NONRESIDENT
TRAINING
COURSE

May 1994

Blueprint Reading and Sketching

NAVEDTRA 14040

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Although the words “he,” “him,” and “his” are used sparingly in this course to enhance communication, they are not intended to be gender driven or to affront or discriminate against anyone.

COMMANDING OFFICER
NETPDTC
6490 SAUFLEY FIELD RD
PENSACOLA, FL 32509-5237

ERRATA #1 19 Oct 1998

Specific Instructions and Errata for
Nonresident Training Course

BLUEPRINT READING AND SKETCHING

1. No attempt has been made to issue corrections for errors in typing, punctuation, etc., that do not affect your ability to answer the question or questions.

2. To receive credit for deleted questions, show this errata to your local course administrator (ESO/scorer). The local course administrator is directed to correct the course and the answer key by indicating the question deleted.

3. Assignment Booklet

Delete the following questions, and leave the corresponding spaces blank on the answer sheets:

Questions

1-21
1-22
2-48
3-28
4-21
4-34
4-62

PREFACE

By enrolling in this self-study course, you have demonstrated a desire to improve yourself and the Navy. Remember, however, this self-study course 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.

COURSE OVERVIEW: Upon completing this nonresident training course, you should understand the basics of blueprint reading including projections and views, technical sketching, and the use of blueprints in the construction of machines, piping, electrical and electronic systems, architecture, structural steel, and sheet metal.

THE COURSE: This self-study course 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, which are listed in the *Manual of Navy Enlisted Manpower Personnel Classifications and Occupational Standards*, NAVPERS 18068.

THE QUESTIONS: The questions that appear in this course are designed to help you understand the material in the text.

VALUE: In completing this course, 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.

1994 Edition Prepared by
MMC(SW) D. S. Gunderson

Published by
NAVAL EDUCATION AND TRAINING
PROFESSIONAL DEVELOPMENT
AND TECHNOLOGY CENTER

NAVSUP Logistics Tracking Number
0504-LP-026-7150

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."

CONTENTS

INSTRUCTIONS FOR TAKING THE COURSE

ASSIGNMENTS

The text pages that you are to study are listed at the beginning of each assignment. Study these pages carefully before attempting to answer the questions. Pay close attention to tables and illustrations and read the learning objectives. The learning objectives state what you should be able to do after studying the material. Answering the questions correctly helps you accomplish the objectives.

SELECTING YOUR ANSWERS

Read each question carefully, then select the BEST answer. You may refer freely to the text. The answers must be the result of your own work and decisions. You are prohibited from referring to or copying the answers of others and from giving answers to anyone else taking the course.

SUBMITTING YOUR ASSIGNMENTS

To have your assignments graded, you must be enrolled in the course with the Nonresident Training Course Administration Branch at the Naval Education and Training Professional Development and Technology Center (NETPDTC). Following enrollment, there are two ways of having your assignments graded: (1) use the Internet to submit your assignments as you complete them, or (2) send all the assignments at one time by mail to NETPDTC.

Grading on the Internet: Advantages to Internet grading are:

- you may submit your answers as soon as you complete an assignment, and
- you get your results faster; usually by the next working day (approximately 24 hours).

In addition to receiving grade results for each assignment, you will receive course completion confirmation once you have completed all the assignments. To submit your assignment answers via the Internet, go to:

http://courses.cnet.navy.mil

Grading by Mail: When you submit answer sheets by mail, send all of your assignments at one time. Do NOT submit individual answer sheets for grading. Mail all of your assignments in an envelope, which you either provide yourself or obtain from your nearest Educational Services Officer (ESO). Submit answer sheets to:

COMMANDING OFFICER
NETPDTC N331
6490 SAUFLEY FIELD ROAD
PENSACOLA FL 32559-5000

Answer Sheets: All courses include one “scannable” answer sheet for each assignment. These answer sheets are preprinted with your SSN, name, assignment number, and course number. Explanations for completing the answer sheets are on the answer sheet.

Do not use answer sheet reproductions: Use only the original answer sheets that we provide—reproductions will not work with our scanning equipment and cannot be processed.

Follow the instructions for marking your answers on the answer sheet. Be sure that blocks 1, 2, and 3 are filled in correctly. This information is necessary for your course to be properly processed and for you to receive credit for your work.

COMPLETION TIME

Courses must be completed within 12 months from the date of enrollment. This includes time required to resubmit failed assignments.

PASS/FAIL ASSIGNMENT PROCEDURES

If your overall course score is 3.2 or higher, you will pass the course and will not be required to resubmit assignments. Once your assignments have been graded you will receive course completion confirmation.

If you receive less than a 3.2 on any assignment and your overall course score is below 3.2, you will be given the opportunity to resubmit failed assignments. **You may resubmit failed assignments only once.** Internet students will receive notification when they have failed an assignment--they may then resubmit failed assignments on the web site. Internet students may view and print results for failed assignments from the web site. Students who submit by mail will receive a failing result letter and a new answer sheet for resubmission of each failed assignment.

COMPLETION CONFIRMATION

After successfully completing this course, you will receive a letter of completion.

ERRATA

Errata are used to correct minor errors or delete obsolete information in a course. Errata may also be used to provide instructions to the student. If a course has an errata, it will be included as the first page(s) after the front cover. Errata for all courses can be accessed and viewed/downloaded at:

http://www.advancement.cnet.navy.mil

STUDENT FEEDBACK QUESTIONS

We value your suggestions, questions, and criticisms on our courses. If you would like to communicate with us regarding this course, we encourage you, if possible, to use e-mail. If you write or fax, please use a copy of the Student Comment form that follows this page.

For subject matter questions:

E-mail: n314.products@cnet.navy.mil
Phone: Comm: (850) 452-1001, Ext. 1826
DSN: 922-1001, Ext. 1826
FAX: (850) 452-1370
(Do not fax answer sheets.)
Address: COMMANDING OFFICER
NETPDTC N314
6490 SAUFLEY FIELD ROAD
PENSACOLA FL 32509-5237

For enrollment, shipping, grading, or completion letter questions

E-mail: fleetservices@cnet.navy.mil
Phone: Toll Free: 877-264-8583
Comm: (850) 452-1511/1181/1859
DSN: 922-1511/1181/1859
FAX: (850) 452-1370
(Do not fax answer sheets.)
Address: COMMANDING OFFICER
NETPDTC N331
6490 SAUFLEY FIELD ROAD
PENSACOLA FL 32559-5000

NAVAL RESERVE RETIREMENT CREDIT

If you are a member of the Naval Reserve, you may earn retirement points for successfully completing this course, if authorized under current directives governing retirement of Naval Reserve personnel. For Naval Reserve retirement, this course is evaluated at 6 points. (Refer to *Administrative Procedures for Naval Reservists on Inactive Duty,* BUPERSINST 1001.39, for more information about retirement points.)

Student Comments

Course Title: *Blueprint Reading and Sketching*

NAVEDTRA: 14040 **Date**: ______

We need some information about you:

Rate/Rank and Name: ______ SSN: ______ Command/Unit ______

Street Address: ______ City: ______ State/FPO: ______ Zip ______

Your comments, suggestions, etc.:

Privacy Act Statement: Under authority of Title 5, USC 301, information regarding your military status is requested in processing your comments and in preparing a reply. This information will not be divulged without written authorization to anyone other than those within DOD for official use in determining performance.

NETPDTC 1550/41 (Rev 4-00

CHAPTER 1

BLUEPRINTS

When you have read and understood this chapter, you should be able to answer the following learning objectives:

- *Describe blueprints and how they are produced.*
- *Identify the information contained in blueprints.*
- *Explain the proper filing of 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.

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 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-STD) and American National Standards Institute (ANSI) standards. The *Department of Defense Index of Specifications and Standards* lists these standards; it is issued on 31 July of each year. The following list contains common MIL-STD and ANSI standards, listed by number and title, that concern engineering drawings and blueprints.

Number	Title
MIL-STD-100A	Engineering Drawing Practices
ANSI Y14.5M-1982	Dimensioning and Tolerancing
MIL-STD-9A	Screw Thread Conventions and Methods of Specifying
ANSI 46.1-1962	Surface Texture
MIL-STD-12C	Abbreviations for Use on Drawings
MIL-STD-14A	Architectural Symbols
ANSI Y32.2	Graphic Symbols for Electrical and Electronic Diagrams
MIL-STD-15	Electrical Wiring Part 2, and Equipment Symbols for Ships and Plans, Part 2
ANSI Y32.9	Electrical Wiring Symbols for Architectural and Electrical Layout Drawings
MIL-STD-16C	Electrical and Electronic Reference Designations
MIL-STD-17B, Part 1	Mechanical Symbols
MIL-STD-17B, Part 2	Mechanical Symbols for Aeronautical, Aerospace craft and Spacecraft use
MIL-STD-18B	Structural Symbols
MIL-STD-21A	Welded-Joint Designs, Armored-Tank Type
MIL-STD-22A	Welded Joint Designs
MIL-STD-25A	Nomenclature and Symbols for Ship Structure

PARTS OF A BLUEPRINT

MIL-STD-100A specifies the size, format, location, and type of information that should be included in military blueprints. These include the information blocks, finish marks, notes, specifications, legends, and symbols you may find on a blueprint, and which are discussed in the following paragraphs.

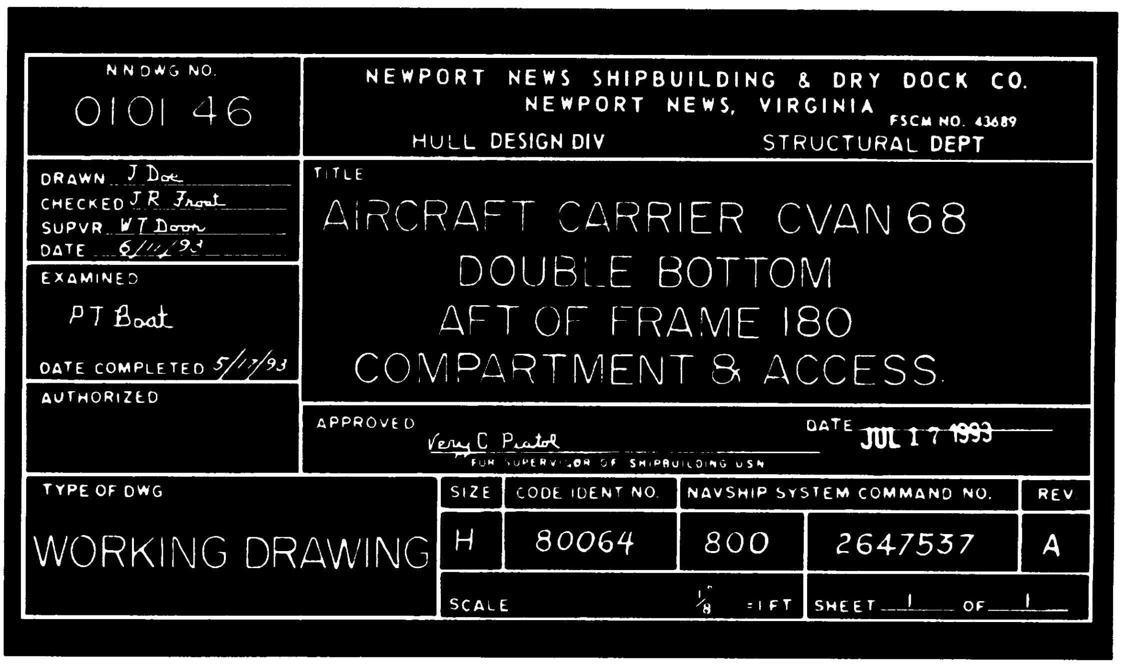
INFORMATION BLOCKS

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

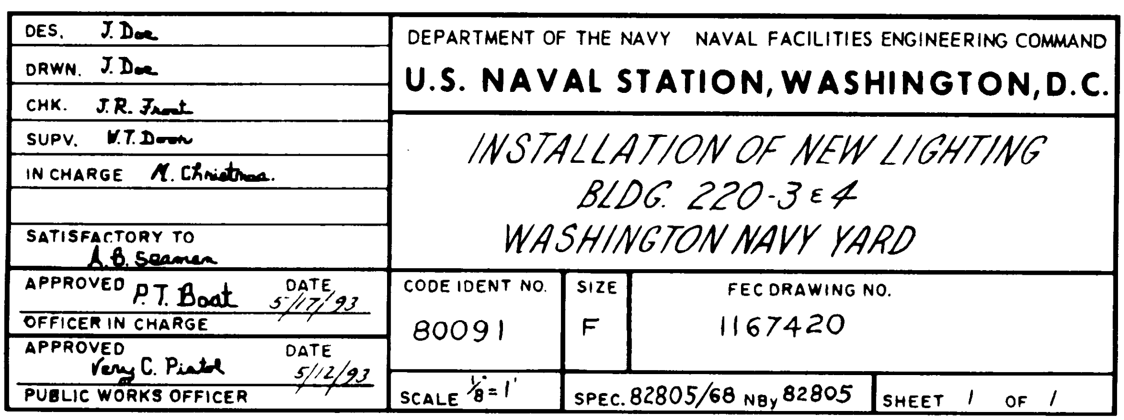
Title Block

The title block 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 govemment agency or organization preparing the drawing,



A



B

Figure 1-1.—Blueprint title blocks. (A) Naval Ship Systems Command; (B) Naval Facilities Engineering Command.

the scale, drafting record, authentication, and date (fig. 1-1).

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.

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

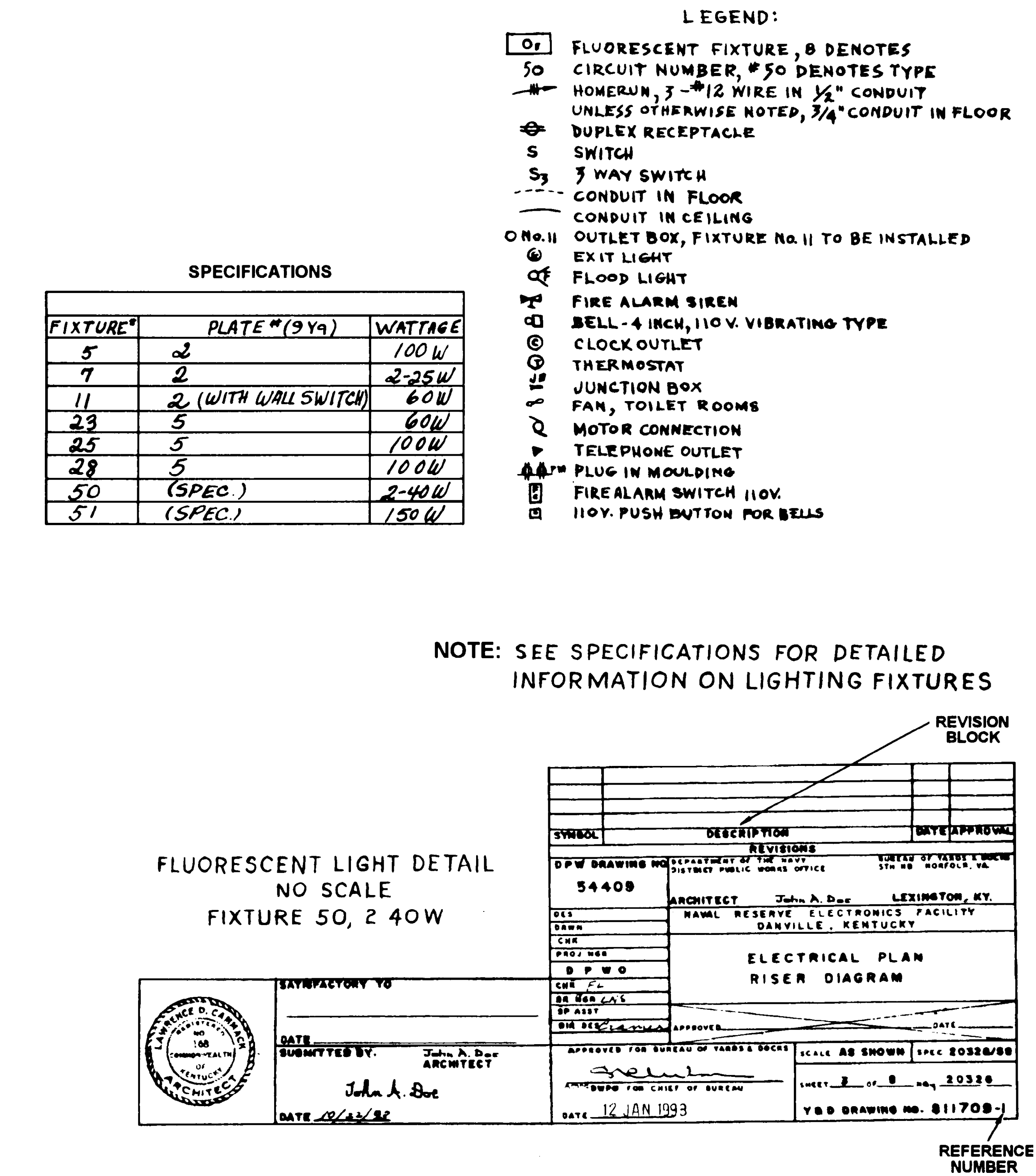


Figure 1-2.—Electrical plan.

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 1-1, view A. When the print is revised, the letter A in the revision block is replaced by the letter B and so forth.

Drawing Number

Each blueprint has a drawing number (fig. 1-1, views A and B), 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, note that the title blocks shown in figure 1-1, show sheet 1 of 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 is the number 811709-1 in the lower right corner of figure 1-2.

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-hand and left-hand parts. Many aircraft parts on the left-hand side of an aircraft are mirror images of the corresponding parts on the right-hand side. The left-hand part is usually shown in the drawing.

On some prints you may see a notation above the title block such as “159674 LH shown; 159674-1 RH opposite.” Both parts carry the same number. LH means left hand, and RH means right hand. Some companies use odd numbers for right-hand parts and even numbers for left-hand 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). Parts numbered in the title block are found by looking up the numbers in squares along the lower border. Read zone numbers from right to left.

Scale Block

The scale block 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. It also may be shown as full size, one-half size, one-fourth size, and so forth. See the examples in figure 1-1, views A and B.

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 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 one 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″ = 1000´ 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 (fig. 1-3). Aircraft drawings use various systems of station markings. For example, the centerline of the

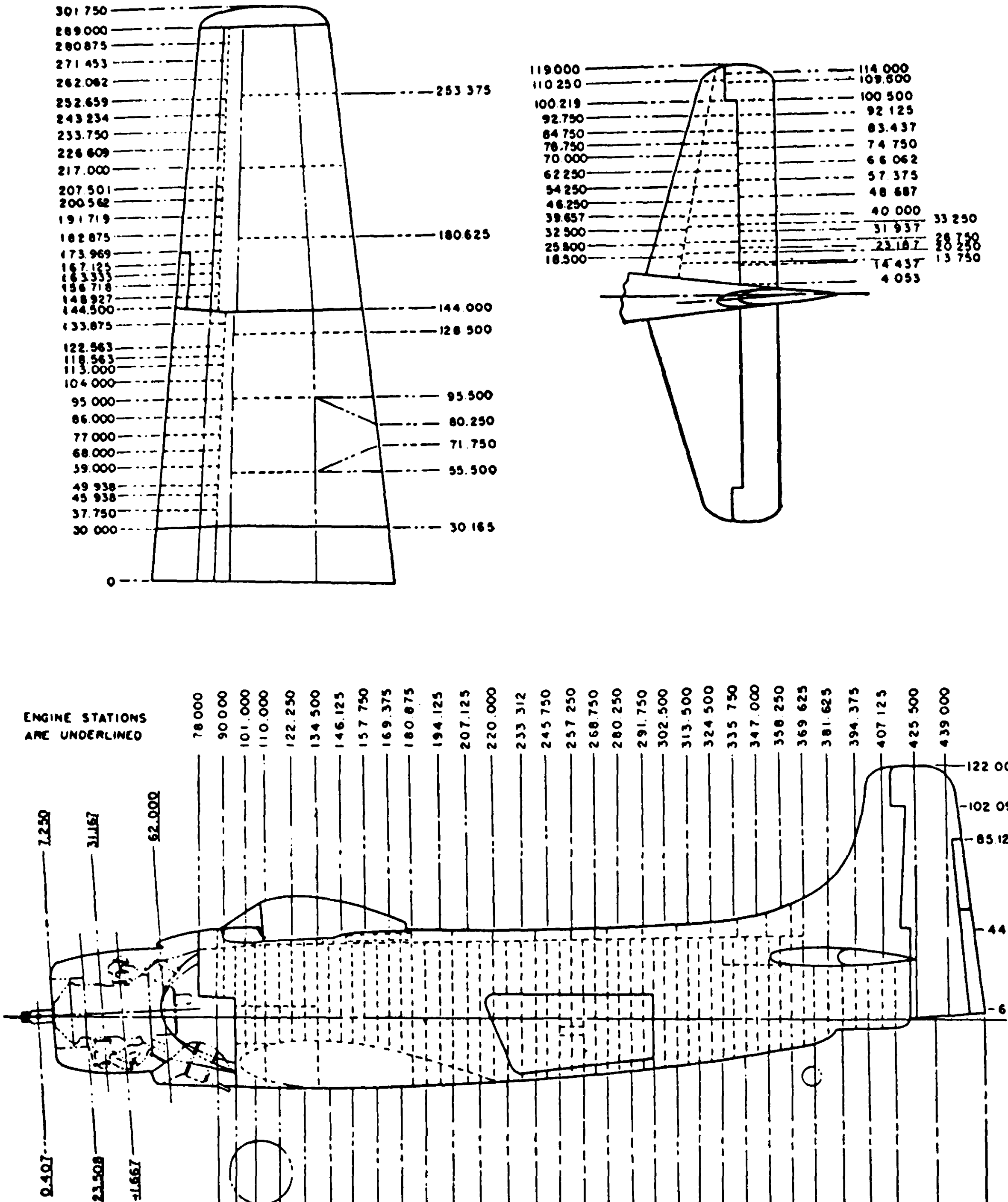


Figure 1-3.—Aircraft stations and frames.

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 centerline 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. Figure 1-3 shows station numbers for a typical aircraft.

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 other 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. Figure 1-4 shows a bill of material for an electrical plan.

Application Block

The application block on a blueprint of a part or assembly (fig. 1-5) identifies directly or by reference the larger unit that contains the part or assembly on the drawing. The NEXT ASS'Y (next assembly) column will contain the drawing number or model

2A	1AB
NEXT ASS'Y	USED ON
APPLICATION	

Figure 1-5.—Application block.

BILL OF MATERIAL					
ITEM NO.	DESCRIPTION	UNIT	ASSEMBLY OR FSN NO.	QUANTITIES	
				TROP	NORTH
3 - 1	LIGHTING CIRCUIT — NAVFAC DWG NO. 283414	EA.	3016	3	3
3 - 2	POWER BUS, 100A — NAVFAC DWG NO 504131	EA	3047	1	1
3 - 3	RECEPTACLE CKT — NAVFAC DWG NO 303668	EA	3019	2	2
3 - 4	BOX, RECEPTACLE W/CLAMP FOR NONMETALLIC SHEATH WIRE	EA	5325-102-604	5	5
3 - 5	LAMP ELECTRIC, MED BASE, INSIDE FROSTED, 200W, 120 V	EA	6240-180-314	60	60
3 - 6	PLUG: ATTACHMENT, 3 WIRE, 15 AMP, 125 V.	EA	5935-102-309	10	10
3 - 7	PLATE BRASS, DUPLEX RECEPTACLE	EA	5325-800-101	5	5
3 - 8	RECEPTACLE, DUPLEX, 3 WIRE, 15 AMP, 125V.	EA	5326-100-102	5	5
3 - 9	ROD, GROUND, 3/4" x 10'-0"	EA	5308-200-180	12	12
3-10	WIRE, NO 2 1/C STRANDED, HARD DRAWN, BARE	LB	6145-134-200	52	52
3-11	SWITCH, SAFETY, 2P, ST 30 AMP, 250 V, PLUG FUSE	EA	5930-142-401	2	2
3-12	CLAMP, GROUND ROD	EA	5209-100-101	15	15
3-13	SWITCH, SAFETY, 200 AMP, 250V, 3P	EA	5930-201-903	1	1
3-14	FUSE, RENEWABLE, 200 AMP, 250 V	EA	5920-100-000	6	6
3-15	LINK, FUSE, 200 AMP, 250 V	EA	5920-100-001	6	6
	FUSE PLUG, 30 AMP, 125V	EA	5920-100-102	12	12

Figure 1-4.—Bill of material.

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 units part.

FINISH MARKS

Finish marks (✓) used on machine drawings show surfaces to be finished by machining (fig. 1-6). 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, and similar coatings.

NOTES AND SPECIFICATIONS

Blueprints show all of the information about an object or part graphically. However, supervisors, contractors, manufacturers, and craftsmen need more information that is not 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 are placed on drawings to give additional information to clarify the object on the blueprint (fig. 1-2). Leader lines show the precise part notated.

A SPECIFICATION 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 blue print or drawing (fig. 1-2). 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. Figure 1-2 shows a legend for an electrical plan.

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, a draftsman arranges the different views in a certain way, and then uses different types of lines to convey information. Figure 1-6 shows the use of standard lines in a simple drawing. Line characteristics

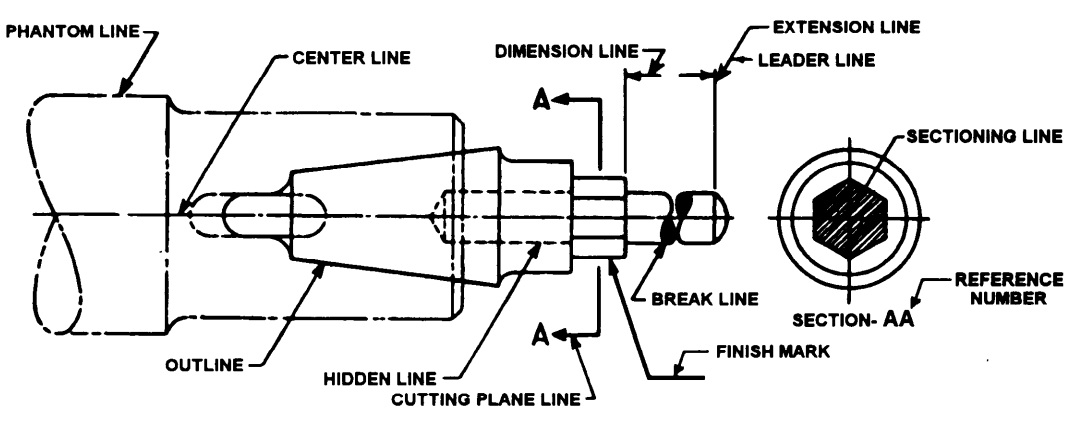


Figure 1-6.—Use of standard lines.

such as width, breaks in the line, and zigzags have meaning, as shown in figure 1-7.

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.

PRELIMINARY PLANS are submitted with bids or other plans before a contract is awarded.

CONTRACT PLANS illustrate mandatory design features of the ship.

CONTRACT GUIDANCE PLANS illustrate design features of the ship subject to development.

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 those the contractor uses to construct the ship.

CORRECTED PLANS are those that have been corrected to illustrate the final ship and system arrangement, fabrication, and installation.

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

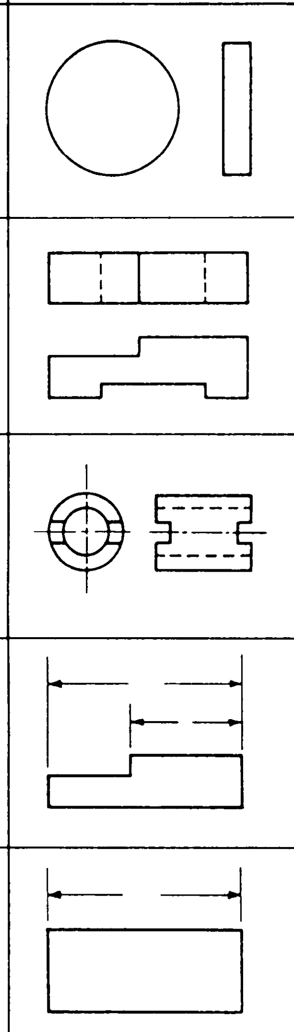


Figure 1-7.—Line characteristics and conventions for MIL-STD drawings.

ONBOARD PLANS are those 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 NAVSHIPS or the supervisor of ship building consider necessary for shipboard reference. The SPI is NOT a check list for the sole purpose of getting a complete set of all plans.

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 9001 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: (1) size, (2) federal supply code identification number, (3 and 4) a system command number in two parts, and (5) a revision letter. The following list explains each part.

1. The letter under the SIZE block in figure 1-1, view A, shows the size of the blueprint according to a table of format sizes in MIL-STD-100.

2. The federal supply code identification number shows the design activity. Figure 1-1, view A, shows an example under the block titled CODE IDENT NO

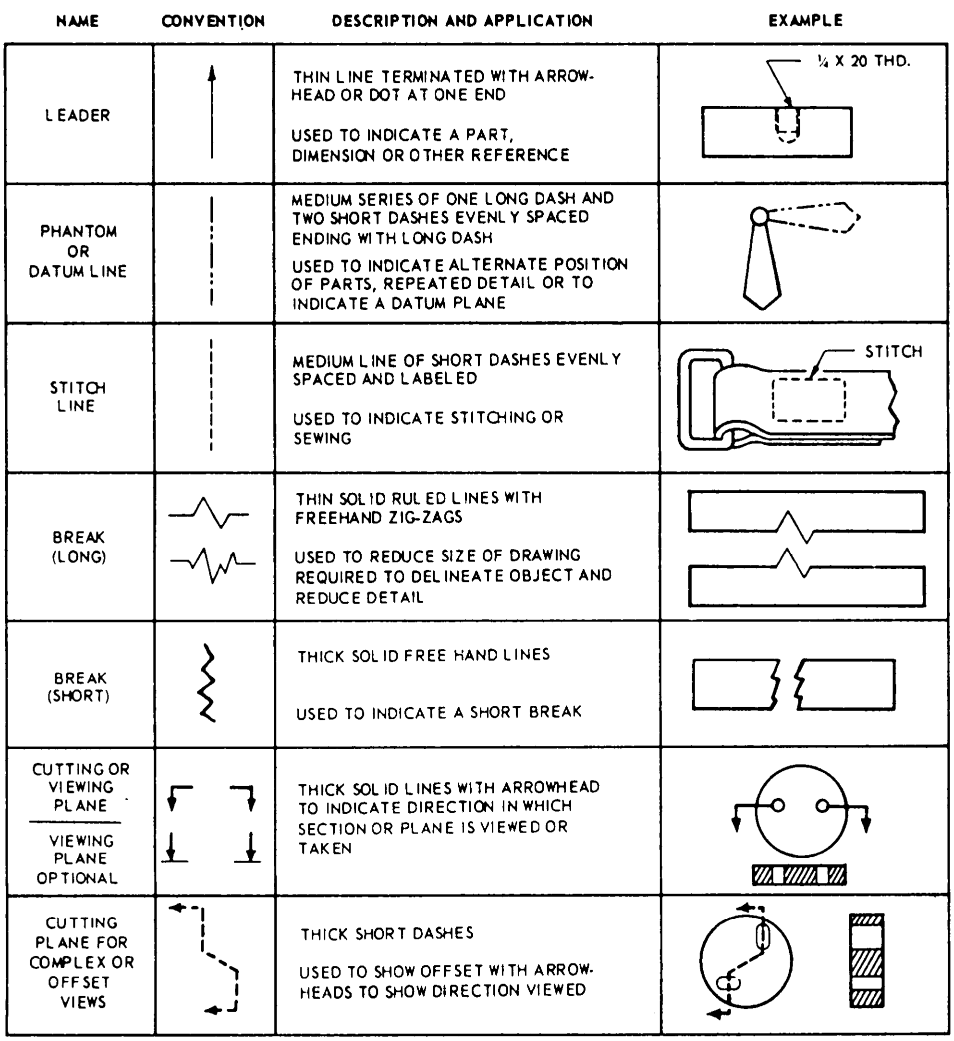


Figure 1-7.—Line characteristics and conventions for MIL-SDT drawings—Continued.

where the number 80064 identifies NAVSHIPS. In view B, the number 80091 identifies the Naval Facilities Engineering Command.

3. 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. In figure 1-1, view A, the number 800 under the NAVSHIP SYSTEM COMMAND NO. block identifies the plan as a contract plan.

4. The second part of the system command number is the serial or file number assigned by the supervisor of shipbuilding. Figure 1-1, view A, shows the number 2647537 as an example under the NAVSHIP SYSTEM COMMAND NO. block.

5. The revision letter was explained earlier in the chapter. It is shown under the REV block as A in figure 1-1, view A.

Figure 1-8, view B, shows the shipboard plan numbering system that was in use before the adoption of the current system (view A). They 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.

The first block contains the ship identification number. The examples in views A and B are DLG 16 and DD 880. Both refer to the lowest numbered ship to which the plan applies.

The second block contains the group number. In view A, it is a three-digit number 303 taken from NAVSHIPS 0902-002-2000 and it identifies a lighting system plan. View B shows the group number system

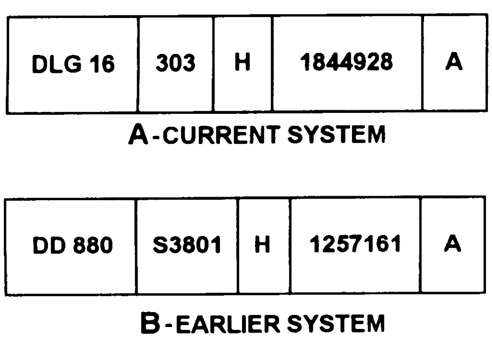


Figure 1-8.—Shipboard plan numbers.

in use before adoption of the three-digit system. That system used S group numbers that identify the equipment or system concerned. The example number S3801 identifies a ventilating system. To use this number, relate it to the proper chapter of an NSTM. Replace the S with the 9 of an NSTM chapter number and drop the last digit in the number. For example, the number S3801 would produce the number 9380, or chapter 9380 of the NSTM titled "Ventilation and Heating."

Blocks 3, 4, and 5 use the same information in the old and new 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 logroom 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 them out of strong sunlight; they fade.
- Don't allow them to become wet or smudged with oil or grease. Those substances seldom dry out completely and the prints can become unreadable.
- Don't 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. You may receive some that are not properly folded and you must refold them correctly.

CHAPTER 2

TECHNICAL SKETCHING

When you have read and understood this chapter, you should be able to answer the following learning objectives:

- *Describe the instruments used in technical sketching.*
- *Describe the types of lines used in technical sketching.*
- *Explain basic computer-aided drafting (CAD).*
- *Explain computer numerical control (CNC) design techniques used in machining.*

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 instruments.

There is no 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.

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

There are two types of pencils (fig. 2-1), those with conventional wood bonded cases known as wooden pencils and those with metal or plastic cases known as mechanical pencils. With the mechanical pencil, the lead is ejected to the desired length of projection from the clamping chuck.

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. The harder grades are 9H, 8H, 7H and 6H. The medium grades are 5H, 4H, 3H, and 2H. The medium soft grades are H and F. The soft grades are HB, B, and 2B; and the very soft grades are 6B, 5B, 4B, and 3B. The latter grade is not recommended for drafting. The selection of the grade of lead is important. A harder lead might penetrate the drawing, while a softer lead may smear.

Plastic and graphite-plastic 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

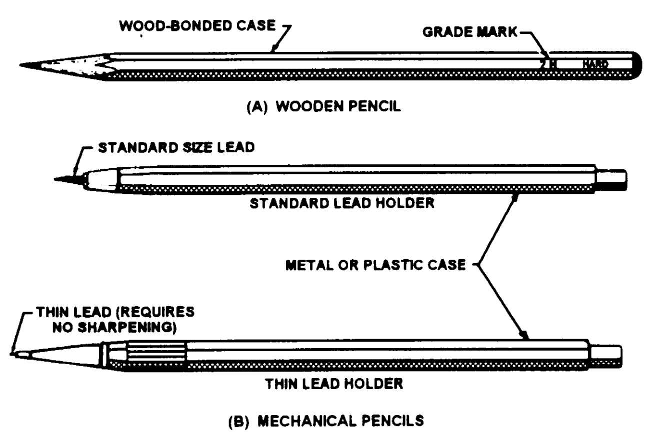


Figure 2-1.—Types of pencils.

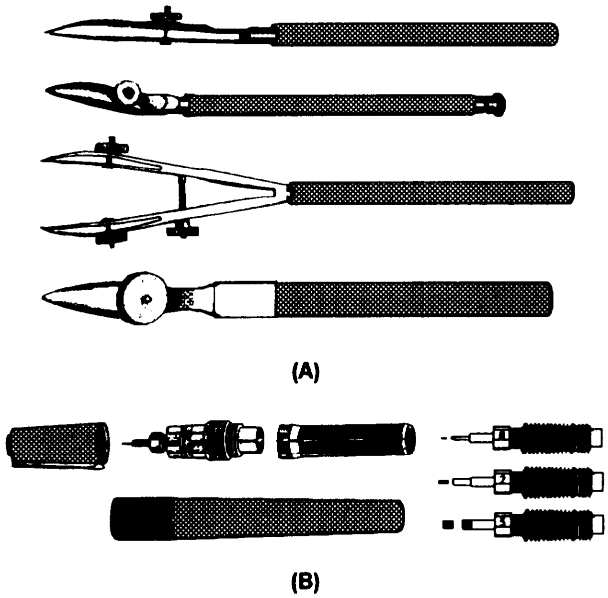


Figure 2-2—Types of pens.

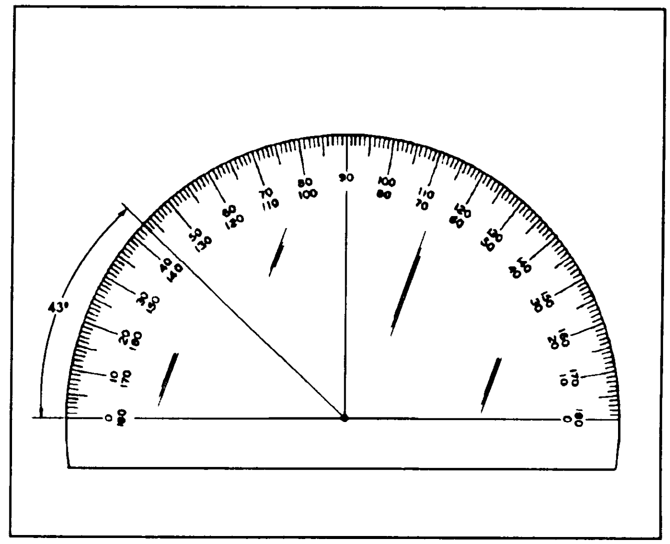


Figure 2-3.—Protractor.

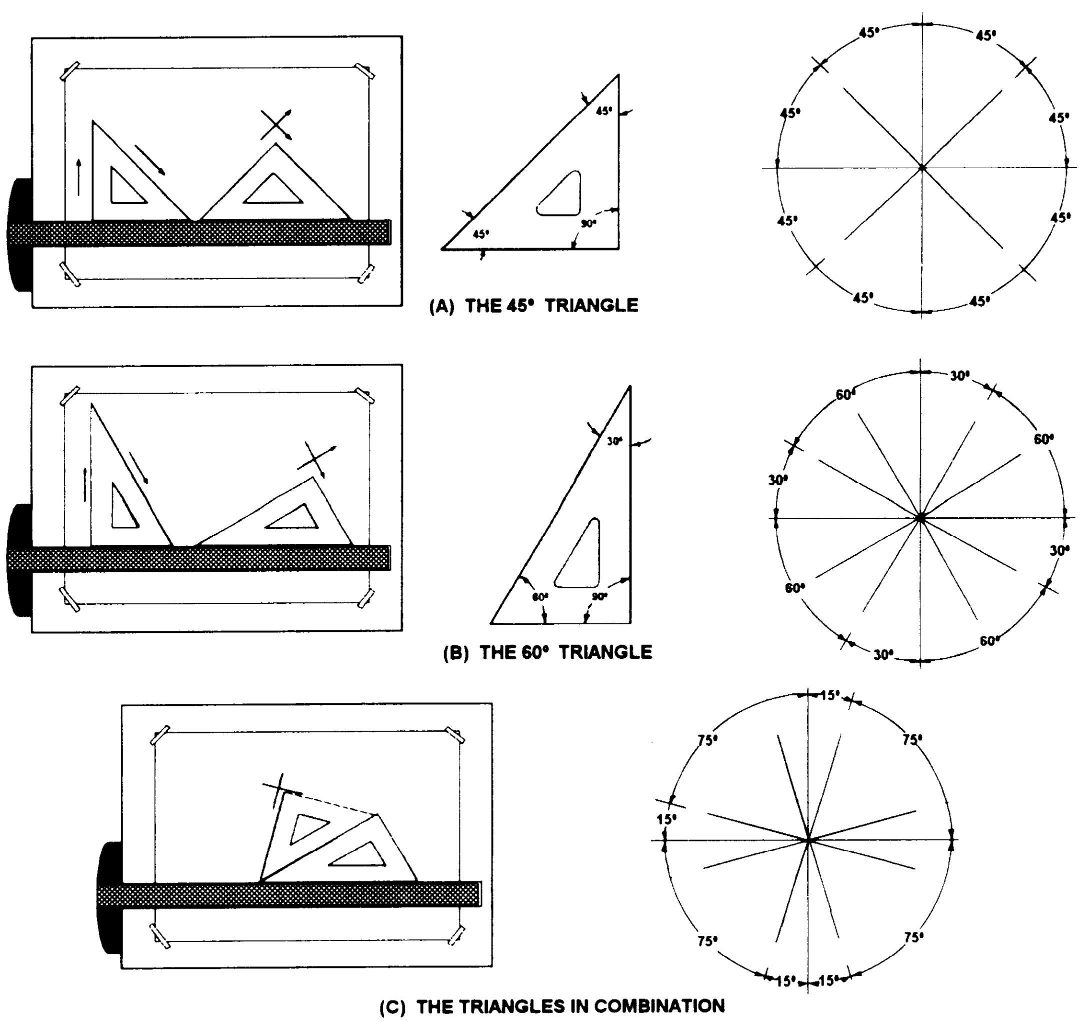


Figure 2-4.—The triangles

microform reproduction. There are two types: fired and extruded. They are similar in material content to plastic fired lead, but they are produced differently. The main drawback with this type of lead is that it does not hold a point well.

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 (fig. 2-2). 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, or needle-in-tube type of pen. It is suitable for drawing both lines and letters.

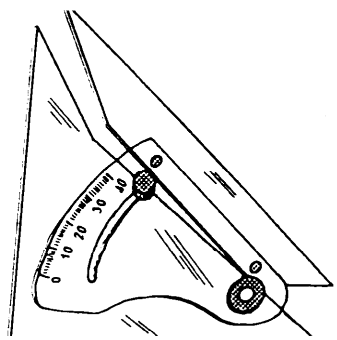


Figure 2-5—Adjustable triangle.

The draftsman uses different interchangeable needle points to produce different line widths. Several types of these pens now offer compass attachments that allow them to be clamped to, or inserted on, a standard compass leg.

DRAWING AIDS

Some of the most common drawing aids are protractors, triangles, and French curves. A protractor (fig. 2-3), is used to measure or lay out angles other than those laid out with common triangles. The common triangles shown in figure 2-4 may be used to measure or lay out the angles they represent, or they may be used in combination to form angles in multiples of 15°. However, you may lay out any angle with an adjustable triangle (fig. 2-5), which replaces the protractor and common triangles.

The French curve (fig. 2-6) is usually used to draw irregular curves with unlike circular areas where the curvature is not constant.

TYPES OF LINES

The lines used for engineering drawings must be clear and dense to ensure good reproduction. When making additions or revisions to existing drawings, be sure the line widths and density match the original work. Figure 2-7 shows the common types of straight

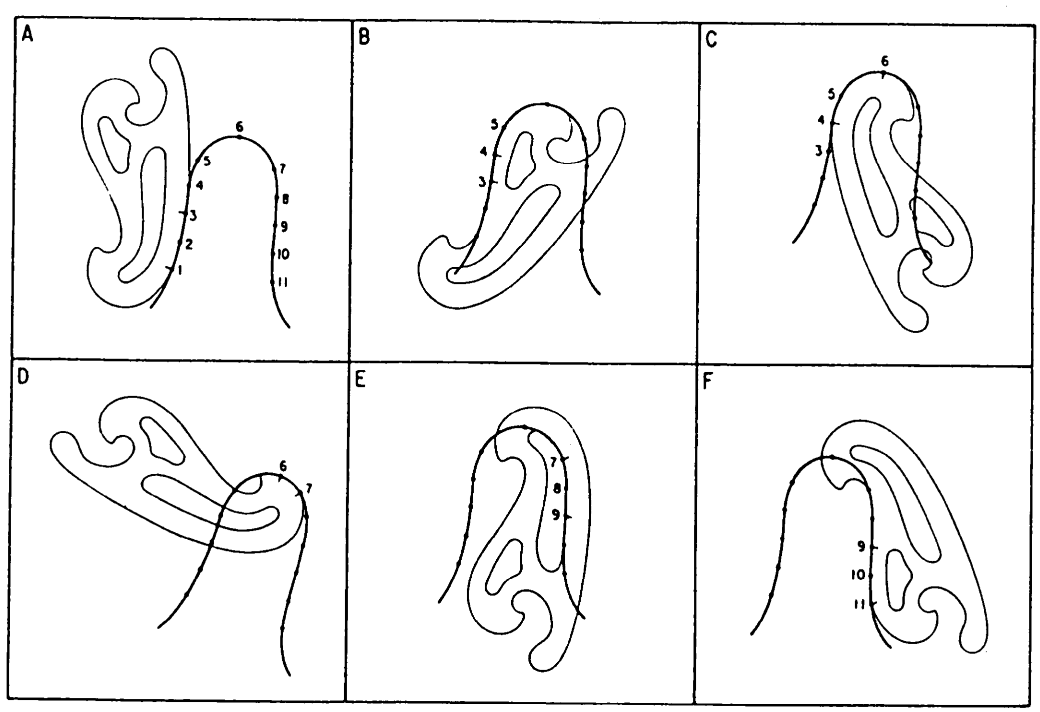


Figure 2-6.—French (irregular) curves.

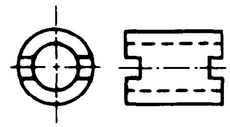
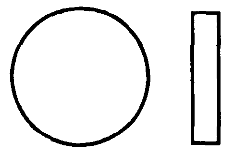
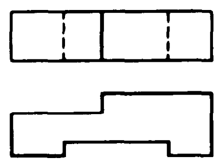
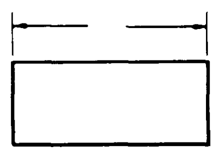
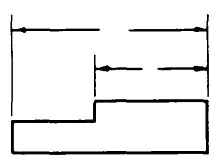
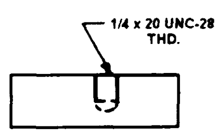
LINE STANDARDS			
NAME	CONVENTION	DESCRIPTION AND APPLICATION	EXAMPLE
CENTER LINES		THIN LINES MADE UP OF LONG AND SHORT DASHES ALTERNATELY SPACED AND CONSISTENT IN LENGTH USED TO INDICATE SYMMETRY ABOUT AN AXIS AND LOCATION OF CENTERS	
VISIBLE LINES		HEAVY UNBROKEN LINES USED TO INDICATE VISIBLE EDGES 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 ARROW-HEAD OR DOT AT ONE END USED TO INDICATE A PART, DIMENSION OR OTHER REFERENCE	

Figure 2-7.—Types of lines.

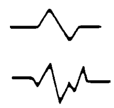
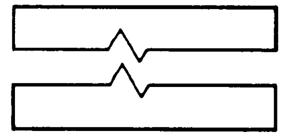
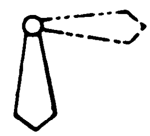
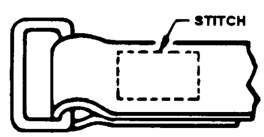
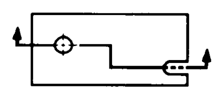
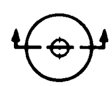
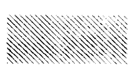
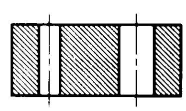
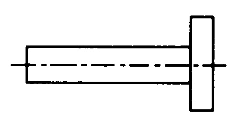
LINE STANDARDS			
NAME	**CONVENTION**	**DESCRIPTION AND APPLICATION**	**EXAMPLE**
BREAK (LONG)		THIN, SOLID RULED LINES WITH FREE-HAND ZIG-ZAGS USED TO REDUCE SIZE OF DRAWING REQUIRED TO DELINEATE OBJECT AND REDUCE DETAIL	
BREAK (SHORT)		THICK, SOLID FREE HAND LINES USED TO INDICATE A SHORT BREAK	
PHANTOM OR DATUM LINE		MEDIUM SERIES OF ONE LONG DASH AND TWO SHORT DASHES EVENLY SPACED ENDING WITH LONG DASH USED TO INDICATE ALTERNATE POSITION OF PARTS, REPEATED DETAIL OR TO INDICATE A DATUM PLANE	
STITCH LINE		MEDIUM LINE OF SHORT DASHES EVENLY SPACED AND LABLED USED TO INDICATE STITCHING OR SEWING	
CUTTING-PLANE LINE VIEWING-PLANE LINE	 	USED TO DESIGNATE WHERE AN IMAGINARY CUTTING TOOK PLACE USED TO INDICATE DIRECTION OF SIGHT WHEN A PARTIAL VEIW IS USED	 
SECTION LINES		USED TO INDICATE THE SURFACE IN THE SECTION VIEW IMAGINED TO HAVE BEEN CUT ALONG THE CUTTING-PLANE LINE	
CHAIN LINE		USED TO INDICATE THAT A SURFACE OR ZONE IS TO RECEIVE ADDITIONAL TREATMENT OR CONSIDERATIONS	

Figure 2-7.—Types of lines—Continued.

lines we will explain in the following paragraphs. In addition, we will explain the use of circles and curved lines at the end of this section.

VISIBLE LINES represent visible edges or contours of objects. Draw visible lines so that the views they outline stand out clearly on the drawing with a definite contrast between these lines and secondary lines.

HIDDEN LINES consist of short, evenly-spaced dashes and are used to show the hidden features of an object (fig. 2-8). You may vary the lengths of the dashes slightly in relation to the size of the drawing. Always begin and end hidden lines with a dash, in contrast with the visible lines from which they start, except when a dash would form a continuation of a visible line. Join dashes at comers, and start arcs with dashes at tangent points. Omit hidden lines when they are not required for the clarity of the drawing.

Although features located behind transparent materials may be visible, you should treat them as concealed features and show them with hidden lines.

CENTER LINES consist of alternating long and short dashes (fig. 2-9). Use them to represent the axis of symmetrical parts and features, bolt circles, and paths of motion. You may vary the long dashes of the center lines in length, depending upon the size of the drawing. Start and end center lines with long dashes and do not let them intersect at the spaces between dashes. Extend them uniformly and distinctly a short distance beyond the object or feature of the drawing unless a longer extension line is required for

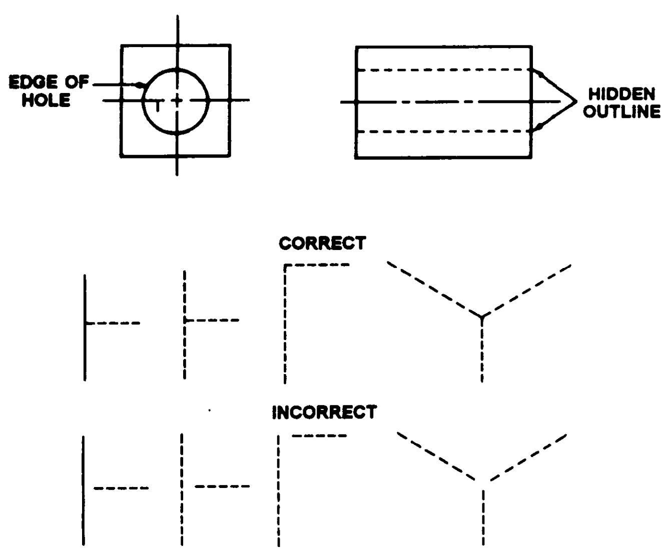


Figure 2-8.—Hidden-line technique.

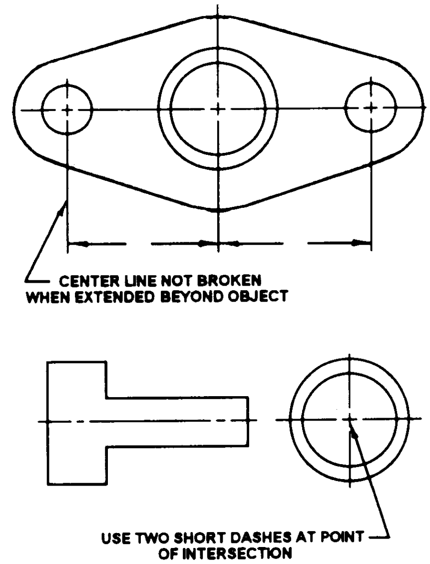


Figure 2-9.—Center-line technique.

dimensioning or for some other purpose. Do not terminate them at other lines of the drawing, nor extend them through the space between views. Very short center lines may be unbroken if there is no confusion with other lines.

SYMMETRY LINES are center lines used as axes of symmetry for partial views. To identify the line of symmetry, draw two thick, short parallel lines at right angles to the center line. Use symmetry lines to represent partially drawn views and partial sections of symmetrical parts. You may extend symmetrical view visible and hidden lines past the symmetrical line if it will improve clarity.

EXTENSION and DIMENSION LINES show the dimensions of a drawing. We will discuss them later in this chapter.

LEADER LINES show the part of a drawing to which a note refers.

BREAK LINES shorten the view of long uniform sections or when you need only a partial view. You may use these lines on both detail and assembly drawings. Use the straight, thin line with freehand zigzags for long breaks, the thick freehand line for short breaks, and the jagged line for wood parts.

You may use the special breaks shown in figure 2-10 for cylindrical and tubular parts and when an end view is not shown; otherwise, use the thick break line.

CUTTING PLANE LINES show the location of cutting planes for sectional views.

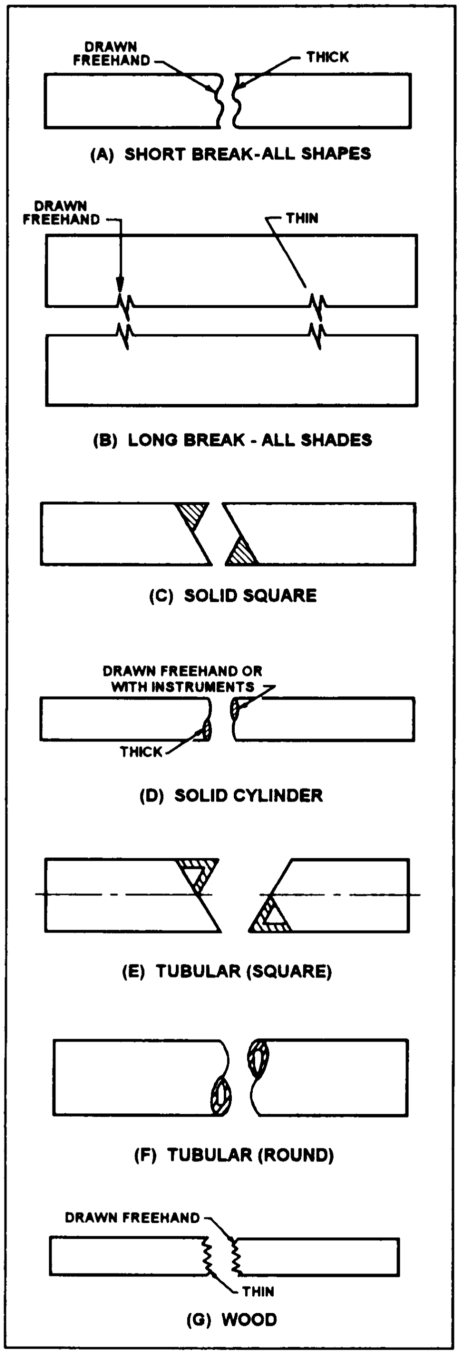


Figure 2-10.—Conventional break lines.

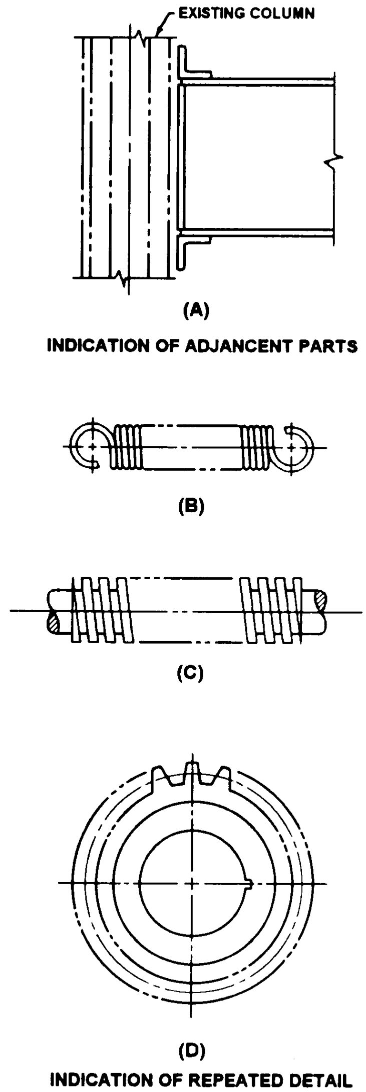


Figure 2-11.—Phantom-line application.

SECTION LINES show surface in the section view imagined to be cut along the cutting plane.

VIEWING-PLANE LINES locate the viewing position for removed partial views.

PHANTOM LINES consist of long dashes separated by pairs of short dashes (fig. 2-11). The long dashes may vary in length, depending on the size of the drawing. Phantom lines show alternate positions of related parts, adjacent positions of related parts, and repeated detail. They also may show features such as bosses and lugs to delineate machining stock and blanking developments, piece parts in jigs and fixtures, and mold lines on drawings or formed metal parts. Phantom lines always start and end with long dashes.

STITCH LINES show a sewing and stitching process. Two forms of stitch lines are approved for general use. The first is made of short thin dashes and spaces of equal lengths of approximately 0.016, and the second is made of dots spaced 0.12 inch apart.

CHAIN LINES consist of thick, alternating long and short dashes. These lines show that a surface or surface zone is to receive additional treatment or considerations within limits specified on a drawing.

An ELLIPSE is a plane curve generated by a point moving so that the sum of the distance from any point on the curve to two fixed points, called foci, is a constant (fig. 2-12). Ellipses represent holes on oblique and inclined surfaces.

CIRCLES on drawings most often represent holes or a circular part of an object.

An IRREGULAR CURVE is an unlike circular arc where the radius of curvature is not constant. This curve is usually made with a French curve (fig. 2-6).

An OGEE, or reverse curve, connects two parallel lines or planes of position (fig. 2-13).

BASIC COMPUTER AIDED DRAFTING (CAD)

The process of preparing engineering drawings on a computer is known as computer-aided drafting (CAD), and it is the most significant development to occur recently in this field. It has revolutionized the way we prepare drawings.

The drafting part of a project is often a bottleneck because it takes so much time. Drafter's spend approximately two-thirds of their time "laying lead."

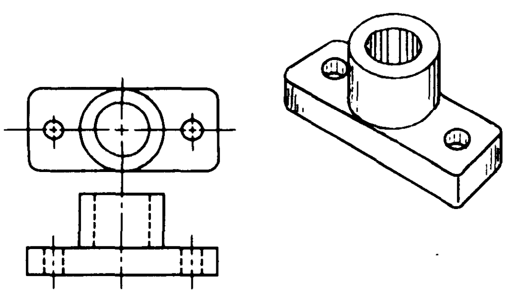


Figure 2-12.—Example of an ellipse.

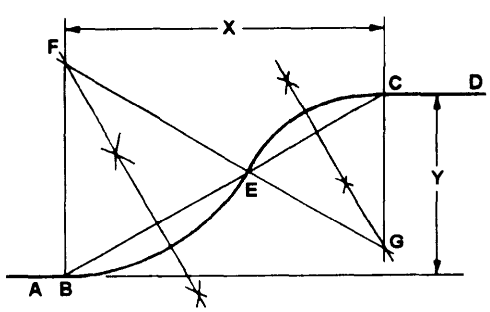


Figure 2-13.—A reverse (ogee) curve connecting two parallel planes.

But on CAD, you can make design changes faster, resulting in a quicker turn-around time.

CAD also can relieve you from many tedious chores such as redrawing. Once you have made a drawing you can store it on a disk. You may then call it up at any time and change it quickly and easily.

It may not be practical to handle all of the drafting workload on a CAD system. While you can do most design and drafting work more quickly on CAD, you still need to use traditional methods for others. 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 cathode-ray tube, a central processing unit, a digitizer, and a plotter replace them. Figure 2-14 shows some of these items at a computer work station. We'll explain each of them later in this section.

GENERATING DRAWINGS ON CAD

A CAD computer contains a drafting program that is a set of detailed instructions for the computer. When you bring up the program, the screen displays each function or instruction you must follow to make a drawing.

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 as you need them. Examples are characters, grid patterns, and types of lines. When you get the symbols you want on the screen, you will order the computer to size, rotate, enlarge, or reduce them, and position them on the screen to produce the image you want. You probably will then order the computer to print the final product and store it for later use.

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

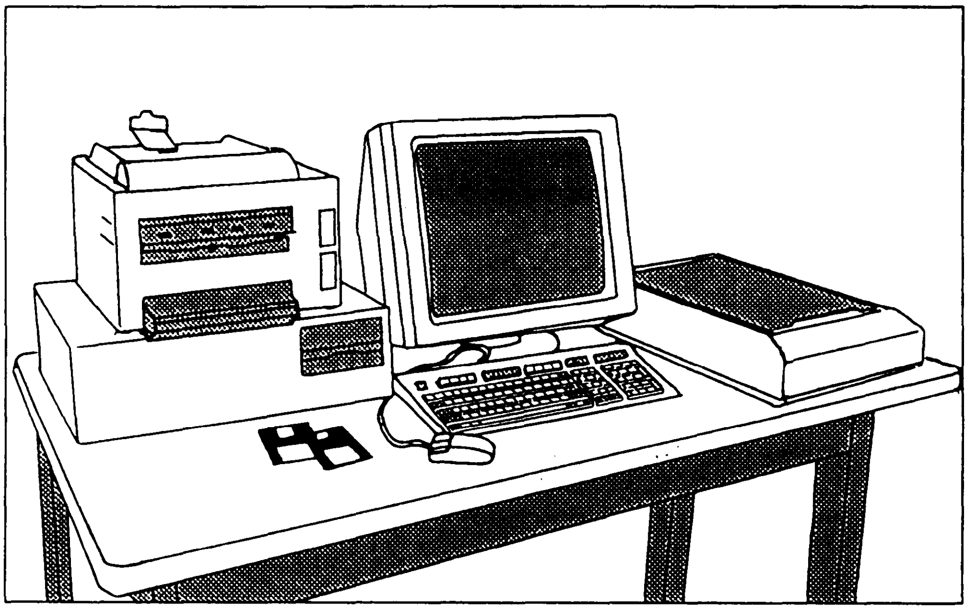


Figure 2-14.—Computer work station.

