3. The 1 output from the delay line is also applied to inhibitor I4, and along with the 0 output from G1 produces a 1 output from I4. The I4 output is recycled back into the delay line, and also applied to OR gate G2. As a result of the 0 and 1 inputs from I3, and I4, the OR gate G2 produces a 1 output.

At time t_2, the 1 input on the A line and the 0 input on the B line of I1 produce a 1 output from I1 and a 0 output from I2. These outputs applied to OR gate G1 produce a 1 output from G1, which is applied to 13 and I4. The delay line now produces a 1 output (recycled in at time t_1), which is applied to I3 and I4. The 1 output from the delay line along with the 1 output from G1 produces a 0 output from I3. The 1 output from G1 along with the 1 output from the delay line produces a 0 output from I4. With 0 outputs from I3 and I4, OR gate G2 produces a 0 output.

Detailed Logic Diagrams

Detailed logic diagrams show all logic functions of the equipment concerned (*Figure 6-21*). In addition, they also include such information as socket locations, pin numbers, and test points to help in troubleshooting. The detailed logic diagram for a complete unit may consist of many separate sheets.

All input lines shown on each sheet of a detailed logic diagram are tagged to show the origin of the inputs. Likewise, all output lines are tagged to show destination. In addition, each logic function shown on the sheet is tagged to identify the function hardware and to show function location both on the diagram and within the equipment.

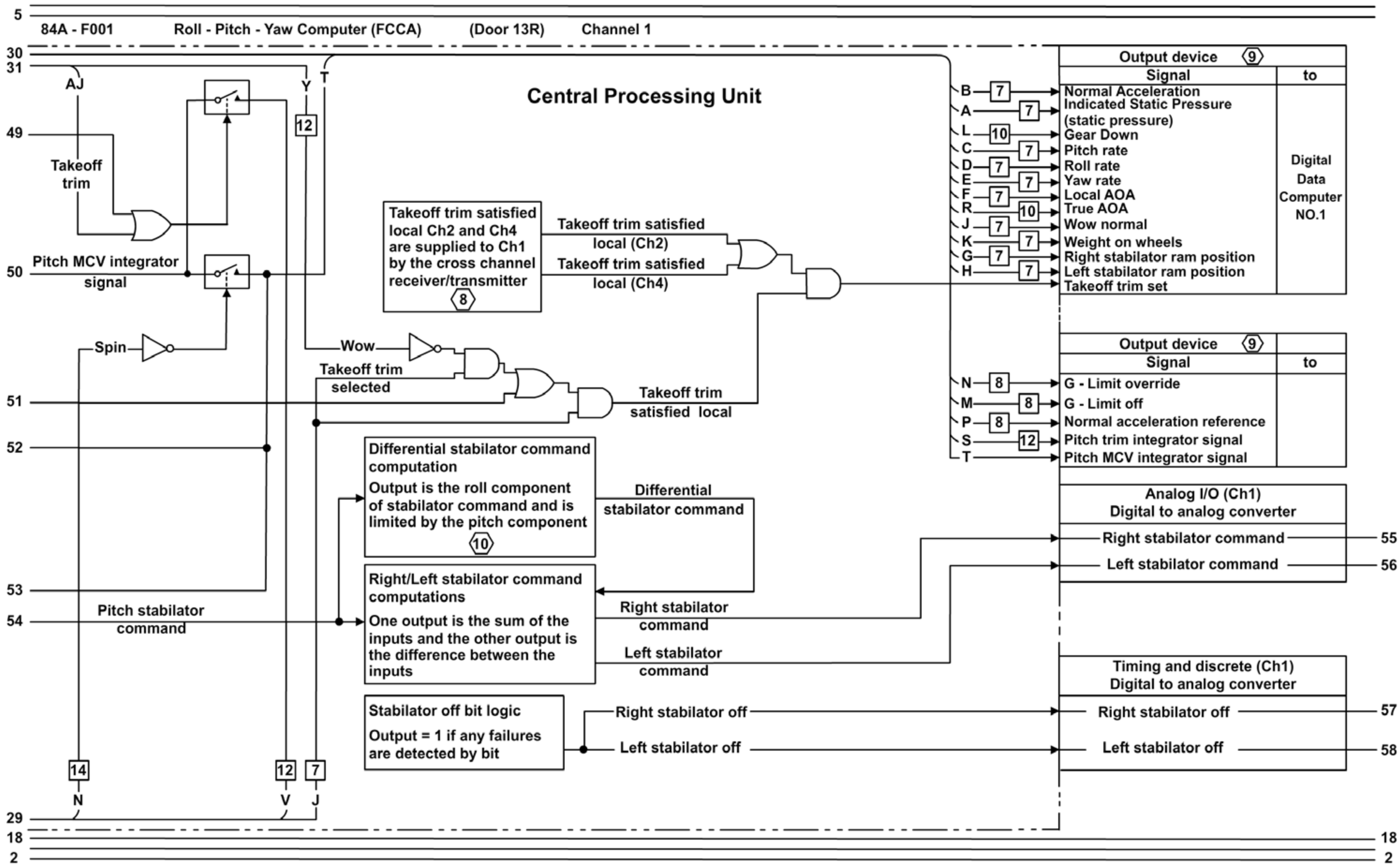


Figure 6-21 — Sample detailed logic diagram.

End of Chapter 6

Electrical and Electronics Prints

Review Questions

6-1. What type of diagram shows a picture or sketch of various components of a specific system?

A. Isometric
B. Pictorial
C. Schematic
D. Wiring

6-2. What type of diagram is used to locate a component within a system?

A. Isometric
B. Pictorial
C. Schematic
D. Wiring

6-3. What type of diagram uses symbols to represent components in a circuit?

A. Isometric
B. Pictorial
C. Schematic
D. Wiring

6-4. What type of diagram is a detailed diagram of each circuit installation showing all connectors, terminal boards, and electrical components of a circuit?

A. Isometric
B. Pictorial
C. Schematic
D. Wiring

6-5. The new electrical cable tag system consists of how many parts?

A. One
B. Two
C. Three
D. Four

6-6. What type of diagram is supplied for each shipboard electrical system?

A. Electrical troubleshooting
B. Ground fault isolation
C. Isometric deck plan
D. Isometric wiring

6-7. What type of print is used by the shipyard electrician to lay out the work for a number of cables without referring to individual isometric wiring diagrams?

A. Block
B. Connection
C. Deck plan
D. Pictorial

6-8. What type of diagram is a valuable troubleshooting tool?

A. Block
B. Connection
C. Deck plan
D. Pictorial

6-9. Aircraft graphic symbols are drawn according to what standard?

A. Institute of Electrical and Electronic Engineers Standard 315A
B. Institute of Electrical and Electronic Engineers Standard 513A
C. Military Specification: Wiring, Aerospace Vehicle, SAE-AS50441
D. Military Specification: Wiring, Aerospace Vehicle, SAE-AS58551

6-10. Aircraft electrical wiring diagrams show what type of information on all electrical systems?

A. Basic
B. Detailed
C. Sequential
D. Troubleshooting

6-11. Aircraft wire and cable identification is a combination of what two markings?

A. Letters and numbers
B. Symbols and letters
C. Numbers and symbols
D. Symbols and classification label

6-12. In aircraft wiring identification, what letters are not used?

A. I and L
B. I and O
C. O and Q
D. P and O

6-13. Shipboard electronic prints include what types of drawings?

A. Advanced and basic
B. Elementary and advanced
C. Isometric and advanced
D. Isometric and elementary

6-14. A reference designation is a combination of letters and numbers used to identify the various parts and components on electronic drawings, diagrams, and what other item?

A. Parts list
B. Parts catalog
C. Wiring schedule
D. Electrical installation guide

6-15. Aircraft electronic wiring diagrams fall into what two basic classes?

A. Basic and advanced
B. Block and interconnecting
C. Wiring and block
D. Wiring and interconnecting

6-16. Computers operate entirely on the principle of logic using what two conditions to make a programmed decision?

A. Logic and reason
B. No and prohibit
C. True and false
D. Yes and or

6-17. The symbolic logic operations used in computers are based on what algebraic system?

A. Algorithm
B. Boolean
C. Monomial
D. Permutation

6-18. Logic operations consist of AND, OR, and what other basic operation?

A. IF
B. IS
C. NOT
D. THEN

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CHAPTER 7

ARCHITECTURAL AND STRUCTURAL STEEL DRAWINGS

Architectural and structural steel drawings are generally considered to be the drawings of steel, wood, concrete, and other materials used to construct buildings, ships, planes, bridges, towers, tanks, and so on. This chapter discusses the common architectural and structural shapes and symbols commonly used for architectural and structural steel drawings, and describe the common types of drawings used in the fabrication and erection of steel structures.

LEARNING OBJECTIVES

When you have completed this chapter, you will be able to do the following:

1. Recognize the elements of architectural drawings.
2. Identify various types of architectural symbols.
3. Recognize the elements of structural steel drawings.
4. Identify various types of structural symbols.
5. Identify various types of construction drawings.

A building project may be broadly divided into two major phases, the design phase and the construction phase. First, the architect conceives the building, ship, or aircraft in his or her mind, and then sets down the concept on paper in the form of presentation drawings, which are usually drawn in perspective by using pictorial drawing techniques.

The architect and engineer work together to decide upon materials and construction methods. The engineer determines the loads the supporting structural members will carry and the strength each member must have to bear the loads. He or she also designs the mechanical systems of the structure, such as heating, lighting, and plumbing systems. The end result is the preparation of architectural and engineering design sketches that will aid in preparing the construction drawings. These construction drawings, plus the specifications, are the chief sources of information for the supervisors and craftsmen who carry out the construction.

STRUCTURAL SHAPES AND MEMBERS

Various structural members are used to manufacture a wide variety of cross section shapes and sizes. Many of the shapes are shown in *Figure 7-1*. These symbols are compiled from part 4 of Military Standard 18B (MIL-STD-18B) and information from the American Society of Construction Engineers (ASCE). The following paragraphs will explain the common structural shapes used in building materials and the common structural members that are made in those shapes.

Shapes

The three most common types of structural members are the W-shape (wide flange), the S-shape (American Standard I-beam), and the C-shape (American Standard channel). These three types are identified by the nominal depth, in inches, along the web and the weight per foot of length, in pounds. As an example, a W 12 x 27 indicates a W-shape (wide flange) with a web 12 inches deep and a weight of 27 pounds per linear foot.

The cross-sectional views of the W-, S-, and C-shapes are illustrated in *Figure 7-2*. The difference between the W-shape and the S-shape is in the design of the inner surfaces of the flange. The W-shape has parallel inner and outer flange surfaces with a constant thickness, while the S-shape has a slope of approximately 17 degrees on the inner flange surfaces. The C-shape is similar to the S-shape in that its inner flange surface is also sloped approximately 17 degrees.

OLD SYMBOL	OLD ILLUSTRATED USE	DESCRIPTION	EXAMPLE	NEW SYMBOL	NEW ILLUSTRATED USE
WF	24 WF 76	W-SHAPE (WIDE FLANGE)		W	W 24 x 76
BP	14 BP 73	BEARING PILE		HP	HP 14 x 73
I	15 I 42.9	S-SHAPE (AMERICAN STD I-BEAM)		S	S 15 x 42.9
⊔	9 ⊔ 13.4	C-SHAPE (AMERICAN STD CHANNEL)		C	C9 x 13.4
M M Jr	8X8 M 34.3 8 M 17 7 Jr. 5.5	M-SHAPE (MISC SHAPES OTHER THAN W, BP, S, & C)		M	M8 x 34.3 M8 x 17 M7 x 5.5
⊔	12 X 4 ⊔ 44.5	MC-SHAPE (CHANNELS OTHER THAN AMERICAN STD)		MC	MC 12 x 45
Jr ⊔	10 Jr ⊔ 8A				MC 12 x 12.6
		ANGLES:			
L	L 3 x 3 x 1/4	EQUAL LEG		L	L 3 x 3 x 1/4
L	L 7 x 4 x 1/2	UN-EQUAL LEG		L	L 7 x 4 x 1/2
		TEES, STRUCTURAL:			
ST	ST 5 WF 10.5	CUT FROM W-SHAPE		WT	WT 12 x 38
		CUT FROM S-SHAPE		ST	ST 12 x 38
		CUT FROM M-SHAPE		MT	MT 12 x 38
PL	PL 18 x 1/2 x 2'-6"	PLATE		PL	PL 1/2 x 18" x 30"
BAR	BAR 2 1/2 x 1/4	FLAT BAR		BAR	BAR 2 1/2 x 1/4
O	O 6 ϕ	PIPE, STRUCTURAL			PIPE 4 STD PIPE 4X - STRG PIPE 4 XX - STRG

Figure 7-1 — Structural shapes and designations.

W-Shape

The W shape is a structural member whose cross section forms the letter H and is the most widely used structural member. It is designed so that its flanges provide strength in a horizontal plane, while the web gives strength in a vertical plane. W-shapes are used as beams, columns, and truss members, and in other load-bearing applications.

Bearing Pile

The bearing pile (HP-shape) is almost identical to the W-shape. The only difference is that the flange thickness and web thickness of the bearing pile are equal, whereas the W-shape has different web and flange thicknesses.

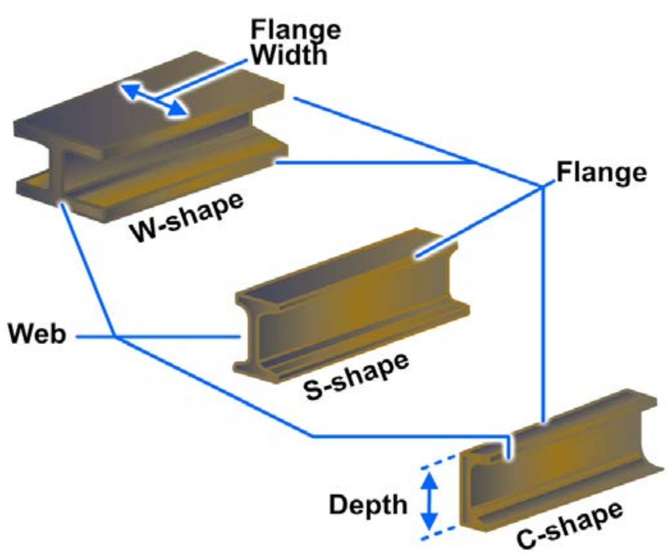


Figure 7-2 — Cross section view of the W-, S-, and C-shape structural members.

S-Shape

The S-shape (American Standard I-beam) is distinguished by its cross section being shaped like the letter I. S-shapes are used less frequently than W-shapes since the S-shapes possess less strength and are less adaptable than W-shapes.

C-Shape

The C-shape (American Standard channel) has a cross section somewhat similar to the letter C. It is especially useful in locations where a single flat face without outstanding flanges on one side is required. The C-shape is not very efficient for a beam or column when used alone. However, efficient built-up members may be constructed of channels assembled together with other structural shapes and connected by rivets or welds.

Channels

A cross section of a channel is similar to the squared letter C. Channels are identified by their nominal depth and weight per foot. For example, the American Standard channel notation C9 x 13.4 in *Figure 7-1* shows a nominal depth of 9 inches and a weight of 13.4 pounds per linear foot, Channels are principally used in locations where a single flat face without outstanding flanges on a side is required. However, the channel is not very efficient as a beam or column when used alone. But the channels may be assembled together with other structural shapes and connected by rivets or welds to form efficient built-up members.

Angles

An angle (*Figure 7-3*) is a structural shape whose cross section resembles the letter L. Two types are commonly used: an equal-leg angle and an unequal-leg angle. The angle is identified by the dimension and thickness of its legs, for example, angle 6 inches by 4 inches by 1/2 inch. The dimension of the legs should be obtained by measuring along the outside of the backs of the legs. When an angle has unequal legs, the dimension of the wider leg is given first, as in the example just cited. The third dimension applies to the thickness of the legs, which always have equal thickness. Angles may be used in combinations of two or four to form main members. A single angle may also be used to connect main parts together.

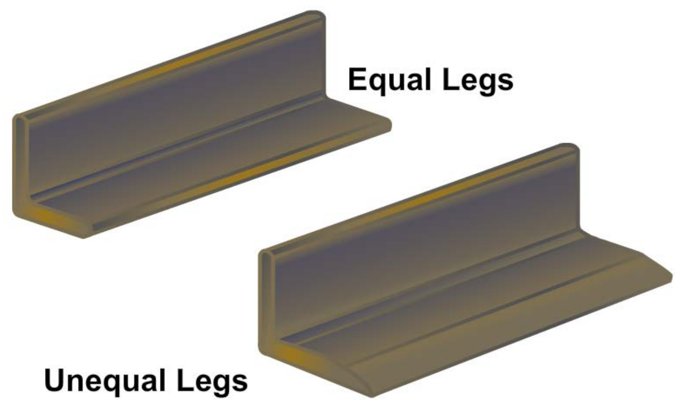


Figure 7-3 — Angles.

Plates

Generally, a main point to remember about plate is that it has a width of greater than 8 inches and a thickness of 1/4 inch or greater. Plates are generally used as connections between other structural members or as component parts of built-up structural members. Plates cut to specific sizes may be obtained in widths ranging from 8 inches to 120 inches or more, and in various thicknesses. The edges of these plates may be cut by shears (sheared plates) or be rolled square (universal mill plates).

Frequently, plates are referred to by their thickness and width in inches, as plate 1/2 inch x 24 inches. The length in all cases is given in inches. Notice in *Figure 7-4* that 1 cubic foot of steel weighs 490 pounds. This weight divided by 12 equaling 40.8, which is the weight (in pounds) of a steel plate 1 foot square and 1-inch thick. The fractional portion is normally dropped and 1-inch plate is called a

40-pound plate. In practice, you may hear plate referred to by its approximate weight per square foot for a specified thickness. An example is 20-pound plate, which indicates a 1/2-inch plate.

The designations generally used for flat steel have been established by the American Iron and Steel Institute (AISI). Flat steel is designated as bar, strip, sheet, or plate, according to the thickness of the material, the width of the material, and (to some extent) the rolling process to which it was subjected.

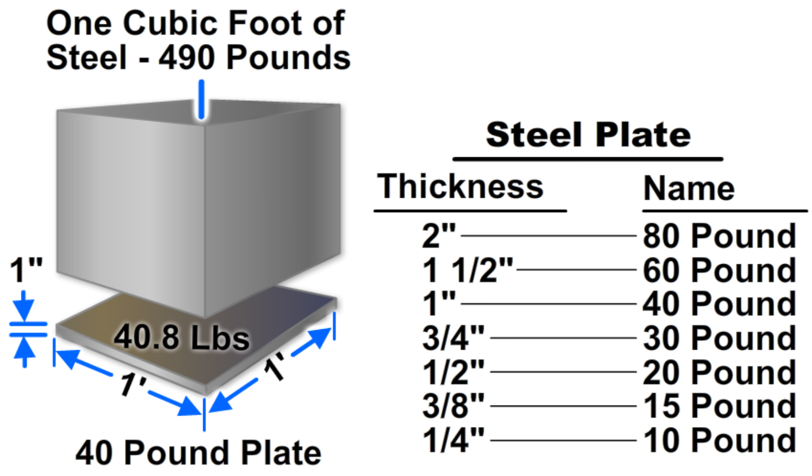


Figure 7-4 — Weight and thickness of a steel plate.

Tees

A structural tee is made by slitting a standard I- or H- beam through the center of its web, thus forming two T-shapes from each beam. In dimensioning, the structural tee symbol is preceded by the letters ST*.* For example, the symbol ST 5 WF 10.5 means the tee has a nominal depth of 5 inches, a wide flange, and weighs 10.5 pounds per linear foot. A rolled tee is a manufactured shape. In dimensioning, the rolled tee symbol is preceded by the letter T*.* The dimension T 4 x 3 x 9.2 means the rolled T has a 4-inch flange, a nominal depth of 3 inches, and a weight of 9.2 pounds per linear foot.

Zee

These shapes are noted by depth, flange width, and weight per linear foot. Therefore, Z 6 x 3 1/2 x 15.7 means the zee is 6 inches in depth, has a 3 1/2-inch flange, and weighs 15.7 pounds per linear foot.

Figure 7-5 — Bars.

Flat Bar

The structural shape referred to as bar has a width of 8 inches or less and a thickness greater than 3/16 of an inch. The edges of bars usually are rolled square, like universal mill plates. The dimensions are expressed in a similar manner as that for plates, for instance, bar 6 inches by 1/2 inch. Bars are available in a variety of cross-sectional shapes—round, hexagonal, octagonal, square, and flat. Four different shapes are illustrated in *Figure 7-5*. Both squares and rounds are commonly used as bracing members of light structures. Their dimensions, in inches, apply to the side of the square or the diameter of the round.

Columns

Typically, wide flange members, as nearly square in cross section as possible, are used for columns, but sometimes large diameter pipe is used, even though pipe columns can present connecting difficulties when you are attaching other members (*Figure 7-6*). Columns may also be fabricated by welding or bolting together a number of other rolled shapes, usually angles and plates (*Figure 7-7*).

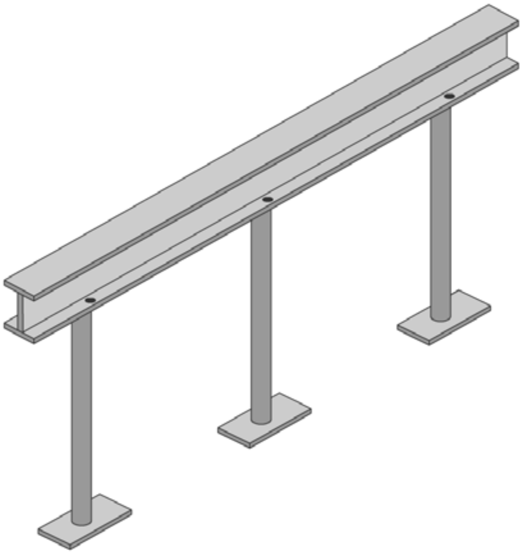


Figure 7-6 — Girder span on pipe columns.

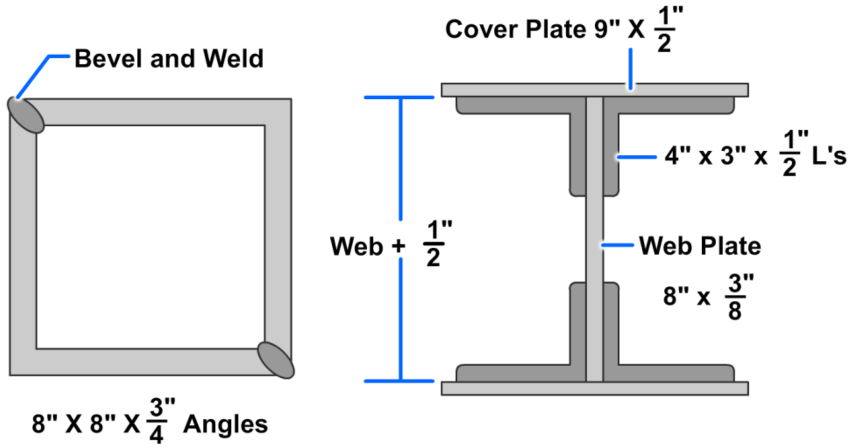


Figure 7-7 — Built-up column section.

Girders

Girders are the primary horizontal members of a steel frame structure. They span from column to column and are usually connected on top of the columns with cap plates (bearing connections) (*Figure 7-8*). An alternate method is the seated connection (*Figure 7-9*). The girder is attached to the flange of the column using angles, with one leg extended along the girder flange and the other against the column. The function of the girders is to support the intermediate floor beams.

Members

The main parts of a structure are the load-bearing members. These support and transfer the loads on the structure while remaining equal to each other. The places where members are connected to other members are called joints. The total sum of the load supported by the structural members at a particular instant is equal to the total dead load plus the total live load.

The total dead load is the total weight of the structure, which gradually increases as the structure rises and remains constant once it is complete. The total live load is the total weight of movable objects, such as people, furniture, and bridge traffic, the structure happens to be supporting at a particular instant.

Figure 7-8 — Girder span on a wide flange column.

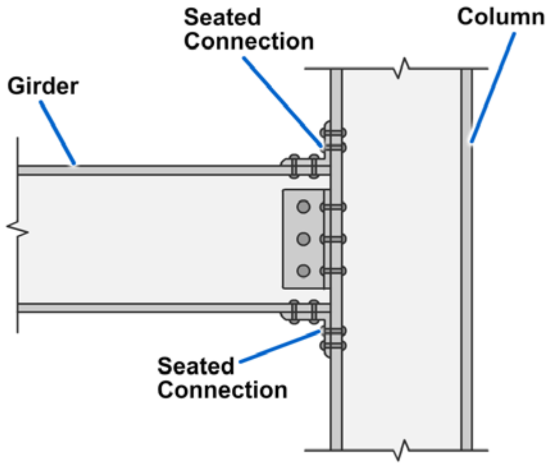


Figure 7-9 — Seated connections.

A structure transmits live loads through the various load-bearing structural members to the ultimate support of the earth. Look at *Figure 7-10*, which illustrates both horizontal and vertical members of a typical light frame structure.

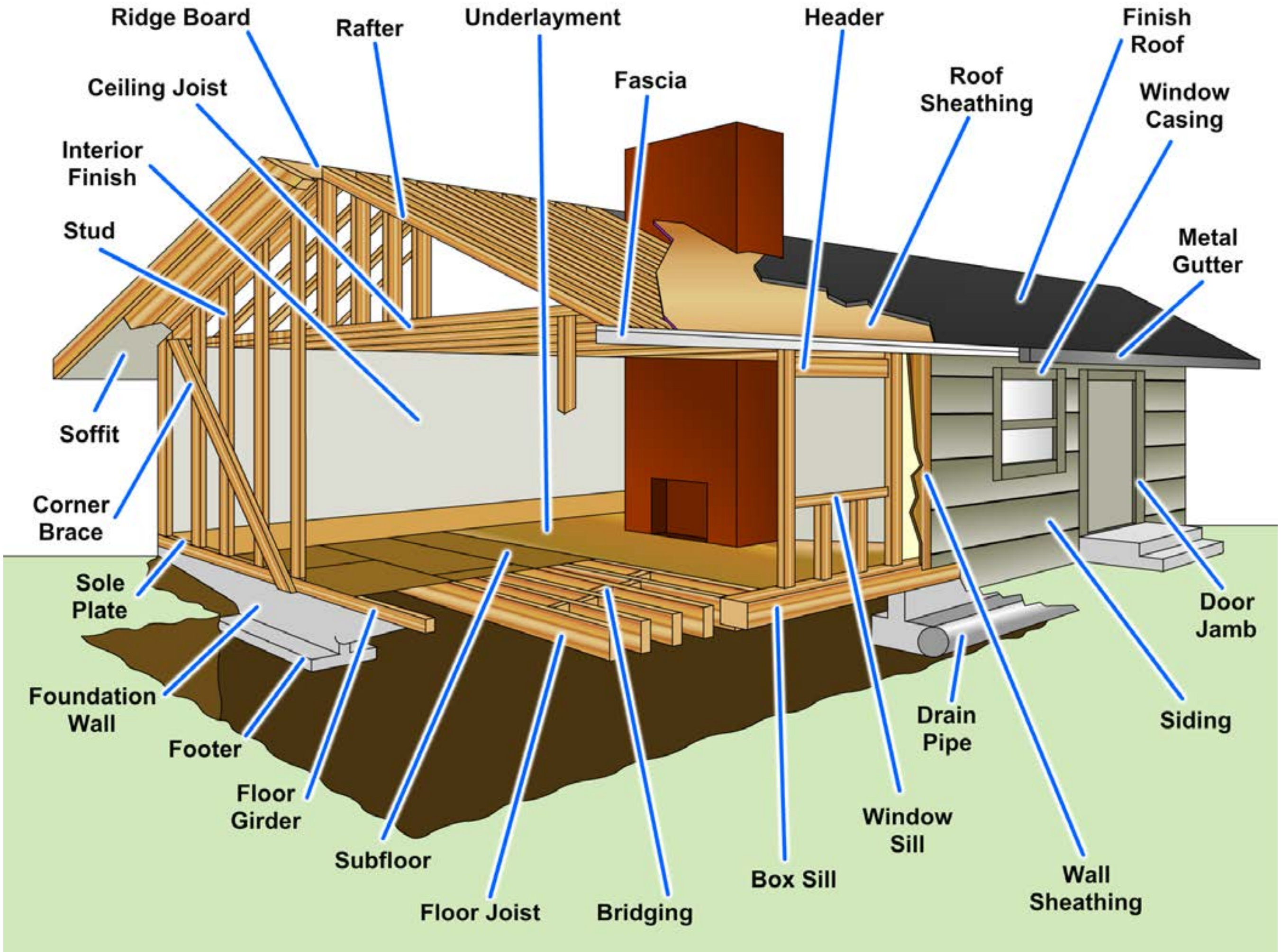


Figure 7-10 — Typical light frame construction.

First, horizontal members provide immediate or direct support for the live loads. Vertical members, in turn, support the horizontal members. Finally, the vertical members are supported by foundations or footings, which are supported by the earth. The weight of the roof material is distributed over the top supporting members and transferred through all joining members to the soil.

The ability of the earth to support a load is called its soil-bearing capacity. This varies considerably with different types of soil. A soil of a given bearing capacity bears a heavier load on a wide foundation or footing than on a narrow one. Loads are covered in much greater detail in the Builder Advanced rate training manual. This section is meant to be a brief introduction to the concept of load.

Vertical Members

In heavy construction, vertical structural members are high-strength columns. In large buildings, these are called pillars. Outside wall columns and inside bottom floor columns usually rest directly on footings. Outside wall columns usually extend from the footing or foundation to the roof line. Inside bottom floor columns extend upward from footings or foundations to the horizontal members, which, in turn, support the first floor or roof, as shown in *Figure 7-11*. Upper floor columns are usually located directly over lower floor columns.

In building construction, a pier, sometimes called a short column, rests either directly on a footing, as shown in the lower center of *Figure 7-12*, or is simply set or driven into the ground. Building piers usually support the lowermost horizontal structural members.

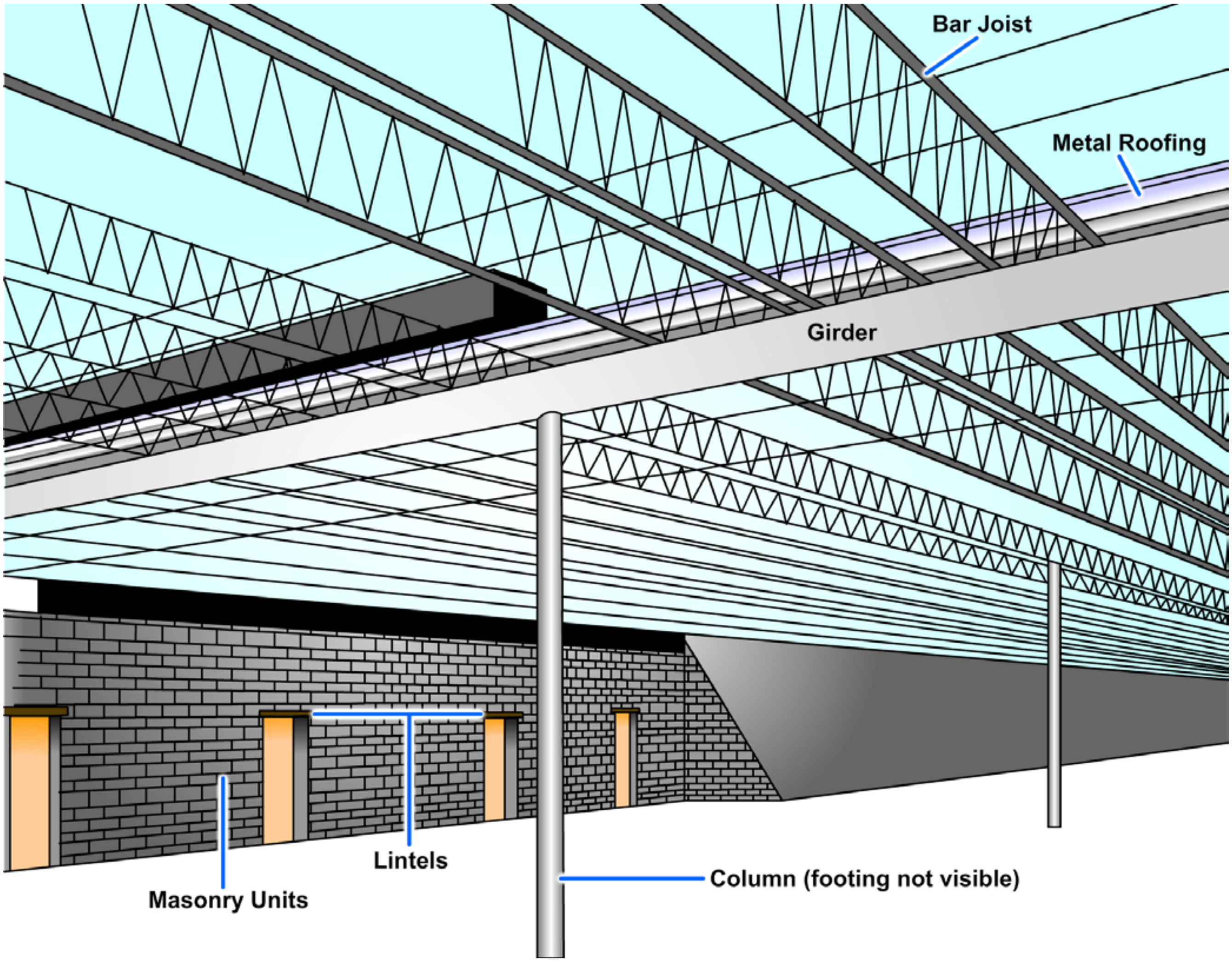


Figure 7-11 — Typical concrete masonry and steel structure.

The chief vertical structural members in light frame construction are called studs, shown in *Figures 7-10 and 7-12*. They are supported by horizontal members called sills or soleplates, shown in *Figure 7-12*. Corner posts are enlarged studs located at the building corners. At one time, in full frame construction, a corner post was usually a solid piece of larger timber. Most modern construction uses built-up corner posts. These consist of various members of ordinary studs nailed together in various ways.

In bridge construction, a pier is a vertical member that provides intermediate support for the bridge superstructure**,** as shown in *Figure 7-13*.

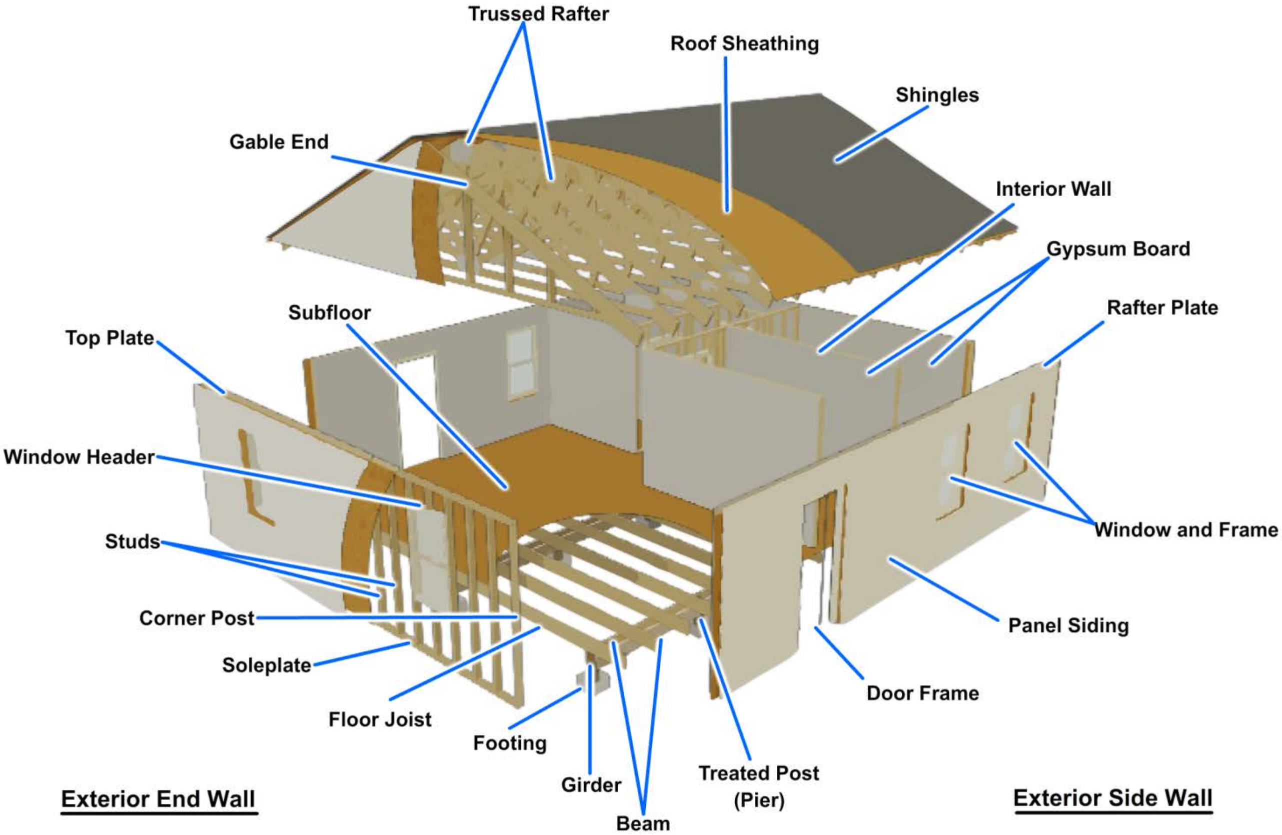


Figure 7-12 — Exploded view of a typical light frame house.

Horizontal Members

Any horizontal load-bearing structural member that spans a space and is supported at both ends is considered a beam. A member fixed at only one end is called a cantilever beam. A joist is a horizontal supporting member generally smaller than a beam. Steel members that consist of solid pieces of regular structural steel are referred to as structural shapes. The girder, shown in *Figure 7-11*, is a structural shape. Other prefabricated, open-web, structural-steel shapes are called bar joists, also shown in *Figure 7-11*.

Horizontal structural members that support the ends of floor beams or joists in wood frame construction are called sills or girders, shown in *Figures 7-10* and *7-12*, depending on the type of framing and the location of the member in the structure. Horizontal members that support studs are called soleplates. They may also have other names, depending on the type of framing. Horizontal members that support the wall ends of rafters are called rafter plates. Horizontal members that assume the weight of concrete or masonry walls above door and window openings are called lintels (*Figure 7-11*).

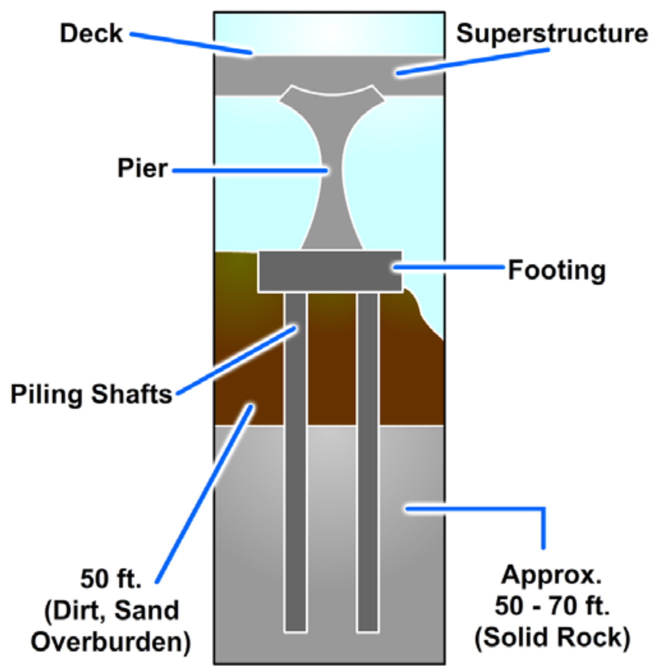


Figure 7-13 — Pier supporting bridge superstructure.

The horizontal or inclined members that provide support to a roof are called rafters (*Figure 7-14*). The lengthwise member at a right angle to the rafters, which supports the peak ends of the rafters in a roof, is called the ridge. The ridge may be called a ridgeboard, the ridge piece, or the ridgepole. Lengthwise members other than ridges are called purlins. In wood frame construction, the wall ends of rafters are supported on horizontal members called rafter plates, which are in turn supported by the outside wall studs. In concrete or masonry construction, the wall ends of rafters may be anchored directly on the walls or on plates bolted to the walls.

Trusses

A beam of given strength, without intermediate supports below; can support a given load over only a specific maximum span. When the span is wider than this maximum space, the beam requires intermediate supports such as columns. Sometimes it is either not feasible or impossible to increase the beam size or to install intermediate supports. In such cases, a truss provides the required support. A truss is a combination of members, such as beams, bars, and ties, usually arranged in triangular units, that forms a rigid framework for supporting loads over a span.

The basic components of a roof truss are the top and bottom chords and the web members. The top chords serve as roof rafters. The bottom chords act as ceiling joists. The web members run between the top and bottom chords. The truss parts are usually made of 2 by 4 inch or 2 by 6 inch material and tied together with metal or plywood gusset plates, shown in *Figure 7-14*.