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

The Digitizer

The digitizer tablet is used in conjunction with a CAD program; it allows the draftsman 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 2-15 illustrates a typical digitizer tablet.

The Plotter

A plotter (fig. 2-16) is used mainly to transfer an image or drawing from the computer screen to some

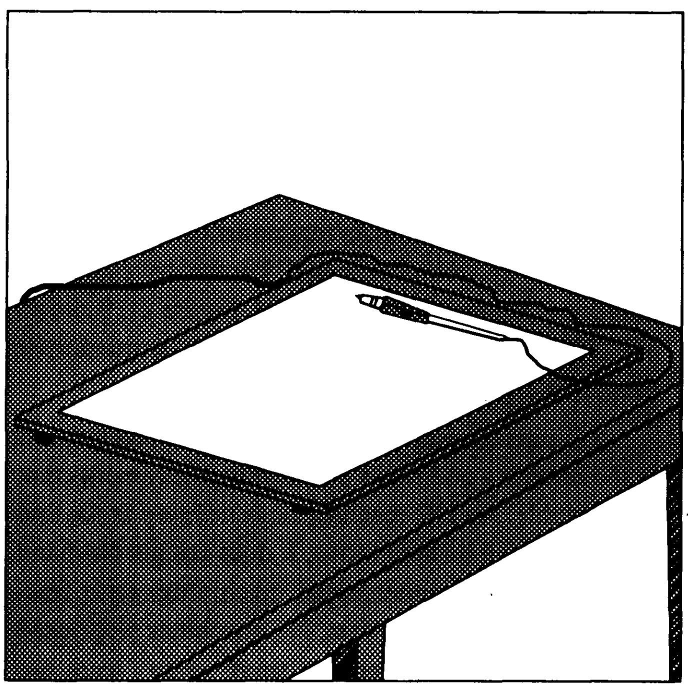


Figure 2-15.—Basic digitizer tablet.

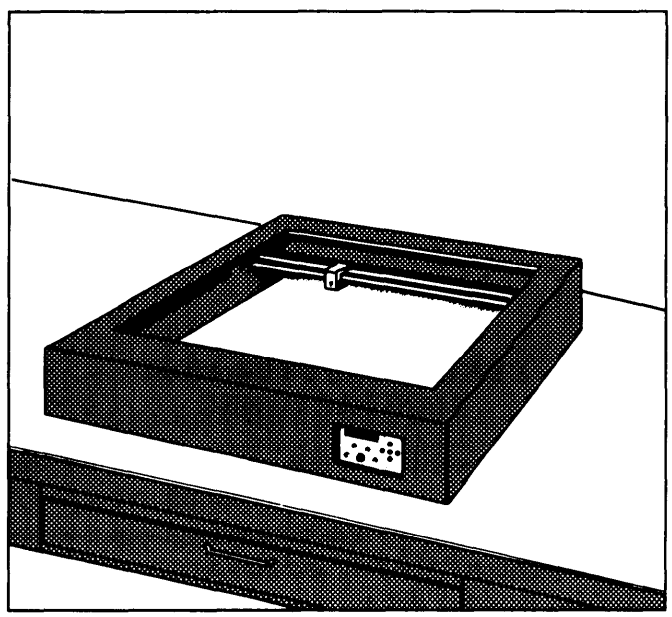


Figure 2-16.—Typical plotter.

form of drawing media. When you have finished producing the drawing on CAD, you will order the computer to send the information to the plotter, which will then reproduce the drawing from the computer screen. A line-type digital plotter is an electro-mechanical graphics output device capable of two-dimensional movement between a pen and drawing media. Because of the digital movement, a plotter is considered a vector device.

You will usually use ink pens in the plotter to produce a permanent copy of a drawing. Some common types are wet ink, felt tip, or liquid ball, and they may be single or multiple colors. These pens will draw on various types of media such as vellum and Mylar. The drawings are high quality, uniform, precise, and expensive. There are faster, lower quality output devices such as the printers discussed in the next section, but most CAD drawings are produced on a plotter.

The Printer

A printer is a computer output device that duplicates the screen display quickly and conveniently. Speed is the primary advantage; it is much faster than plotting. You can copy complex graphic screen displays that include any combination of graphic and nongraphic (text and characters) symbols. The copy, however, does not approach the level of quality produced by the pen plotter. Therefore, it is used primarily to check prints rather than to make a final copy. It is, for example, very useful for a quick preview at various intermediate steps of a design project.

The two types of printers in common use are dot matrix (fig. 2-17) and laser (fig. 2-18). The laser printer offers the better quality and is generally more expensive.

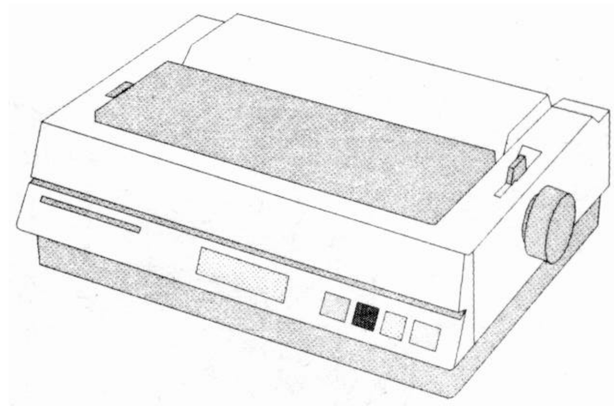


Figure 2-17.—Dot matrix printer.

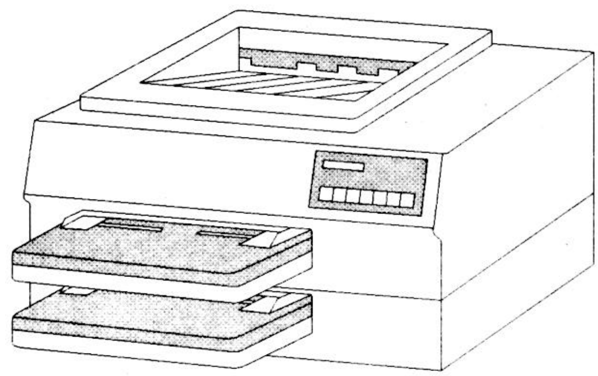


Figure 2-18.—Laser jet printer.

COMPUTER-AIDED DESIGN/COMPUTER-AIDED MANUFACTURING

You read earlier in this chapter how we use computer technology to make blueprints. Now you'll learn how a machinist uses computer graphics to lay out the geometry of a part, and how a computer on the machine uses the design to guide the machine as it makes the part. But first we will give you a brief overview of numerical control (NC) in the field of machining.

NC is the process by which machines are controlled by input media to produce machined parts. The most common input media used in the past 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 2-19 shows a CNC programming station where a machinist programs a machine to do a given job.

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 used for mass production because small orders were too costly. But CNC allows a qualified machinist to program and produce a single part economically.

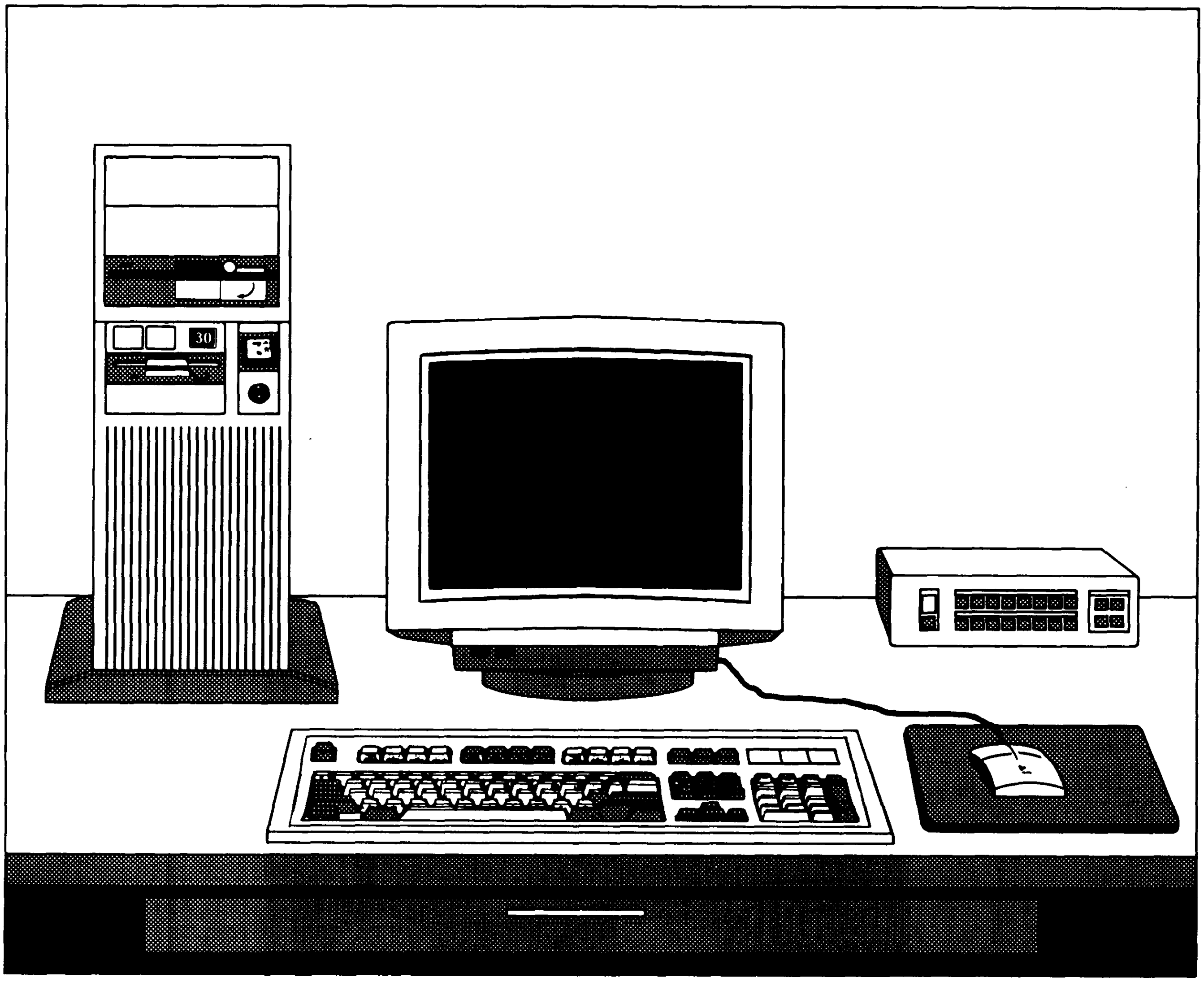


Figure 2-19.—CNC programming station.

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 screen 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 tool path is translated into a detailed sequence of the machine axes movement commands the machine needs to produce the part.

The computer-generated instructions can be stored in a central computer's memory, or on a disk, for direct transfer to one or more CNC machine tools that will make the parts. This is known as direct numerical control (DNC). Figure 2-20 shows a

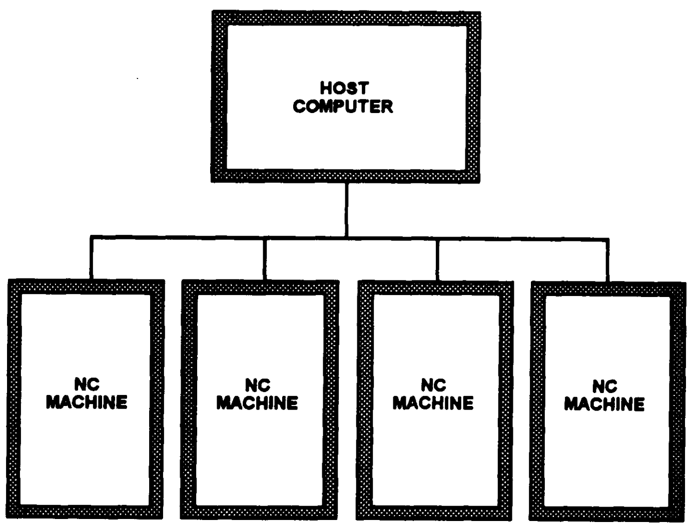


Figure 2-20.—Direct numerical control station.

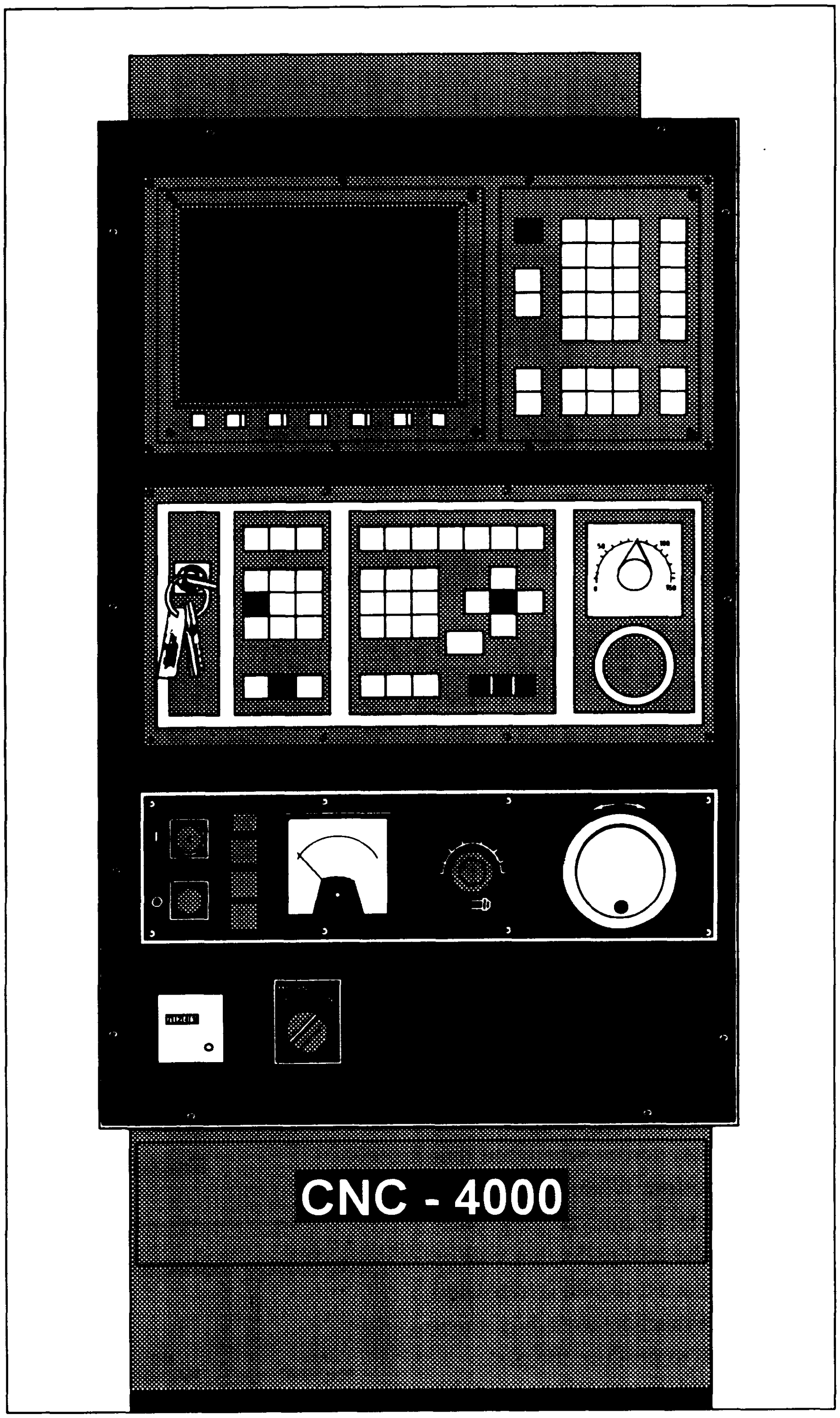


Figure 2-21.—Direct numerical controller.

diagram of a controller station, and figure 2-21 shows a controller.

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 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.

CHAPTER 3

PROJECTIONS AND VIEWS

When you have read and understood this chapter, you should be able to answer the following learning objectives:

- *Describe the types of projections.*
- *Describe the types of views.*

In learning to read blueprints you must develop the ability to visualize the object to be made from the blueprint (fig. 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 multiview drawing, first survey all of the views, 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.

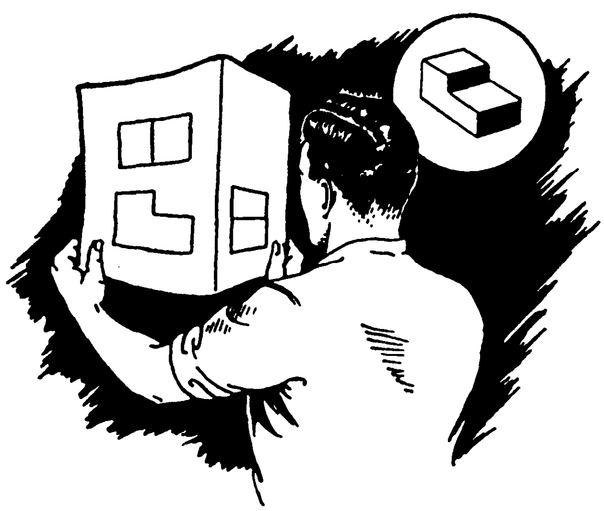


Figure 3-1.—Visualizing a blueprint.

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

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

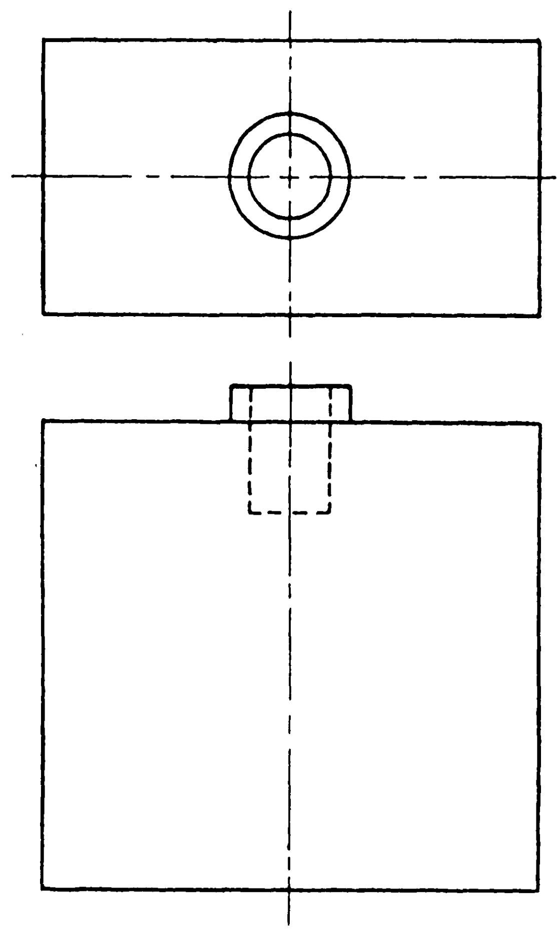


Figure 3-2.—Reading views.

fig. 3-3. 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 3-4. 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 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

An ORTHOGRAPHIC projection is a parallel projection in which the projectors are perpendicular to the plane of projection as in figure 3-4. An OBLIQUE projection is one in which the projectors are other than perpendicular to the plane of projection. Figure 3-5 shows the same object in both orthographic and oblique projections. The block is placed so that its

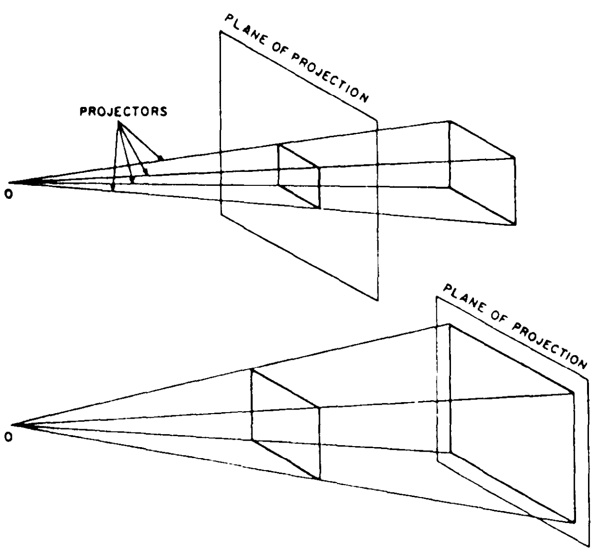


Figure 3-3.—Central projection.

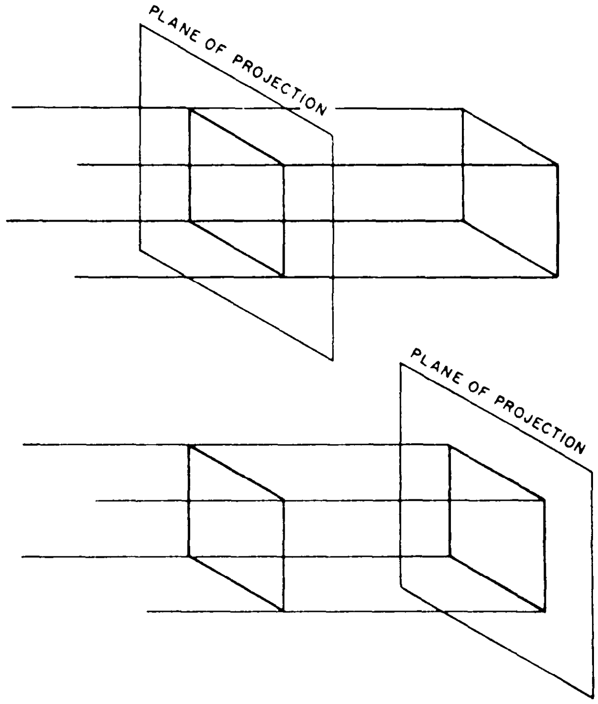


Figure 3-4.—Parallel projections.

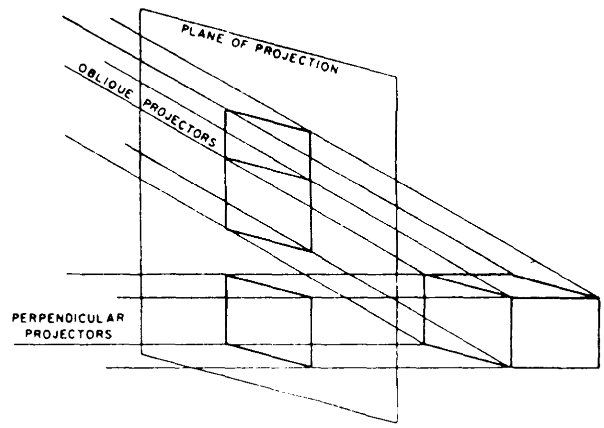


Figure 3-5.—Oblique and orthographic projections.

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 in the next paragraphs.

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 3-6 shows a cube projected by isometric projection. 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 the same scale.

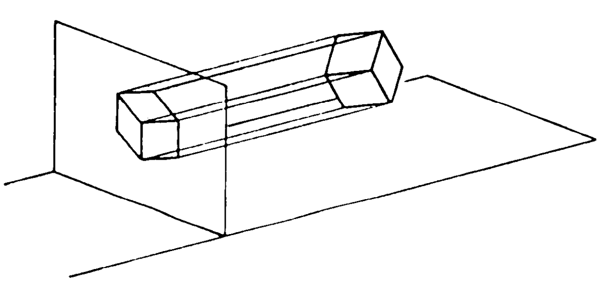


Figure 3-6.—Isometric projection.

VIEWS

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

MULTIVIEW 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 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.

Figure 3-7 shows an object placed in a transparent box hinged at the edges. With the outlines scribed on each surface and the box opened and laid flat as shown in views A and C, the result is a six-view orthographic

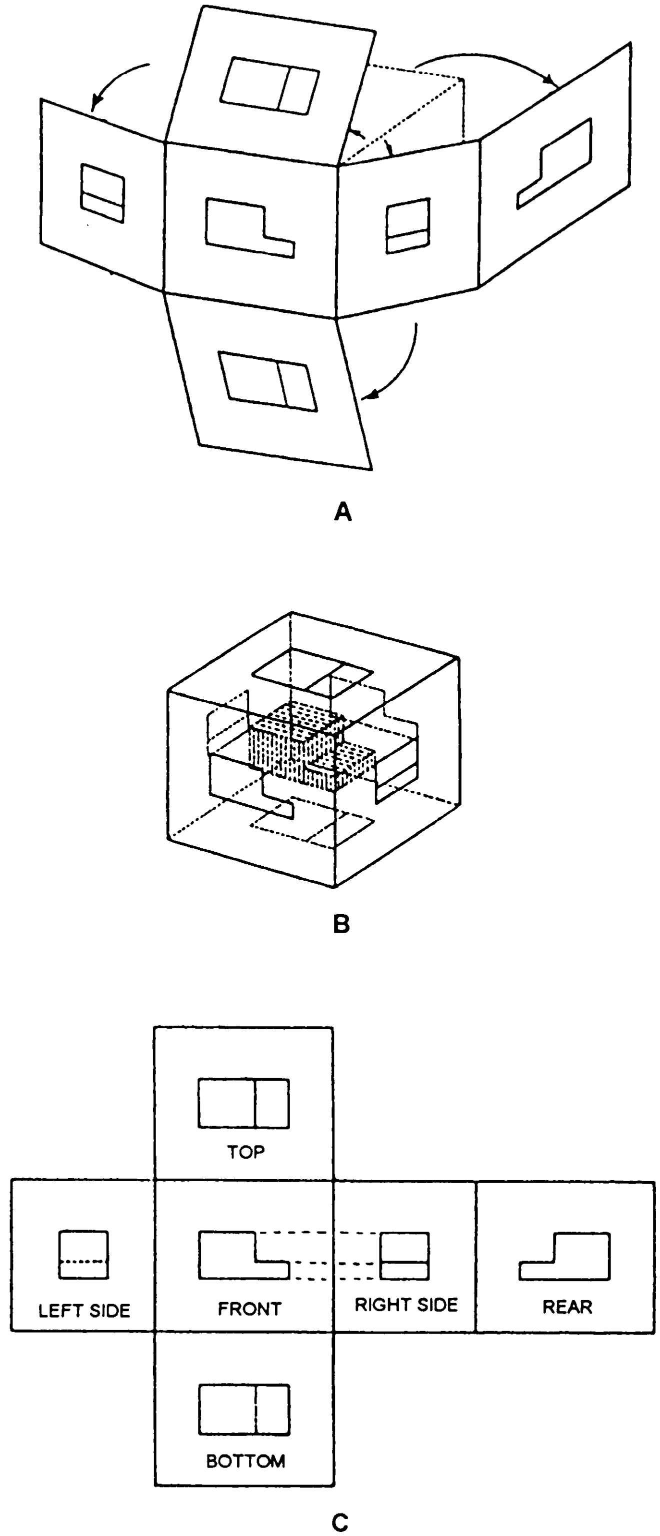


Figure 3-7.—Third-angle orthographic projection.

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. View B shows that 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.

A three-view orthographic projection drawing shows the front, top, and right sides of an object. Refer to figure 3-7, view C, 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 3-8. 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.

After you study each view of the object, you can see it as it is shown in the center of figure 3-9. To clarify the three-view drawing further, think of the object as immovable (fig. 3-10), and visualize yourself moving around it. This will help you relate the blueprint views to the physical appearance of the object.

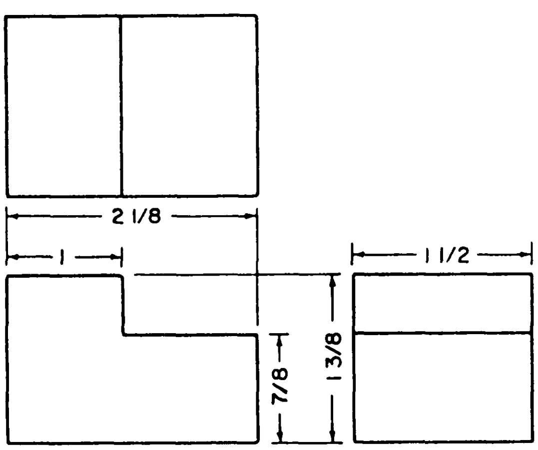


Figure 3-8.—A three-view orthographic projection.

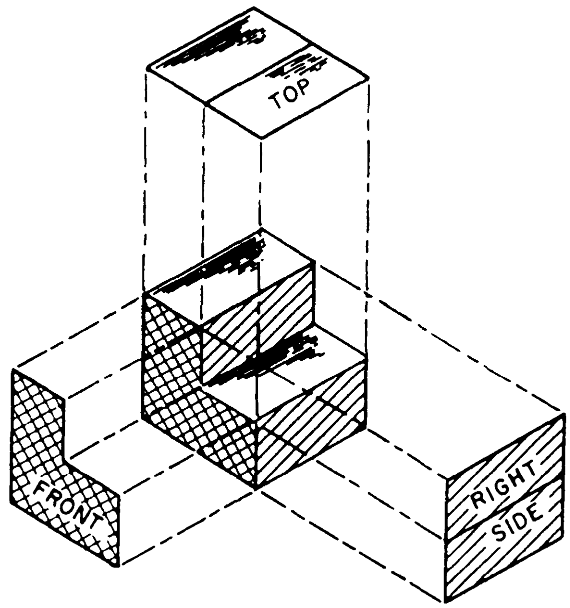


Figure 3-9.—Pull off the views.

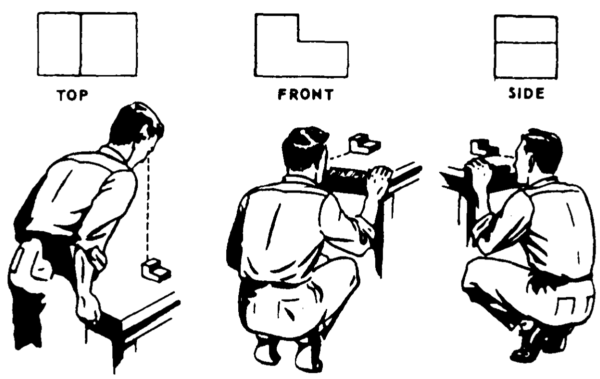


Figure 3-10.—Compare the orthographic views with the model.

Now study the three-view drawing shown in figure 3-11. It is similar to that shown in figure 3-8 with one exception; the object in figure 3-11 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 3-11 introduces two symbols that are not shown in figure 3-8 but are described in chapter 2. They are a hidden line that shows lines you normally can't 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.

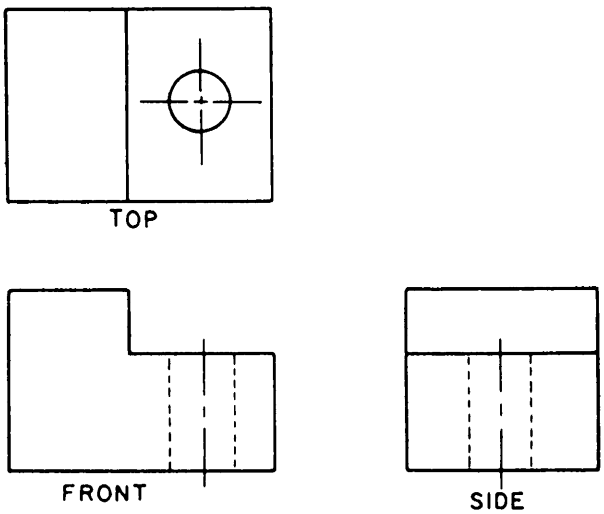


Figure 3-11.—A three-view drawing.

PERSPECTIVE DRAWINGS

A perspective drawing is the most used method of presentation used in technical illustrations in the commercial and architectural fields. The drawn objects appear proportionately smaller with distance, as they do when you look at the real object (fig. 3-12). It is difficult to draw, and since the drawings are drawn in diminishing proportion to the edges represented, they cannot be used to manufacture an object. Other views are used to make objects and we will discus them in the following paragraphs.

SPECIAL VIEWS

In many complex objects it is often difficult to show true size and shapes orthographically. Therefore, the draftsmen must use other views to give engineers and craftsmen 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.

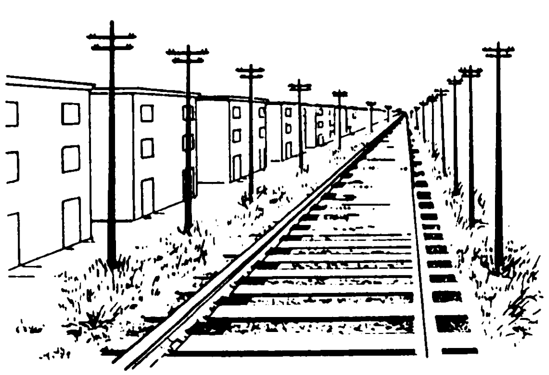


Figure 3-12.—The perspective.

Auxiliary Views

Auxiliary views are often necessary to show the true shape and length of inclined surfaces, or other features that are not parallel to the principal planes of projection.

Look directly at the front view of figure 3-13. Notice the inclined surface. Now look at the right side and top views. The inclined surface appears foreshortened, not its true shape or size. In this case, the draftsman will use an auxiliary view to show the true shape and size of the inclined face of the object. It is drawn by looking perpendicular to the inclined surface. Figure 3-14 shows the principle of the auxiliary view.

Look back to figure 3-10, which shows an immovable object being viewed from the front, top, and side. Find the three orthographic views, and compare them

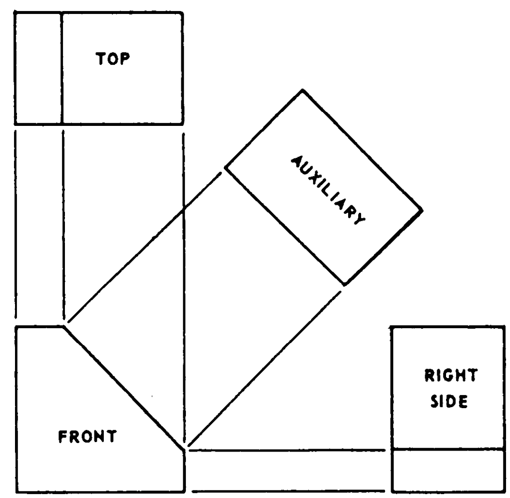


Figure 3-13.—Auxiliary view arrangement.

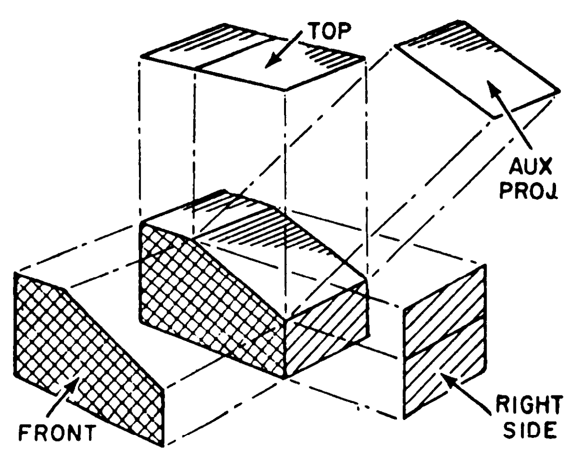


Figure 3-14.—Auxiliary projection principle.

with figure 3-15 together with the other information. It should clearly explain the reading of the auxiliary view. Figure 3-16 shows a side by side comparison of orthographic and auxiliary views. View A shows a foreshortened orthographic view of an inclined or slanted surface whose true size and shape are unclear. View B uses an auxiliary projection to show the true size and shape.

The projection of the auxiliary view is made by the observer moving around an immovable object, and the views are projected perpendicular to the lines of sight. Remember, the object has not been moved; only the position of the viewer has changed.

Section Views

Section views give a clearer view of the interior or hidden features of an object that you normally cannot see clearly in other views. A section view is made by visually cutting away a part of an object to show the shape and construction at the cutting plane.

Notice the cutting plane line AA in the front view shown in figure 3-17, view A. It shows where the imaginary cut has been made. In view B, the isometric view helps you visualize the cutting plane. The arrows point in the direction in which you are to look at the sectional view.

View C is another front view showing how the object would look if it were cut in half.

In view D, the orthographic section view of section A-A is placed on the drawing instead of the confusing front view in view A. Notice how much easier it is to read and understand.

When sectional views are drawn, the part that is cut by the cutting plane is marked with diagonal (or crosshatched), parallel section lines. When two or more parts are shown in one view, each part is sectioned or crosshatched with a different slant. Section views are necessary for a clear understanding of complicated parts. On simple drawings, a section view may serve the purpose of additional views.

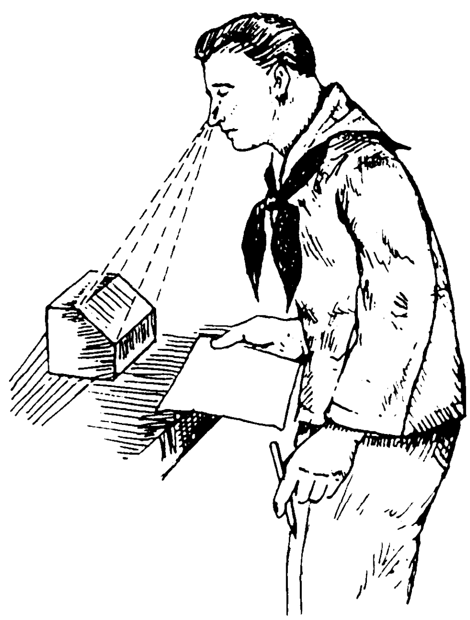


Figure 3-15.—Viewing an inclined surface, auxiliary view.

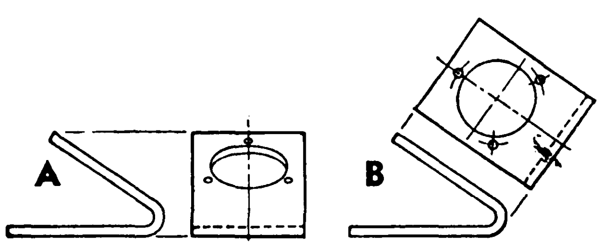


Figure 3-16.—Comparison of orthographic and auxiliary projections.

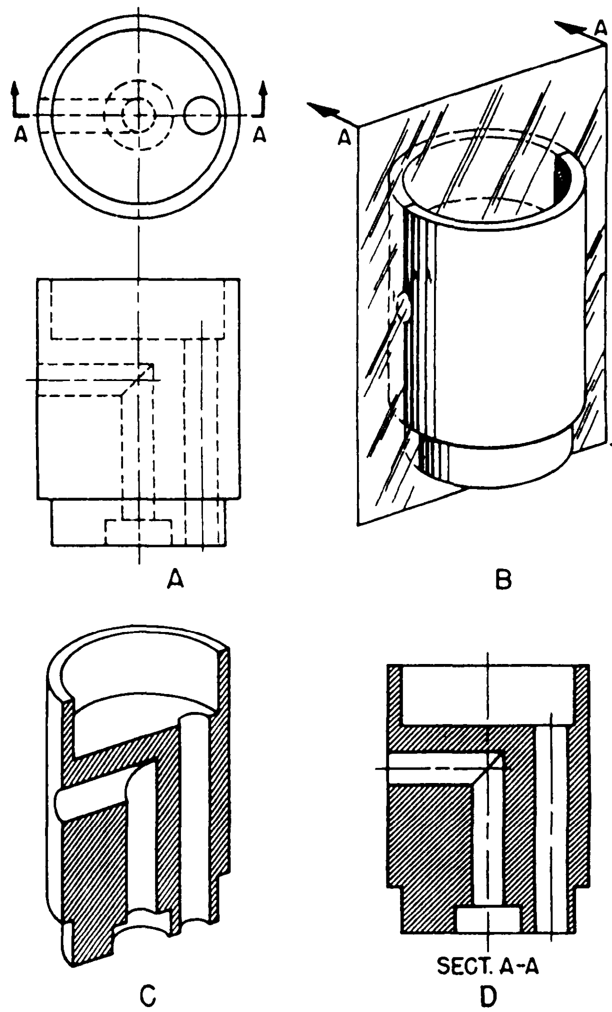


Figure 3-17.—Action of a cutting plane.

Section A-A in view D is known as a full section because the object is cut completely through.

OFFSET SECTION.—In this type of section, the cutting plane changes direction backward and forward (zig-zag) to pass through features that are important to show. The offset cutting plane in figure 3-18 is positioned so that the hole on the right side will be shown in section. The sectional view is the front view, and the top view shows the offset cutting plane line.

HALF SECTION.—This type of section is shown in figure 3-19. It is used when an object is symmetrical in both outside and inside details. One-half of the object is sectioned; the other half is shown as a standard view.

The object shown in figure 3-19 is cylindrical and cut into two equal parts. Those parts are then divided equally to give you four quarters. Now remove a quarter. This is what the cutting plane has done in the pictorial view; a quarter of the cylinder has been removed so you can look inside. If the cutting plane had extended along the diameter of the cylinder, you would have been looking at a full section. The cutting plane in this drawing extends the distance of the radius, or only half the distance of a full section, and is called a half section.

The arrow has been inserted to show your line of sight. What you see from that point is drawn as a half section in the orthographic view. The width of the orthographic view represents the diameter of the circle. One radius is shown as a half section, the other as an external view.

REVOLVED SECTION.—This type of section is used to eliminate the need to draw extra views of rolled shapes, ribs, and similar forms. It is really a drawing within a drawing, and it clearly describes the object's shape at a certain cross section. In figure 3-20, the draftsman has revolved the section view of the rib so you can look at it head on. Because of this revolving feature, this kind of section is called a revolved section.

REMOVED SECTION.—This type of section is used 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 (fig. 3-21). It is

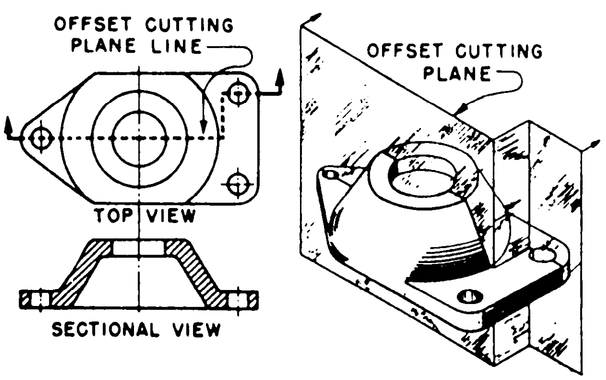


Figure 3-18.—Offset section.

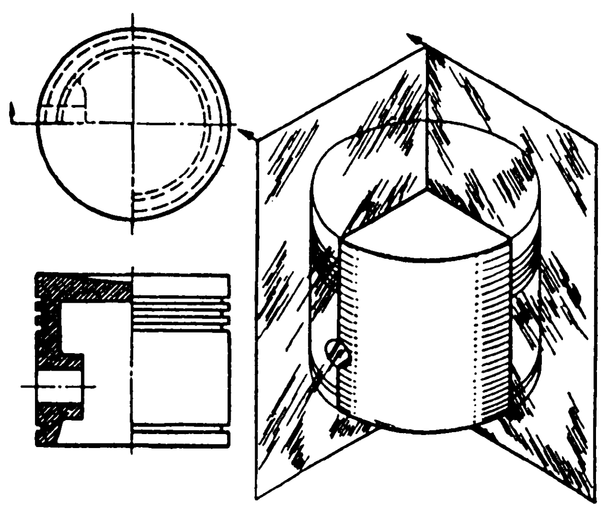


Figure 3-19.—Half section.

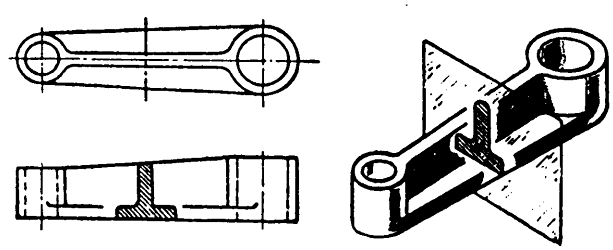


Figure 3-20.—Revolved section.

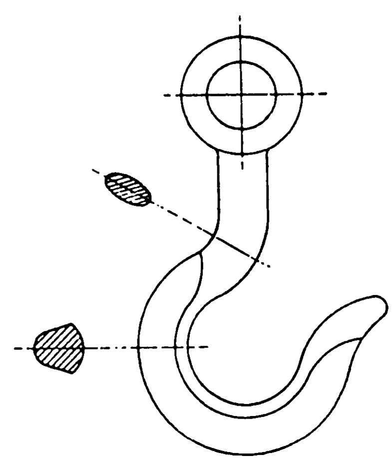


Figure 3-21.—Removed section.

often drawn to a larger scale than the view of the object from which it is removed.

BROKEN-OUT SECTION.—The inner structure of a small area may be shown by peeling back or removing the outside surface. The inside of a counterbored hole is better illustrated in figure 3-22 because of the broken-out section, which makes it possible for you to look inside.

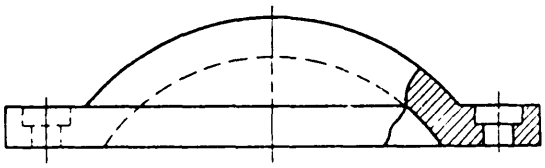


Figure 3-22.—Broken-out section through a counterbored hole.

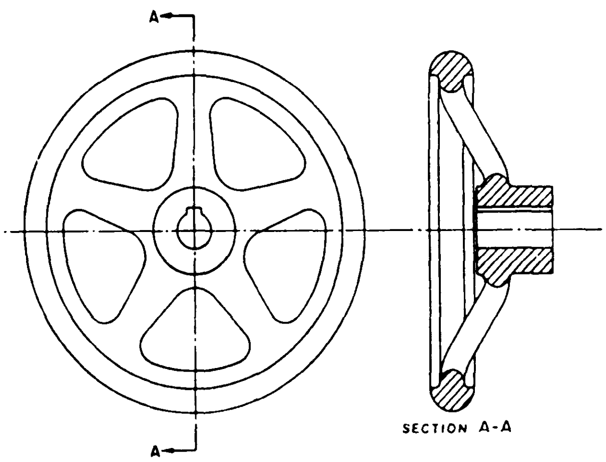


Figure 3-23.—Aligned section.

ALIGNED SECTION.—Figure 3-23 shows an aligned section. 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.

Exploded View

This is another type of view that is helpful and easy to read. The exploded view (fig. 3-24) is used to show 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.

DETAIL DRAWINGS

A detail drawing 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

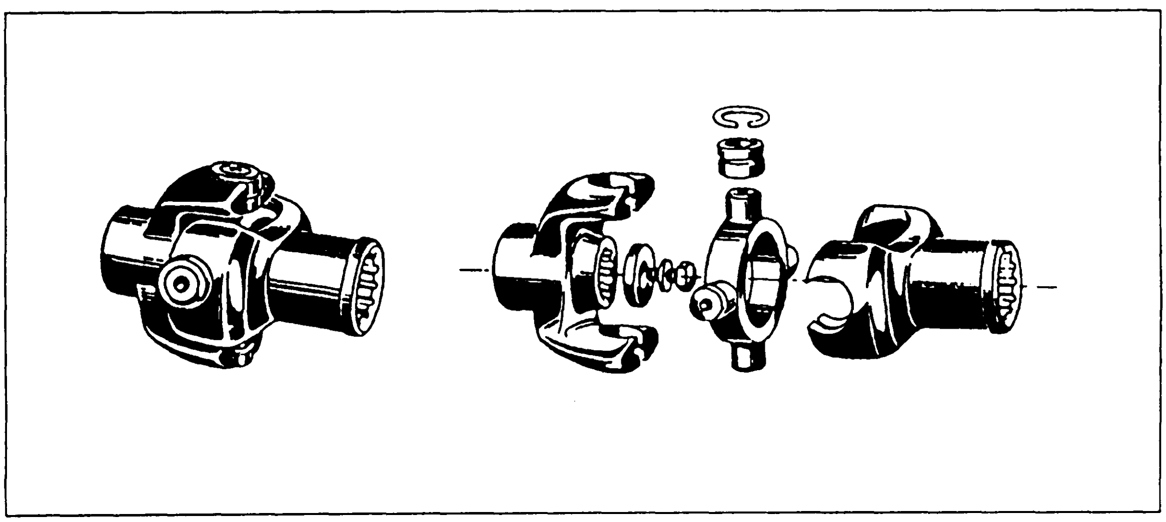


Figure 3-24.—An exploded view.

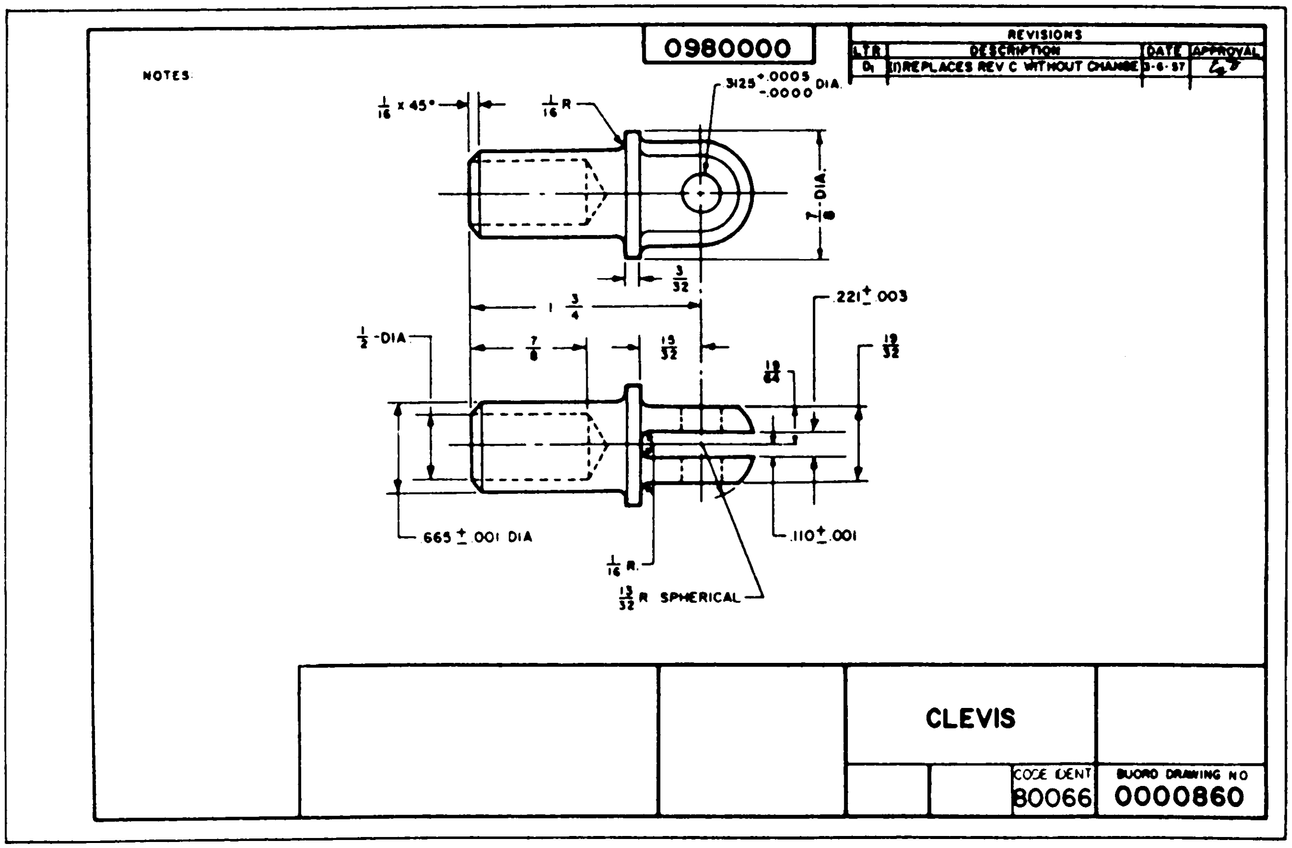


Figure 3-25.—Detailed drawing of a clevis.

detail view. A detail view shows part of a drawing in the same plane and in the same arrangement, but in greater detail to a larger scale than in the principal view.

Figure 3-25 shows a relatively simple detail drawing of a clevis. Study the figure closely and apply the principles for reading two-view orthographic drawings discussed earlier in this chapter. The dimensions on the detail drawing in figure 3-25 are conventional, except for the four toleranced 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 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 means the diameter can be a minimum of 0.664, and a maximum of 0.666. The other two toleranced dimension given are at the left of the bottom view. Figure 3-26 is an isometric view of the clevis shown in figure 3-25.

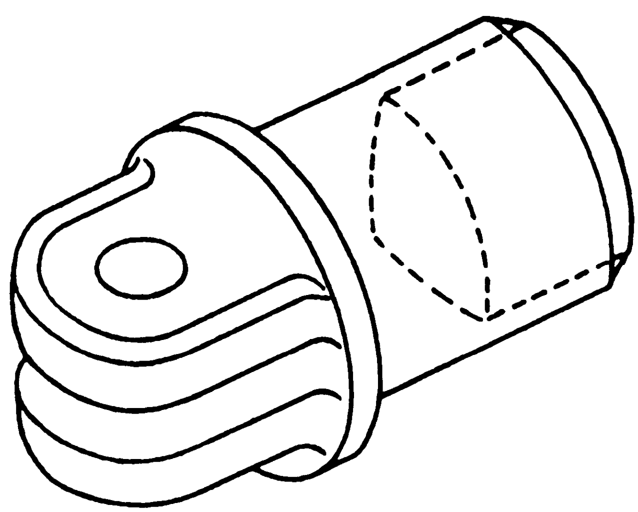


Figure 3-26.—Isometric drawing of a clevis.

Figure 3-27 is an isometric drawing of the base pivot shown orthographically in figure 3-28. You may think the drawing is complicated, but it really is not. It does, however, have more symbols and abbreviations than this book 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 3-28.

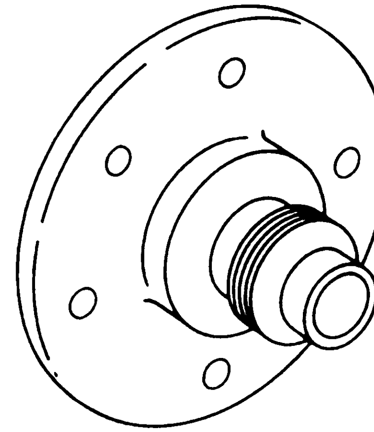


Figure 3-27.—Isometric drawing of a base pivot.

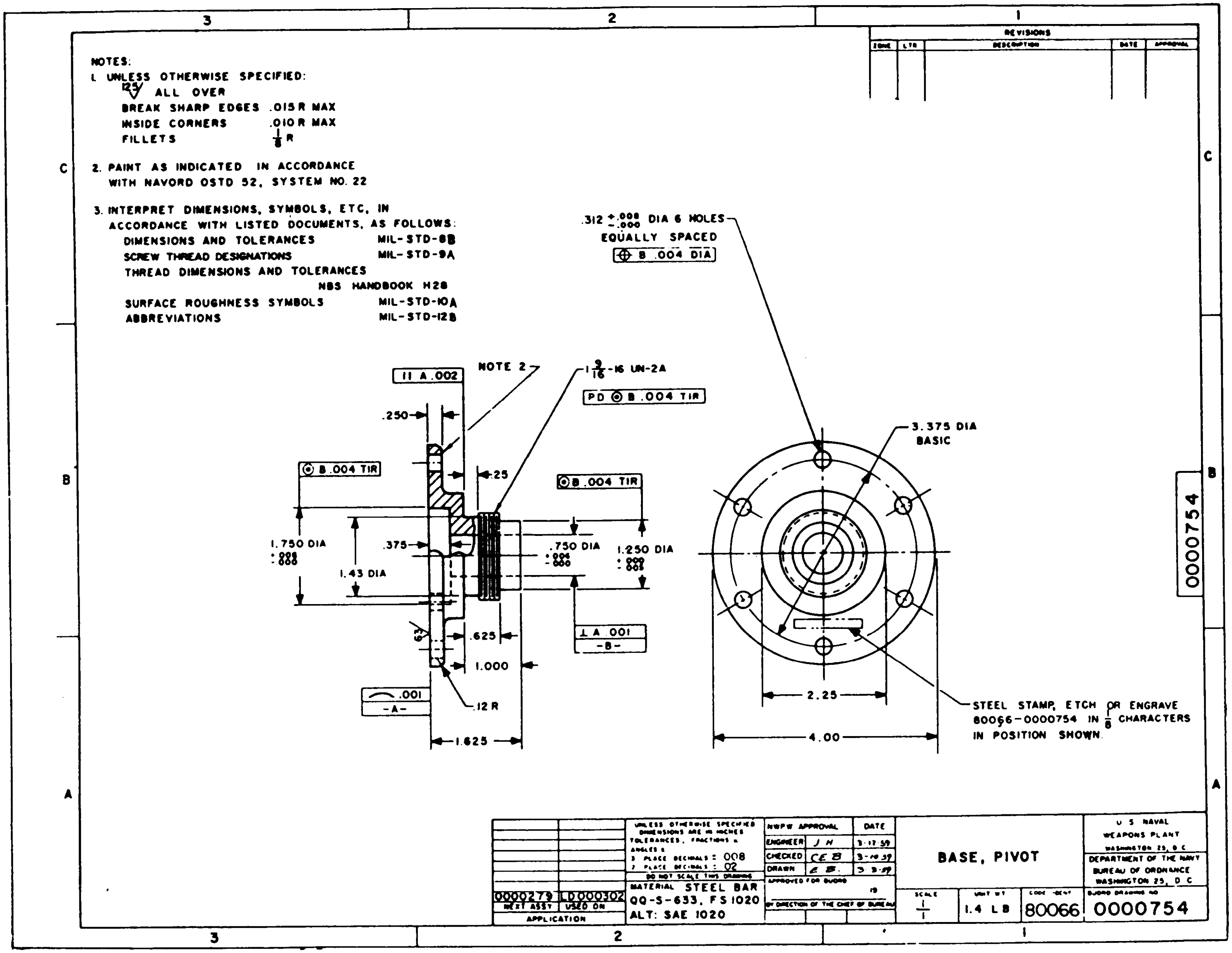


Figure 3-28.—Detail drawing of a base pivot.

CHAPTER 4

MACHINE DRAWING

When you have read and understood this chapter, you should be able to answer the following learning objectives:

- *Describe basic machine drawings.*
- *Describe the types of machine threads.*
- *Describe gear and helical spring nomenclature.*
- *Explain the use of finish marks on drawings.*

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

COMMON TERMS 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 TERMS

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 figure how much variation is permissible. This allowance 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

The surfaces being toleranced have geometrical characteristics such as roundness, or perpendicularity to another surface. Figure 4-2 shows typical geometrical characteristic symbols. A datum is a surface, line, or

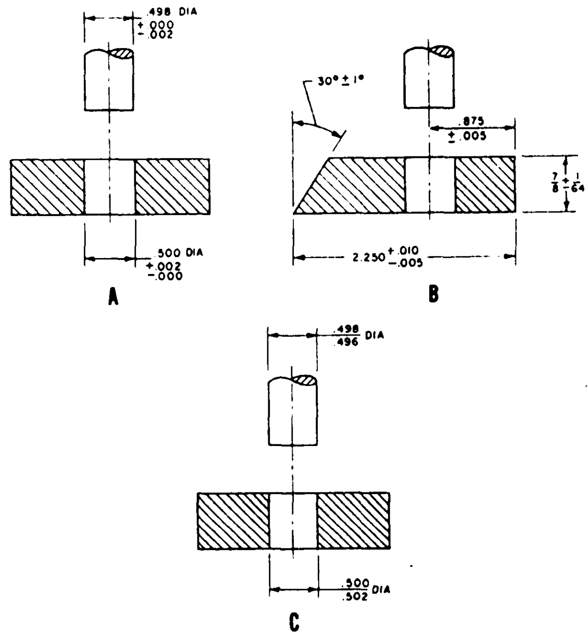


Figure 4-1.—Methods of indicating tolerance.

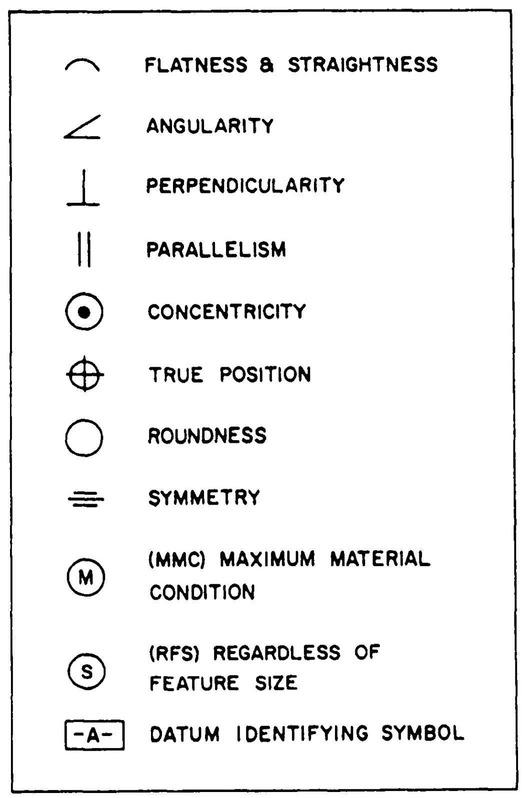


Figure 4-2.—Geometric characteristic symbols.

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. Figure 4-3 shows how a feature control symbol may include datum references.

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. Figure 4-4 shows 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. Figure 4-5 shows two types: the tee slot, and the dovetail slot. For examples, 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.

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.

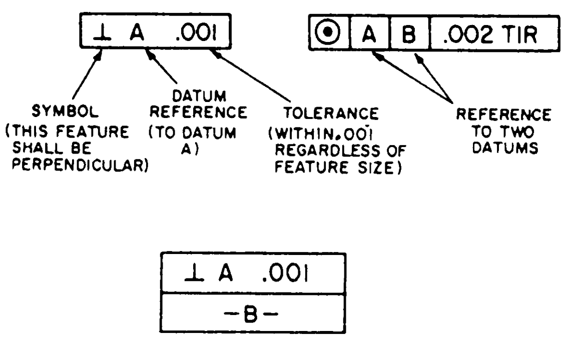


Figure 4-3.—Feature control frame indicating a datum reference.

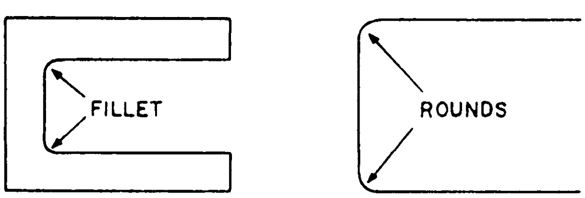


Figure 4-4.—Fillets and rounds

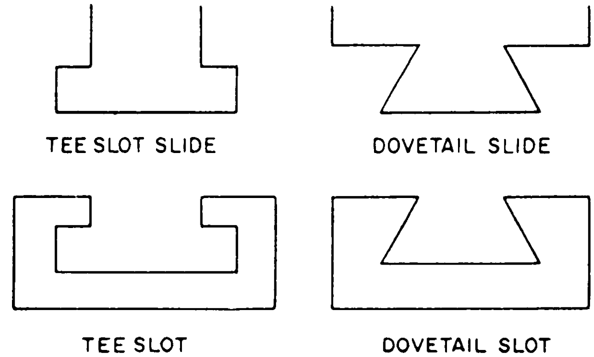


Figure 4-5.—Slots and slides.

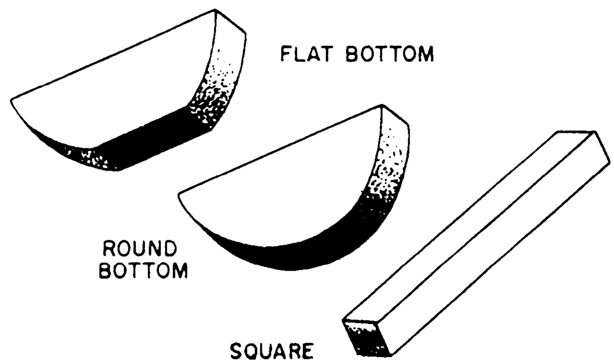


Figure 4-6.—Three types of keys.

Figure 4-7 shows a keyseat and keyway. View A shows a keyseat, which is a slot or groove on the outside of a part into which the key fits. View B shows a keyway, which 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.

SCREW THREADS

Draftsmen use different methods to show thread on drawings. Figures 4-8 through 4-11 show several of

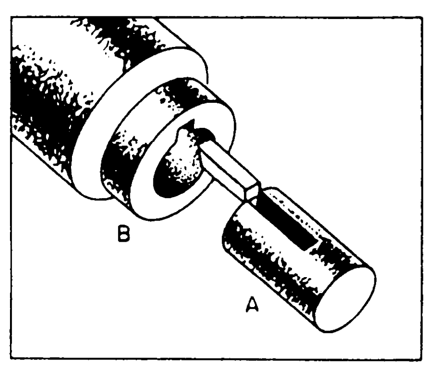


Figure 4-7.—A keyseat and keyway.

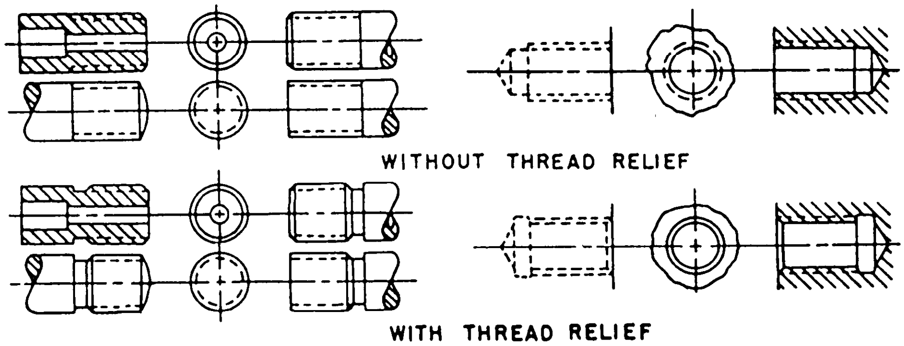


Figure 4-8.—Simplified method of thread representation.

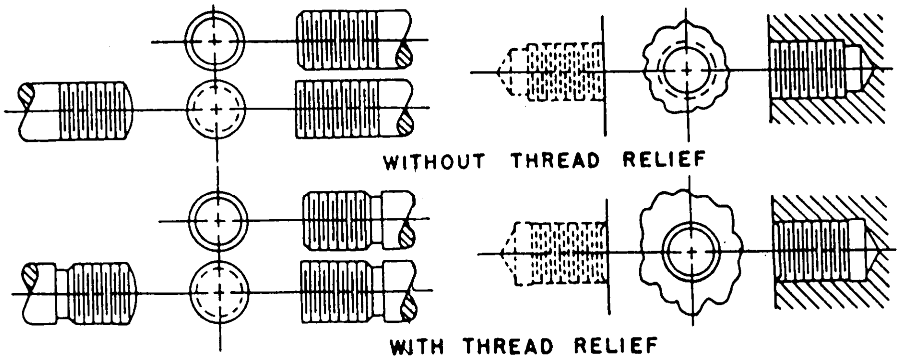


Figure 4-9.—Schematic method of thread representation.

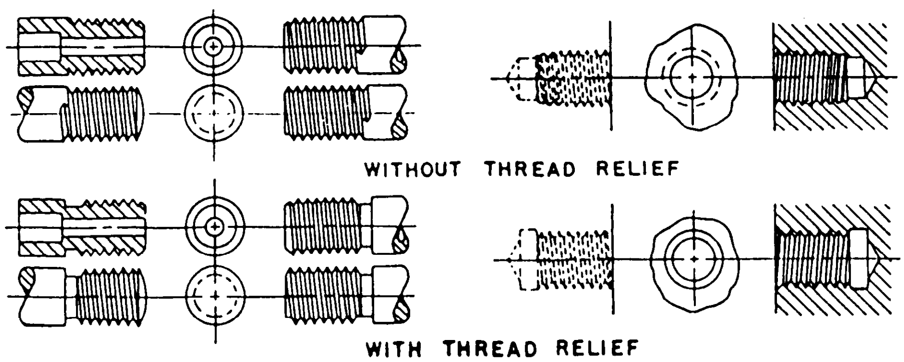


Figure 4-10.—Detailed method of thread representation.

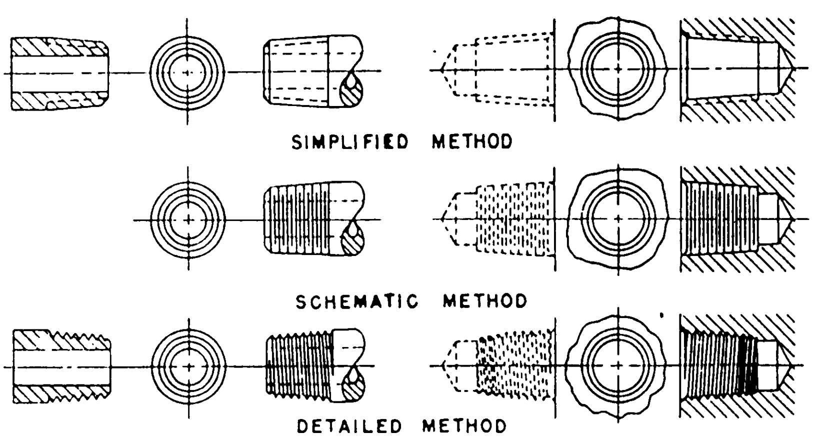


FIgure 4-11.—Tapered pipe thread representation.

them. Now look at 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, the draftsman uses symbols that 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 our 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 letters UNC identify the thread series as Unified National Coarse. 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 (1) Unified or

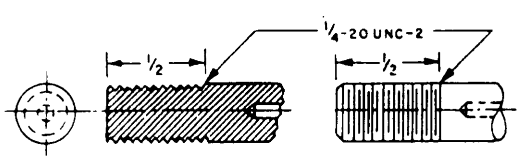


Figure 4-12.—Outside threads.

National Form Threads, which are called National Coarse, or NC, and (2) National Fine, or NF threads. 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. Classes of thread were formerly known as *class of fit,* a term that will probably remain in use for many years. The new term, *class of thread,* was established by the National Bureau of Standards in the *Screw-Thread Standards for Federal Services,* Handbook H-28.

Figure 4-13 shows the terminology used to describe screw threads. Each of the terms is explained in the following list:

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

EXTERNAL THREAD—A thread on the outside of a member. An example is the thread of a bolt.

INTERNAL THREAD—A thread on the inside of a member. An example is the thread inside a nut.

MAJOR DIAMETER—The largest diameter of an external or internal thread

AXIS—The center line running lengthwise through a screw.

CREST—The surface of the thread corresponding to the major diameter of an external thread and the minor diameter of an internal thread.

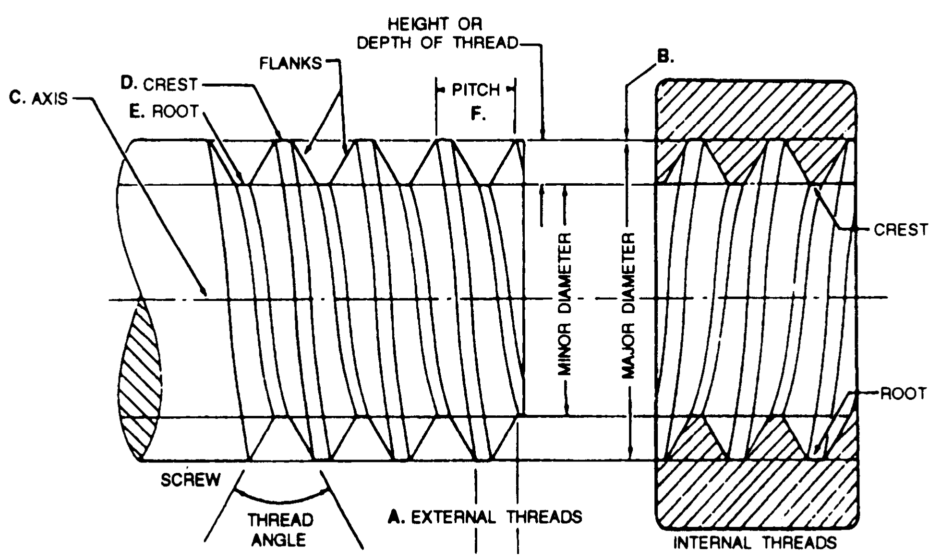


Figure 4-13.—Screw thread terminology.

ROOT—The surface of the thread corresponding to the minor diameter of an external thread and the major diameter of an internal thread

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

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

GEARS

When gears are drawn on machine drawings, the draftsman usually draws only enough gear teeth to identify the necessary dimensions. Figure 4-14 shows gear nomenclature, and the terms in the figure are explained in the following list:

PITCH DIAMETER (PD)—The diameter of the pitch circle (or line), which equals the number of teeth on the gear divided by the diametral pitch

DIAMETRAL PITCH (DP)—The number of teeth to each inch of the pitch diameter or the number of teeth on the gear divided by the pitch diameter. Diametral pitch is usually referred to as simply PITCH.

NUMBER OF TEETH (N)—The diametral pitch multiplied by the diameter of the pitch circle (DP x PD).

ADDENDUM CIRCLE (AC)—The circle over the tops of the teeth.

OUTSIDE DIAMETER (OD)—The diameter of the addendum circle.

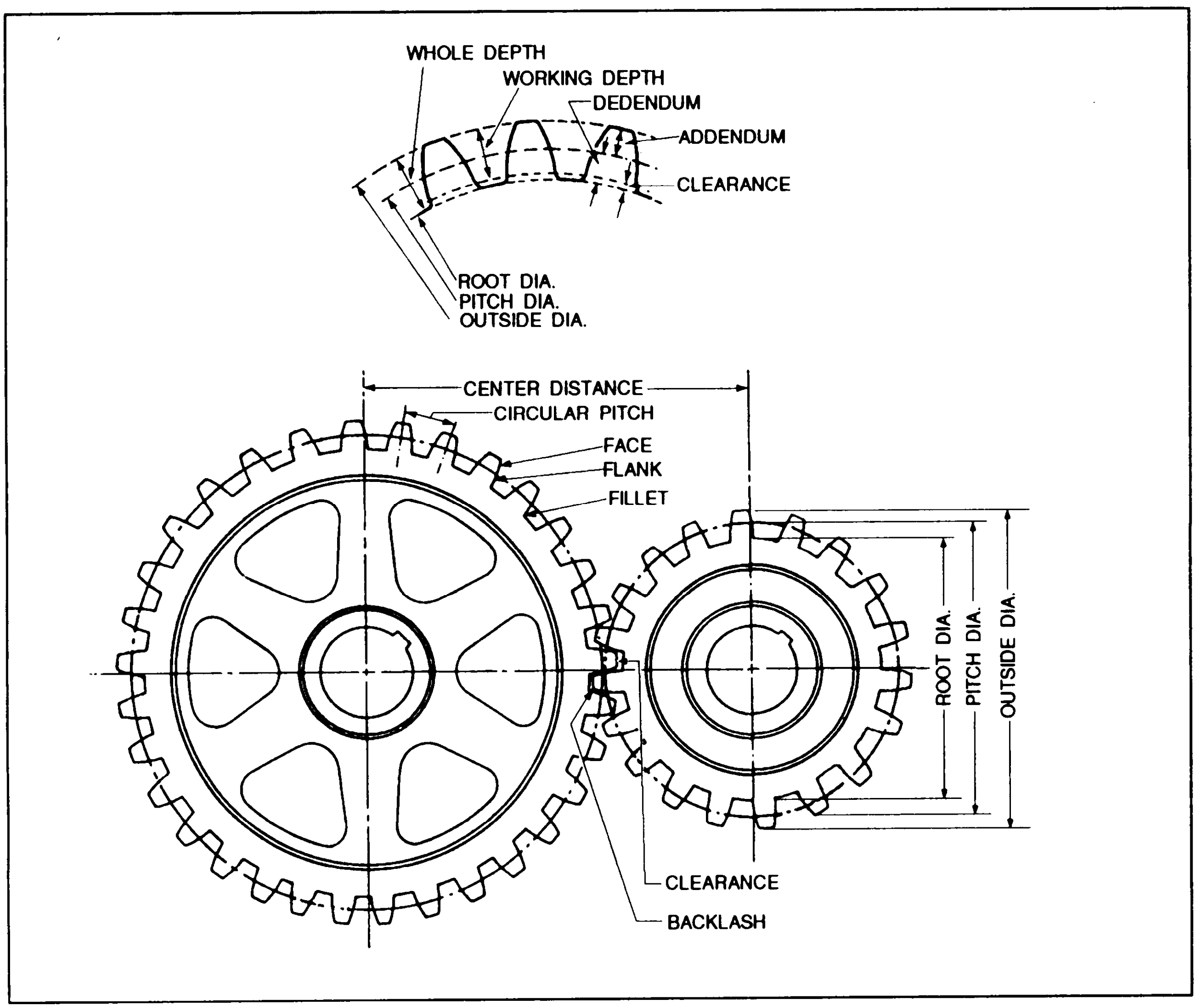


Figure 4-14.—Gear nomenclature.

CIRCULAR PITCH (CP)—The length of the arc of the pitch circle between the centers or corresponding points of adjacent teeth.

ADDENDUM (A)—The height of the tooth above the pitch circle or the radial distance between the pitch circle and the top of the tooth.

DEDENDUM (D)—The length of the portion of the tooth from the pitch circle to the base of the tooth.

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

ROOT DIAMETER (RD)—The diameter of the circle at the root of the teeth.

CLEARANCE (C)—The distance between the bottom of a tooth and the top of a mating tooth.

WHOLE DEPTH (WD)—The distance from the top of the tooth to the bottom, including the clearance.

FACE—The working surface of the tooth over the pitch line.

THICKNESS—The width of the tooth, taken as a chord of the pitch circle.

PITCH CIRCLE—The circle having the pitch diameter.

WORKING DEPTH—The greatest depth to which a tooth of one gear extends into the tooth space of another gear.

RACK TEETH—A rack may be compared to a spur gear that has been straightened out. 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 presentation of the helical shape; instead, they usually show springs with straight lines. Figure 4-15 shows several methods of spring representation including both helical and straight-line drawings. Also, springs are sometimes shown as single-line drawings as in figure 4-16.

FINISH MARKS

The military standards for finish marks are set forth in ANSI 46.1-1962. 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.

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

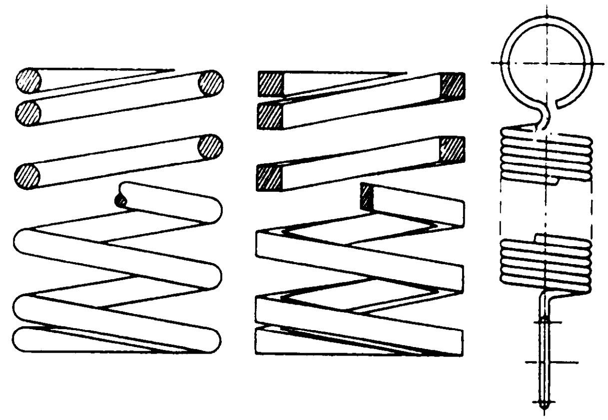


Figure 4-15.—Representation of commm types of helical springs.

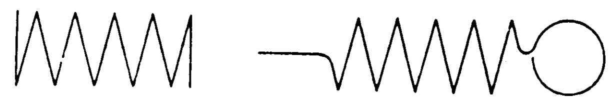


Figure 4-16.—Single line representation of springs

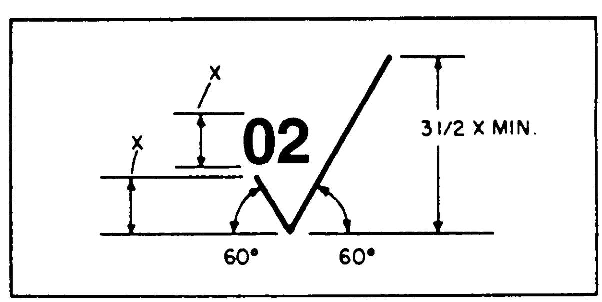


Figure 4-17.—Proportions for a basic finish symbol.

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 (fig. 4-19).

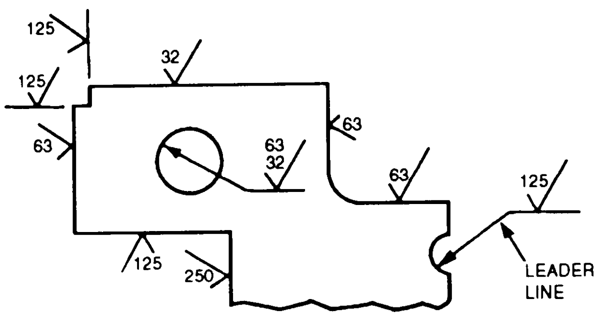


Figure 4-18.—Methods of placing surface roughness symbols.

STANDARDS

American industry has adopted a new standard, *Geometrical Dimensioning and Tolerancing,* ANSI Y14.5M-1982. 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 simplist hand-made job on site to single or multiple-run items produced in a machine shop with computer-aided manufacturing (CAM) which we explained in chapter 2. DOD is now adopting this standard For further information, refer to ANSI Y14.5M-1982 and to *Introduction to Geometrical Dimensioning and Tolerancing,* Lowell W. Foster, National Tooling and Machining Association, Fort Washington, MD, 1986.

The following military standards contain most of the information on symbols, conventions, tolerances, and abbreviations used in shop or working drawings:

ANSI Y14.5M-1982	Dimensioning and Tolerancing
MIL-STD-9A	Screw Thread Conventions and Methods of Specifying
ANSI 46.1	Surface Texture
MIL-STD-12,C	Abbreviations for Use On Drawings and In Technical-Type Publications

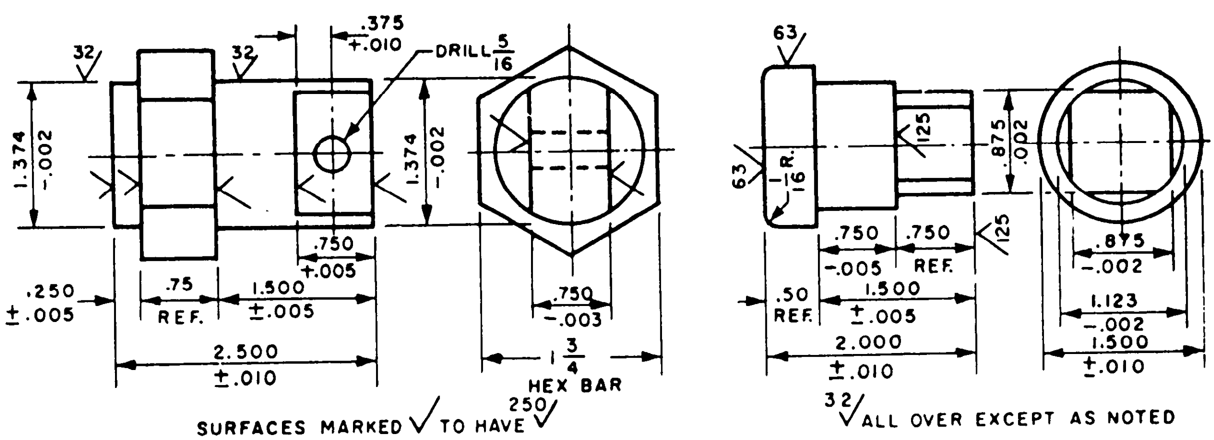


FIgure 4-19.—Typical examples of symbol use.

CHAPTER 5

PIPING SYSTEMS

When you have read and understood this chapter, you should be able to answer the following learning objectives:

- *Interpret piping blueprints.*
- *Identify shipboard hydraulic and plumbing 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, drafters and engineers should become familiar with pipe drawings.

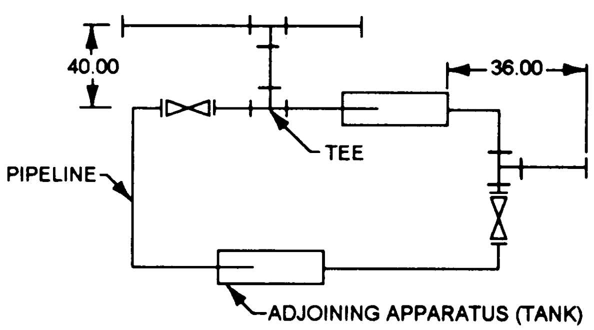


Figure 5-1.—Single-line orthographic pipe drawing.

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. We will show and explain the symbols later in this chapter.

Two methods of projection used in pipe drawings are orthographic and isometric (pictorial). Chapter 3 has a general description of these methods and the following paragraphs explain their use in pipe drawings.

ORTHOGRAPHIC PIPE DRAWINGS

Single- and double-line orthographic pipe drawings (fig. 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.

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.

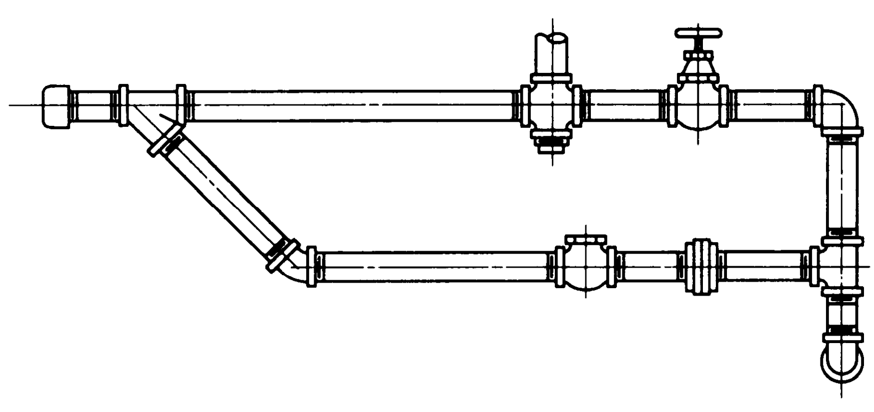


Figure 5-2.—Double-line orthographic pipe drawing.

Draftsmen use single-line drawings to show the arrangement of pipes and fittings. Figure 5-3 is a single-line (isometric) pictorial drawing of figure 5-1. 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.

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

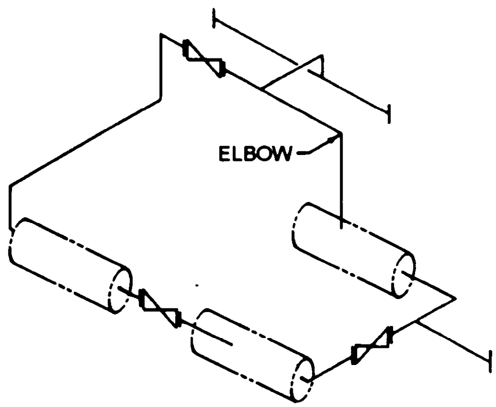


Figure 5-3.—Single-line pictorial piping drawing of figure 5-1.

CROSSINGS

The crossing of pipes without connections is normally shown without interrupting the line representing the hidden line (fig. 5-5, view A). 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, view B.

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 (fig. 5-6). The draftsman normally will use a general note or specification to describe the type of connection.

Detachable connections are shown by a single thick line (figs. 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.

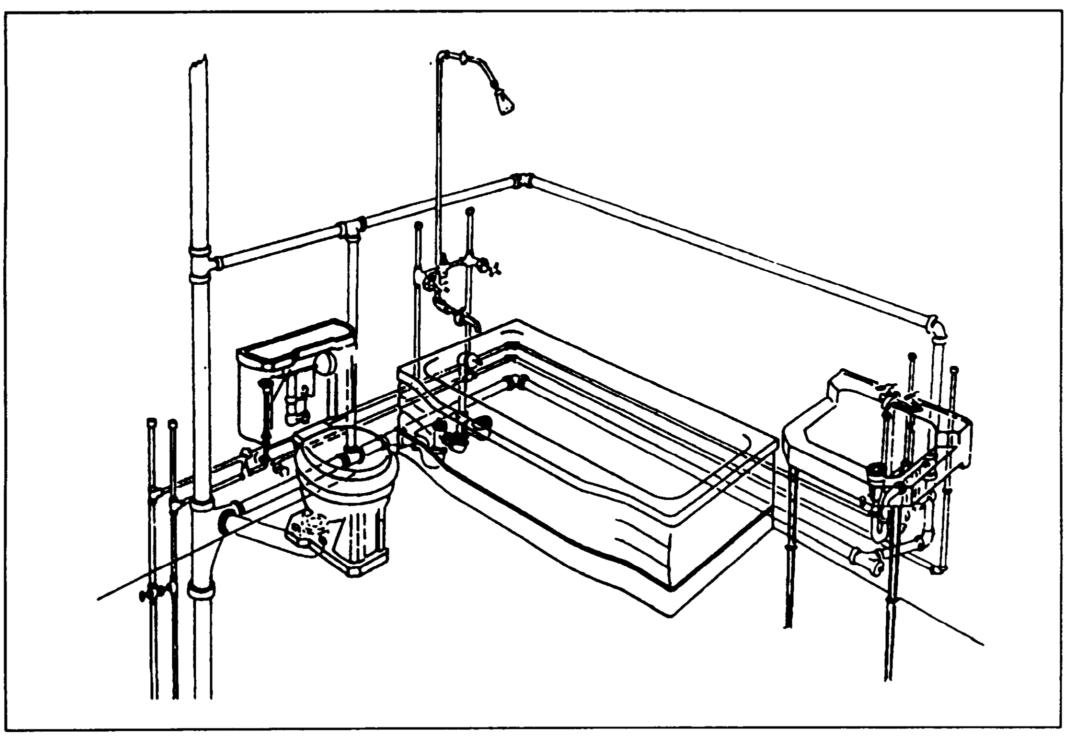


Figure 5-4.—Double-line pictorial piping drawing.

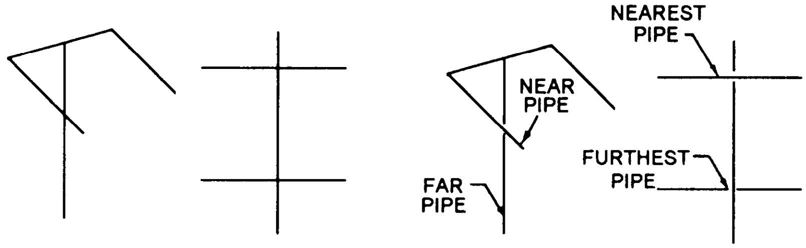


Figure 5-5.—Crossing of pipes.

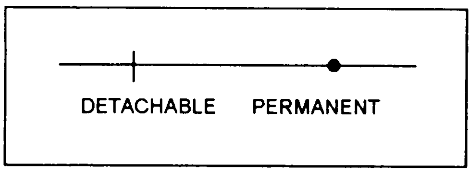


Figure 5-6.—Pipe connection.

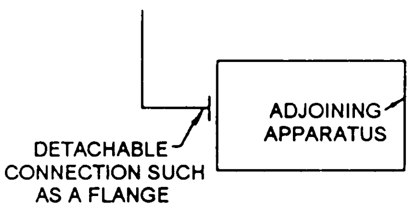


Figure 5-7.—Adjoining apparatus.

FITTINGS

If standard symbols for fittings like tees, elbows, crossings, and so forth are not shown on a drawing, they are represented by a continuous line. The circular symbol for a tee or elbow may be used when it is necessary to show the piping coming toward or moving away from the viewer. Figure 5-8, views A and B, show circular symbols for a connection with and without flanges.

Symbols and Markings

MIL-STD-17B, part I, lists mechanical symbols used on piping prints other than those for aeronautical, aerospacecraft, and spacecraft, which are listed in MIL-STD-17B, part II. Figure 5-9 shows common symbols from MIL-STD-17B, part I. Note that the symbols may show types of connections

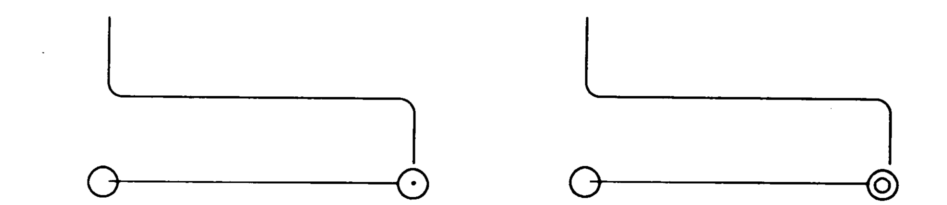


Figure 5-8.—Indicating ends of pipe and fittings.

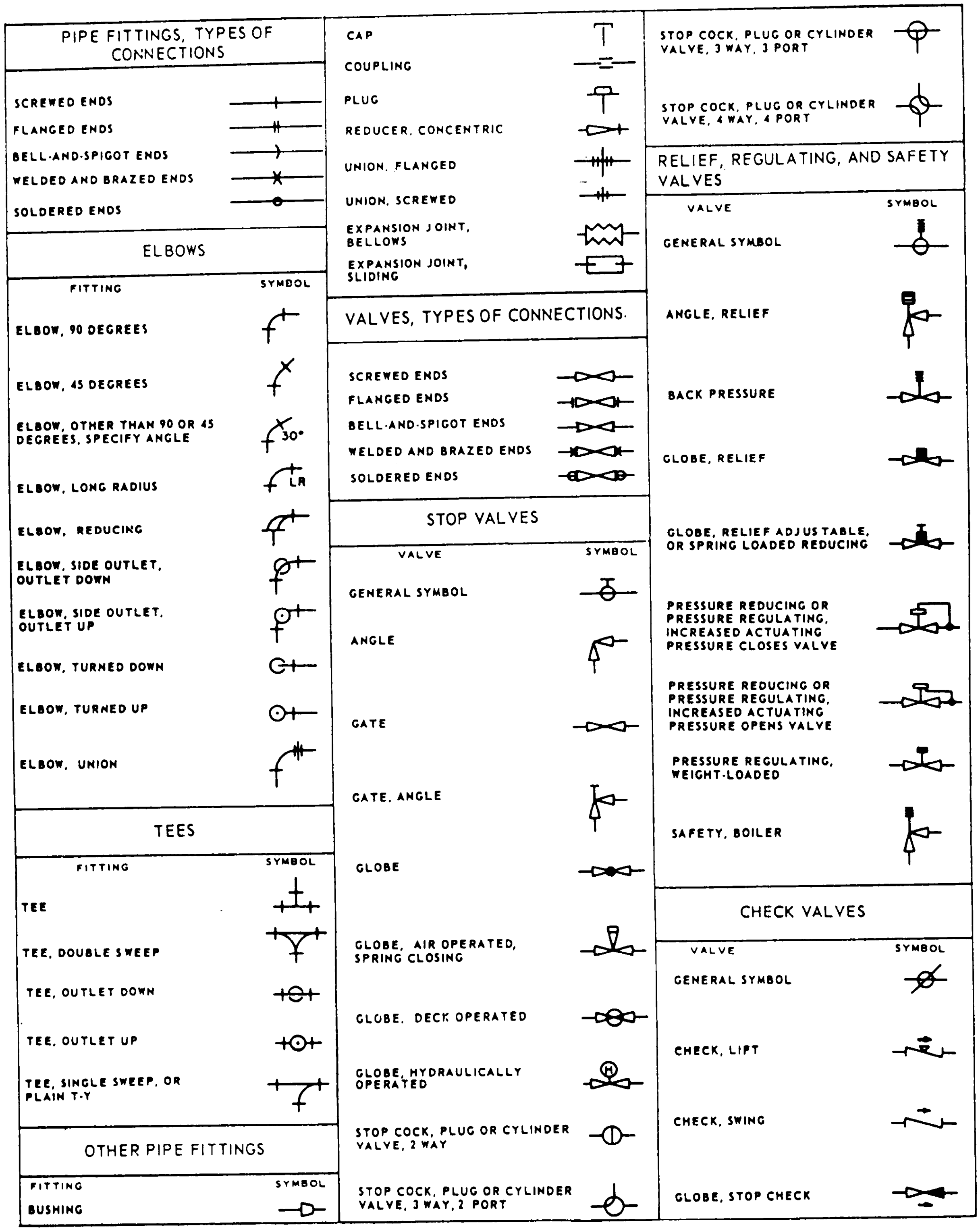


Figure 5-9.—Symbols used in engineering plans and diagrams.

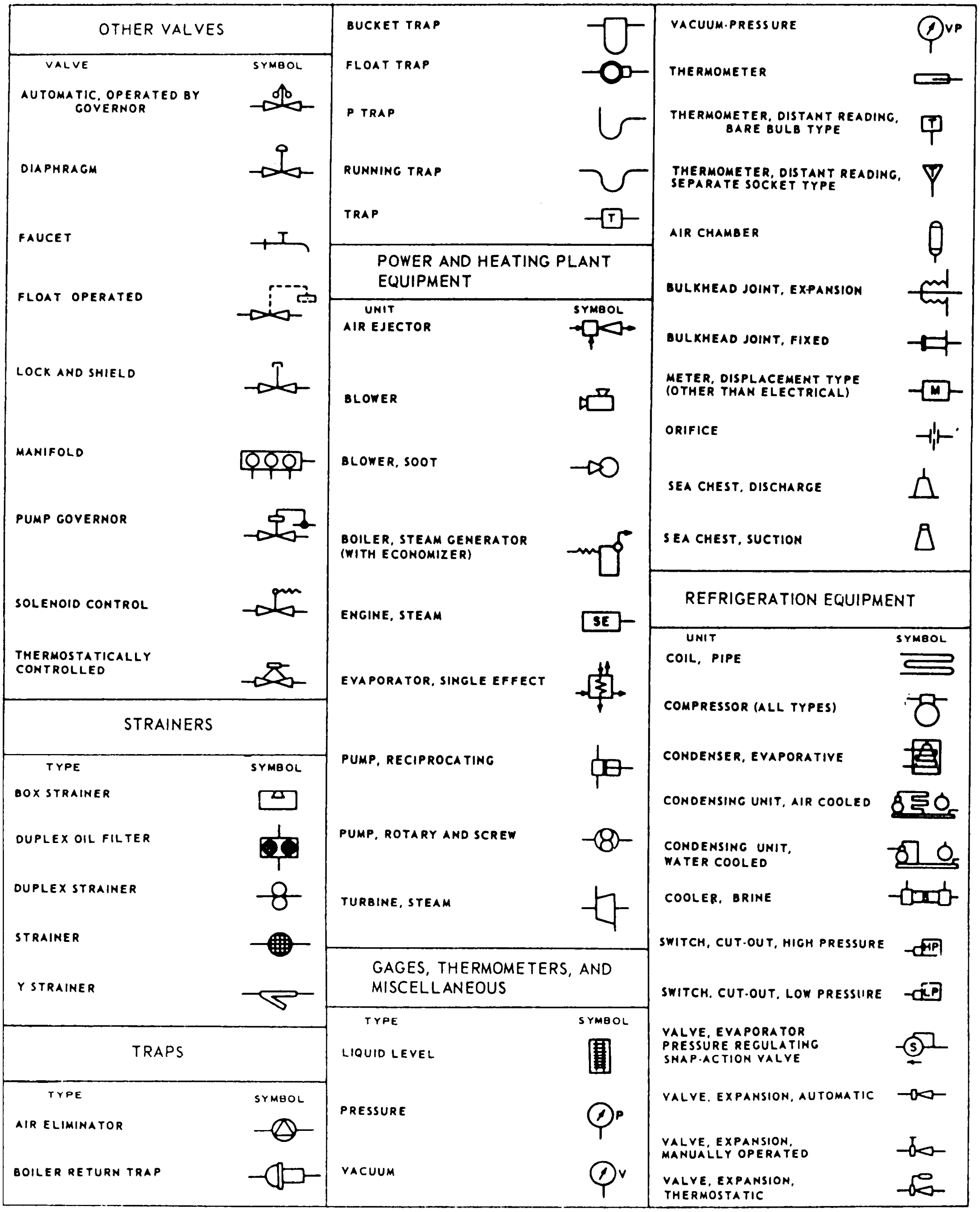


Figure 5-9.—Symbols used in engineering plans and diagram—Continued.

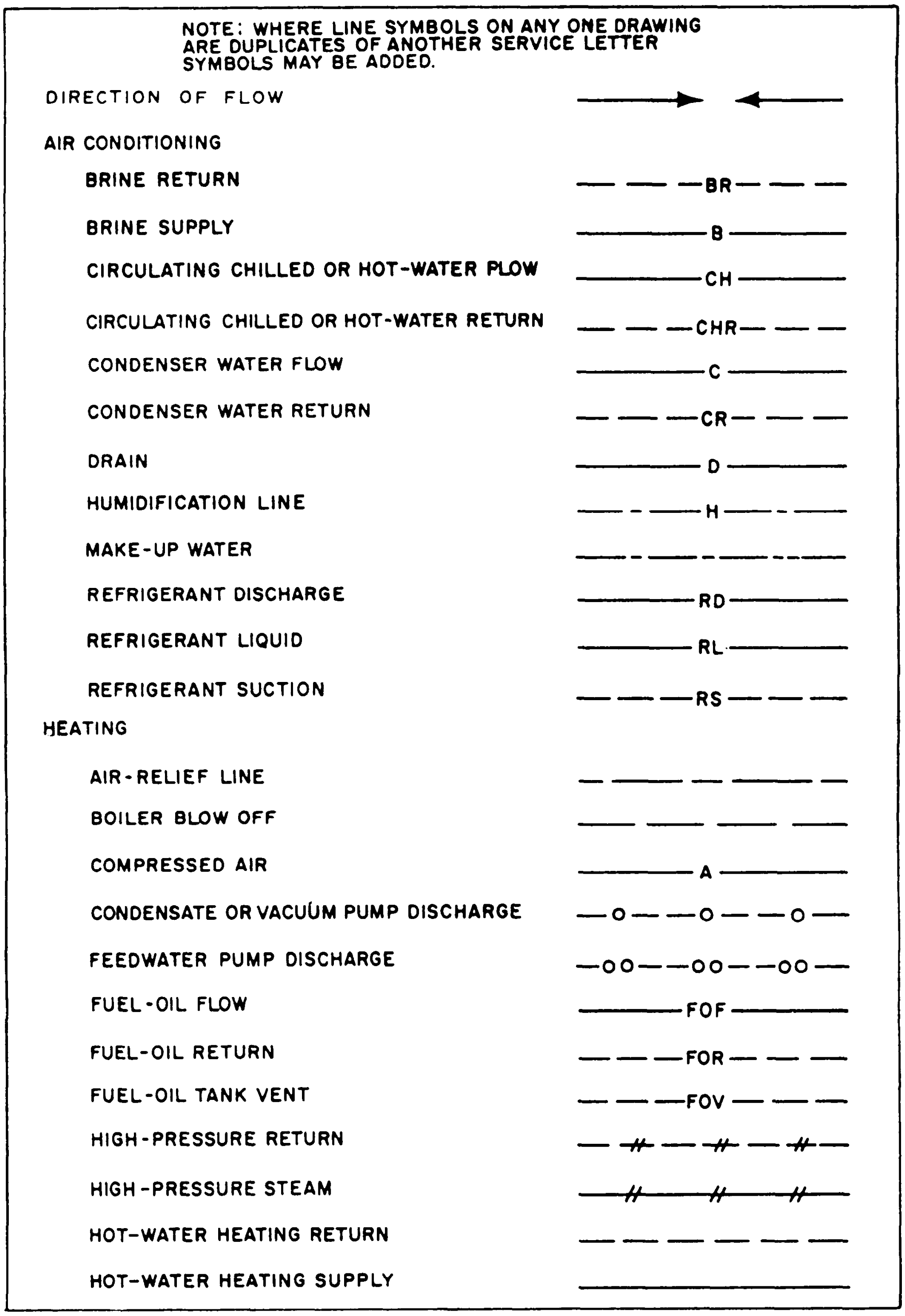


Figure 5-10.—Pipe line symbols.

(screwed, flanged, welded, and so forth) as well as fittings, valves, gauges, and items of equipment. When an item is not covered in the standards, the responsible activity designs a suitable symbol and explains it in a note.

Figure 5-10 shows some of the common piping symbols used in piping prints. 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.

MIL-STD-101C established 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, the piping itself is optional. The following colors are painted on valve wheels and pipe lines carrying hazardous fluids:

Yellow — Flammable materials

Brown — Toxic and poisonous materials

Blue — Anesthetics and harmful materials

Green — Oxidizing materials

Gray — Physically dangerous materials

Red — Fire protection materials

Fluid lines in aircraft are marked according to MIL-STD-1247C, *Markings, Functions, and Designations of Hoses, Piping, and Tube Lines for Aircraft, Missiles, and Space Systems.* Figure 5-11 lists the types of aircraft fluid lines with the color code and symbol for each type. Aircraft fluid lines are also

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	
Deicing	Gray	
Rocket Catalyst	Yellow, Green	
Compressed gas	Orange	
Electrical Conduit	Brown, Orange	
Inerting	Orange, Green	

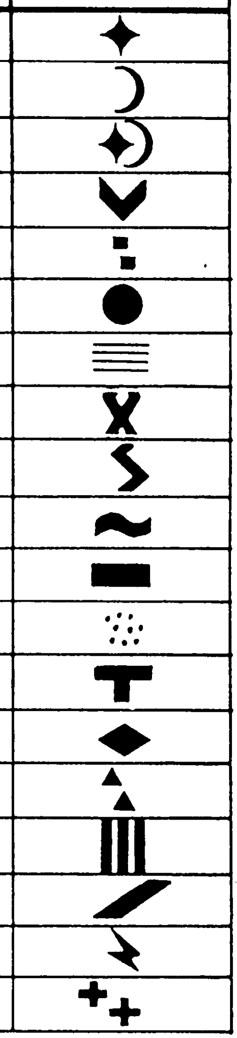


Figure 5-11.—Aircraft fluid line color code and symbols.

marked with an arrow to show direction of flow and hazard marking, as you will see later in this chapter. The following paragraphs contain markings for the four general classes of hazards, and figure 5-12 shows examples of the hazards in each class.

FLAM — This marking identifies all materials ordinarily known as flammable or combustible.

TOXIC — This marking identifies materials that are extremely hazardous to life or health.

AAHM — This marking identifies anesthetics and harmful materials. These include all materials that produce anesthetic vapors. They also include those that do not normally produce dangerous fumes or vapors, but are hazardous to life and property.

PHDAN — This marking identifies a line that carries material that is not dangerous in itself, but is asphyxiating in confined areas. These materials are generally handled in a dangerous physical state of pressure or temperature.

SHIPBOARD PIPING PRINTS

There are various types of shipboard piping systems. Figure 5-13 shows a section of a piping diagram for a heavy cruiser. Note that the drawing uses the standard symbols shown in figure 5-9, and that it includes a symbol list. Some small piping diagrams do not include a symbol list; therefore, you must be familiar with the standard symbols to interpret these diagrams.

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 5-14, or a block diagram arrangement (fig. 5-15) may be used.

HYDRAULIC PRINTS

The Navy has increased its use of hydraulic systems, tools, and machines in recent years. 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 maintenance and repair shop equipment. Hydraulic systems are also used in construction, automotive, and weight-handling equipment. Basic hydraulic principles are discussed in the basic training course *Fluid Power,* NAVEDTRA 12064.

To help you distinguish one hydraulic line from another, the draftsman designates each line according

FLUID	HAZARD
Air (under pressure)	PHDAN
Alcohol	FLAM
Carbon dioxide	PHDAN
FREON	PHDAN
Gaseous oxygen	PHDAN
Liquid nitrogen	PHDAN
LPG (liquid petroleum gas)	FLAM
Nitrogen gas	PHDAN
Oils and greases	FLAM
JP-5	FLAM
Trichloroethylene	AAHM

Figure 5-12.—Hazards associated with various fluids.

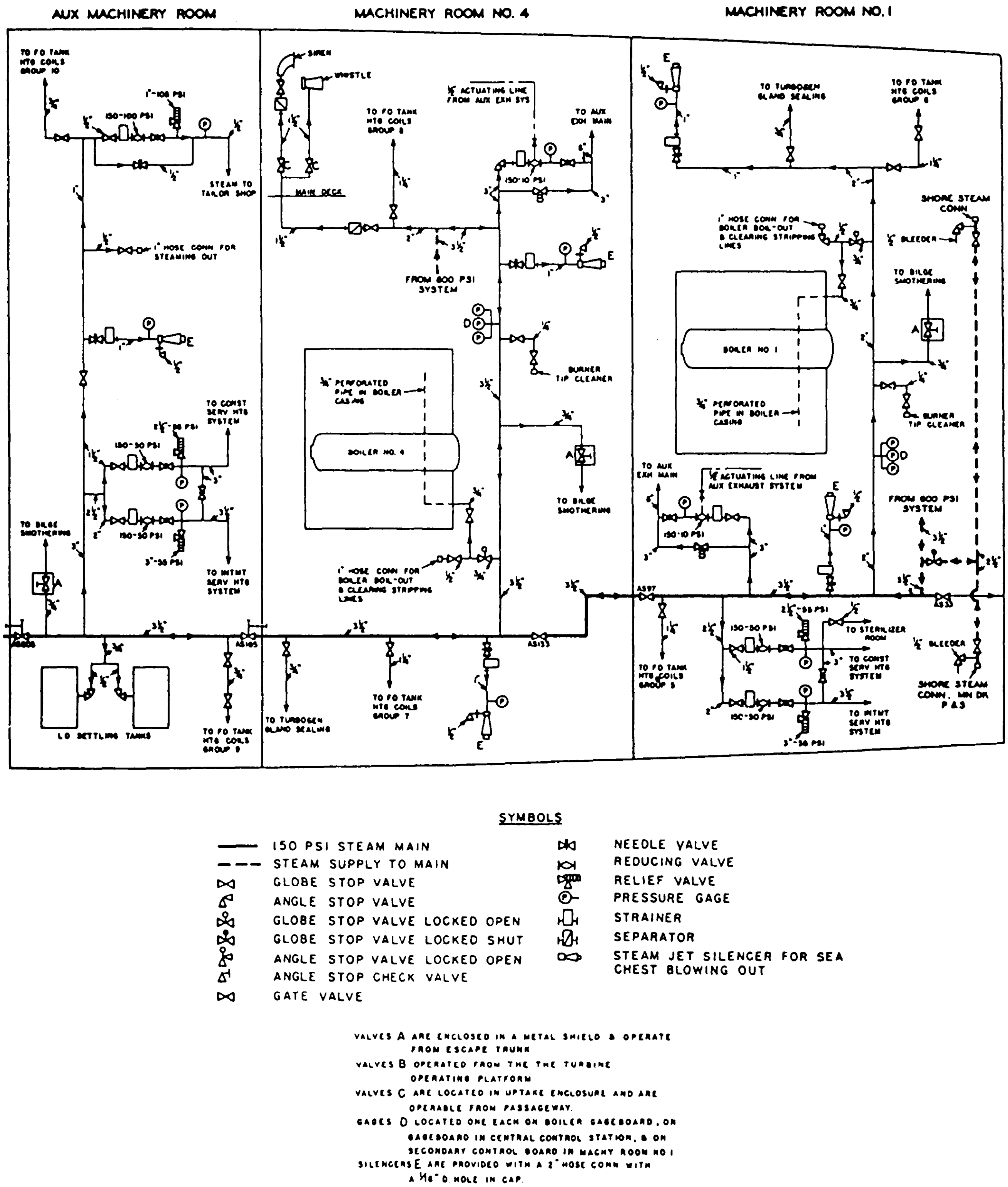


Figure 5-13.—A section of an auxiliary steam system piping diagram.

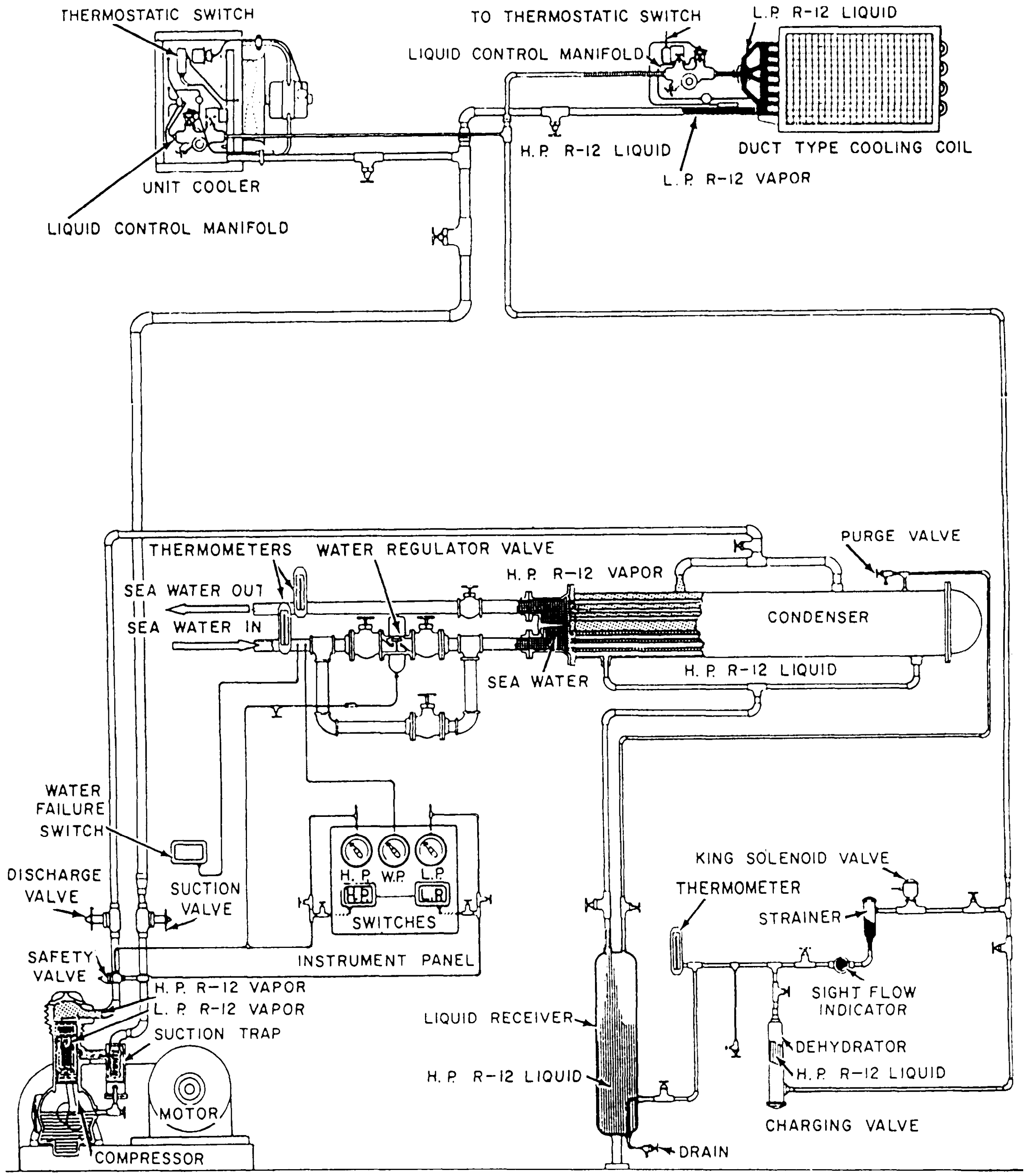


Figure 5-14.—Shipboard refrigerant circulating air-conditioning system.

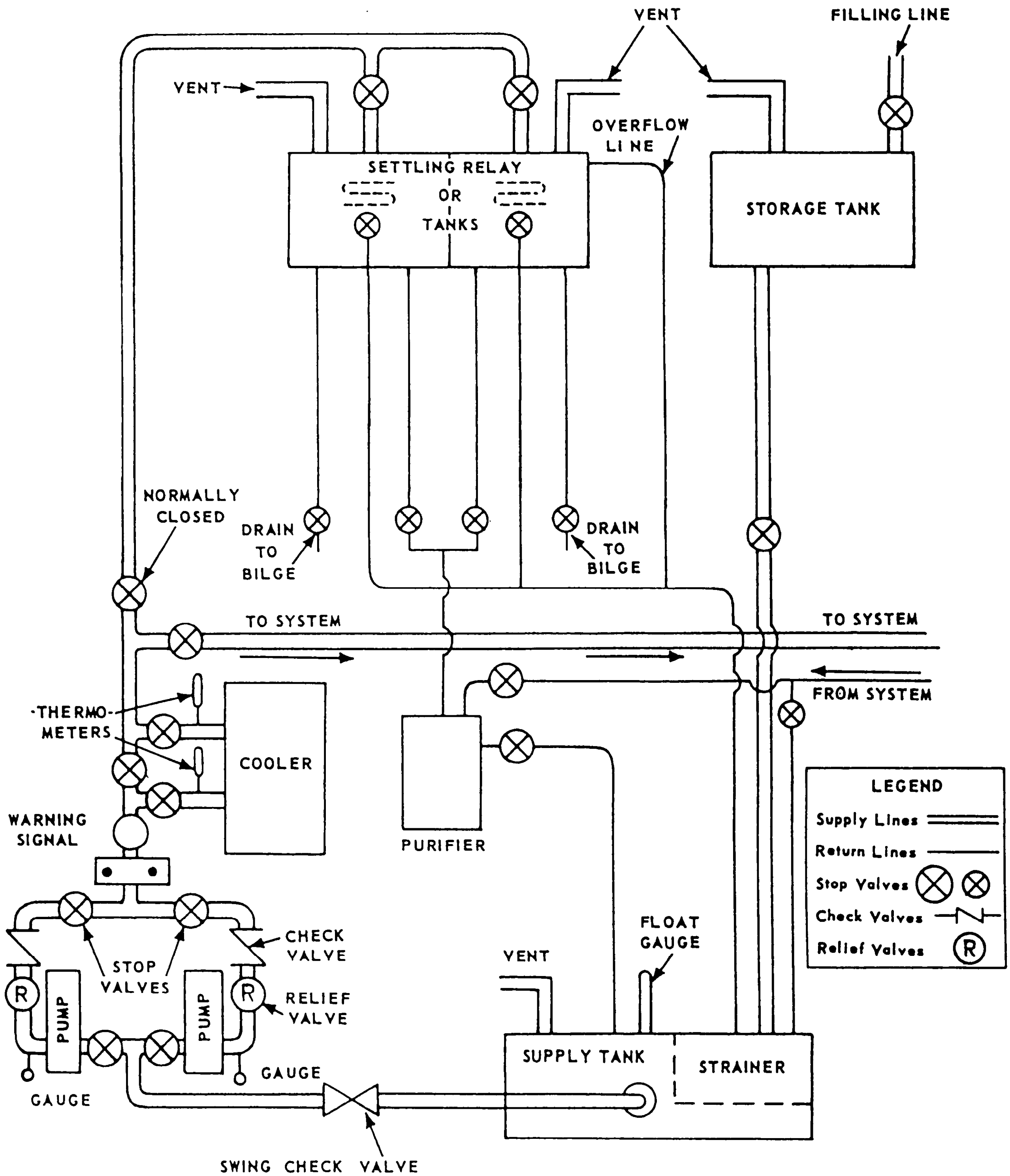


Figure 5-15.—Shipboard forced-lubrication system.

to its function within the system. In general, hydraulic lines are designated as follows:

SUPPLY LINES—These lines carry fluid from the reservoir to the pumps. They may be called suction lines.

PRESSURE LINES—These lines carry only pressure. They 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—These lines alternately carry pressure to, and return fluid from, an actuating unit. They also may be called working lines. Each line is identified according to its specific function.

RETURN LINES—These lines return fluid from any portion of the system to a reservoir.

VENT LINES—These lines carry excess fluid overboard or into another receptacle.

MIL-STD-17B, part II, lists symbols that are used on hydraulic diagrams. Figure 5-16 shows the basic outline of each symbol. In the actual hydraulic diagrams the basic symbols are often improved, showing a cutaway section of the unit.

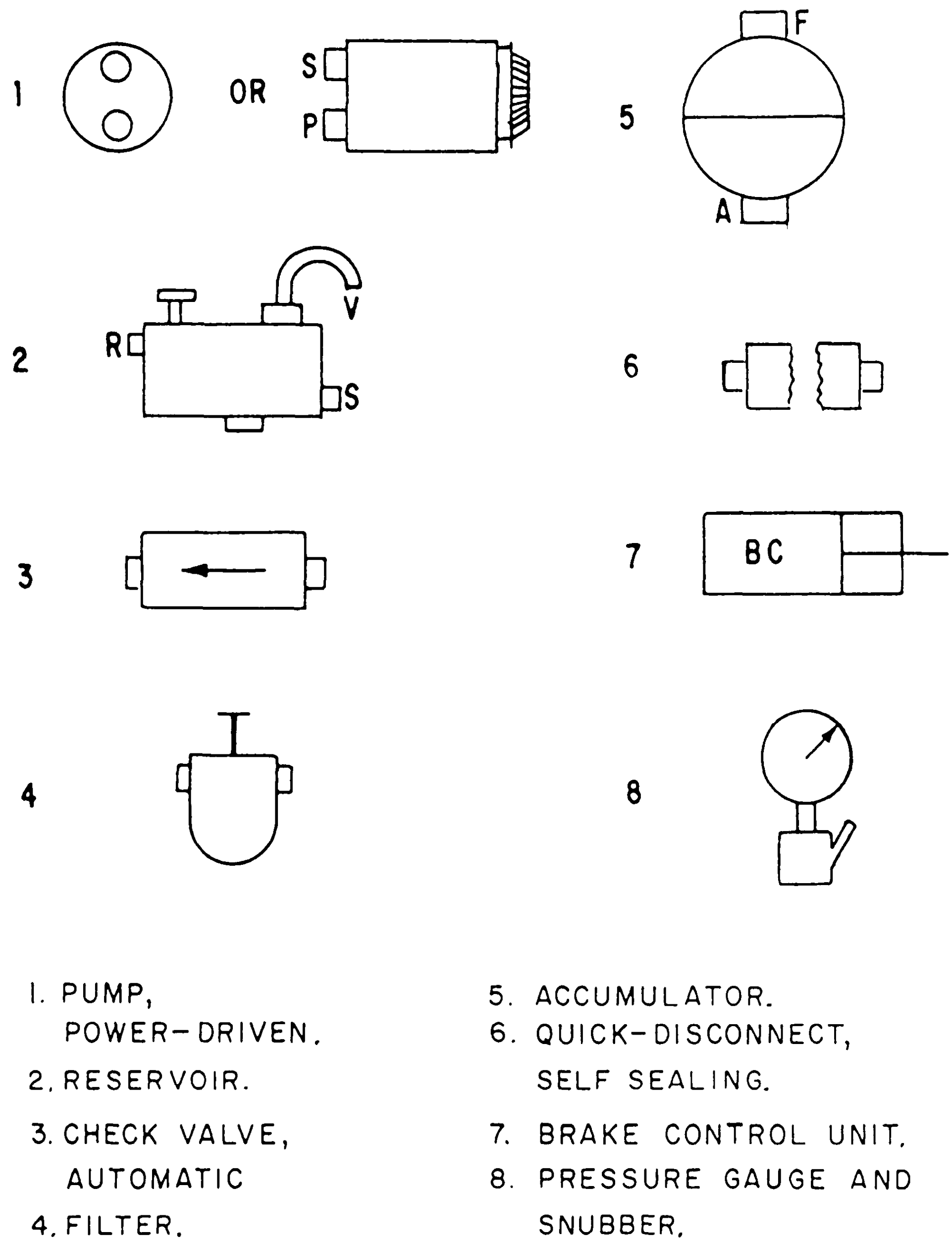


Figure 5-16.—Basic types of hydraulic symbols.

Figure 5-17 shows that the lines on the hydraulic diagram are identified as to purpose and the arrows point the direction of flow. Figure 5-18 and appendix II contain additional symbols and conventions used on aircraft hydraulic and pneumatic systems and in fluid power diagrams.

PLUMBING PRINTS

Plumbing prints use many of the standard piping symbols shown in figure 5-9. MIL-STD-17B Parts I and II lists other symbols that are used only in plumbing prints, some of which are shown in figure 5-19.