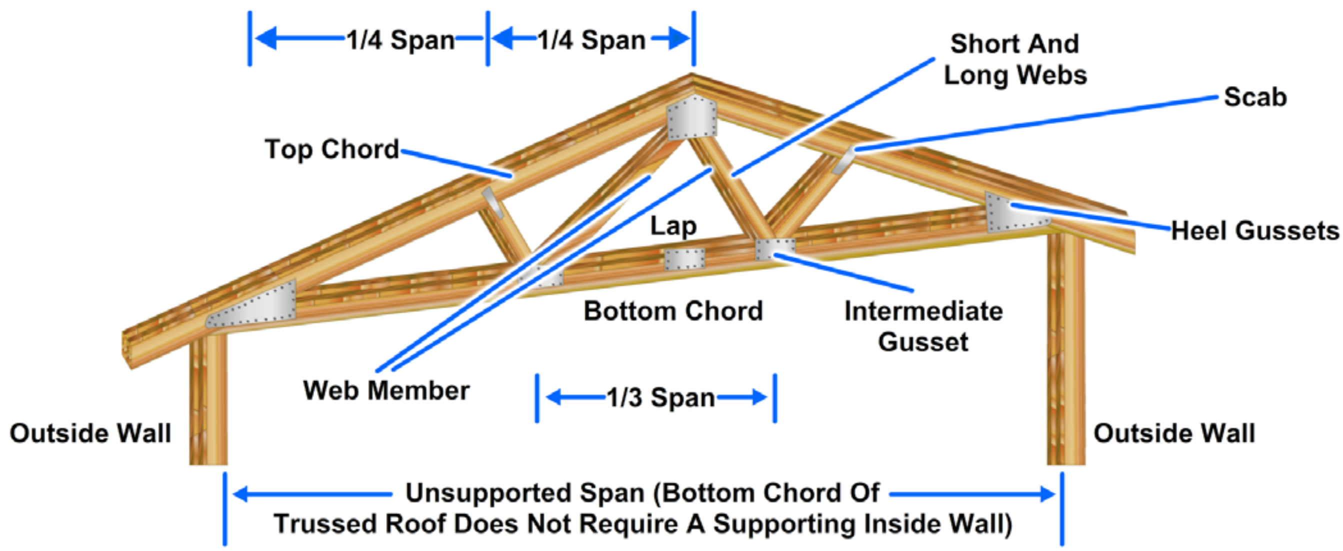


Figure 7-14 — A truss rafter.

WELDED AND RIVETED STEEL STRUCTURES

The following paragraphs will discuss welded and riveted steel structures and will give examples of both methods used to make trusses.

Welded Steel Structures

Generally, welded connections are framed or seated just as they are in riveted connections, which we will discuss later. However, welded connections are more flexible. The holes used to bolt or pin pieces together during welding are usually drilled in the fabrication shop. Beams are not usually welded directly to columns. The procedure produces a rigid connection and results in severe bending that stresses the beam, which must be resisted by both the beam and the weld.

Welding Symbol

Drawings contain special symbols to specify the weld location, type of joint, and size and amount of weld metal to be deposited in the joint. The American Welding Society (AWS) has standardized them. A welder will see them whenever he or she performs a welding job from a set of prints, so you need to be familiar with all the elements of a standard welding symbol, and the location and meaning of the basic weld symbols.

A standard welding symbol (*Figure 7-15*) is: reference line + arrow + tail.

The reference line is the foundation. Weld symbols, dimensions, and other data are applied to it. The arrow connects the reference line to the joint or area to be welded. The direction of the arrow has no bearing on the significance of the reference line. The tail of the welding symbol is used only when necessary to include a process, specification, or other reference information.

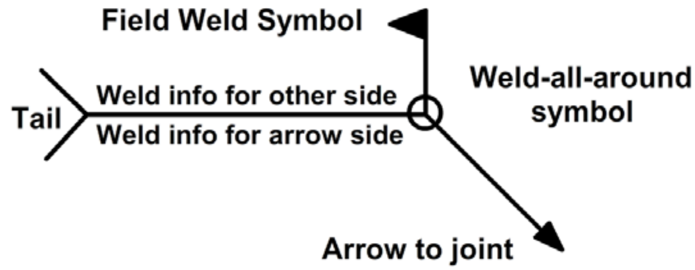


Figure 7-15 — Standard welding symbol.

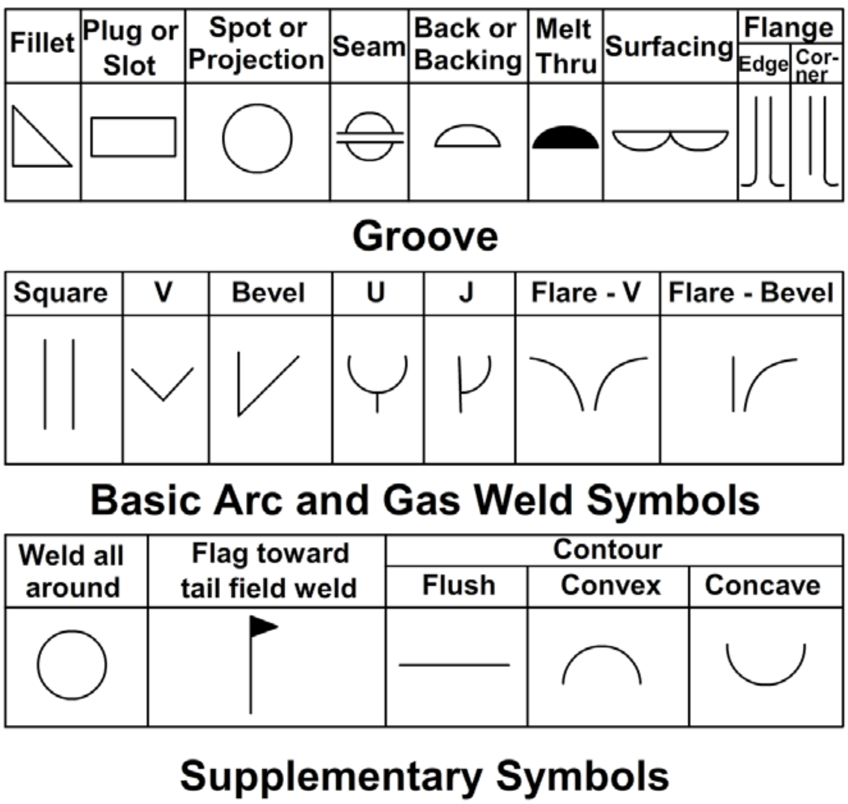


Figure 7-16 — Standard weld symbols.

Type of Weld Symbols

Weld symbols refer to the symbols for a specific type of weld, such as fillet, groove, butt, surfacing, plug, or slot.

The weld symbol (*Figure 7-16*) is only part of the information required in the welding symbol. When used to disseminate information, the term welding symbol refers to the total symbol, which includes all the weld symbols needed to specify the weld(s) required.

How the weld symbol is applied to the reference line is shown in *Figure 7-17*. Notice that the vertical leg of the weld symbol is shown drawn to the left of the slanted or curved leg of the symbol. Regardless of whether the symbol is for a fillet, bevel, J-groove, or flare-bevel weld, the vertical leg is always drawn to the left. The significance of the weld symbol's position on the reference line is depicted in *Figure 7-18*.

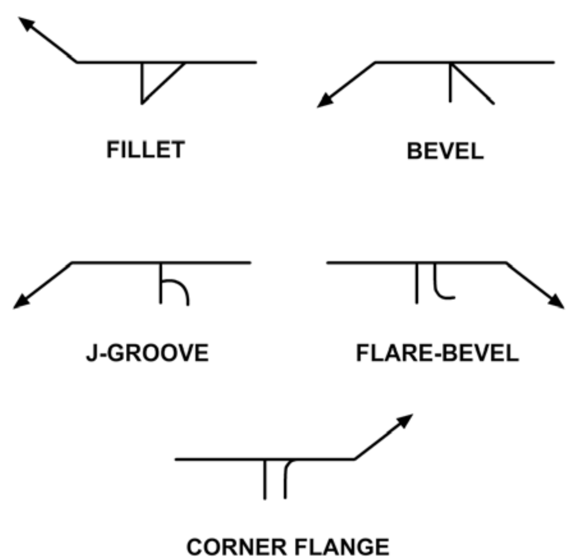


Figure 7-17 — Example of weld symbols applied to a reference line.

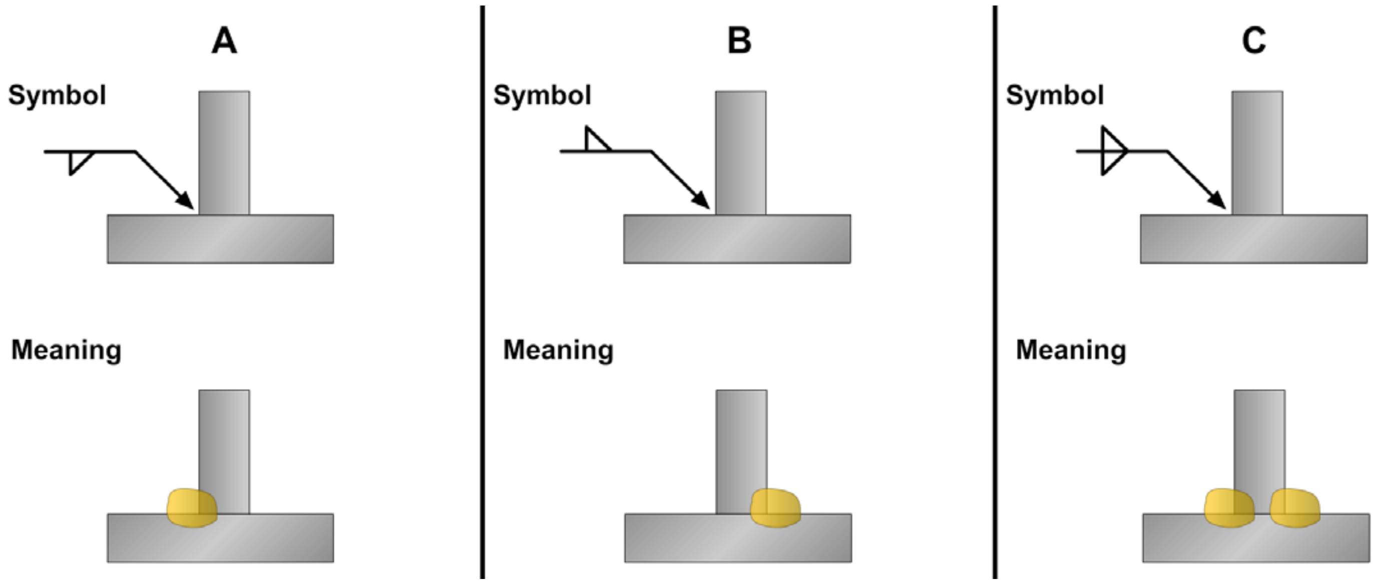


Figure 7-18 — Example of specifying weld location.

When only one edge of a joint is to be beveled, it is necessary to show which member is to be beveled (*Figure 7-19*). When such a joint is specified, the arrow of the welding symbol points with a definite break toward the member to be beveled. Other weld symbols may be added to a welding symbol as necessary to communicate all the information needed for the weld.

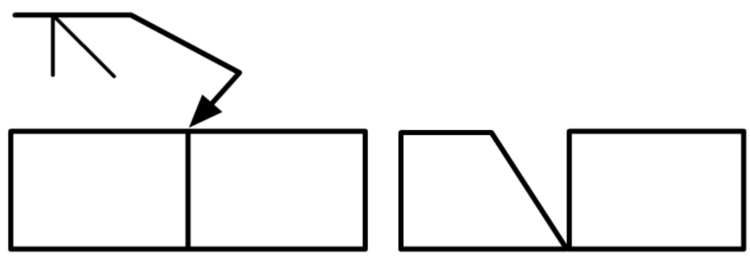


Figure 7-19— Example of arrowhead indicating bevel plate.

However, regardless of the direction of the arrow, all information applied to the reference line on a welding symbol is read from left to right. A listing of welding symbols is shown in *Figure 7-20*.

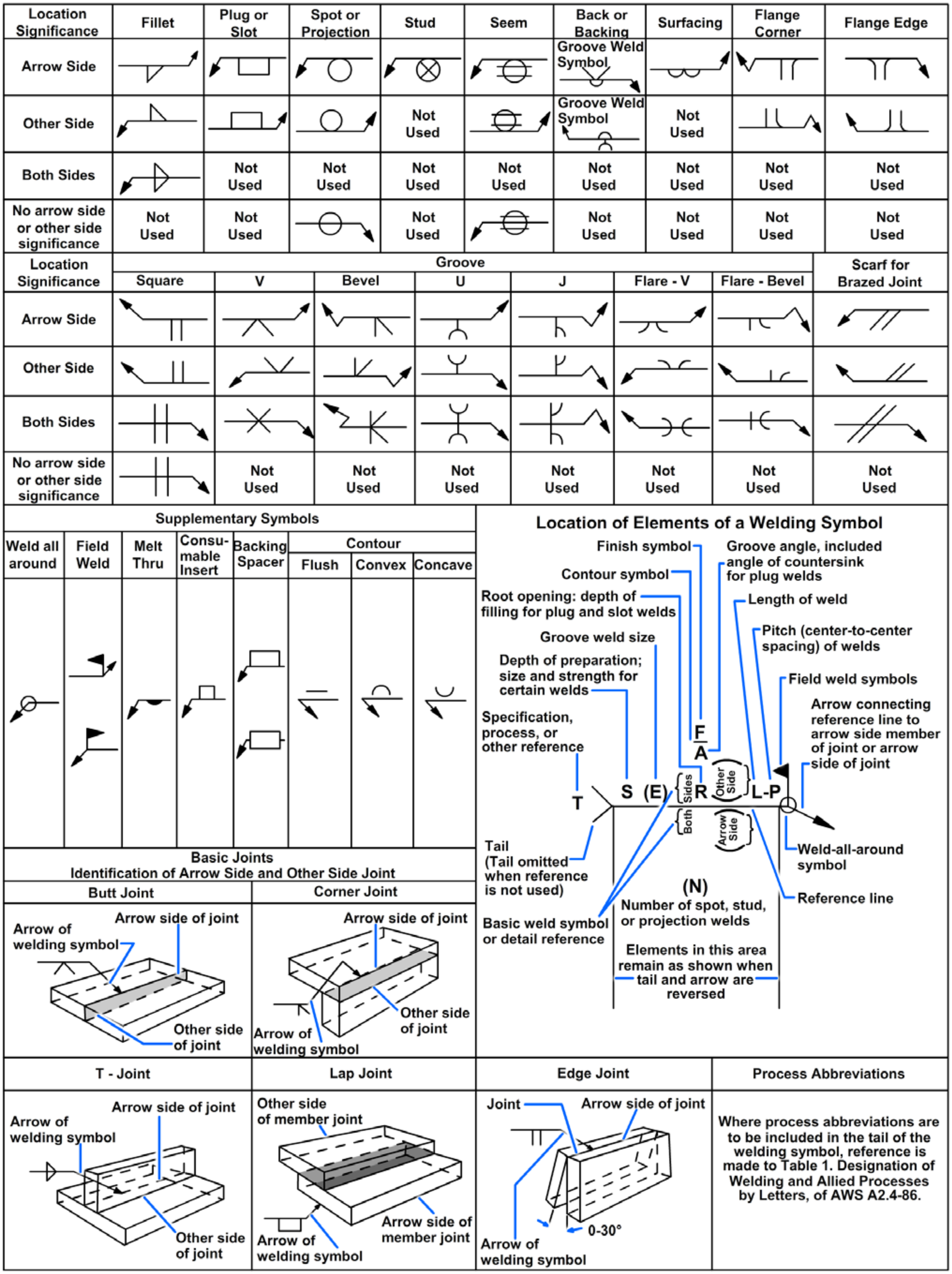


Figure 7-20 — Typical welding symbols.

Dimensioning

Notice in *Figure 7-21* that some specified information has designated locations.

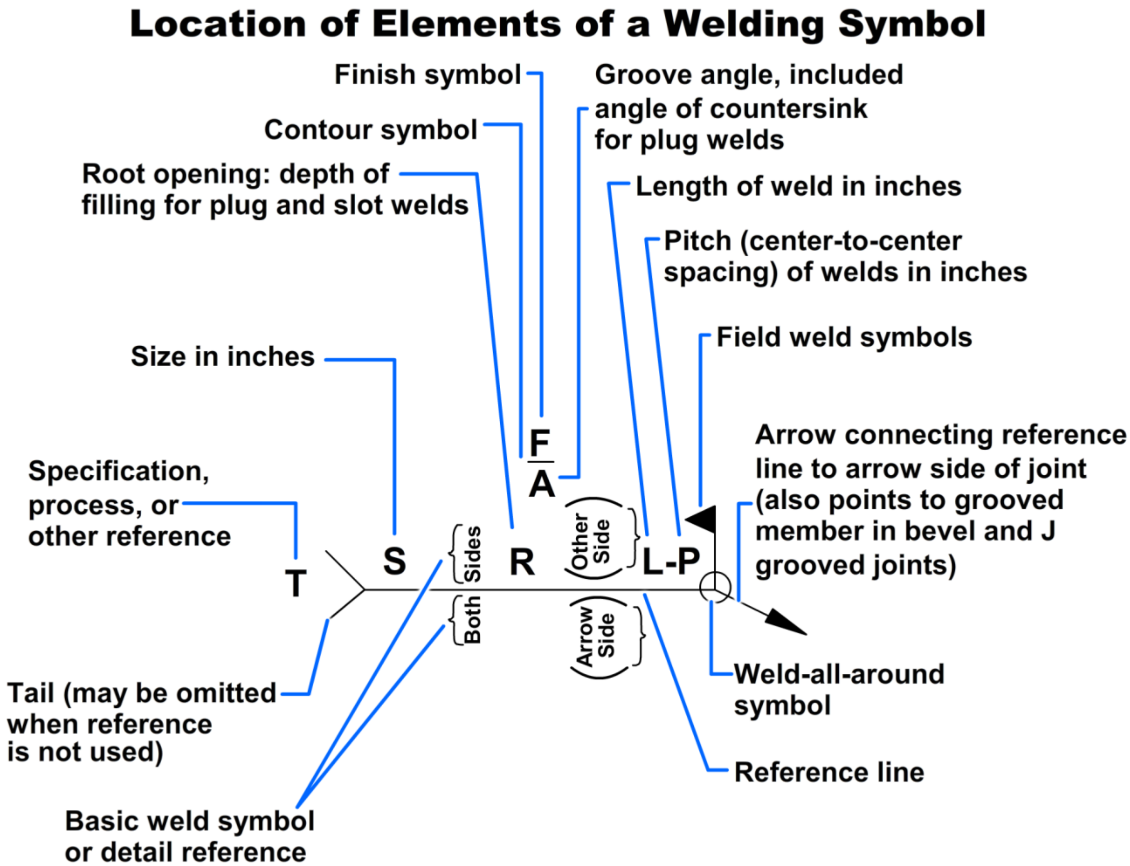


Figure 7-21 — Standard location for specific elements of a welding symbol.

The size, length, pitch (center-to-center spacing), groove angle, and root opening of a weld all have designated locations. These locations are determined by the side of the reference line on which the weld symbol is placed.

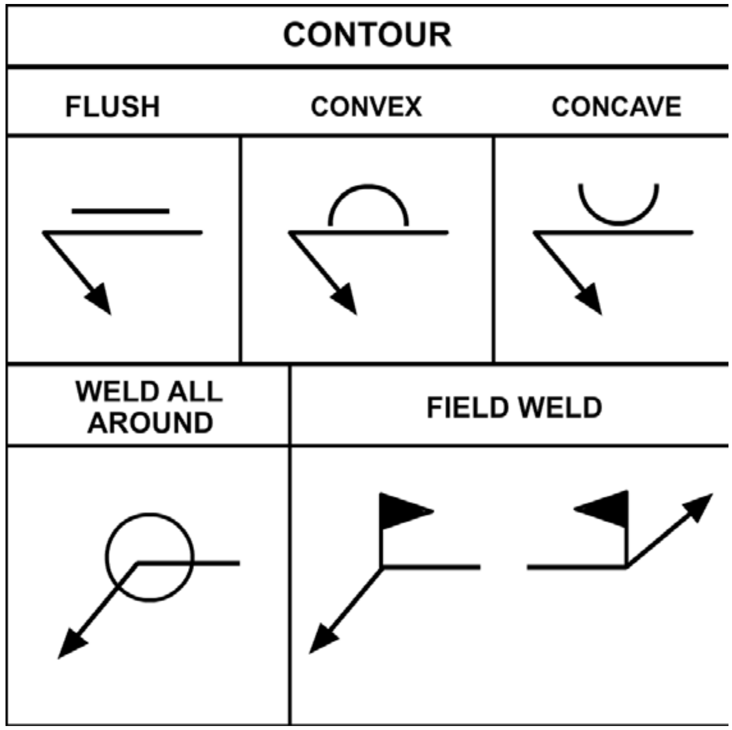


Figure 7-22 — Supplementary symbols.

Supplementary

Besides the basic weld symbols, the welding symbol may include supplementary symbols (*Figure 7-22*). Contour symbols show how the face is to be formed; finish symbols indicate the method to use to form the contour.

A finish symbol (when used) shows the method of finish, C represents chipping, M means machining, and G indicates grinding, not the degree of finish. How contour and finish symbols are applied to a welding symbol is illustrated in *Figure 7-23*. This symbol indicates the weld is to be ground flush. Also, notice that the symbols are placed on the same side of the reference line as the weld symbol.

Another supplementary symbol is the weld-all-around symbol. When this symbol is placed on a welding symbol, welds are to continue all around the joint.

Yet another symbol on *Figure 7-22* is the field weld symbol, a black flag that points toward the tail of the welding symbol. For welds that cannot be made in the shop, for size, transportation, constructability, or other reasons, this symbol directs the welder to make the weld in the field, which could be "in situ" or on site.

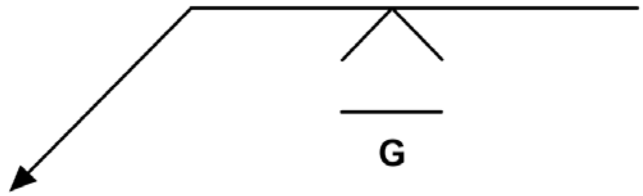


Figure 7-23 — Welding finish symbol.

Welded Steel Trusses

A drawing of a typical welded steel truss is illustrated in *Figure 7-24*. When you interpret the welding symbols, you will see that most of them show that the structural angles will be fillet welded. The fillet will have a 1/4 inch radius (thickness) on both sides and will run along the angle for 4 inches.

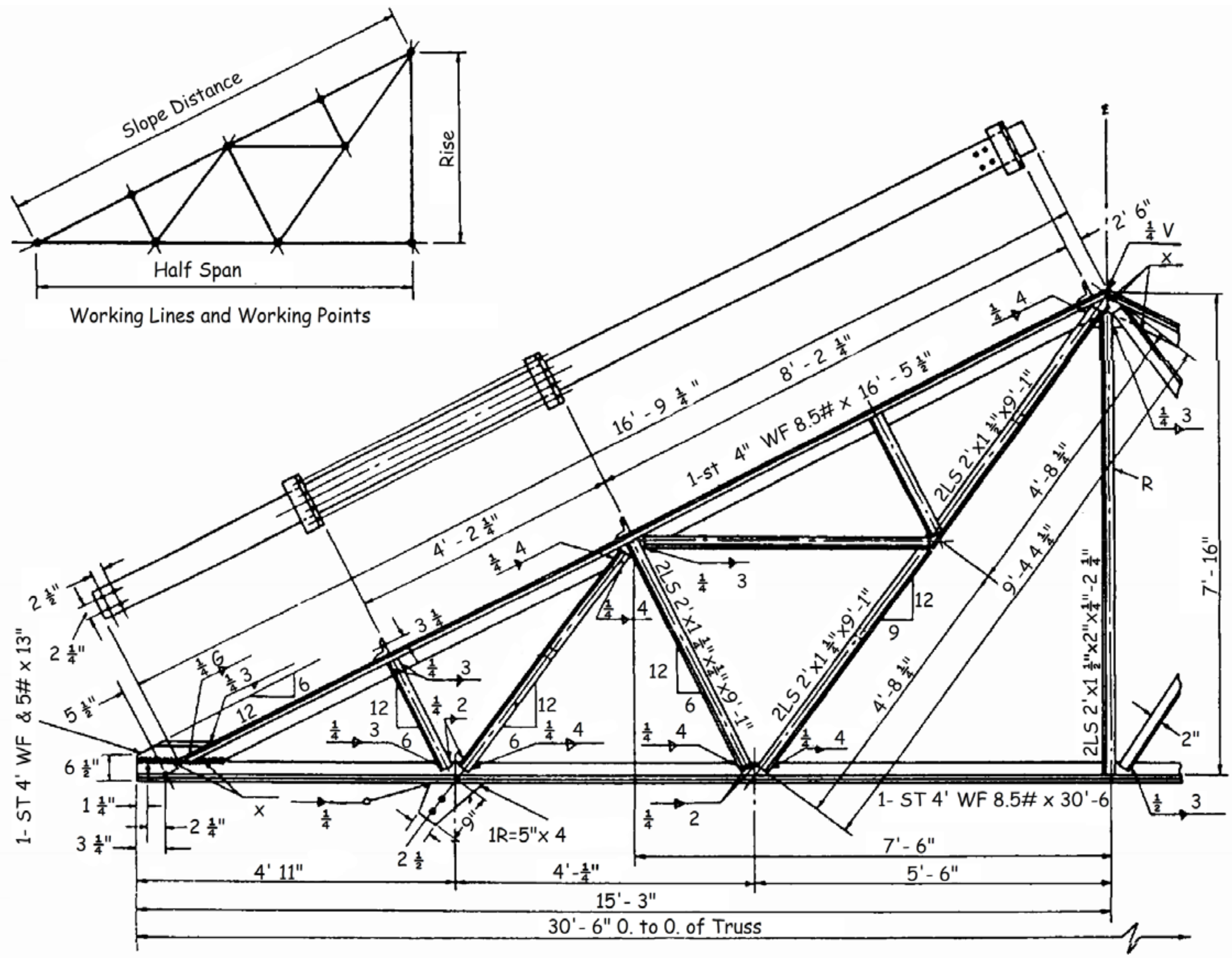


Figure 7-24 — Welded steel truss.

Riveted Steel Structures

Steel structural members are riveted in the shop where they are fabricated to the extent allowed by shipping conditions. During fabrication, all rivet holes are punched or drilled whether the rivets are to be driven in the field or in the shop.

Look at the shop fabrication drawing of a riveted steel roof truss in *Figure 7-25*. At first look, it appears cluttered and hard to read. This is caused by the many dimensions and other pertinent facts required on the drawing, but you can read it once you understand what you are looking for, as we will explain in the next paragraphs.

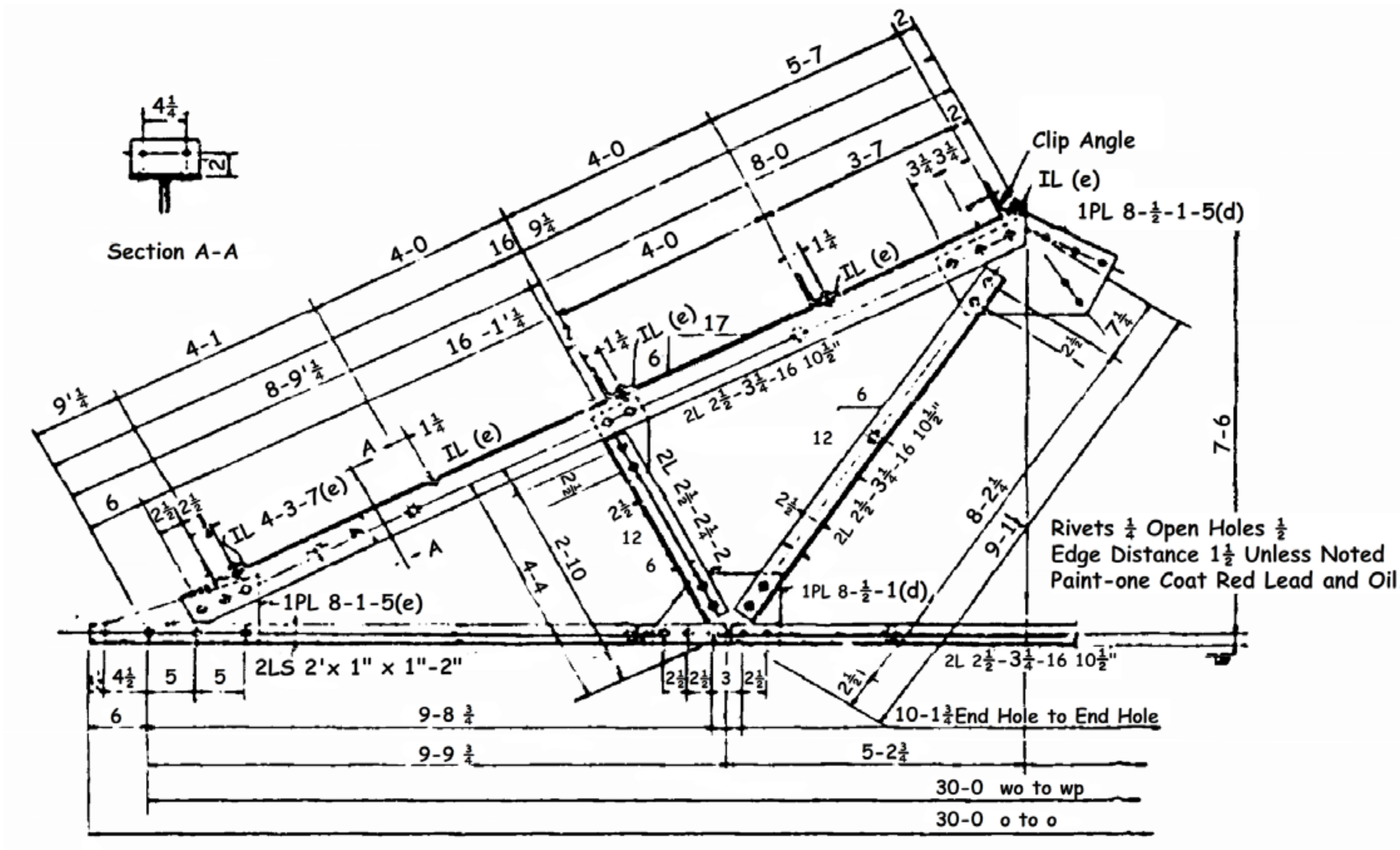


Figure 7-25 — Riveted steel truss shop drawing.

The top chord is made up of two angles labeled with specification 2L 4 x 3 1/2 x 5/16 x 16´-5 1/2". This means the chord is 4 inches by 3 1/2 inches by 5/16 inch thick and 16 feet 5 1/2 inches long.

The top chord also has specification IL 4 x 3 x 3/8 x 7(e). This means it has five clip angles attached, and each of them is an angle 4 inches by 3 inches by 3/8 inch thick and 7 inches in length.

The gusset plate (a) on the lower left of the view is labeled PL 8 x 3/8 x 1´-5 (a). That means it is 8 inches at its widest point, 3/8 inch thick, 1 foot 5 inches long at its longest point.

The bottom chord is made up of two angles 2 1/2 inches by 2 inches by 5/16 inches by 10 feet 3 7/16 inches which are connected to gusset plates A and B, and two more angles 2 1/2 inches by 2 inches by 1/4 inches by 10 feet 4 1/8 inches which are connected to gusset plate B and continue to the other half of the truss. Two more angles are connected to gusset plates C and B on the top and bottom chords; they are 2 1/2 inches by 2 inches by 1/4 inches by 2 feet 10 1/2 inches. The other member between the top and bottom chords, connected to gusset plate B and the purlin gusset D, is made up of two angles 2 1/2 inches by 2 inches by 1/4 inches by 8 feet 5 inches.

In *Figure 7-26*, the same truss is shown with only the names of some members and the sizes of the gusset plates (A, C, and D) between the angles.

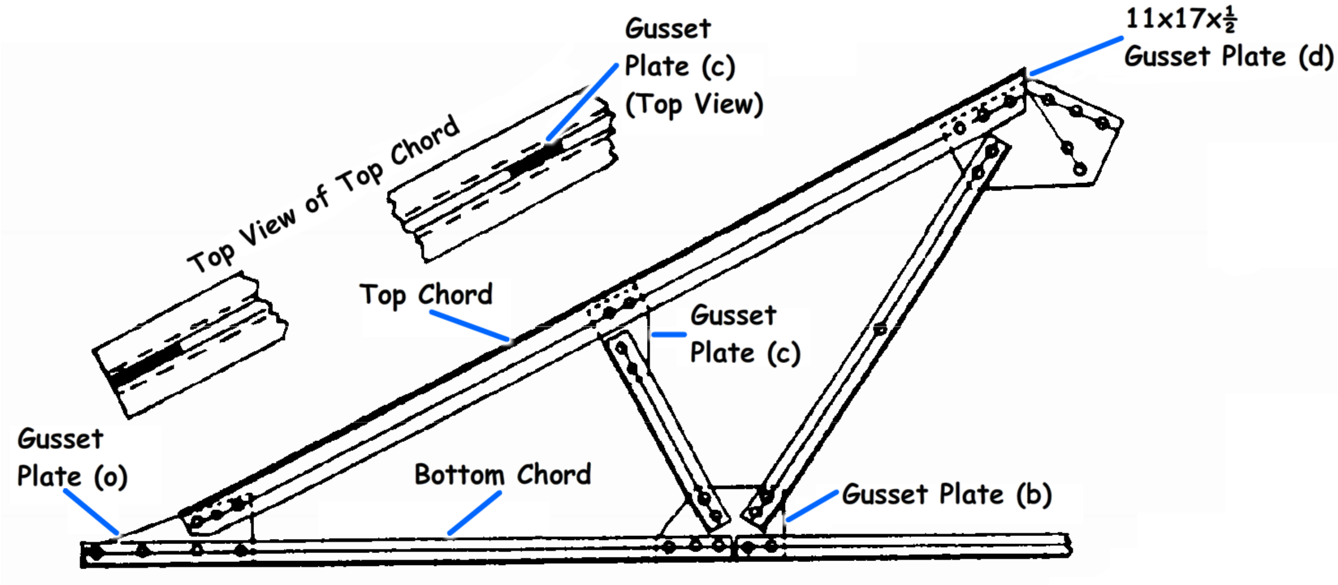


Figure 7-26 — Nomenclature, member sizes and top view of the riveted steel truss.

In *Figure 7-27*, the same truss is shown with only a few of the required dimensions to make it easier to read the complete structural shop drawing.

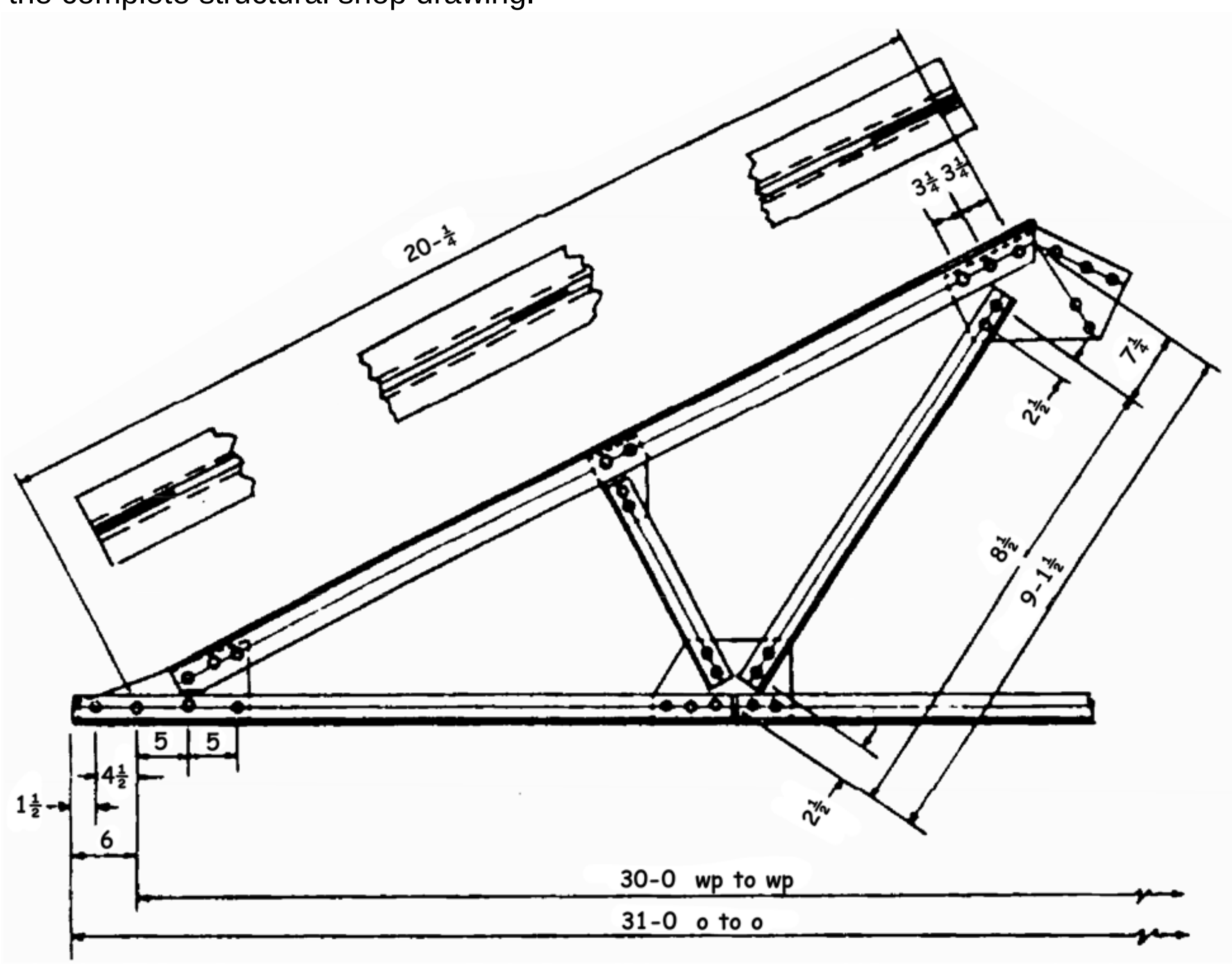


Figure 7-27 — Dimensions of the riveted steel truss.

Most of the rivets will be driven in the shop with the exception of five rivets in the purlin gusset plate d and the two rivets shown connecting the center portion of the bottom chord, which is connected to gusset plate b. These seven rivets will be driven at the jobsite. Conventional symbols for rivets driven in the shop and in the field are shown in *Figure 7-28*.

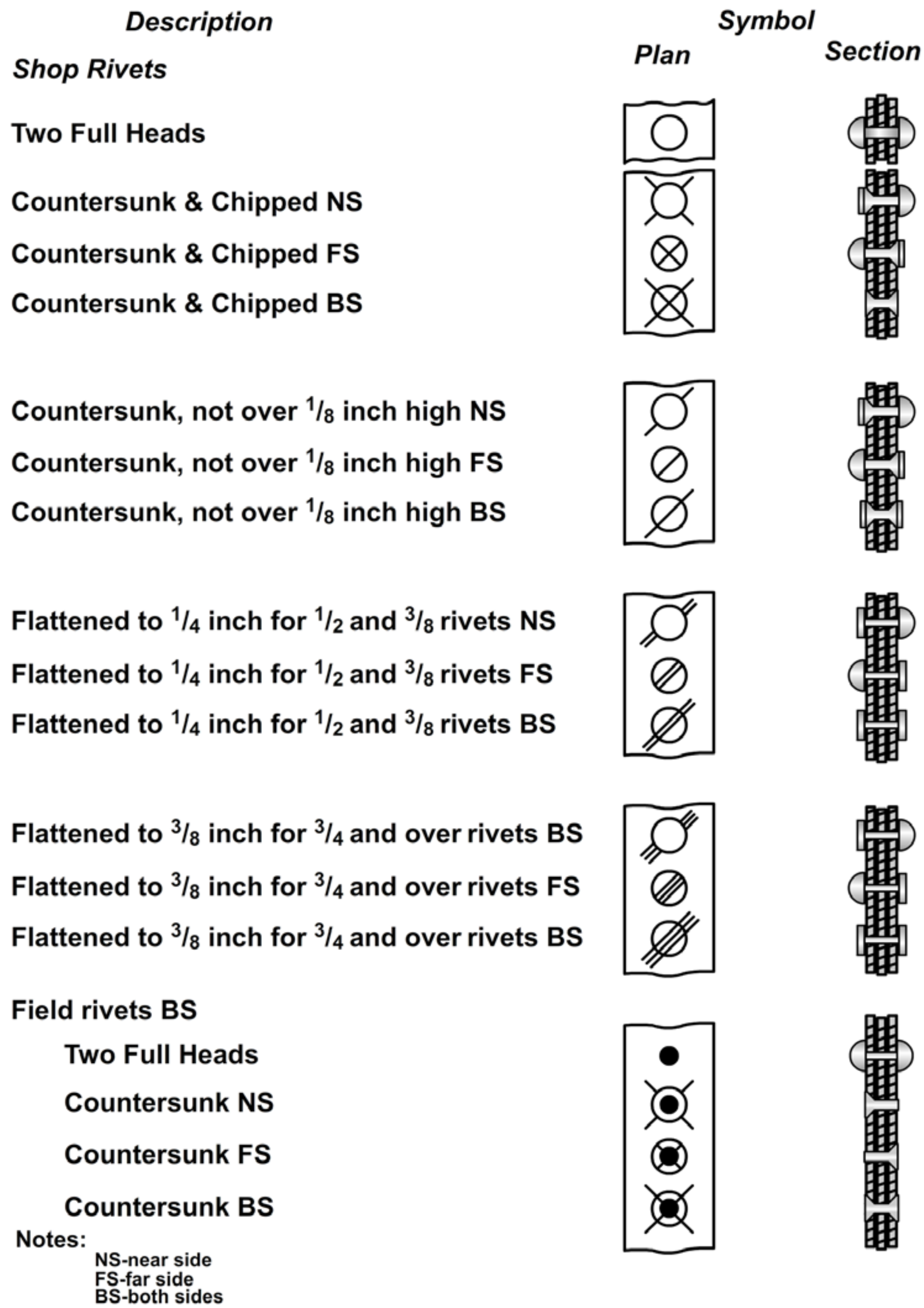


Figure 7-28 — Riveting symbols.

DRAWINGS OF STEEL STRUCTURES

Blueprints used for the fabrication and erection of steel structures usually consist of a group of different types of drawings such as layout, general, fabrication, erection, and falsework. These drawings are described in the following paragraphs.

Layout Drawings

Layout drawings are also called general plans and profile drawings. They provide the necessary information on the location, alignment, and elevation of the structure and its principal parts in relation to the ground at the site. They also provide other important details, such as the nature of the underlying soil or the location of adjacent structures and roads. These drawings are supplemented by instructions and information known as written specifications.

General Plans

General plans contain information on the size, material, and makeup of all main members of the structure, their relative position and method of connection, as well as the attachment of other parts of the structure. The number of general plan drawings supplied is determined by such factors as the size and nature of the structure, and the complexity of operations. General plans consist of plan views, elevations, and sections of the structure and its various parts. The amount of information required determines the number and location of sections and elevations.

Fabrication Drawings

Fabrication drawings, or shop drawings, contain necessary information on the size, shape, material, and provisions for connections and attachments for each member. This information is in enough detail to permit ordering the material for the member concerned and its fabrication in the shop or yard. Component parts of the members are shown in the fabrication drawing, as well as dimensions and assembly marks.

Erection Drawings

Erection drawings, or erection diagrams, show the location and position of the various members in the finished structure. They are especially useful to personnel performing the erection in the field. For instance, the erection drawings supply the approximate weight of heavy pieces, the number of pieces, and other helpful data.

Falsework Drawings

The term falsework refers to temporary supports of timber or steel required in the erection of difficult or important structures. When falsework is required on an elaborate scale, drawings similar to the general and detail drawings already described may be provided to guide construction. For simple falsework, field sketches may be all that is needed.

CONSTRUCTION PLANS

Construction drawings are those in which as much construction information as possible is presented graphically, or by means of pictures (*Figure 7-29*). Most construction drawings consist of orthographic views. General drawings consist of plans and elevations drawn on relatively small scale. Detail drawings consist of sections and details drawn on a relatively large scale; we will discuss detail drawing in greater depth later in this chapter.

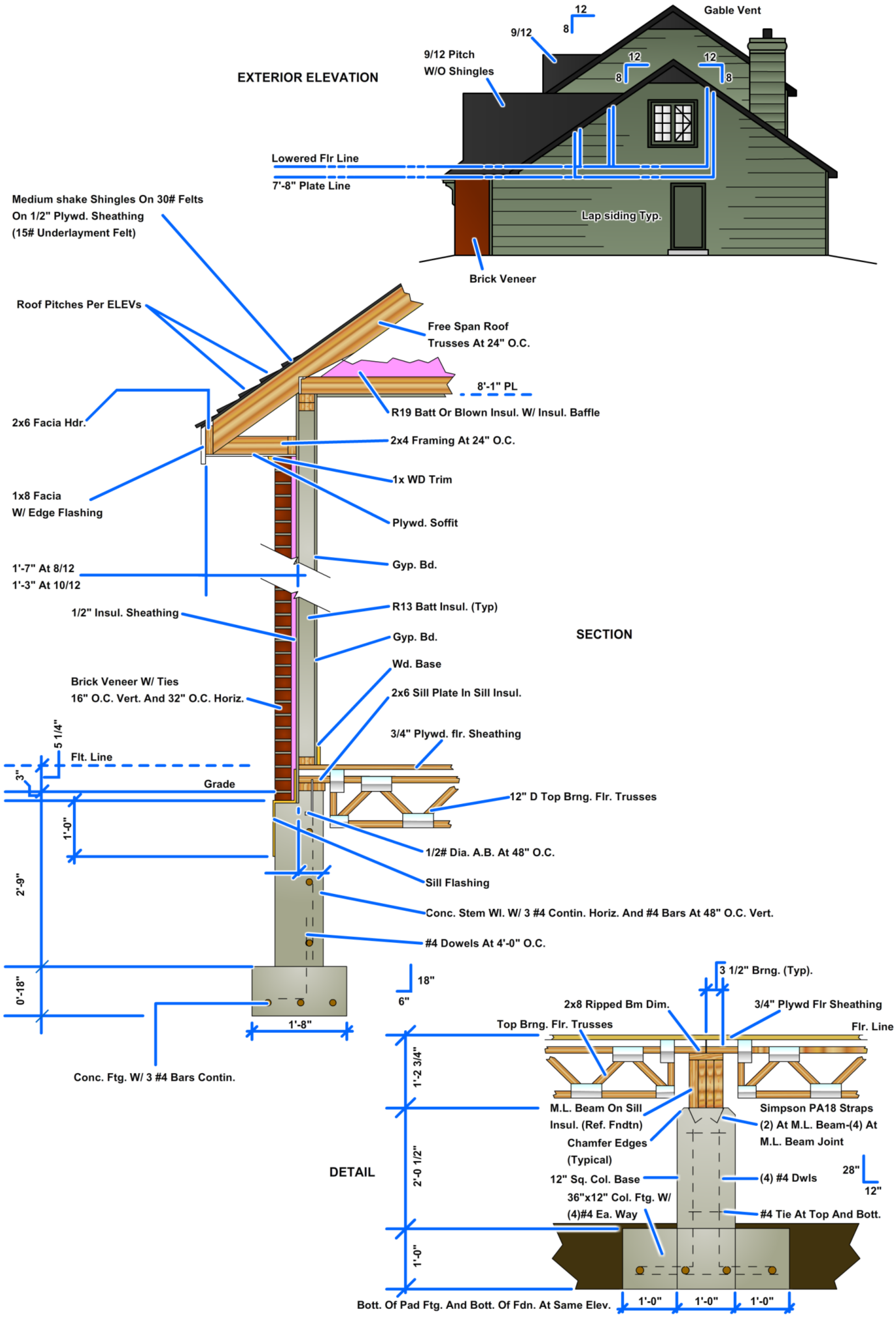


Figure 7-29 — Construction drawings.

General Drawings

General drawings consist of plans (views from above) and elevations (side or front views) drawn on a relatively small scale. Both types of drawings use a standard set of architectural symbols. The most common construction plans are site plans, plot plans, foundation plans, floor plans, and framing plans. We will discuss each of them in the following paragraphs.

Site Plan

The site plan shown in *Figure 7-30* shows the contours, boundaries, roads, utilities, trees, structures, and any other significant physical features on or near the construction site. It shows the locations of proposed structures in outline. This plan also shows corner locations relative to reference lines, shown on the plot, which can be located at the site. By showing both existing and finished contours, the site plan furnishes essential data for the graders and excavators.

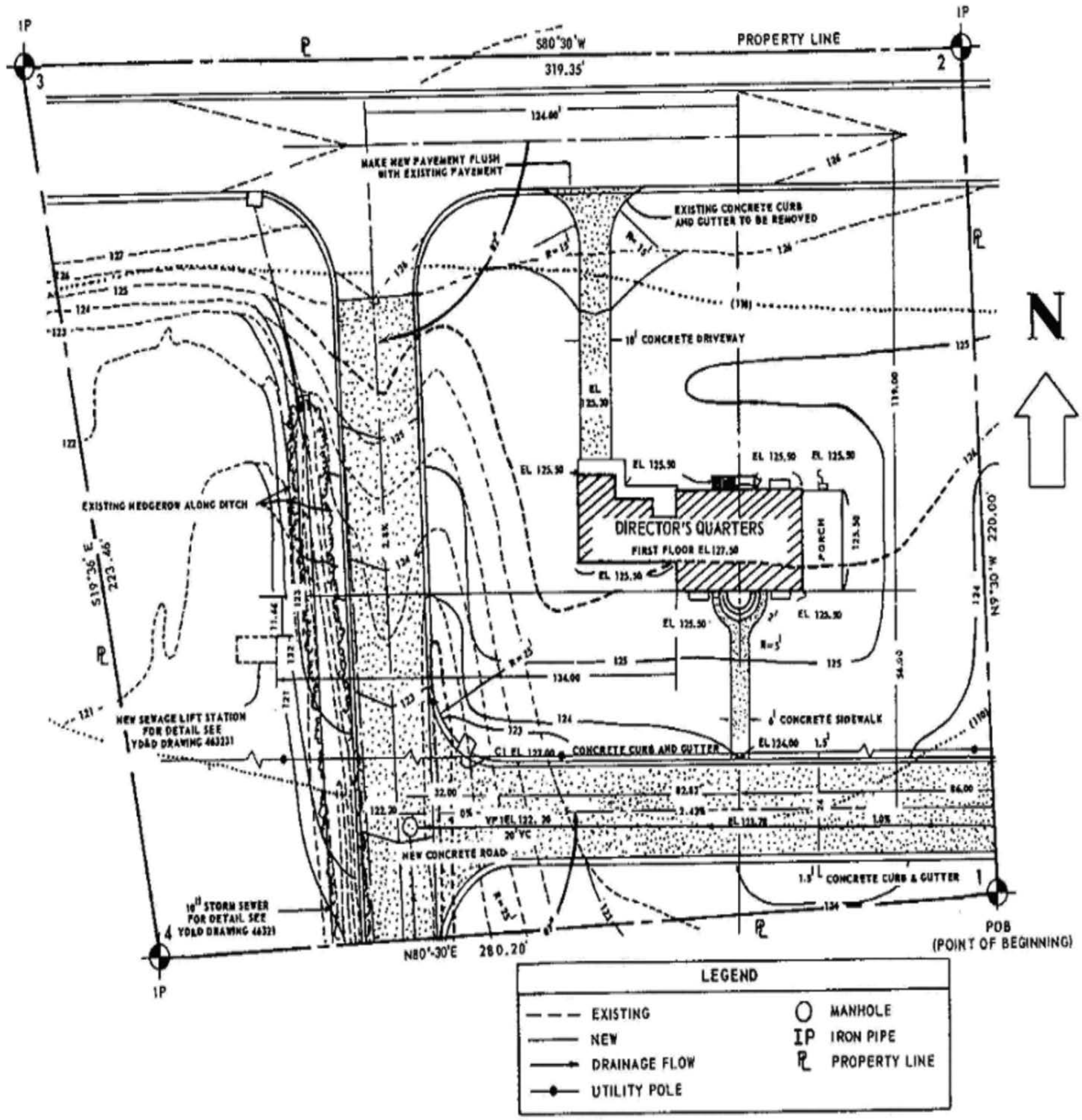


Figure 7-30 — Site plan.

Plot Plans

The plot plan shows the survey marks, including the bench mark (BM), with the elevations and the grading requirements. Surveyors use the plot plan shown in *Figure 7-31* to set up the corners and perimeter of the building using batter boards and line stakes. The plot plan furnishes the essential data for laying out the building.

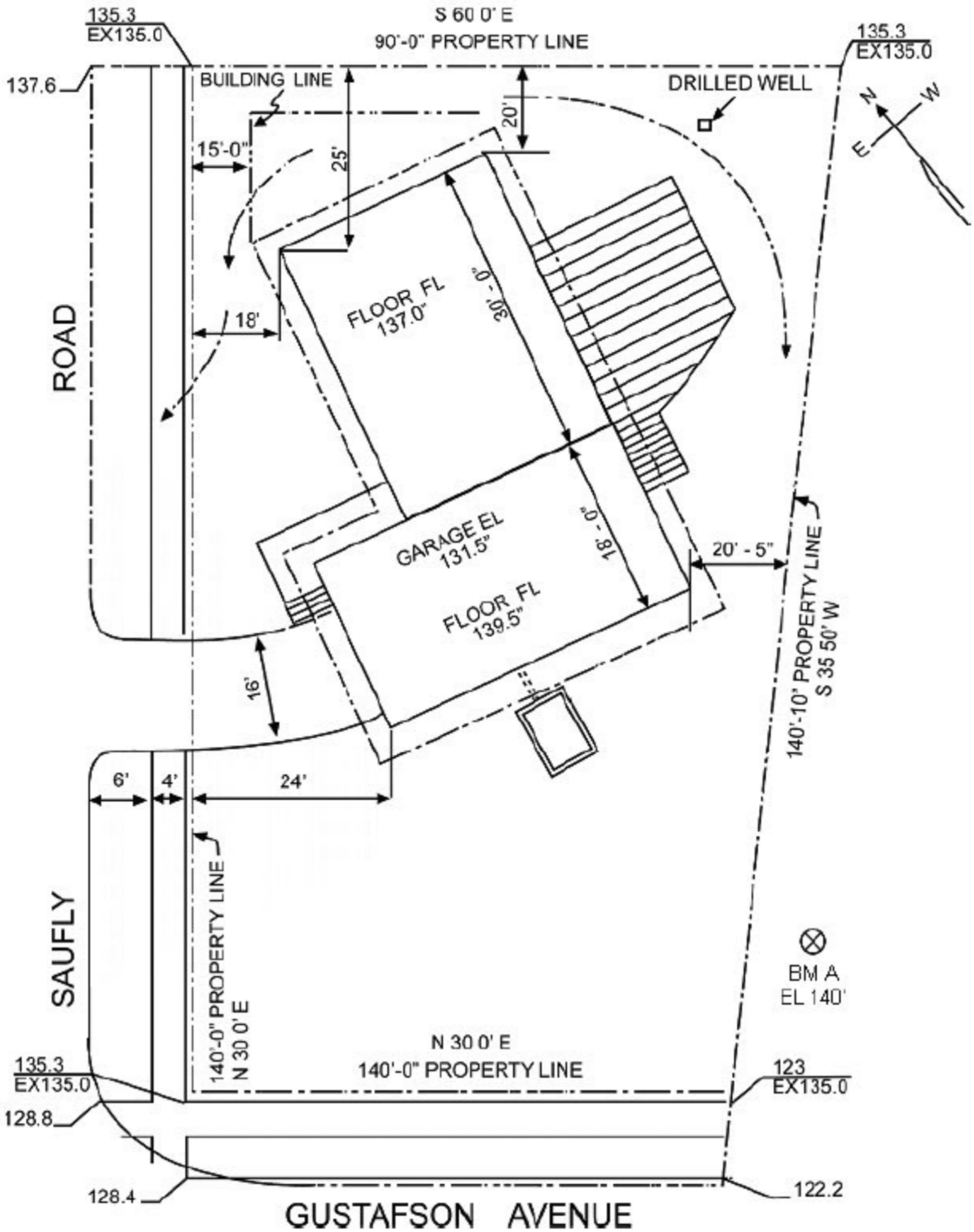


Figure 7-31 — Plot plan.

Foundation Plan

A foundation plan is a plane view of a structure. That is, it looks as if it were projected onto a horizontal plane and passed through the structure. In the case of the foundation plan, the plane is slightly below the level of the top of the foundation wall. The plan in *Figure 7-32* shows that the main foundation consists of 12 inch and 8 inch concrete masonry unit (CMU) walls measuring 28 feet lengthwise and 22 feet crosswise. The lower portion of each lengthwise section of wall is to be 12 inches thick to provide a concrete ledge 4 inches wide.

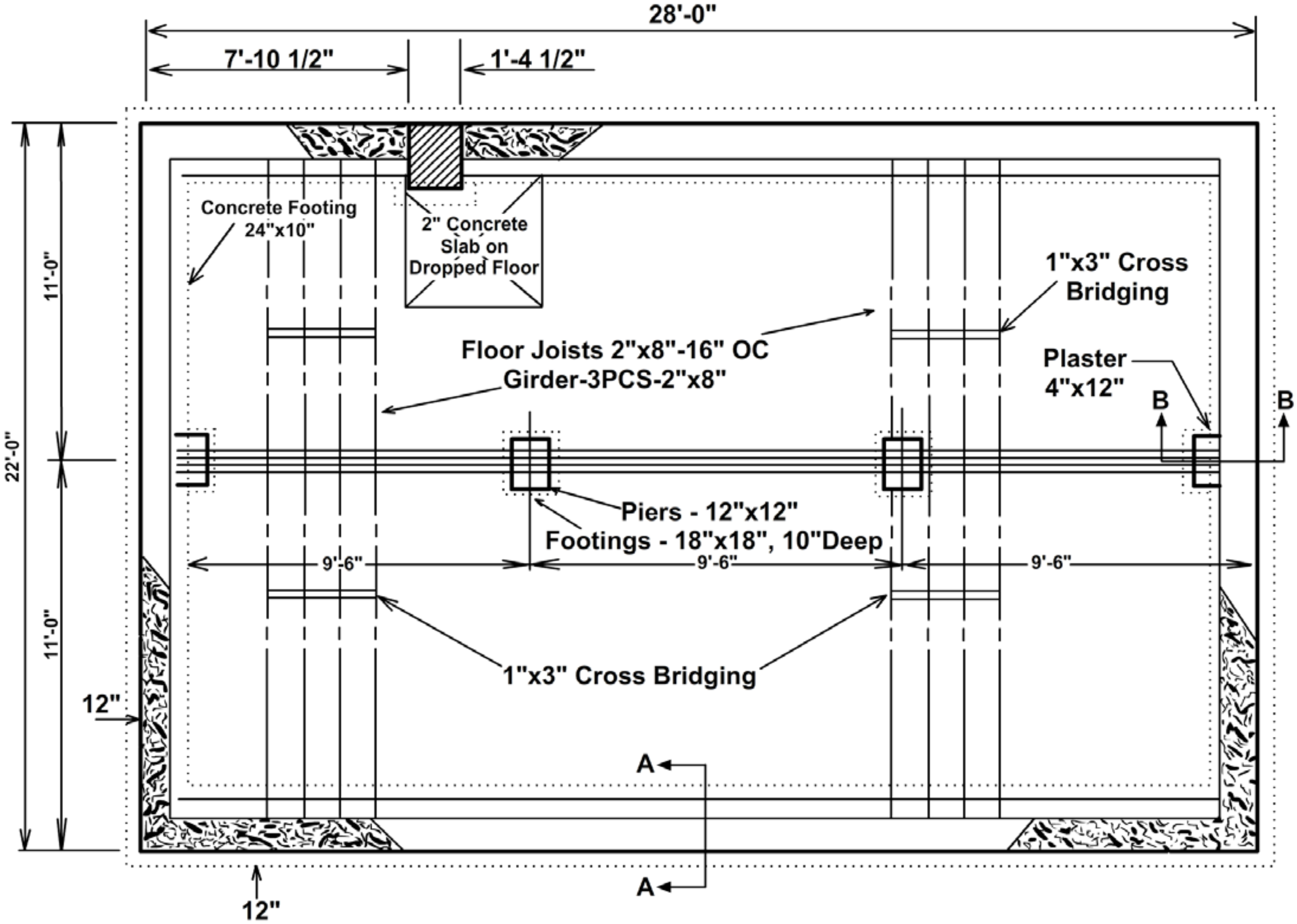


Figure 7-32 — Foundation plan.

A girder running through the center of the building will be supported at the ends by two 4 by 12 inch concrete pilasters butting against the end foundation walls. Intermediate support for the girder will be provided by two 12 by 12 inch concrete piers, each supported on 18 by 18 inch spread footings, which are 10 inches deep. The dotted lines around the foundation walls indicate that these walls will also rest on spread footings.

Floor Plan

Floor plans are views of a building as though cutting planes were made through the building horizontally. The cutting plane is generally taken 5 feet 0 inches above the floor being shown.

The way a floor plan is developed from elevation, to cutting plane, to floor plan is depicted in *Figure 7-33*. An architectural or structural floor plan shows the structural characteristics of the building at the level of the plane of projection. A mechanical floor plan shows the plumbing and heating systems and any other mechanical components other than those that are electrical. An electrical floor plan shows the lighting systems and any other electrical systems.

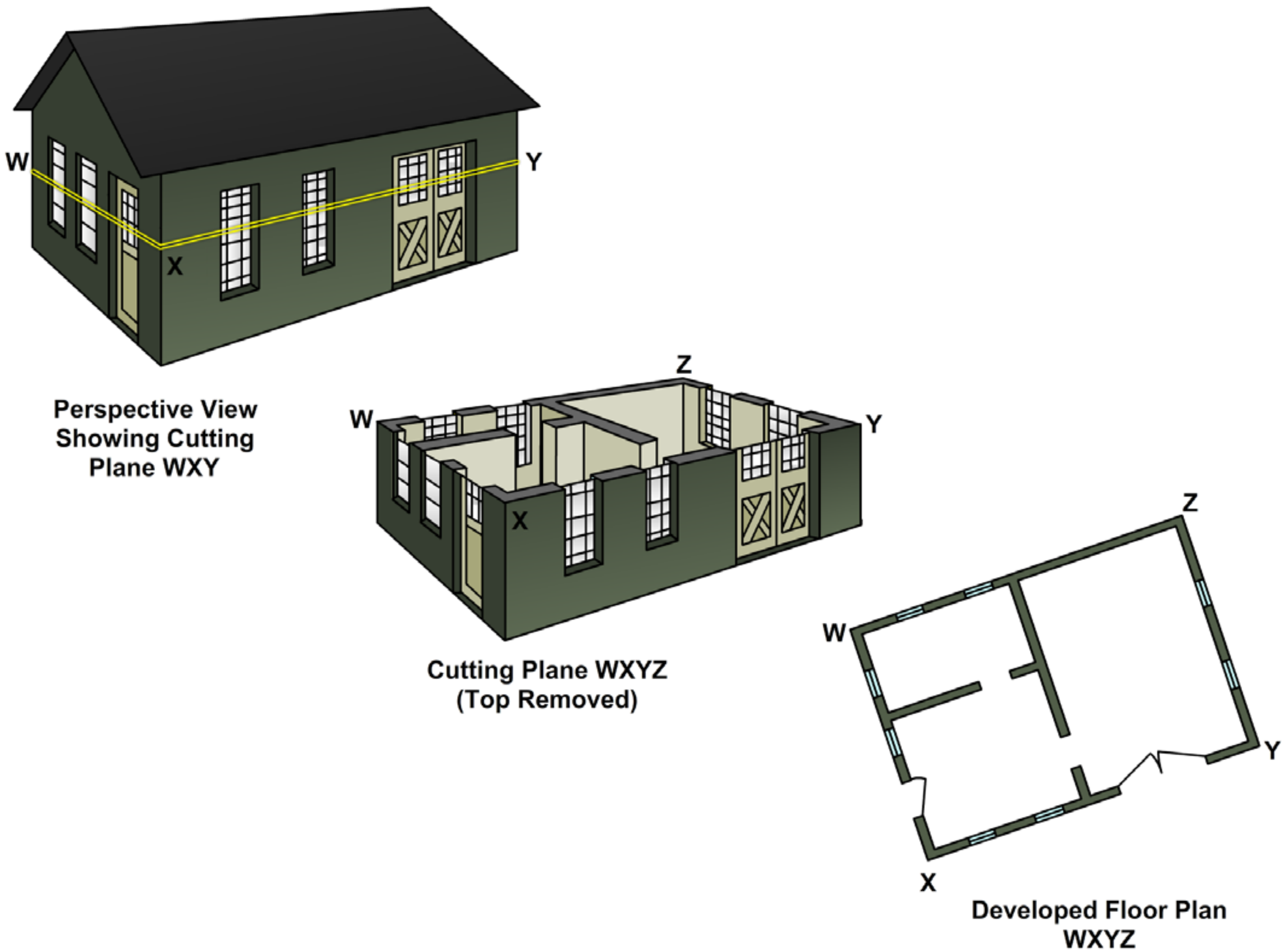


Figure 7-33 — Typical floor plan.

Framing Plan

The floor framing plan (*Figure 7-34*) is a plan view of the layout of girders, beams, and joists. Joists and double framing are drawn in the position they will occupy in the completed building. Joists do not need dimensions at every location. Notes provide the necessary information, in this case “2" by 8" joists at 16 inches on center (O.C.).

Bridging is also drawn in position perpendicular to the joist but called out by note as “2- 1” x 3” bridging”. The span of the joist controls the number of required rows of cross bridging. The rows should not be more than 7 or 8 feet apart. Hence, a 14 foot span may need only one row of bridging, but a 16 foot span needs two rows. Notes also identify floor openings, trimmers, plates, or doubles to support heavier floor loads.

Floor framing plans do not indicate length dimensions for individual pieces. The builder is able to determine those from overall building dimensions, dimensions for each bay, or distances between columns or posts.

Wall framing plans (*Figure 7-35*) show the location and method of framing openings and ceiling heights so that studs and posts can be cut. Since it is a view on a vertical plane, a wall framing plan is not a plan in the strict technical sense. However, the practice of calling it a plan has become a general custom.

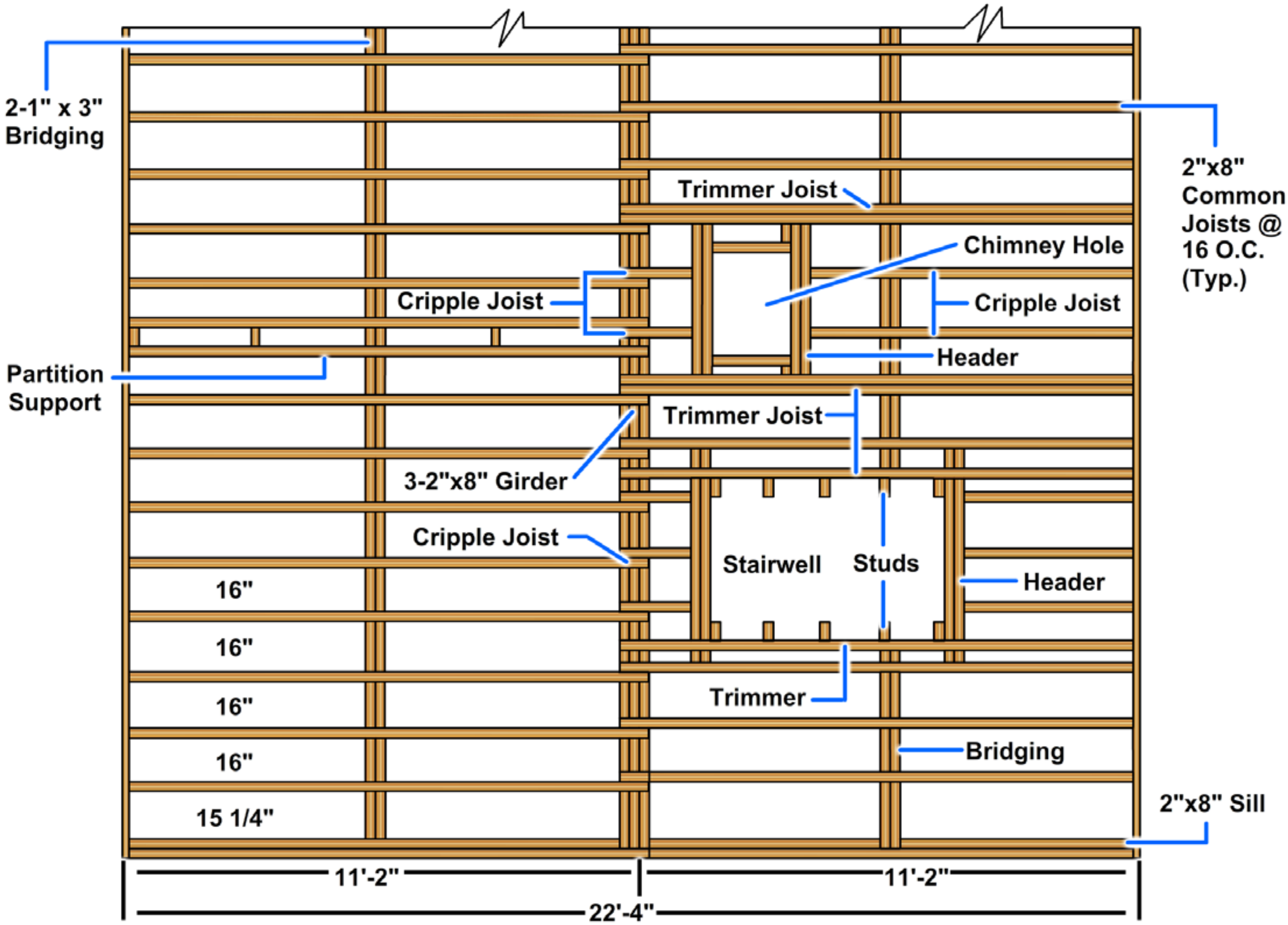


Figure 7-34 — Floor framing plan.

Roof framing plans for wood frame construction are drawn in the same manner as the floor framing plan. The rafters are shown in the same manner as joists, with rafters shown spanning the building and supporting the roof.

A utility plan is a floor plan that shows the layout of heating, electrical, plumbing, or other utility systems. Utility plans are used primarily by the ratings responsible for the utilities, and are equally important to the builder. Most utility installations require that openings be left in walls, floors, and roofs for the admission or installation of utility features. The builder who is placing a concrete foundation wall must study the utility plans to determine the number, sizes, and locations of openings he or she must leave for utilities.

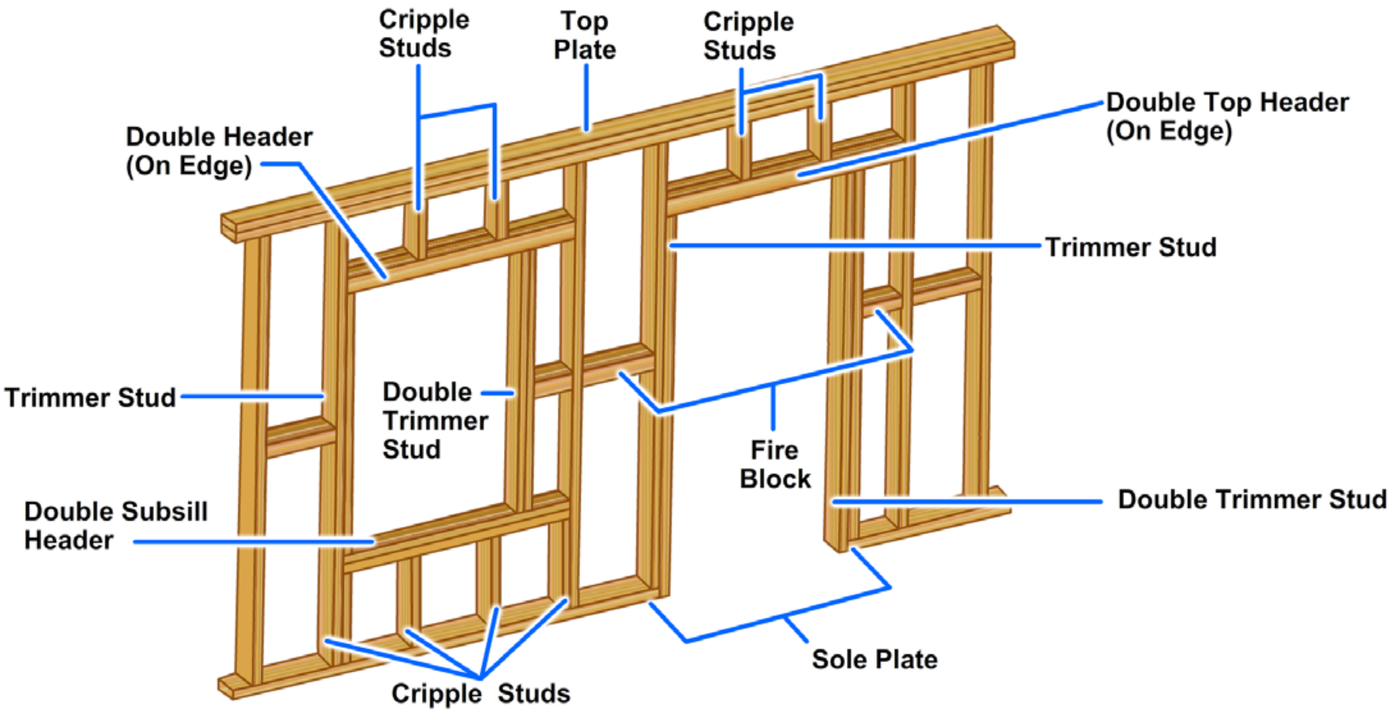


Figure 7-35 — Wall framing plans.

Elevations

Elevations show the front, rear, and sides of a structure, as they would appear projected on vertical planes. Studying the elevation drawing (*Figure 7-36*) gives you a working idea of the appearance and layout of the structure.

Notice that the wall surfaces of this house will consist of brick and the roof covering of composition shingles. The top of the rafter plate will be 8 feet 2 1/4 inches above the level of the finished first floor, and the tops of the finished door and window openings 7 feet 1 3/4 inches above the same level. The roof will be a gable roof with 4 inches of rise for every 12 inches length. Each window shown in the elevations is identified by a capital letter that goes with a window schedule.

Detail Drawings

Sectional Views

Sectional views, or sections, provide important information about the height, materials, fastening and support systems, and concealed features of a structure. The initial development of a section and how a structure looks when cut vertically by a cutting plane is shown *Figure 7-37*. The cutting plane is not necessarily continuous, but, as with the horizontal cutting plane in building plans, may be staggered to include as much construction information as possible. Like elevations, sectional views are vertical projections. They are also detail drawings drawn to large scale. This aids in reading, and provides information that cannot be given on elevation or plan views. Sections are classified as typical and specific.

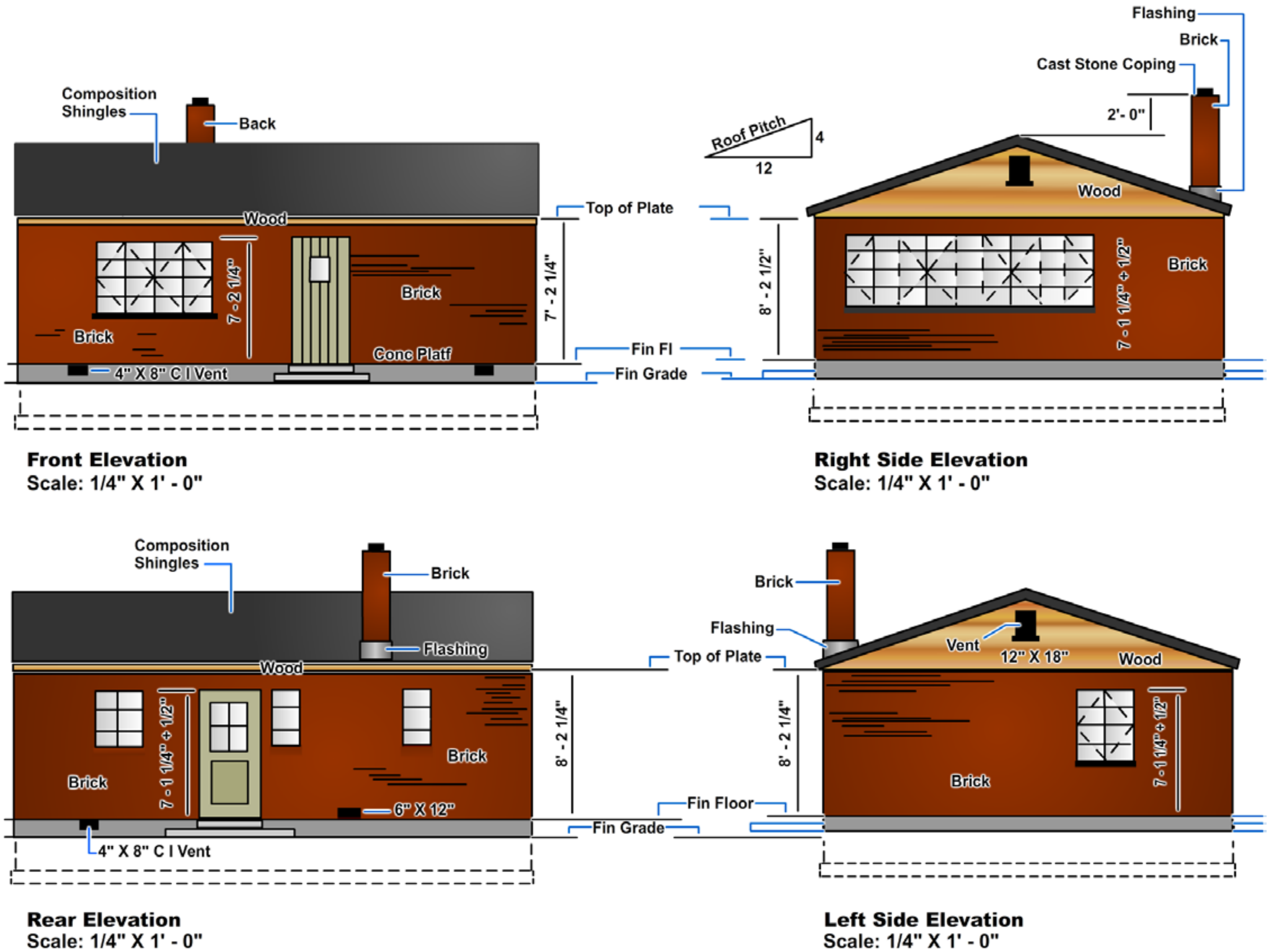
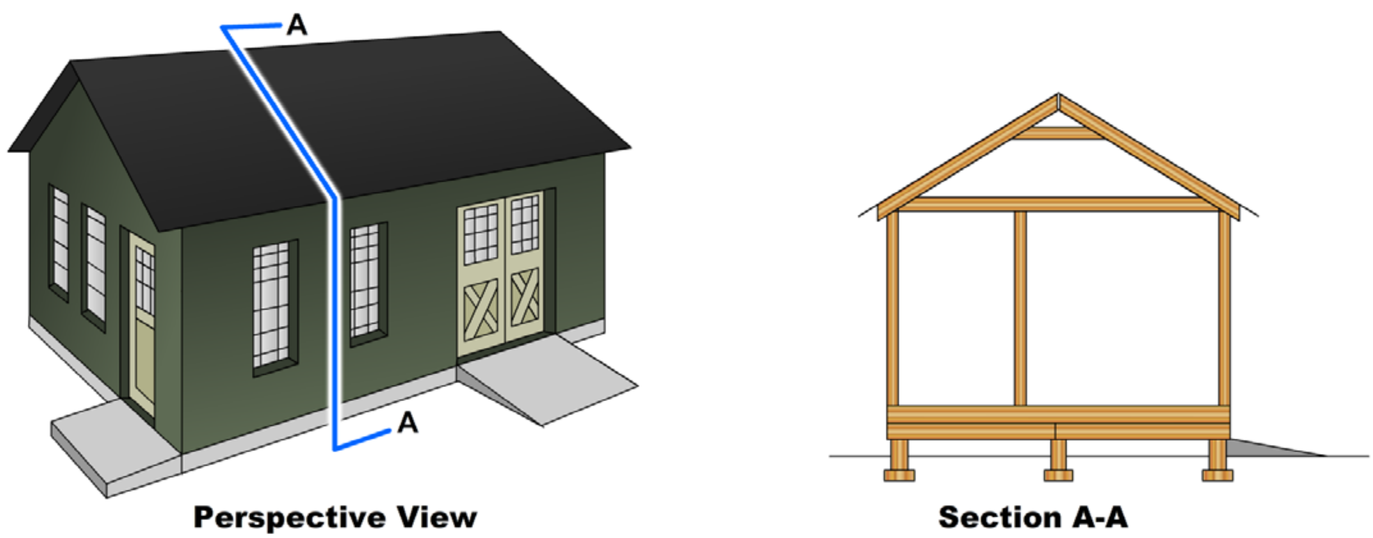


Figure 7-36 — Elevations.



Typical Small Building Showing Cutting Plane A-A And Section Developed From The Cutting Plane

Figure 7-37 — Development of a sectional view.

Typical sections (*Figure 7-38*) represent the average condition throughout a structure and are used when construction features are repeated many times. You can see that it gives a great deal of information necessary for those constructing the building.

The foundation plan shown in *Figure 7-32* specifies that the main foundation of this structure will consist of a 22 by 28 foot concrete block rectangle. In *Figure 7-38*, the section A-A of the foundation plan shows that the front and rear portions of the foundation (28 foot measurements) are made of 12 by 8 by 16 inch CMUs centered on a 10 by 24 inch concrete footing to an unspecified height. These are followed by 8 inch CMUs, which form a 4 inch ledger for floor joist support on top of the 12 inch units. In this arrangement, the 8 inch CMUs serve to form a 4 inch support for the brick. The main wall is then laid with standard 2 1/2 by 4 by 8 inch face brick backed by 4 by 8 by 16 inch CMUs.

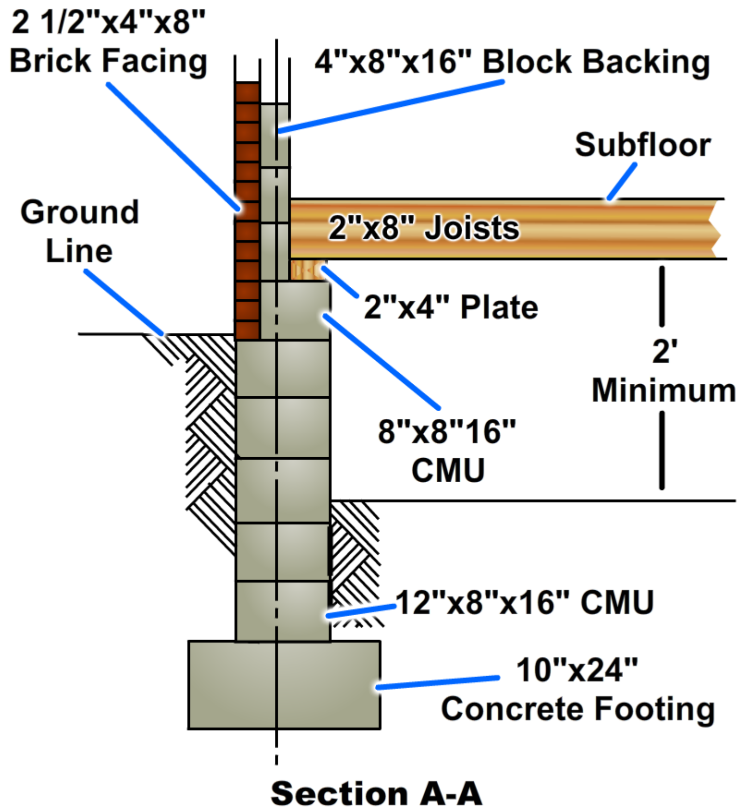


Figure 7-38 — Typical section of a masonry building.