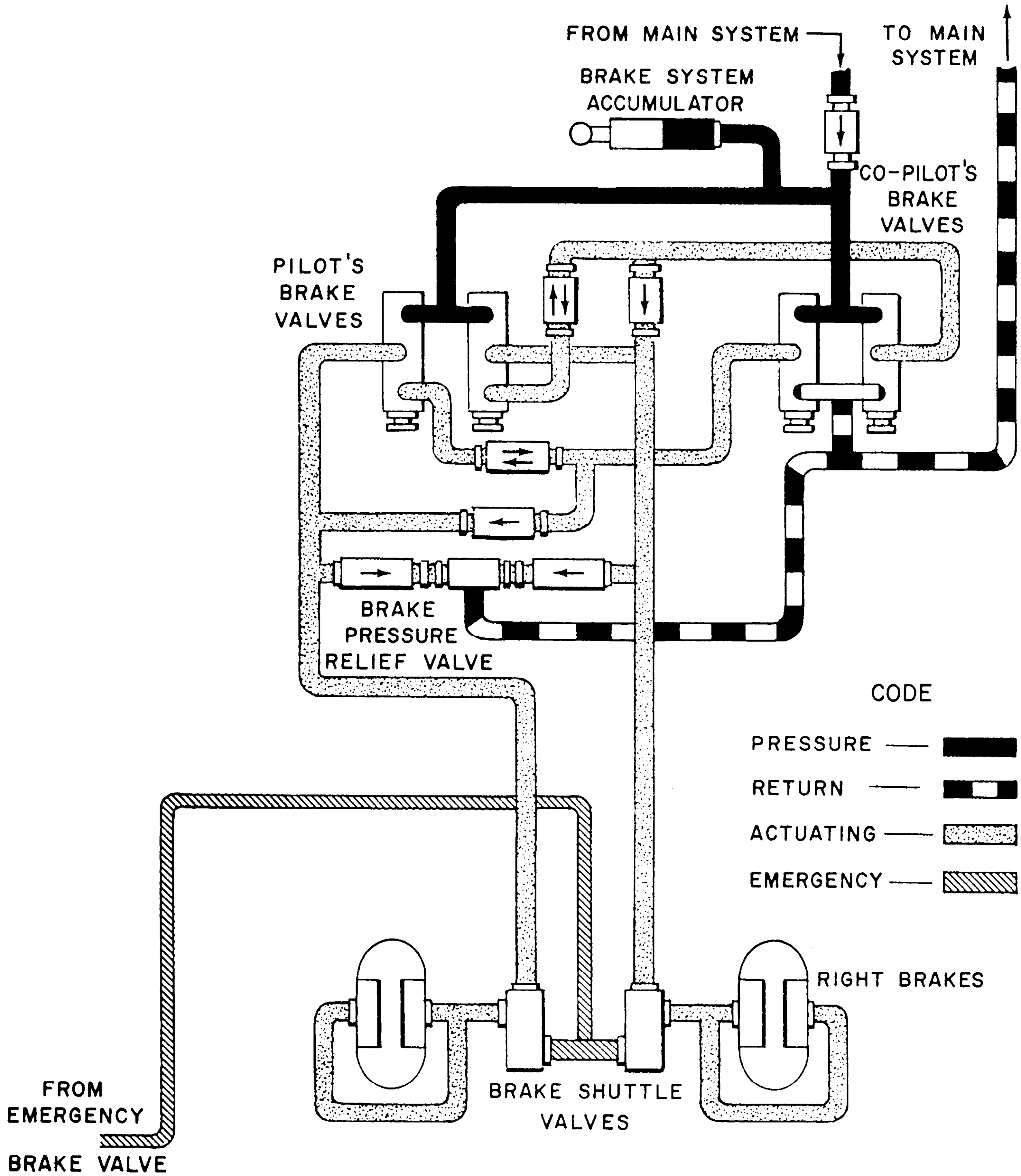


Figure 5-17.—Aircraft power brake control valve system.

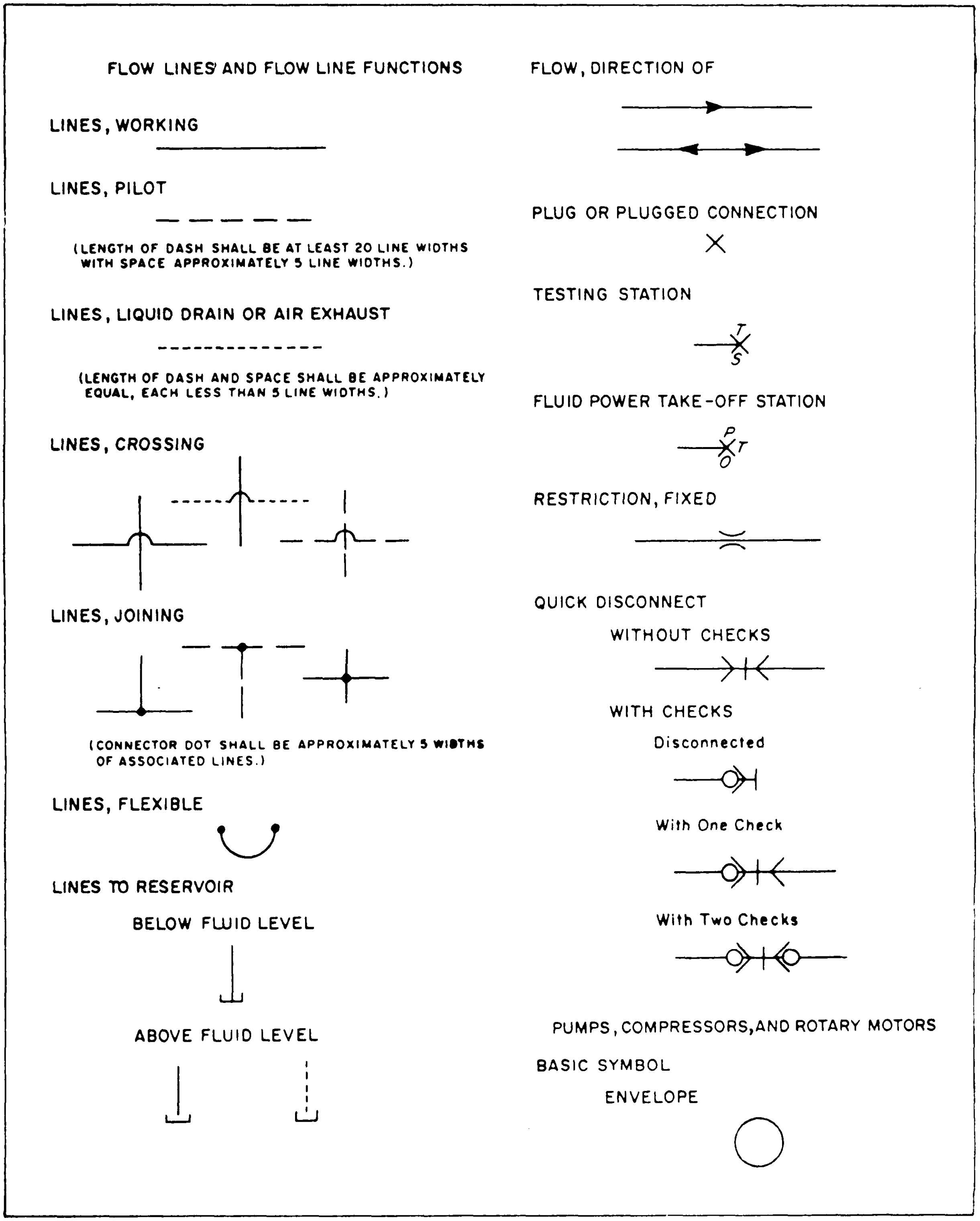


Figure 5-18.—Fluid power symbols.

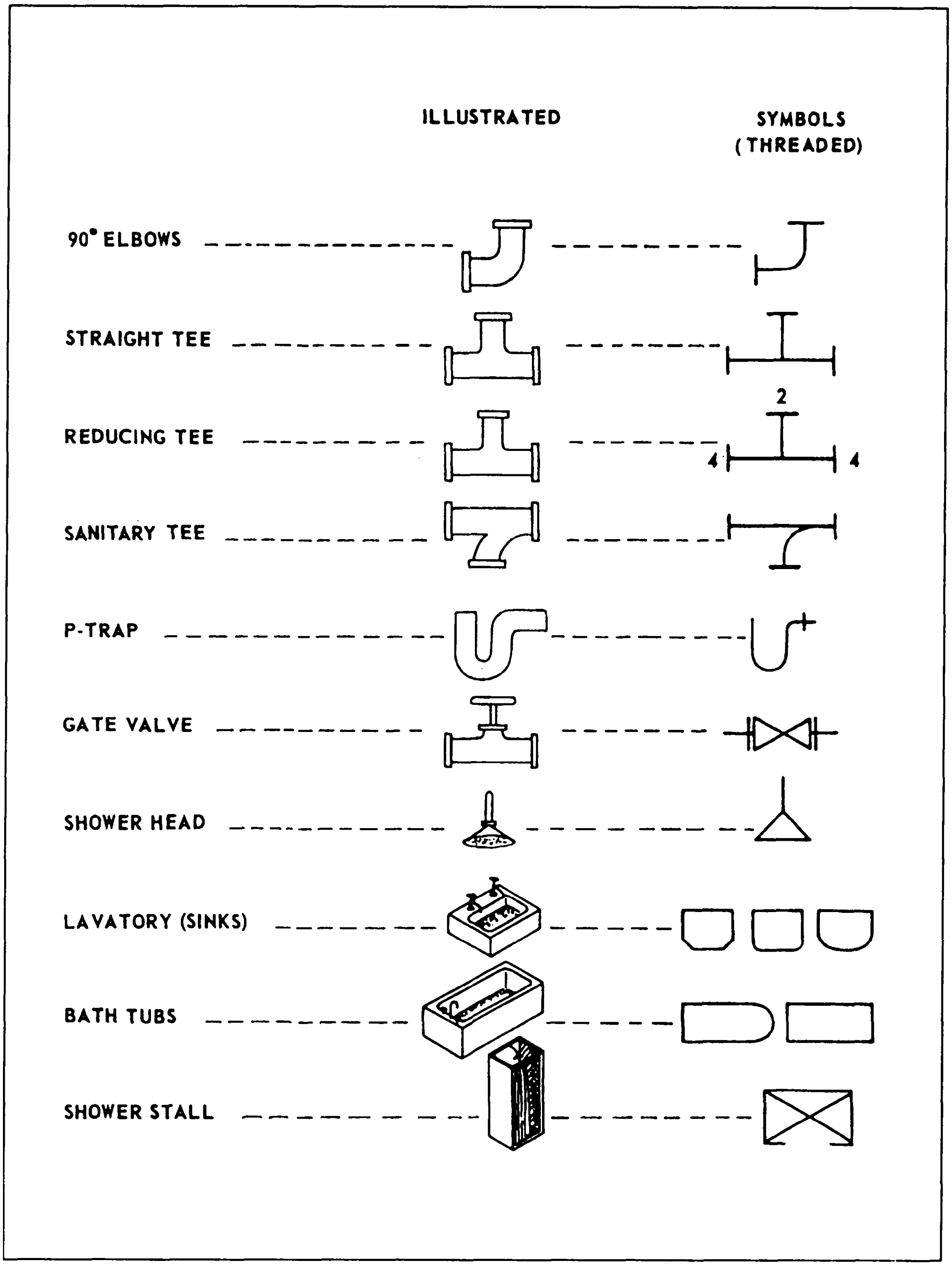


Figure 5-19.—Common plumbing symbols.

Figure 5-20 is a pictorial drawing of a bathroom. 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 5-21, views A and B, are isometric diagrams of the piping in the bathroom shown in figure 5-20. Figure 5-22 is a floor plan of a small house showing the same bathroom, including the locations of fixtures and piping.

To interpret the isometric plumbing diagram shown in figure 5-21, view A, 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 goes to the vent, and the portion leading downward goes 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

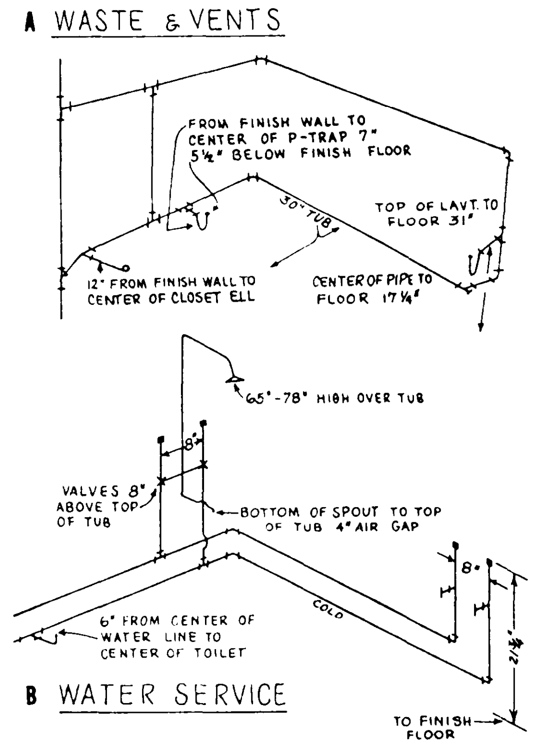


Figure 5-21.—Isometric diagram of a bathroom showing waste, vents, and water service.

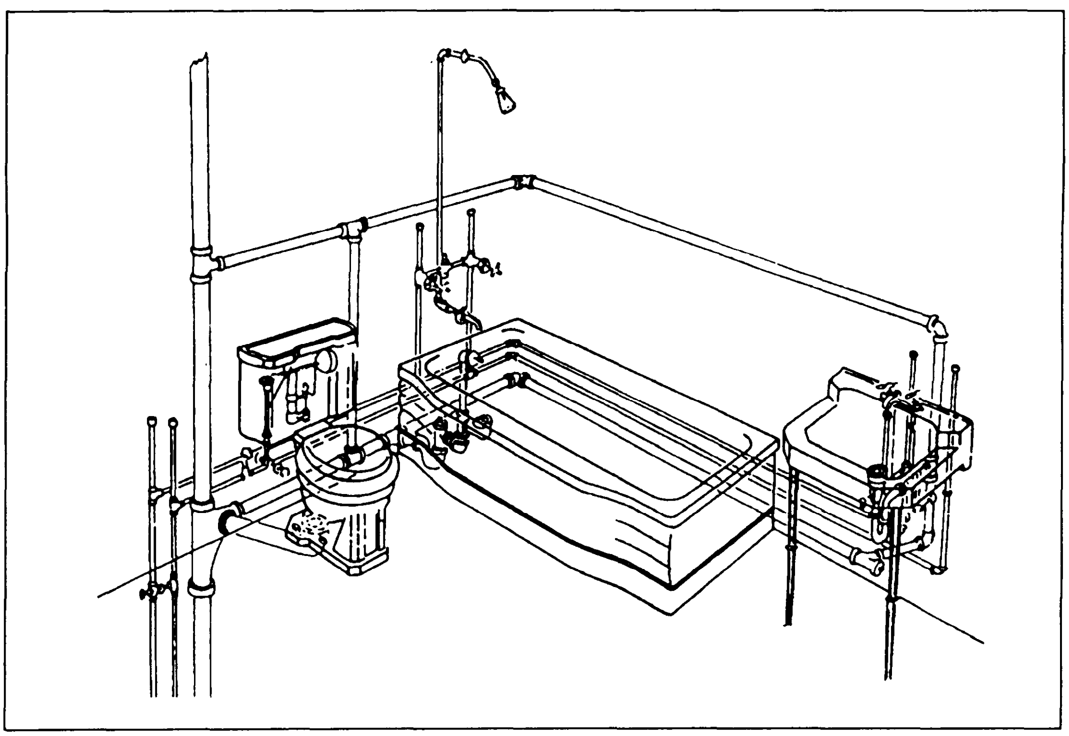


Figure 5-20.—Pictorial view of a typical bathroom.

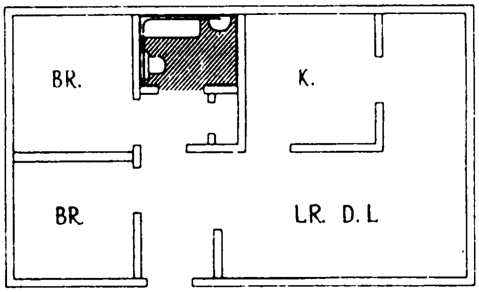


Figure 5-22.—Floor plan of a typical bathroom.

fitting) that leads to a 4-inch main house drain. The vent pipe runs parallel to the floor drain, slightly above the lavatory.

Figure 5-21, view B, 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 5-20 and you can see that the water service pipes are located above the drain pipe.

Figure 5-23 shows you how to read the designations for plumbing fittings. 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, you always read the largest opening first and then follow the alphabetical order. So, if the fitting has openings sized 2 x 1/2 by 1 1/2 by 2 1/2 by 1 1/2 inches, you should read them in this order: A = 2 l/2, B = 1 1/2, C = 2 1/2, and D = 1 1/2 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 5-23 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.

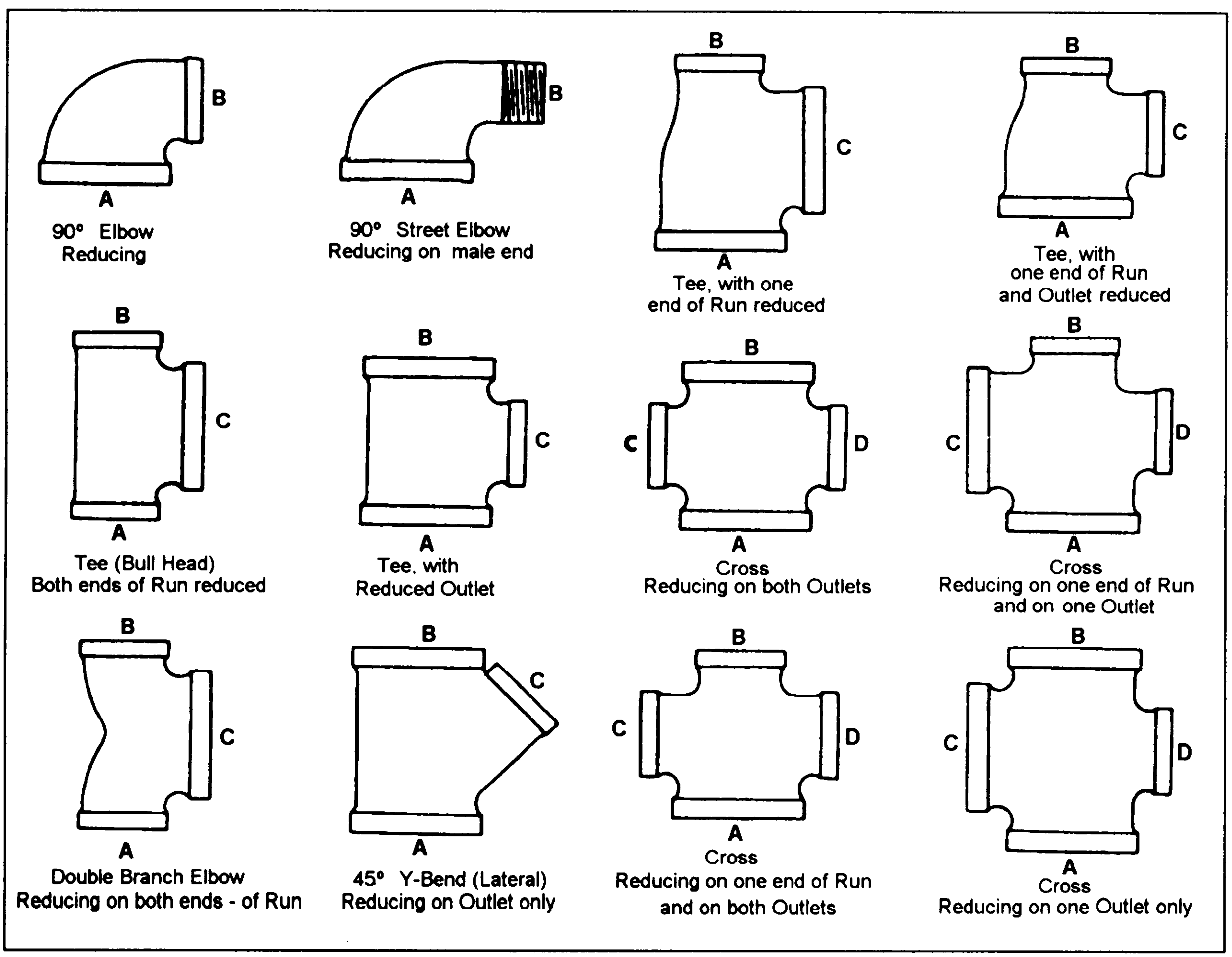


Figure 5-23.—How to read fittings.

CHAPTER 6

ELECTRICAL AND ELECTRONICS PRINTS

When you have read and understood this chapter, you should be able to answer the following learning objectives.

- *Describe shipboard electrical and electronics prints.*
- *Describe aircraft electrical and electronics prints.*
- *Explain basic logic diagrams on blueprints.*

This chapter is divided into two parts: electrical prints and electronics prints. Each part deals with the use of prints on ships and aircraft.

ELECTRICAL PRINTS

A large number of Navy ratings may use Navy electrical prints to install, maintain, and repair equipment. In the most common examples, Navy 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. These prints will make use of the various electrical diagrams defined in the following paragraphs.

A PICTORIAL WIRING DIAGRAM is made up of pictorial sketches of the various parts of an item of equipment and the electrical connections between the parts.

An ISOMETRIC WIRING DIAGRAM shows the outline of a ship or aircraft or other structure, and the location of equipment such as panels, connection boxes, and cable runs.

A SINGLE-LINE DIAGRAM uses lines and graphic symbols to simplify complex circuits or systems.

A SCHEMATIC DIAGRAM uses graphic symbols to show how a circuit functions electrically.

An ELEMENTARY WIRING DIAGRAM shows how each individual conductor is connected within the various connection boxes of an electrical circuit or system. It is sometimes used interchangeably with SCHEMATIC DIAGRAM, especially a simplified schematic diagram.

In a BLOCK DIAGRAM, the major components 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.

Before you can read any blueprint, you must be familiar with the standard symbols for the type of print concerned. To read electrical blueprints, you should know various types of standard symbols and the methods of marking electrical connectors, cables, and equipments. The first part of this chapter discusses these subjects as they are used on ships and aircraft.

SHIPBOARD ELECTRICAL PRINTS

To interpret shipboard electrical prints, you need to recognize the graphic symbols for electrical diagrams and the electrical wiring equipment symbols for ships as shown in *Graphic Symbols for Electrical and Electronic Diagrams*, ANSI Y32.2, and *Electrical Wiring Equipment Symbols for Ships' Plans*, Part 2, MIL-STD-15-2. Appendix 2 contains the common symbols from these standards. In addition, you must also be familiar with the shipboard system of numbering electrical units and marking electrical cables as described in the following paragraphs.

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. It 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, then, 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,* NAVEDTRA 12043. 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 port side 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 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 a system of distribution called zone control. In a zone control 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 discussed previously.

Cable Marking

Metal tags embossed with the cable designations are used to identify all permanently installed shipboard electrical cables. These tags (fig. 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; the old system on pre-1949 ships, and the new system on those built since 1949. We will explain both systems in the following paragraphs.

OLD CABLE TAG SYSTEM.—In the old 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 following basic letters that designate power and lighting cables for the different services:

C	Interior communications
D	Degaussing
F	Ship's service lighting and general power
FB	Battle power
G	Fire control
MS	Minesweeping
P	Electric propulsion
R	Radio and radar
RL	Running, anchor, and signal lights
S	Sonar
FE	Emergency lighting and power

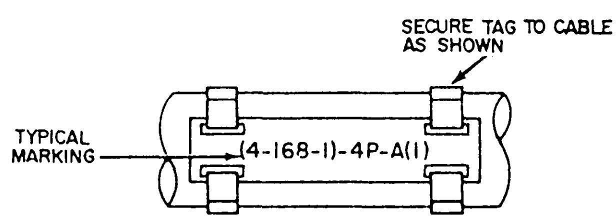


Figure 6-1.—Cable tag.

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.—The new system consists of three parts in sequence; source, voltage, and service, and where practical, destination. These parts are separated by hyphens. The following letters are used to designate the different services:

C Interior communication

D Degaussing

G Fire control

K Control power

L Ship's service lighting

N Navigational lighting

P Ship's service power

R Electronics

CP Casualty power

EL Emergency lighting

EP Emergency power

FL Night flight lights

MC Coolant pump power

MS Minesweeping

PP Propulsion power

SF Special frequency power

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; 2, voltages between 200 and 299; 4, voltages between 400 and 499, and so on. For a three-wire (120/240) 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* shows that this is the first cable from the panel and the (1) shows that it is 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

Phase and polarity in ac and dc electrical systems are designated by a wiring color code as shown in table 6-1. Neutral polarity, where it exists, is identified by the white conductor.

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 athwartship 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.

"Figure 6-2 (four pages at the end of this chapter) shows an isometric diagram of a section of the ship's service and emergency lighting system for a DLG." This figure shows the forward quarter of the decks concerned, whereas the actual blueprint will show the entire decks. Note the reference to another isometric diagram at the top of the figure. It shows that the diagram of the complete lighting system for this ship required two blueprints. All electrical fittings and fixtures shown on the isometric wiring diagram are identified by a symbol number as stated previously. The symbol number is taken from the *Standard Electrical Symbol List*, NAVSHIPS 0960-000-4000. This publication contains a complete list of standard symbol numbers for the various standard electrical fixtures and fittings for shipboard applications. For example, look at the distribution box symbol 615 located on the second platform starboard at frame 19 (fig. 6-2). It is identified in NAVSHIPS 0960-000-4000 as a type D-62A four-circuit distribution box with switches and midget fuses. Its federal stock number is 6110-152-0262.

Cables shown on the isometric wiring diagram are identified by the cable marking system described earlier in this chapter. 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

Table 6-1.—Color Code for Power and Lighting Cable Conductors

System	No. of Conductors in Cable	Phase of Polarity	Color Code
3-phase ac	3	A B C	Black White Red
	2	AB	A, black B, white
	2	BC	B, white C, black
	2	AC	A, black C, white
3-wire dc	3	+ +/-	Black White Red
	2	+ and +/-	+, black +/-, white
	2	+/- and -	+/-, white -, black
	2	+ and -	+, black -, white
2-wire dc	2	+	Black White

two-, T for three-, and F for four-conductor cables. The number following this letter denotes the wire's circular mil area in thousands. For example, the cable supplying distribution box symbol 615 (fig. 6-2) is marked (2-38-1)-L-Al-T-g. This marking identifies a three-conductor, 9000-circular mil, 120-volt, ship's service submain lighting cable supplied from panel 2-38-1. Note that you would need the isometric wiring diagram for the main deck and above to follow the complete run of this cable. This print would show lighting main 2(38-l)-lL-A-T-30 supplying a distribution box somewhere on the main deck (or above), and submain cable (2-38-l)-IL-Al-T-9 coming from this distribution box to supply distribution box symbol 615 on the second platform, frame 19 starboard.

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 MIL-STD-15-2 are used to represent fixtures just as they do in the isometric wiring diagram.

Elementary Wiring Diagram

These diagrams show in detail each conductor, terminal, and connection in a circuit. They are used to check for proper connections in circuit or to make the initial hookup.

In interior communication (IC) circuits, for example, the lugs on the wires in each connection are stamped with conductor markings. The elementary wiring diagrams show these conductor markings alongside each conductor and how they connect in the circuit. Elementary wiring diagrams usually do not show the location of connection boxes, panels, and so on; therefore, they are not drawn to any scale.

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 NAVSHIPS' and manufacturers' technical manuals.

BLOCK DIAGRAM.—These diagrams of electrical systems show major units of the system in block form. They are used with text material to present a general description of the system and its functions. Figure 6-3 shows a block diagram of the electrical steering system for a large ship. Look at the diagram along with the information in the following paragraphs to understand the function of the overall system.

The steering gear system (fig. 6-3) consists of two similar synchro-controlled electrohydraulic systems; one for each rudder (port and starboard). They are separate systems, but they are normally controlled by the same steering wheel (helm) and they move both port and starboard rudders in unison. Each port and starboard system has two 100 hp main motors driving a variable-stroke pump through reduction gears. Each also has two 5-hp servo pump motors interconnected electrically with the main pump motors so both operate simultaneously. During normal operation, one main pump motor and one servo pump motor are used with the other units on standby. If the normal power supply fails, both port and starboard transfer switchboards may be transferred to an emergency 450-volt supply.

The steering system may be operated from any one of three steering stations located in the pilothouse, at a secondary conn, and on the open bridge. A transmitter selector switch in the IC room is used to assign steering control to any of the three. To transfer steering control from the pilothouse to the open bridge station, the selector switch in the IC room must be in the pilothouse position. Duplicate power and control cables (port and starboard) run from a cable selector in the IC room to port and starboard cable selector switches in the steering gear room. From these switches, power and control cables connect to receiver selector switches. These selector switches allow selection of the appropriate synchro receiver for the system in operation.

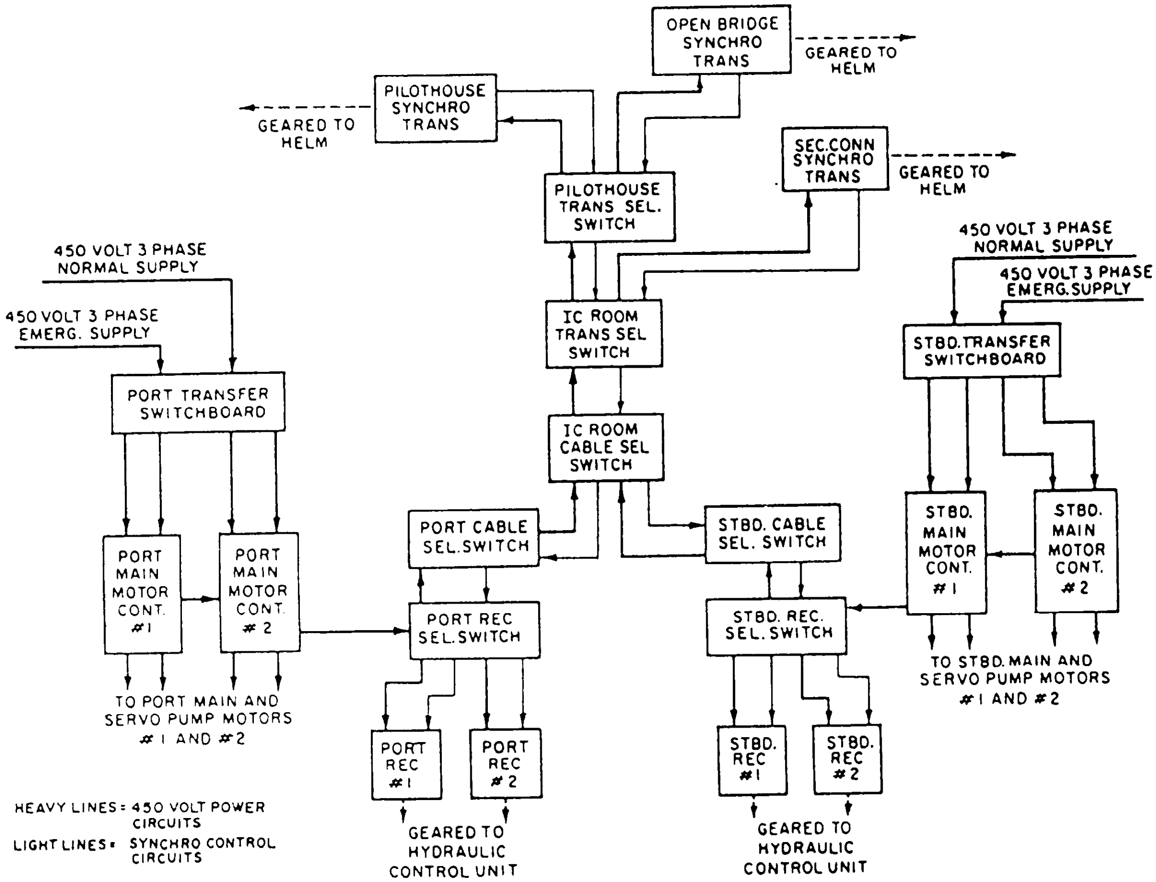


Figure 6-3.—Steering system block diagram.

The following paragraphs explain a normal operating setup for pilothouse steering control of the complete system.

PORT SYSTEM—Main and servo pump motors #2 operating; port receiver selector switch to #2 position, steering gear port cable select switch to the port cable position; IC cable selector switch (port system section) to the port cable position; and IC and pilothouse transmitter selector switches to the pilothouse position.

STARBOARD SYSTEM—Main and servo pump motors #1 operating; starboard receiver selector switch to the #1 position; steering gear starboard cable selector switch to the starboard cable position; and IC cable selector switch (starboard system section) to the starboard cable position.

When the control switches are set up in this manner, the motor and stator leads of the synchro transmitter at the pilothouse steering station are paralleled with the rotor and stator leads of the starboard #1 and port #2 synchro receivers in the steering gear room. 450 volts single phase is applied to the stator leads from main motor controllers #1 and #2. (The synchros have two stator and three rotor leads.) Due to synchro action, the receiver rotors will now follow all movements of the transmitter rotor and thus actuate the hydraulic system to move the rudders in response to the helm.

SINGLE-LINE DIAGRAM.—This type of diagram shows a general description of a system and how it functions. It has more detail than the block diagram; therefore, it requires less supporting text.

Figure 6-4 shows a single-line diagram of the ship's service generator and switchboard connections for a destroyer. It shows the type of ac and dc generators used to supply power for the ship. It also shows in simplified form actual switching arrangements used to parallel the generators, to supply the different power lighting busses, and to energize the casualty power terminals.

EQUIPMENT WIRING DIAGRAM.—Earlier in this chapter, we said a block diagram is useful to show the functional operation of a system. However, to troubleshoot a system, you will need wiring diagrams for the various equipments in the system.

The wiring diagram for a particular piece of electrical equipment shows the relative position of the various components of the equipment and how each individual conductor is connected in the circuit. Some examples are coils, capacitors, resistors, terminal strips, and so on.

Figure 6-5, view A, shows the main motor controller wiring diagram for the steering system shown in figure 6-3. This wiring diagram can be used to troubleshoot, check for proper electrical connections, or completely rewire the controller.

SCHEMATIC DIAGRAM.—The electrical schematic diagram describes the electrical operation of a particular piece of equipment, circuit, or system. It is not drawn to scale and usually does not show the relative positions of the various components. Graphic symbols from ANSI Y32.2 represent all components. Parts and connections are omitted for simplicity if they are not essential to show how the circuit operates. Figure 6-5, view B, shows the schematic diagram for the steering system main motor controller that has the following electrical operation:

Assume 450-volt, 3-phase power is available on lines 1L1, 1L2, and 1L3; and 2L1, 2L2 and 2L3; and the receiver selector is set so that the motors are to idle as standby equipment. Then turn the master switch (MM and SPM push-button station) to the start position to energize coil 3M. Coil 3M will close main line contacts 3M, starting the servo pump motor. When contacts 3M close, auxiliary contacts 3Ma and 3Mb also close. Contacts 3Ma shunt (bypass) the master switch start contacts to maintain power to coil 3M after the master switch is released. When released, the master switch spring returns to the run position, closing the run contacts and opening the start contacts. Turning the switch to the stop position opens the run contacts. Contacts 3Mb energize latching coil CH, closing contacts CH, and energizing coil 1M, which closes main line contacts 1M to start the main pump motor. (Solenoid latch CH prevents contacts 1M from opening or closing due to high-impact shock.)

Before the motors can deliver steering power, the receiver selector switch must be set to the appropriate receiver, closing contacts RSSa and RSSb. Contacts RSSa energize coil 2M, which closes contacts 2M to supply single-phase power to the synchro system. Contacts RSSb shunt the start and 3Ma contacts so that in case of a power failure the motors will restart automatically upon restoration of power.

In case of overload on the main or servo pump motor (excessive current through IOL or 3OL), overload contacts 1OL or 3OL will open, de-energizing coil 3M to open line contacts 3M and stop the servo pump motor. When line contacts 3M open, contacts 3Ma and 3Mb open, deenergizing

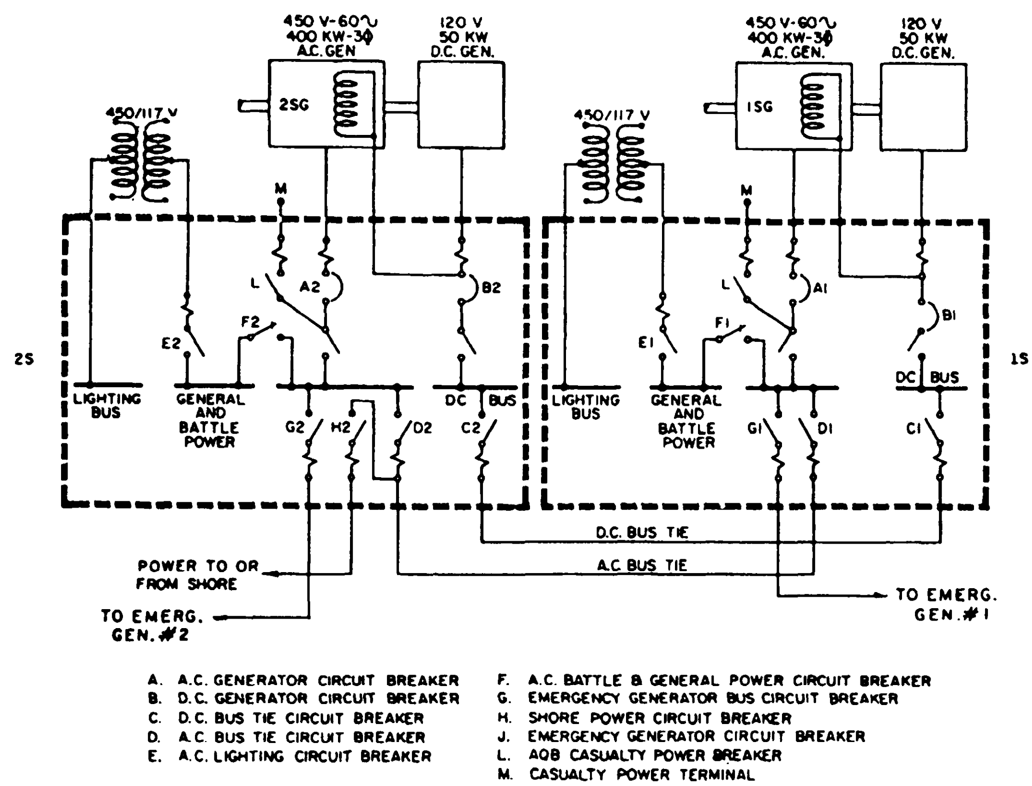


Figure 6-4.—Ship's service generator and switchboard interconnections, single-line diagram.

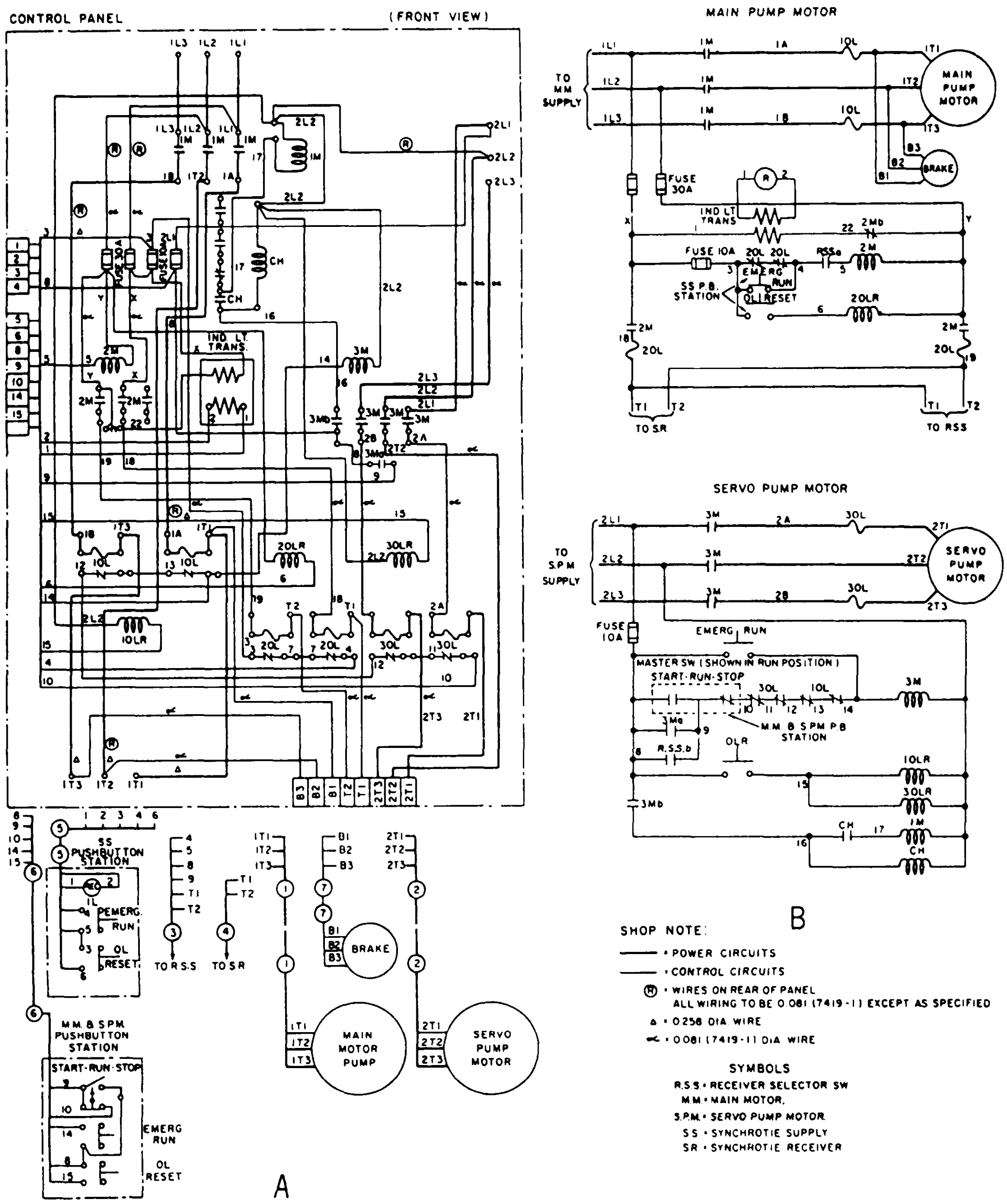


Figure 6-5.—Main motor controller. A. Wiring diagram. B. Schematic.

latching coil CH, and opening contacts CH. The opening of contacts CH de-energizes coil 1M, which opens contacts 1M to stop the main motor. If an overload occurs in the synchro supply circuit (excessive current through 2OL), contacts 2OL will open, deenergizing coil 2M to open contacts 2M. The overloads are reset after tripping by pressing the overload reset buttons. The equipment may be operated in an overloaded condition by pressing the emergency run buttons to shunt the overload contacts.

AIRCRAFT ELECTRICAL PRINTS

Aircraft electrical prints include schematic diagrams and wiring diagrams. Schematic diagrams show electrical operations. They are drawn in the same manner and use the same graphic symbols from ANSI Y32.2 as shipboard electrical schematics.

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, as shown in figure 6-6, view

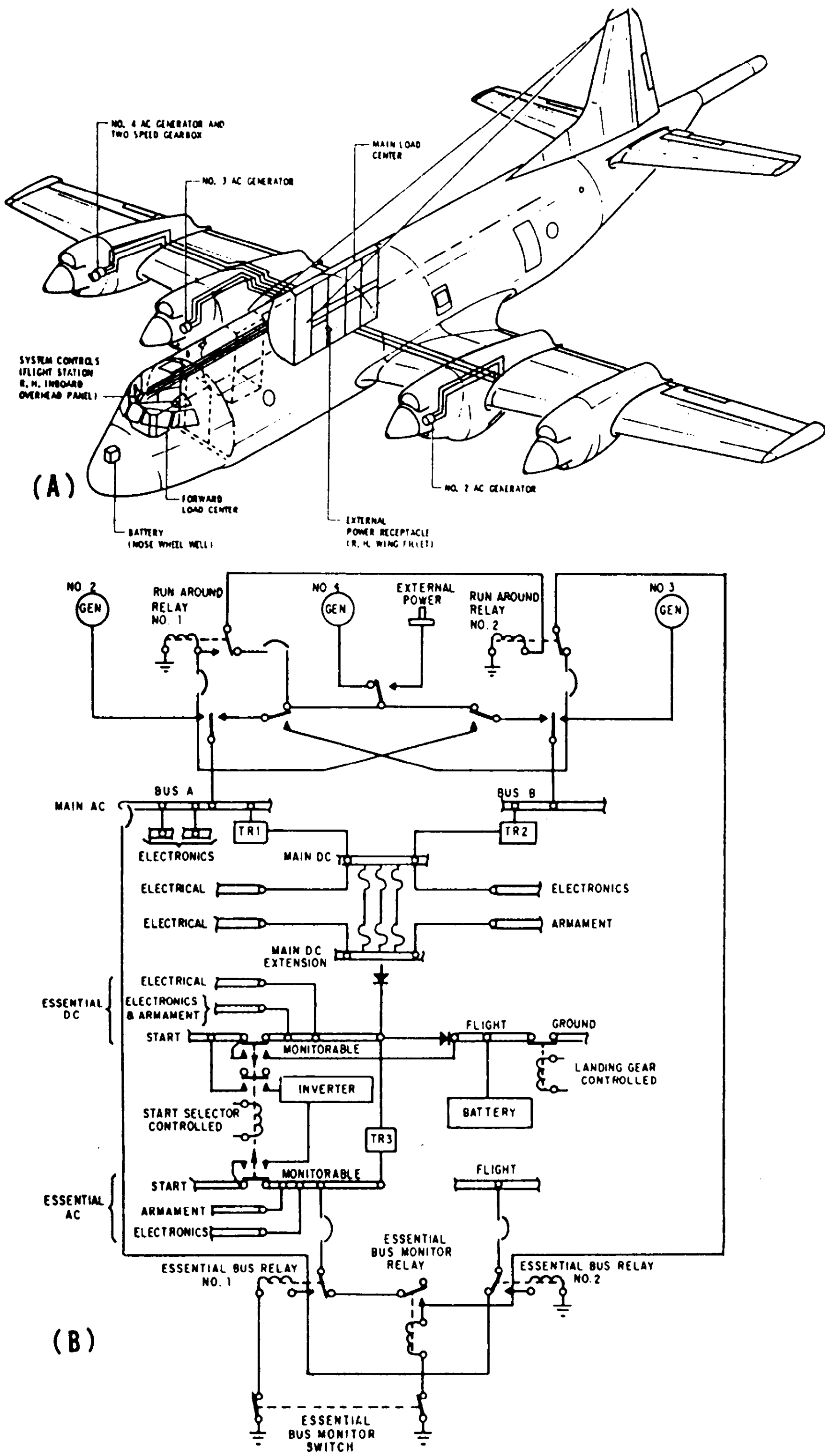


Figure 6-6.—Electrical power distribution in P-3A aircraft.

A. This diagram is similar to a shipboard isometric wiring diagram.

The simplified wiring diagram (fig. 6-6, view B) 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 Identification Coding

All aircraft wiring is identified on the wiring diagrams exactly as marked in the aircraft. Each wire is coded by a combination of letters and numbers imprinted at prescribed intervals along the run. You need to look at figure 6-7 as you read the following paragraphs.

The unit number shown dashed (fig. 6-7) is used only in those cases where more that one identical unit is installed in an identical manner in the same aircraft. The wiring for the first such unit would bear the prefix 1, the second unit the prefix 2, and so on. The rest of the designation remains the same in both units.

The circuit function letter identifies the basic function of the unit concerned according to the codes shown in figure 6-8. Note the dashed L after the circuit function R in figure 6-7. On R, S, and T wiring, this letter designates a further breakdown of the circuit.

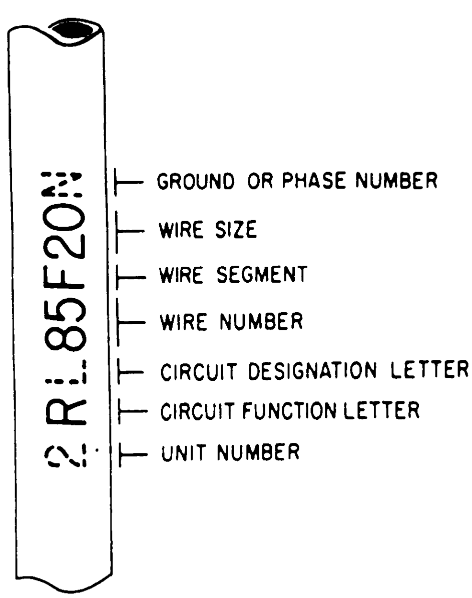


Figure 6-7.—Aircrafl wire identification.

Circuit function letter	Circuits
A	Armament
B	Photographic
C	Control surface
D	Instrument
E	Engine instrument
F	Flight instrument
G	Landing gear
H	Heating, ventilating, and deicing
J	Ignition
K	Engine control
L	Lighting
M	Miscellaneous
P	DC power — Wiring in the dc power or power control system will be identified by the circuit function letter P.
Q	Fuel and oil
R	Radio (navigation and communication) RN-Navigation RP-Intercommunications RZ-Interphone, headphone
S	Radar SA-Altimeter SN-Navigation SQ-Track SR-Recorder SS-Search
T	Special electronic TE-Countermeasures TN-Navigation TR-Rece ivers TX-Television transmitters TZ-Computer
V	DC power and dc control wires for ac systems will be identified by the circuit function letter V.
W	Warning and emergency
X	AC power Wiring in the ac power system will be identified by the circuit function letter X.
Y	Armament special systems

Figure 6-8.—Aircraft wiring, circuit function code.

ELECTRONICS PRINTS

Electronics prints are similar to electrical prints, but they are usually more difficult to read because they represent more complex circuitry and systems. This part of the chapter discusses common types of shipboard and aircraft electronic prints and basic logic diagrams.

SHIPBOARD ELECTRONICS PRINTS

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

Cables that supply power to electronic equipment are tagged as explained in the electrical prints part of this chapter. However, cables between units of electronic equipment are tagged with electronic designations. Figure 6-9 shows a partial listing of these designations. The complete designation list (contained in NAVSHIPS 0967-000-0140), breaks down all system designation as shown for radar in figure 6-9.

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 cable, ES identifies the cable as a surface search radar cable, 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.

Circuit or system designation	Circuit or system title
R-A	Meteorological
R-B	Beacons
R-C	Countermeasures
R-D	Data
R-E	Radar
R-EA	Air search radar
R-EC	Carrier controlled approach radar
R-ED	Radar identification
R-EE	Air search with height determining capability
R-EF	Height determining radar
R-EG	Guided missile tracking radar
R-EI	Instrumentation radar
R-EM	Mortar locator radar
R-ER	Radar remote indicators
R-ES	Surface search radar
R-ET	Radar trainer
R-EW	Aircraft early warning radar
R-EZ	Three-coordinate radar
R-F	Weapon control radar
R-G	Electronic guidance remote control or remote telemetering
R-H	CW passive tracking
R-I	IFF equipment
R-K	Precision timing
R-L	Automatic vectoring
R-M	Missile support
R-N	Infrared equipment
R-P	Special purpose
R-R	Radio communication
R-S	Sonar
R-T	Television

Figure 6-9.—Electronics circuit or system designations.

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 trouble-shooting, which will be discussed later.

A simplified block diagram is usually shown first, followed by a more detailed block diagram. Figure 6-10 shows a simplified block diagram of a shipboard tactical air navigation (TACAN) system.

The TACAN system is an electronic air navigation system that provides a properly equipped aircraft with bearing and distance from a shipboard or ground radio beacon selected by the pilot. The system is made up of a radio beacon (consisting of the receiver-transmitter group, the antenna group, and the power supply assembly) and the radio set in the aircraft.

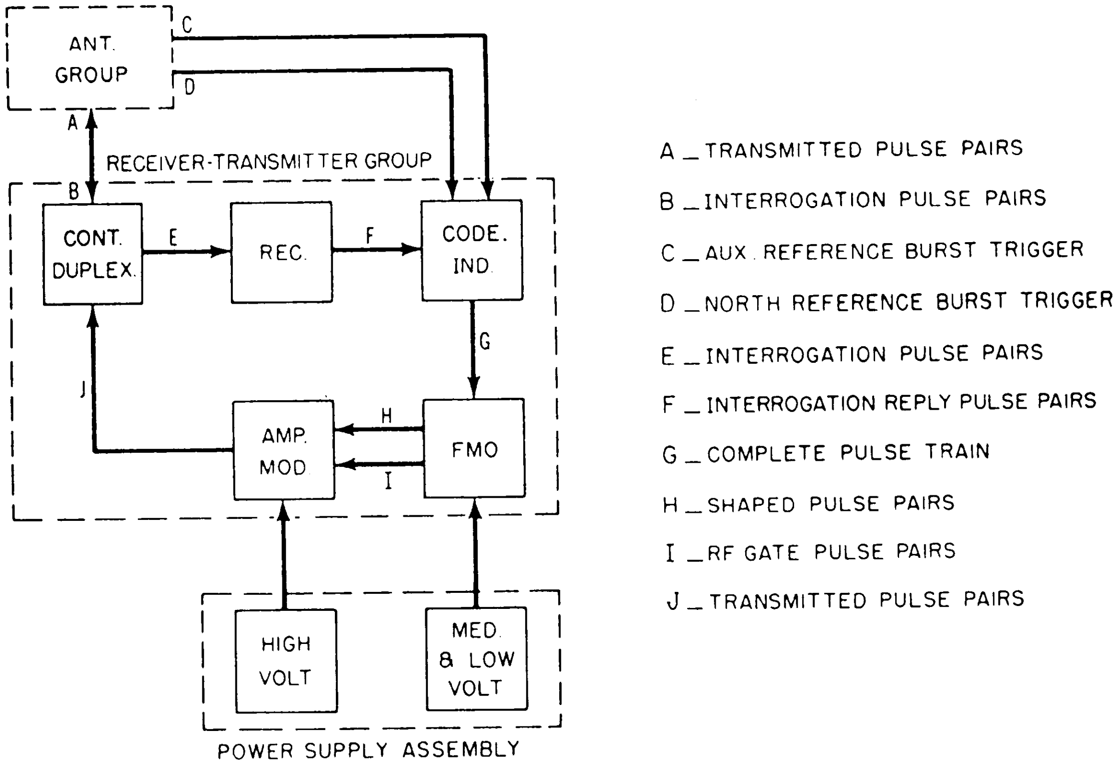


Figure 6-10.—Shipboard TACAN system, simplified block diagram.

Figure 6-11 shows how the code indicator section would appear in a detailed block diagram for the TACAN system shown in figure 6-10. Note that this diagram shows the shape and amplitude of the wave forms at various points and the location of test points. Tube elements and pin numbers are also identified. For example, the interrogation reply pulse (top left corner of fig. 6-11) is applied to the grid (pin 7) of V604B, and the output from the cathode (pin 8) of V604B is applied to the grid (pin 2) of V611. Therefore, this kind of block diagram is sometimes called a servicing block diagram because it can be used to troubleshoot as well as identify function operations. Block diagrams that break down the simplified diagram into enough detail to show a fairly detailed picture of functional operation, but do not include wave forms, test points, and so on, are usually called functional block diagrams.

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. Note the graphic symbol for the single-pole, two-position switch S603 at the bottom left corner in figure 6-11. Figure 6-12 shows other examples of graphic symbols in a block diagram.

Detailed block diagrams of the type shown in figure 6-12 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 ANSI Y32.2 for all parts, such as tubes, transistors, capacitors, and inductors. Appendix III in this textbook shows common electronic symbols from this standard. Simplified schematic diagrams are used to show how a particular circuit operates electronically. However, detailed schematic diagrams are necessary for trouble-shooting.

Figure 6-13 shows a section of the detailed schematic diagram of the coder indicator show in figure 6-11. Some of the components in figure 6-13 are not numbered. In an actual detailed schematic, however, all components, such as resistors and capacitors, 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. Input signals are shown entering on the left (fig. 6-13) and signal flow is from left to right, which is the general rule for schematic diagrams.

In the block diagram in figure 6-11, the north reference burst signal is shown applied to the pin 7 grid of V601B. The pin 6 plate output of V601B is fed to the pin 7 grid of V602, and the pin 3 cathode output of V602

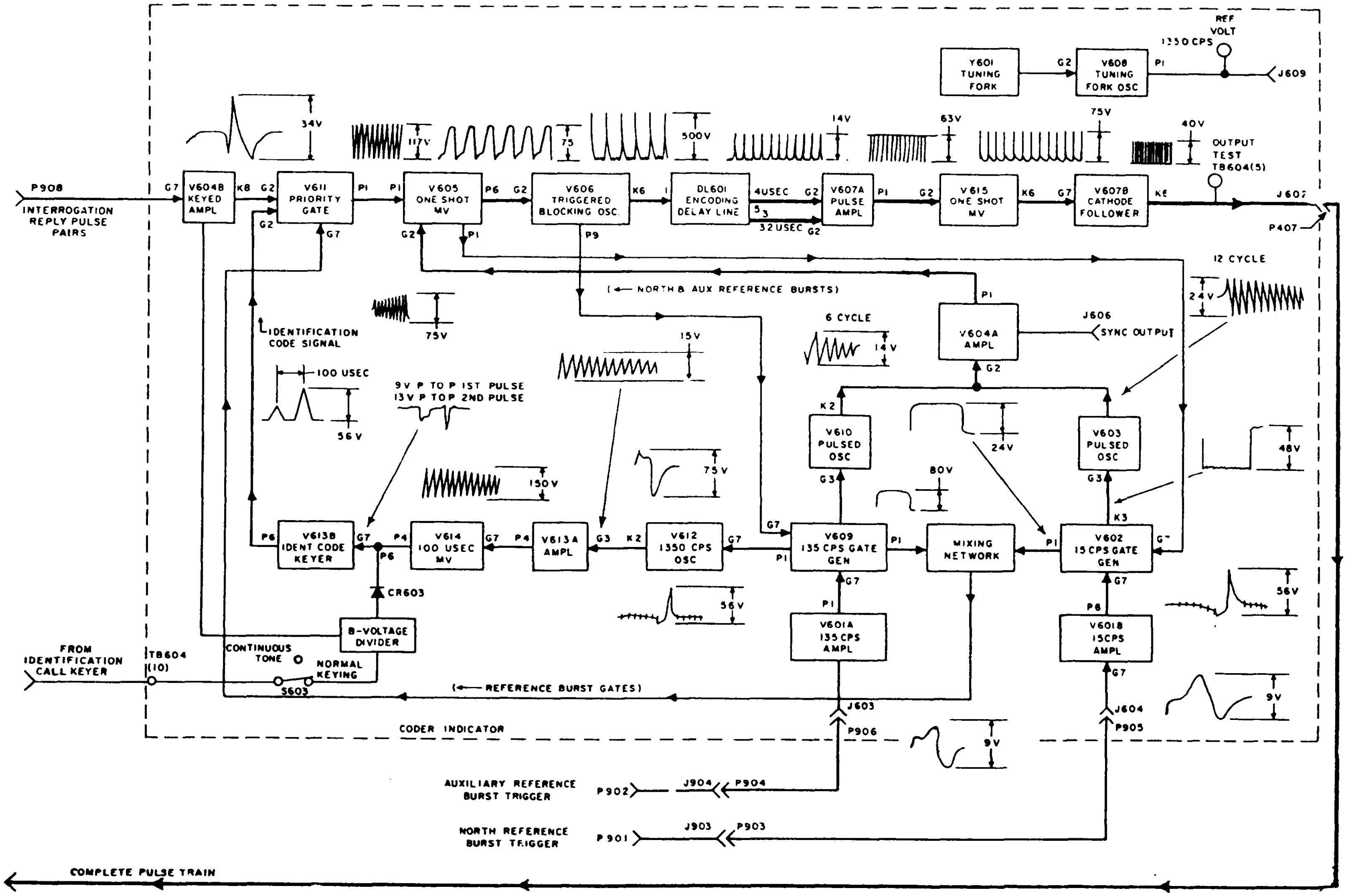


Figure 6-11.—Coder indicator, detail block diagram.

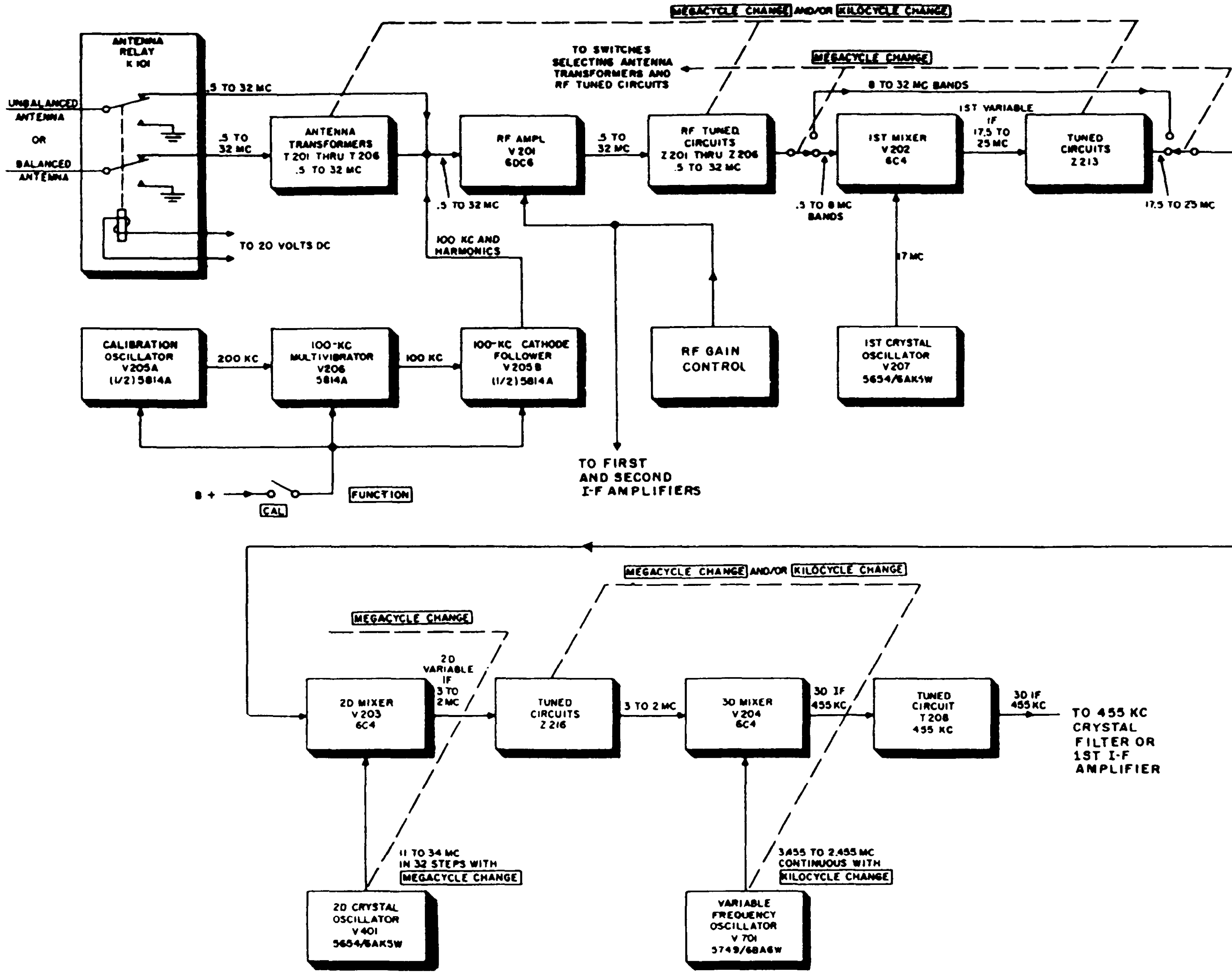


Figure 6-12.—Section of radio receiver R-390A/URR, functional block diagram.