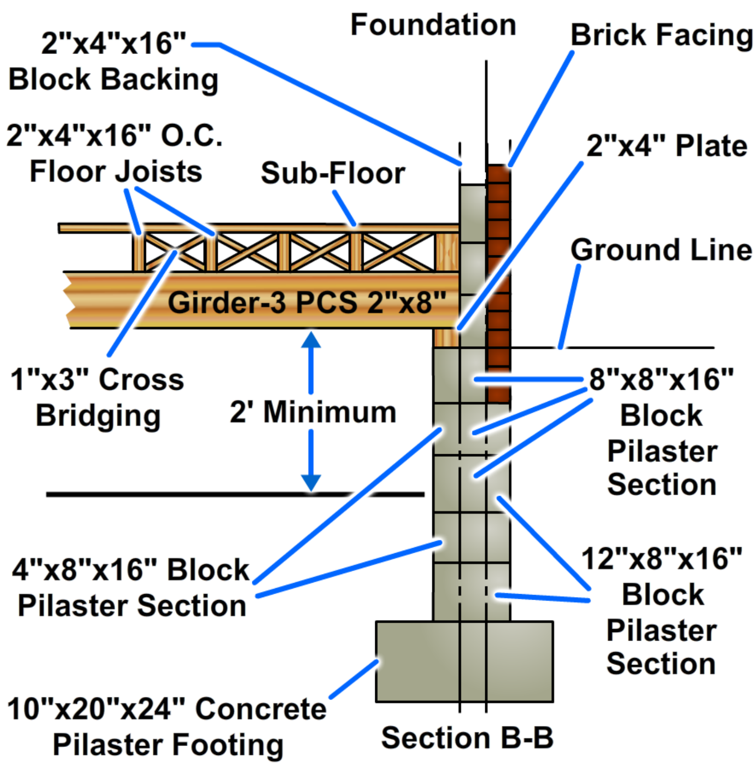


Figure 7-39 — Specific section of a concrete masonry wall.

Section B-B, shown in *Figure 7-39* of the foundation plan, shows that both side walls (22 foot measurements) are 8 inches thick centered on a 24 inch concrete footing to an unspecified height. It also illustrates the pilaster, a specific section of the wall to be constructed for support of the girder. It shows that the pilaster is constructed of 12 by 8 by 16 inch CMUs alternated with 4 by 8 by 16 inch and 8 by 8 by 16 inch CMUs. The hidden lines (dashed lines) on the 12 inch wide units indicate that the thickness of the wall beyond the pilaster is 8 inches. Notice how the extra 4 inch thickness of the pilaster provides a center support for the girder, which will support the floor joists.

Detail Views

Detail views are large-scale drawings of construction assemblies and installations that cannot be clearly shown in the sections. These enlarged drawings show the various parts in more detail and how they will be connected and placed.

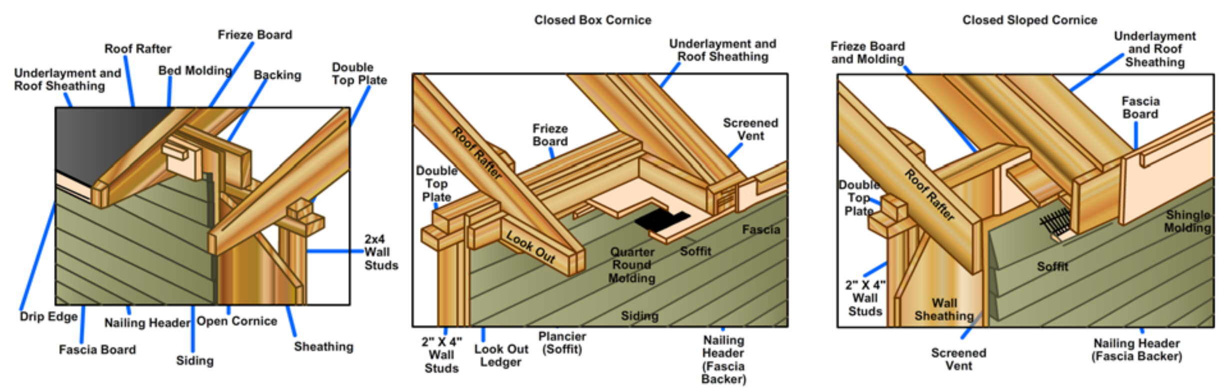
The scale depends on how large the drawing needs to be magnified to explain the required information clearly. Details are usually drawn at a larger scale than the sections, generally 1-, 1 1/2-, or 3-inch = 1 foot.

Architectural drawing standards contain details commonly used for installation of items such as doorframes, window frames, fireproofing, and material connections; they do, however, need to be adapted to the particular building being drawn. When different conditions actually exist, avoid the use of “typical” details; they will be misleading and cause confusion. The designer needs to understand construction well enough to make accurate detail drawings for each unique situation.

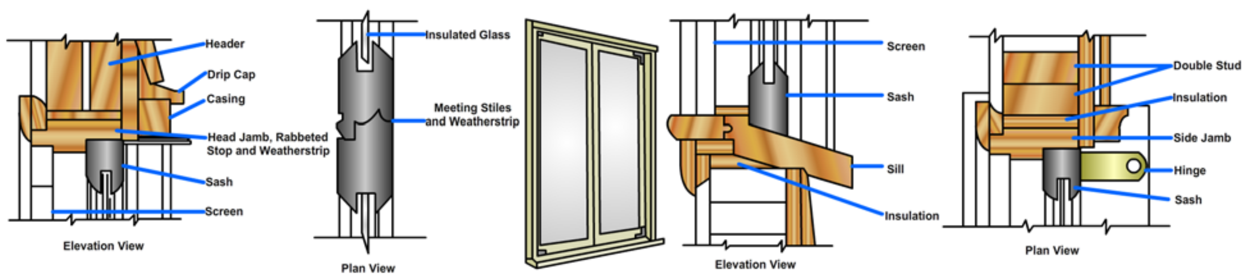
Details are commonly used for some specific phases and elements of construction such as foundations, doors, windows, cornices, and so forth (*Figure 7-40*). Show their details with the applicable main division of construction drawings and group them so that references can be made easily from the general drawing.

Use architectural symbols (*Figure 7-41*) to provide reference locations for doors and windows in general, sectional, and detail drawings.

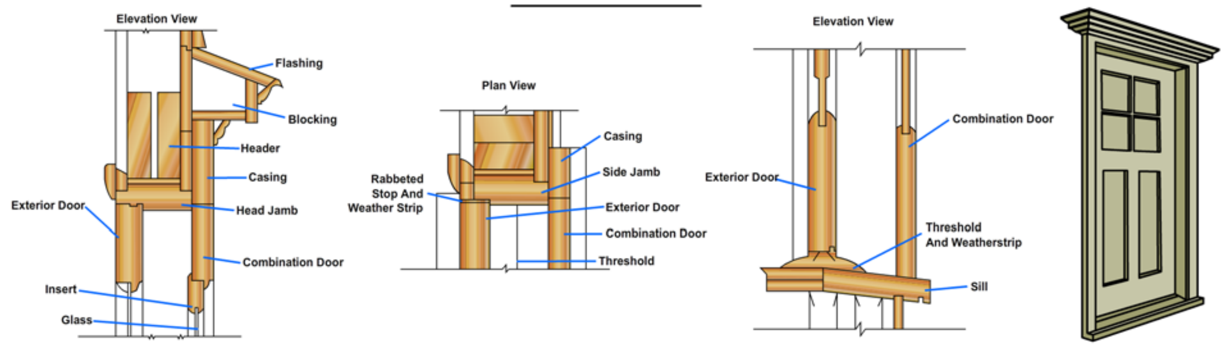
Typical Cornice Details



Detail of Window



Detail of Door



Typical Sill Details

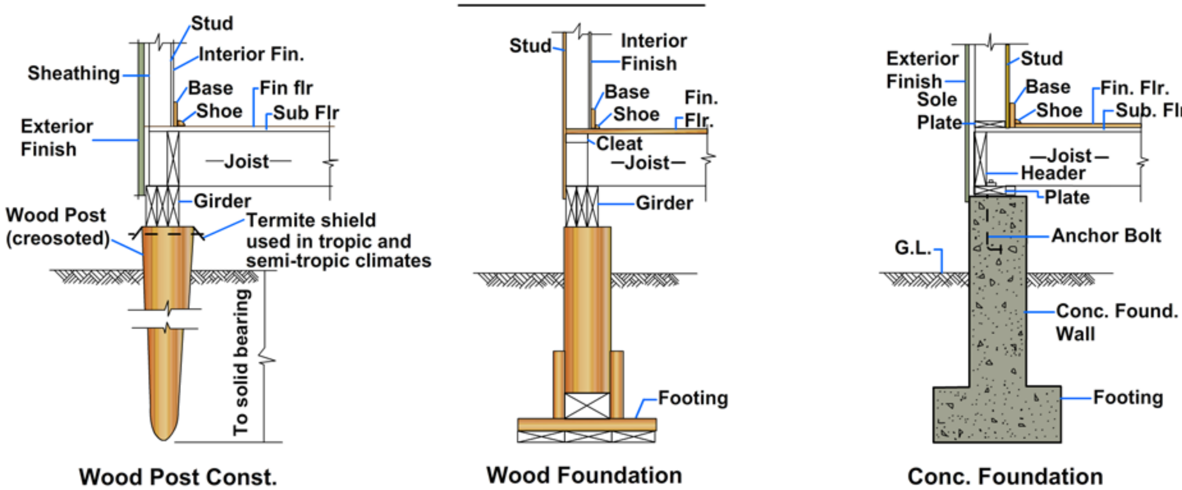


Figure 7-40 — Example of detail grouping.

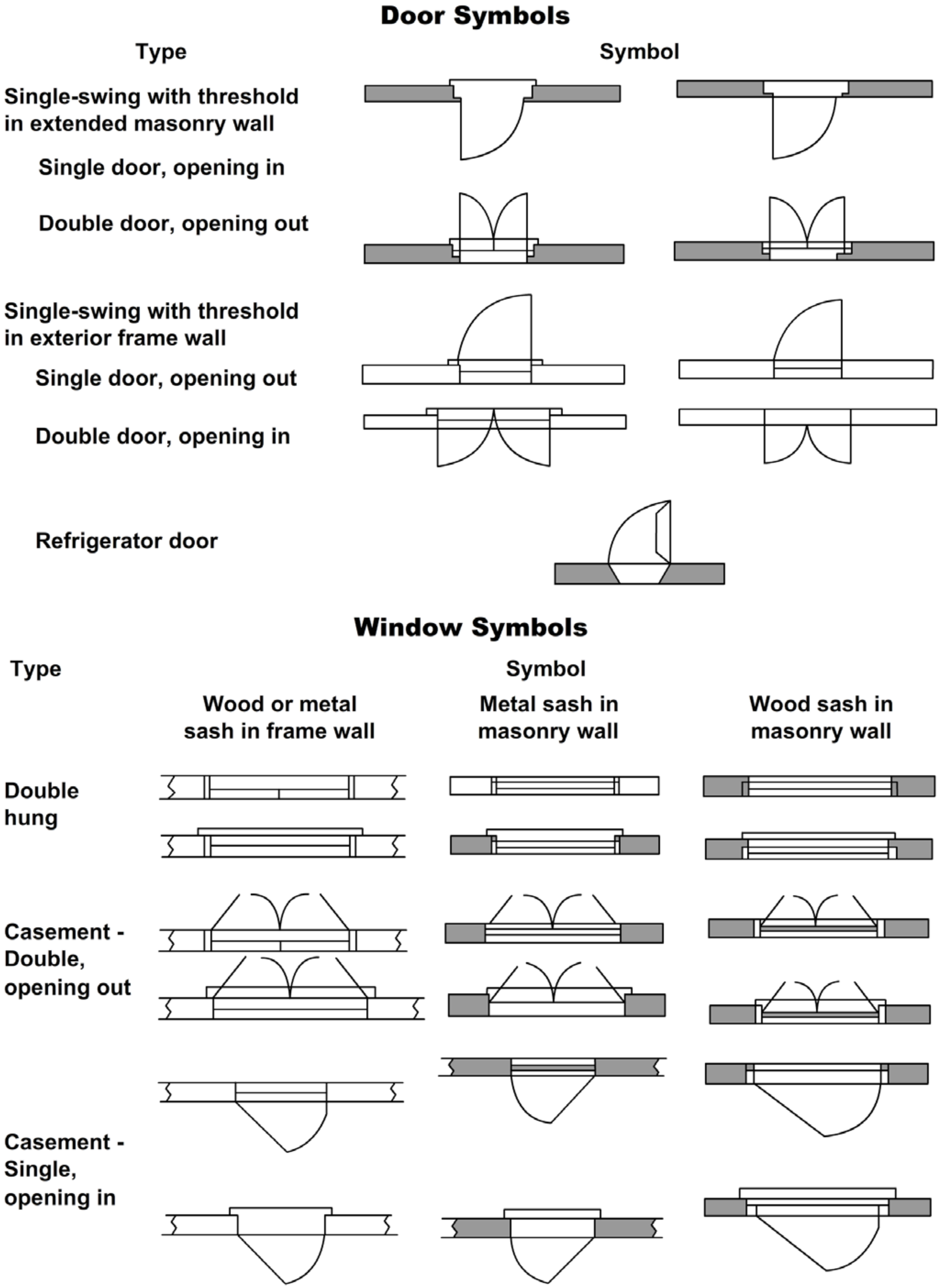


Figure 7-41 — Common architectural symbols for doors and windows.

Specifications

Because many aspects of construction cannot be shown graphically, even the best prepared construction drawings often inadequately show some portions of a project. For example, how can anyone show on a drawing the quality of workmanship required for the installation of doors and windows? Or, who is responsible for supplying the materials? These are things that can be conveyed only by hand lettered notes. The standard procedure is to supplement construction drawings with detailed written instructions. These written instructions, called specifications, or more commonly specs, define and limit materials and fabrication to the intent of the engineer or designer.

The drawings, together with the project specifications, define the project in detail and show exactly how to construct it. Usually, drawings for an important project are accompanied by a set of project specifications. The drawings and project specifications are inseparable. Drawings indicate what the project specifications do not cover. Project specifications indicate what the drawings do not portray, or they further clarify details that are not covered amply by the drawings and notes on the drawings. When you are preparing project specifications, it is important that you closely coordinate the specifications and drawings in order to minimize discrepancies and ambiguities.

When preparing drawings, you will need to be familiar with the general format and terminology used in the specifications. After the last specification, list the definitions of the terms used. Certain routine declarations of responsibility and certain conditions to be maintained on the job may accompany the specifications. A flow chart for selection and documentation of concrete proportions is illustrated in *Figure 7-42*.

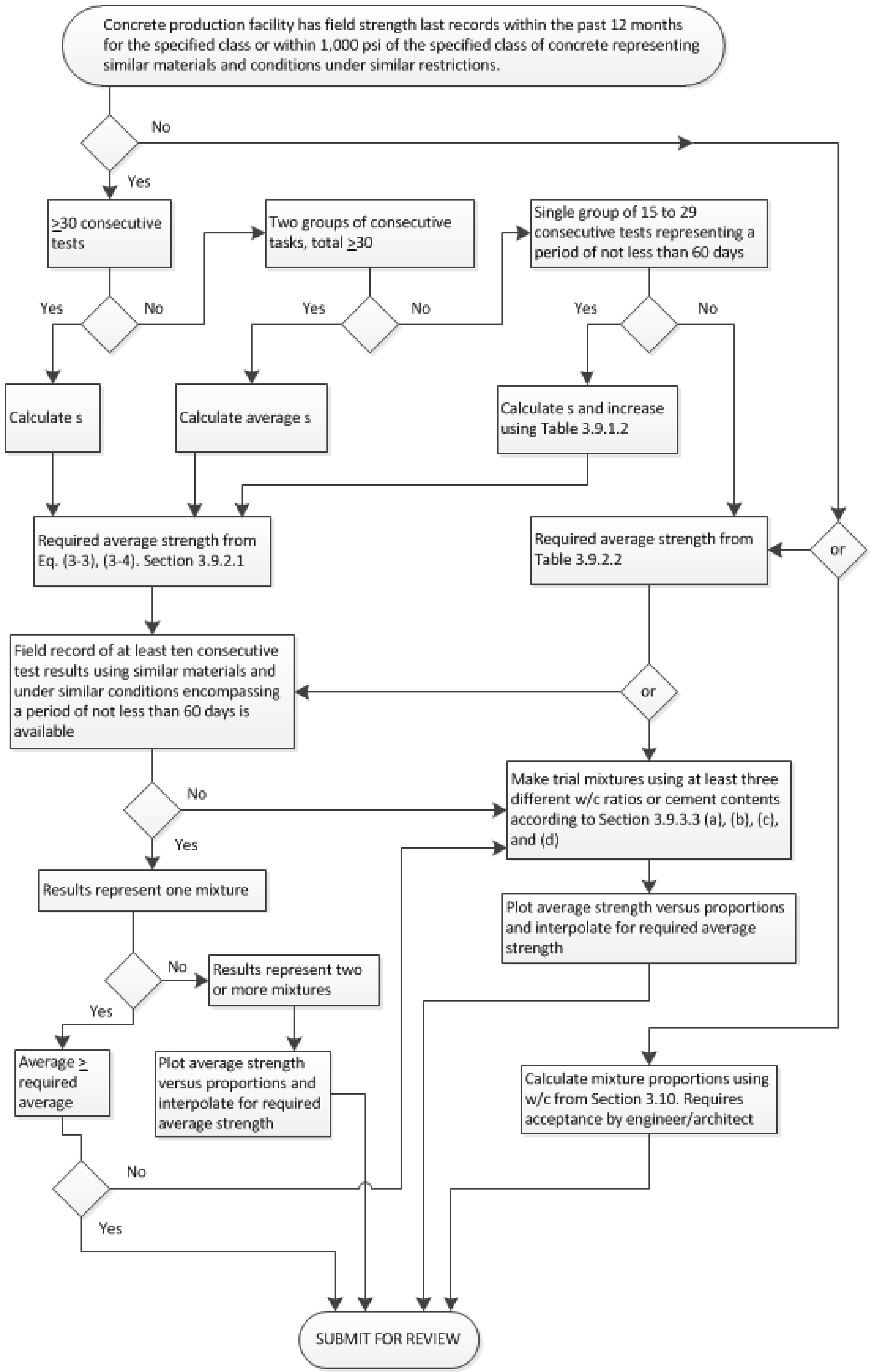


Figure 7-42 — Flow Chart for selection and documentation of concrete proportions.

End of Chapter 7

Structural and Architectural Drawings

Review Questions

7-1. Which of the following techniques is used to create the architect's concept of a building, ship, or aircraft?

A. Isometric view
B. Orthographic projection
C. Pictorial drawing
D. Revolved view

7-2. What document provides common symbols used in an architectural drawing?

A. ASME Y41.3.4
B. ASTM F3000-1D
C. IEEE 101G
D. MIL-STD-18B

7-3. Which of the following types of shapes are the most common structural members?

A. A, C, and H
B. A, S, and W
C. C, H, and J
D. C, S, and W

7-4. Which of the following symbols is used to identify wide-flange steel beams?

A. W
B. HP
C. S
D. C

7-5. Which of the following symbols is used to identify a bearing pile?

A. W
B. HP
C. S
D. C

7-6. Which of the following types of angle shapes are most commonly used?

A. Acute and obtuse angles
B. Equal-leg and acute angle
C. Equal-leg and unequal-leg
D. Obtuse and unequal-leg

7-7. In dimensioning, the structural tee symbol is preceded by what letters?

A. HP
B. HT
C. PL
D. ST

7-8. What component is the primary horizontal member of a steel frame structure?

A. Pillar
B. Girder
C. Flat bar
D. Column

7-9. Which of the following terms is the total weight of a structure?

A. Load bearing capacity
B. Structural integrity
C. Total dead load
D. Total live load

7-10. Which of the following supplementary symbols is used to identify a flush contour?

A. Circle
B. Flag
C. Line
D. Square

7-11. On a finish symbol, what letter indicates chipping method of finishing?

A. C
B. F
C. G
D. M

7-12. Which of the following supplementary symbols is used to identify weld all around?

A. Circle
B. Flag
C. Line
D. Square

7-13. Which of the following types of drawings provide important details, such as the nature of the underlying soil and location of adjacent structures?

A. Erection
B. Fabrication
C. Falsework
D. Layout

7-14. Layout drawings are supplemented by instructions and information known as what?

A. General notes
B. Modifications
C. References
D. Specifications

7-15. A general plan contains information on the size, material and makeup of what components in a structure?

A. Main members
B. Preliminary structures
C. Surrounding structures
D. Temporary members

7-16. Which of the following types of drawings contains necessary information on the size, shape, material, and provisions for connections and attachments for each member?

A. Erection
B. Fabrication
C. Falsework
D. Layout

7-17. Which of the following types of drawings shows the location and position of the various members in the finished structure?

A. Erection
B. Fabrication
C. Falsework
D. Layout

7-18. Which of the following types of drawings refers to temporary supports of timber or steel required in the erection of difficult structures?

A. Erection
B. Fabrication
C. Falsework
D. Layout

7-19. Most construction drawings consist of what type of view?

A. Isometric view
B. Orthographic projection
C. Pictorial drawing
D. Revolved view

7-20. The most common construction plans are site, plot, foundation, and which other type of plan?

A. Falsework
B. Framing
C. Phase
D. Supplementary

7-21. A site plan shows contours, boundaries, roads, and what other feature?

A. Attachment of other parts of a structure
B. Bench marks
C. Concealed features of a structure
D. Utilities

7-22. Which construction plan is used to set up corners and perimeters of the building using batter boards and stakes?

A. Plot
B. Site
C. Floor
D. Foundation

7-23. At what distance above the floor being shown is the cutting plane of a floor plan generally taken?

A. 4 feet 0 inches
B. 4 feet 6 inches
C. 5 feet 0 inches
D. 5 feet 6 inches

7-24. A sectional view provides important information about the height, materials, and what other feature in a drawing?

A. Utilities
B. Concealed features of a structure
C. Bench marks
D. Attachment of other parts of a structure

7-25. Concerning detail views, which of the following is true?

A. Enlarged drawings to show various parts in more detail
B. Exploded view of a part for location of finish marks
C. Highlighted drawing to show importance
D. Reduced drawings to show insignificance

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CHAPTER 8

DEVELOPMENTS AND INTERSECTIONS

Sheet metal drawings are also known as sheet metal developments and pattern drawings, and we may use all three terms in this chapter. These terms are used because the layout, when made on heavy cardboard, thin metal, or wood, is often used as a pattern to trace the developed shape on flat material. These drawings are used to construct various sheet metal items, such as ducts for heating, ventilation, and air-conditioning systems; flashing, valleys, and downspouts in buildings; and parts on boats, ships, and aircraft.

A sheet metal development serves to open up an object that has been rolled, folded, or a combination of both, and makes that object appear to be spread out on a plane or flat surface. Sheet metal layout drawings are based on three types of development: parallel, radial, and triangulation.

The most common method to create simple sheet metal development drawings is by manual drafting and sketching methods. Sheet metal drafting/sketching templates are designed to facilitate layouts of sheet metal air conditioning and heating conduits and are available from manufacturers like Rapidesign®, Pickett®, Staedtler-Mars®, and Timely®. Computer-aided drafting (CAD) accelerates the sheet metal development design and template drawing process. CAD enables designer the flexibility to work with any CAD data to create, edit, and prepare models for high precision sheet metal fabrication. Sheet metal development CAD programs may be standalone software packages or add-on packages to powerful CAD applications such as AutoCAD®.

LEARNING OBJECTIVES

When you have completed this chapter, you will be able to do the following:

1. Recognize sheet metal developments.
2. Recognize the differences among parallel developments.
3. Recognize the differences among radial developments.
4. Recognize the differences among triangular developments.

SEAMS, JOINTS, AND EDGES

A development of an object that will be made of thin metal, such as a duct or part of an aircraft skin, must include consideration of the developed surfaces, the joining of the edges of these surfaces, and the exposed edges. The drawing must allow for the additional material needed for those seams, joints, and edges.

A variety of ways to illustrate seams, joints, and edges are shown in *Figures 8-1 through 8-3*. Seams are used to join edges. The seams may be fastened together by seams, solder, rivets, adhesive, or welds. Exposed edges are folded or wired to give the edges added strength and to eliminate sharp edges.

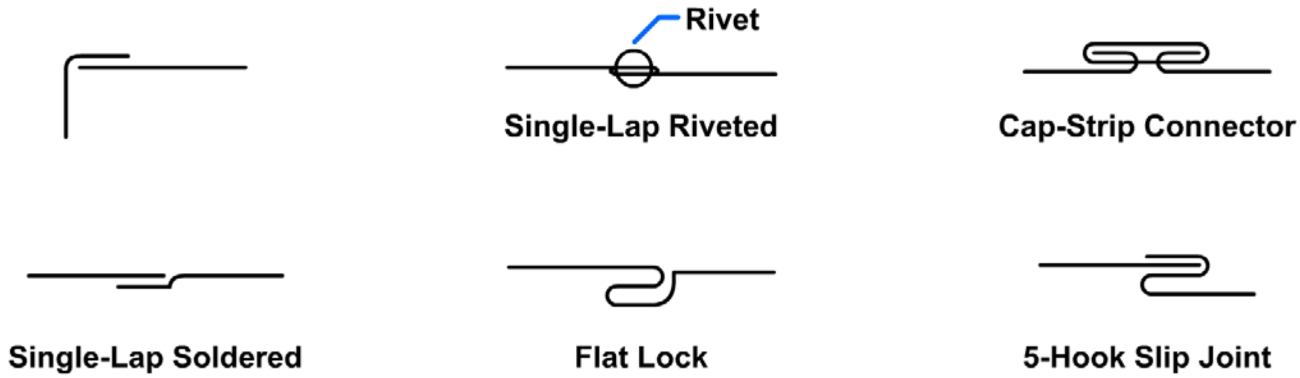

Figure 8-1 — Seams.

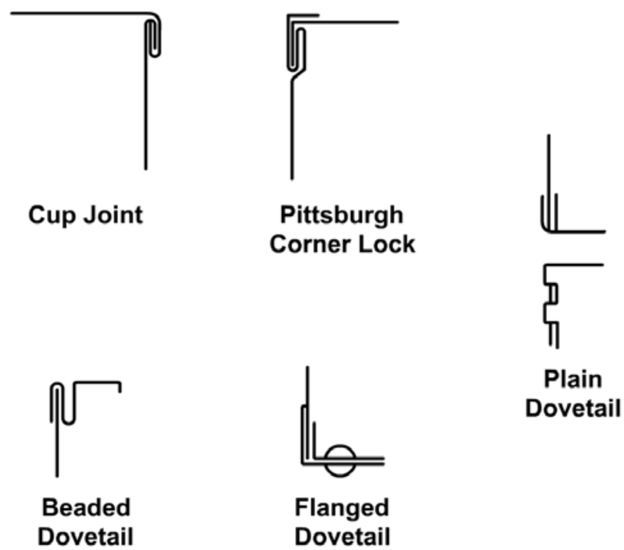

Figure 8-2 — Joints.

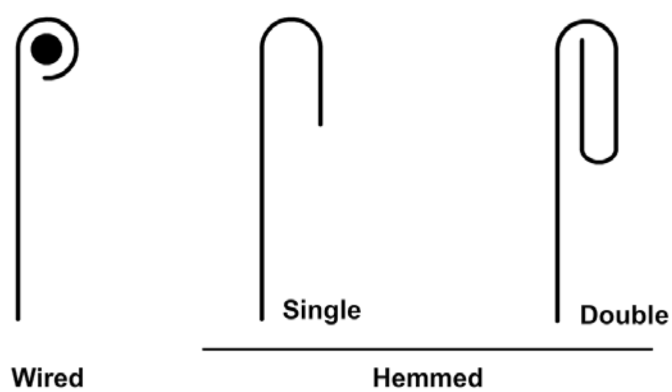

Figure 8-3 — Edges.

There are three types of lap seams: the plain lap seam, the offset lap seam, and the corner lap seam (*Figure 8-4*). Lap seams can be joined by drilling and riveting, by soldering, or by both riveting and soldering. To figure the allowance for a lap seam, you must first know the diameter of the rivet that you plan to use. The center of the rivet must be set in from the edge a distance of 2 1/2 times its diameter; therefore, the allowance must be 5 times the diameter of the rivet that you are using.

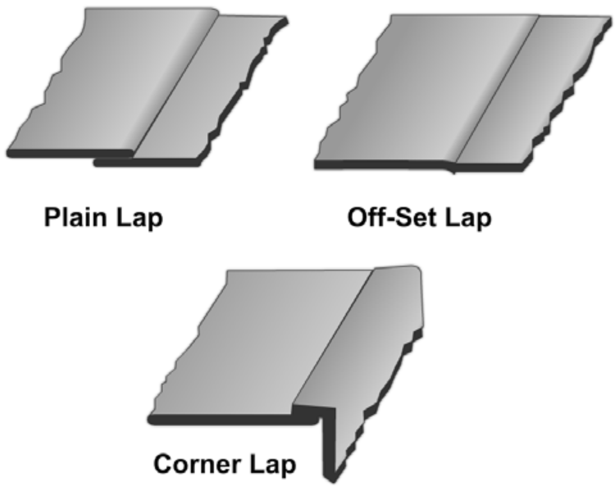

Figure 8-4 — Lap seams.

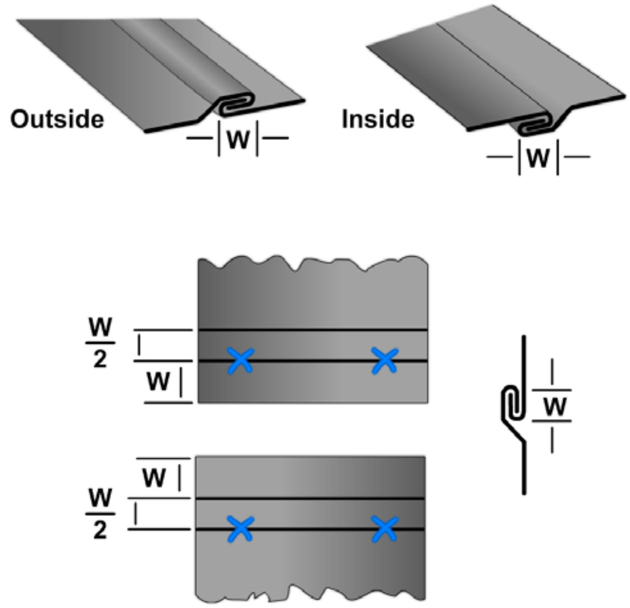

Figure 8-5 — Grooved seams.

Grooved seams are useful in the fabrication of cylindrical shapes. There are two types of grooved seams: the outside grooved seam and the inside grooved seam (Figure 8-5). The allowance for a grooved seam is three times the width (W) of the lock. One-half of the total allowance width is added to each edge. For example, if you are to have a 1/4 inch grooved seam, 3 x 1/4 = 3/4 inch, or the total allowance; 1/2 of 3/4 inch = 3/8 inch, or the allowance that you are to add to each edge.

The Pittsburgh lock seam (*Figure 8-6*) is a corner lock seam. This seam is used as a lengthwise seam at corners of square and rectangular pipes and elbows as well as fittings and ducts.

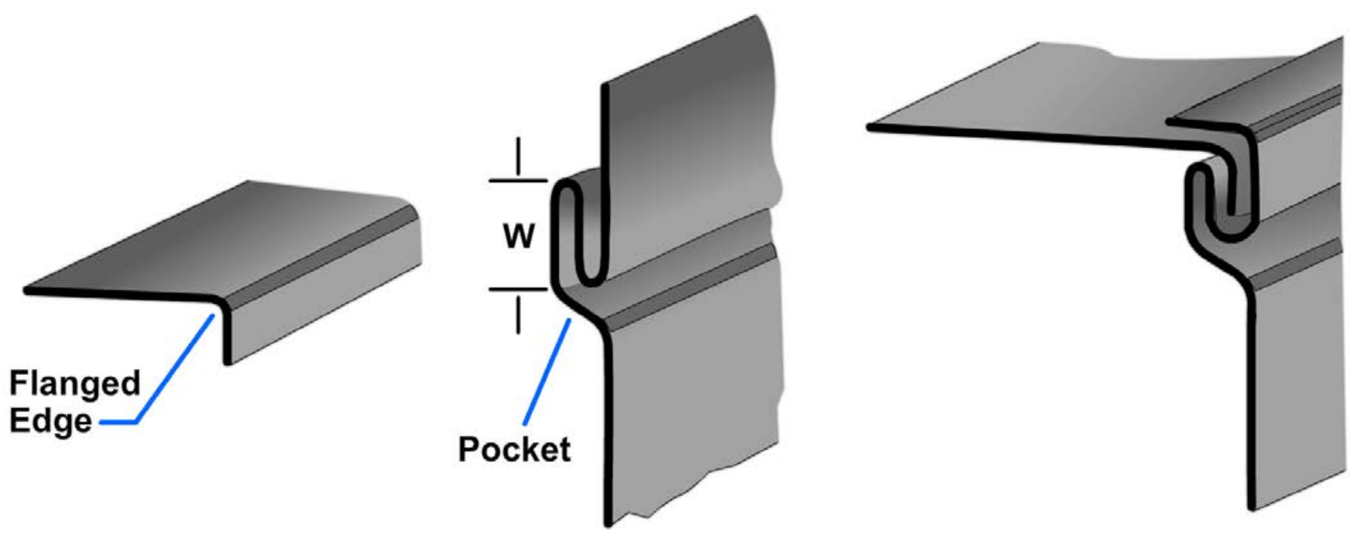

Figure 8-6 — Pittsburgh lock seam.

The Pittsburgh lock seam can be made in a brake but it has proved to be so universal in use that special forming machines have been designed and are available. The lock seam appears to be quite complicated, but like lap and grooved seams, it consists of only two pieces. The two parts are the flanged, or single, edge and the pocket that forms the lock. The pocket is formed when the flanged edge is inserted into the pocket, and the extended edge is turned over the inserted edge to complete the lock.

Note that most of the sheet metal developments illustrated in this chapter do not make any allowances for edges, joints, or seams. However, the designer who lays out a development must add extra metal where needed.

BENDS

The designer must also show where the material will be bent, and *Figure 8-7* shows several methods used to mark bend lines. If the finished part is not shown with the development, then drawing instructions, such as “bend up 90 degrees,” “bend down 180 degrees,” or “bend up 45 degrees,” should be shown beside each bend line.

When bending metal to exact dimensions, the amount of material needed to form the bend must be known. The term for the amount of material that is actually used in making the bend is known as bend allowance.

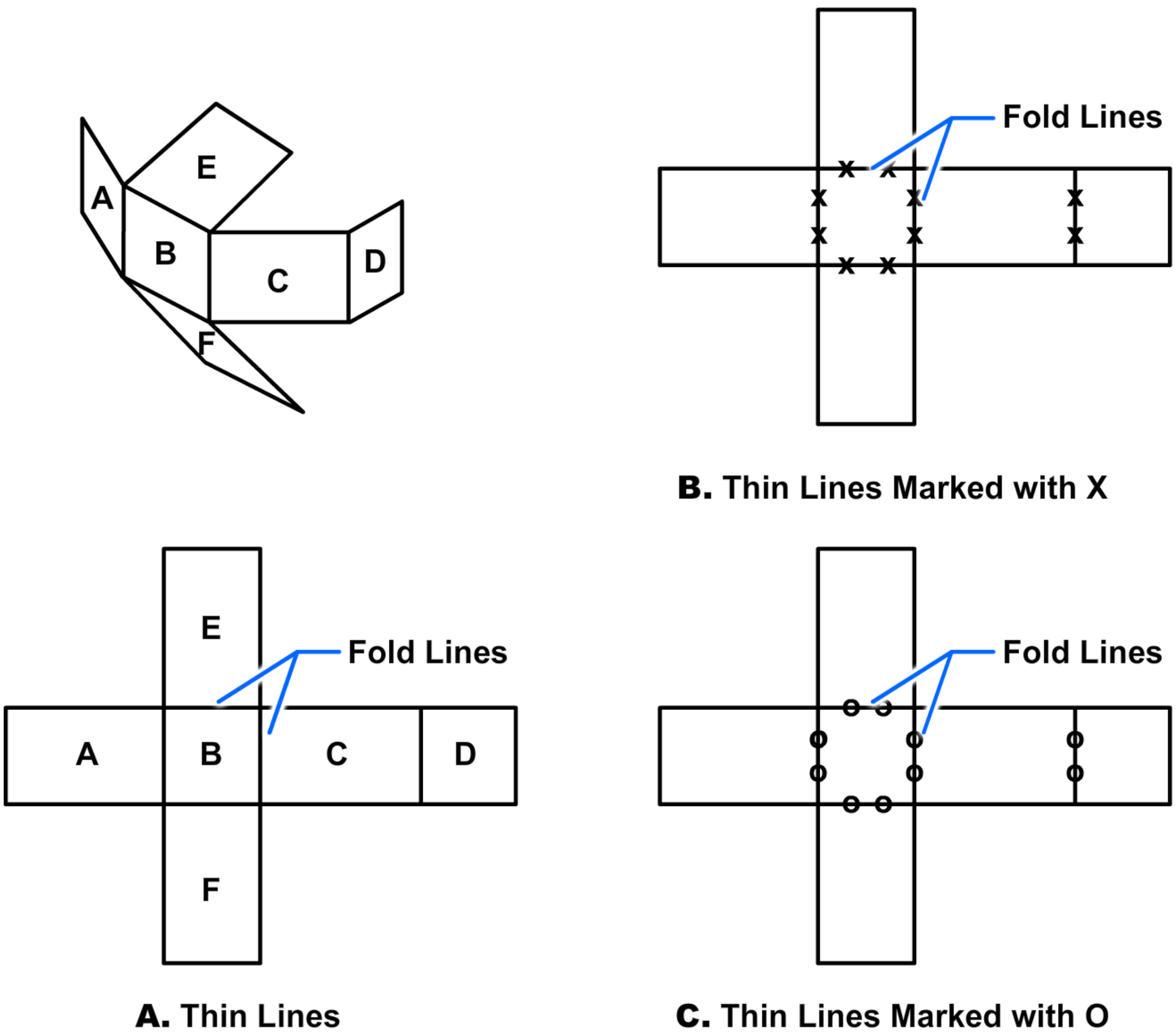

Figure 8-7 — Methods used to identify fold or bend lines.

Bending compresses the metal on the inside of the bend and stretches the metal on the outside of the bend. Approximately halfway between these two extremes lays a space that neither shrinks nor stretches. This space is known as the neutral line or neutral axis (*Figure 8-8*). It is along the neutral axis that bend allowance is computed.

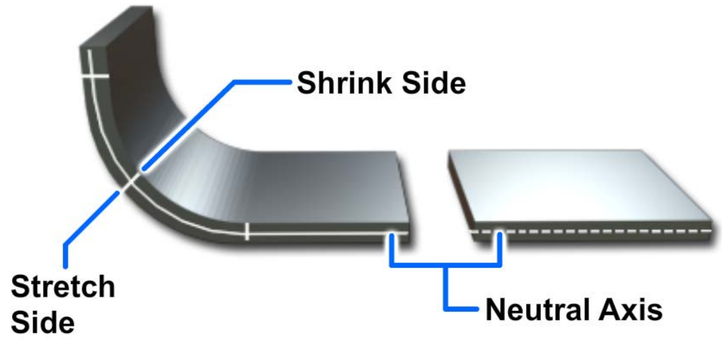

Figure 8-8 — Neutral axis.

Bend Allowance Terms

It is important to be familiar with the following terms related to a bending job. The bend allowance terminology location is illustrated in *Figure 8-9*.

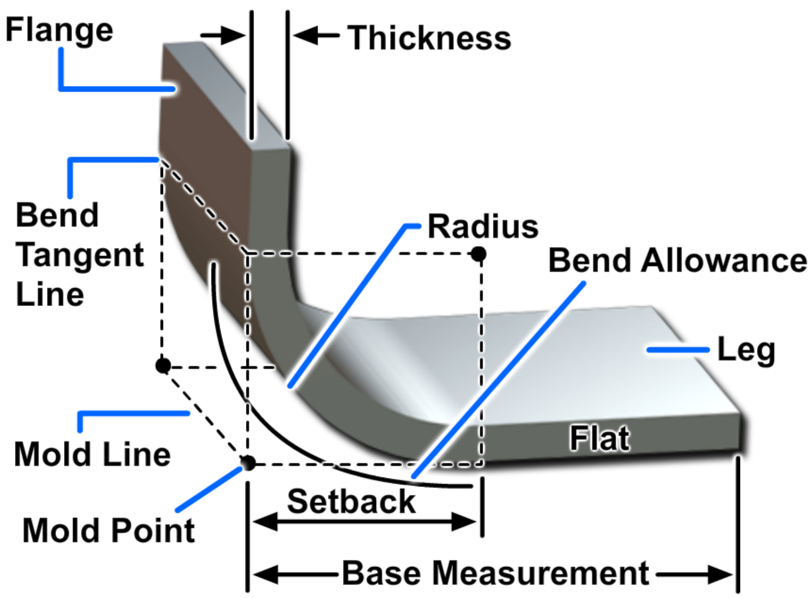

Figure 8-9 — Bend allowance terms.

- Bend allowance—is the amount of material consumed in making a bend.
- Leg—is the longer part of a formed angle.
- Flange—is the shorter part of a formed angle, the opposite of leg. If each side of the angle is the same length, then each is known as a leg.
- Flat—is that flat portion not included in the bend. It is equal to the base measurement minus the setback.
- Base measurement—is the outside dimension of a formed part. Base measurement will be given on the drawing or blueprint, or it may be obtained from the original part.
- Setback (SB)—is the distance from the bend tangent line to the mold point. In a 90-degree bend, SB = R + T (radius of the bend plus thickness of the metal). The setback dimension must be determined prior to making the bend because setback is used to determine the location of the beginning bend tangent line.
- Radius (R)—of the bend is always to the inside of the metal being formed unless otherwise stated. The minimum allowable radius for bending a given type and thickness of material should always be determined before proceeding with any bend allowance calculations.
- Mold line—is the line formed by extending the outside surfaces of the leg and the flange. (An imaginary point from which real base measurements are provided on drawings.)
- Bend tangent line—is the line at which the metal starts to bend and the line at which the metal stops curving. All the space between the bend tangent lines is the bend allowance.

- K number—is one of 179 numbers on the K chart that corresponds to one of the angles between 0 and 180 degrees to which metal can be bent. When metal is to be bent to any angle other than 90 degrees (K number of 1.0), the corresponding K number is selected from the chart and multiplied by the sum of the radius and the thickness of the metal. The product is the amount of setback for the bend.
- Closed angle—is less than 90 degrees when measured between legs. When the closed angle is 45 degrees, the amount of bend is 180 minus 45 or 135 degrees.
- Open angle—is more than 90 degrees when measured between legs or less than 90 degrees when the amount of bend is measured.

Bend Allowance Formula

By experimentation with actual bends in metals, aircraft engineers have found that accurate bending results could be obtained by using the following formula for any degree of bend from 1 to 180:

$(0.0173 \times R + 0.0078 \times T) \times N = BA$

where

R = the desired bend radius,

T = the thickness of the material, and

N = the number of degrees of bend.

Refer to the General Manual for Structural Repair, Naval Air Systems Command (NAVAIR) manual 01-1A-1, for the appropriate bend allowance tables.

SHEET METAL SIZES

The thickness of sheet metal is usually specified by the non-linear measure known as its gauge. Thick sheet metal gauge sizes have low gauge numbers, while thinner sheet metal gauge numbers are high. Steel sheet metal sizes from 30 gauge to about 7 gauge are the most commonly used gauges. Gauge differs between iron based metals and non-iron based metals such as copper and aluminum.

There are many different metals that can be made into sheet metal, such as aluminum, brass, copper, steel, tin, nickel, and titanium. For decorative uses, important sheet metals include silver, gold, and platinum (platinum sheet metal is also utilized as a catalyst.)

Metal thicknesses up to 0.25 inch (6 millimeters) are usually designated by a series of gauge numbers. Metal 0.25 inch and over is given in inch and millimeter sizes. In calling for the material size of sheet metal developments, it is customary to give the gauge number, type of gauge, and its inch or millimeter equivalent in brackets followed by the developed width and length in one sheet metal size (*Figure 8-10*). A gauge system is used for carbon steels but not appropriate for stainless steels where thickness is specified in decimals. The USS in *Figure 8-10* identifies the type of gauge system, in this case the United States Standard gauge system.

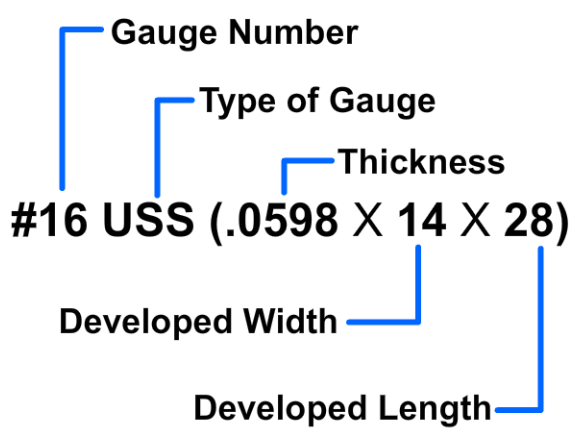

Figure 8-10 — Example of a sheet metal size.

TYPES OF DEVELOPMENT

A surface is said to be developable if a thin sheet of flexible material, such as paper, can be wrapped smoothly about its surface. Therefore, objects that have plane, flat, or single-curved surfaces are developable. But a surface that is double-curved or warped is not considered developable, and approximate methods must be used to develop it. Typical sheet metal developments are illustrated in *Figure 8-11*.

A spherical shape would be an example of an approximate development. The material would be stretched to compensate for small inaccuracies. For example, the coverings for a football or basketball are made in segments. Each segment is cut to an approximate developed shape, and the segments are then stretched and sewed together to give the desired shape.

The three procedures commonly used in developing patterns are parallel-line, radial-line, and triangular development.

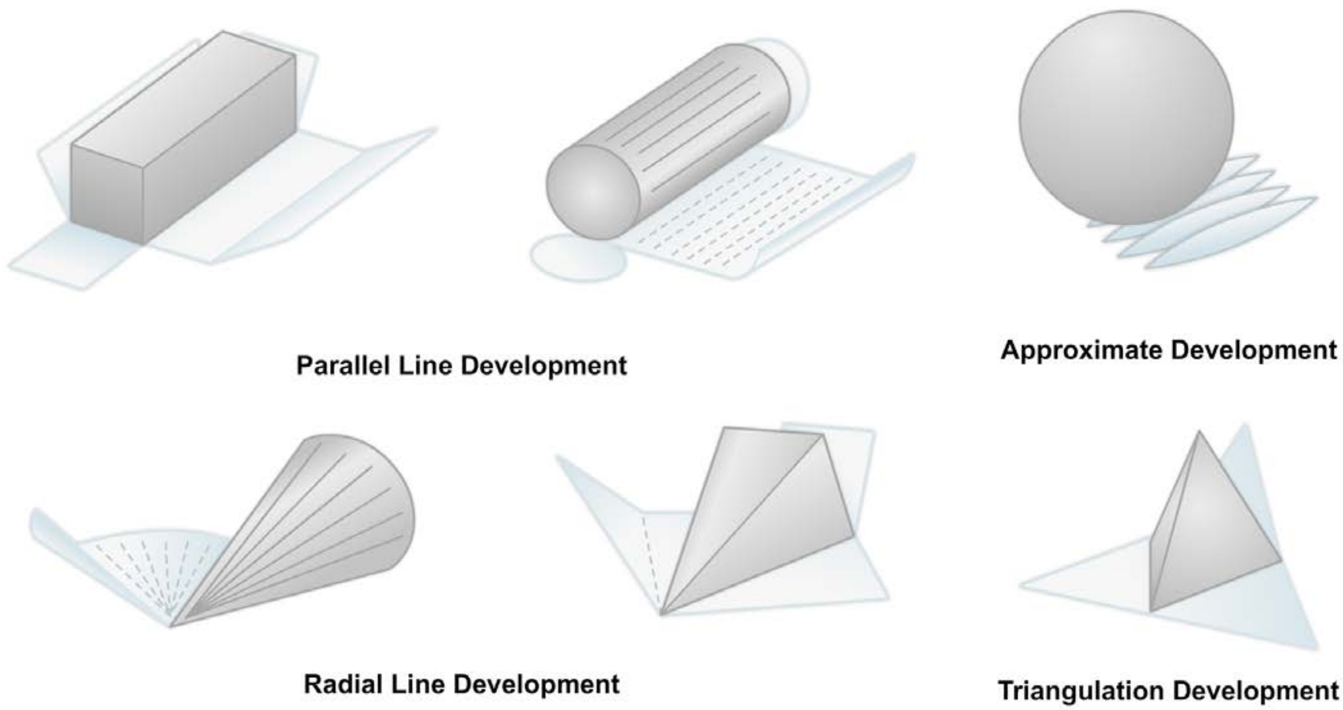

Figure 8-11 — Typical sheet metal development.

Parallel-Line Development

Parallel-line development refers to the development of an object that has surfaces on a flat plane of projection. The true size of each side of the object is known and the sides can be laid out in successive order. The development of a simple rectangular box with a bottom and four sides is illustrated in *Figure 8-12*. There is an allowance for lap seams at the corners and for a folded edge. The fold lines are shown as thin unbroken lines. Note that all lines for each surface are straight.

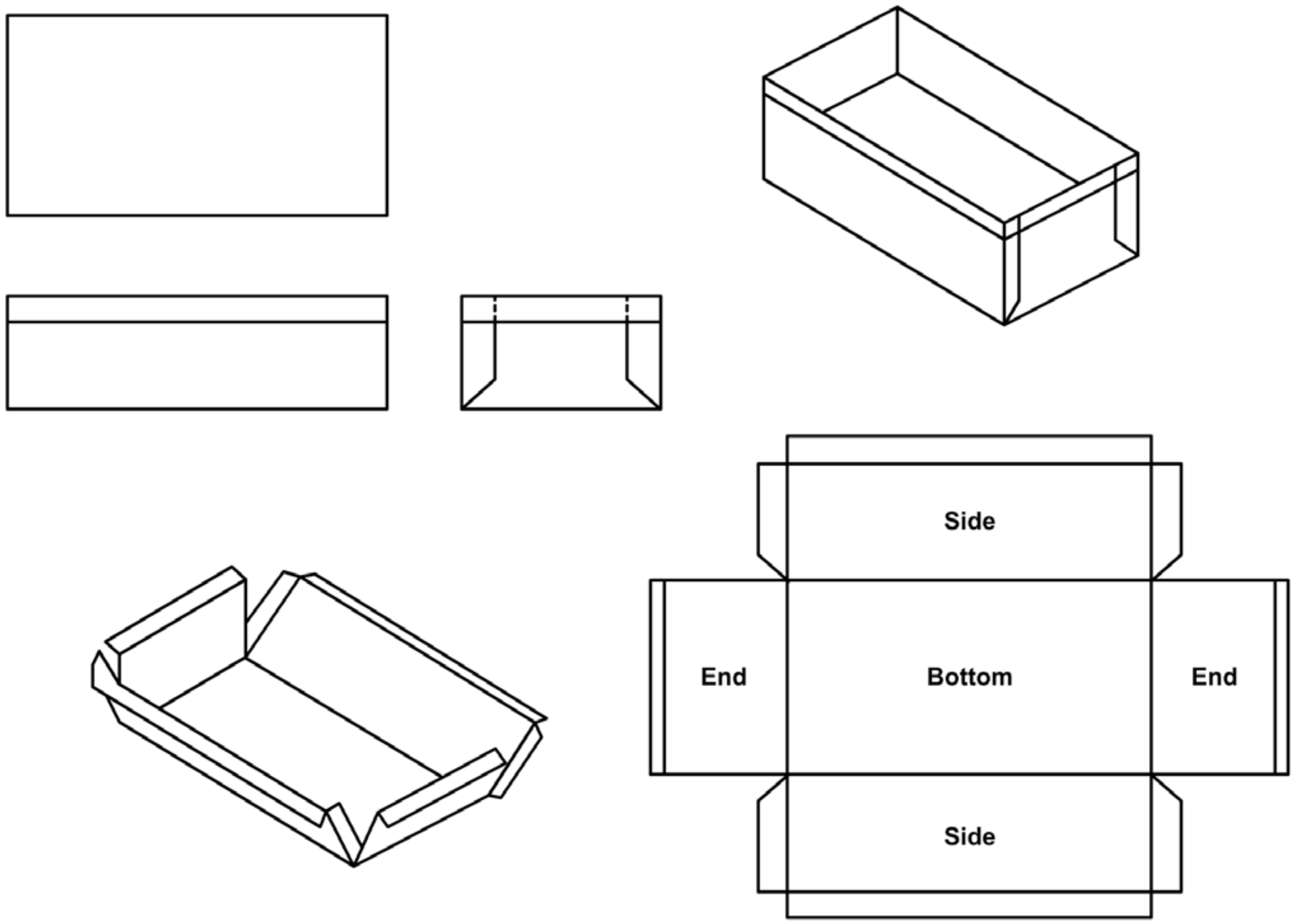

Figure 8-12 — Development of a rectangular box.

A parallel-line development drawing may include a complete set of folding instructions as shown in *Figure 8-13*. A letter box development drawing (*Figure 8-14*) illustrates that the back is higher than the front surface.

Parallel-line development is based upon the fact that a line that is parallel to another line is an equal distance from that line at all points. Objects that have opposite lines parallel to each other or that have the same cross-sectional shape throughout their length are developed by this method.

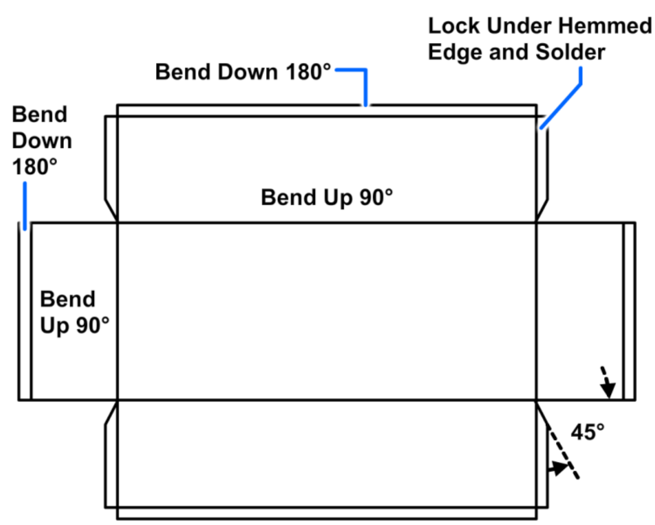

Figure 8-13 — Development drawing with folding instructions.

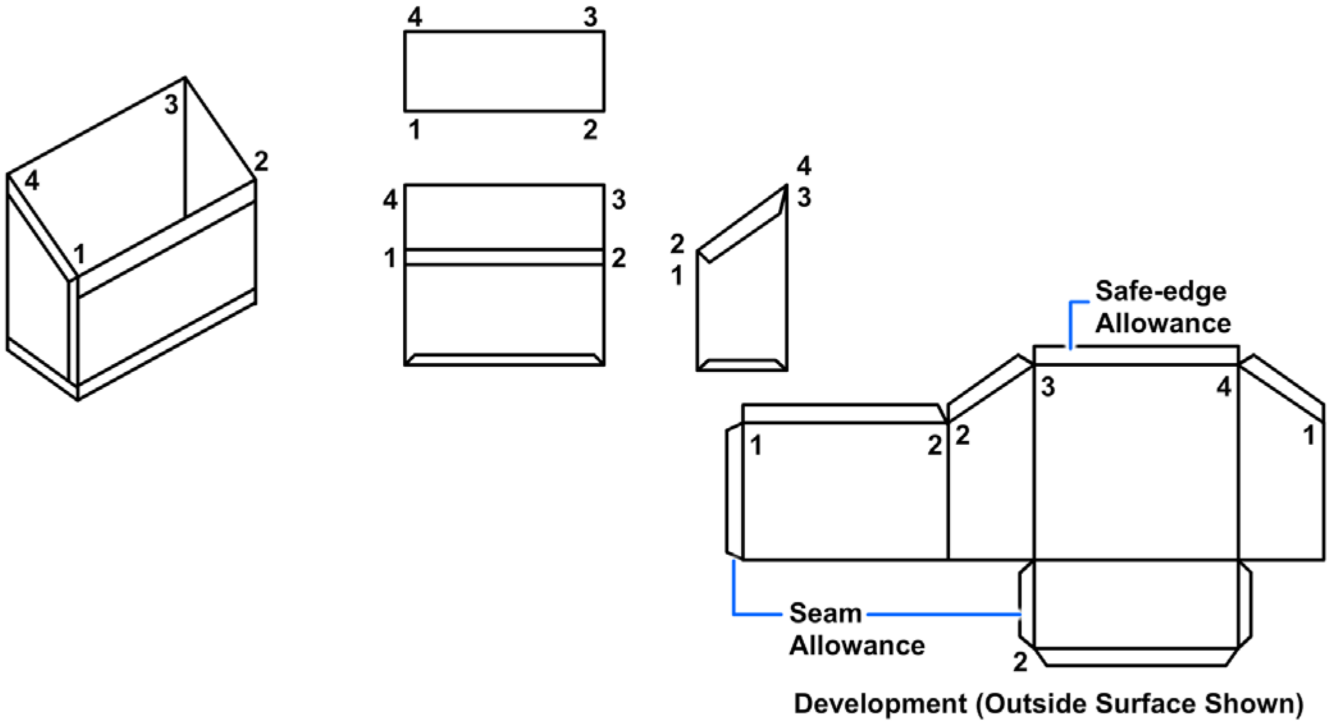

Figure 8-14 — Development drawing of a letter box.

Truncated Cylinder

To gain a clear understanding of the parallel-line method, we will develop a layout of a truncated cylinder (*Figure 8-15*). Such a piece can be used as one half of a two-piece 90-degree elbow.

A truncated cylinder is developed in *Figure 8-16*:

1. Mark out reference lines using a set square.
2. Identify the diameter measurement and draw a circle. Here the diameter is 1 1/2 inches (40 millimeters).
3. Use the radius of the circle to divide the circumference into 12 equal sectors.
4. Label the marks 1 to 12. Note the numbers begin on the right-hand side and go in a clockwise direction.
5. Identify and mark the height of the cylinder. Here the height is 2 1/2 inches (60 millimeters).
6. Determine the angle of the top of the cylinder and use a setsquare. Here the angle is 45 degrees.
7. Mark off the radius on both sides of the reference line to construct the sides of the cylinder. Transfer numbers 1 to 12 from the circle to the base of the cylinder. Project these points to the top of the cylinder.

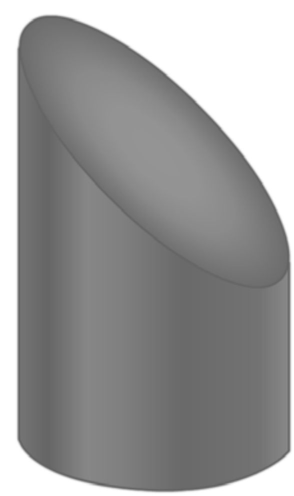

Figure 8-15 — Truncated cylinder.

8. Calculate the circumference of the cylinder to determine the stretch out length of the pattern. Use the formula $C = \pi D$. The diameter here is 1 1/2 inches (40 millimeters). Mark out the circumference on the horizontal base line.

9. Divide the length of the circumference into 12. Draw a reference line and mark on it one-twelfth of the circumference. Use this measurement to set the dividers. Splitting the circumference into halves and quarters reduces tolerance error.
10. Use the dividers to mark the circumference into 12 equal divisions on the base line. Mark these divisions 1 to 12. The final division is numbered 1. Project these divisions upward at 90 degrees.
11. Now develop the stretch out pattern. Transfer the length of the lines on the side view to the corresponding lines on the stretch out. Draw the top line curve of the pattern freehand, by using material like packing cord bent to the curve or by using a flexible curve.

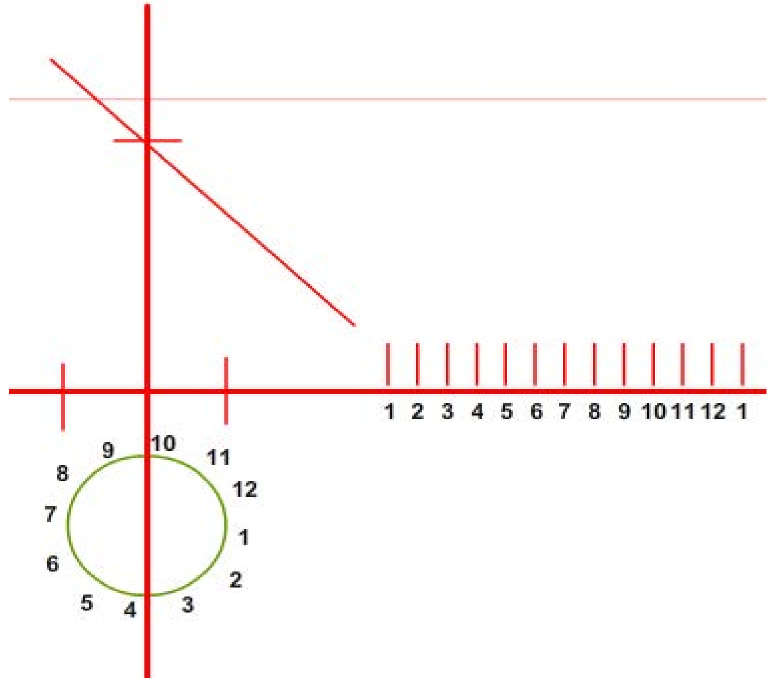

Figure 8-16 — Truncated cylinder development.

Interaction Available

12. This final shape is the stretch out pattern of the cylindrical shape and can be cut to shape to use as a template.

When the development is finished, the machinist will cut out the pattern. It is normal practice in sheet metal work to place the seam on the shortest side. However, in the development of elbows, the practice would result in considerable waste of material, as shown in *Figure 8-17, view A*. To avoid the waste and to simplify cutting the pieces, the seams are alternately placed 180 degrees apart, as shown in *Figure 8-17, view B* for a two-piece elbow, and *view C* for a three-piece elbow.

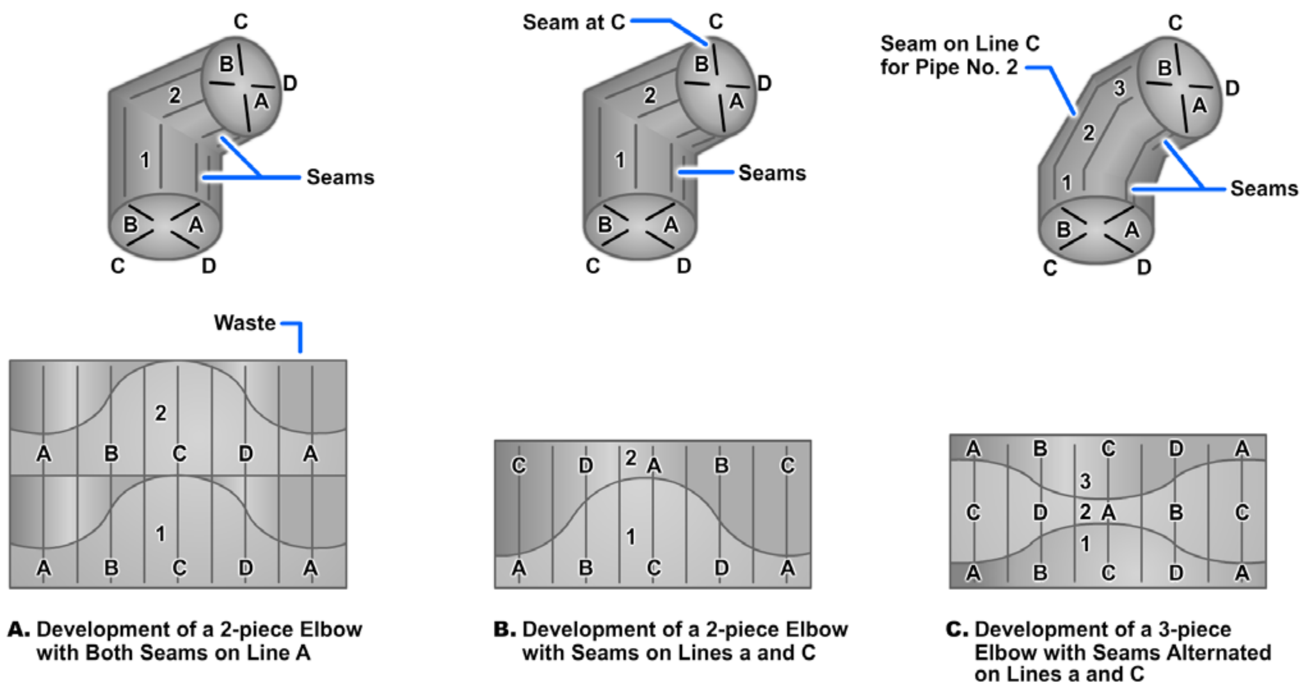

Figure 8-17 — Location of seams on elbows.

Radial-Line Development

In radial-line development, the slanting lines of pyramids and cones do not always appear in their true lengths in an orthographic view; the designer must find other means to depict them.

The radial-line method is similar in some respects to the parallel-line method. Evenly spaced reference lines are necessary in both of these methods. However, in parallel-line development, the reference lines are parallel—like a picket fence. In radial-line development, the reference lines radiate from the apex of a cone—like the spokes of a wheel.

The reference lines in parallel-line development project horizontally. In radial-line development, the reference lines are transferred from the front view to the development with the dividers.

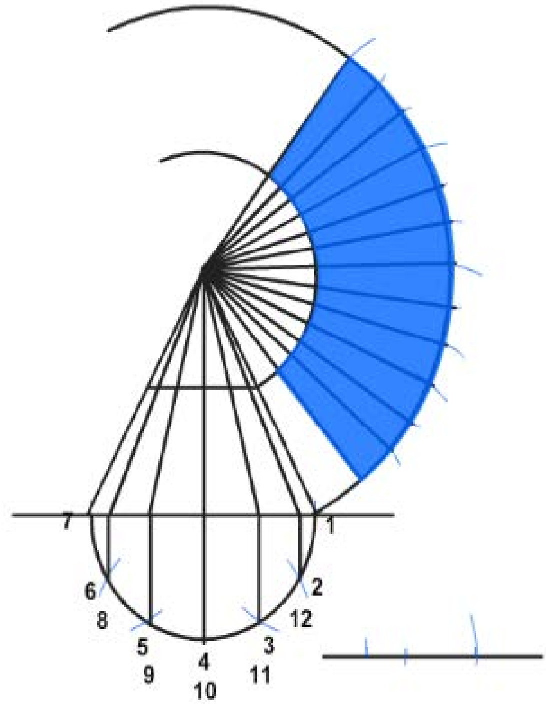

Figure 8-18 — Radial-ine development.

Interaction Available

Developing a pattern for the frustum of a right cone is a typical practice project that will help you get the feel of the radial-line method. You are familiar with the shape of a cone. A right cone is one that, if set flat side down on a flat surface, would stand straight up. In other words, a centerline drawn from the point, or vertex, to the base line would form a right angle with that line. The frustum of a cone is that part that remains after the point, or top, has been removed.

The procedure for developing a frustum of a right cone is given below. Check each step of the procedure against the development shown in *Figure 8-18*.

1. First establish the apex point (H).
2. Draw reference lines using a set square. Mark out the measurements of the:
   a. Base (D) – 2 3/4 inches (70 millimeters).
   b. Apex (H) – 4 inches (100 millimeters).
   c. Frustum height (h) – 2 inches (50 millimeters).
3. Draw in the reference lines from the apex (H) to the base (D). Check that the frustum diameter (d) is 1 3/8 inches (35 millimeters).
4. Develop the half circle representing half the bottom view.
5. Set the dividers at 1 3/8 inches (35 millimeters) - the radius of the base of the frustum (D). Divide the half circle into 6 equal sectors.
6. Label the marks 1 to 12 as indicated.
7. Project each of the sectors up to the base line at 90 degrees. Project these lines to the apex.
8. Develop the stretch out pattern of the frustum. Place the compass point on the apex. Set the radius to A and swing an arc as indicated. Repeat with the radius set to B.
9. Draw a line from the apex to the bottom circumference, away from the base of the frustum. The intersection point will be the start for marking out the base circumference into 12 sectors.

10. The frustum circumference is D = 3.14 x 2 3/4 inches = 8 43/64 inches (220 millimeters). Mark the base circumference into 12 equal sectors. Calculate the length of each sector:

$$= 8\,\frac{43}{64}\ inches\ (220\ millimeters)/12\ =\ 0.72\ inches\ (18.3\ millimeters)$$

11. Draw a reference line and mark out 23/32 inch (18.3 millimeters). Set the dividers to this distance. Mark off the 12 divisions along the circumference.
12. Project each of these to the apex to form the radial lines. The radial lines will be used in the forming process. The shape shaded in blue is the radial-line stretch out pattern for the right cone frustum.

Oblique Pyramid

The oblique pyramid in *Figure 8-19* has all its lateral edges of unequal length. The true length of each of these edges must first be found as shown in the true-length diagram. The development may now be constructed as follows:

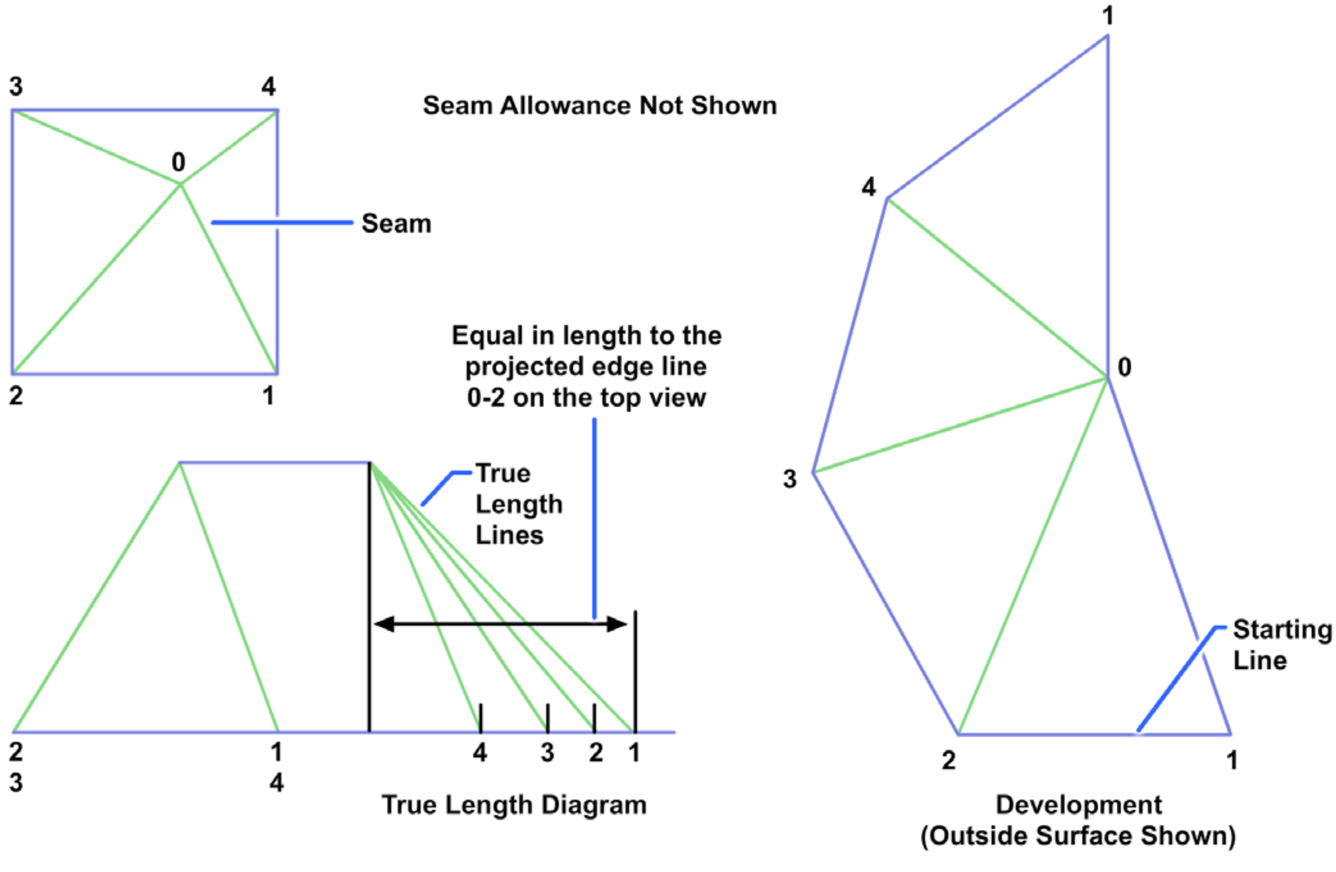

Figure 8-19 — Development of an oblique pyramid by triangulation.

1. Lay out base line 1-2 in the development view equal in length to base line 1-2 found in the top view.
2. With point 1 as center and a radius equal in length to line 0-1 in the true diagram, swing an arc.
3. With point 2 as center and a radius equal in length to line 0-2 in the true-length diagram, swing an arc intersecting the first arc at 0.

4. With point 0 as center and a radius equal in length to line 0-3 in the true-length diagram, swing an arc.
5. With point 2 as center and radius equal in length to base line 2-3 found in the top view, swing an arc intersecting the first arc at point 3.
6. Locate points 4 and 1 in a similar manner, and join those points, as shown, with straight lines.

The base and seam lines have been omitted on the development drawing.

Truncated Pyramid

The truncated pyramid in *Figure 8-20* has all its lateral edges of unequal length. The true length of each of these edges must first be found. The procedure for developing a truncated pyramid is given below. Check each step of the procedure against the development shown in *Figure 8-20*.

1. First draw the orthographic views of the truncated pyramid.
2. Identify the base diameter. Here the base diameter is 12 inches.
3. Identify and mark the height of the apex. Here the height is 12 inches.
4. Identify and mark the height of the truncated pyramid. Here the height is 8 inches.
5. Determine the angle of the top of the truncated pyramid and use a setsquare. Here the angle is 45 degrees.

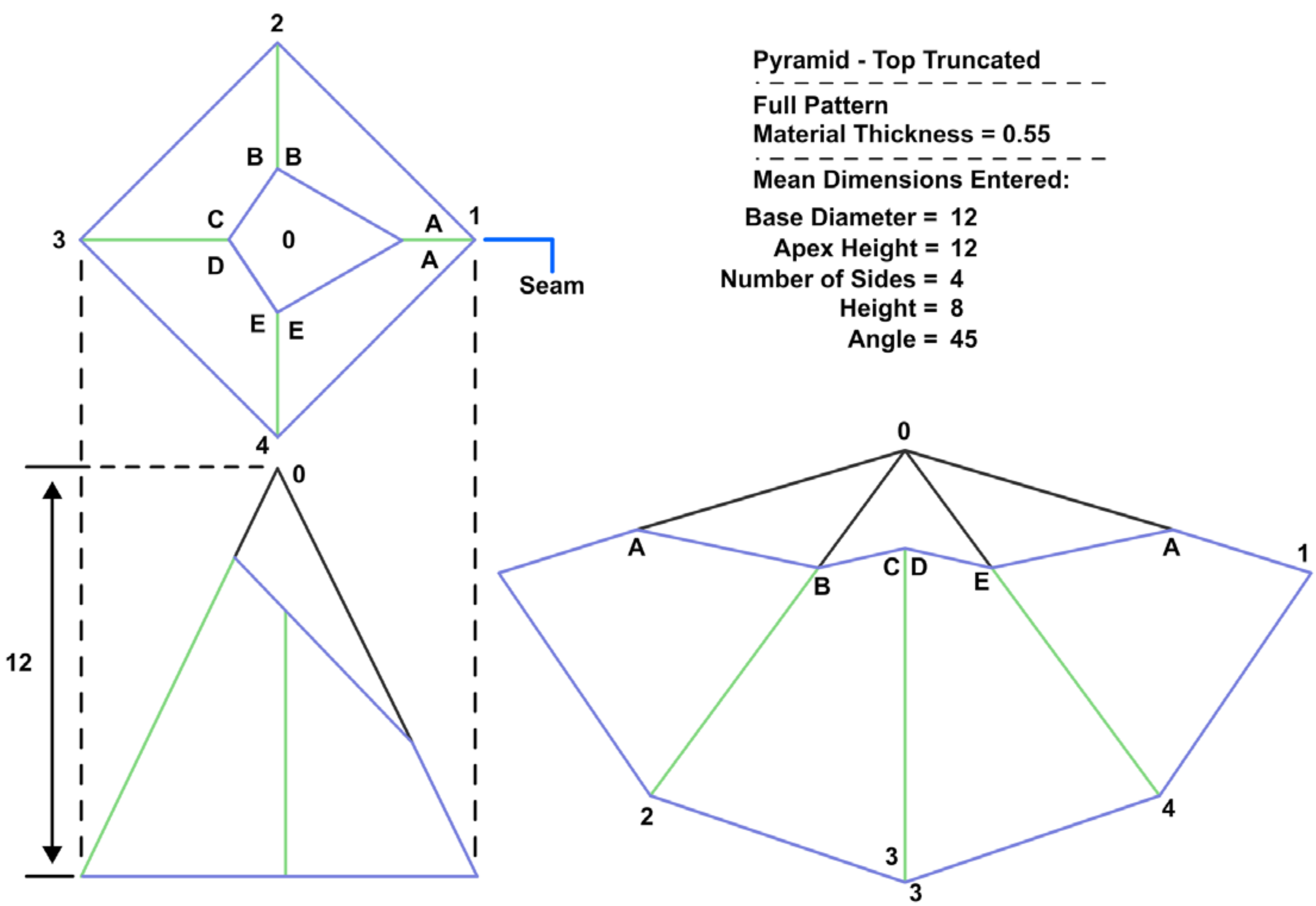

Figure 8-20 — Development of a truncated pyramid.

6. Mark off the radius on both sides of the reference line to construct the sides of the truncated pyramid.
7. The intersecting points establish the true length of all segments.
8. Now develop the stretch out pattern. Transfer the length of the lines on the side view to the corresponding lines on the stretch out view.
9. The final shape is the stretch out pattern of the cylindrical shape and can be cut to shape to use as a template.

Triangular Development

Triangulation is slower and more difficult than parallel-line or radial-line development, but it is more practical for many types of figures. Additionally, it is the only method by which the development of warped surfaces may be estimated. In development by triangulation, the piece is divided into a series of triangles, as in radial-line development. However, there is no one single apex for the triangles. The problem becomes one of finding the true lengths of the varying oblique lines. Drawing a true-length diagram solves the problem.

An example of a layout using triangulation is the development of a transition piece (*Figure 8-21*). Transition pieces are usually made to connect two different shapes of pipes, such as square to round, rectangular to round, and hexagonal to round. Transition pieces can be used to form parallel and oblique joints where the piping may not be perpendicular to the pipe axis. These transition pieces will usually fit the definition of a non-developable surface that must be developed by approximation.

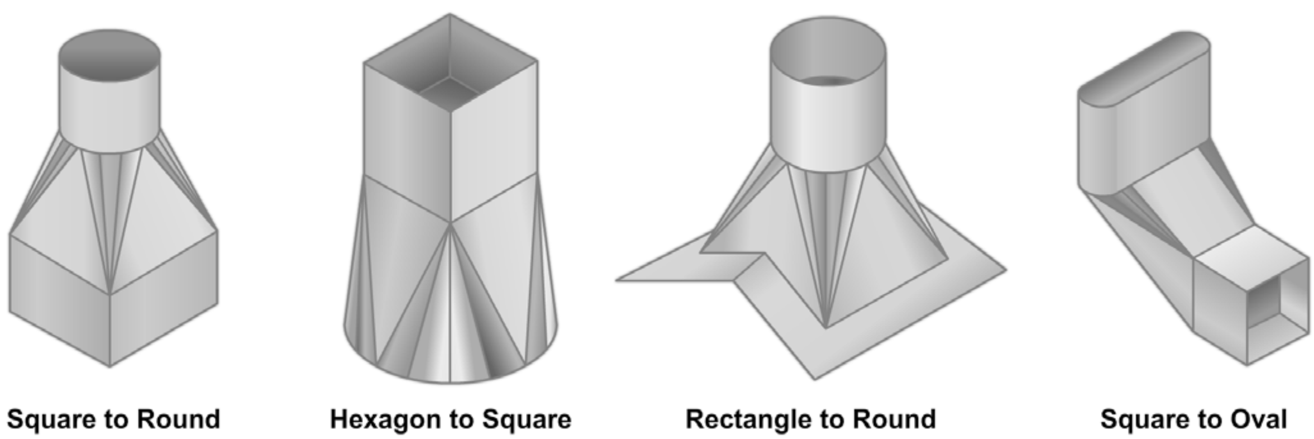

Figure 8-21 — Transition pieces.

Oblique Cone

An oblique cone is generally developed by the triangulation method.

The base of the cone is divided into an equal number of divisions. The elements 0-1, 0-2, and so on are drawn in the top view, projected down, and drawn in the front view. The true lengths of the elements are not shown in either the top or front view, but would be equal in length to the hypotenuse of a right triangle, having one leg equal in length to the projected element in the top view and the other leg equal to the height of the projected element in the front view. When it is necessary to find the true length of a number of edges, or elements, then a true-length diagram can be drawn adjacent to the front view, preventing the front view from being cluttered with lines.

Since the development of the oblique cone (*Figure 8-22*) will be symmetrical, the starting line will be element 0-13. The development is constructed as follows:

1. With 0 as center and the radius equal to the true length of element 0-12, draw an arc.
2. With 13 as center and the radius equal to distance 12-13 in the top view, draw a second arc intersecting the first point at 12. Draw element 0-12 on the development.
3. With 0 as center and the radius equal to the true length of element 0-11, draw an arc. With 11 as center and the radius equal to distance 11-12 in the top view, draw a second arc intersecting the first point at 11. Draw element 0-11 on the development.
4. Repeat these steps with the remaining elements until all element lines are located on the development view.