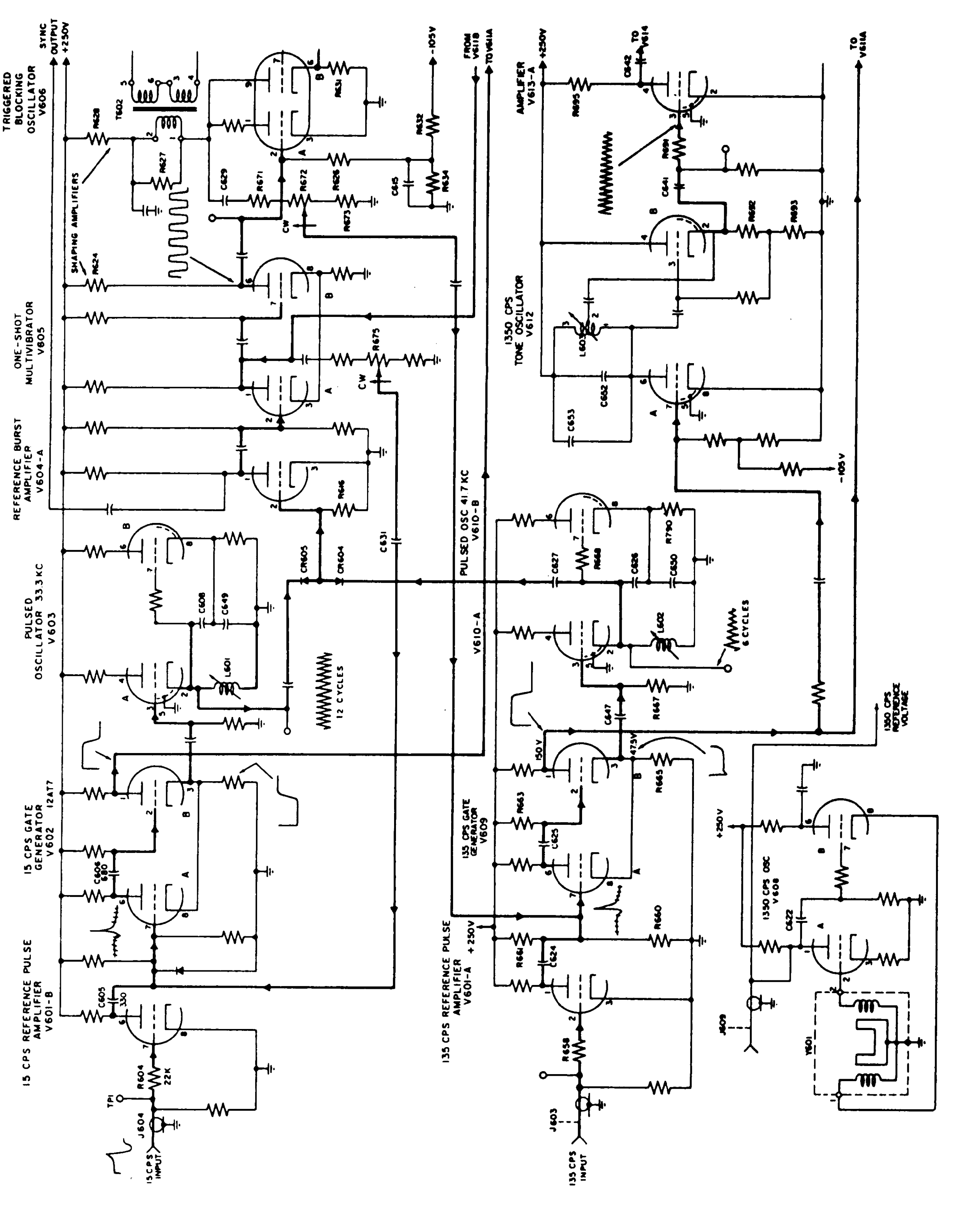


Figure 6-13.—Section of coder indicator, detailed schematic diagram.

is applied to the pin 3 grid of V603, and so on. In addition, the schematic diagram in figure 6-13 shows that the north reference burst signal is fed through 22K (22,000 ohms) resistor R604 grid 7 and that the plate output of V601B is coupled through capacitor C605 (a 330 picofared capacitor) to the grid of section A of V602, twin-triode type 12AT7 tube. Therefore, the detailed schematic diagram shows detailed information about circuits and parts and must be used in conjunction with the detailed block diagram to effectively troubleshoot a 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. Figure 6-14 shows a sample wiring diagram. Designations 1A1, 1A1A1, and 1A1A2 are reference designations and will be discussed later.

Figure 6-15 shows the basic wiring color code for electronic equipment.

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 prints you work with will have one of two systems of reference designations. The old one is called a block numbering system and is no longer in use. The current one is called a unit numbering system. We will discuss both in the following paragraphs.

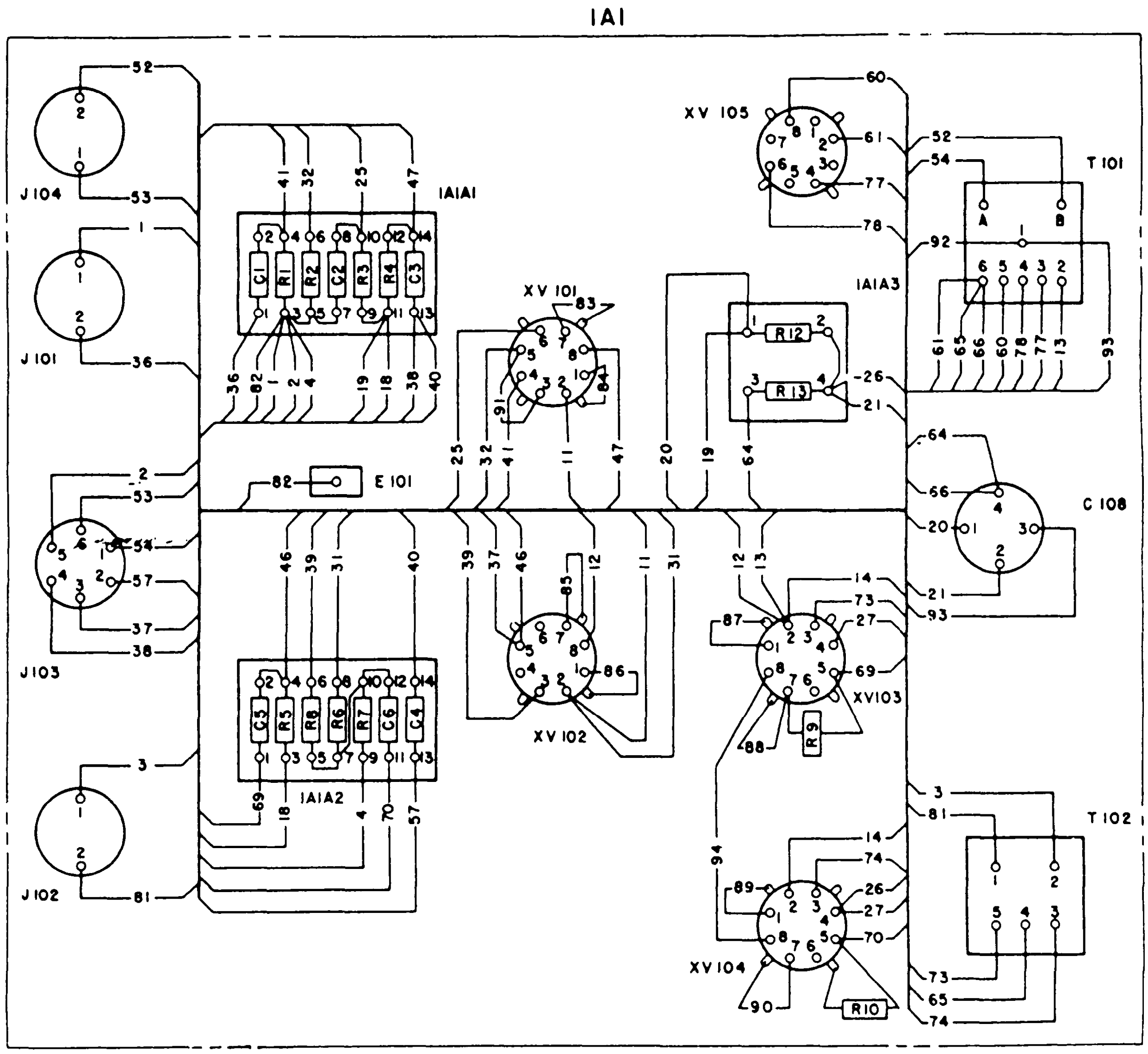


Figure 6-14.—Sample wiring diagram.

CIRCUIT	COLOR
Grounds, grounded elements, and returns	Black
Heaters or filaments, off ground	Brown
Power supply, B plus	Red
Screen grids	Orange
Cathodes	Yellow
Control grids	Green
Plates	Blue
Power supply, minus	Violet (purple)
AC power lines	Gray
Miscellaneous, above or below ground returns, AVC, etc.	White

Figure 6-15.—Wiring color code for electronic equipment.

BLOCK NUMBERING SYSTEM.—Parts designations in figures 6-11, 6-12, and 6-13 were made according to the block numbering system, which is no longer in use. In that system, a letter identifies 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.—In this currently used reference designation system, electronic systems are broken into sets, units, assemblies, subassemblies, and parts. 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 (fig. 6-16) is defined as one or more units

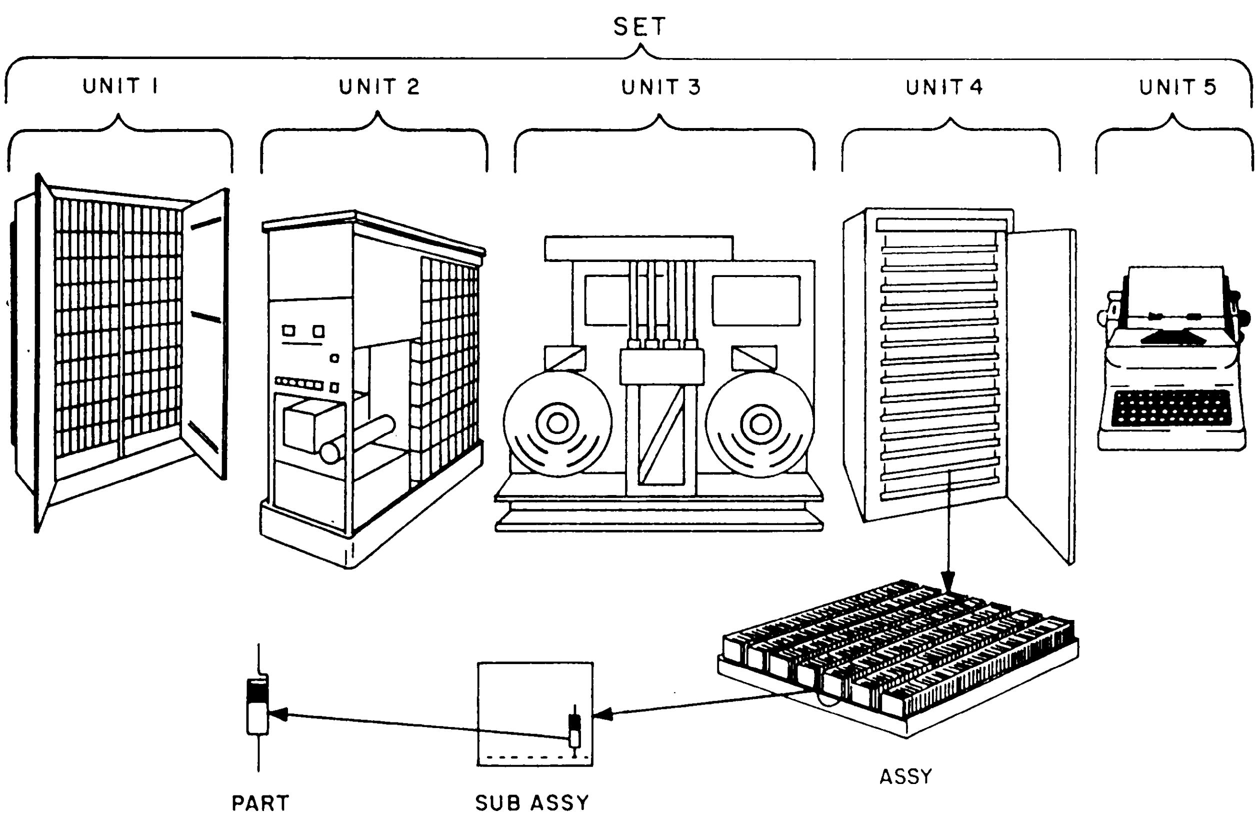


Figure 6-16.—A five-unit set.

and the necessary assemblies, subassemblies, and parts connected or associated together to perform an operational function.

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. This number is the complete reference designation for the unit. If there is only one unit, the unit number is omitted.

Assemblies and subassemblies are assigned reference designations consisting of the unit number that identifies the unit of which the assembly or subassembly is a part, the letter *A* indicating an assembly or subassembly, and a number identifying the specific assembly or subassembly as shown in figure 6-17.

Parts are assigned reference designations that consist of the unit and assembly or subassembly designation, plus a letter or letters identifying the class to which the part belongs (as in the block numbering system), and a number identifying the specific part.

For each additional subassembly, an additional letter *A* and number are added to the part reference designation. For example, if the resistor shown in figure 6-16 is the number 1 resistor in the subassembly, its complete reference designation would be 4A13A5AlRl. This number identifies the number 1 resistor on the number card of rack number 5 in assembly 13 of unit 4. On electronic diagrams, the usual procedure is to use partial (abbreviated) reference designations. In this procedure, only the letter and number identifying the part is shown on the part itself, while the reference designation prefix appears at some other place on the diagram as shown in figure 6-14. 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 (fig. 6-18). 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 *Standard Terminal Designations for Electronic Equipment,* NAVSHIPS 0967-146-0010.

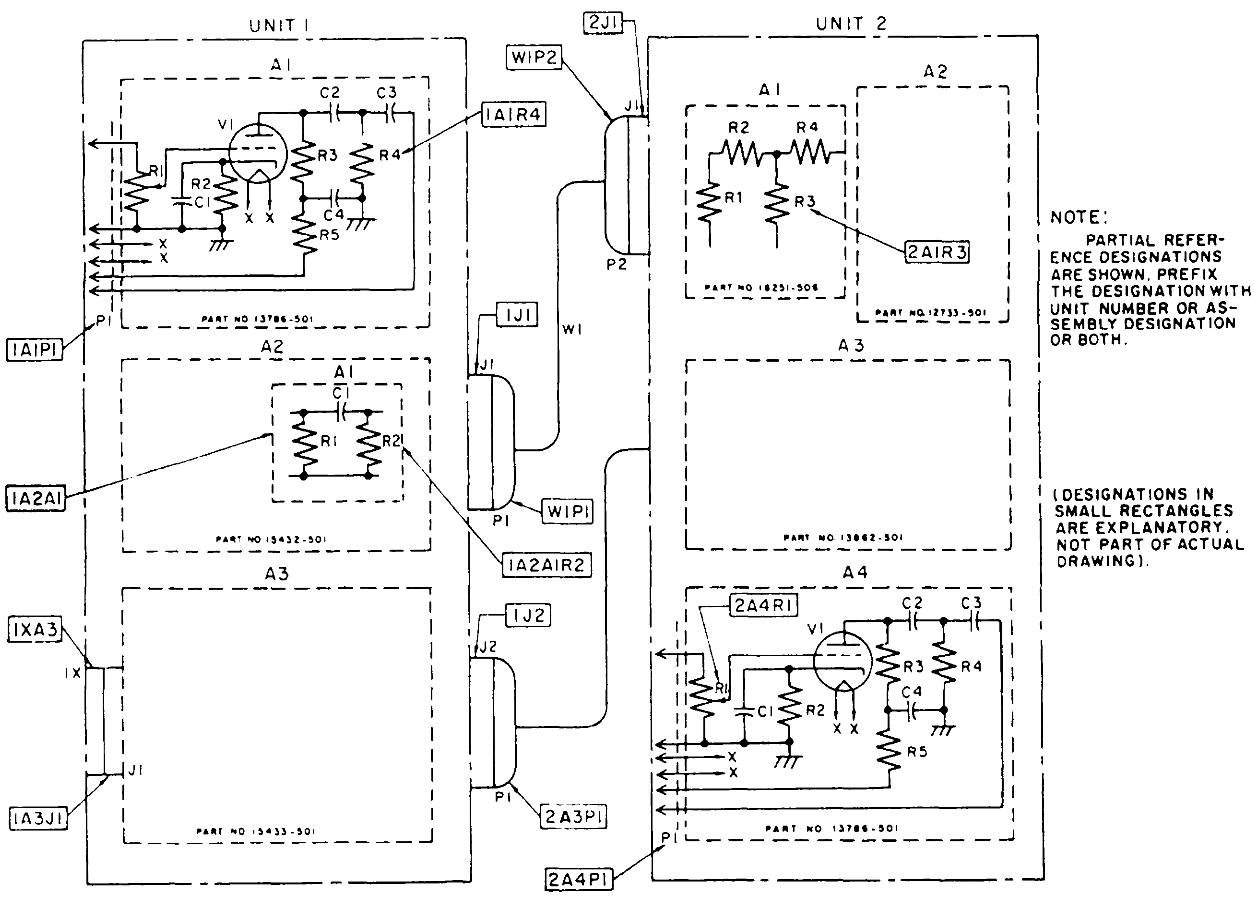


Figure 6-17.—Application of reference designations using unit numbering methods.

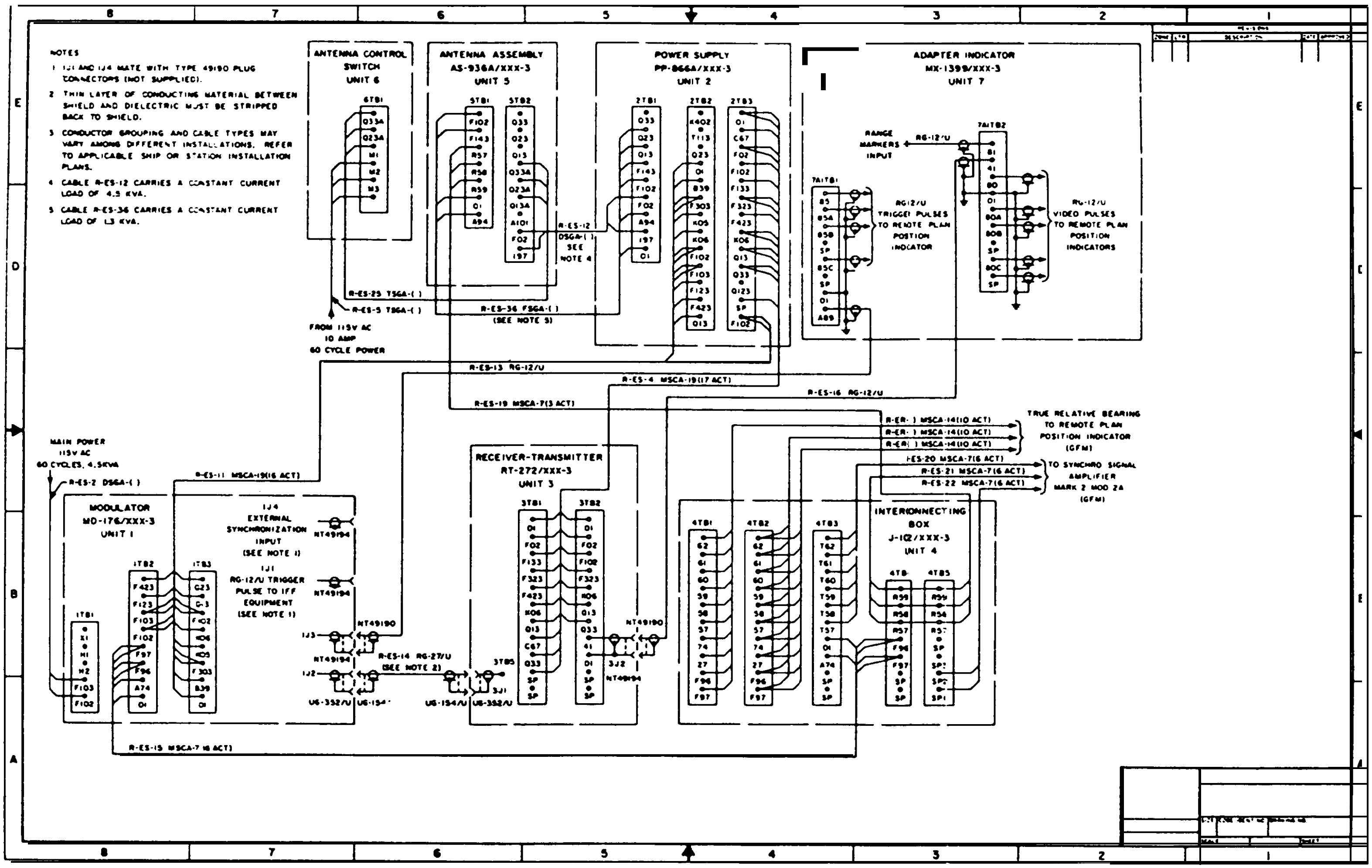


Figure 6-18.—Sample interconnection diagram.

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. For example, look at cable R-ES11 between the power supply unit and the modulator unit in figure 6-18. R-ES11 identifies the cable as the number 11 cable of a surface search radar system. The MSCA-19 (16 ACT) is the designation for a multiconductor ship control armored cable with 19 conductors, 16 active and 3 spares.

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. For example, the ends of the conductor in cable R-ES11 connected to terminals F423 on ITB2 and 2TB2 would be tagged as shown in figure 6-19.

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

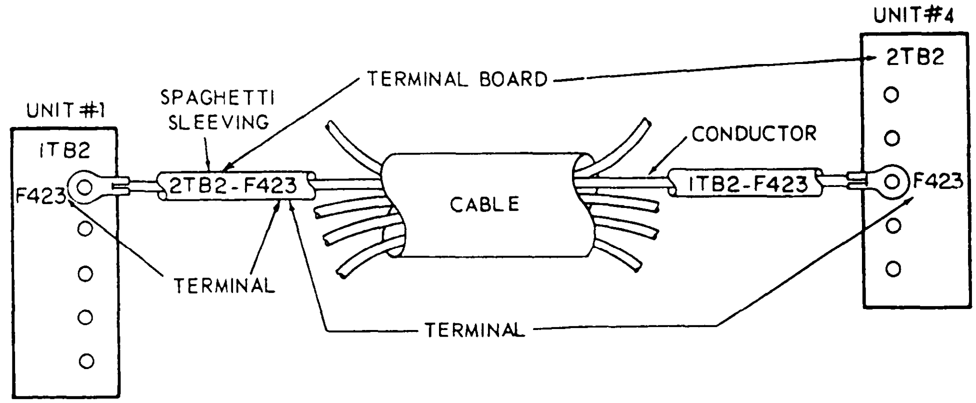


Figure 6-19.—Conductor markings.

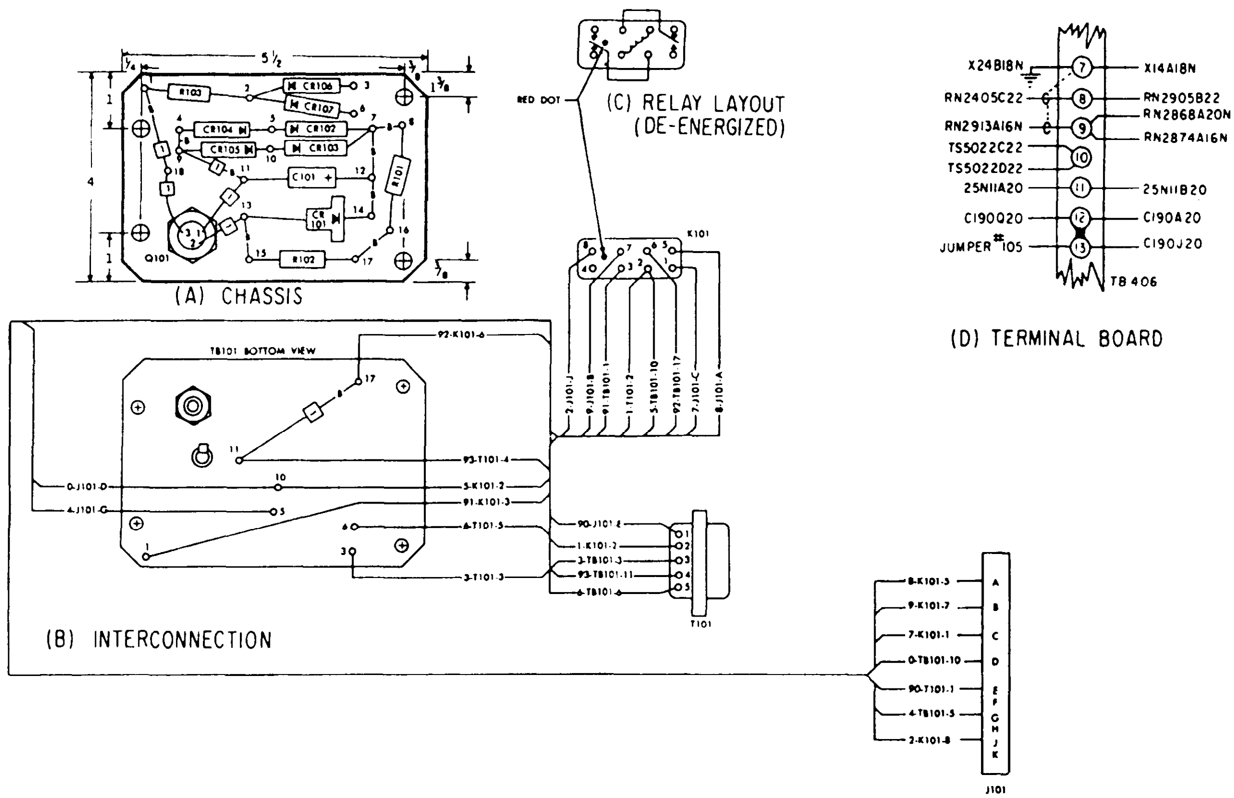


Figure 6-20.—Aircraft wiring diagram.

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: chassis wiring diagrams and interconnecting diagrams. There are many variations of each class, depending on the application.

Figure 6-20, view A, shows an example of one type of chassis wiring diagram. This diagram shows the physical layout of the unit and all component parts and interconnecting tie points. Each indicated part is identified by a reference designation number that helps you use 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.) Since this specific diagram shows physical layout and dimensioning details for mounting holes, it could be used as an assembly drawing and as an installation drawing.

Figure 6-20, view B, shows the reverse side of the same mounting board, together with 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 entering at an angle.

The wire identification coding on this diagram consists of a three-part designation. The first part is a number representing the color code of the wire according to Military Specification MIL-W-76B. (Many other chassis wiring diagrams designate color coding by abbreviation of the actual colors.) 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.

Figure 6-20, view C, is not a wiring diagram, but it illustrates a method commonly used to show some functional aspect of sealed or special components.

Figure 6-20, view D, illustrates several methods used to show connections at terminal strips, as discussed earlier.

Electromechanical Drawings

Electromechanical devices such as synchros, gyros, accelerometers, autotune systems, an 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. Figure 6-21 shows an example of one type of electromechanical drawing.

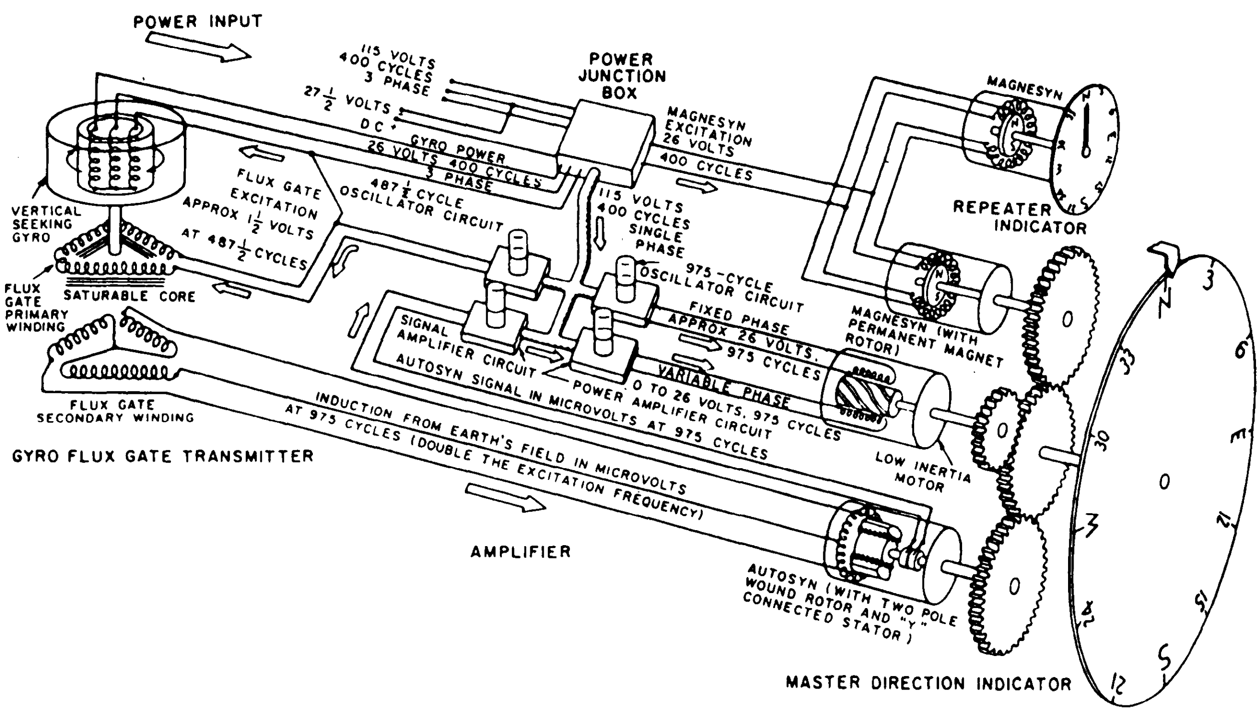


Figure 6-21.—Aircraft gyro fluxgate compass, electromechanical drawing.

LOGIC DIAGRAMS

Logic diagrams are used in the operation and maintenance of digital computers. Graphic symbols from ANSI Y32.14 are used in these diagrams.

Computer Logic

Digital computers are used to make logic 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. Digital computers never apply reason and think out an answer. They operate entirely on instructions prepared by someone who has done the thinking and reduced the problem to a point where logical decisions can deliver the correct answer. 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, if, 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 more usefully be represented by symbols. Thus, the operations are expressed in what is known as symbolic logic.

The symbolic logic operations used in digital 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 the mathematics with which you are familiar, 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 in figure 6-22.

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

Logic Operations

Figure 6-23 shows the three basic logic operations (AND, OR, and NOT) and four of the simpler combinations of the three (NOR, NAND, INHIBIT, and EXCLUSIVE OR). 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. (Note the block diagrams representing the NOT circuit in the figure.) 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.

Operation	Meaning
A•B	A AND B
A+B	A OR B
A	A NOT or NOT A
(A + B) (C)	A OR B, AND C
AB+C	A AND B, OR C
A•B	A NOT, AND B

Figure 6-22.—Logic symbols.

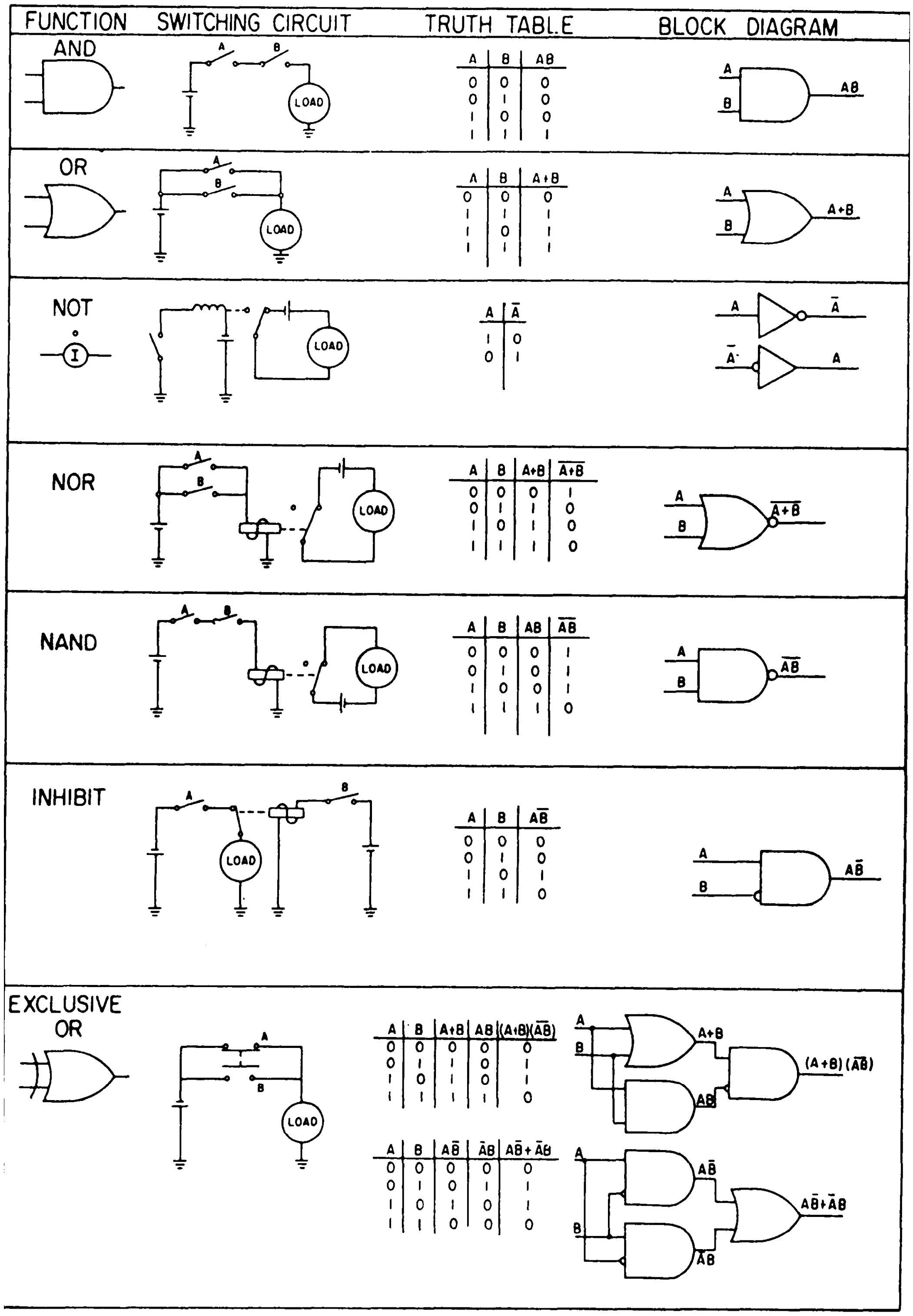


Figure 6-23.—Logic operations comparison chart.

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 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.

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. Figure 6-24 shows a basic logic diagram for a serial subtractor. The operation of the unit is described briefly in the next paragraph.

In the basic subtractor in figure 6-24, assume you want to subtract binary 011 (decimal 1) from binary 100 (decimal 4). At time I_o, the 0 input at A and 1 input at B of inhibitor I_1 results in a 0 output from inhibitor I_1 and a 1 output from inhibitor I_2. The 0 output from I_1 and the 1 output from I_2 are applied to OR gate G_1, producing a 1 output from G_1. The 1 output from I_2 is also applied to the delay line. The I output from G_1 along with the 0 output from the delay line produces 1 output from I_3. The 1 input from G_1 and the 0 input from the delay line produce a 0 output from inhibitor I_4. The 0 output from L and the 1 output from I_3 are applied to OR gate G_2 producing a 1 output.

At time t_1 the 0 inputs on the A and B input lines of I_1 produce 0 outputs from I_1 and I_2. The 0 inputs on both input lines of OR gate G_1 result in a 0 output from G_1. The I input applied to the delay line at time t_o emerges (1 bit time delay) and is now applied to the inhibit line of 13 producing an 0 output from I_3. The 1 output from the delay line is also applied to inhibitor I_4, and along with the 0 output from G_1 produces a 1 output from I_4. The I_4 output is recycled back into the delay line, and also applied to OR gate G_2. As a result of the 0 and 1 inputs from I3, and I4, OR gate G_2 produces a 1 output.

At time t_2, the 1 input on the A line and the 0 input on the B line of I_1 produce a 1 output from I_1 and a 0 output from I_2. These outputs applied to OR gate G1 produce a 1 output from G_1, which is applied to 13 and I_4. The delay line now produces a 1 output (recycled in at time t_1), which is applied to I_3 and I_4. The 1 output from the delay line along with the 1 output from G_1 produces a 0 output from I_3. The 1 output from G_1 along with the 1 output from the delay line produces a 0 output from I_4. With 0 outputs from I_3 and I_4, OR gate G_2 produces a 0 output.

Detailed Logic Diagrams

Detailed logic diagrams show all logic functions of the equipment concerned. 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, as shown in the note on the sample sheet in figure 6-25.

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

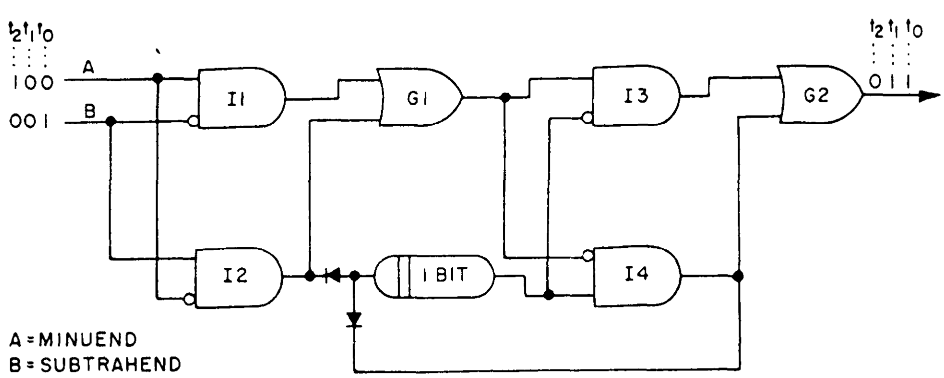


Figure 6-24.—Serial subtractor, basic logic diagrams.

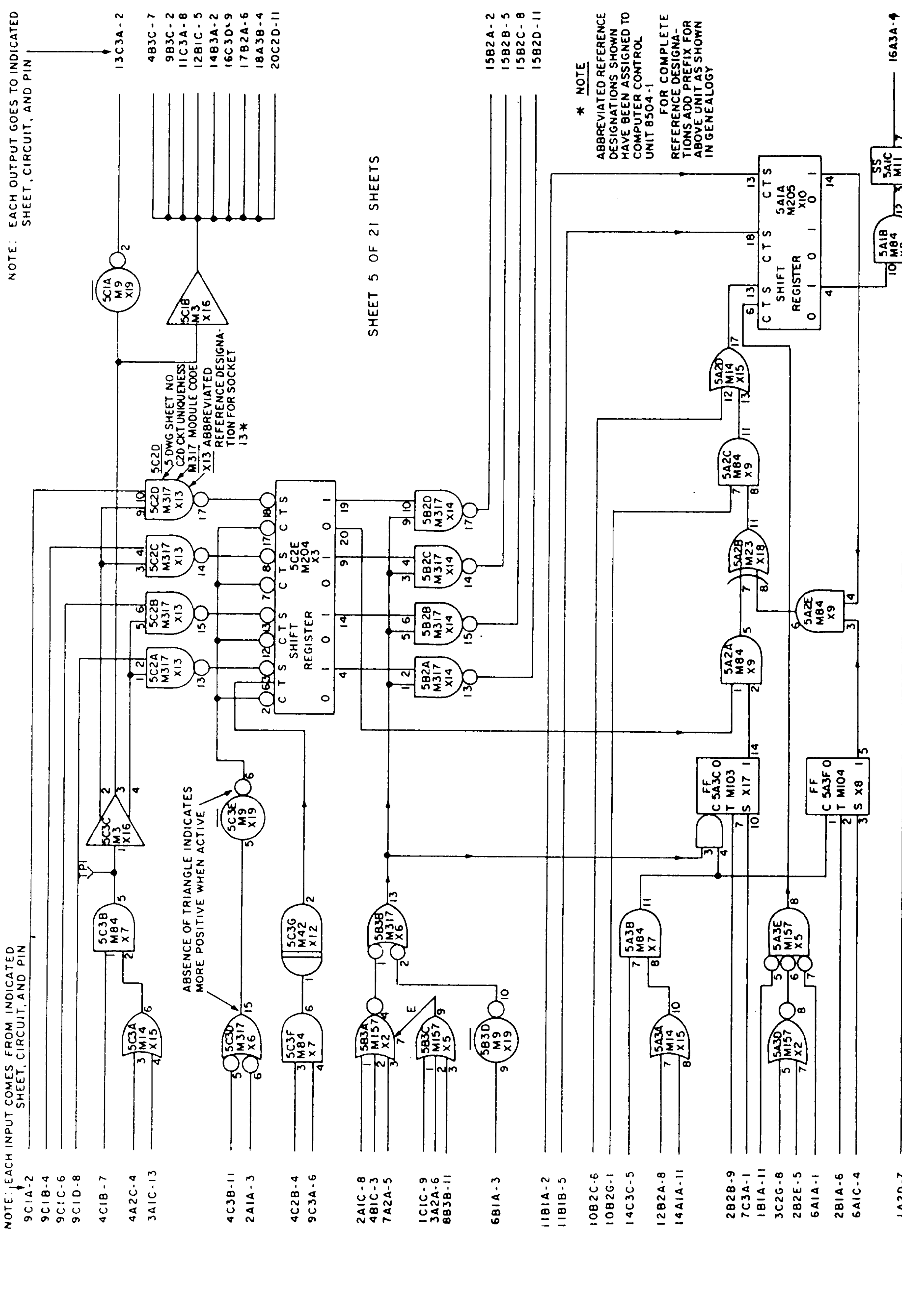
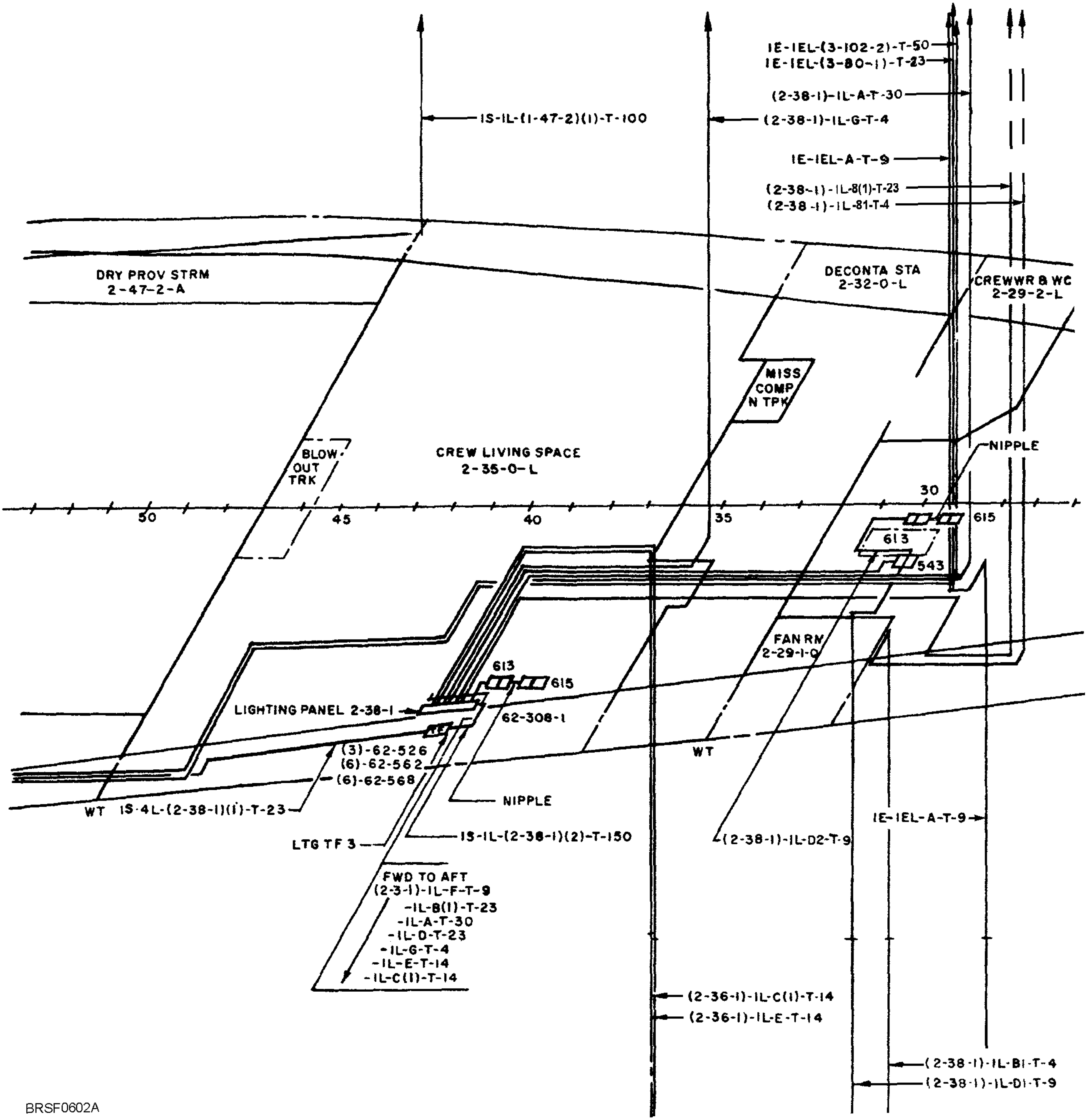


Figure 6-25.—Sample detailed logic diagram.

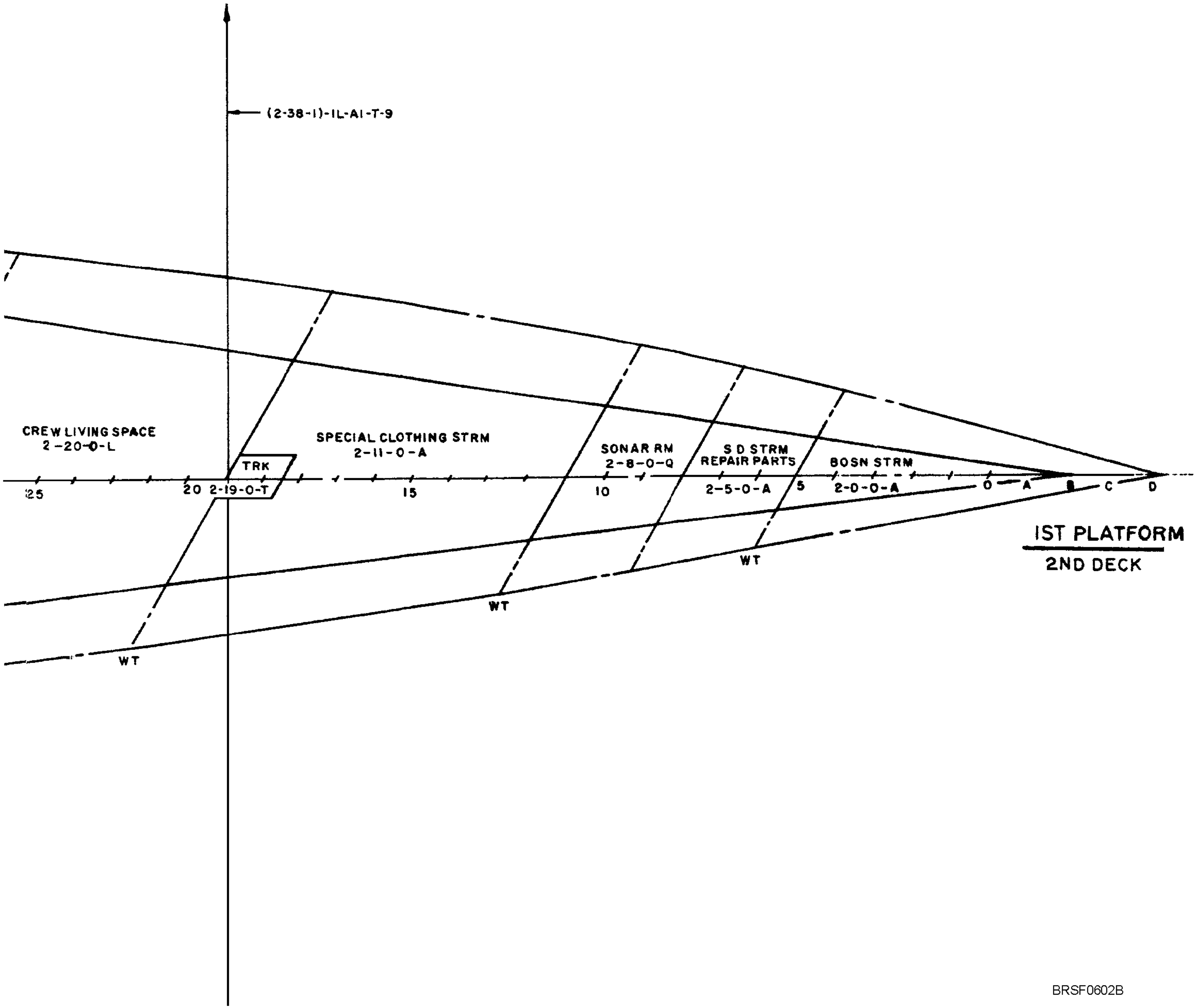
destination. In addition, each logic function shown on the sheet is tagged to identify the function hardware and to show function location both on the diagram and within the equipment.

For example, in the OR function 5C3A at the top left in figure 6-13, the 5 identifies sheet number 5, C3 the drawing zone, and A the drawing subzone (the A section of module 5C3). The M14 is the module code number, which identifies the circuit by drawing number. The X15 is the partial reference designation, which when preceded by the proper reference designation prefix, identifies the function location within the equipment as described earlier.



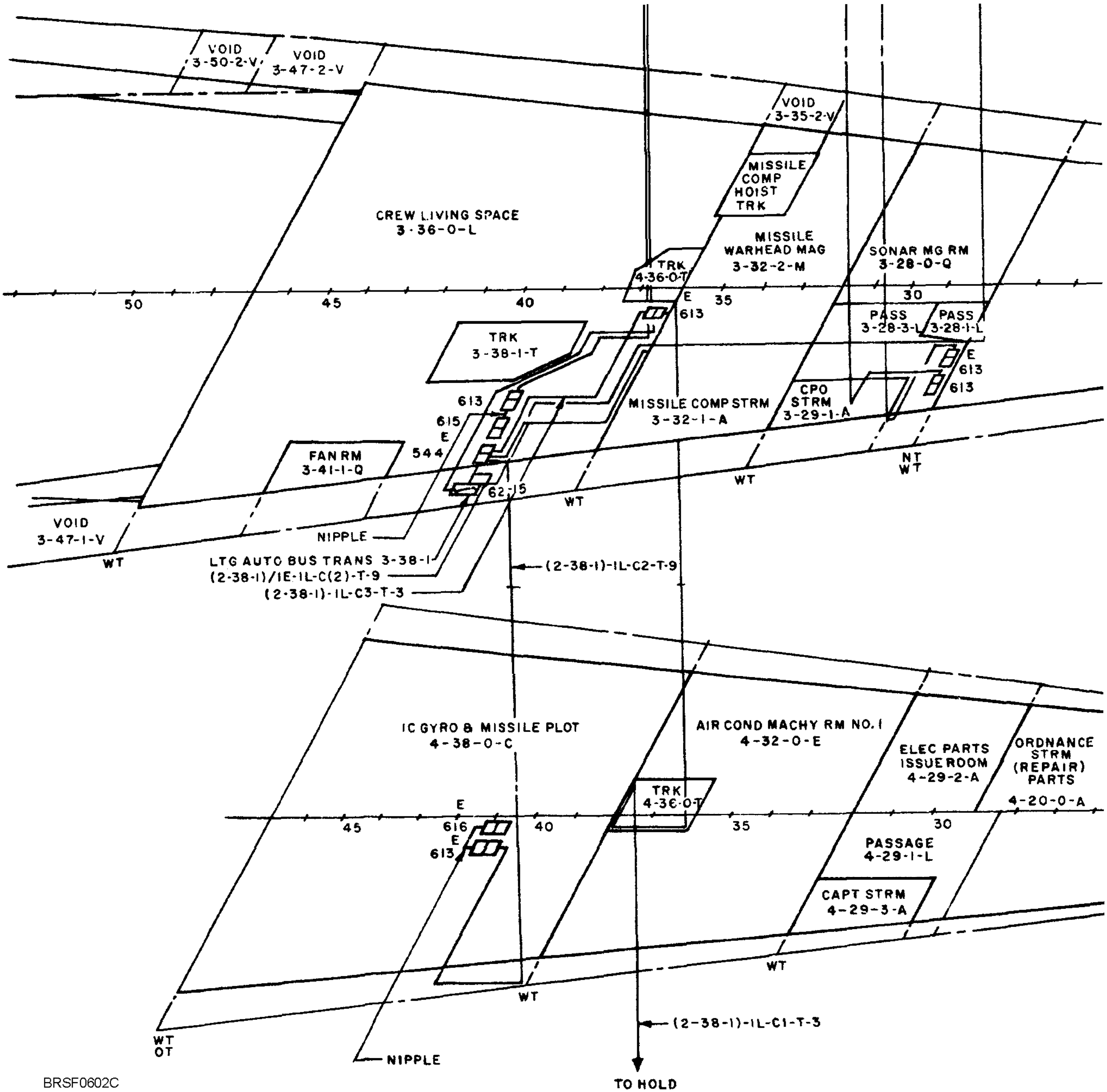
IE-IEL-(3-102-2)-T-50
IE-IEL-(3-80-1)-T-23
(2-38-1)-IL-A-T-30
IS-IL-(1-47-2)(1)-T-100
(2-38-1)-IL-G-T-4
IE-IEL-A-T-9
(2-38-1)-IL-8(1)-T-23
(2-38-1)-IL-81-T-4
DRY PROV STRM
2-47-2-A
DECONTA STA
2-32-0-L
CREWWR & WC
2-29-2-L
MISS
COMP
N TPK
BLOW
OUT
TRK
CREW LIVING SPACE
2-35-0-L
NIPPLE
30
50
45
40
35
615
613
543
FAN RM
2-29-1-0
613
615
LIGHTING PANEL 2-38-1
62-308-1
(3)-62-526
(6)-62-562
(6)-62-568
WT
NIPPLE
WT
IS-4L-(2-38-1)(1)-T-23
IE-IEL-A-T-9
IS-IL-(2-38-1)(2)-T-150
LTG TF 3
(2-38-1)-IL-D2-T-9
FWD TO AFT
(2-3-1)-IL-F-T-9
-IL-B(1)-T-23
-IL-A-T-30
-IL-D-T-23
-IL-G-T-4
-IL-E-T-14
-IL-C(1)-T-14
(2-36-1)-IL-C(1)-T-14
(2-36-1)-IL-E-T-14
(2-38-1)-IL-B1-T-4
(2-38-1)-IL-D1-T-9

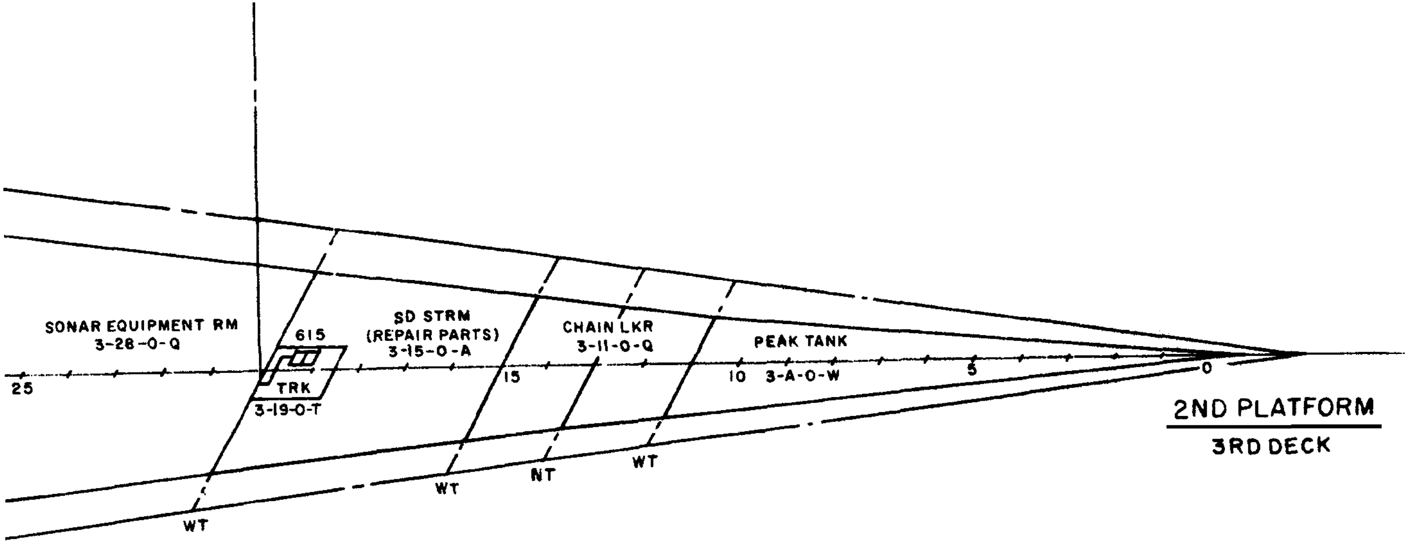
BRSF0602A

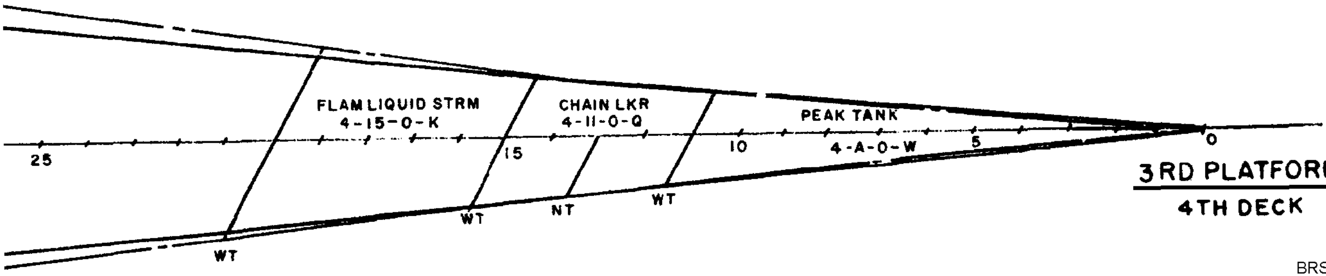


(2-38-1)-1L-A1-T-9
CREW LIVING SPACE
2-20-0-L
SPECIAL CLOTHING STRM
2-11-0-A
TRK
2-19-0-T
SONAR RM
2-8-0-Q
S D STRM
REPAIR PARTS
2-5-0-A
BOSN STRM
2-0-0-A
25
20
15
10
5
0
A
B
C
D
WT
WT
WT
WT
1ST PLATFORM
2ND DECK

BRSF0602B


VOID
3-50-2-V
VOID
3-47-2-V
VOID
3-35-2-V
MISSILE
COMP
HOIST
TRK
CREW LIVING SPACE
3-36-0-L
MISSILE
WARHEAD MAG
3-32-2-M
SONAR MG RM
3-28-0-Q
TRK
4-36-0-T
50
45
40
35
30
E
613
PASS
3-28-3-L
PASS
3-28-1-L
TRK
3-38-1-T
E
613
613
613
615
E
544
CPO
STRM
3-29-1-A
MISSILE COMP STRM
3-32-1-A
FAN RM
3-41-1-Q
62-15
NT
WT
WT
WT
WT
VOID
3-47-1-V
WT
NIPPLE
LTG AUTO BUS TRANS 3-38-1
(2-38-1)/1E-1L-C(2)-T-9
(2-38-1)-1L-C3-T-3
(2-38-1)-1L-C2-T-9
IC GYRO & MISSILE PLOT
4-38-0-C
AIR COND MACHY RM NO. 1
4-32-0-E
ELEC PARTS
ISSUE ROOM
4-29-2-A
ORDNANCE
STRM
(REPAIR)
PARTS
4-20-0-A
TRK
4-36-0-T
E
616
E
613
45
40
35
30
PASSAGE
4-29-1-L
CAPT STRM
4-29-3-A
WT
WT
WT
OT
NIPPLE
(2-38-1)-1L-C1-T-3
TO HOLD
BRSF0602C


SONAR EQUIPMENT RM
3-28-0-Q
615
TRK
3-19-0-T
SD STRM
(REPAIR PARTS)
3-15-0-A
CHAIN LKR
3-11-0-Q
PEAK TANK
3-A-0-W
25
15
10
5
0
WT
WT
NT
WT
2ND PLATFORM
3RD DECK


FLAM LIQUID STRM
4-15-0-K
CHAIN LKR
4-11-0-Q
PEAK TANK
4-A-0-W
25
15
10
5
0
WT
WT
NT
WT
3RD PLATFORM
4TH DECK

BRSF0602D

CHAPTER 7

STRUCTURAL AND ARCHITECTURAL DRAWINGS

When you have read and understood this chapter, you should be able to answer the following learning objectives:

- *Describe the elements of architectural drawings.*
- *Describe the elements of structural steel drawings.*
- *Identify various types of construction drawings.*

Architectural and structural 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 used on structural drawings, and describes the common types of drawings used in the fabrication and erection of steel structures.