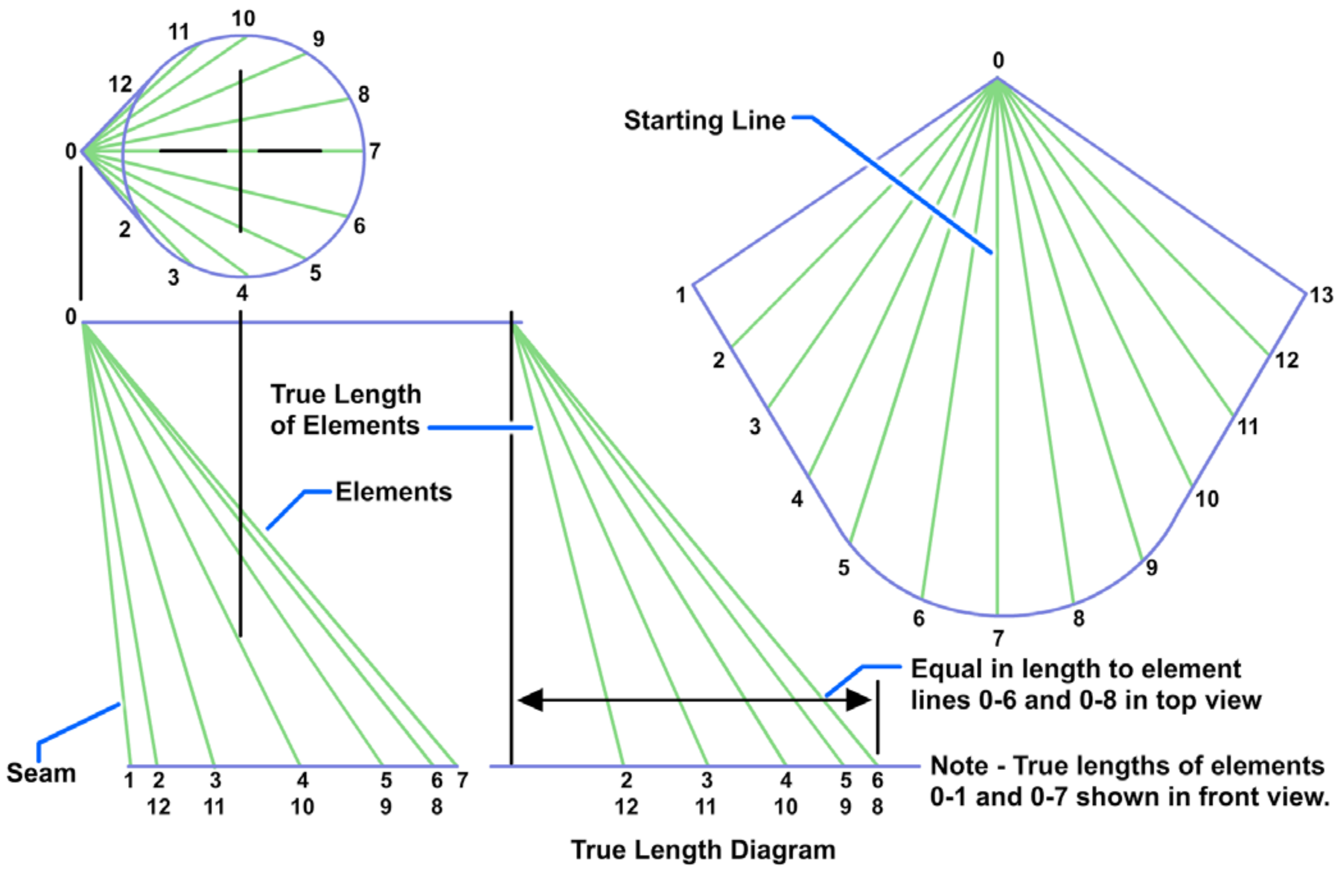

Figure 8-22 — Development of an oblique cone.

Square-to-Round

The steps in the triangulation of a warped transition piece joining a large, square duct and a small, round duct are shown in *Figure 8-23*. The steps are as follows:

1. First establish the reference lines.
2. Develop the top view. With a set square, mark out the measurements for half the base, and label each corner (from the top left-hand corner, moving clockwise) A to D.
3. From the center of the half base, draw a semicircle with radius 1 inch (25 millimeter). Check that the diameter (D) is 2 inches (50 millimeters).

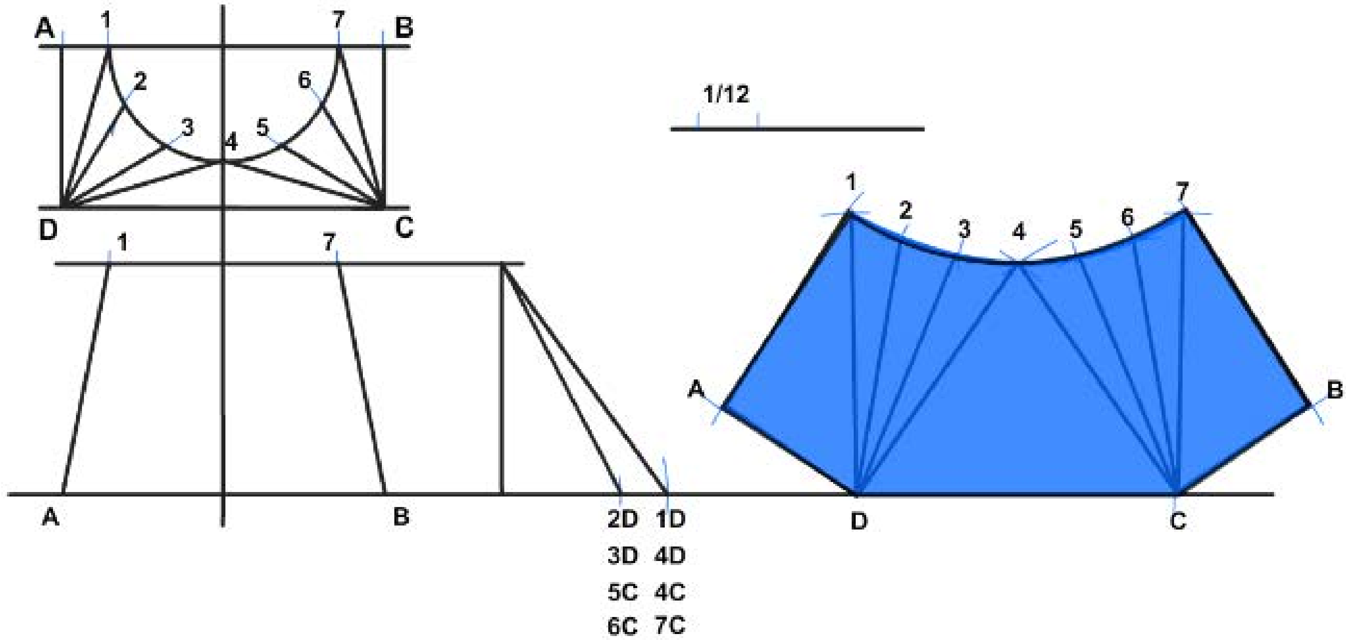

Figure 8-23 — Triangular development of a transition piece.

Interaction Available

4. Divide the half circle into six equal spaces by placing the compass point on the three points where the semicircle intersects the reference lines and swinging small arcs (R = 1 inch (25 millimeter)) to intersect the circle. Number the points 1 to 7 as shown.
5. Using a set square, draw lines from point D on the base of the shape to points 1 through to 4 on the half circle. Next, draw lines from C on the base of the shape to points 4 through to 7, which completes (half) the top view.
6. Draw the side view. First, draw a reference line. Remember, the vertical height is 50 millimeters, and the diameter of the top is 50 millimeters.
7. The base is 2 3/4 inches (70 millimeters) square. Draw lines from the base to the top. Label the base points A and B. Label the top points 1 and 7.
8. Now develop the stretch out pattern for the square-to-round. First establish a reference line (extending to the right from point B on the side view) for the base of the stretch out pattern. Draw the vertical height of the square-to-round somewhere to the right of the side view, perpendicular to the base line.
   a. Now place the compass point on D in the top view. Set the radius to point 2 on the half circle. Place the compass point at the intersection of the base line and the vertical height line and swing an arc to mark the base line. Label this point 2D. Note this point is the shortest distance from point D to the top of the half circle, the same length as 3D, 5C, and 6C.
   b. Now place the compass at D and set the radius to point 1 on the half circle. Transfer the compass to the intersection of the base line and the vertical height line and swing an arc to mark the base line. Label the point 1D. Note this point is the longer distance from point D to the top of the half diameter, the same length as 4D, 4C, and 7C.
   c. Now draw a line from the top of the vertical height line to point 2D, and then from the top to point 1D. This diagram is called the true-length diagram.

9. Mark a point on the base line to the right of point 1D.
10. Set the compass at the distance between D and C on the top view (the true length), then transfer the distance D to C to the base line. Label the points D and C. Reset the compass to the length of the line 4D. Placing one point on D, draw an arc midway between D and C. Shift the compass to C, draw an arc to bisect the previous one. Label this point 4.
11. Mark out a new short reference line for one-twelfth of the circumference of the top of the square-to-round shape. Calculate the circumference of the top of the shape, and then divide it by 12.

    $C = \pi D$

    C = 3.14 x 2 inches (50 millimeters)

    = 6 13/64 inches (157 millimeters)

    One-twelfth of the circle

    = 6 13/64 inches (157 millimeters) ÷ 12

    = 1/2 inch (13 millimeters)
12. Measure and mark out 1/2 inch (13 millimeters) on the reference line. Set the compass at 1/2 inch (13 millimeters) (one-twelfth circumference).
    a. Place the compass on point 4, and swing arcs to mark to the right and to the left. Set the compass at the true length of reference line 2D. Place the compass on point D, and swing an arc to intersect the arc on the left. Label this point 3. Place the compass on C, and swing an arc to intersect the arc on the right. Label this point 5.
    b. Reset the compass at 1/2 inch (13 millimeters), using the measure on the reference line. Place the compass on point 5 and swing an arc to the right hand side. Swing an arc to the left of point 3.
    c. Reset the compass at the length of the reference line 2D. Place the compass on point D, make a mark intersecting the arc, and label this point 2. Place the compass on C, make a mark intersecting the arc, and label this point 6.
    d. Repeat the process, swinging an arc R13 to the left of 2 and right of 6. This time, however, reset the compass to the length of reference line 1D. Place the compass point on D, make a mark intersecting the arc, and label this point 1. Place the compass on C and make a mark intersecting the arc. Label this point 7.
13. Develop the half square base from point D to point A.
    a. Using the side view diagram, set the compass at the distance between B and 7. Place the compass at point 1 on the stretch out pattern, and draw an arc to the lower left. Repeat the process from point 7 to the lower right.
    b. Reset the compass to the distance between B and C on the top view diagram. Place the compass on D and make a mark intersecting the arc. Label this point A. Place the compass on C, make a mark intersecting the arc, and label this point B.
    c. Using a set square or ruler, draw lines joining 1 and A; A and D; 7 and B; and B and C. Draw lines from D to 1, 2, 3, and 4. Draw lines from C to 4, 5, 6, and 7.
14. Use a flexible ruler, or freehand to join points 1 to 7.

This completes the stretch out half pattern for a square-to-round shape, using the triangulation method. This development does not show a seam allowance.

Rectangular-to-Round

The transition piece shown in *Figure 8-24* is constructed in the same manner as the square-to-round except that all the elements are of different lengths. To avoid confusion, four true-length diagrams are drawn and the true-length lines are clearly labeled.

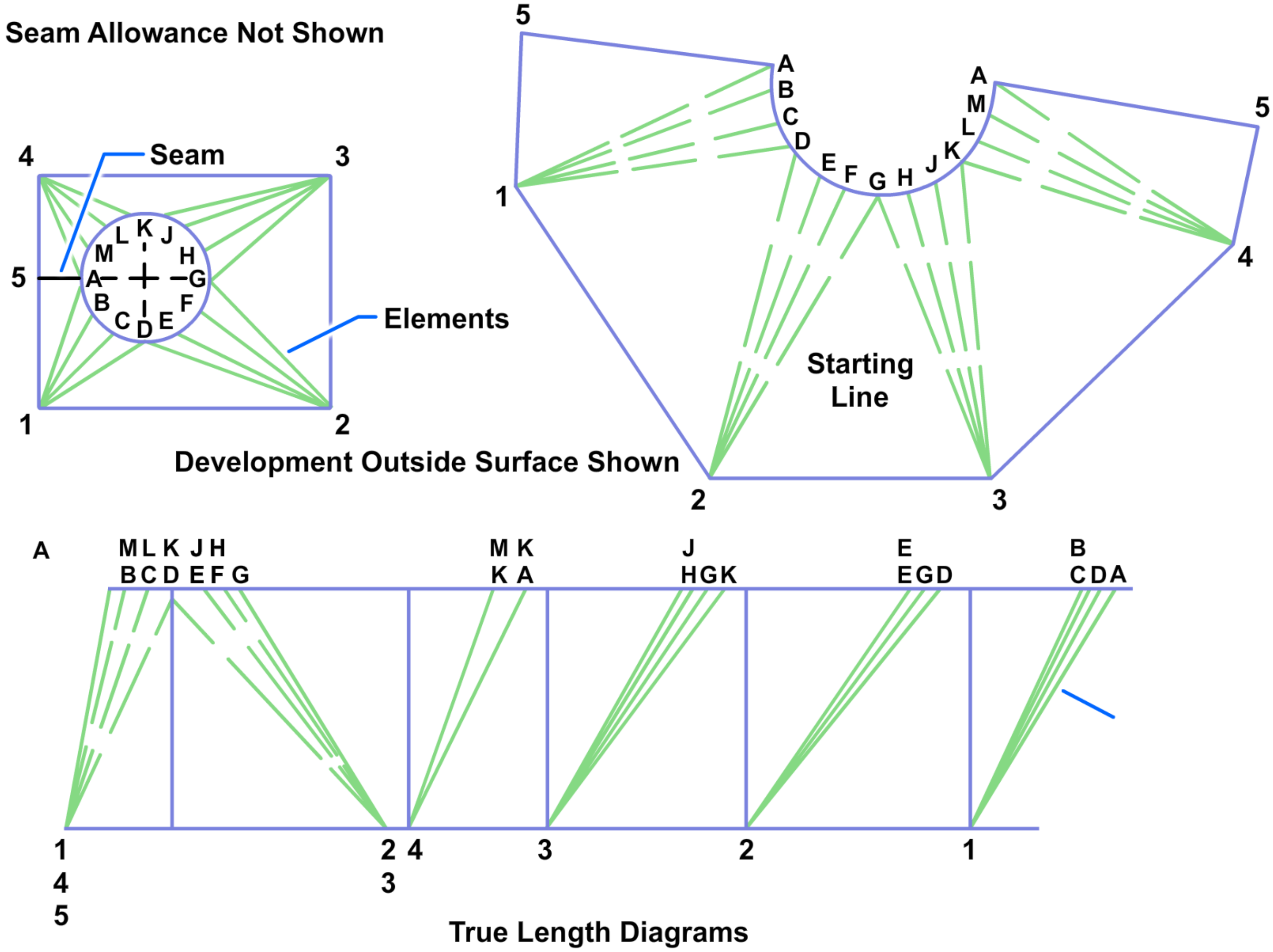

Figure 8-24 — Development of an offset transition piece—rectangular to round.

Hexagon-to-Round

The transition piece shown in *Figure 8-25* is constructed in the same manner as the square-to-round and the rectangular-to-round transition pieces, as all of the elements are, once again, different lengths.

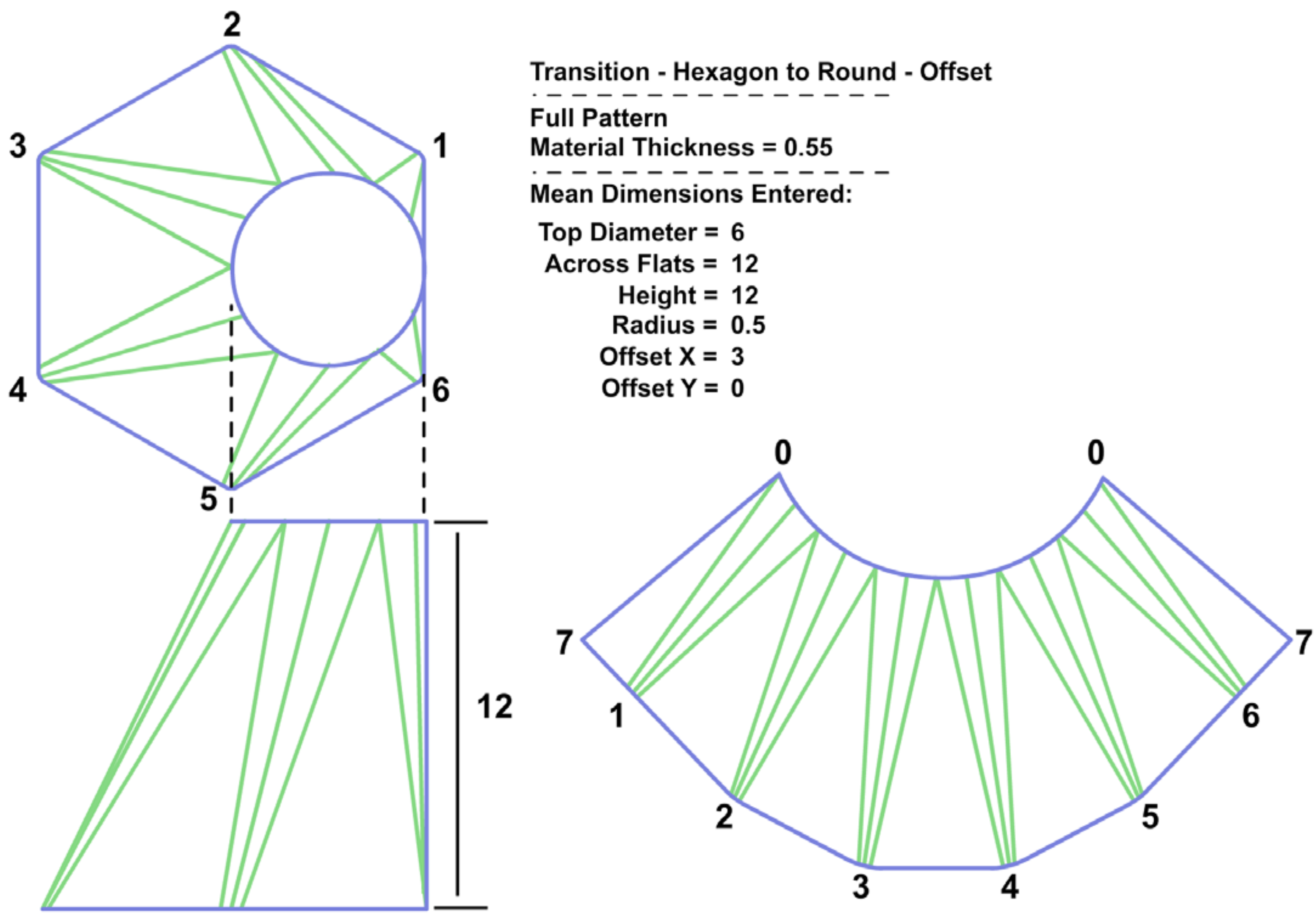

Figure 8-25 — Development of a transition piece—hexagon to round.

End of Chapter 8

Developments and Intersections

Review Questions

8-1. For which of the following reasons should the sheet metal development drawings allow additional material?

A. Compression during shaping
B. Damage to the material
C. Joining of edges
D. Miscalculations

8-2. When drawing a lap seam, the allowance must be how many times the diameter of the rivet being used?

A. 1
B. 3
C. 5
D. 7

8-3. If the finished part is not shown with the development, what item should be included?

A. A scale model
B. Drawing instructions
C. Color code list
D. Marking instructions

8-4. Which of the following terms describes the amount of material consumed in making a bend?

A. Base measurement
B. Bend allowance
C. Bend tangent line
D. Setback

8-5. The three procedures commonly used in developing patterns are parallel-line, radial-line, and what other type of development?

A. Circular
B. Perspective
C. Rectangular
D. Triangular

8-6. Which of the following statements defines parallel-line development?

A. The development of an object that has surfaces on a flat plane of projection
B. The development of an object that has surfaces on a slanting plane of projection
C. The first series of prints used in construction and manufacturing
D. The perspective print of the development of parallel roadways

8-7. The parallel-line development is based upon which of the following principles?

A. A line parallel to another line is an equal distance from that line at all points
B. A line perpendicular to another line will intersect at only one point
C. The lines radiate from the apex of a cone
D. When finished, the lines form a three-dimensional drawing

8-8. What type of development is used when an object has the same cross-sectional shape throughout the length?

A. Orthographic-perspective
B. Parallel-line
C. Radial-line
D. Triangular

8-9. Which of the following shapes is an exception to the normal practice of placing seams on the shortest side in sheet metal development?

A. Cone
B. Cylinder
C. Elbow
D. Pyramid

8-10. In what type of development do the slanting lines of pyramids and cones not always appear in the true lengths?

A. Orthographic-perspective
B. Parallel-line
C. Radial-line
D. Triangular

8-11. Concerning radial-line developments, which of the following statements is true?

A. A line parallel to another line is an equal distance from that line at all points
B. A line perpendicular to another line will intersect at only one point
C. The lines radiate from the apex of a cone
D. When finished, the lines form a three-dimensional drawing

8-12. In a radial-line development, the reference lines are transferred from what view to the development?

A. Front
B. Rear
C. Side
D. Top

8-13. In a radial-line development of an oblique pyramid, what measurement must be found first?

A. Apex height
B. Base
C. Frustum height
D. Lateral edges

8-14. What type of development is slow and difficult to draw?

A. Orthographic-perspective
B. Parallel-line
C. Radial-line
D. Triangular

8-15. When using triangular development, to find the true length of the varying oblique lines, what type of diagram is drawn?

A. Block
B. True length
C. Reference
D. Architect scale

8-16. Which of the following items is an example of using triangular development?

A. Rectangular box
B. Straight connections
C. Transition pieces
D. Truncated pyramid

8-17. In drawing an oblique cone, the elements are first drawn in which of the following views?

A. Front
B. Rear
C. Side
D. Top

8-18. Which of the following is the first step in developing a square-to-round transition piece?

A. Establish reference lines
B. Create a true-length diagram
C. Develop the top view
D. Draw a semicircle

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INDEX

APPENDIX I

GLOSSARY

NOTE

When entering a new occupation, you must learn the vocabulary of the trade to understand your fellow workers and to make yourself understood by them. Shipboard life requires that Navy personnel learn a relatively new vocabulary. The reasons for this need are many, but most of them boil down to convenience and safety. Under certain circumstances, a word or a few words mean the exact thing or a certain sequence of actions, making it unnecessary to give a lot of explanatory details. An incorrectly interpreted instruction can cause confusion, breakage of machinery, or even loss of life. Avoid the confusion and avoid the danger by learning the meaning of terms common to the occupation. This glossary is not all-inclusive, but it does contain many terms that every craftsman should know. The terms given in this glossary may have more than one definition; only those definitions as related to drafting are given.

ALIGNED SECTION—A section view in which some internal features are revolved into or out of the plane of the view.

ANALOG—The processing of data by continuously variable values.

ANGLE—A figure formed by two lines or planes extending from, or diverging at, the same point.

APEX—The highest point or peak.

APPLICATION BLOCK—A part of a drawing of a subassembly showing the reference number for the drawing of the assembly or adjacent subassembly.

ARC—A portion of the circumference of a circle.

ARCHITECT'S SCALE—Scale used when dimensions or measurements need to be expressed in feet and inches.

AUXILIARY VIEW—An additional plane of an object, drawn as if viewed from a different location. It is used to show features not visible in the normal projections.

AXIS—The center line running lengthwise through a screw.

AXONOMETRIC PROJECTION—A set of three or more views in which the object appears to be rotated at an angle, so that more than one side is seen.

BAR JOISTS—Light steel joists of open-web construction with a single zigzag bar welded to upper and lower chords at the points of contact. Bar joists are used as floor and roof supports.

BATTER BOARDS—Pairs of horizontal boards nailed to wood stakes adjoining an excavation. Used with strings as a guide to elevation and to outline a proposed building.

BEAM—Any horizontal load-bearing structural member that spans a space and is supported at both ends.

BEARING CAPACITY—The maximum unit pressure that soil or other material can withstand without failure or excessive settlement.

BENCH MARK—A mark made by a surveyor or contractor that is used as a reference point when measuring the elevation or location of other points.

BEND ALLOWANCE—An additional amount of metal used in a bend in metal fabrication.

BILL OF MATERIAL—A list of standard parts or raw materials needed to fabricate an item.

BISECT—To divide into two equal parts.

BLOCK DIAGRAM—A diagram in which the major components of a piece of equipment or a system are represented by squares, rectangles, or other geometric figures, and the normal order of progression of a signal or current flow is represented by lines.

BLUEPRINTS—Copies of mechanical or other types of technical drawings. Although blueprints used to be blue, modern reproduction techniques now permit printing of black-on-white as well as colors.

BORDER LINES—Dark lines defining the inside edge of the margin on a drawing.

BREAK LINES—Lines to reduce the graphic size of an object, generally to conserve paper space. There are two types: the long, thin, ruled line with freehand zigzag and the short, thick, wavy freehand line.

BROKEN-OUT SECTION—Similar to a half section; used when a partial view of an internal feature is sufficient.

CANTILEVER—A horizontal structural member supported only by one end.

CAST—A metal object made by pouring melted metal into a mold.

CENTER LINES—Lines that indicate the center of a circle, arc, or any symmetrical object; consist of alternate long and short dashes evenly spaced.

CHORDS—The basic components of a roof truss are the top and bottom chords and the web members. The top chords serve as roof rafters. The bottom chords act as ceiling joists.

CIRCLE—A closed plane figure having every point on its circumference (perimeter) equidistant from its center.

CIRCUMFERENCE—The length of a line that forms a circle.

CLEVIS—An open-throated fitting for the end of a rod or shaft, having the ends drilled for a bolt or a pin. It provides a hinging effect for flexibility in one plane.

COLUMN—High-strength vertical structural members.

COMPUTER LOGIC—The electrical decision process used by a computer to perform calculations and other functions.

COMPUTER NUMERICAL CONTROL—A process in which a machine is controlled by the input media from a computer to produce machined parts.

COMPUTER-AIDED DRAFTING (CAD)—A process in which engineering drawings are developed using a computer.

COMPUTER-AIDED MANUFACTURING (CAM)—A method by which a computer uses a design to guide a machine that produces parts.

CONE—A solid figure that tapers uniformly from a circular base to a point.

CONSTRUCTION LINES—Lightly drawn lines used in the preliminary layout of a drawing.

CORNER POSTS—Vertical members located at the corners of a timber structure.

CORNICE—The projecting or overhanging structural section of a roof.

CREST—The surface of the thread corresponding to the major diameter of an external thread and the minor diameter of an internal thread.

CUBE—Rectangular solid figure in which all six faces are square.

CUTTING PLANE LINE—A line indicating a plane or planes from which a sectional view is taken.

CYLINDER—A solid figure with two equal circular bases.

DEAD LOAD—A calculation of the weight of a building's structural components, fixtures, and permanently attached equipment, used in designing a building and its foundations.

DEPTH—The distance from the root of a thread to the crest, measured perpendicularly to the axis.

DEVELOPMENT—The process of making a pattern from the dimensions of a drawing, used in fabricating sheet metal objects.

DIGITAL—The processing of data by numerical or discrete units.

DIMENSION LINE—A thin broken line (except in the case of structural drafting) with each end terminating with an arrowhead; used to define the dimensions of an object.

DRAWING NUMBER—An identifying number assigned to a drawing or a series of drawings.

DRAWINGS—The original graphic design from which a blueprint may be made; also called plans.

ELECTROMECHANICAL DRAWING—A special type of drawing combining electrical symbols and mechanical drawing to show the position of equipment that combines electrical and mechanical features.

ELEMENTARY WIRING DIAGRAM—A wiring diagram that shows the electrical connections and functions of a specific circuit arrangement. Elementary wiring diagram is sometimes used interchangeably with schematic diagram, especially for a simplified schematic diagram.

ELEVATION—A drawing showing the front, rear, and sides of a structure, as they would appear projected on vertical planes.

EXPLODED VIEW—A special view of a device that shows the relative location of part. An exploded view can be particularly helpful in assembling complex objects.

EXTERNAL THREAD—A thread on the outside of a member. For example, the thread of a bolt.

FALSEWORK—Temporary supports of timber or steel sometimes required in the erection of difficult or important structures.

FILLET—A concave internal corner of a metal component.

FINISH MARKS—Marks used to indicate the degree of finish to be achieved on surfaces to be machined.

FOOTINGS—Weight-bearing elements at the lower end of a wall used to distribute a load to a wider area of supporting soil.

FORMAT—The general makeup or style of a drawing.

FRENCH CURVE—An instrument used to draw smooth irregular curves.

FRUSTUM—A truncated cone or pyramid in which the plane cutting off the apex is parallel to the base.

FULL SECTION—A sectional view that passes entirely through the object.

GIRDER—A large principal beam of steel, reinforced concrete, wood, or a combination of these, used to support other structural members at isolated points along its length.

GUSSET PLATES—A plate fastened across a joint for reinforcement in wood or steel framework members.

HALF SECTION—A combination of an orthographic projection and a section view to show two halves of a symmetrical object.

HATCHING—Lines that are drawn on the internal surface of sectional views. Hatching is used to define the kind or type of material the section surface consists of.

HELIX—The curve formed on any cylinder by a straight line in a plane that is wrapped around the cylinder with a forward progression.

HIDDEN LINES—Medium, short, dashed lines that indicate the hidden features of the object being drawn.

INTERCONNECTION DIAGRAM—Used to show the cabling between electronic units and to indicate the terminal connections.

INTERNAL THREAD—A thread on the inside of a member. For example, the thread inside a nut.

ISOMETRIC DRAWING—A type of pictorial drawing. See **ISOMETRIC PROJECTION**.

ISOMETRIC PROJECTION—A form of graphical projection, or more specifically, a form of axonometric projection; a method of visually representing three-dimensional objects in two dimensions, in which the three coordinate axes appear equally foreshortened and the angles between any two of them are 120 degrees.

ISOMETRIC WIRING DIAGRAM—A diagram showing the outline of a ship, an aircraft, or other structure, and the location of equipment such as panels and connection boxes and cable runs.

JOIST—A horizontal supporting member that runs from wall to wall, wall to beam, or beam to beam to support a ceiling, roof, or floor.

KEY—A small wedge or rectangular piece of metal inserted in a slot or groove between a shaft and a hub to prevent slippage.

KEYSEAT—A slot or groove into which the key fits.

KEYWAY—A slot or groove within a cylindrical tube or pipe into which a key fitted into a key seat will slide.

LEAD—The distance a screw thread advances in one turn, measured parallel to the axis. On a single-thread screw the lead and the 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.

LEADER LINES—Thin lines used to connect numbers, references, or notes to appropriate surfaces or lines.

LEGEND—A description of any special or unusual marks, symbols, or line connections used in the drawing.

LINTEL—A horizontal beam used in the construction of buildings. It usually supports the masonry above a window or door opening, and is also known as a header.

LOGIC DIAGRAM—A type of schematic diagram using special symbols to show components that perform a logic or information processing function.

MAJOR DIAMETER—The largest diameter of an internal or external thread.

MILITARY STANDARD (MIL-STD)—A formalized set of standards for supplies, equipment, and design work purchased by the United States Armed Forces.

MINOR DIAMETER—The smallest diameter of an internal or external thread.

NOTES—Descriptive writing on a drawing to give verbal instructions or additional information.

OBLIQUE PROJECTION—A view produced when the projectors are at an angle to the plane of the object illustrated. Vertical lines in the view may not have the same scale as horizontal lines.

OFFSET SECTION—A section view of two or more planes in an object to show features that do not lie in the same plane.

ONBOARD PLANS—See **SHIP'S PLANS.**

ORTHOGRAPHIC PROJECTION—A means of representing a three-dimensional object in two dimensions; with multiview orthographic projections, up to six pictures of an object are produced, with each projection plane parallel to one of the coordinate axes of the object.

PARTIAL SECTION—A sectional view consisting of less than a half section, which is used to show the internal structure of a small portion of an object, also known as a broken section.

PERPENDICULAR—The line or view from an object at 90 degrees.

PERSPECTIVE—The visual impression that, as parallel lines project to a greater distance, the lines move closer together.

PHANTOM LINES—Lines showing the alternate position of a movable object.

PHASE—An impulse of alternating current. The number of phases is dependent on the generator windings. Most large generators produce a three-phase current that must be carried on at least three wires.

PICTORIAL DRAWING—A drawing that gives the real appearance of the object, showing general location, function, and appearance of parts and assemblies.

PICTORIAL WIRING DIAGRAM—A diagram showing various parts of a piece of equipment or system and the electrical wiring between the parts.

PIER—A vertical support for a building or structure, usually designed to hold substantial loads.

PILASTERS—Columns built within a wall, usually projecting beyond the wall.

PILLAR—A high-strength vertical structural member.

PITCH—The distance from a point on a screw thread to a corresponding point on the next thread, measured parallel to the axis.

PLAN VIEW—A view of an object or area as it would appear from directly above.

PLANE—A longitudinal section through the axis of an object.

PLOT PLAN—A map or plan view of a lot showing the survey marks, including the bench mark (BM), with the elevations and the grading requirements.

POLARITY—The direction of magnetism or direction of flow of current.

PROJECTION—A technique for showing one or more sides of an object to give the impression of a drawing of a solid object.

PROJECTOR—The theoretical extended line of sight used to create a perspective view or pictorial drawing of an object.

RADIUS—A straight line from the center of a circle or sphere to its circumference or surface.

RAFTER—The horizontal or inclined members that provide support to a roof.

RAFTER PLATES—Horizontal members that support the wall ends of rafters.

REFERENCE DESIGNATION—A combination of letters and numbers to identify parts on electrical and electronic drawings, diagrams, parts lists.

REFERENCE NUMBERS—Numbers used on a drawing to refer the reader to another drawing for more detail or other information.

REMOVED SECTION—A special view to illustrate a particular cross section of an object.

REVISION BLOCK—This block is located in the upper right corner of a print. It provides a space to record any changes made to the original print.

REVOLVED SECTION—A drawing of an object's internal cross section superimposed on the basic drawing of the object.

RIDGE—The lengthwise member at a right angle to the rafters, which supports the peak ends of the rafters in a roof.

RIDGEBOARD—The longitudinal board, set on edge, used to support the upper ends of the rafters, also known as a ridgepole.

ROOT—The area at the bottom of the thread. This area of the thread corresponds to the minor diameter of an external thread and the major diameter of an internal thread.

ROUND—The outside corners of a metal object that have been rounded to prevent chipping and to avoid sharp edges.

SCALE—The relationship between the measurement used on a drawing and the measurement of the actual object. Also a measuring device, such as a ruler, having special graduations.

SCHEMATIC DIAGRAM—A picture of a circuit that uses symbols to represent the components in the circuit.

SECTION—A view showing a clearer view of interior or hidden features of an object that cannot be observed in conventional outside views.

SECTION LINES—Thick solid lines with an arrowhead used to indicate the direction in which a section or plane is viewed or taken.

SECTIONAL VIEWS—Provide important information about the height, materials, fastening and support systems, and concealed features of a structure.

SHIP'S PLANS—A set of drawings that show all of the significant construction features and equipment needed to operate and maintain a ship, also known as onboard plans.

SILL—A horizontal structural member that supports the ends of floor beams or joists in wood frame construction.

SINGLE-LINE DIAGRAM—A diagram using single lines and graphic symbols to show all components in a circuit or system.

SITE PLAN—Shows the contours, boundaries, roads, utilities, trees, structures, and any other significant physical features on or near the construction site.

SOLEPLATE—A horizontal structural member used as a base for studs or columns.

SPECIFICATION—A detailed description or identification describing items so they can be manufactured, assembled, and maintained according to their performance requirements.

SPREAD FOOTINGS—Generally rectangular prisms of concrete, larger in lateral dimensions than the column or wall they support; used to distribute the load of a column or wall to the subgrade.

STATION NUMBERS—Designations of reference lines used to indicate linear positions along a component such as an airframe or a ship's hull.

STEEL PLATE—Flat steel that has a width of greater than 8 inches and a thickness of 1/4 inch or greater.

STUD—The chief vertical structural members in light frame construction, used as part of a wall and for supporting moderate loads.

SUPERSTRUCTURE—The part of a bridge above the beam seats or the spring line of an arch.

SYMBOL—A graphical representation of the component or part shown in a drawing.

TEMPLATE—A piece of thin material used as a true-scale guide or as a model for reproducing various shapes.

TITLE BLOCK—A blocked area in the lower right corner of the print. Provides information to identify the drawing number, name of the part or assembly that it represents, and all information required to identify the part or assembly.

TOLERANCE—The amount that a manufactured part may vary from its specified size.

TOP PLATE—A horizontal member at the top of an outer building wall; used to support a rafter.

TOTAL DEAD LOAD—The total weight of the structure, which gradually increases as the structure rises and remains constant once it is complete.

TOTAL LIVE LOAD—The total weight of movable objects, such as people, furniture, and bridge traffic, the structure happens to be supporting at a particular instant.

TRACING PAPER—High-grade, white, translucent paper that takes pencil well; can be used to make reproductions of drawings.

TRIANGULATION—A technique for making developments of complex sheet metal forms using geometrical constructions to translate dimensions from the drawing to the pattern.

TRUSS—A beam of given strength without intermediate supports. A truss can support a given load over a specific maximum span.

TRUSS—A combination of members, such as beams, bars, and ties, usually arranged in triangular units, that forms a rigid framework for supporting loads over a span.

UTILITY PLAN—A floor plan that shows the layout of heating, electrical, plumbing, or other utility systems.

VERTEX—A corner or a point where lines meet.

VIEW—A drawing of a side or plane of an object as seen from one point.

WIRING (CONNECTION) DIAGRAM—A detailed diagram of each circuit installation showing all of the wiring, connectors, terminal boards, and electrical or electronic components of the circuit.

ZONE NUMBERS—Numbers and letters printed on the borders of maps used to locate a particular point or part on the map.

APPENDIX II

GRAPHIC SYMBOLS FOR HYDRAULIC AND PNEUMATIC SYSTEMS

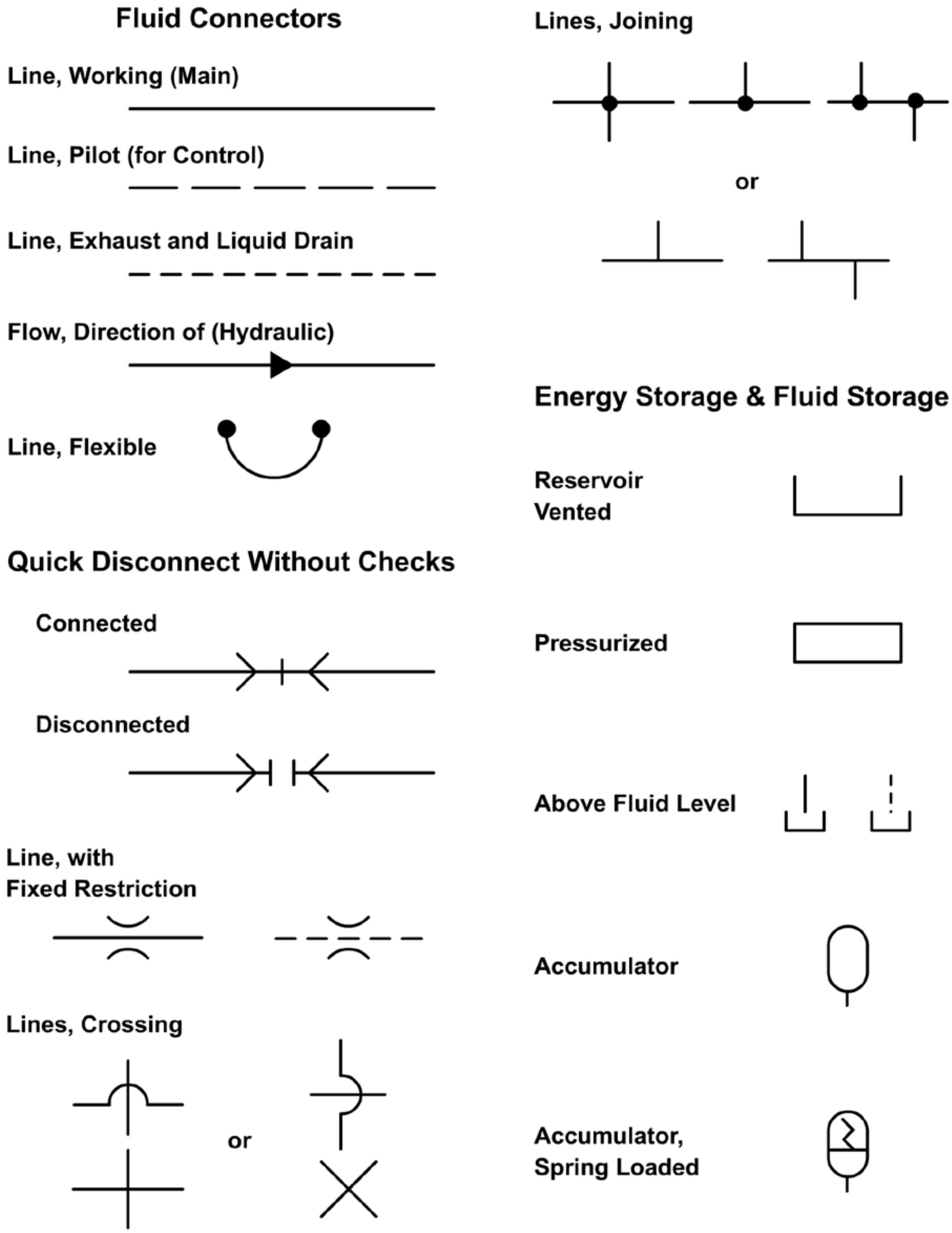


Figure AII-1 — Hydraulic and pneumatic graphic symbols.