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, then sets down the concept on paper in the form of presentation drawings, which are usually drawn in perspective by using pictorial drawing techniques.

Next, the architect and the 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 guide the draftsmen who prepare 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

The following paragraphs will explain the common structural shapes used in building materials and the common structural members that are made in those shapes.

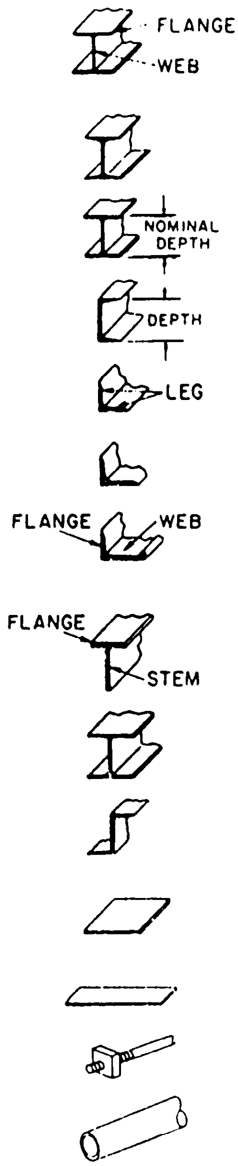
SHAPES

Figure 7-1 shows common single structural shapes. The symbols used to identify these shapes in bills of material, notes, or dimensions for military construction drawings are listed with typical examples of shape notations. These symbols are compiled from part 4 of MIL-STD-18B and information from the American Society of Construction Engineers (ASCE).

The sequence in which dimensions of shapes are noted is described in the following paragraphs. Look at figure 7-1 for the position of the symbol in the notation sequence. Inch symbols are not used; a practice generally followed in all cross-sectional dimensioning of structural steel. Lengths (except for plate) are not given in the Illustrated Use column of figure 7-1. When noted, lengths are usually given in feet and inches. An example is 9′ - 2 1/4″. The following paragraphs explain many of the shapes shown in figure 7-1.

BEAMS—A beam is identified by its nominal depth, in inches and weight per foot of length. The cross section of a wide-flange beam (WF) is in the form of the letter *H*. In the example in figure 7-1, 24 WF 76 designates a wide-flange beam section 24 inches deep weighing 76 pounds per linear foot. Wide-flange shapes are used as beams, columns, truss members, and in any other applications where their shape makes their use desirable. The cross section of an American Standard beam (I) forms the letter *I*. These I-beams, like wide-flange beams, are identified by nominal depth and weight per foot. For example, the notation 15 I 42.9 shows that the I-beam has a nominal depth of 15 inches and weighs 42.9 pounds per linear foot. I-beams have the same general use as wide-flange beams, but wide-flange beams have greater strength and adaptability.

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 9 ⊔ 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



DESCRIPTION	PICTORIAL	MIL-STD SYMBOL	ILLUSTRATED USE	AISC SYMBOL	ILLUSTRATED USE
WIDE FLANGE SHAPE		WF	24 WF 76	W	W24 X 76
BEAMS				S	S15 X 14.29
AMERICAN STANDARD		I	15 I 42.9		
LIGHT BEAMS AND JOISTS		B	6 B 12		
STANDARD MILL		M	8 M 17		
JUNIOR		Jr	7 Jr 5.5		
LIGHT COLUMNS		M	8 X 8M 34.3	M	M8 X 34.3
CHANNELS				C	C9 X 13.4
AMERICAN STANDARD		⊔	9 ⊔ 13.4		
CAR AND SHIP		⊔	12 X 4 ⊔ 44.5		
JUNIOR		Jr ⊔	10 Jr ⊔ 8.4		
ANGLES				L	L3 X 3 X $\frac{1}{4}$
EQUAL LEG		L	L 3 X 3 X $\frac{1}{4}$		
UNEQUAL LEG		L	L 7 X 4 X $\frac{1}{2}$	L	L7 X 4 X $\frac{1}{2}$
BULB		BULB L	BULB L 6 X 3$\frac{1}{2}$ X 17.4		
TEES				WT	WT12 X 38
STRUCTURAL		ST	ST5 WF 10.5		
ROLLED		T	T4 X 3 X 9.2		
BEARING PILE		BP	14 BP 73	HP	HP14 X 73
ZEE		Z	Z6 X 3$\frac{1}{2}$ X 15.7		
PLATE		Pl	Pl 18 X $\frac{1}{2}$ X 2'-6"	PL	PL18 X $\frac{1}{2}$ X 2'-6
FLAT BAR		Bar	Bar 2$\frac{1}{2}$ X $\frac{1}{4}$	Bar	Bar2$\frac{1}{2}$ X $\frac{1}{4}$
TIE ROD		TR	$\frac{3}{4}$ Φ TR		
PIPE COLUMN		○	○ 6Φ	⌖	pipe 4 std

Figure 7-1.—Symbols for single structural shapes

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—The cross section of an angle resembles the letter *L*. Angles are identified by the dimensions in inches of their legs, as L 7 x 4 x 1/2. Dimensions of structural angles are measured in inches along the outside or backs of the legs; the dimension of the wider leg is given first (7 in the example). The third dimension is the thickness of the legs; both legs always have equal thickness. Angles may be used singly or in combinations of two or four angles to form members. Angles also are used to connect main members or parts of members together.

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.

BEARING PILES—A bearing pile is the same as a wide-flange or H-beam, but is much heavier per linear foot. Therefore, the dimension 14-inch (nominal depth) bearing pile weighs 73 pounds per linear foot. Note that this beam weighs nearly as much as the 24-inch wide-flange shape mentioned earlier.

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.

PLATES—Plates are noted by width, thickness, and length. Therefore, PI 18 x 1/2 x 2´-6" means the plate is 18 inches wide, 1/2 inch thick, and 2 feet 6 inches long.

FLAT BAR—This shape is a plate with a width less than 6 inches and a thickness greater than 3/16 inch. Bars usually have their edges rolled square. The dimensions are given for width and thickness. Therefore, 2 1/2 x 1/4 means that the bar is 2 1/2 inches wide and 1/4 inch thick

TIE ROD AND PIPE COLUMN—Tie rods and pipe columns are designated by their outside diameters. Therefore, 3/4 ϕ TR means a tie rod with a diameter of 3/4 inch. The dimension **O** 6 ϕ, indicates a 6-inch diameter pipe. Figure 7-2 illustrates the methods whereby three of the more common types of structural shapes just described are projected on a drawing print.

MEMBERS

The main parts of a structure are the load-bearing structural members that support and transfer the loads on the structure while remaining in equilibrium with each other. The places where members are connected to other members are called joints. The total 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 completed. The total live load is the total weight of movable objects, such as people, furniture, and bridge traffic, that the

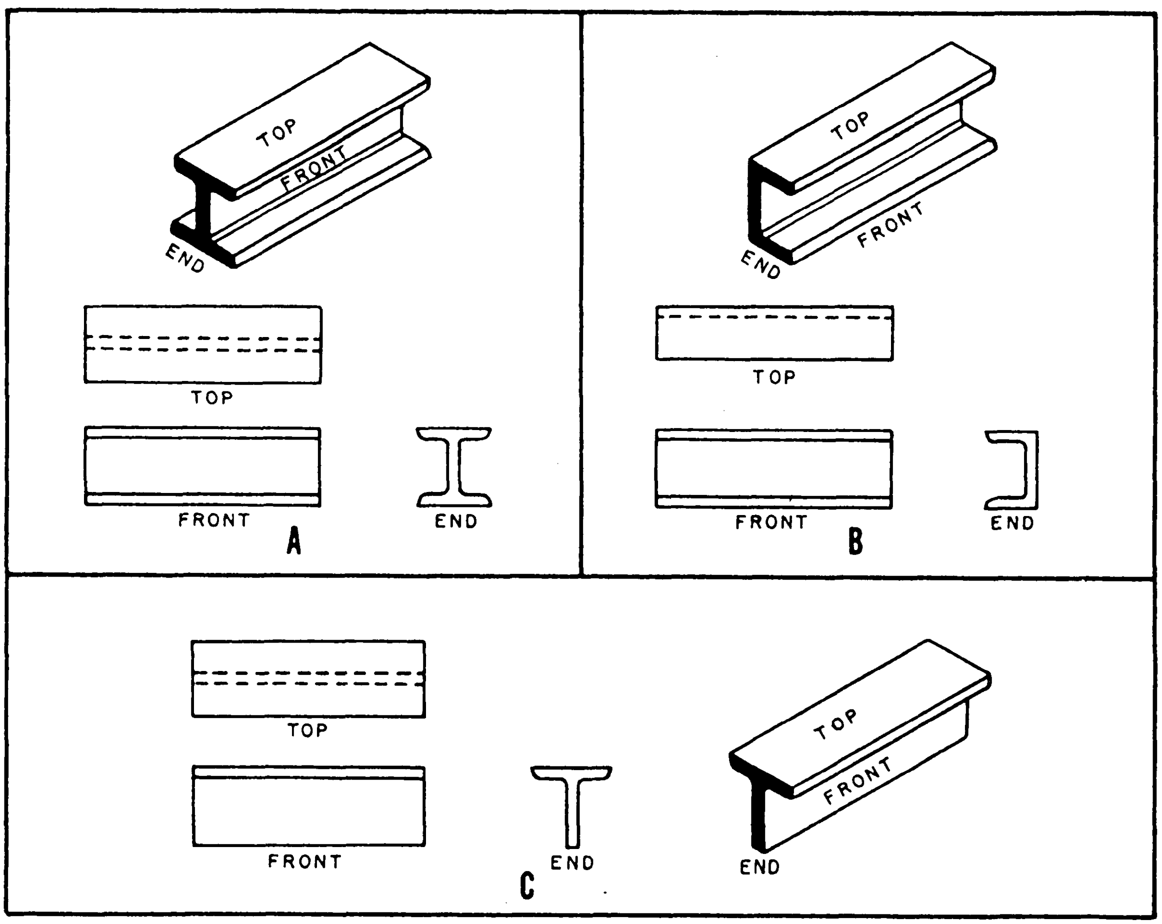


Figure 7-2.—Projecting structural shapes. A. I- or H-beam. B. Channel. C. Tee.

structure is supporting at a particular instant. The live loads in a structure are transmitted through the various load-bearing structural members to the ultimate support of the earth.

Horizontal members provide immediate or direct support for the loads. These in turn are supported by vertical members, which in turn are supported by foundations and/or footings, which are finally supported by the earth.

The ability of the earth to support a load is called *the soil-bearing capacity.* It is determined by test and measured in pounds per square foot. Soil-bearing capacity varies considerably with different types of soil, and a soil with a given bearing capacity will bear a heavier load on a wide foundation or footing than it will a narrow one.

Vertical Members

Columns are high-strength vertical structural members; in buildings they are sometimes called *pillars.* Outside-wall columns and bottom-floor inside columns usually rest directly on footings. Outside-wall columns usually extend from the footing or foundation to the roof line. Bottom-floor inside columns extend upward from footings or foundations to horizontal members that support the first floor. Upper floor columns usually are located directly over lower-floor columns.

A *pier* in building construction might be called a short column. It may rest directly on a footing, or it may be simply set or driven in the ground. Building piers usually support the lowermost horizontal structural members. In bridge construction a pier is a vertical member that provides intermediate support for the bridge superstructure.

The chief vertical structural members in light-frame construction are called *studs. They* are supported on horizontal members called *sills* or *sole plates,* and are topped by horizontal members called *top plates or stud caps. Corner posts* are enlarged studs located at the building corners. In early full-frame construction, a corner post was usually a solid piece of larger timber. Built-up corner posts are used in most modern construction. They consist of two or more ordinary studs nailed together in various ways.

Horizontal Members

In technical terminology, a horizontal load-bearing structural member that spans a space and is supported at both ends is called a *beam.* A member that is fixed at one end is called a *cantilever.* Steel members that consist of solid pieces of regular structural steel shapes are called beams. However, one type of steel member is actually a light truss (discussed later) and is called an *open-web steel joist* or a *bar-steel joist.*

Horizontal structural members that support the ends of floor beams or joists in wood-frame construction are called *sills, girts,* or *girders.* The choice of terms depends on the type of framing being done and the location of the member in the structure. Horizontal members that support studs are called *sills* or *sole plates.* Horizontal members that support the wall ends of rafters are called *rafter plates* or *top plates,* depending on the type of framing. Horizontal members that support the weight of concrete or masonry walls above door and window openings are called *lintels.*

Trusses

A beam of given strength, without intermediate supports below, can support a given load over only a certain maximum span. If the span is wider than this maximum, the beam must have intermediate supports, such as columns. Sometimes it is not feasible to install intermediate supports. In these cases, a truss may be used instead of a beam.

A truss is a framework consisting of two horizontal (or nearly horizontal) members joined together by a number of vertical and/or inclined members to form a series of triangles. The loads are applied at the joints. The horizontal members are called the upper or top chords and lower or bottom chords. The vertical and/or inclined members that connect the top and bottom chords are called web members.

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 symbols are a means of placing complete information on drawings. The top of figure 7-3 shows the welding symbol with the weld arrow. The arrow serves as a base on which all basic and supplementary symbol information is placed in standard locations. The assembled welding symbol is made up of weld symbols in their respective positions on the reference line and arrow, together with dimensions and other data (fig. 7-3).

Look at figures 7-3 and 7-4 to help you read the eight elements of a welding symbol. Each element is numbered and illustrated separately in figure 7-4, and explained in the following paragraphs:

1. This shows the reference line, or base, for the other symbols.
2. This shows the arrow. The arrow points to the location of the weld.

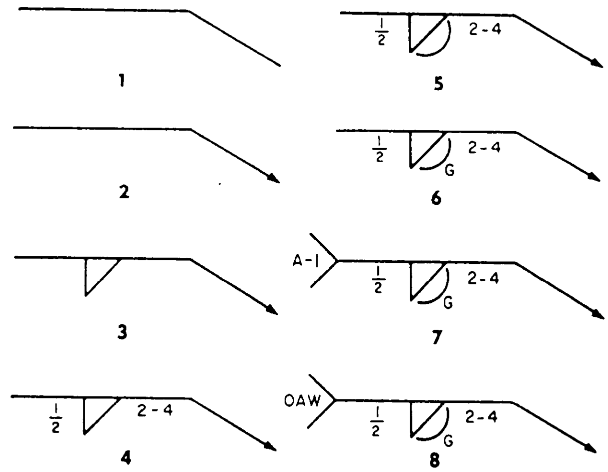


Figure 7-4.—Elements of a welding symbol.

3. This shows the basic weld symbols. In this case it should be a fillet weld located on the arrow side of the object to be welded.
4. This shows the dimensions and other data. The 1/2 means the weld should be 1/2 inch thick, and

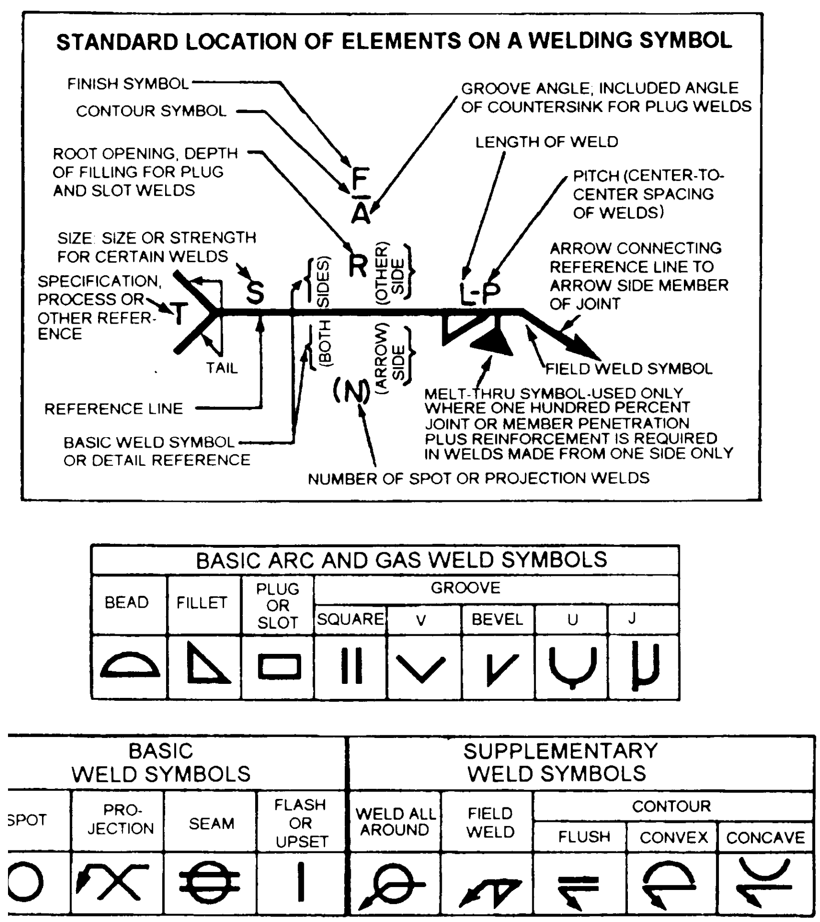


Figure 7-3.—Standard location of elements and types of welding symbols.

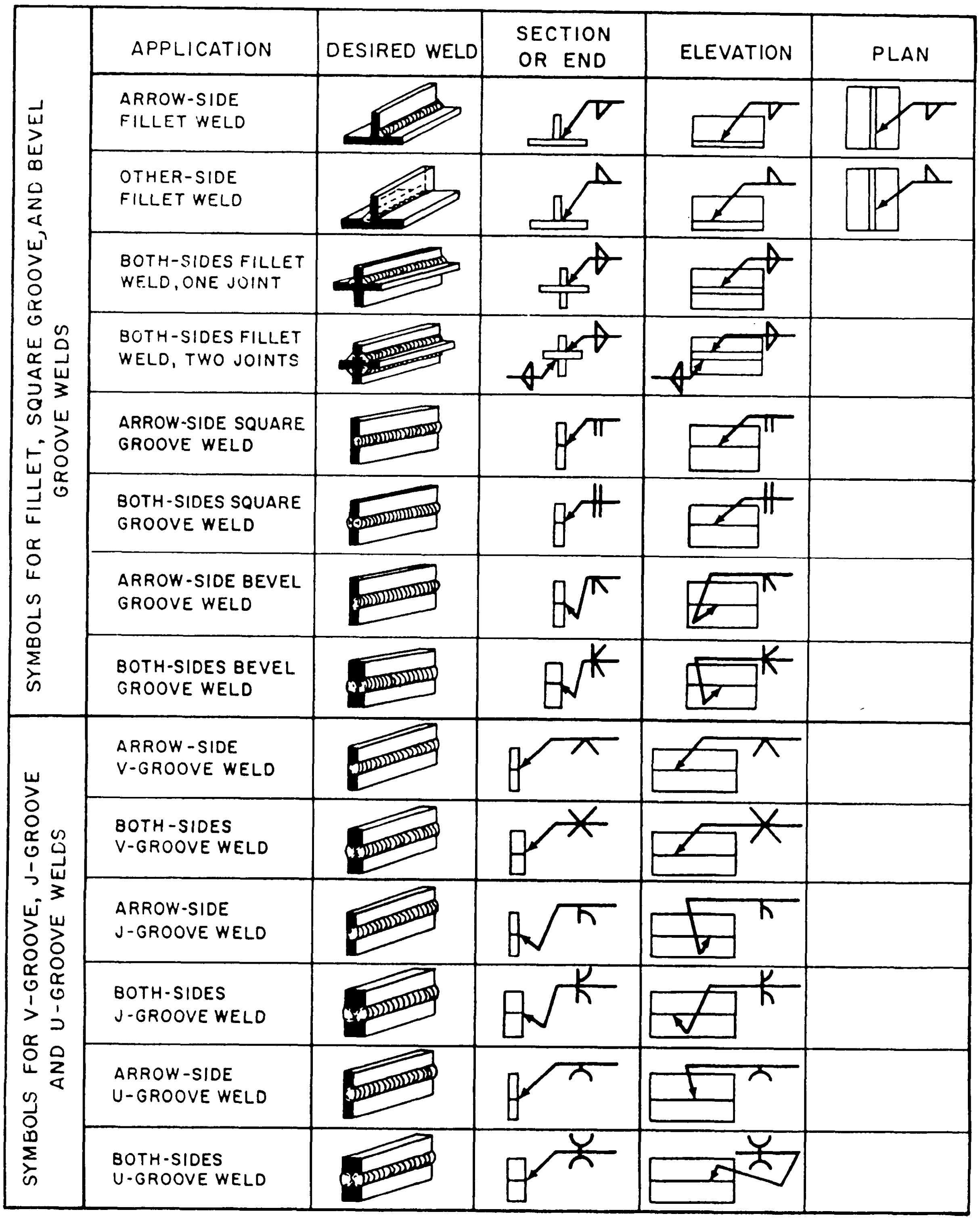


Figure 7-5.—Application of welding symbols.

the 2-4 means the weld should be 2 inches long (L) with a center spacing or pitch (P) of 4 inches.

5. This shows the supplementary symbols. This supplementary symbol means the weld should be convex.
6. This shows the finish symbol, G, which means the weld should be finished by grinding. Note that the finish *markings* that show the degree of finish are different; they are explained in chapter 4.
7. This shows the tail. It is used to set off symbols that order the machinist to use a certain process or to follow certain specifications or other references; in this case, specification A-1. The tail will be omitted if it is not needed for this purpose.
8. This shows the specifications, process, or other reference explained in item 7. In this example, the tail of the symbol indicates the abbreviation of a process-oxyacetylene welding (OAW).

(The abbreviation standards for every welding process are beyond the scope of this manual and have been omitted.)

Figure 7-5 illustrates the various welding symbols and their application.

WELDED STEEL TRUSSES

Figure 7-6 is a drawing of a typical welded steel truss. 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.

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.

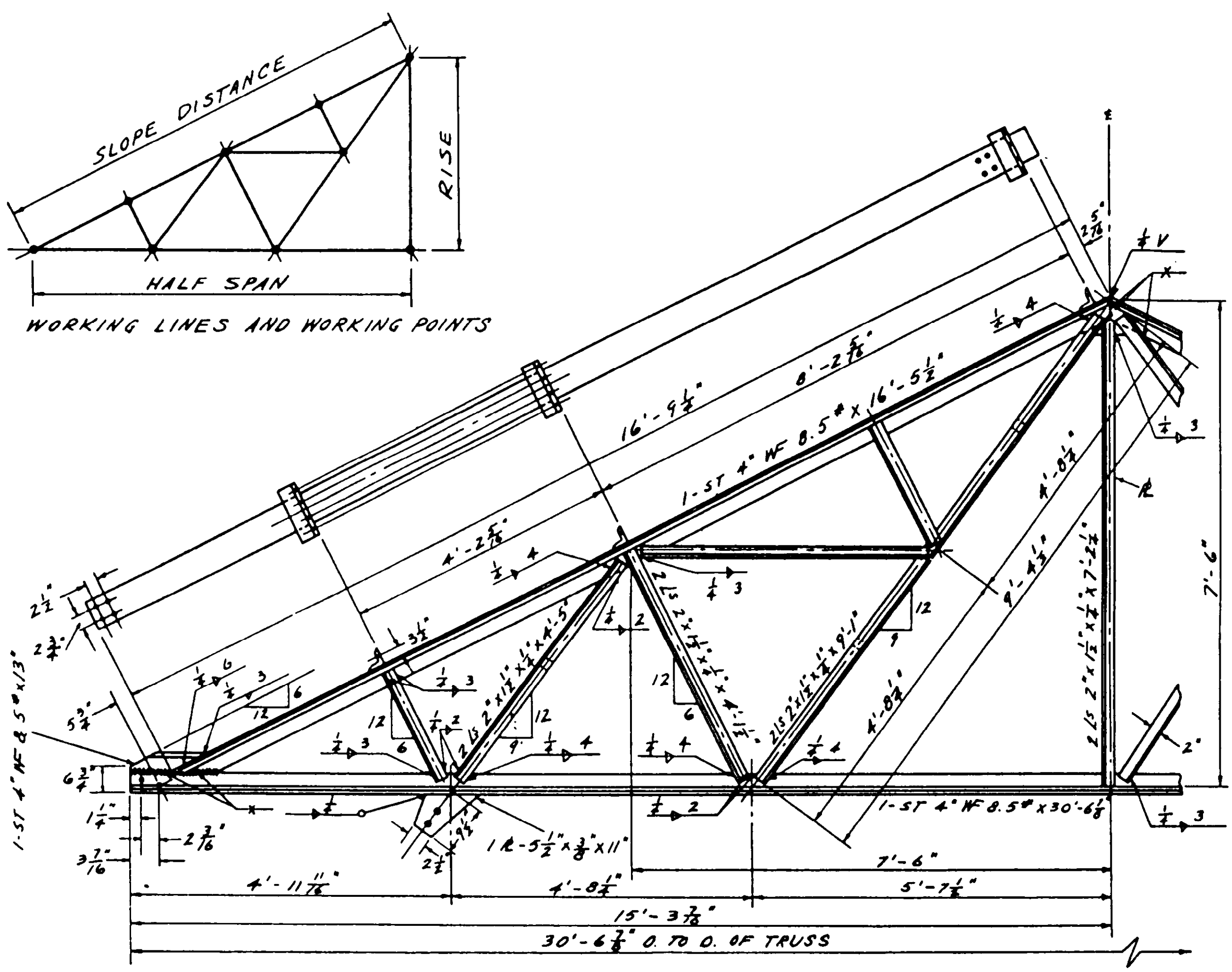


Figure 7-6.—Welded steel truss.

Go to figure 7-7 and look at the shop fabrication drawing of a riveted steel roof truss. 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. For example, note the following specifications in view A:

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.

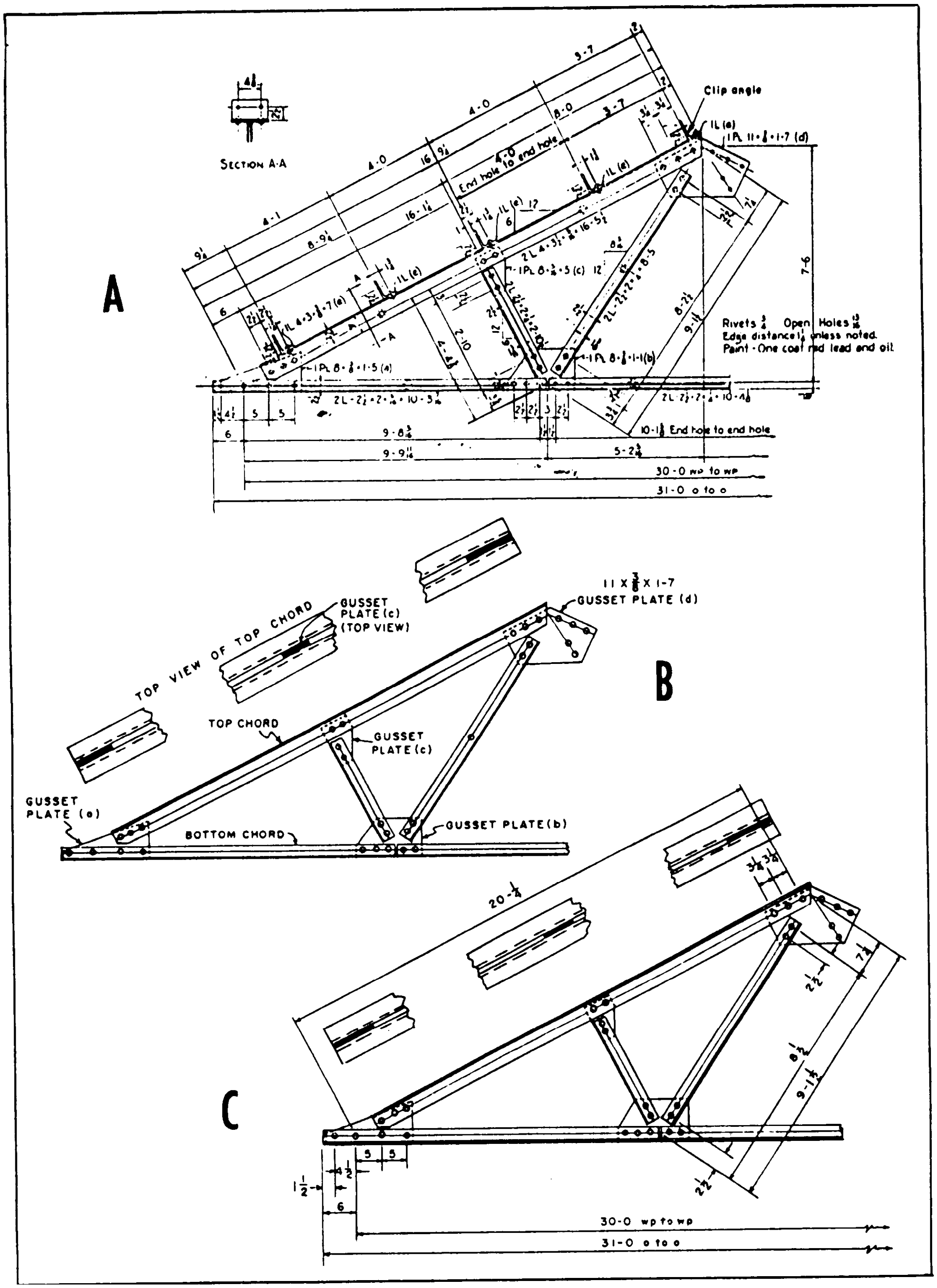


Figure 7-7.—Riveted steel truss. A. Typical shop drawing. B. Nomenclature, member sizes, and top view. C. Dimensions

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 x 2 x 5/16 x 10´-3 7/16″, which are connected to gusset plates a and b, and two more angles 2 1/2 x 2 x 1/4 x 10´-4 1/8″, 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 x 2 x 1/4 x 2´- 10 1/2″. 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 x 2 x 1/4 x 8´-5″.

View A also shows that 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. Figure 7-8 shows

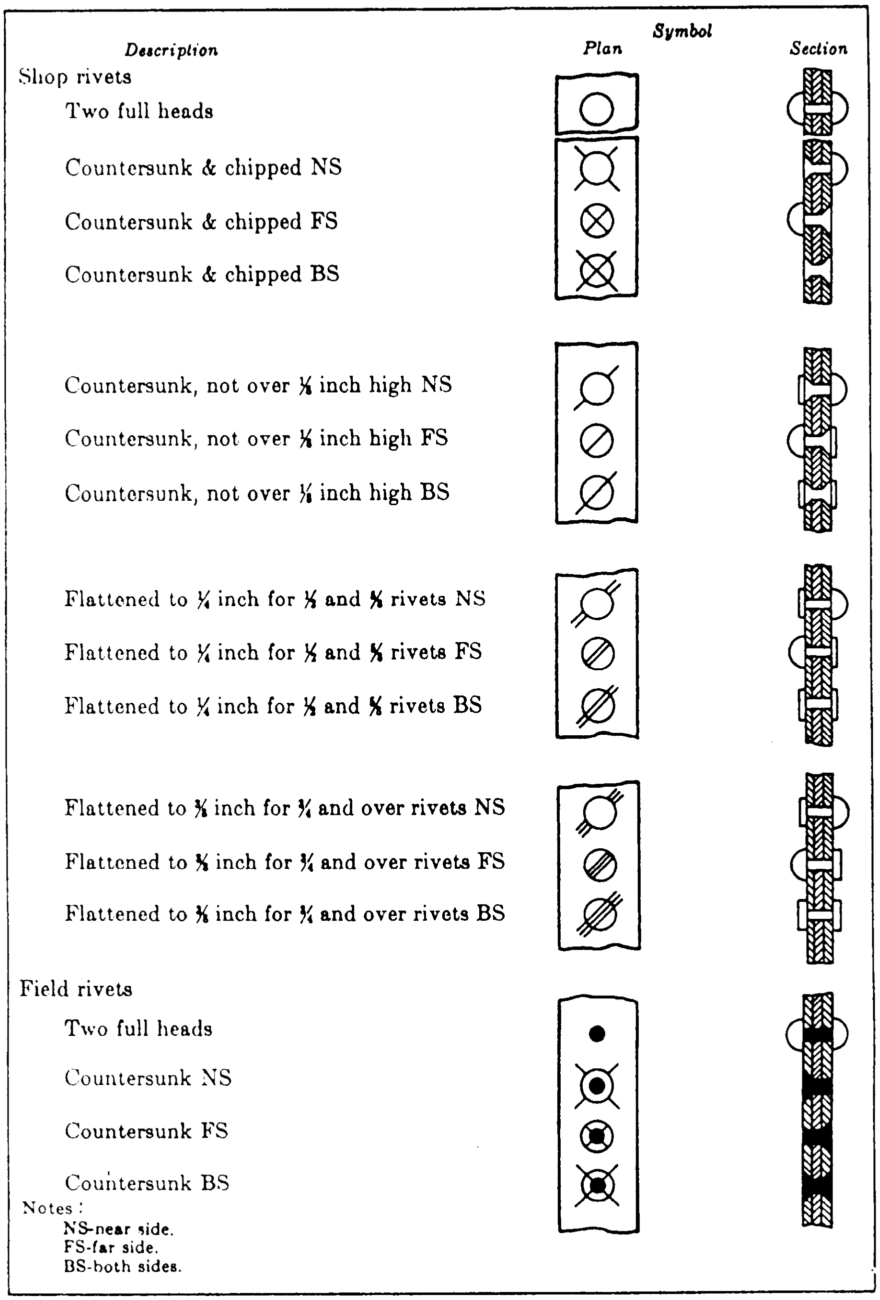


Figure 7-8.—Riveting symbols.

conventional symbols for rivets driven in the shop and in the field.

Figure 7-7, view B, shows the same truss with only the names of some members and the sizes of the gusset plates (a, c, and d) between the angles.

Figure 7-7, view C, is the same truss with only a few of the required dimensions to make it easier for you to read the complete structural shop drawing.

DRAWINGS OF STEEL STRUCTURES

Blueprints used far 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 that sometimes are 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. 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.

A plan view is a view of an object or area as it would appear if projected onto a horizontal plane passed through or held above the object area. The most common construction plans are plot plans (also called site plans), foundation plans, floor plans, and framing plans. We will discuss each of them in the following paragraphs.

A plot plan shows the contours, boundaries, roads, utilities, trees, structures, and other significant physical features about structures on their sites. The locations of the proposed structures are indicated by appropriate outlines or floor plans. As an example, a plot may locate the comers of a proposed structure at a given distance from a reference or base line. Since the reference or base line can be located at the site, the plot plan provides essential data for those who will lay out the building lines. The plot also can have contour lines that show the elevations of existing and proposed earth surfaces, and can provide essential data for the graders and excavators.

A foundation plan (fig. 7-9) is a plan view of a structure projected on a imaginary horizontal plane passing through at the level of the tops of the foundations. The plan shown in figure 7-9 tells you that the main foundation of this structure will consist of a rectangular 8-inch concrete block wall, 22 by 28 feet, centered on a concrete footing 10 inches wide. Besides the outside wall and footing, there will be two 12-inch square piers, centered on 18-inch square footings, and located 9 feet 6 inches from the end wall building lines. These piers will support a ground floor center-line girder.

Figure 7-10 shows the development of a typical floor plan, and figure 7-11 shows the floor plan itself.

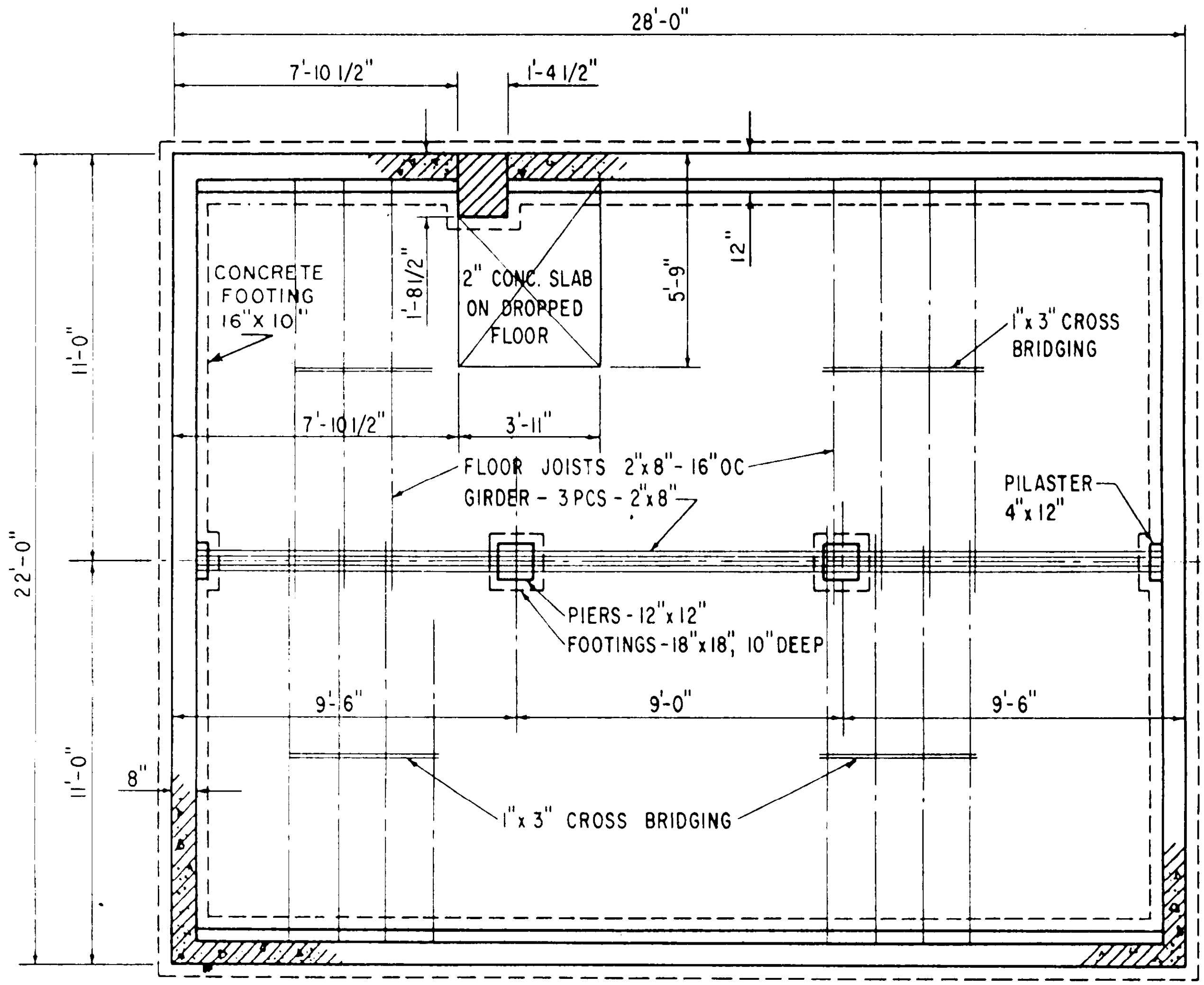


Figure 7-9.—Foundation plan.

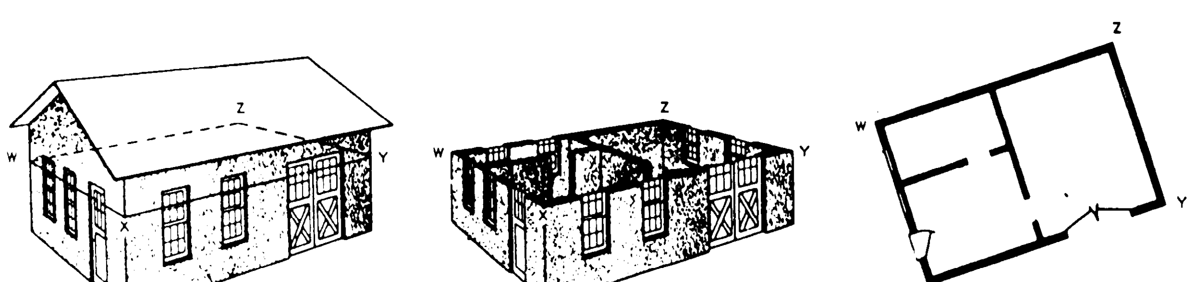


Figure 7-10.—Floor plan development.

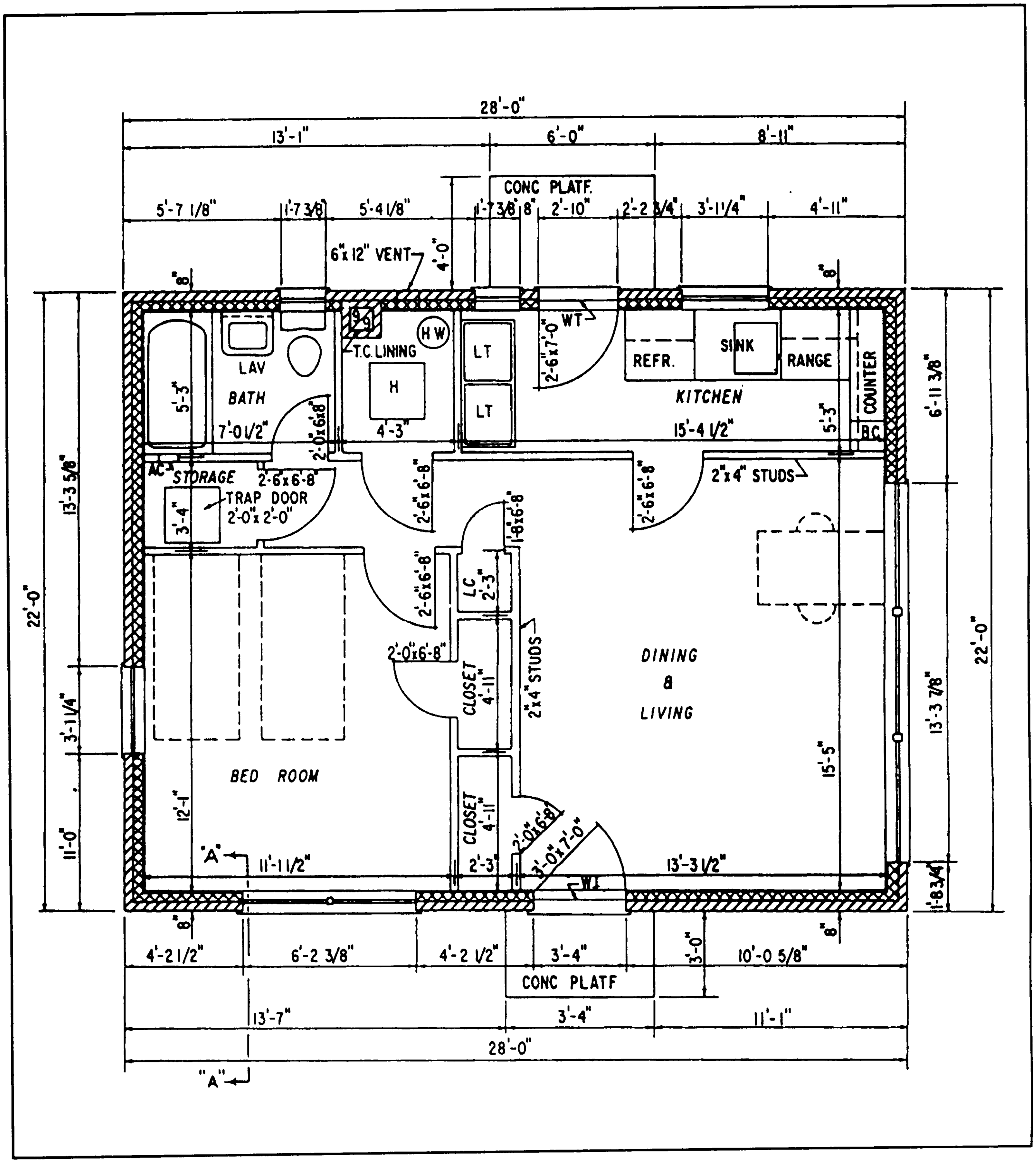


Figure 7-11.—Floor plan.

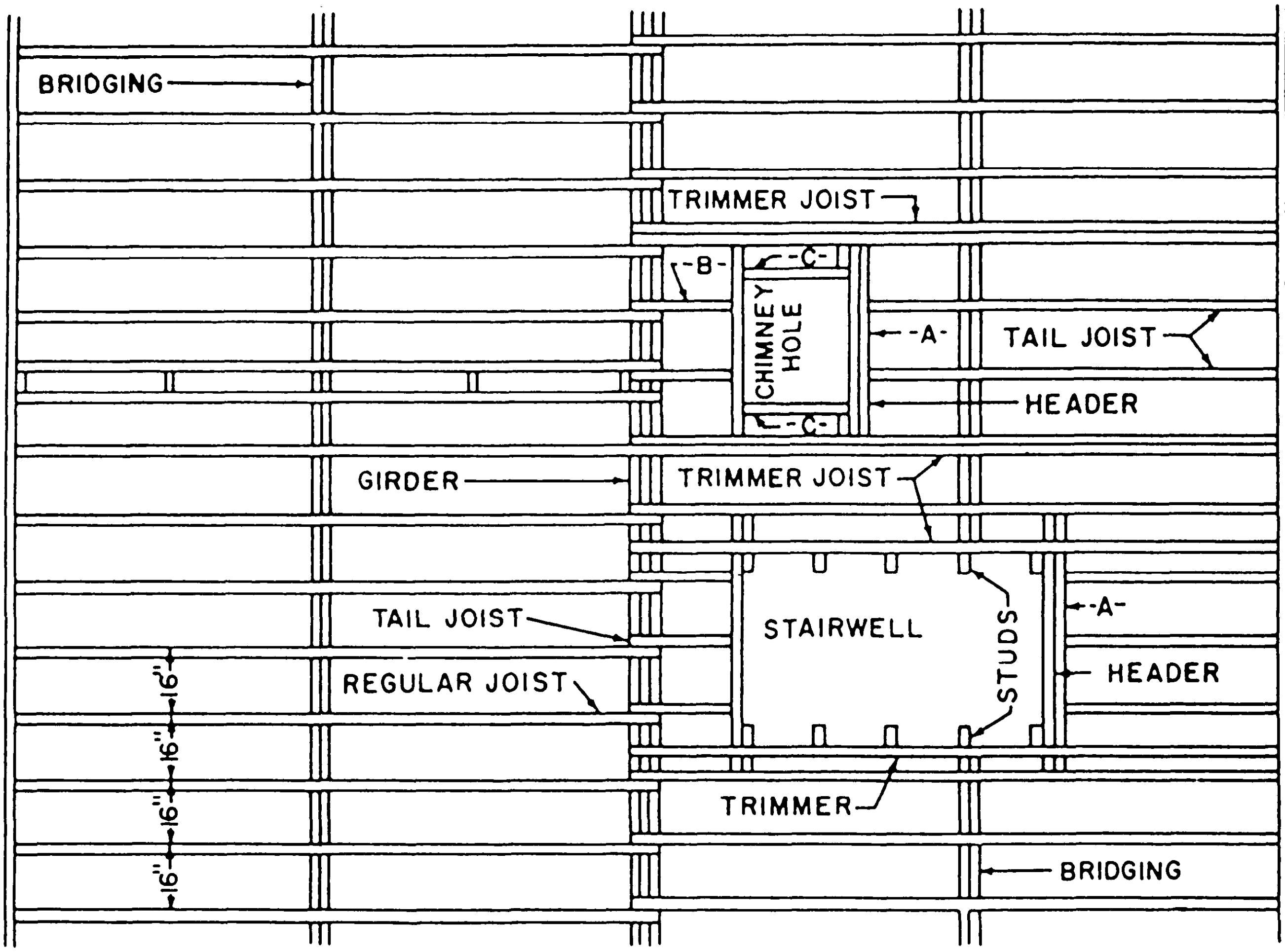


Figure 7-12.—Floor framing plan.

Information on a floor plan includes the lengths, thicknesses, and character of the building walls on that particular floor, the widths and locations of door and window openings, the lengths and character of partitions, the number and arrangement of rooms, and the types and locations of utility installations.

Framing plans show the dimension numbers and arrangement of structural members in wood-frame construction. A simple floor framing plan is superimposed on the foundation plan shown in figure 7-9. From this foundation plan you learn that the ground floor joists in this structure will consist of 2 by 8s, lapped at the girder, and spaced 16 inches on center (OC). The plan also shows that each row of joists is to be braced by a row of 1 by 3 cross bridges. More complicated floor framing problems require a framing plan like the one shown in figure 7-12. That plan, among other things, shows the arrangement of joists and other members around stairwells and other floor openings.

A wall framing plan provides information similar to that in figure 7-11 for the studs, corner posts, bracing, sills, plates, and other structural members in the walls. 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. A roof framing plan gives similar information with regard to the rafters, ridge, purlins, and other structural members in 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.

ELEVATIONS

Elevations show the front, rear, and sides of a structure projected on vertical planes parallel to the planes of the sides. Figure 7-13 shows front, rear, right side, and left side elevations of a small building.

As you can see, the elevations give you a number of important vertical dimensions, such as the perpendicular distance from the finish floor to the top of the rafter plate and from the finish floor to the tops of door and window finished openings. They also show the locations and characters of doors and windows. However, the dimensions of window sashes and dimensions and character of lintels are usually set forth in a window schedule.

SECTION VIEWS

A section view is a view of a cross section, developed as shown in figure 7-14. The term is confined to views of cross sections cut by vertical planes. A floor plan or foundation plan, cut by a horizontal plane, is a section as well as a plan view, but it is seldom called a section.

The most important sections are the wall sections. Figure 7-15 shows three wall sections for three alternate types of construction for the building shown in figures 7-9 and 7-11.

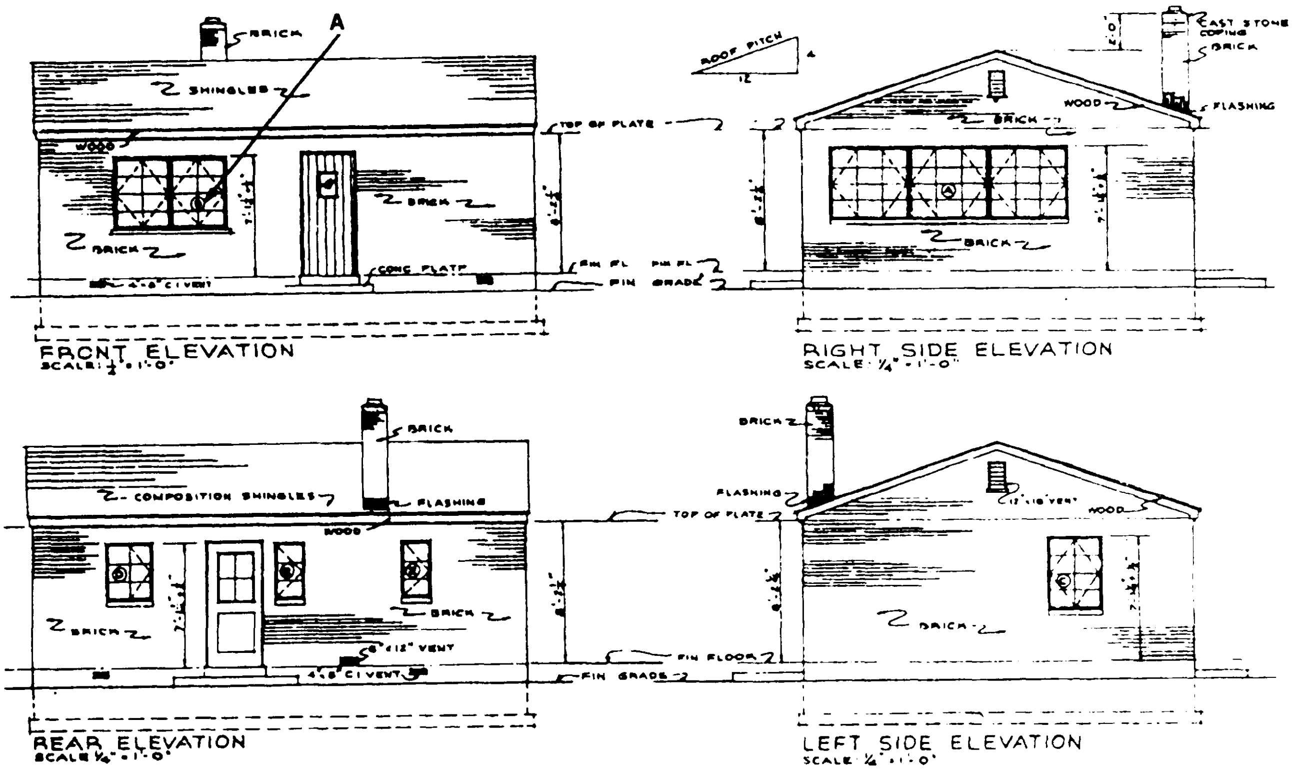


Figure 7-13.—Elevations.

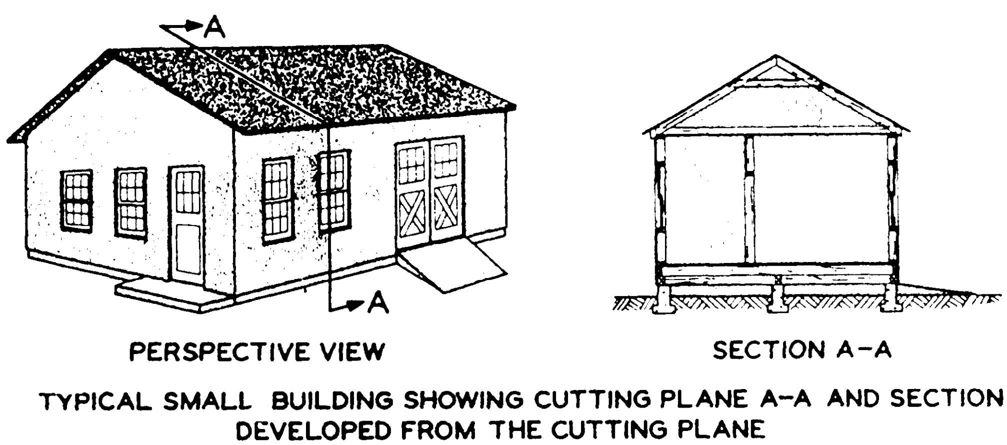


Figure 7-14.—Development of a sectional view.

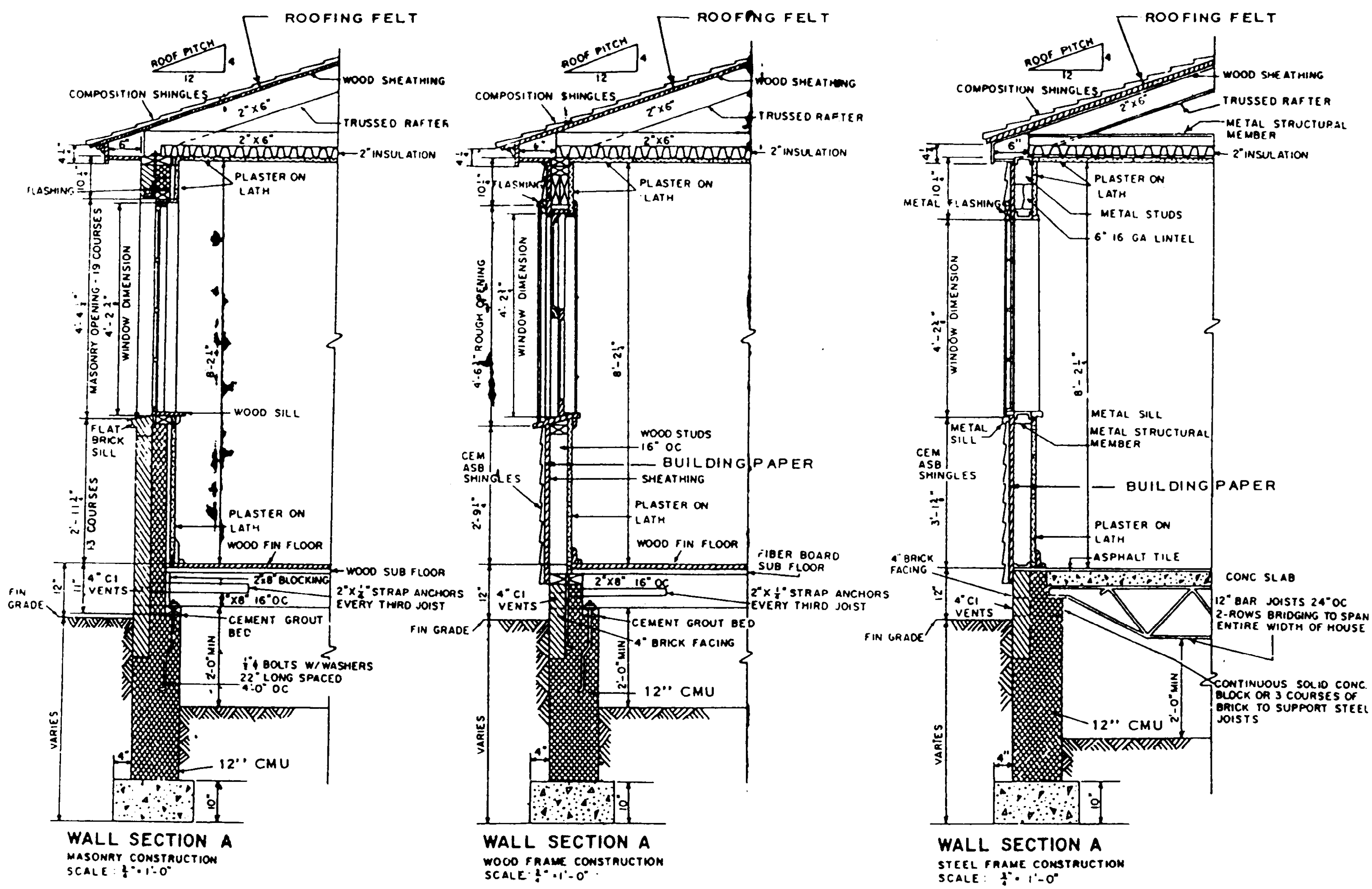


Figure 7-15.—Wall sections.

The angled arrows marked “A” in figure 7-11 indicate the location of the cutting plane for the sections.

To help you understand the importance of wall sections to the craftsmen who will do the actual building, look at the left wall section in figure 7-15 marked “masonry construction.” Starting at the bottom, you learn that the footing will be concrete, 1 foot 8 inches wide and 10 inches high. The vertical distance to the bottom of the footing below FIN GRADE (finished grade, or the level of the finished earth surface around the house) varies-meaning that it will depend on the soil-bearing capacity at the particular site. The foundation wall will consist of 12-inch concrete masonry units (CMU) centered on the footing. Twelve-inch blocks will extend up to an unspecified distance below grade, where a 4-inch brick facing (dimension indicated in the mid-wall section) begins. Above the line of the bottom of the facing, it is obvious that 8-inch instead of 12-inch blocks will be used in the foundation wall.

The building wall above grade will consist of a 4-inch brick facing tier, backed by a backing tier of 4-inch cinder blocks. The floor joists consist of 2 by 8s placed 16 inches OC and will be anchored on 2 by 4 sills bolted on the top of the foundation wall. Every third joist will be additionally secured by a 2 by 1/4 strap anchor embedded in the cinder block backing tier of the building wall.

Window A in the plan front elevation in figure 7-13 will have a finished opening 2 5/8 inches high. The bottom of the opening will be 2 feet 11 3/4 inches above the line of the finished floor. As shown in the wall section of figure 7-15, 13 masonry courses (layers of masonry units) above the finished floor line will equal a vertical distance of 2 feet 11 3/4 inches. Another 19 courses will amount to the prescribed vertical dimension of the finished window opening.

Figure 7-15 also shows window framing details, including the placement and cross-sectional character of the lintel. The building wall will be carried 10 1/4 inches, less the thickness of a 2 by 8 rafter plate, above the top of the finished window opening. The total vertical distance from the top of the finished floor to the top of the rafter will be 8 feet 2 1/4 inches. Ceiling joists and rafters will consist of 2 by 6s, and the roof covering will consist of composition shingles on wood sheathing.

Flooring will consist of a wood finished floor on a wood subfloor. Inside walls will be finished with plaster on lath (except on masonry, which would be with or without lath as directed). A minimum of 2 vertical feet of crawl space will extend below the bottoms of the floor joists.

The middle wall section in figure 7-15 gives similar information for a similar building constructed with wood-frame walls and a double-hung window. The third wall section in the figure gives you similar information for a similar building constructed with a steel frame, a casement window, and a concrete floor finished with asphalt tile.

DETAILS

Detail drawings are on a larger scale than general drawings, and they show features not appearing at all, or appearing on too small a scale, in general drawings. The wall sections in figure 7-15 are details as well as sections, since they are drawn on a considerably larger scale than the plans and elevations. Framing details at doors, windows, and cornices, which are the most common types of details, are nearly always shown in sections.

Details are included whenever the information given in the plans, elevations, and wall sections is not sufficiently “detailed” to guide the craftsmen on the job. Figure 7-16 shows some typical door and window wood framing tails, and an eave detail for a very simple type of cornice. Figure 7-17 shows architectural symbols for doors and windows.

SPECIFICATIONS

The construction drawings contain as much information about a structure as can be presented graphically. A lot of information can be presented this way, but there is more information that the construction craftsman must have that is not adaptable to the graphic form of presentation. Information of this kind includes quality criteria for materials (for example, maximum amounts of aggregate per sack of cement), specified standards of workmanship, prescribed construction methods, and so on. When there is a discrepancy between the drawings and the specifications, always use the specifications as authority.

This kind of information is presented in a list of written specifications, familiarly known as the specs. A list of specifications usually begins with a section on general conditions. This section starts with a general description of the building, including type of foundation, types of windows, character of framing, utilities to be installed, and so on. A list of definitions of terms used in the specs comes next, followed by certain routine declarations of responsibility and certain conditions to be maintained on the job, Figure 7-18 shows a flow chart for selection and documentation of concrete proportions.