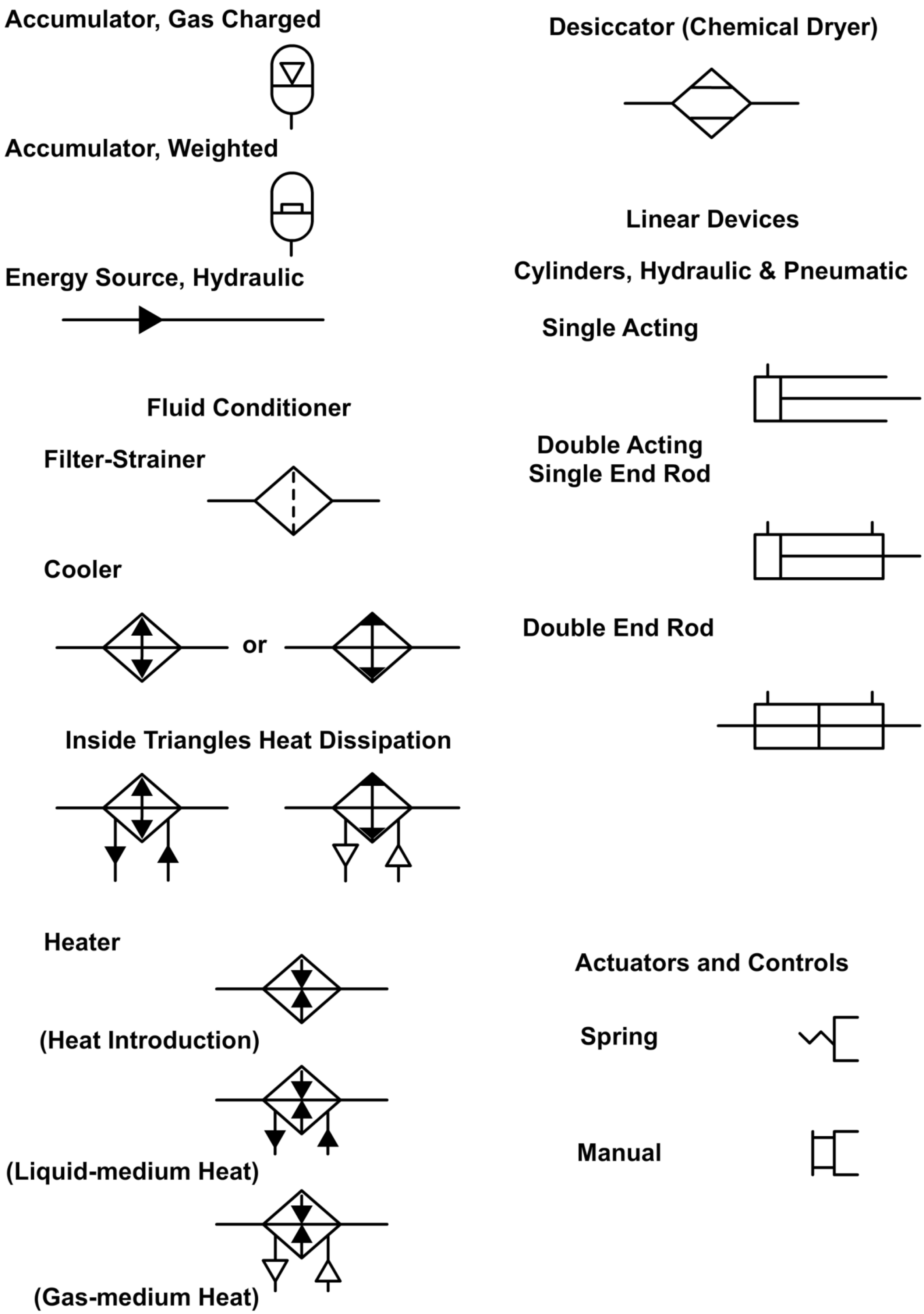
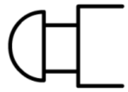
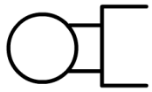


Figure AII-1 — Hydraulic and pneumatic graphic symbols (continued).

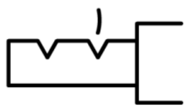
Push Button



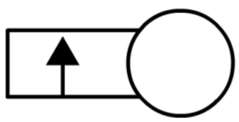
Mechanical



Detent

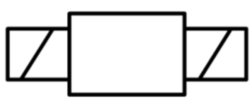


Pressure Compensated



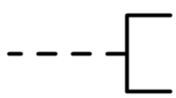
Electrical

Solenoid (Single Winding)

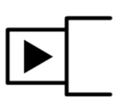


Pilot Pressure

Remote Supply

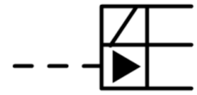


Internal Supply



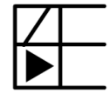
Solenoid or Pilot

External Pilot Supply



Internal Pilot

Supply and Exhaust

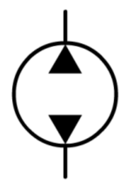


Rotary Devices

Hydraulic Pump

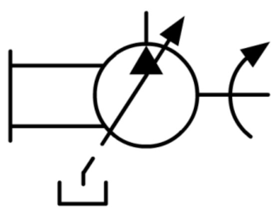
Fixed Displacement
Unidirectional

Bidirectional



Variable Displacement,
Non Compensated

Unidirectional



Bidirectional

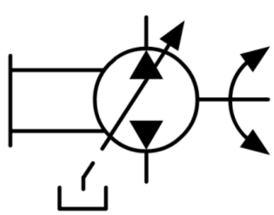


Figure AII-1 — Hydraulic and pneumatic graphic symbols (continued).

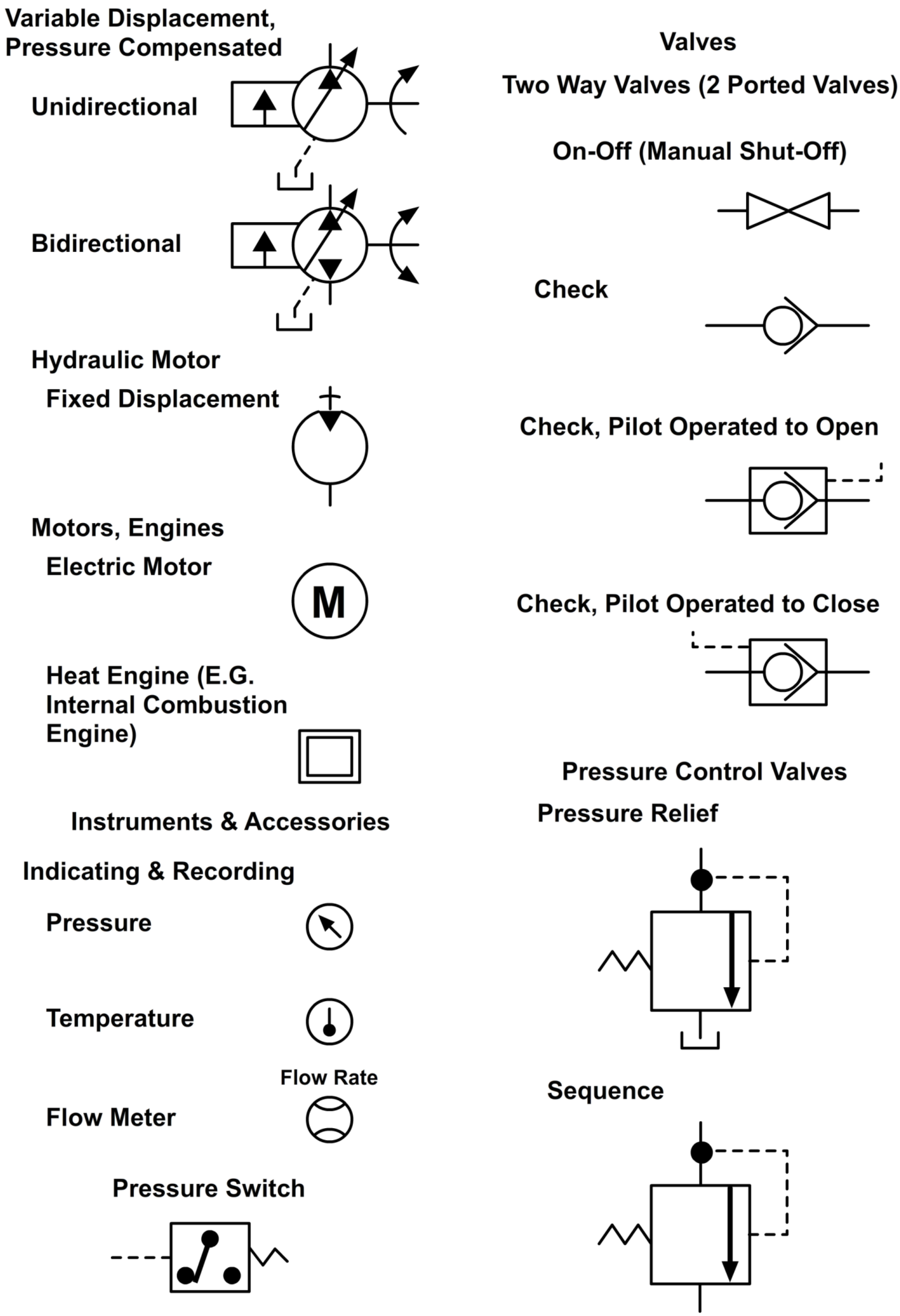


Figure AII-1 — Hydraulic and pneumatic graphic symbols (continued).

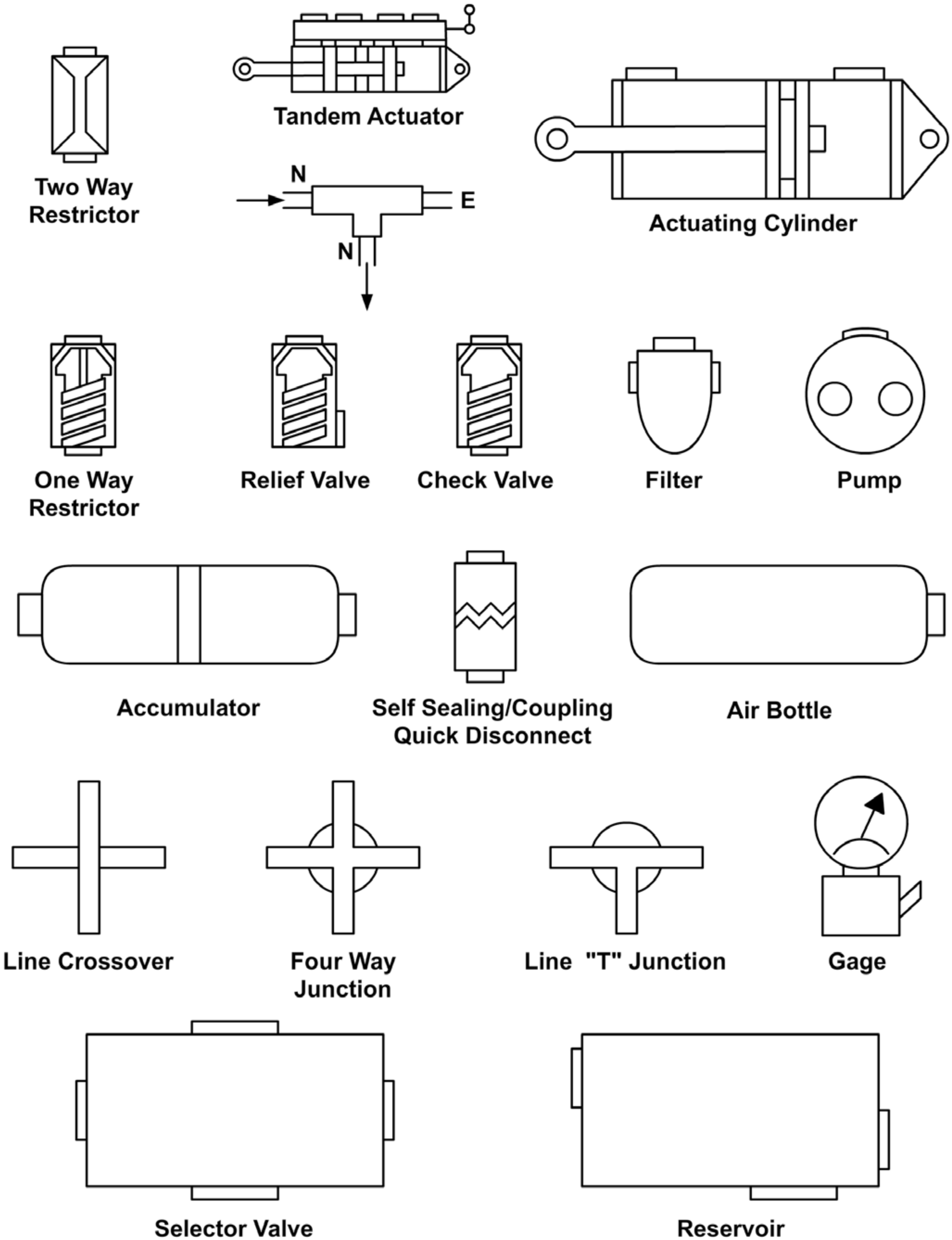
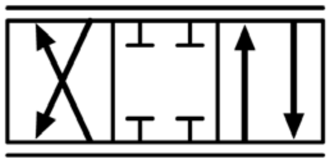


Figure AII-1 — Hydraulic and pneumatic graphic symbols (continued).

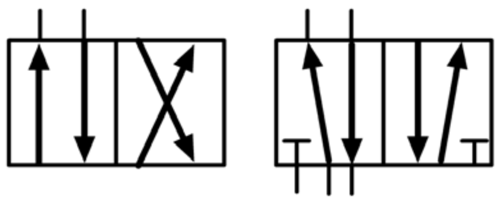
Servovalve, Variable Position
(Indicated by Parallel lines)



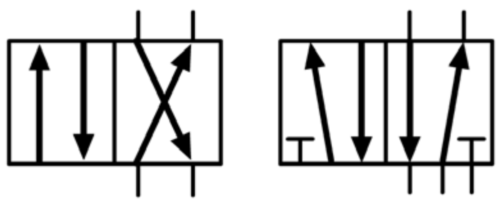
Four Way Valves

Two Position

Normal

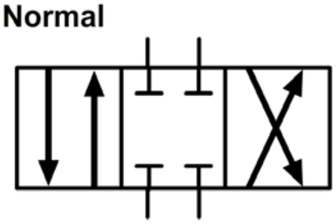


Actuated

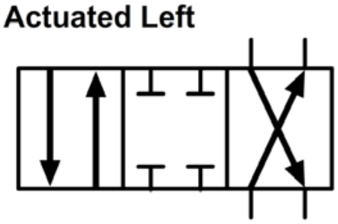


Three Position

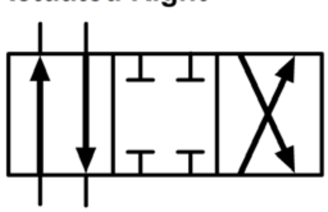
Normal



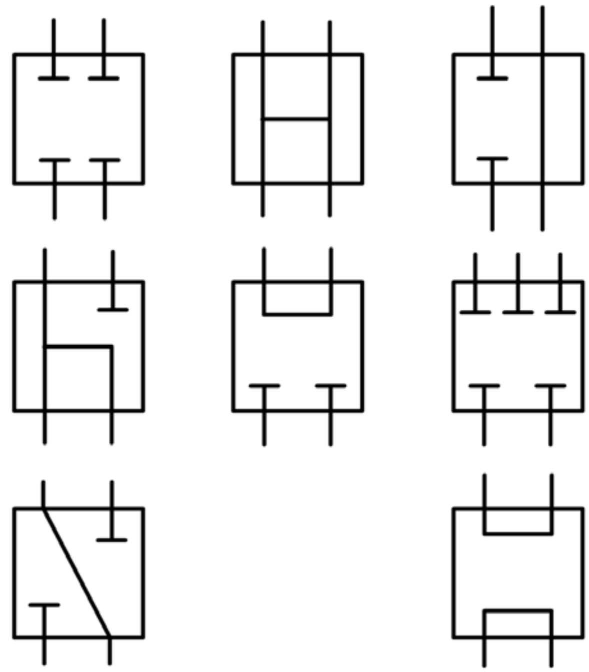
Actuated Left



Actuated Right



Typical Flow Paths for Center Condition of Three Position Valves



Flow Control Valves

Adjustable, Non Compensated
(Flow Control in Each Direction)

Adjustable, Temperature & Pressure Compensated

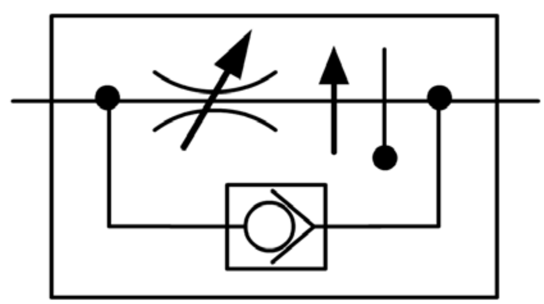


Figure AII-1 — Hydraulic and pneumatic graphic symbols (continued).

APPENDIX III

GRAPHIC SYMBOLS FOR ELECTRICAL AND ELECTRONICS DIAGRAMS

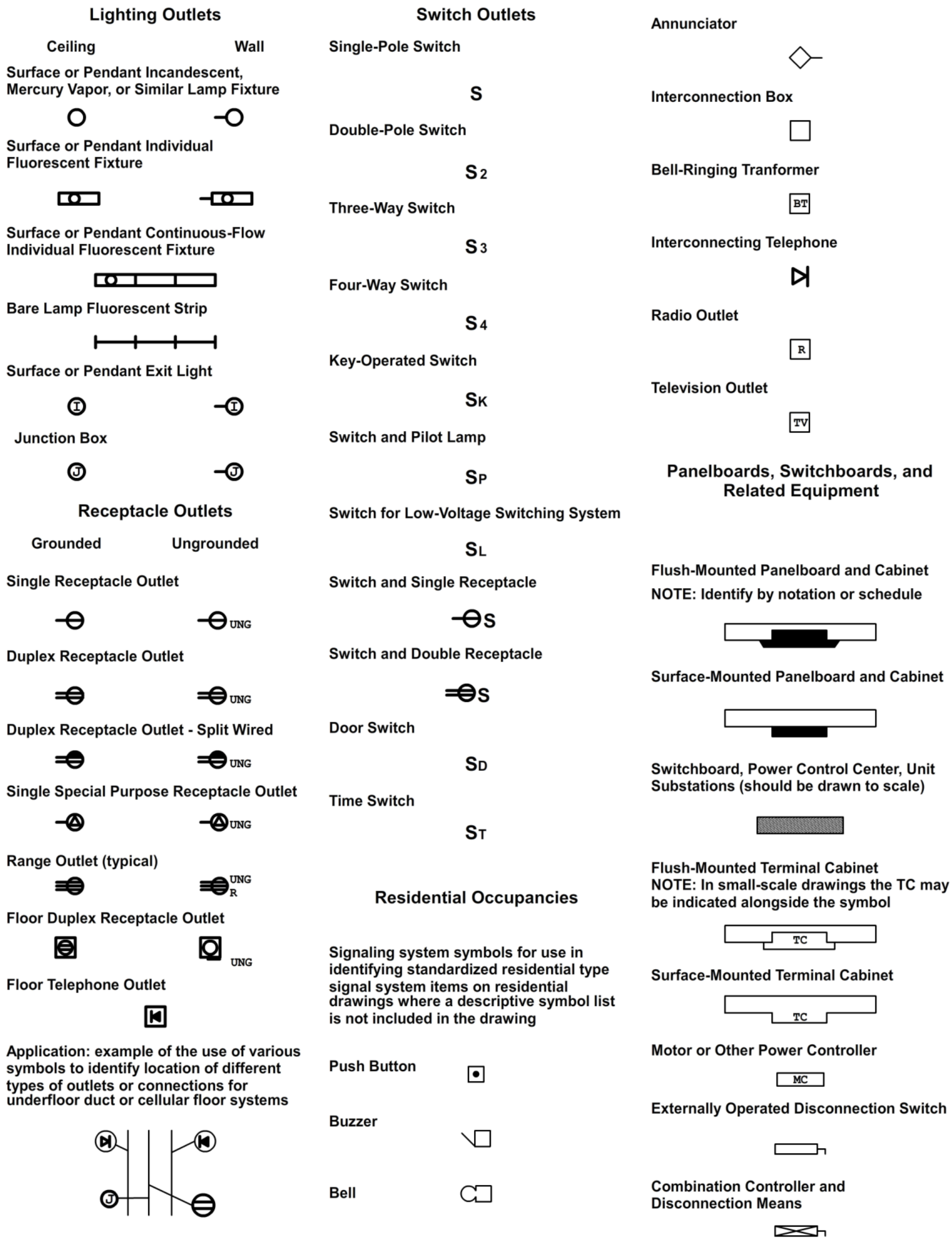
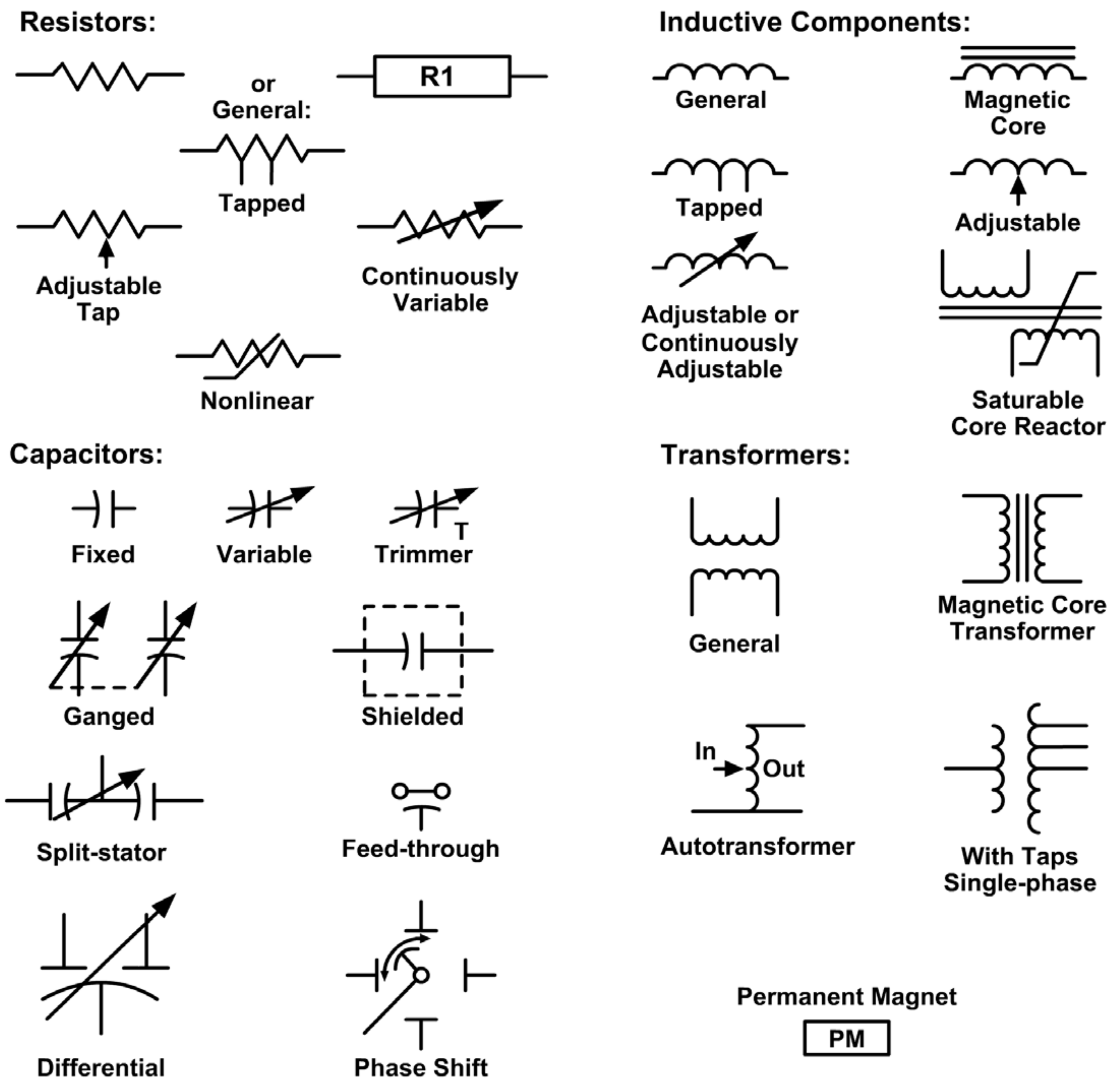


Figure AIII-1 — Electrical and Electronic graphic symbols.

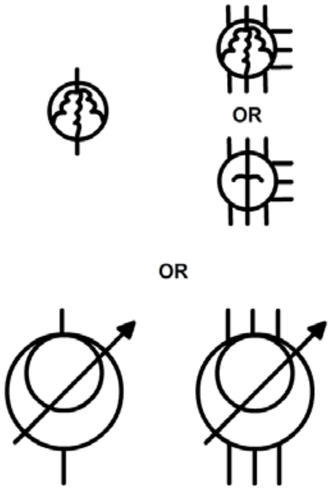


(When Capacitor Electrode Identification Is Necessary, the Curved Element Shall Represent the Outside Electrode Electrode In Fixed Paper-dielectric and Ceramic-dielectric; The Negative Electrode In Electrolytic Capacitors; The Moving Element In Variable and Adjustable Capacitors, and the Low Potential Element In Feed-through Capacitors.)

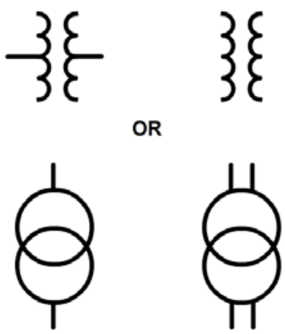
Note: For Further Information Concerning Symbols Refer to IEEE Standards and American National Standard Graphics Symbols For Electrical and Electronics Diagrams, ANSI Y32 2/IEEE No. 315, Which Has Been Adopted For Mandatory Use By the DoD.

Figure AIII-1 — Electrical and Electronic graphic symbols (continued).

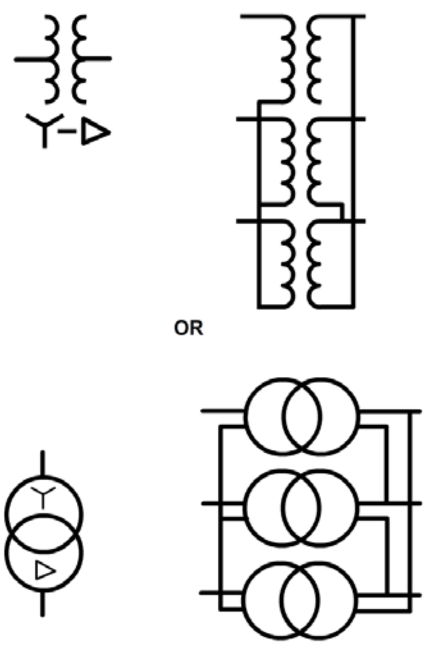
3-phase induction voltage regulator



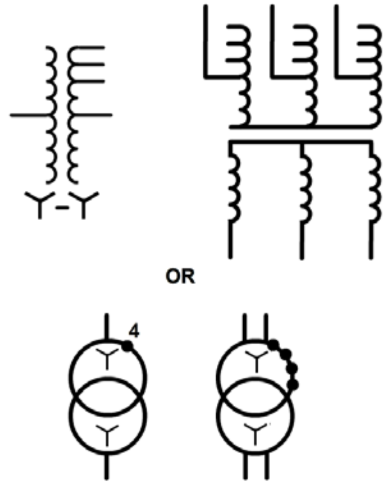
1-phase, 2-winding transformer



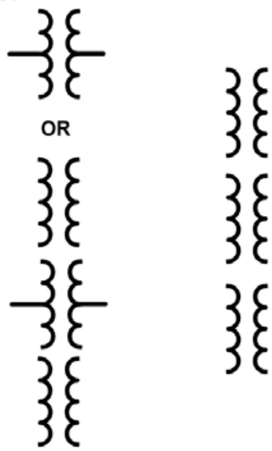
3-phase bank of 1-phase, 2-winding transformers with wye-delta connections



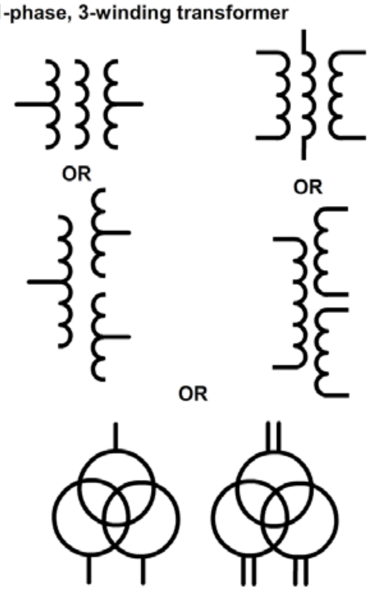
These phases transformer with 4 taps with wye-wye connections



Polyphase transformer

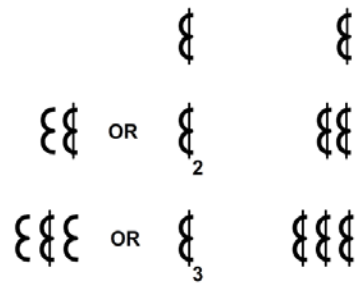


1-phase, 3-winding transformer

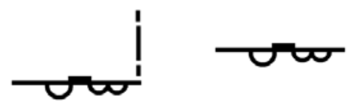


Current transformer(s)

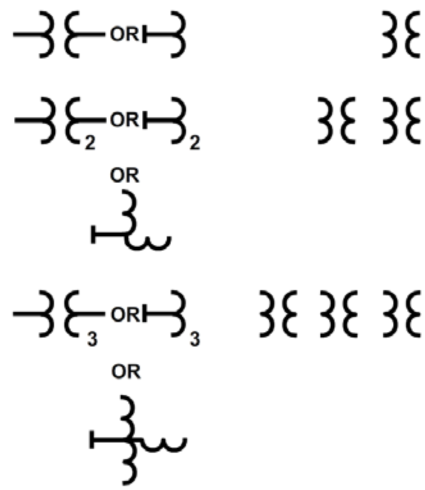
Avoid conflict with symbol for loaded line if used on the same diagram.



Bushing-type current transformer



Potential transformer(s)



Outdoor metering device

SHOW ACTUAL CONNECTION INSIDE BORDER

Graphic Symbols for Circuit Protectors

Fuse (one-time thermal current-over-load device)

General

OR

Figure AIII-1 — Electrical and Electronic graphic symbols (continued).

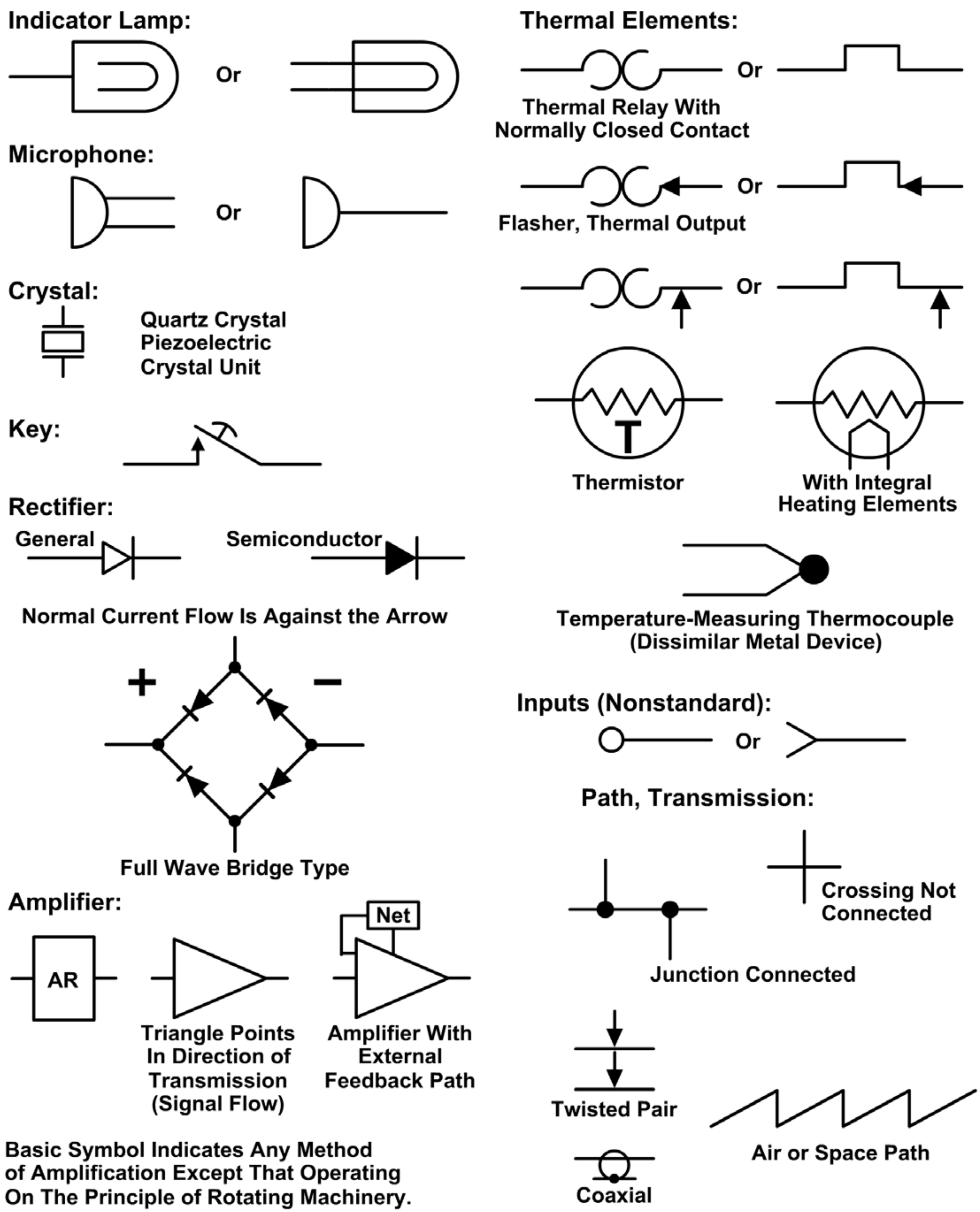


Figure AIII-1 — Electrical and Electronic graphic symbols (continued).

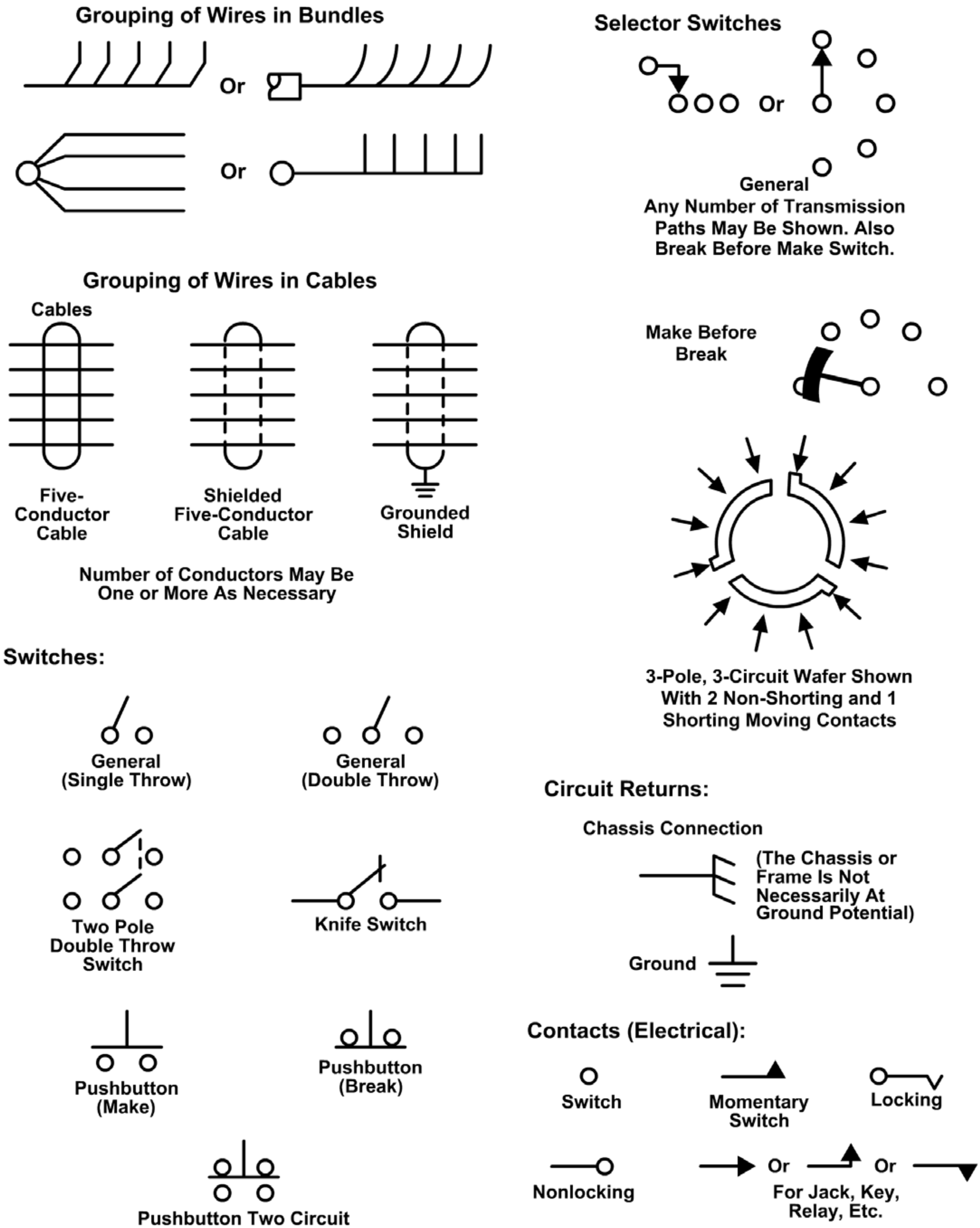


Figure AIII-1 — Electrical and Electronic graphic symbols (continued).

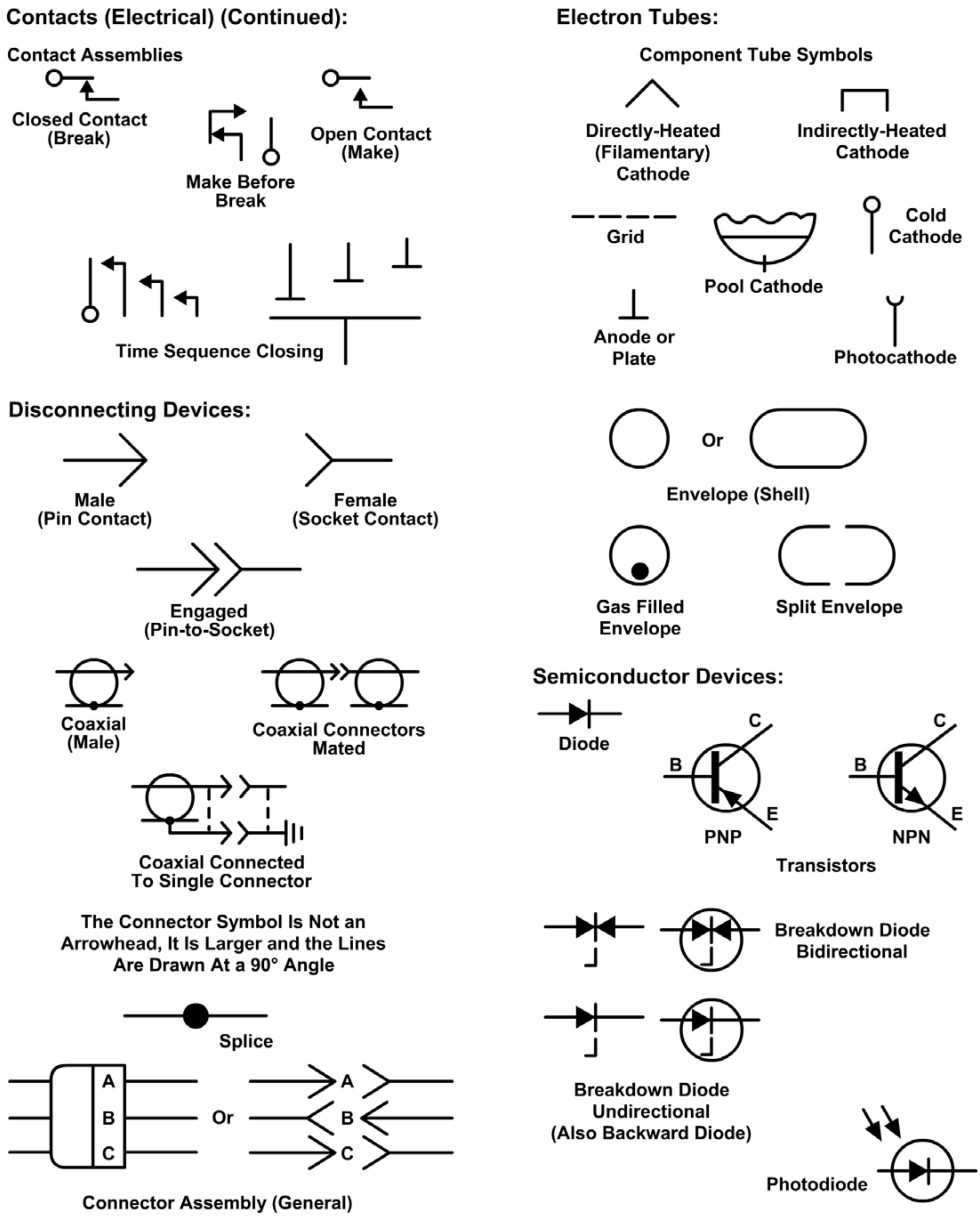


Figure AIII-1 — Electrical and Electronic graphic symbols (continued).