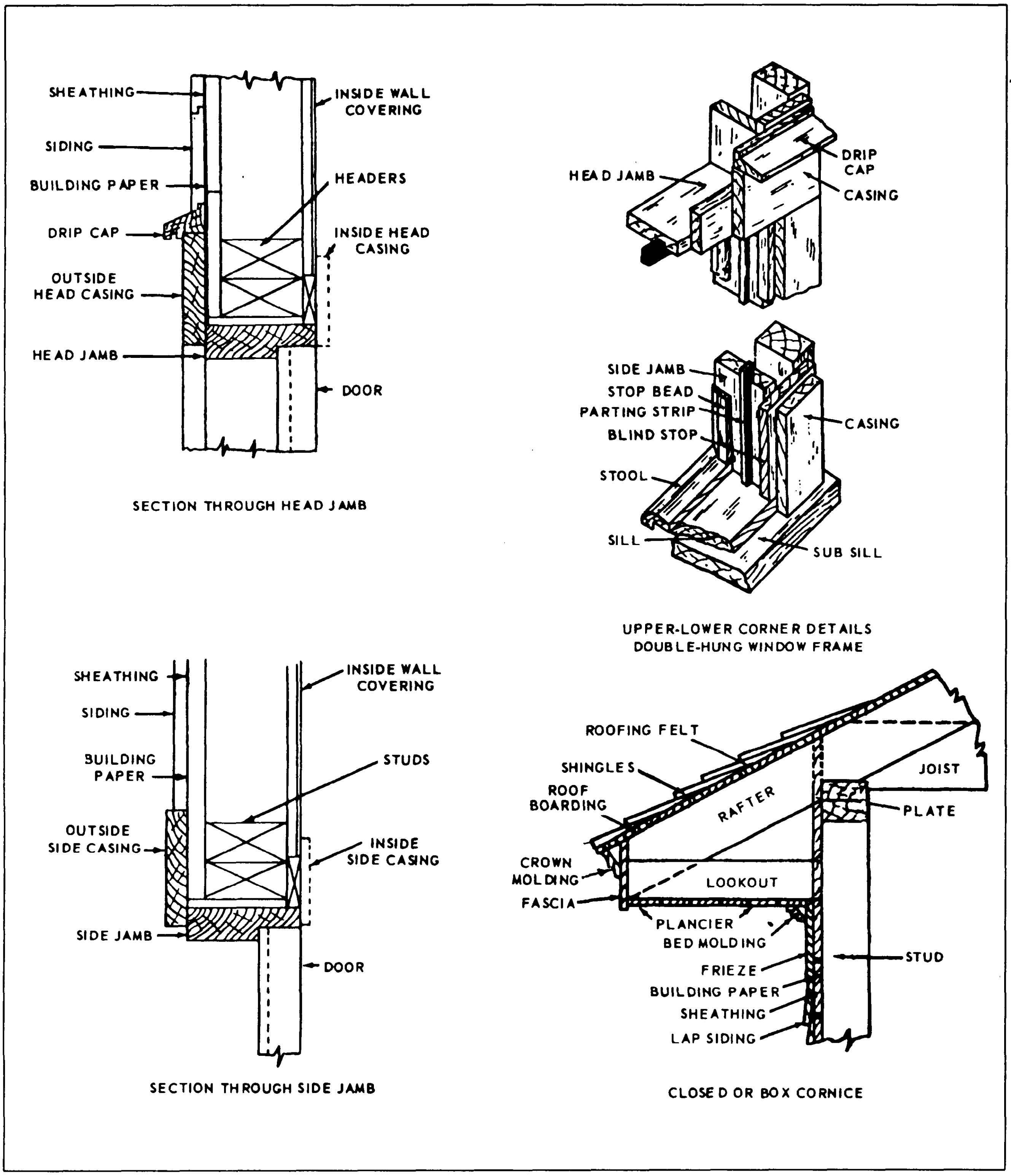


Figure 7-16.—Door, window, and eave details.

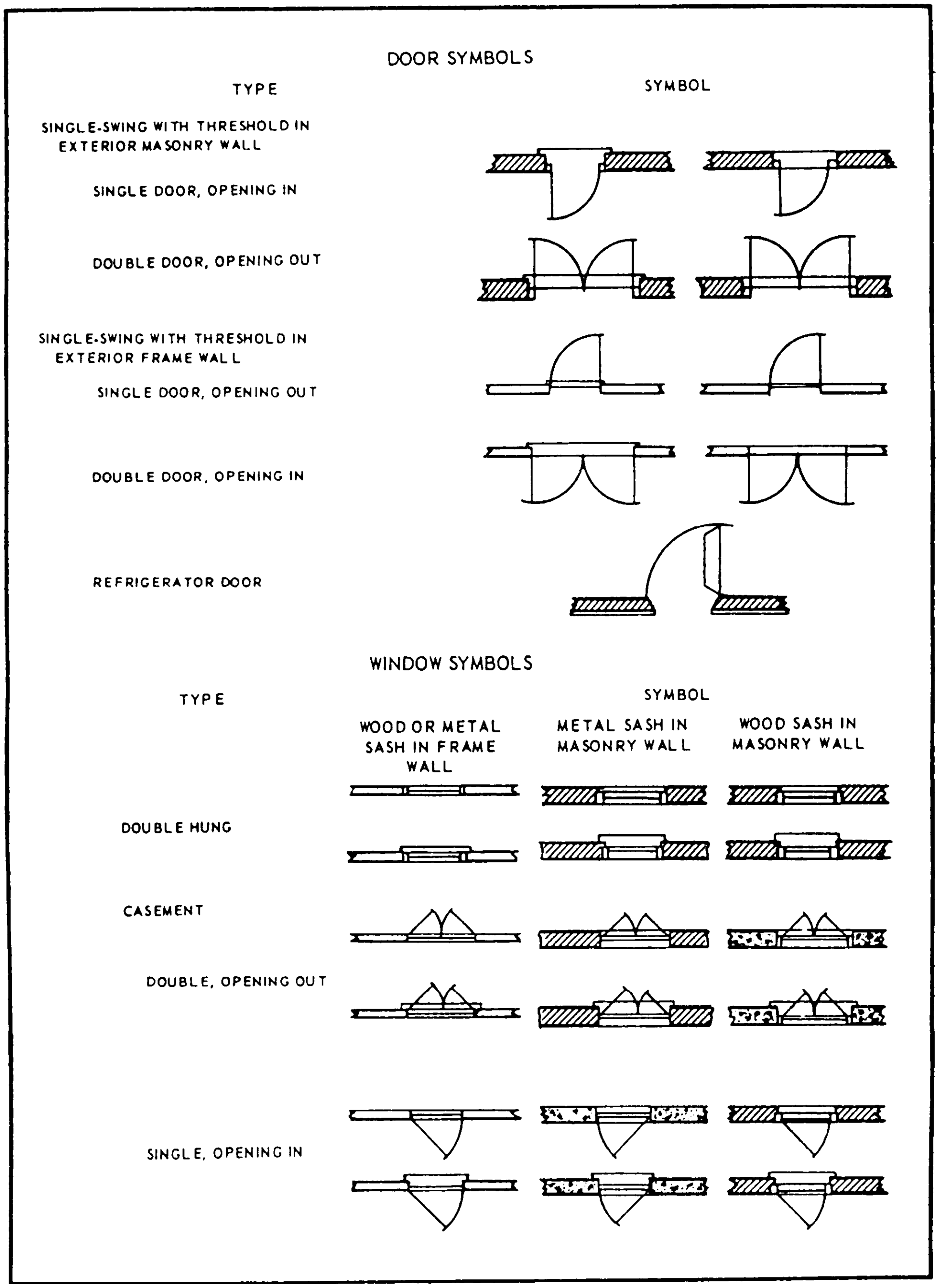


Figure 7-17.—Architectural symbols.

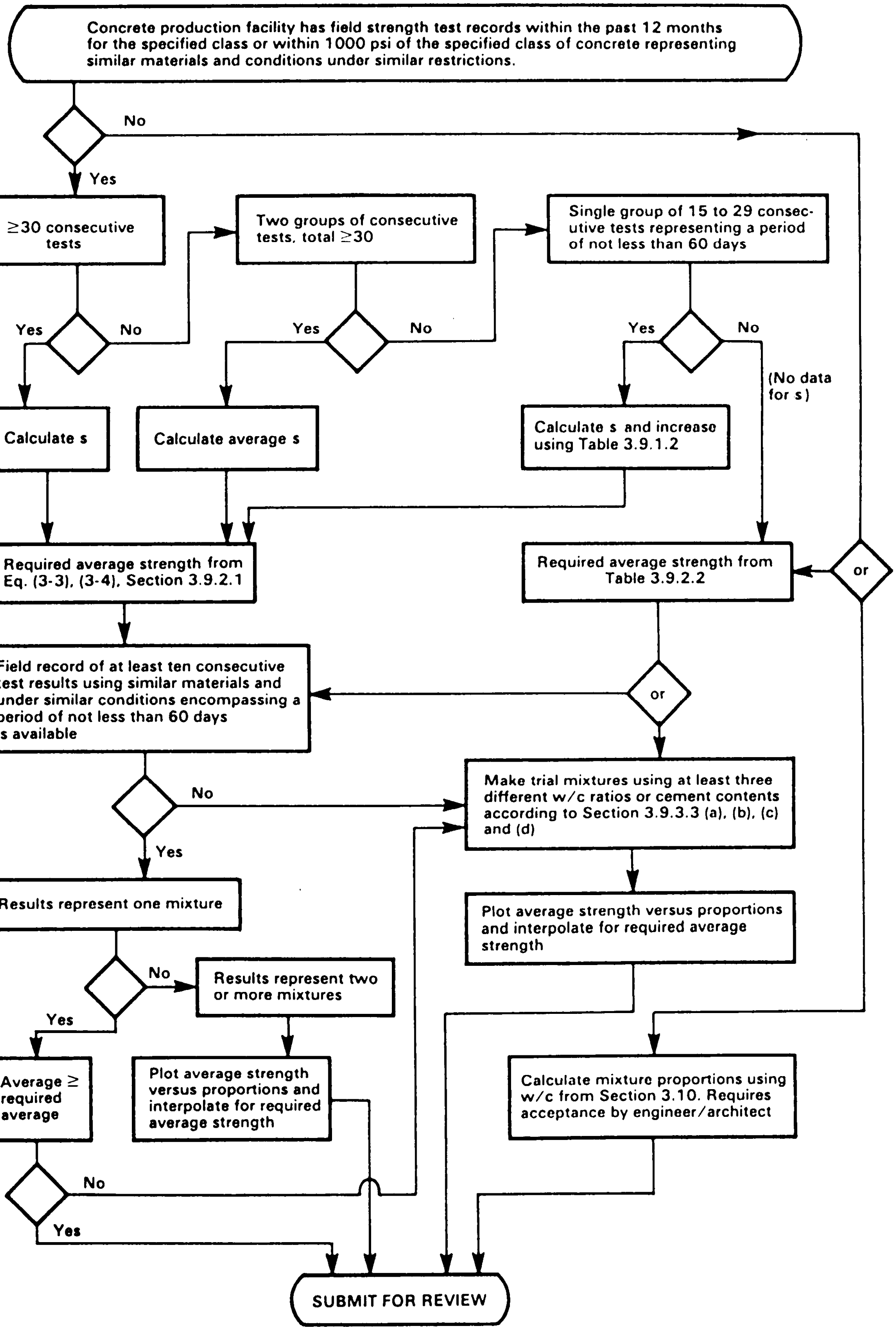


Figure 7-18.—Flow Chart for selection and documentation of concrete proportions.

CHAPTER 8

DEVELOPMENTS AND INTERSECTIONS

When you have read and understood this chapter, you should be able to answer the following learning objectives:

- *Describe sheet metal developments.*
- *Explain the differences among parallel, radial, and triangulation developments.*

Sheet metal drawings are also known as sheet metal developments and pattern drawings, and we may use all three terms in this chapter. This is true because the layout, when made on heavy cardboard thin metal, a 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. We will discuss each of these, but first we will look at the drawings of corrections used to join sheet metal objects.

JOINTS, SEAMS, 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 exposed edges. The drawing must allow for the additional material needed for those joints, seams, and edges.

Figure 8-1 shows various ways to illustrate seams, and edges. Seams are used to join edges. The seams may be fastened together by lock seams, solder, rivets, adhesive, or welds. Exposed edges are folded or wired to give the edges added strength and to eliminate sharp edges.

The lap seam shown is the least difficult. The pieces of stock are merely lapped one over the other, as shown in view C, and secured either by riveting, soldering, spot welding, or by all three methods, depending on the nature of the job. A flat lock seam (view C) is used to construct cylindrical objects, such as funnels, pipe sections, and containers.

Note that most of the sheet metal developments illustrated in this chapter do not make any allowances for edges, joints, or seams. However, the draftsman who lays out a development must add extra metal where needed

BENDS

The drafter must also show where the material will be bent, and figure 8-2 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, and bend up 45 degrees*, should be shown beside each bend line.

Anyone who bends metal to exact dimensions must know the bend allowance, which is the amount of material used to form the bend. Bending compresses the metal on the inside of the bend and stretches the metal on its outside. About halfway between these two extremes lies a space that neither shrinks nor stretches; it is known as the neutral line or neutral axis, as shown in figure 8-3. Bend allowance is computed along this axis.

You should understand the terms used to explain bend allowance. These terms are illustrated in figure 8-4 and defined in the following paragraphs:

LEG—The longer part of a formed angle.

FLANGE—The shorter part of a formed angle. If both parts are the same length, each is called a leg.

MOLD LINE (ML)—The line formed by extending the outside surfaces of the leg and flange so they intersect. It is the imaginary point from which base measurements are shown on drawings.

BEND TANGENT LINE (BL)—The line at which the metal starts to bend.

BEND ALLOWANCE (BA)—The amount of metal used to make the bend.

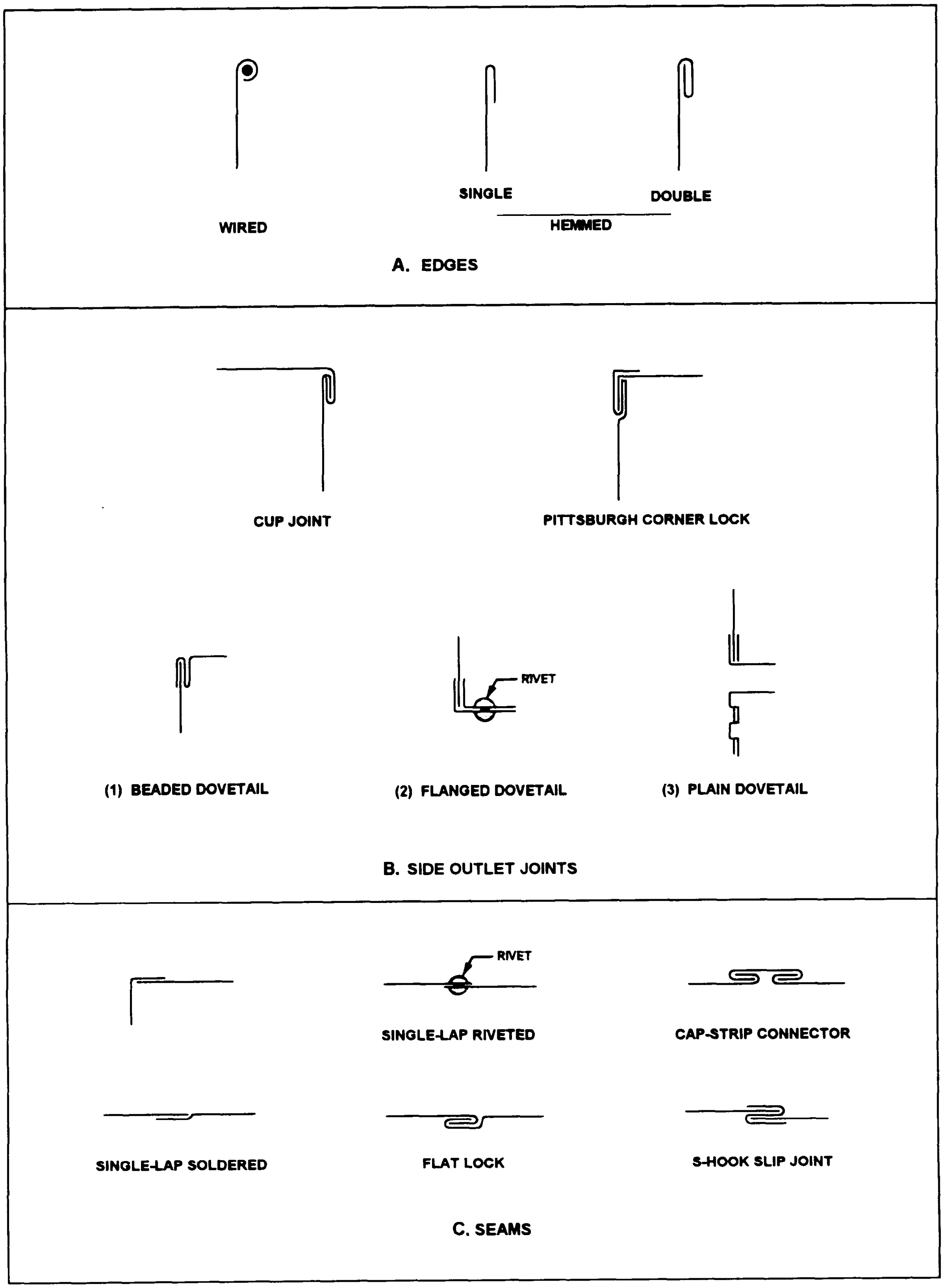


Figure 8-1.—Joints, seams, and edges

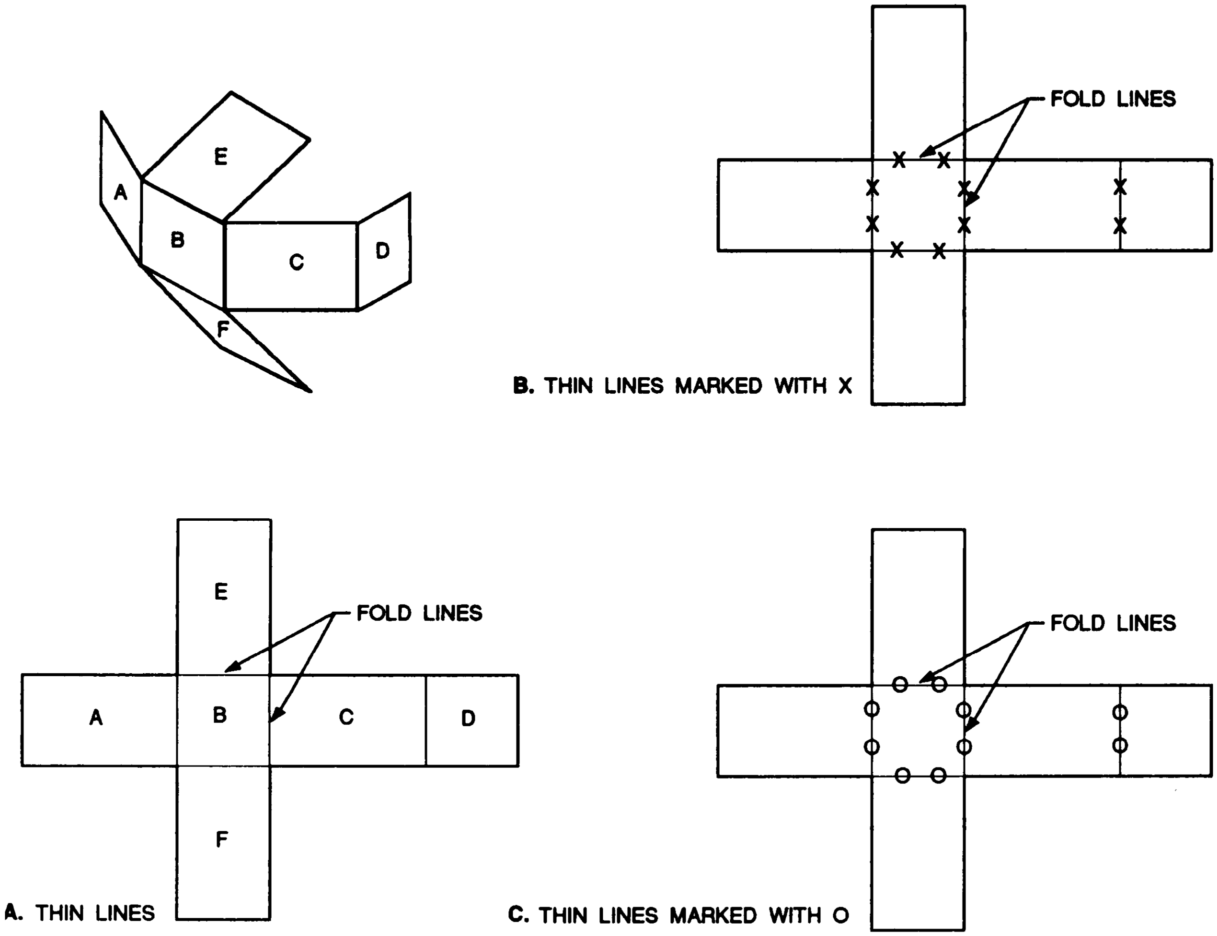


Figure 8-2.—Methods used to identify fold or bend lines

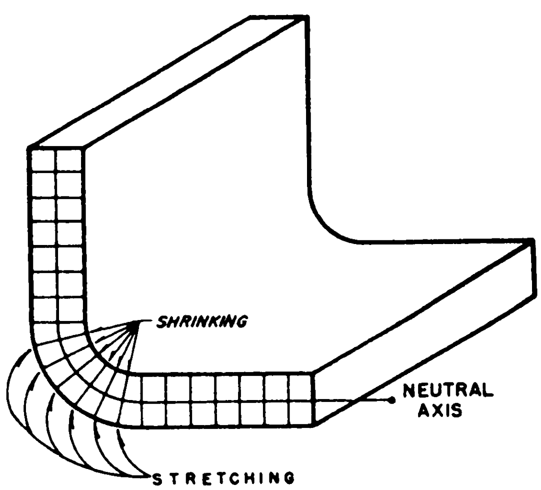


Figure 8-3.—Bend characteristics.

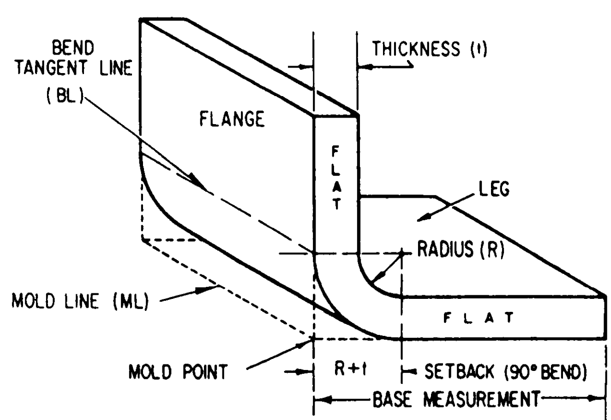


Figure 8-4.—Bend allowance terms.

RADIUS (R)—The radius of the bend. It is always measured from the inside of the bend unless stated otherwise.

SETBACK (SB)—The distance from the bend tangent line to the mold point. In a 90-degree bend, SB = R + T (radius of bend plus thickness of metal).

FLAT—That portion not including the bend. It is equal to the base measurement minus the setback.

BASE MEASUREMENT—The outside diameter of the formed part.

Engineers have found they can get accurate bends by using the following formula:

$$BA = N \times 0.01743 \times R + 0.0078 \times T$$

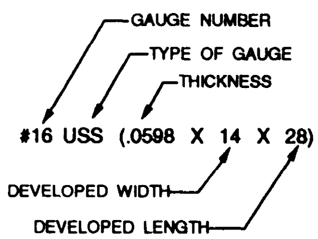


Figure 8-5.—Reading sheet metal sizes.

Where BA = bend allowance, N = number of degrees of bend, R = the desired bend radius, and T = the thickness of the metal.

SHEET METAL SIZES

Metal thicknesses up to 0.25 inch (6mm) are usually designated by a series of gauge numbers. Figure 8-5 shows how to read them. 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 (fig. 8-5).

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.

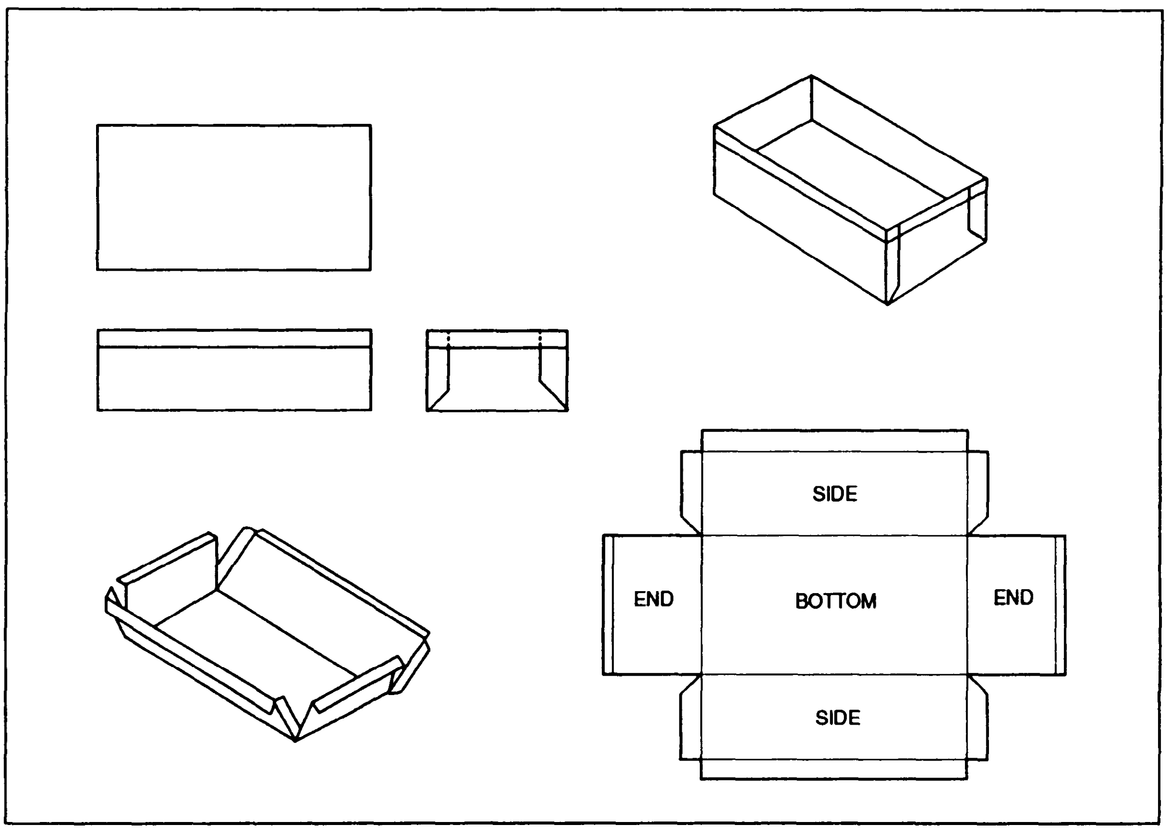


Figure 8-6.—Development of a rectangular box.

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 following pages cover developable and nondevelopable, or approximate, methods. For examples, straight-line and radial-line development are developable forms. However, triangular development requires approximation.

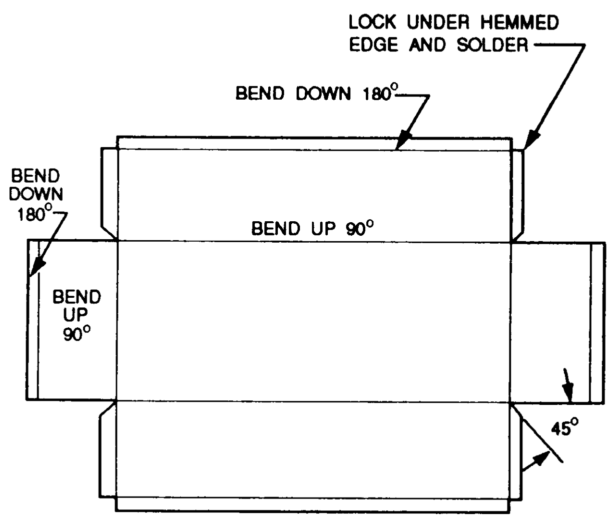


Figure 8-7.—Development drawing with folding instructions.

STRAIGHT-LINE DEVELOPMENT

This term 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. Figure 8-6 shows the development of a simple rectangular box with a bottom and four sides. 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 8-7 shows a development drawing with a complete set of folding instructions. Figure 8-8 shows a letter box development drawing where the back is higher than the front surface.

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 draftsman must find other means, as we will discuss in the following paragraphs on the development of right, oblique, and truncated pyramids.

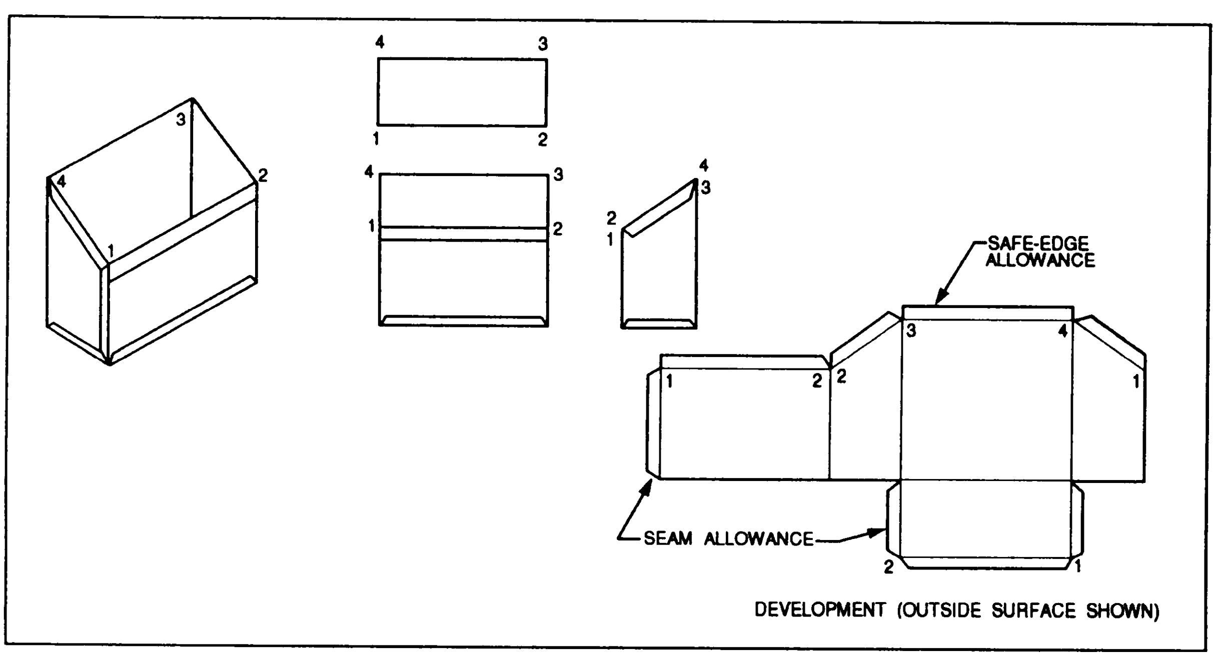


Figure 8-8.—Development drawing of a letter box.

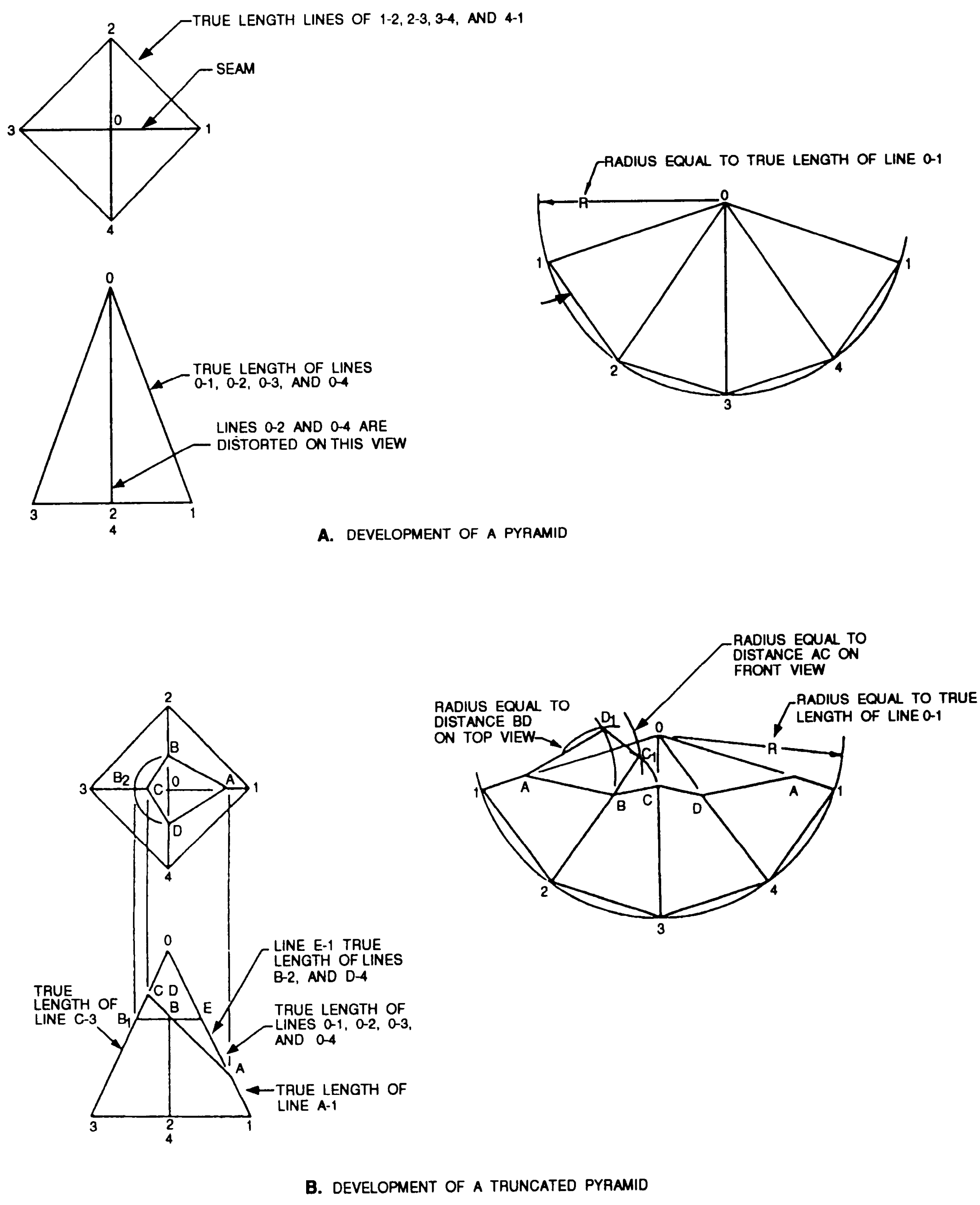


Figure 8-9.—Development of a right pyramid with true length-of-edge lines shown.

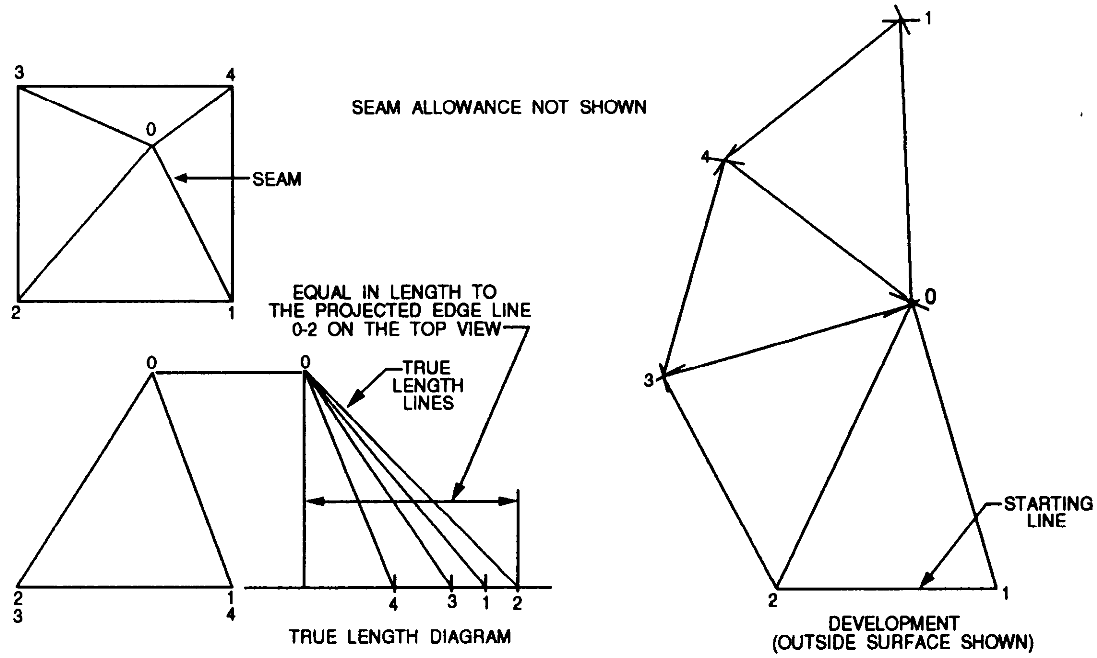


Figure 8-10.—Development of an oblique pyramid by triangulation.

Right Pyramid

Construct a radial-line development of a triangle with a true length-of-edge line (fig. 8-9) and a right pyramid having all the lateral edges (from vertex to the base) of equal length. Since the true length of the lateral edges is shown in the front view (line (0-1 or 0-3) and the top view shows the true lengths of the edges of the base (lines 1-2, 2-3, and so on), the development may be constructed as follows:

With 0 as center (corresponding to the apex) and with a radius equal to the true length of the lateral edges (line 0-1 in the front view), draw an arc as shown. Drop a perpendicular line from 0 to intersect the arc at point 3. With a radius equal to the length of the edge of the base (line 1-2 on the top view), start at point 3 and step off the distances 3-2, 2-1, 3-4, and 4-1 on the large arc. Join these points with straight lines. Then connect the points to point 0 by a straight line to complete the development. Lines 0-2, 0-3, and 0-4 are the fold lines on which the development is folded to shape the pyramid The base and seam allowance have been omitted for clarity.

Oblique Pyramid

The oblique pyramid in figure 8-10 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:

Lay out base line 1-2 in the development view equal in length to base line 1-2 found in the top view. With point 1 as center and a radius equal in length to line 0-1 in the true diagram, swing an arc. 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. With point 0 as center and a radius equal in length to line 0-3 in the true-length diagram, swing an arc. 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. 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

Figure 8-11 shows a truncated pyramid that is developed in the following manner: Look at the views in figure 8-11 as you read the explanation.

Draw the orthographic views, extending the lines of the sides to the apex at the top in view A. Draw three horizontal construction lines on the right side of the orthographic view (view B), one from the center of the top view; one from the top of the front view; and one from the bottom of the front view. With the point of the compass in the center of the top view, scribe two arcs (view C). Draw one from the inside corner of the top view to the horizontal line (point W), and the other from the outside corner of the top view to the horizontal line (point X). Draw two vertical lines, one from point W in

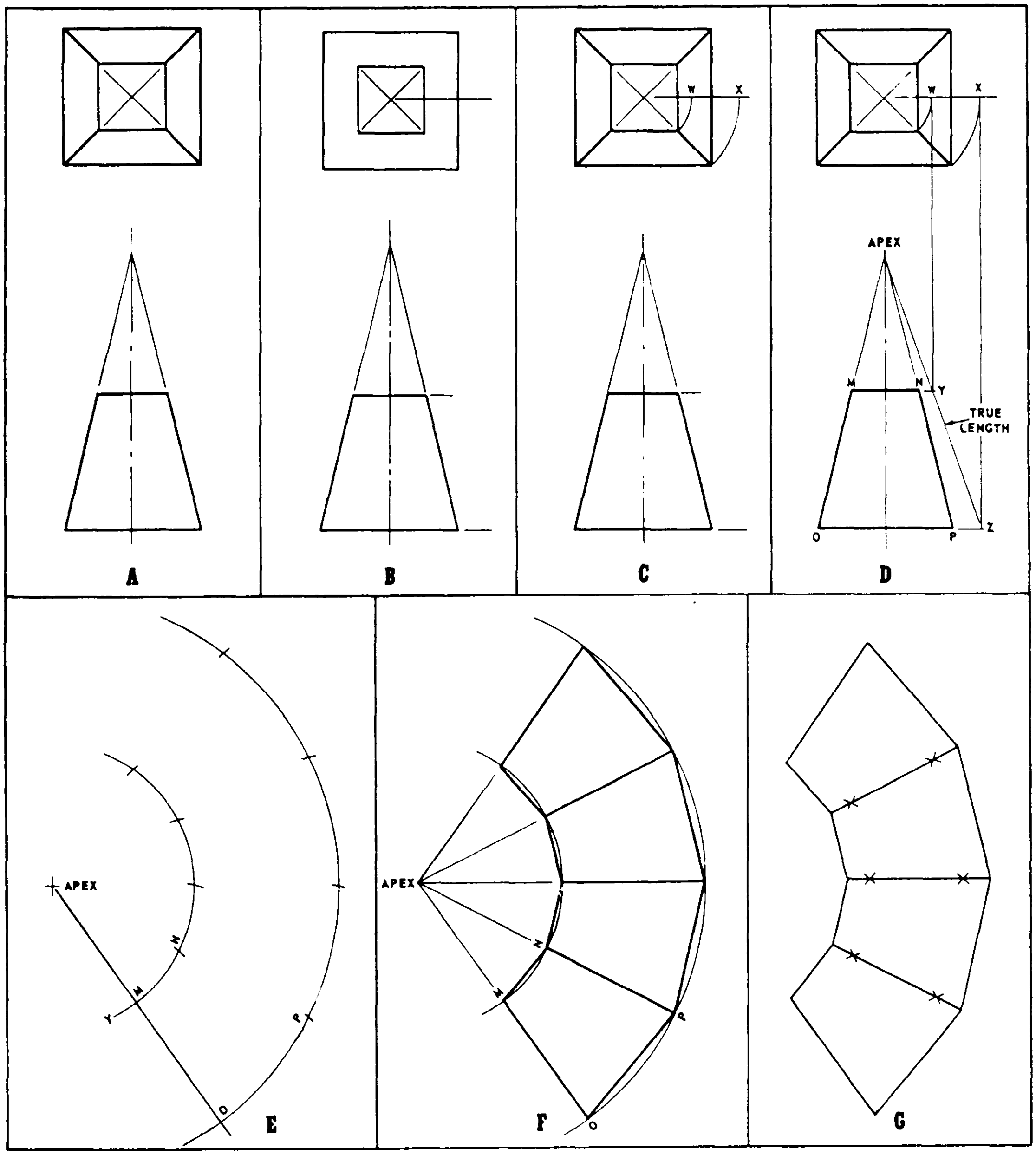


Figure 8-11.—Development of a truncated pyramid.

view D to the upper horizontal line on the front view (point Y), and the other from X to the lower horizontal line of the front view (point 2). Draw a line from the apex through points Y and 2 in view D. The distance between points Y and Z equals the true length of the truncated pyramid With the compass point at the apex of view E, find any convenient point to the right of the orthographic view, scribe an arc with a radius equal to the distance between the apex and point Y in view D, and a second arc with a radius equal to the distance between the apex and point Z in view D. The two arcs are shown in view E. Draw a radial line beginning at the apex and cutting across arcs Y and Z in view E. Step off lengths along these arcs equal to the length of the sides of the pyramid: MN for the inside arc and OP for the outside arc (view E); the lengths MN and OP are taken from the orthographic view in view D. Connect the points along each arc with heavy lines (for example, points MN along the inner arc and points OP along the outer arc); Also use light lines to connect the apex with points M and 0, and the apex with points N and P, and so on, as shown in view F.

View G is the completed stretchout of a truncated pyramid complete with bend lines, which are marked (X).

PARALLEL-LINE DEVELOPMENT

Look at figure 8-12 as you read the following material on parallel-line development.

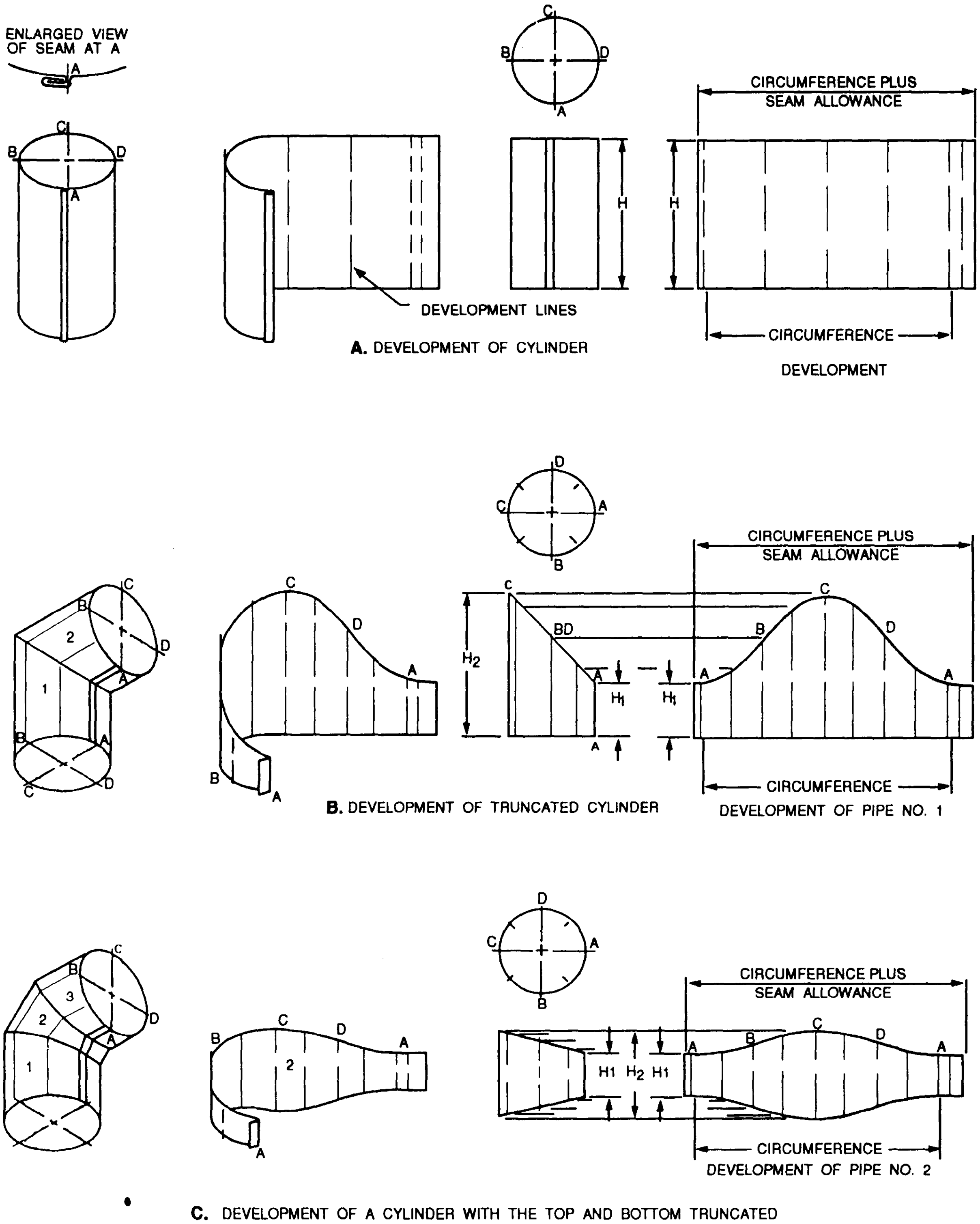


Figure 8-12.—Development of cylinders.

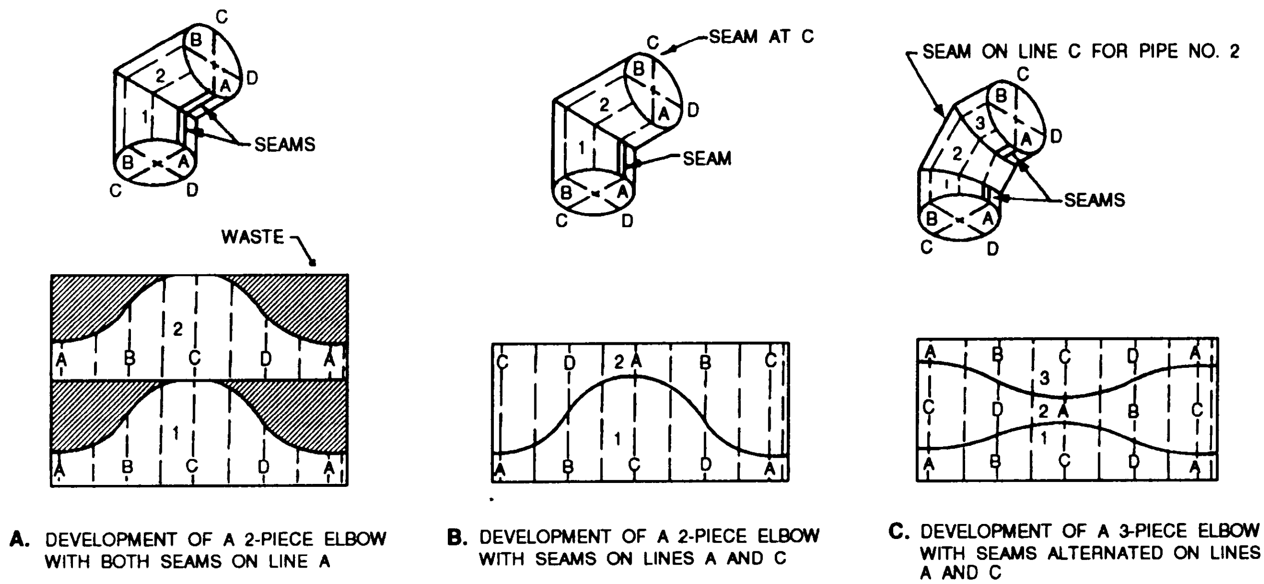


Figure 8-13.—Location of seams on elbows.

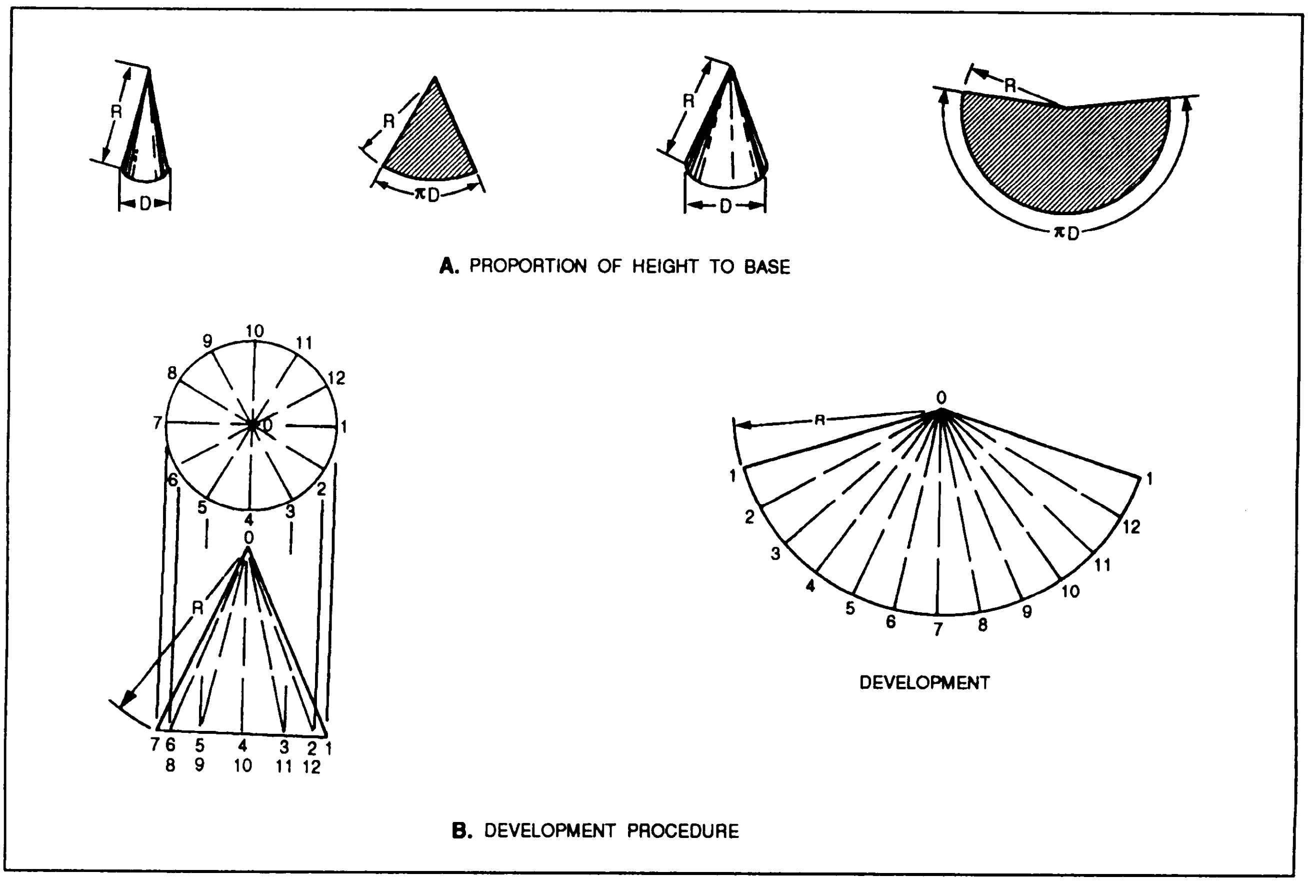


Figure 8-14.—Development of a cone.

View A shows the lateral, or curved, surface of a cylindrically shaped object, such as a tin can. It is developable since it has a single-curved surface of one constant radius. The width of the development is equal to the height of the cylinder, and the length of the development is equal to the circumference of the cylinder plus the seam allowance.

View B shows the development of a cylinder with the top truncated at a 45-degree angle (one half of a two-piece 90-degree elbow). Points of intersection are established to give the curved shape on the development. These points are derived from the intersection of a length location, representing a certain distance around the circumference from a starting point, and the height location at that same point on the circumference. The closer the points of intersection are to one another, the greater the accuracy of the development. An irregular curve is used to connect the points of intersection.

View C, shows the development of the surface of a cylinder with both the top and bottom truncated at an angle of 22.5° (the center part of a three-piece elbow). It is normal practice in sheet metal work to place the seam on the shortest side. In the development of elbows, however, the practice would result in considerable waste of material, as shown in view A. To avoid this waste and to simplify cutting the pieces, the seams are alternately placed 180° apart, as shown in figure 8-13, view B, for a two-piece elbow, and view C for a three-piece elbow.

RADIAL-LINE DEVELOPMENT OF CONICAL SURFACES

The surface of a cone is developable because a thin sheet of flexible material can be wrapped smoothly about it. The two dimensions necessary to make the development of the surface are the slant height of the cone and the circumference of its base. For a right circular cone (symmetrical about the vertical axis), the developed shape is a sector of a circle. The radius for this sector is the slant height of the cone, and the length around the perimeter of the sector is equal to the circumference of the base. The proportion of the height to the base diameter determines the size of the sector, as shown in figure 8-14, view A.

The next three subjects deal with the development of a regular cone, a truncated cone, and an oblique cone.

Regular Cone

In figure 8-14, view B, the top view is divided into an equal number of divisions, in this case 12. The chordal distance between these points is used to step off the length of arc on the development. The radius for the development is seen as the slant height in the front view. If a cone is truncated at an angle to the base, the inside shape on the development no longer has a constant radius; it is an ellipse that must be plotted by establishing points of intersection. The divisions made on the top view are projected down to the base of the cone in the front view. Element lines are drawn from these points to the apex of the cone. These element lines are seen in their true length only when the viewer is looking at right angles to them. Thus the points at which they cross the truncation line must be carried across, parallel to the base, to the outside element line, which is seen in its true length. The development is first made to represent the complete surface of the cone. Element lines are drawn from the step-off points about the circumference to the center point. True-length settings for each element line are taken for the front view and marked off on the corresponding element lines in the development. An irregular curve is used to connect these points of intersection, giving the proper inside shape.

Truncated Cone

The development of a frustum of a cone is the development of a full cone less the development of the part removed, as shown in figure 8-15. Note that, at all times, the radius setting, either R_1 or R_2, is a slant height, a distance taken on the surface of the cones.

When the top of a cone is truncated at an angle to the base, the top surface will not be seen as a true circle. This shape must be plotted by established points of intersection. True radius settings for each element line are taken from the front view and marked off on the corresponding element line in the top view. These points are connected with an irregular curve to give the correct oval shape for the top surface. If the development of the sloping top surface is required, an auxiliary view of this surface shows its true shape.

Oblique Cone

An oblique cone is generally developed by the triangulation method. Look at figure 8-16 as you read this explanation. The base of the cone is divided into an equal number of divisions, and 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

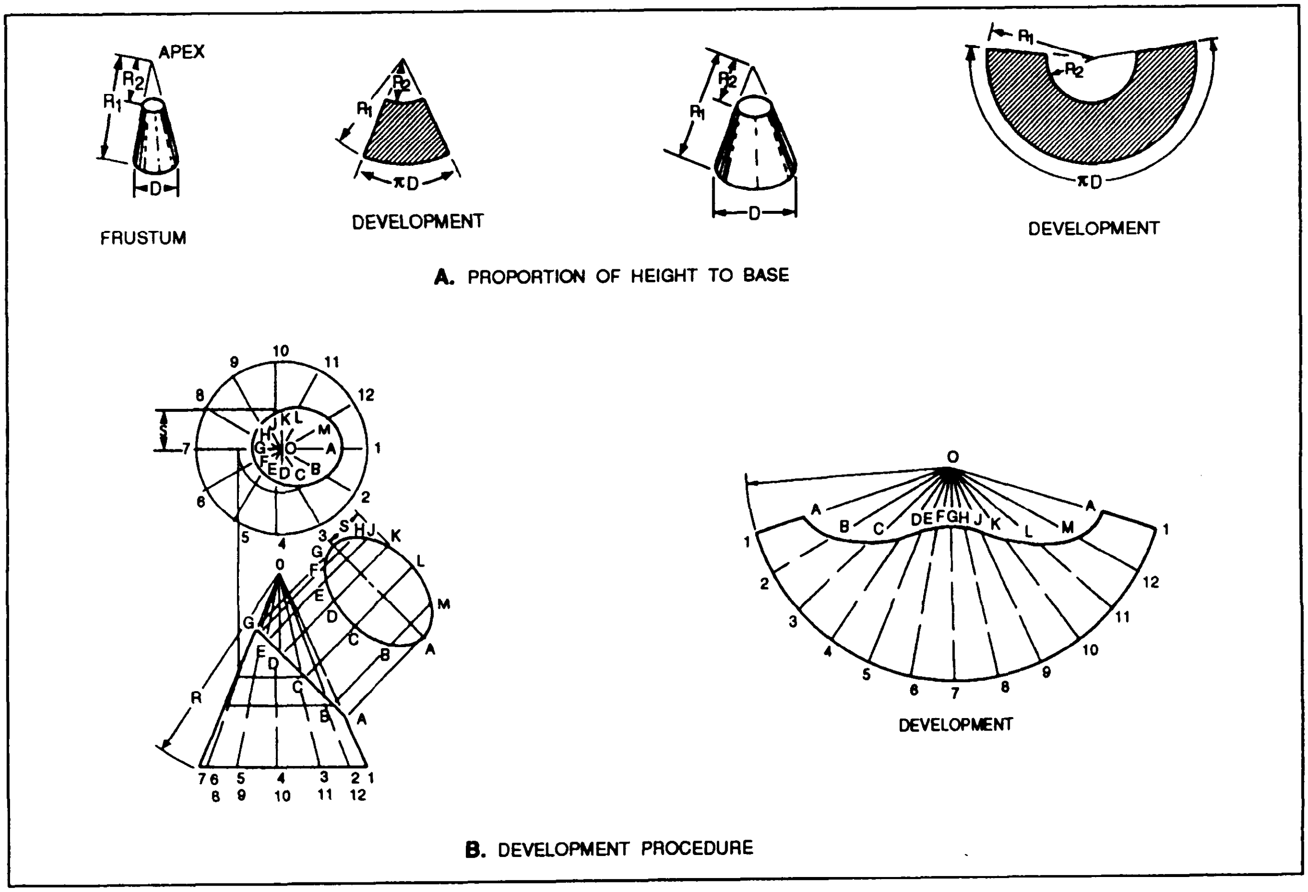


Figure 8-15.—Development of a truncated cone.

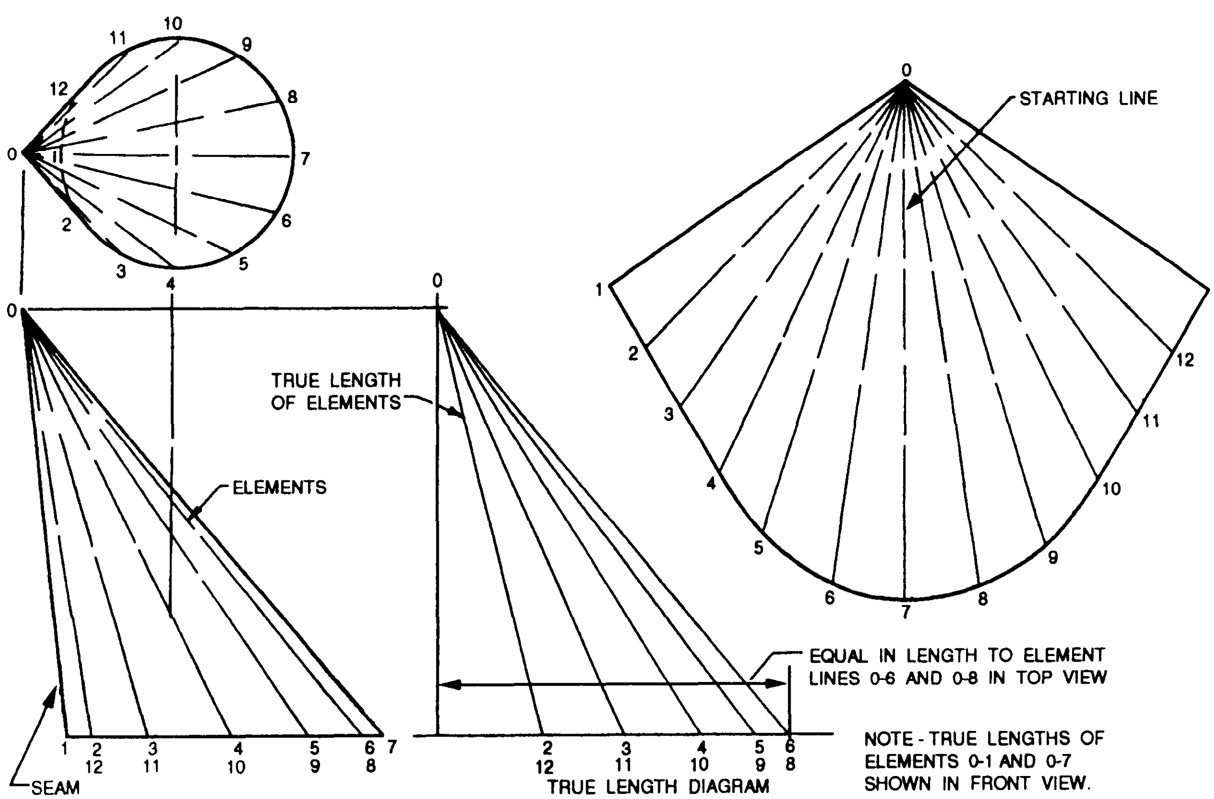


Figure 8-16.—Development of an oblique cone.