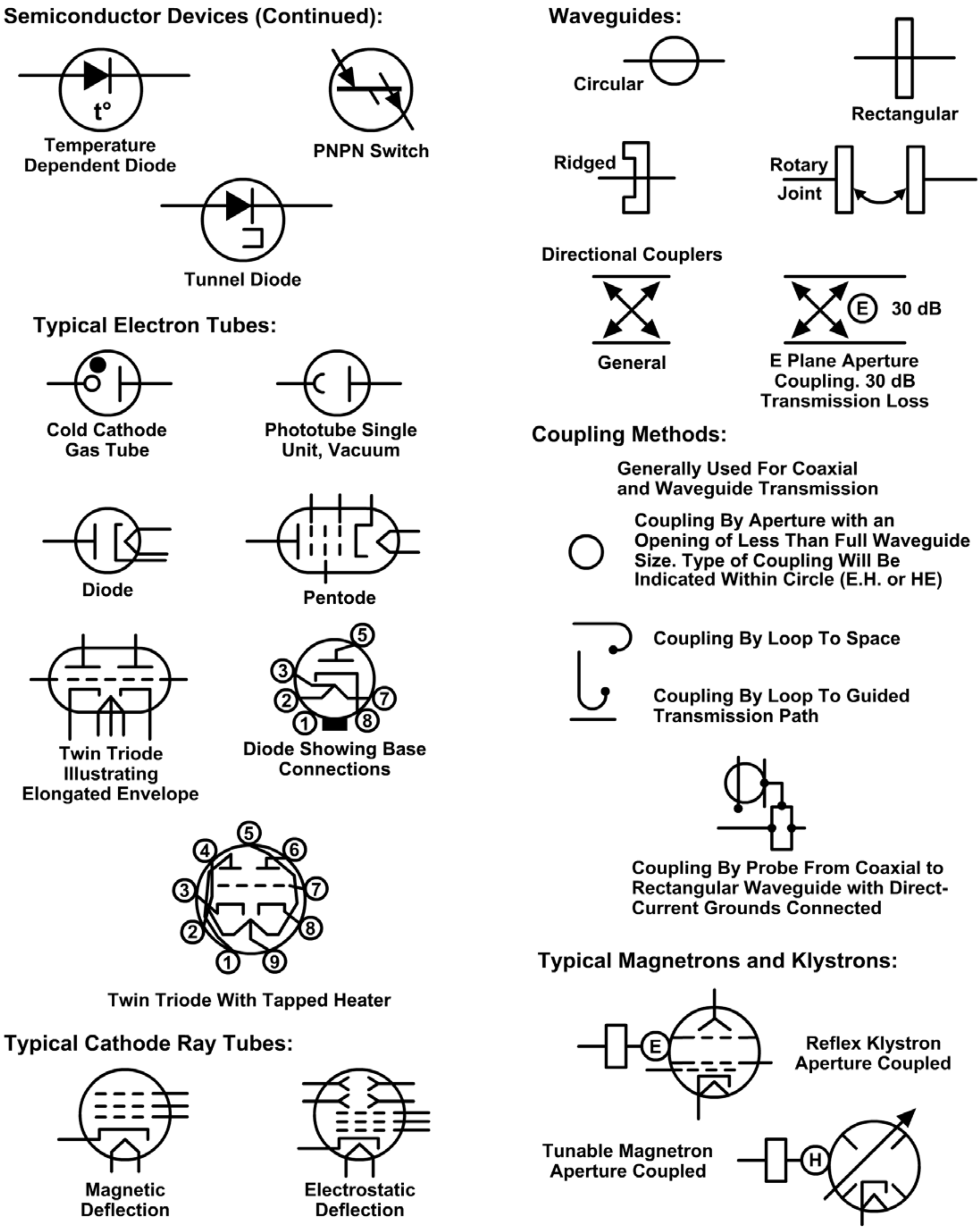


Figure AIII-1 — Electrical and Electronic graphic symbols (continued).

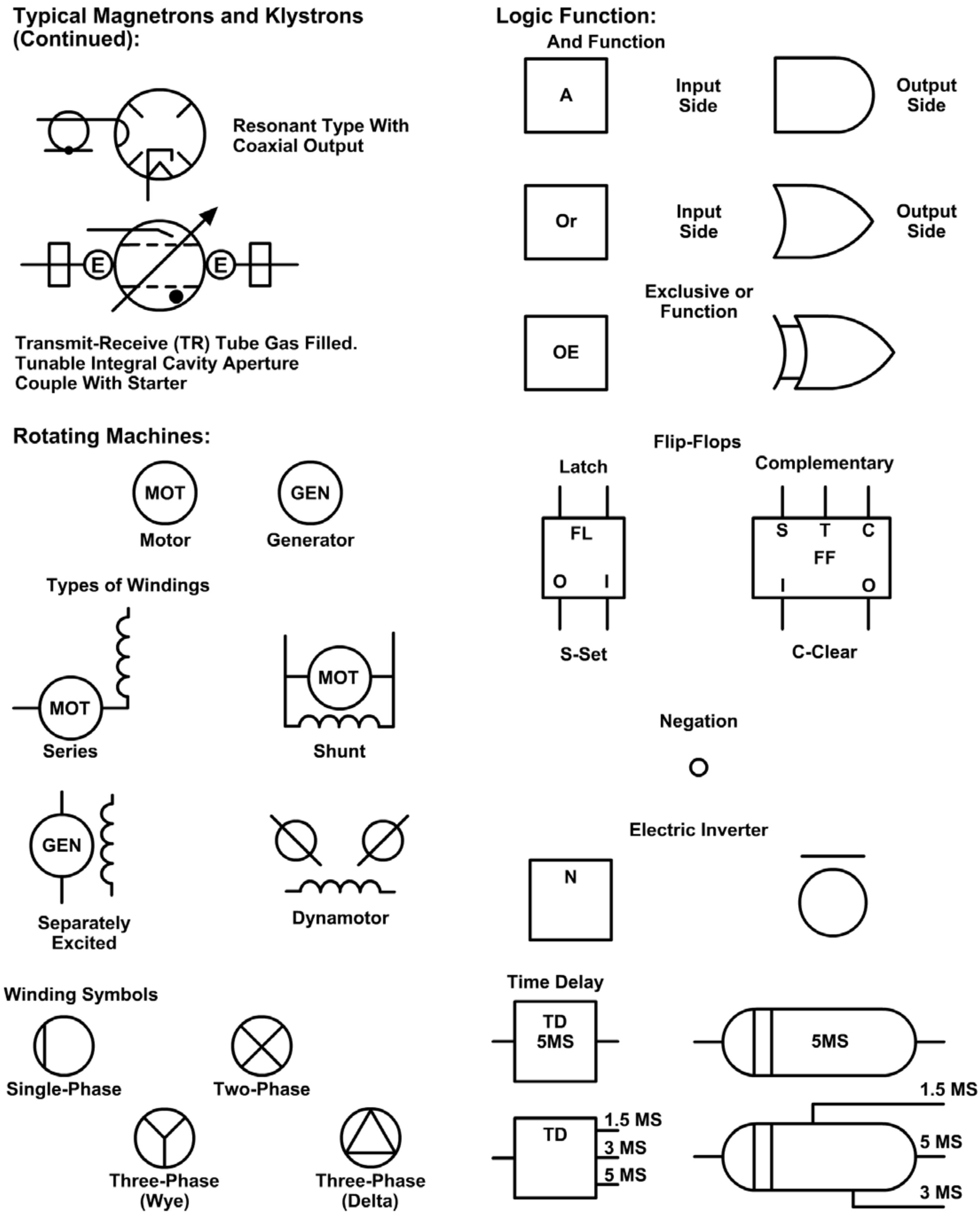


Figure AIII-1 — Electrical and Electronic graphic symbols (continued).

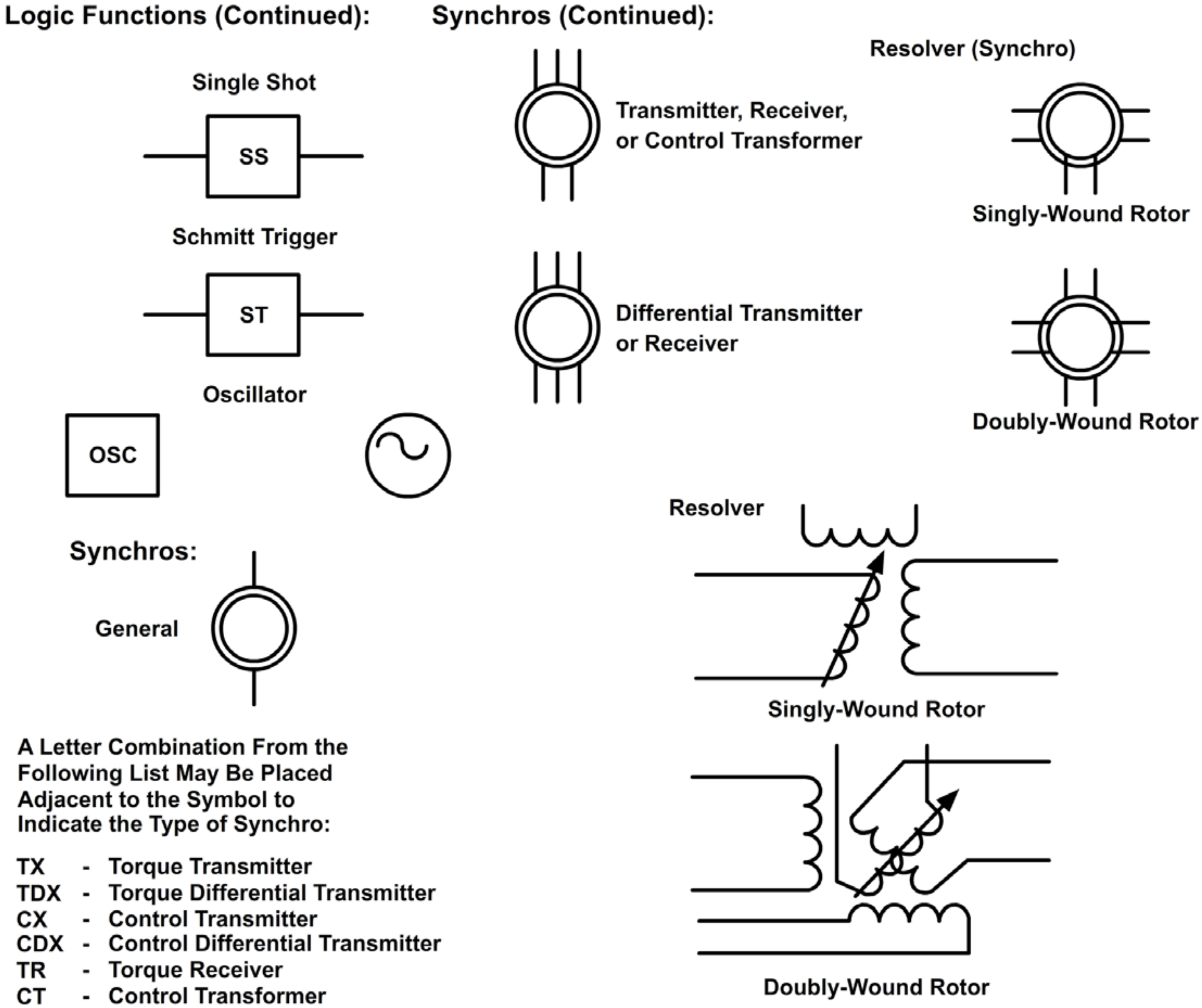


Figure AIII-1 — Electrical and Electronic graphic symbols (continued).

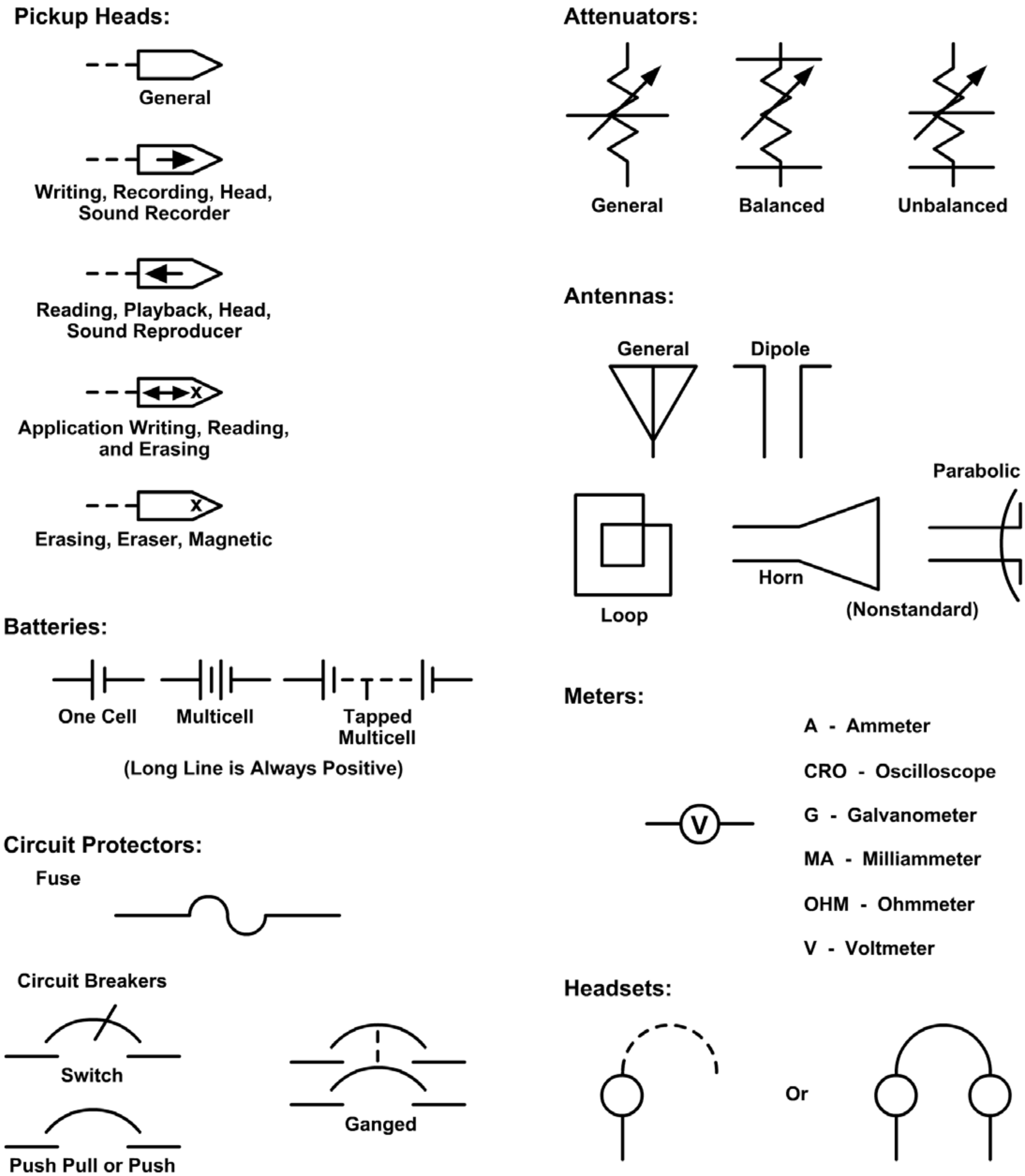


Figure AIII-1 — Electrical and Electronic graphic symbols (continued).

APPENDIX IV

REFERENCES

> **NOTE**
>
> Although the following references were current when this NRTC was published, their continued currency cannot be assured. When consulting these references, keep in mind that they may have been revised to reflect new technology or revised methods, practices, or procedures; therefore, you need to ensure that you are studying the latest references.
>
> If you find an incorrect or obsolete reference, please use the Rate Training Manual User Update Form provided at the end of each chapter to contact the SWOS Rate Training Manager.

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Dimensioning and Tolerancing, ASME Y14.5-2009, The American Society of Mechanical Engineers (ASME), 22 Law Drive, P.O. Box 2900, Fairfield, NJ 07007-2900.

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APPENDIX V

Answers to End of Chapter Questions

Chapter 1 – Blueprints

1-1.	A
1-2.	D
1-3.	D
1-4.	A
1-5.	C
1-6.	A
1-7.	B

1-8.	B
1-9.	D
1-10.	D
1-11.	A
1-12.	B
1-13.	B
1-14.	C

1-15.	C
1-16.	B
1-17.	B
1-18.	C
1-19.	A
1-20.	D

Chapter 2 – Technical Sketching

2-1.	D
2-2.	A
2-3.	A
2-4.	B
2-5.	C
2-6.	D
2-7.	C

2-8.	B
2-9.	A
2-10.	D
2-11.	C
2-12.	A
2-13.	B
2-14.	C

2-15.	D
2-16.	A
2-17.	B
2-18.	C
2-19.	C
2-20.	D
2-21.	B

Chapter 3 – Projections and Views

3-1.	B
3-2.	D
3-3.	D
3-4.	C
3-5.	C

3-6.	A
3-7.	A
3-8.	B
3-9.	C
3-10.	A

3-11.	C
3-12.	D
3-13.	C
3-14.	B
3-15.	A

Chapter 4 – Machine Drawing

4-1.	D
4-2.	B
4-3.	A
4-4.	A
4-5.	D
4-6.	A
4-7.	C
4-8.	B
4-9.	D

4-10.	B
4-11.	A
4-12.	A
4-13.	C
4-14.	A
4-15.	D
4-16.	A
4-17.	C
4-18.	C

4-19.	D
4-20.	B
4-21.	D
4-22.	C
4-23.	A
4-24.	D
4-25.	C

Chapter 5 – Piping Systems

5-1.	D
5-2.	B
5-3.	B
5-4.	A
5-5.	B

5-6.	B
5-7.	D
5-8.	C
5-9.	A
5-10.	C

5-11.	A
5-12.	D
5-13.	D
5-14.	A
5-15.	A

Chapter 6 – Electrical and Electronic Prints

6-1.	B
6-2.	A
6-3.	C
6-4.	D
6-5.	C
6-6.	D

6-7.	C
6-8.	B
6-9.	A
6-10.	B
6-11.	A
6-12.	B

6-13.	D
6-14.	A
6-15.	D
6-16.	C
6-17.	B
6-18.	C

Chapter 7 – Structural and Architectural Drawings

7-1.	C
7-2.	D
7-3.	D
7-4.	A
7-5.	B
7-6.	C
7-7.	D
7-8.	B
7-9.	C

7-10.	C
7-11.	A
7-12.	A
7-13.	D
7-14.	D
7-15.	A
7-16.	B
7-17.	A
7-18.	C

7-19.	B
7-20.	B
7-21.	D
7-22.	A
7-23.	C
7-24.	B
7-25.	A

Chapter 8 – Developments and Intersections

8-1.	C
8-2.	C
8-3.	B
8-4.	B
8-5.	D
8-6.	A

8-7.	A
8-8.	B
8-9.	C
8-10.	C
8-11.	C
8-12.	A

8-13.	D
8-14.	D
8-15.	B
8-16.	C
8-17.	D
8-18.	A

End of Book Questions Chapter 1

Blueprints

1-1. What term describes showing the construction details of parts, machines, ships, aircraft, buildings, and so on?

A. Blueprint
B. Design
C. Diagram
D. Schematic

1-2. What copy of the drawing is rarely sent to a shop or site?

A. Architect
B. Customer
C. Machinist
D. Master

1-3. What type of patented paper produces black lines on a white background?

A. BG
B. BM
C. BW
D. RW

1-4. What standard describes engineering drawing practices?

A. ANSI Y32.9
B. ASME Y14.100-2013
C. ASME Y14.38-2007
D. IEEE-315-1975

1-5. What standard describes welded joint designs?

A. ANSI Y32.9
B. ASTM F1000-13
C. MIL-STD-22D
D. MIL-STD-25B

1-6. What standard describes the ship's structural symbols for use on ship drawings?

A. ANSI Y32.9
B. ASTM F1000-13
C. MIL-STD-22D
D. MIL-STD-25B

1-7. What information block contains the drawing number, name of the part or assembly, and all information required to identify the part?

A. Application
B. Bill of material
C. Legend
D. Title

1-8. What number in the title block refers to other blueprints?

A. Drawing
B. Reference
C. Station
D. Zone

1-9. What block on a blueprint shows the size of the drawing compared with the actual size of the part?

A. Application
B. Bill of material
C. Revision
D. Scale

1-10. What block on blueprints identifies directly or by reference the larger unit that contains the part or assembly on the drawing?

A. Application
B. Bill of material
C. Revision
D. Scale

1-11. What indication used on machine drawings shows surfaces to be finished by machining?

A. Finish marks
B. Note
C. Specification
D. Symbol

1-12. What type of information describes items so they can be manufactured, assembled, and maintained according to their performance requirements?

A. Finish marks
B. Note
C. Specification
D. Symbol

1-13. What line characteristic is used to indicate visible edges of an object?

A. Center lines
B. Dimension lines
C. Leader lines
D. Visible lines

1-14. What line characteristic is used to indicate distance measured?

A. Center lines
B. Dimension lines
C. Leader lines
D. Visible lines

1-15. What type of plan illustrates design features of the ship subject to development?

A. Contract guidance
B. Contract
C. Onboard
D. Working

1-16. What type of plan is considered necessary as reference materials in the operation of a ship?

A. Contract guidance
B. Contract
C. Onboard
D. Working

1-17. In the current and earlier shipboard plan, what block number indicates the size of the plan?

A. 1
B. 2
C. 3
D. 4

1-18. In the current and earlier shipboard plan, what block number indicates the version of the plan?

A. 2
B. 3
C. 4
D. 5

1-19. On tenders and repair ships, what personnel file and maintain the plans?

A. Supply
B. Operations
C. Engineering log room
D. Technical library

1-20. What action occurs if the prints become wet or smudged with oil or grease?

A. Prints will fade
B. Prints will wrinkle
C. Prints will become unreadable
D. White lines will become brighter

End of Book Questions Chapter 2

Technical Sketching

2-1. Which of the following codes identifies the hardest grade of pencil lead?

A. 9H
B. 5H
C. 2H
D. 6B

2-2. What type of eraser is used by artists?

A. Kneaded
B. Pink pearl
C. Plastic
D. Ruby red

2-3. When erasing lines, what sketching instrument prevents erasing other lines?

A. Electric eraser
B. Eraser guide
C. Erasing shield
D. Steel ruler

2-4. What common length, in inches, is the T-square?

A. 18
B. 24
C. 36
D. 72

2-5. How many basic types of drafting triangles are used?

A. 1
B. 2
C. 3
D. 4

2-6. What instrument is used to produce irregular curves?

A. A combination triangle
B. A French curve
C. A protractor
D. A T-square

2-7. What instrument is used to ink small circles with a diameter of less than 1/4 inch?

A. Adjustable compass
B. Drop bow pen
C. Proportional divider
D. Protractor

2-8. What instrument is used to transfer measurements from one scale to another?

A. Beam compass
B. Compass
C. Proportional divider
D. T-square

2-9. Which of the following lines is used to indicate symmetry about an axis of an object?

A. Center
B. Hidden
C. Phantom
D. Stitch

2-10. Which of the following lines is terminated with arrow heads at each end?

A. Break
B. Dimension
C. Extension
D. Leader

2-11. Which of the following lines is used to indicate concealed edges?

A. Center
B. Dimension
C. Hidden
D. Visible

2-12. What type of line indicates a short break?

A. Heavy unbroken line
B. Medium line with evenly spaced dashes
C. Thick, solid freehand zigzags
D. Thin solid line with arrowhead at one end

2-13. What part of a project is often the bottleneck?

A. Approval
B. Drafting
C. Ordering supplies
D. Printing the blueprint

2-14. Which of the following CAD components allows the operator to move from one command to another without the use of the function keys?

A. The computer program
B. The digitizer tablet
C. The plotter
D. The printer

2-15. The drawings from a plotter are high quality, uniform, and what other characteristic?

A. Cheap
B. Precise
C. Sectional
D. Three-dimensional

2-16. Which of the following is an advantage of producing prints on a printer?

A. The print will be in color
B. The print will be in high definition
C. The printer can be stopped and checked for accuracy
D. The speed is faster than on a plotter

2-17. What computer-aided drafting component produces the drawing after it has been completed on the computer screen?

A. The computer numerical control computer
B. The digitizer
C. The numerical control machine
D. The plotter

2-18. What is the main advantage of using numerical control machines rather than manually operated machines?

A. They are operated by skilled machinists
B. They can only be operated when an operator is changing the switches
C. They are only used for mass production
D. They allow unerring and rapid positioning movements

2-19. Which of the following best describes direct numerical control?

A. Allows the technician to program the computer to operate various machines used to produce the final print
B. Stores instructions in a central computer memory for direct transfer to one or more machines that will make the part
C. Acts as a central file where all drawings may be stored without having to store a large number of prints
D. Provides more rapid and precise manufacturing of parts

2-20. Which of the following best describes the computer-aided design/computer-aided manufacturing systems used in manufacturing?

A. CAD controls the machine used to make the part; CAM is the drawing medium used to convert instructions to the machine making the part
B. CAD draws the part and defines the tool path; CAM converts the tool path into codes the machine's computer understands
C. CAD is the process in which all instructions are sent to the DNC operating stations; CAM is the receiving station that converts instructions from the CAD to the machine used to make the part
D. CAD uses the input from the engineer to relay design changes to the print; CAM receives those changes and converts them to codes used by the machine that makes the part

2-21. What types of training are required to operate computer-aided drafting and computer-aided manufacturing systems?

A. Specialized and formal
B. Correspondence courses provided by the manufacturer of the system
C. Formal and on-the-job
D. On-the-job training and correspondence courses

End of Book Questions Chapter 3

Projections and Views

3-1. While learning to read a blueprint, you need to develop which of the following abilities?

A. Computer skills
B. Memorization
C. Technical sketching
D. Visualizing

3-2. To understand the object to be made from a blueprint, you should take what step first?

A. Interpret each line on the notes section
B. Look at the front view only
C. Look at the top and right side view only
D. Study all views

3-3. What type of projection is assumed most for technical drawings?

A. Central
B. Parallel
C. Perpendicular
D. Perspective

3-4. Oblique and axonometric projections show which of the following dimensions?

A. Height and width only
B. Length only
C. Width only
D. Height, width, and length

3-5. What term means one-scale?

A. Isometric
B. Oblique
C. Orthographic
D. Trimetric

3-6. Which of the following statements best describes non-isometric lines?

A. Lines that are not parallel to any one of the three legs of the isometric axis
B. Lines that are parallel to each other
C. Lines that form dimensions for isometric views
D. Normal lines in a normal multi-view projection of the object

3-7. What occurs to angles in isometric drawing?

A. All angles appear as 90-degree corners.
B. All angles appear as obtuse angles.
C. The angles appear distorted.
D. The degrees are divided in half prior to drawing.

3-8. What total number of views do complex drawings normally have?

A. Two
B. Four
C. Six
D. Eight

3-9. A three-view drawing is drawn by eliminating which of the following views from the three-view orthographic projection?

A. Right side, bottom, and rear
B. Left side, top, and bottom
C. Left side, rear, and top
D. Left side, bottom, and rear

3-10. Of all three-dimensional, single-plane drawings, what type of drawings look the most natural?

A. Auxiliary
B. Detailed
C. Orthographic
D. Perspective

3-11. What special view is identical to the other half of the object?

A. Exploded
B. Half-section
C. Removed
D. Section

3-12. What special view may be shown by removing the outside surface?

A. Aligned
B. Broken-out
C. Exploded
D. Partial section

3-13. What special view is drawn as if the part were rotated into or out of the cutting plane?

A. Aligned
B. Broken-out
C. Exploded
D. Partial section

3-14. What special view is drawn to show relative location of parts?

A. Aligned
B. Broken-out
C. Exploded
D. Partial section

3-15. A detail drawing includes which of the following characteristics of an object?

A. Delivery date
B. Machine setup
C. Manufacturing steps
D. Tolerance

End of Book Questions Chapter 4

Machine Drawings

4-1. What method of indicating tolerance allows a variation from design specifications in one direction only?

A. Unilateral
B. Bilateral
C. Limited dimension
D. Minimum value

4-2. What letters of the alphabet may NOT be used in a datum reference?

A. A, C, and D
B. F, I, and O
C. I, H, and P
D. I, O, and Q

4-3. In what location are rounds placed to prevent chipping and to avoid sharp edges?

A. Exterior surfaces of all joints
B. Inside corners
C. Interior surfaces of all joints
D. Outside corners

4-4. Which of the following terms describes specially shaped parts that are mated together but still movable?

A. Fillets
B. Rounds
C. Slots and slides
D. Key

4-5. What item is placed in a groove or slot between a shaft and a hub to prevent slippage?

A. Slots and slides
B. Key
C. Keyway
D. Keyseat

4-6. What term defines a slot or groove on the inside of a cylinder, tube, or pipe?

A. Slots and slides
B. Key
C. Keyway
D. Keyseat

4-7. Which of the following thread dimensions shows a 1/4-20 left-hand National Coarse screw with a tolerance or fit of 2?

A. 1/4-20 UNC
B. 1/4-20-RH-UNC
C. 1/4-20 UNC-2 LH
D. 1/4-20

4-8. Classes of threads are different from each other in which of the following characteristics?

A. Specified tolerance and/or allowance
B. Minimum and maximum pitch
C. Major diameter only
D. Major diameter and root clearance

4-9. The thread on the outside of a bolt is an example of what type of thread?

A. Axial
B. Diametral
C. External
D. Internal

4-10. The center line that runs lengthwise through a screw is known by what term?

A. External thread
B. Major diameter
C. Axis
D. Crest

4-11. Which of the following terms describes the area of the thread corresponding to the major diameter of an external thread and minor diameter of the internal thread?

A. Major diameter
B. Axis
C. Crest
D. Root

4-12. The pitch is the distance from a point on a screw thread to what other location?

A. Center point of the screw
B. Corresponding point on the next thread
C. Corresponding point on the opposite side of the screw
D. The root of the thread

4-13. Which of the following terms describes the number of teeth on the gear divided by the pitch diameter?

A. Diametral pitch
B. Root diameter
C. Clearance
D. Whole depth

4-14. Which of the following terms expresses the diametral pitch multiplied by the pitch diameter?

A. Pitch diameter
B. Outside diameter
C. Number of teeth
D. Addendum circle

4-15. The addendum is the height of the tooth between the pitch circle and what other location?

A. Base of the tooth
B. Bottom of the tooth of the mating gear
C. Center of the adjacent tooth
D. Top of the tooth

4-16. The dedendum is the length of the portion of the tooth from the pitch circle to what other location?

A. Base of the tooth
B. Bottom of the tooth of the mating gear
C. Center of the adjacent tooth
D. Top of the tooth

4-17. The outside diameter contains which of the following circles?

A. Addendum
B. Dedendum
C. Pitch
D. Root diameter

4-18. Circular pitch is the distance from center to center of teeth measured along what axis?

A. Addendum circle
B. Diametral pitch
C. Pitch circle
D. Root diameter

4-19. Chordal point is the distance from center to center of teeth measured along what axis?

A. Addendum circle
B. Diametral pitch
C. Pitch circle
D. Root diameter

4-20. The root diameter is the diameter of the gear measured at what location?

A. Across the center of the gear
B. Center of the teeth
C. Root of the teeth
D. Top of the teeth

4-21. Which of the following terms defines the distance from top of the tooth to the bottom, including the clearance?

A. Root diameter
B. Clearance
C. Whole depth
D. Face

4-22. Which of the following terms describes the greatest depth to which a tooth of one gear extends into the tooth space of another gear?

A. Thickness
B. Pitch circle
C. Working depth
D. Rack teeth

4-23. The thickness of the tooth is the width taken at what location?

A. Diameter of the gear
B. Pitch circle of the tooth
C. Root of the tooth
D. Top of the tooth

4-24. The acceptable roughness of a part depends on which of the following requirements?

A. How the part will be used
B. The type of equipment used to make the finish
C. The method used to achieve the desired roughness
D. The designer's personal preference

4-25. What information does the number within the angle of a finish mark symbol provide?

A. The degree of finish
B. The roughness height in thousandths
C. The roughness height in hundred-thousandths
D. The ability to adhere to its mating part

End of Book Questions Chapter 5

Piping Systems

5-1. Piping can be used as which of the following types of structural element?

A. Hand rail
B. Framing
C. Girders
D. Trusses

5-2. What method of drawing is used for complicated piping systems?

A. Isometric
B. Orthographic
C. Topographic
D. View

5-3. What method of drawing is used to show a three-dimensional view of an object in a single plane?

A. Isometric
B. Orthographic
C. Topographic
D. View

5-4. What type of pipe drawing is generally used for catalogs where visual appearance is more important than drawing time?

A. Double-line
B. Projections
C. Schematics
D. Single-line

5-5. On a piping drawing, what marking indicates a permanent connection made by welding or other processes such as gluing or soldering?

A. Diamond
B. Heavy dot
C. Square
D. Triangle

5-6. What information on the drawing describes the type of connection?

A. Reference number
B. Schedule
C. Specification
D. Title block

5-7. What factor determines the piping material to be used?

A. Length of run
B. Purpose of the pipe
C. Quantity of material available
D. When the piping is installed

5-8. When an item is NOT covered in the standards, the responsible activity can design a suitable symbol and provide what information?

A. Approval letter
B. Colored drawing
C. Explanation in a note
D. Reference list

5-9. What standard color is used for flammable materials?

A. Yellow
B. Brown
C. Green
D. Red

5-10. Shipboard piping system fittings may be drawn in which of the following types of arrangements?

A. Orthographic
B. Pictorial
C. Topographic
D. View

5-11. What hydraulic line leads from the pumps to a pressure manifold and from the pressure manifold to the various selector valves?

A. Operating
B. Pressure
C. Return
D. Vent

5-12. What hydraulic line is also called a working line?

A. Operating
B. Pressure
C. Return
D. Vent

5-13. What hydraulic line directs fluid from any portion of the system to a reservoir?

A. Operating
B. Pressure
C. Return
D. Vent

5-14. In a hydraulic diagram, basic symbols are often improved by showing what section of the unit?

A. Bottom portion
B. Cutaway
C. Placement
D. Top portion

5-15. When interpreting piping designations of tees, 45-degree Y-bends, and double-branch elbows, you should read what opening first?

A. Largest
B. Smallest
C. The one facing right
D. The one facing left

End of Book Questions Chapter 6

Electrical and Electronic Prints

6-1. What type of diagram shows the various components without regard to their physical location?

A. Block
B. Isometric
C. Pictorial
D. Schematic

6-2. What diagram has the components drawn in their respective locations?

A. Block
B. Isometric
C. Pictorial
D. Schematic

6-3. What type of diagram is used primarily to present a general description of a system?

A. Block
B. Isometric
C. Pictorial
D. Schematic

6-4. The numbering of shipboard electrical units begins at what compartment?

A. Highest, aft port
B. Highest, aft starboard
C. Lowest, foremost port
D. Lowest, foremost starboard

6-5. The phase and polarity in an alternating current electrical system is designated by what type of marking?

A. Color code
B. System
C. Wire location
D. Wiring size

6-6. The wiring diagram shows the wiring between components and what type of position of the components?

A. Approximate
B. Estimated
C. Exact
D. Relative

6-7. More complicated schematic diagrams can be broken down into what type of diagrams?

A. Block
B. Connection
C. One line
D. Special

6-8. Aircraft circuit wiring diagrams show equipment part numbers, wire numbers, and what other type of information?

A. All terminal strips and plugs
B. Cable maintenance instructions
C. Electrical flow between components
D. Exact location of electrical components

6-9. The aircraft wire marking identifies the circuit the wire or cable belongs to, the gauge size, and what other information?

A. Information that relates the wire to a manufacturer
B. Information that relates the wire to a wiring diagram
C. The number of components in the circuit
D. The number of wires in the wiring bundle

6-10. What part of the aircraft wire and cable identification number identifies the material the wire is made of?

A. Circuit function code
B. Prefix
C. Segment letters
D. Suffix

6-11. In electronic equipment wiring diagrams, all terminals, wired, tube sockets, and capacitors are shown as what in the actual equipment?

A. The actual color
B. The approximate position
C. The relative position
D. They appear

6-12. In the unit numbering system, the electronic systems are broken into which of the following categories?

A. Sets, units, and assemblies
B. Sets, units, and voltages
C. Voltages, amperes, and assemblies
D. Voltages, parts, and subassemblies

6-13. Aircraft electronic detailed block diagrams that contain details of signal paths and wave shapes are usually called what?

A. Electromechanical diagrams
B. Signal flow diagrams
C. Operating diagram
D. Wiring diagrams

6-14. To understand synchros, gyros, and accelerometers adequately, what drawing should be used?

A. Electromechanical diagrams
B. Signal flow diagrams
C. Operating diagram
D. Wiring diagrams

6-15. In computer logics, Boolean algebra is based upon elements having what number of possible stable states?

A. One
B. Two
C. Three
D. Four

6-16. In computer logic, what symbol identifies the OR operation?

A. Addition
B. Division
C. Multiplication
D. Subtraction

6-17. In a logic system, a 1 indicates the presence of a signal corresponding to what type of switch?

A. Broken
B. Closed
C. Open
D. Secured

6-18. The detailed logic diagrams show what type of logic functions of the equipment concerned?

A. High voltages only
B. Input only
C. Output only
D. All

End of Book Questions Chapter 7

Structural and Architectural Drawings

7-1. A building project is divided into what phases?

A. Design and construction
B. Design and production
C. Design, presentation, and construction
D. Presentation, construction, and approval

7-2. Which of the following people will decide the structural load a proposed building will carry?

A. Building inspectors
B. Construction workers
C. Engineers
D. Shop supervisors

7-3. Which of the following symbols is used to identify American standard I-beam?

A. W
B. HP
C. S
D. C

7-4. Which of the following symbols is used to identify a structural tee?

A. WT
B. HP
C. LC
D. CM

7-5. Which of the following symbols is used to identify a plate?

A. BAR
B. HP
C. PL
D. FLAT

7-6. Which of the following structural shapes is the most widely used structural member?

A. C
B. D
C. S
D. W

7-7. Which of the following structural shapes is used in locations where a single flat face without outstanding flanges on one side is required?

A. C
B. D
C. S
D. W

7-8. What component is used to connect other structural members?

A. Girder
B. Plate
C. Tee
D. Truss

7-9. The total weight of all people and movable objects that a structure supports at any one time is what type of load?

A. Cumulative
B. Dead
C. Live
D. Transfer

7-10. In a light frame construction, what term describes the chief vertical structural members?

A. Pier
B. Pillar
C. Rafter
D. Stud

7-11. The basic components of a truss are the top and bottom chords and what other component?

A. Brace
B. Joist
C. Stud
D. Web member

7-12. What organization standardized the welding symbols?

A. American National Standards Institute
B. American Society of Mechanical Engineers
C. American Welding Society
D. Society of Automotive Engineers

7-13. Which of the following steel structural symbols is used to identify a fillet?

A. Circle
B. Rectangle
C. Square
D. Triangle

7-14. Which of the following steel structural symbols is used to identify a plug or slot?

A. Circle
B. Rectangle
C. Square
D. Triangle

7-15. Which of the following steel structural symbols is used to identify a spot or projection?

A. Circle
B. Rectangle
C. Square
D. Triangle

7-16. Blueprints for fabrication and erection of steel structures consist of layout, erection, fabrication and which other type of drawing?

A. General
B. Isometric
C. Perspective
D. Pictorial

7-17. These drawings provide information on the location, alignment, and elevation of the structure and principle parts in relation to the ground at the site.

A. Layout
B. General
C. Fabrication
D. Erection

7-18. The number of these drawings needed depends on the size and nature of the structure and the complexity of the operation.

A. Layout
B. General
C. Fabrication
D. Erection

7-19. These drawings show component parts of the members as well as dimensions and assembly marks.

A. Layout
B. General
C. Fabrication
D. Erection

7-20. These drawings contain approximate weight of heavy pieces and number of pieces.

A. General
B. Fabrication
C. Erection
D. Falsework

7-21. The corner locations relative to reference lines on a plot are shown in which type of plan?

A. Foundation
B. Framing
C. Plot
D. Site

7-22. Survey marks and bench marks with the elevations and grading requirements are shown in which of the following plans?

A. Foundation
B. Framing
C. Plot
D. Site

7-23. Which of the following plans show the lighting systems and any other electrical systems?

A. Elevation
B. Floor
C. Foundation
D. Framing

7-24. A builder decides where to leave openings for heating, electrical, and plumbing systems by using what type of plan?

A. Floor
B. Framing
C. Plot
D. Utility

7-25. Which of the following drawings are classified as typical and specific?

A. Detail
B. Floor
C. General
D. Sectional

End of Book Questions Chapter 8

Developments and Intersections

8-1. A development of an object that will be made of thin metal must include consideration of the developed surfaces, the joining of the edges, and what other characteristic?

A. Exposed edges
B. Quality of metal
C. Type of paint
D. Type of system

8-2. When drawing a grooved seam, the allowance must be how many times the width of the lock?

A. 1
B. 3
C. 5
D. 7

8-3. What axis is used to compute the bend allowance?

A. Negative
B. Neutral
C. Positive
D. Vertical

8-4. Before proceeding with any bend allowance calculations, what minimum allowance must be determined?

A. Leg
B. Mold line
C. Radius
D. Setback

8-5. What term defines a surface that a thin sheet of flexible material can be wrapped smoothly around?

A. Developable
B. Nondevelopable
C. Orthographic
D. Perspective

8-6. What term describes the process that occurs when the true size of each side of the object is known and the sides can be laid out in successive order?

A. Parallel-line development
B. Perspective drawing
C. Radial-line development
D. Triangular development

8-7. What type of instructions may be included in a parallel-line development drawing?

A. Assembly
B. Final inspection
C. Folding
D. Operator

8-8. What type of development is used for a truncated cylinder?

A. Orthographic-perspective
B. Parallel-line
C. Radial-line
D. Triangular

8-9. To avoid considerable waste of material in developing an elbow, the seams are alternately placed how many degrees apart?

A. 45
B. 90
C. 180
D. 270

8-10. Which of the following types of pyramid has lateral edges of unequal length?

A. Isometric
B. Oblique
C. Orthographic
D. Right

8-11. What types of reference lines are necessary in radial-line and parallel-line developments?

A. Dashed
B. Evenly spaced
C. Intersecting
D. Unevenly spaced

8-12. Which of the following is the first step in developing a frustum of a right cone?

A. Develop a perspective view
B. Develop an orthographic view
C. Establish reference lines
D. Establish the apex point

8-13. In a radial-line development of an oblique pyramid, what should be constructed first?

A. Orthographic view
B. Perspective view
C. The development
D. True-length diagram

8-14. What type of development is practical for many types of figures?

A. Orthographic-perspective
B. Parallel-line
C. Radial-line
D. Triangular

8-15. Transition pieces will usually fit the definition of a non-developable surface that must be developed by what means?

A. Approximation
B. Calculations
C. Imagination
D. Precise measurements

8-16. An oblique cone is generally developed by what method?

A. Orthographic-perspective
B. Parallel-line
C. Radial-line
D. Triangular

8-17. In a triangular development, at what location in relation to the front view is the true length drawing placed?

A. Adjacent
B. Behind
C. Diagonally
D. On top

8-18. For drawing a rectangular-to-round transition piece, what number of true length diagrams are drawn?

A. 1
B. 2
C. 3
D. 4