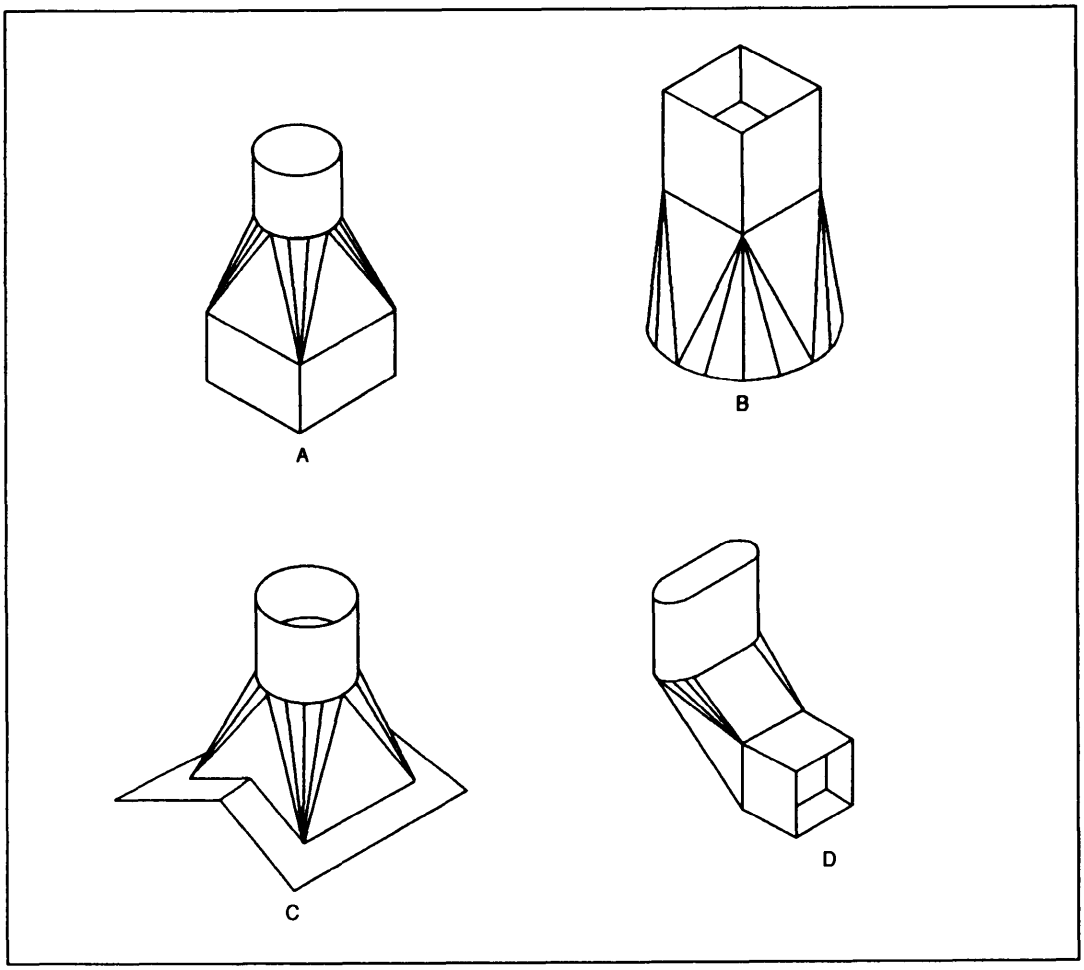


Figure 8-17.—Transition pieces.

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 is drawn adjacent to the front view. This prevents the front view from being cluttered with lines.

Since the development of the oblique cone will be symmetrical, the starting line will be element 0-7. The development is constructed as follows: With 0 as center and the radius equal to the true length of element 0-6, draw an arc. With 7 as center and the radius equal to distance 6-7 in the top view, draw a second arc intersecting the first at point 6. Draw element 0-6 on the development. With 0 as center and the radius equal to the true length of element 0-5, draw an arc. With 6 as center and the radius equal to distance 5-6 in the top view, draw a second arc intersecting the fast point 5. Draw element 0-5 on the development. This is repeated until all the element lines are located on the development view. This development does not show a seam allowance.

DEVELOPMENT OF TRANSITION PIECES

Transition pieces are usually made to connect two different forms, such as round pipes to square pipes. These transition pieces will usually fit the definition of a nondevelopable surface that must be developed by approximation. This is done by assuming the surface to be made from a series of triangular surfaces laid side-by-side to form the development. This form of development is known as triangulation (fig. 8-17).

Square to Round

The transition piece shown in figure 8-18 is used to connect round and square pipes. It can be seen from both the development and the pictorial drawings that the transition piece is made of four isosceles triangles, whose bases connect with the square duct, and four parts of an oblique cone having the circle as the base and the corners of the square pipe as the vertices. To make the development, a true-length diagram is drawn first. When the true length of line 1A is known, the four equal isosceles triangles can be developed After the triangle G-2-3 has been developed, the partial developments of the oblique cone are added until points D and K have been located Next the isosceles triangles D-1-2 and K-3-4 are added, then the partial cones, and, last, half of the isosceles triangle is placed at each side of the development.

Rectangular to Round

The transition piece shown in figure 8-19 is constructed in the same manner as the one previously developed 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.

Connecting Two Circular Pipes

The following paragraphs discuss the developments used to connect two circular pipes with parallel and oblique joints.

PARALLEL JOINTS.—The development of the transition piece shown in figure 8-20 connecting two circular pipes is similar to the development of an oblique cone except that the cone is truncated The apex of the cone, 0, is located by drawing the two given pipe diameters in their proper position and extending the radial lines $1\text{-}1_1$ and $7\text{-}7_1$ to intersect at point 0. Fit the development is made to represent the complete development of the cone, and then the top portion is removed. Radius settings for distances $0\text{-}2_1$ and $0\text{-}3_1$ on the development are taken from the true-length diagram.

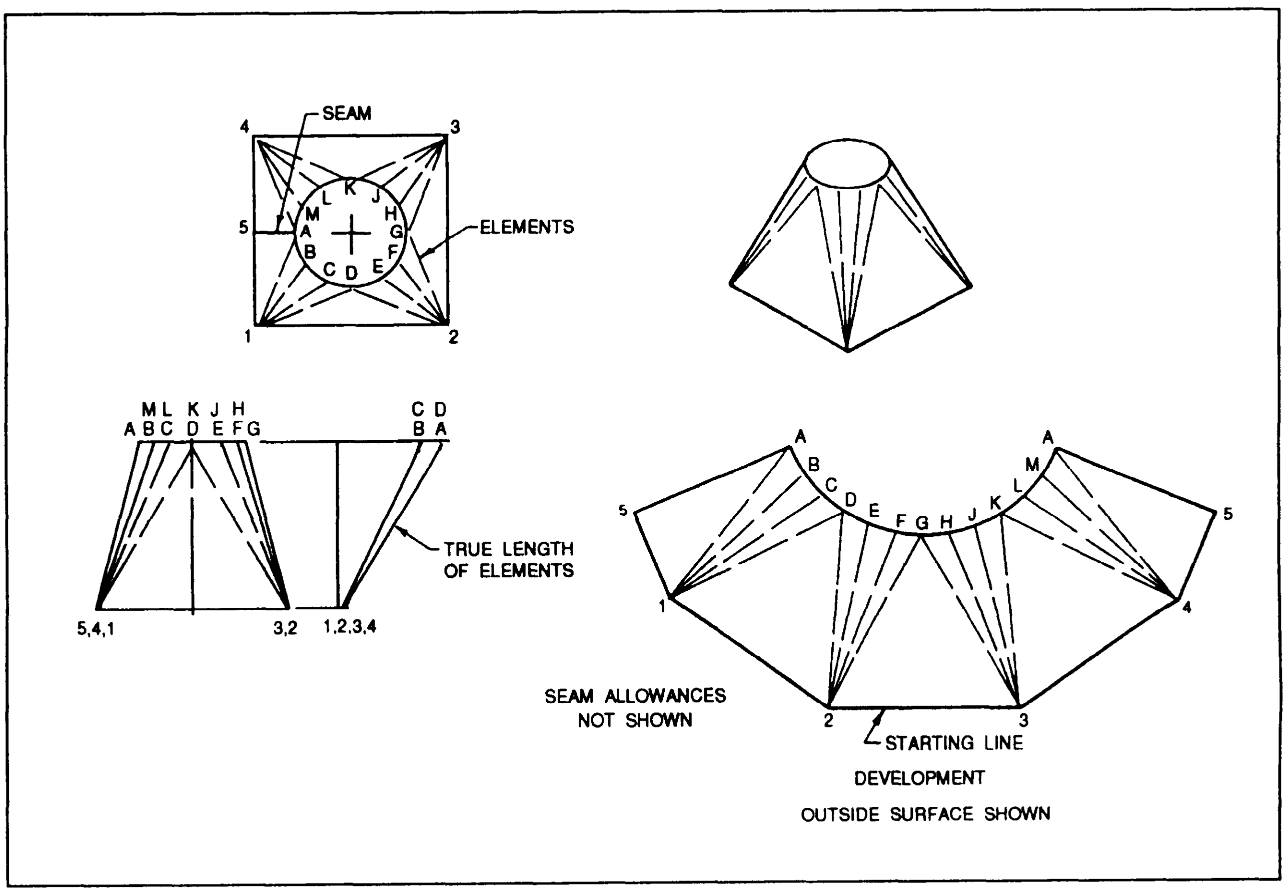


Figure 8-18.—Development of a transition piece—square to round.

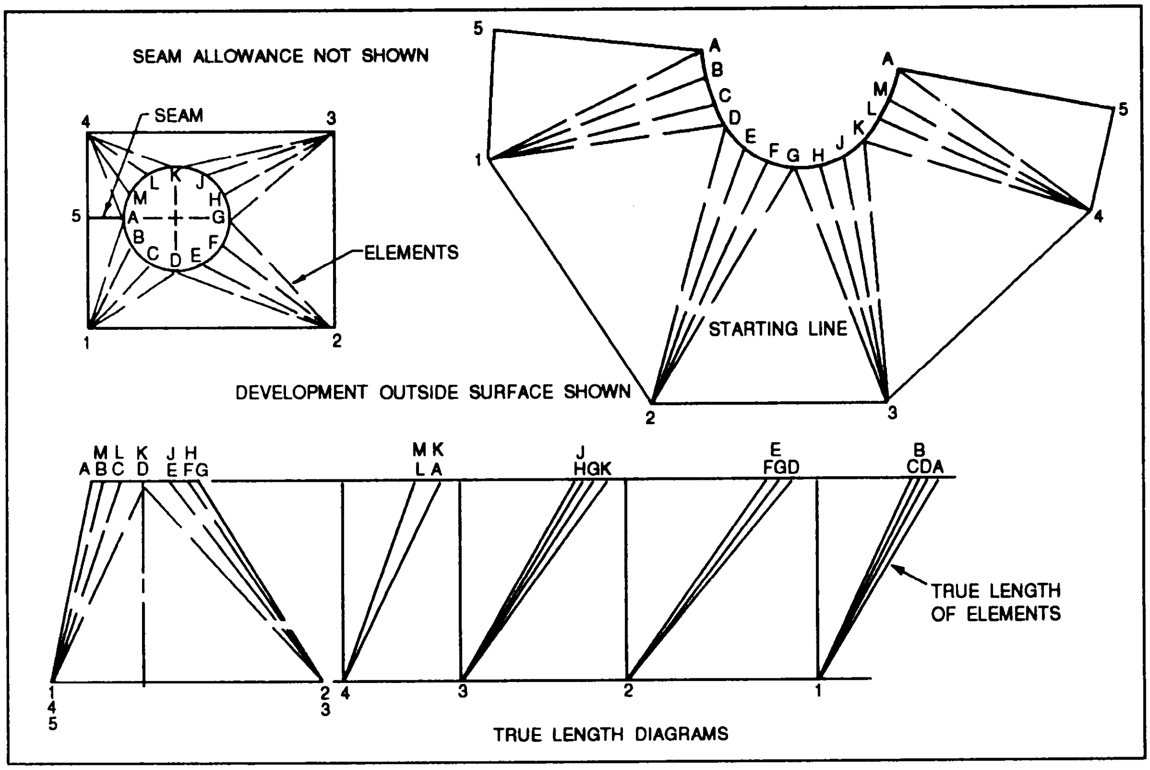


Figure 8-19.—Development of an offset transition piece— rectangular to round.

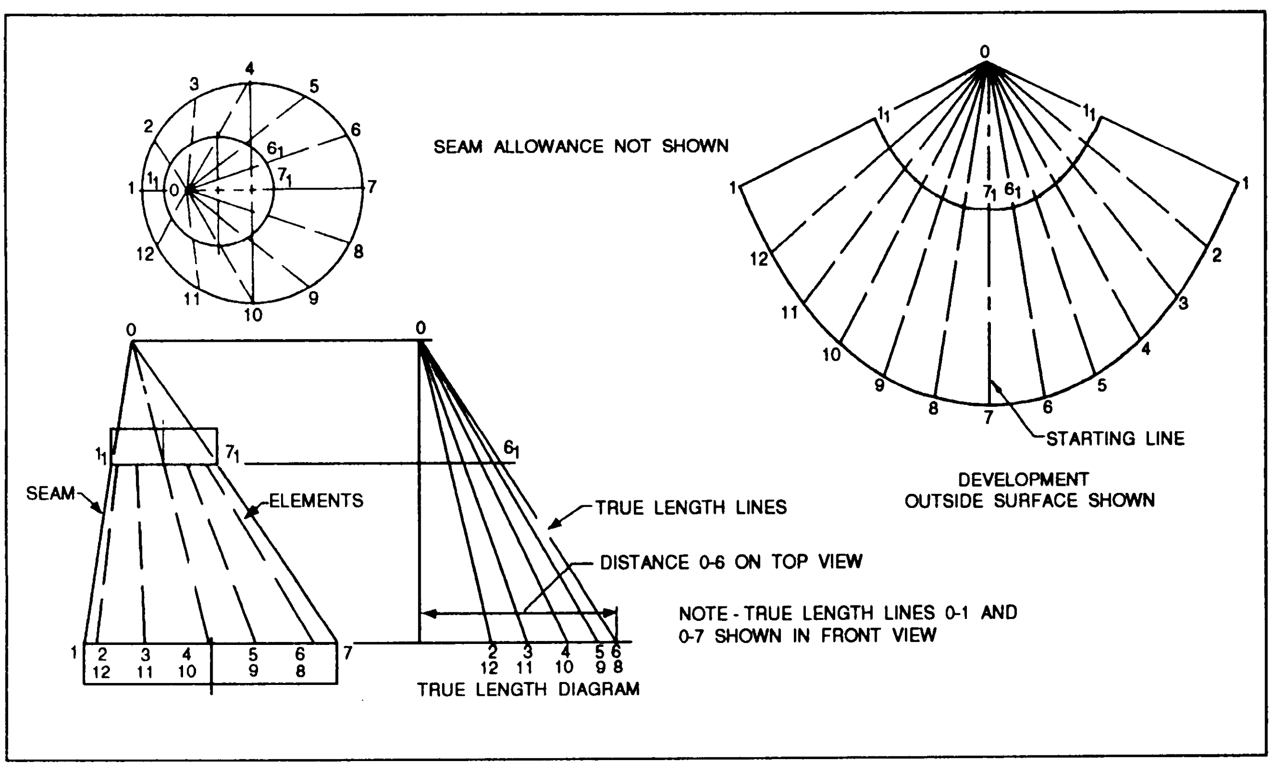


Figure 8-20.—Transition piece connecting two circular pipes—parallel joints

OBLIQUE JOINTS.—When the joints between the pipe and transition piece are not perpendicular to the pipe axis (fig. 8-21), then a transition piece should be developed. Since the top and bottom of the transition piece will be elliptical, a partial auxiliary view is required to find the true length of the chords between the end points of the elements. The development is then constructed in the same way as the development used to connect two circular pipes with parallel joints.

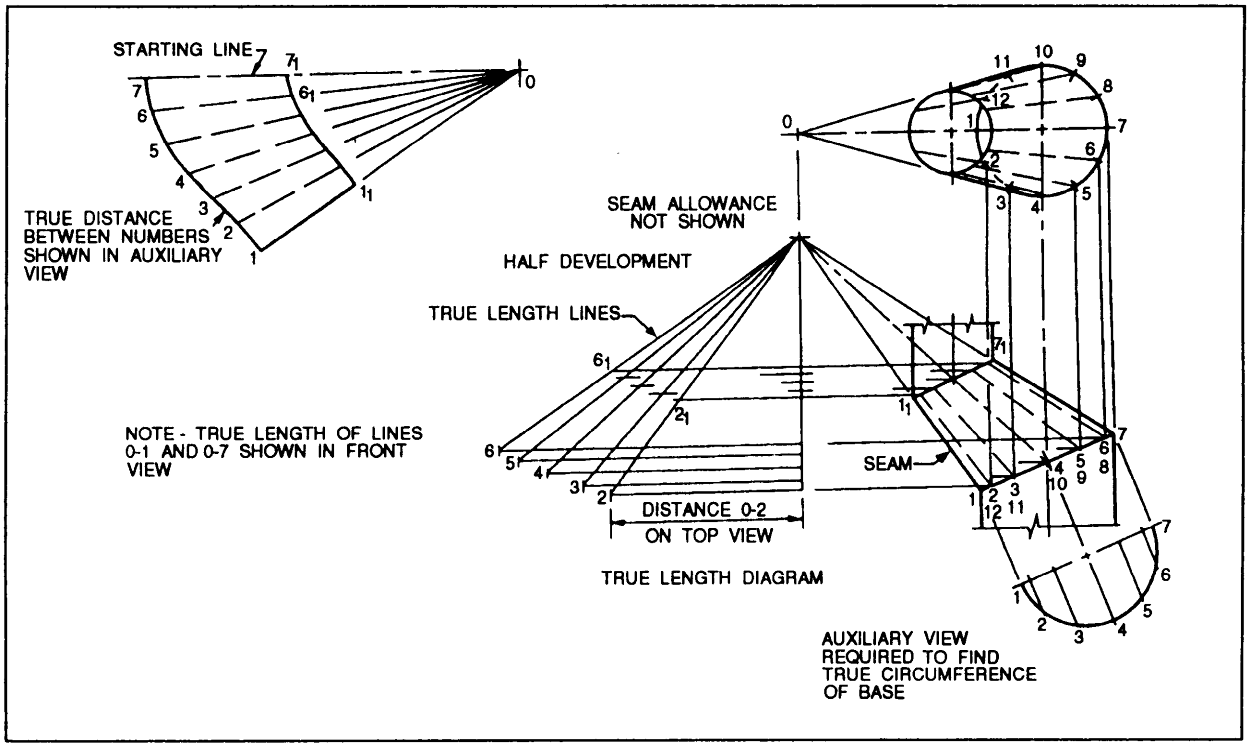


Figure 8-21.—Transition piece connecting two circular pipes—oblique joints.

APPENDIX I

GLOSSARY

When you enter a new occupation, you must learn the vocabulary of the trade in order 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 an exact thing or a certain sequence of actions, making it unnecessary to give a lot of explanatory details. A great deal of the work of a technician is such that an incorrectly interpreted instruction could cause confusion, breakage of machinery, or even loss of life. Avoid this confusion and its attendant danger by learning the meaning of terms common to drafting. 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.

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—The scale used when dimensions or measurements are 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

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, modem reproduction techniques now permit printing of black-on-white as well as colors.

BODY PLAN—An end view of a ship's hull, composed of superimposed frame lines.

BORDER LINES—Darklines 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.

BUTTOCK LINE—The outline of a vertical, longitudinal section of a ship's hull.

CABINET DRAWING—A type of oblique drawing in which the angled receding lines are drawn to one-half scale.

CANTILEVER—A horizontal structural member supported only by one end.

CASTING—A metal object made by pouring melted metal into a mold

CAVALIER DRAWING—A form of oblique drawing in which the receding sides are drawn full scale, but at 45° to the orthographic front view.

CENTER LINES—Lines that indicate the center of a circle, arc, or any symmetrical object; consist of alternate long and short dashes evenly spaced.

CIRCLE—A plane closed 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-AIDED DRAFTING (CAD)—A method by which engineering drawings may be developed on a computer.

COMPUTER-AIDED MANUFACTURING (CAM)—A method by which a computer uses a design to guide a machine that produces parts.

COMPUTER LOGIC—The electrical processes used by a computer to perform calculations and other functions.

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.

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 showing where a theoretical cut has been made to produce a section view.

CYLINDER—A solid figure with two equal circular bases.

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

DESIGNER'S WATERLINE—The intended position of the water surface against the hull.

DEVELOPMENT—The process of making a pattern from the dimensions of a drawing. Used to fabricate sheet metal objects.

DIGITAL—The processing of data by numerical or discrete units.

DIMENSION LINE—A thin unbroken line (except in the case of structural drafting) with each end terminating with an arrowhead; used to define the dimensions of an object. Dimensions are placed above the line, except in structural drawing where the line is broken and the dimension placed in the break

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—(1) A shipboard wiring diagram showing how each individual conductor is connected within the various connection boxes of an electrical circuit system. (2) A schematic diagram; the term *elementary wiring diagram* is sometimes used interchangeably with schematic diagram, especially a simplified schematic diagram.

ELEVATION—A four-view drawing of a structure showing front, sides, and rear.

ENGINEER'S SCALE—The scale used whenever dimensions are in feet and decimal parts of a foot, or when the scale ratio is a multiple of 10.

EXPLODED VIEW—A pictorial view of a device in a state of disassembly, showing the appearance and interrelationship of parts.

EXTERNAL THREAD—A thread on the outside of a member. Example: a 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 in a metal component, usually a casting.

FINISH MARKS—Marks used to indicate the degree of smoothness of finish to be achieved on surfaces to be machined

FOOTINGS—Weight-bearing concrete construction elements poured in place in the earth to support a structure.

FORGING—The process of shaping heated metal by hammering or other impact.

FORMAT—The general makeup or style of a drawing.

FRAME LINES—The outline of transverse plane sections of a hull.

FRENCH CURVE—An instrument used to draw smooth irregular curves.

FULL SECTION—A sectional view that passes entirely through the object.

HALF SECTION—A combination of an orthographic projection and a section view to show two halves of a symmetrical object.

HATCHING—The lines that are drawn on the internal surface of sectional views. Used to define the kind or type of material of which the sectioned surface consists.

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—Thick, short, dashed lines indicating the hidden features of an object being drawn.

INSCRIBED FIGURE—A figure that is completely enclosed by another figure.

INTERCONNECTION DIAGRAM—A diagram showing the cabling between electronic units, as well as how the terminals are connected

INTERNAL THREAD—A thread on the inside of a member. Example: the thread inside a nut.

ISOMETRIC DRAWING—A type of pictorial drawing. *See* ISOMETRIC PROJECTION.

ISOMETRIC PROJECTION—A set of three or more views of an object that appears rotated, giving the appearance of viewing the object from one corner. All lines are shown in their true length, but not all right angles are shown as such.

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 beam used to support a ceiling.

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 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—Two, unbroken 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 load-bearing structural member supported at its ends. Usually located over a door or window.

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.

MANIFOLD—A fitting that has several inlets or outlets to carry liquids or gases.

MECHANICAL DRAWING—*See* DRAWINGS. Applies to scale drawings of mechanical objects.

MIL-STD (military standards)—A formalized set of standards for supplies, equipment, and design work purchased by the United States Armed Forces.

NOTES—Descriptive writing on a drawing to give verbal instructions or additional information.

OBLIQUE DRAWING—A type of pictorial drawing in which one view is an orthographic projection and the views of the sides have receding lines at an angle.

OBLIQUE PROJECTION—A view produced when the projectors are at an angle to the plane 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 view produced when projectors are perpendicular to the plane of the object. It gives the effect of looking straight at one side.

PARTIAL SECTION—A sectional view consisting of less than a half section. Used to show the internal structure of a small portion of an object. Also known as a broken section.

PERPENDICULAR—Vertical lines extending through the outlines of the hull ends and the designer's waterline.

PERSPECTIVE—The visual impression that, as parallel lines project to a greater distance, the lines move closer together.

PHANTOM VIEW—A view showing the alternate position of a movable object, using a broken line convention.

PHASE—An impulse of alternating current. The number of phases depends 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 actual pictorial sketches of the various parts of a piece of equipment and the electrical connections between the parts.

PIER—A vertical support for a building or structure, usually designed to hold substantial loads.

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.

PLAT—A map or plan view of a lot showing principal features, boundaries, and location of structures.

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 or view of an object.

RAFTER—A sloping or horizontal beam used to support a roof.

RADIUS—A straight line from the center of a circle or sphere to its circumference or surface.

REFERENCE DESIGNATION—A combination of letters and numbers to identify parts on electrical and electronic drawings. The letters designate the type of part, and the numbers designate the specific part. Example: reference designator R-12 indicates the 12th resistor in a circuit.

REFERENCE NUMBERS—Numbers used on a drawing to refer the reader to another drawing for more detail or other information.

REFERENCE PLANE—The normal plane that all information is referenced

REMOVED SECTION—A drawing of an object's internal cross section located near the basic drawing of the 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.

ROOT—The surface of the thread corresponding to the minor diameter of an external thread and the major diameter of an internal thread

ROTATION—A view in which the object is apparently rotated or turned to reveal a different plane or aspect, all shown within the view.

ROUND—The rounded outside corner of a metal object.

SCALE—The relation between the measurement used on a drawing and the measurement of the object it represents. A measuring device, such as a ruler, having special graduations.

SCHEMATIC DIAGRAM—A diagram using graphic symbols to show how a circuit functions electrically.

SECTION—A view showing internal features as if the viewed object has been cut or sectioned

SECTION LINES—Thin, diagonal lines used to indicate the surface of an imaginary cut in an object.

SHEER PLAN—The profile of a ship's hull, composed of superimposed buttock lines.

SHEET STEEL—Flat steel weighing less than 5 pounds per square foot.

SHIP'S PLANS—A set of drawings of all significant construction features and equipment of a ship, as needed to operate and maintain the ship. Also called ONBOARD PLANS.

SHRINK RULE—A special rule for use by patternmakers. It has an expanded scale, rather than a true scale, to allow for shrinkage of castings.

SILL—A horizontal structural member supported by its ends.

SINGLE-LINE DIAGRAM—A diagram using single lines and graphic symbols to simplify a complex circuit or system.

SOLE PLATE—A horizontal structural member used as a base for studs or columns.

SPECIFICATION—A detailed description or identification relating to quality, strength, or similar performance requirement

STATION NUMBERS—Designations of reference lines used to indicate linear positions along a component such as an air frame or ship's hull.

STEEL PLATE—Flat steel weighing more than 5 pounds per square foot.

STRETCH-OUT LINE—The base or reference line used in making a development.

STUD—A light vertical structure member, usually of wood or light structural steel, used as part of a wall and for supporting moderate loads.

SYMBOL—Stylized graphical representation of commonly used component parts shown in a drawing.

TEMPER—To harden steel by heating and sudden cooling by immersion in oil, water, or other coolant.

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, its subject matter, origins, scale, and other data.

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.

TRACING PAPER—High-grade, white, transparent paper that takes pencil well; used when reproductions are to be made of drawings. Also known as tracing vellum.

TRIANGULATION—A technique for making developments of complex sheet metal forms using geometrical constructions to translate dimensions from the drawing to the patten.

TRUSS—A complex structural member built of upper and lower members connected by web members.

UTILITY PLAN—A floor plan of a structure showing locations of heating, electrical, plumbing and other service system components.

VIEW—A drawing of a side or plane of an object as seen from one point.

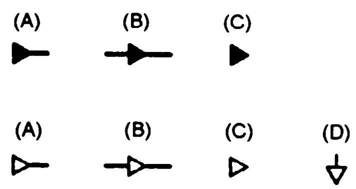
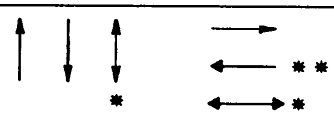
WATERLINE—The outline of a horizontal longitudinal section of a ship's hull.

WIRING (CONNECTION) DIAGRAM—A diagram showing the individual connections within a unit and the physical arrangement of the components.

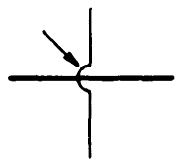
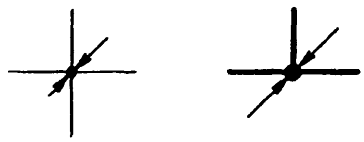
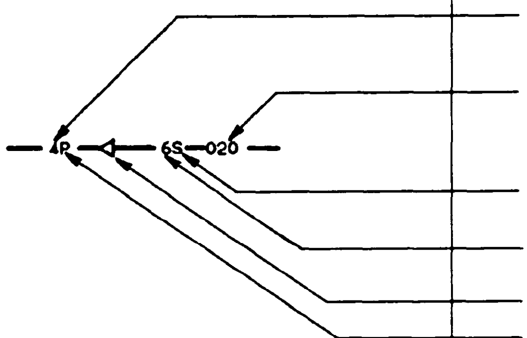
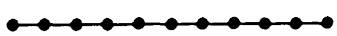
ZONE NUMBERS—Numbers and letters on the border of a drawing to provide reference points to aid in indicating or locating specific points on the drawing.

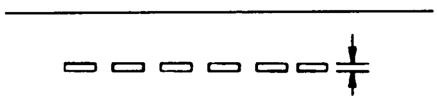
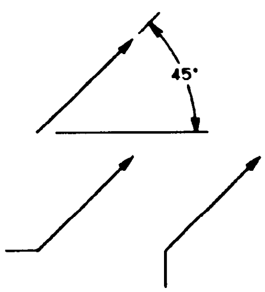
APPENDIX II

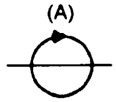
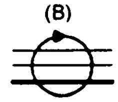
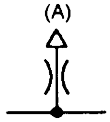
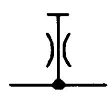
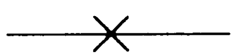
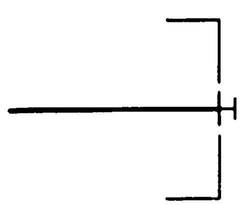
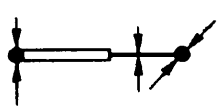
GRAPHIC SYMBOLS FOR AIRCRAFT HYDRAULIC AND PNEUMATIC SYSTEMS

BASIC SYMBOLS		
	FLUID FLOW LINES - GENERAL	
		FLOW - SOURCES AND DIRECTION (A) INDICATION OF HYDRAULIC PRESSURE SOURCE. (B) DIRECTION OF HYDRAULIC FLOW. (C) INTERNAL HYDRAULIC PILOT VALVE; PUMP OR MOTOR ELEMENT. (A) INDICATION OF PNEUMATIC PRESSURE SOURCE. (B) DIRECTION OF PNEUMATIC FLOW. (C) INTERNAL PNEUMATIC PILOT VALVE, PUMP OR MOTOR ELEMENT; GAS PRESSURE. (D) PNEUMATIC EXHAUST PORT, OR ATMOSPHERIC TERMINATION OF FLUID DRAIN LINE.
		NORMAL DIRECTION OF FLOW IN LINES OR VALVES. * FLOW IN EITHER DIRECTION IS POSSIBLE. * * ALTERNATE ARROW HEAD CONFIGURATION.
		DIRECTION OF FREE FLOW.

BASIC SYMBOLS

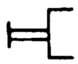
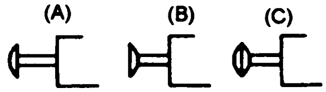
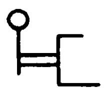
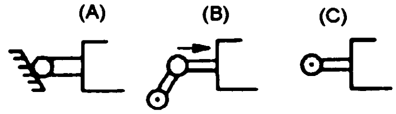
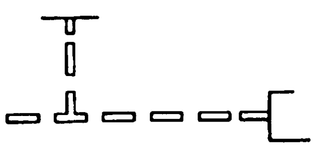
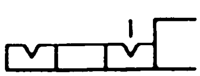
	FLUID FLOW LINES - GENERAL (CONT'D)	
		**CROSSING/JOINING** LINES CROSSING.
		LINES JOINING.
		**LINE CODING** FLUID SYSTEM NO. TUBE WALL THICKNESS TUBE MATERIAL - A - ALUMINUM ALLOY S - STEEL (CORROSION RESISTING) T - TITANIUM TUBE OUTSIDE DIAMETER PRIMARY FLOW DIRECTION AND FLUID (GAS OR LIQUID) LINE FUNCTION P - PRESSURE R - RETURN S - SUCTION ETC.
		FUEL LINE. TO COMPLETE OIL-FUEL HEAT EXCHANGER SYMBOL WHERE NO OTHER FUEL LINE STANDARD EXISTS.
		CAPILLARY LINE.

BASIC SYMBOLS		
	MECHANICAL, ELECTRICAL, AND FUNCTIONAL	
		MECHANICAL LINKAGE.
	 VARIABLE	SHAFT OR PISTON ROD. USE SINGLE LINE FOR VALVE SHAFTS.
		ELECTRICAL LINE.
		DIRECTION OF ROTATION.
		FACILITY FOR VARIABLE CONTROL OF PUMP, SPRING, SOLENOID, ETC. GENERAL SYMBOL. THE ARROW MAY BE BENT, AS SHOWN, TO ADD THE METHOD OF VARIABILITY. FOR AIRCRAFT APPLICATIONS, THE MOST LIKELY COMMON USAGE IS IN THE SYMBOL FOR A VARIABLE DELIVERY PUMP, WHERE THE ADDED PRESSURE COMPENSATION SYMBOL INDICATES AUTOMATIC VARIATION BETWEEN WIDE LIMITS OF FLOW WITH A NARROW VARIATION IN PRESSURE; VALVES, ETC., IS NOT SYMBOLIZED.
		SPRING USED AS A MECHANICAL LINK, CYLINDER INTERNAL RETURN SPRING, ETC.
		PIVOTING DEVICE WITH FIXED FULCRUM, GROUND OR EARTHING POINT. MOVING BODY COMPONENTS, WHICH PART IS FIXED TO STRUCTURE.
		PRESSURE COMPENSATION, GAUGE NEEDLE.

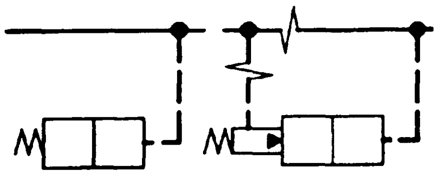
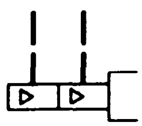
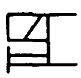
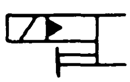
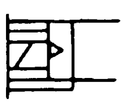
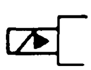
BASIC SYMBOLS		
	CONNECTORS, FLEXIBLE LINES	
		FLEXIBLE LINE (GENERAL SYMBOL).
		FLEXIBLE HOSE.
		COILED TUBING, OR TUBING DESIGNED FOR TORSION ORFLEXURE.
	(A)  (B) 	ROTARY OR SWIVEL CONNECTOR, OR JOINT (A) SINGLE FLOW LINE. (B) MORE THAN ONE FLOW LINE REPRESENTS CONCENTRIC, BUT SEPARATE, FLOW PATHS IN ROTARY CONNECTOR.
	(A)  (B) 	BLEEDER FITTING - (A) CONTINUOUS (B)TEMPORARY
		JOINTS
		PERMANENT JOINTS
		RECONNECTABLE JOINT
		PLUGGED PORT, FILL PORT, PRESSURE CAP, DUST CAP.
		CAPPED LINE
		EXTENSION FITTING SIMPLIFIED SYMBOL. (PRESSURE AND VOLUME BALANCED).

BASIC SYMBOLS

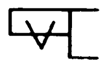
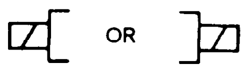
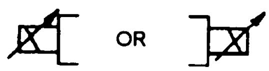
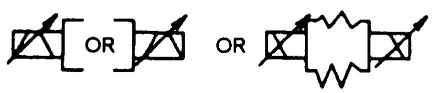
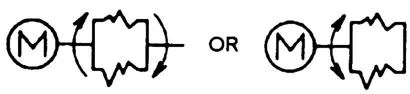
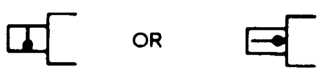
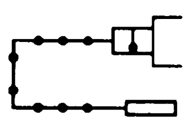
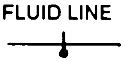
CONTROLS

	MECHANICAL OR MUSCULAR (MANUAL)
	SPRING FOR VALVE CONTROL.
	MANUAL CONTROL
(A) (B) (C) 	(A) PUSH BUTTON (B) PULL BUTTON (C) PUSH-PULL BUTTON
	LEVER
(A) (B) 	(A) PEDAL (B) TREADLE
(A) (B) 	(A) MECHANICAL - GENERAL SYMBOL (B) PLUNGER
(A) (B) (C) 	(A) MECHANICAL - ROLLER (B) MECHANICAL - ROLLER - ONE DIRECTION (C) MECHANICAL - ROLLER - TWO DIRECTIONS
	REMOTE MANUAL OR MECHANICAL
	DETENT. SHOW A NOTCH FOR EACH DETENT IN THE ACTUAL COMPONENT BEING SYMBOLIZED. A SHORT LINE INDICATES WHICH DETENT IS IN USE. DETENT MAY, FOR CONVENIENCE, BE POSTITIONED ON EITHER END OF SYMBOL. NOTCH USED IN ACTUATORS INDICATES AND INTERNAL LOCK.

BASIC SYMBOLS

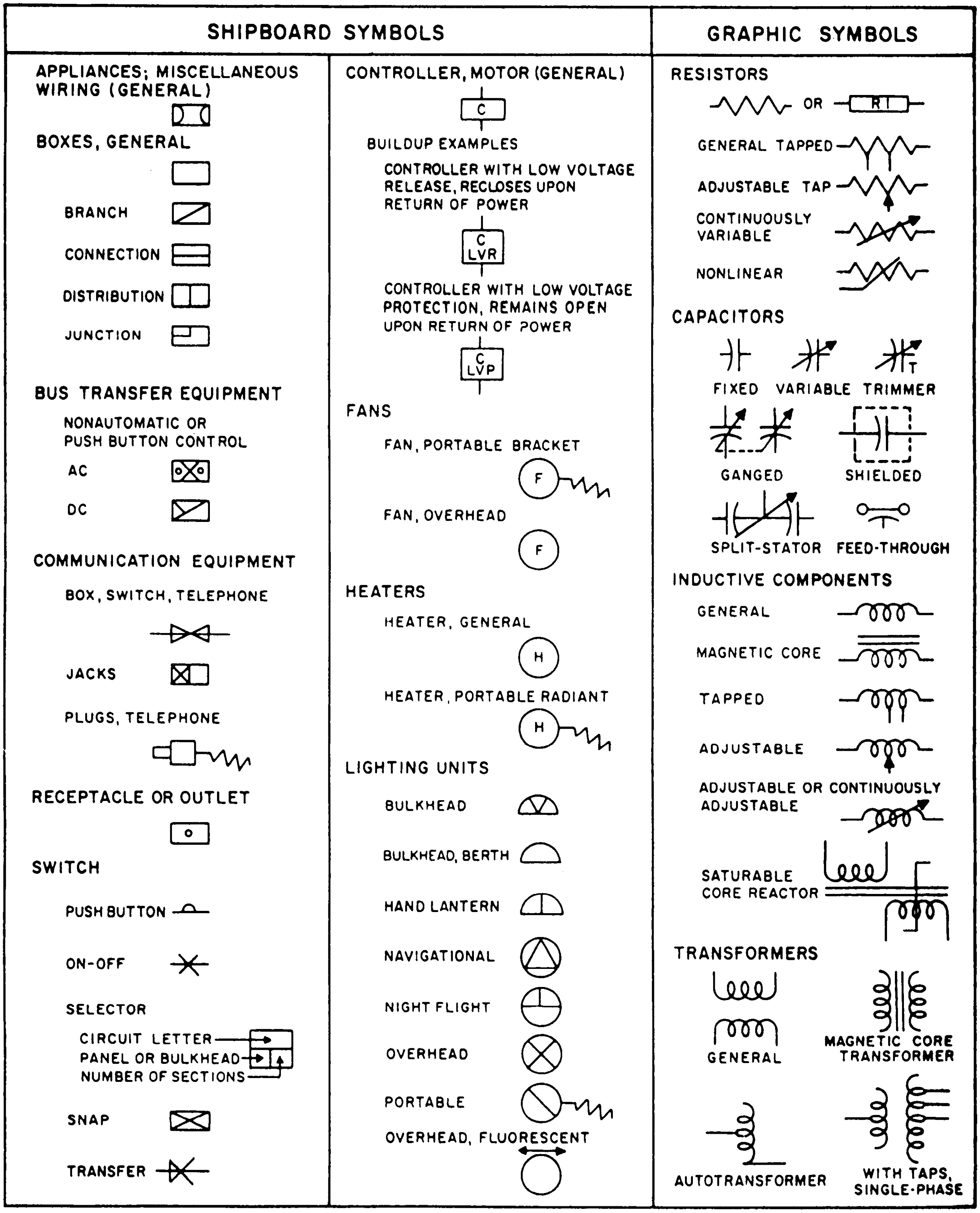
	CONTROLS (CONT'D)	
		PRESSURE (CONT'D)
		DIFFERENTIAL PILOT
		DIRECT PILOT AND COMPOUND OPERATION IN BOTH (A) AND (B), WHEN PRESSURE EXCEEDS SPRING FORCE, R.H. PANEL OPERATES
		FOR NEW SYMBOLS OR FOR SPECIAL EMPHASIS WRITTEN CONTROL OPTIONAL
		ONE SIGNAL, AND A SECOND SIGNAL, BOTH CAUSE THE DEVICE TO OPERATE
		ONE SIGNAL OR THE OTHER SIGNAL, CAUSE THE DEVICE TO OPERATE
		THE SOLENOID AND THE PILOT, OR THE MANUAL OVERRIDE ALONE, CAUSE THE DEVICE TO OPERATE
		THE SOLENOID AND THE PILOT, OR THE MANUAL OVERRIDE AND THE PILOTS, CAUSE THE DEVICE TO OPERATE (PRESSURE CENTERED)
		THE SOLENOID AND THE PILOT, OR THE MANUAL OVERRIDE AND THE PILOT, OR A MANUAL OVERRIDE ALONE, CAUSE THE DEVICE TO OPERATE
		GENERAL SYMBOL FOR SOLENOID-OPERATED PILOT

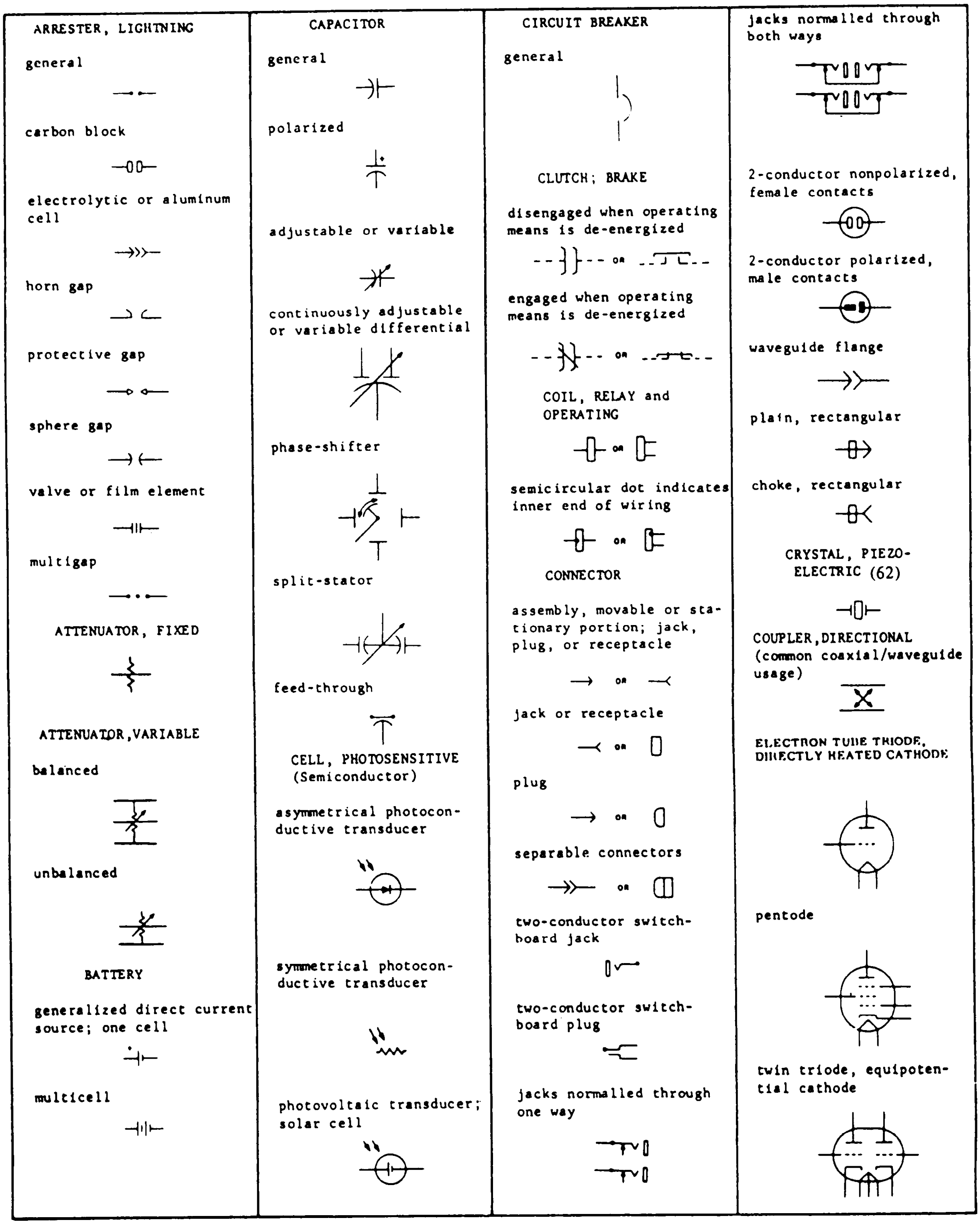
BASIC SYMBOLS

	CONTROLS (CONT'D)	
		PREVENTS STOPPING IN DEAD CENTER
		ELECTRICAL
		SOLENOID, SINGLE WINDING, FINITE CURRENT INPUT
		TORQUEMOTOR, SINGLE COIL - VARIABLE CURRENT INPUT
		TORQUEMOTOR, DUAL COIL
		REVERSING MOTOR
		TEMPERATURE
		TEMPERATURE (OR THERMAL) - LOCAL SENSING
		REMOTE SENSING
	FLUID LINE 	TEMPERATURE COMPENSATED

APPENDIX III

GRAPHIC SYMBOLS FOR ELECTRICAL AND ELECTRONICS DIAGRAMS




ARRESTER, LIGHTNING
general
carbon block
electrolytic or aluminum cell
horn gap
protective gap
sphere gap
valve or film element
multigap
ATTENUATOR, FIXED
ATTENUATOR, VARIABLE
balanced
unbalanced
BATTERY
generalized direct current source; one cell
multicell
CAPACITOR
general
polarized
adjustable or variable
continuously adjustable or variable differential
phase-shifter
split-stator
feed-through
CELL, PHOTOSENSITIVE (Semiconductor)
asymmetrical photoconductive transducer
symmetrical photoconductive transducer
photovoltaic transducer; solar cell
CIRCUIT BREAKER
general
CLUTCH; BRAKE
disengaged when operating means is de-energized
OR
engaged when operating means is de-energized
OR
COIL, RELAY and OPERATING
OR
semicircular dot indicates inner end of wiring
OR
CONNECTOR
assembly, movable or stationary portion; jack, plug, or receptacle
OR
jack or receptacle
OR
plug
OR
separable connectors
OR
two-conductor switchboard jack
two-conductor switchboard plug
jacks normalled through one way
jacks normalled through both ways
2-conductor nonpolarized, female contacts
2-conductor polarized, male contacts
waveguide flange
plain, rectangular
choke, rectangular
CRYSTAL, PIEZO-ELECTRIC (62)
COUPLER, DIRECTIONAL (common coaxial/waveguide usage)
ELECTRON TUBE TRIODE, DIRECTLY HEATED CATHODE
pentode
twin triode, equipotential cathode

(transmission path recognition symbol replaces (*) asterisk) coaxial type in rectangular waveguide circular waveguide type in rectangular waveguide SEMICONDUCTOR DEVICE (Two Terminal, diode) semiconductor diode; rectifier OR OR capacitive diode (also Varicap, Varactor, reactance diode, parametric diode) OR breakdown diode, unidirectional (also backward diode, avalanche diode, voltage regulator diode, Zener diode, voltage reference diode) OR breakdown diode, bidirectional and backward diode (also bipolar voltage limiter) OR tunnel diode (also Esaki diode) OR temperature-dependent diode photodiode (also solar cell)	semiconductor diode, PNPN switch (also Shockley diode, four-layer diode and SCR). OR (Multi-Terminal, transistor, etc.) PNP transistor NPN transistor unijunction transistor, N-type base unijunction transistor, P-type base field-effect transistor, N-type base OR field-effect transistor, P-type base OR semiconductor triode, PNPN-type switch semiconductor triode, NPNP-type switch	NPN transistor, transverse-biased base OR PNIP transistor, ohmic connection to the intrinsic region NPIN transistor, ohmic connection to the intrinsic region PNIN transistor, ohmic connection to the intrinsic region NPIP transistor, ohmic connection to the intrinsic region SQUIB explosive igniter sensing link; fusible link operated SWITCH push button, circuit closing (make) push button, circuit opening (break)	nonlocking; momentary circuit closing (make) OR nonlocking; momentary circuit opening (break) OR transfer OR locking, circuit closing (make) OR locking, circuit opening (break) OR transfer, 3-position OFF wafer (example shown: 3-pole 3-circuit with 2 non-shorting and 1 shorting moving contacts) safety interlock, circuit opening and closing SYNCHRO Synchro Letter Combinations CDX Control-differential transmitter CT Control transformer CX Control transmitter TDR Torque-differential receiver TDX Torque-differential transmitter TR Torque receiver TX Torque transmitter RS Resolver

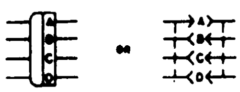
CIRCUIT BREAKER

with magnetic overload

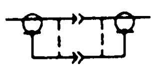
drawout type

CONNECTOR

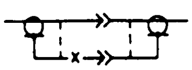
engaged 4-conductor; the plug has 1 male and 3 female contacts, individual contact designations shown



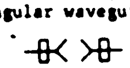
coaxial, outside conductor shown carried through



coaxial, center conductor shown carried through; outside conductor not carried through



mated choke flanges in rectangular waveguide



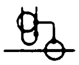
COUPLER, DIRECTIONAL

(common coaxial/waveguide usage)

E-plane aperture-coupling, 30-decibel transmission loss

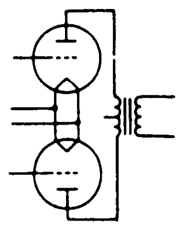
COUPLING

by loop from coaxial to circular waveguide, direct-current grounds connected



ELECTRON TUBE

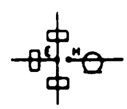
typical wiring figure to show tube symbols placed in any convenient position



HYBRID

(common coaxial/waveguide usage)

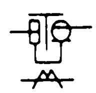
rectangular waveguide and coaxial coupling



MODE TRANSDUCER

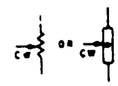
(common coaxial/waveguide usage)

transducer from rectangular waveguide to coaxial with mode suppression, direct-current grounds connected



MOTION, MECHANICAL

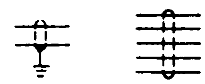
rotation applied to a resistor



(identification replaces (*) asterisk)

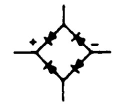
PATH, TRANSMISSION (58)

cable; 2-conductor, shield grounded and 5-conductor shielded



RECTIFIER

fullwave bridge-type



RESISTOR

with adjustable contact

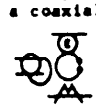
adjustable or continuously adjustable (variable)

(identification replaces (*) asterisk)

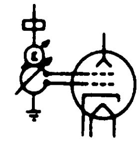
RESONATOR, TUNED CAVITY

(common coaxial/waveguide usage)

resonator with mode suppression coupled by an E-plane aperture to a guided transmission path and by a loop to a coaxial path



tunable resonator with direct-current ground connected to an electron device and adjustably coupled by an E-plane aperture to a rectangular waveguide



SWITCH

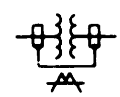
2-pole field-discharge knife, with terminals and discharge resistor

(identification replaces (*) asterisk)

TRANSFORMER

with direct-current connections and mode suppression between two rectangular waveguides

(common coaxial/waveguide usage)



shielded, with magnetic core

with a shield between windings, connected to the frame

APPENDIX IV

THIS APPENDIX HAS BEEN DELETED.

APPENDIX V

REFERENCES USED TO DEVELOP THE TRAMAN

NOTE: Although the following references were current when this TRAMAN was published, their continued currency cannot be assured. Therefore, you need to be sure that you are studying the latest revision.

Chapter 1

Drawing Sheet Size and Format, ANSI Y14.1, American National Standards Institute, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47 Street, New York, N.Y. 10017.

Pictorial Drawing, ANSI Y14.4M, American National Standards Institute, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47 Street, New York, N.Y. 10017.

Chapter 2

Dimensioning and Tolerancing, ANSI Y14.5M-1982, American National Standards Institute, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47 Street, New York, N.Y. 10017.

Line Convection and Lettering, ANSI Y14.2M, American National Standards Institute, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47 Street, New York, N.Y. 10017.

Chapter 3

Drawing Sheet Size and Format, ANSI Y14.1, American National Standards Institute, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47 Street, New York, N.Y. 10017.

Line Convection and Lettering, ANSI Y14.2M, American National Standards Institute, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47 Street, New York, N.Y. 10017.

Pictorial Drawing, ANSI Y14.4M, American National Standards Institute, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47 Street, New York, N.Y. 10017.

Projections, ANSI Y14.3M, American National Standards Institute, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47 Street, New York, N.Y. 10017.

Chapter 4

Dimensioning and Tolerancing, ANSI Y14.5M-1982, American National Standards Institute, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47 Street, New York, N.Y. 10017.

Gears, Splines, and Serrations, ANSI Y14.7, American National Standards Institute, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47 Street, New York, N.Y. 10017.

Screw Thread Presentation, ANSI Y14.6, American National Standards Institute, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47 Street, New York, N.Y. 10017.

Square and Hex Bolts and Screws, ANSI B4.2, American National Standards Institute, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47 Street, New York, N.Y. 10017.

Surface Texture Symbols, ANSI Y14.36, American National Standards Institute, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47 Street, New York, N.Y. 10017.

United Screw Threads, ANSI B1.1, American National Standards Institute, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47 Street, New York, N.Y. 10017.

Chapter 5

Fluid Power Diagrams, ANSI Y14.17, American National Standards Institute, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47 Street, New York, N.Y. 10017.

Graphic Symbols for Aircrafi Hydraulic and Pneumatic Systems, AS 1290A, Aerospace Standard, Society of Automotive Engineers, Inc. (SAE), 400 Commonwealth Drive, Warrendale, Pa. 15096.

Pictorial Drawing, ANSI Y14.4M, American National Standards Institute, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47 Street, New York, N.Y. 10017.

Projections, ANSI Y14.3M, American National Standards Institute, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47 Street, New York, N.Y. 10017.

Chapter 6

Electrical and Electronics Diagrams, ANSI Y14.15, American National Standards Institute, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47 Street, New York, N.Y. 10017.

Graphic Electrical Wiring Symbols for Architectural and Electrical Layout Drawings, ANSI Y32.9, American National Standards Institute, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47 Street, New York, N.Y. 10017.

Projections, ANSI Y14.3M, American National Standards Institute, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47 Street, New York, N.Y. 10017.

Supplement to Graphic Symbols for Electrical and Electronics Diagrams, ANSI/IEEE STD 315A-1986, American National Standards Institute, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47 Street, New York, N.Y. 10017.

Chapter 7

Architectural Graphics Standards, Student Edition, Robert J. Packard, John Wiley & Sons Publishing, 1989.

Blueprint Reading and Sketching for Carpenters: Residential, Leo McDonald & John Ball, Delmar Publishing Co., 1981.

Blueprint Reading for Commercial Construction, Charles D. Willis, Delmar Publishing Company, 1979.

Blueprint Reading for Welders, 4th Edition, A. E. Bennett/Louis J. Sly, Delmar Publishing Inc., 1988.

Construction Blueprint Reading, Robert Putnam, Prentice-Hall, Inc., 1985.

Electrical and Electronics Diagrams, ANSI Y14.15, American National Standards Institute, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47 Street, New York, N.Y. 10017.

Engineering Drawing and Design, Jay D. Helsel, Gregg Division, McGraw-Hill Book Company, Atlanta, Ga., 1985.

Reading Architectural Working Drawings, Volumes 1 & 2, Edward J. Muller, Practice Hall Publishing, 1988.

Specifications for Structural Concrete for Buildings, ACI 301-89, American Concrete Institute, Redford Station, Detroit, Mich. 48219.

Technical Illustration, T.A. Thomas, McGraw-Hill Publishing, 1960.

Chapter 8

Drawing Sheet Size and Format, ANSI Y14.1, American National Standards Institute, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47 Street, New York, N.Y. 10017.

Engineering Drawing and Design, Jay D. Helsel, Gregg Division, McGraw-Hill Book Company, Atlanta, Ga., 1985.

Pictorial Drawing, ANSI Y14.4M, American National Standards Institute, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47 Street, New York, N.Y. 10017.

Projections, ANSI Y14.3M. American National Standards Institute, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47 Street, New York, N.Y. 10017.

Technical Drawing Problems, Series 2, H. C. Spencer, MacMillian Publishing, 1980.

Technical Illustration, 2nd Edition, A. B. Pyeatt, Higgins Ink Co., 1960.

Technical Illustration, T. A. Thomas, McGraw-Hill Publishing, 1960.

INDEX

Assignment Questions

Information: The text pages that you are to study are provided at the beginning of the assignment questions.

ASSIGNMENT 1

Textbook Assignment: "Blueprint Reading," "Technical Sketching," and Projections and Views," chapters 1 through 3.

1-1. Which of the following statements best describes the term "blueprint reading"?

1. Interpreting the ideas expressed by the engineer or craftsman
2. Transferring the blueprint to the part to be made
3. Understanding the symbols used to prepare blueprints
4. Reproducing the print with a microprocessor

1-2. The standards and procedures prescribed by military and American National standards are published in which of the following publications on 31 July of each year?

1. Military Standards (MIL-STD)
2. Department of Defence Index of Specifications and Standards
3. American National Standards Institute (ANSI)
4. MIL-STD and ANSI standards

1-3. To find the correct drawing symbols to show fittings and electrical wiring on ships, you should refer to what standards?

1. ANSI Y32.9 and MIL-STD-100A
2. MIL-STD-15 and MIL-STD-25A
3. MIL-STD-17B and ANSI 46.1-1962
4. ANSI Y31.2 and MIL-STD-22A

1-4. What is the primary difference in the various methods of producing blueprints?

1. The type of paper used
2. The color and transparency of the paper
3. The type of plotter used
4. The type of paper and the processes used

A. Information block
B. Title block
C. Revision block
D. Scale block
E. Bill of material
F. Application block

Figure 1A

IN ANSWERING QUESTIONS 1-5 THROUGH 1-10, REFER TO THE PARTS OF A BLUEPRINT IN FIGURE 1A.

1-5. This block is used when a change has been made to the drawing.

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

1-6 This block includes information required to identify the part, name, and address of the organization that prepared the drawing.

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

1-7 This block gives the reader additional information about material, specifications and so on, to manufacture the part.

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

1-8. This block shows the size of the drawing compared to the actual size of the part.

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

1-9. This block contains a list of the parts and/or material needed for the project.

1. C
2. D
3. E
4. F

1-10. This block identifies directly or by reference the larger unit that contains the part or assembly.

1. C
2. D
3. E
4. F

1-11 Which of the following information provides contractors, supervisors, and manufacturers with more information than is shown graphically on a blueprint?

1. Finish marks
2. Station numbers
3. Notes and specifications
4. Zone numbers

IN ANSWERING QUESTIONS 1-12 THROUGH 1-14, SELECT FROM THE FOLLOWING LIST THE TYPE OF NUMBER YOU SHOULD USE FOR THE PURPOSE DESCRIBED IN THE QUESTION.

A. Drawing number
B. Reference number
C. Station number
D. Zone number

1-12. Evenly spaced numbers on a drawing that begin with zero and number outward in one or both directions.

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

1-13. Numbers placed to help locate a point or part on a drawing.

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

1-14. Numbers that refer to the numbers of other blueprints.

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

1-15. In figure 1-2 in the text, the list of parts and symbols shown in the upper right corner is known by what term?

1. Legend
2. Symbol
3. Note
4. Specification

A. Preliminary plan B. Contract plan C. Contract guidance plan D. Standard plan E. Type plan F. Working plan G. Corrected plan H. Onboard plan

Figure 1B

IN ANSWERING QUESTIONS 1-16 THROUGH 1-23, CHOOSE FROM FIGURE 1B THE TYPE OF PLAN DESCRIBED BY THE QUESTION.

1-16. The plan used by the contractor to construct the ship.

1. C
2. D
3. E
4. F

1-17. The plan used to illustrate design features of the ship subject to development.

1. C
2. D
3. E
4. F

1-18. The plan furnished by the ship builder that is needed to operate and maintain the ship.

1. E
2. F
3. G
4. H

1-19. The plan that illustrates the general arrangement of equipment or parts that do not require strict compliance to details.

1. E
2. F
3. G
4. H

1-20. The plan that illustrates the arrangement or details of equipment, systems, or parts where specific requirements are mandatory.

1. C
2. D
3. E
4. F

1-21. The plan submitted before the contract is awarded.

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

1-22. The plan that illustrates the mandatory design features of the ship.

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

1-23 The plan that has been corrected to illustrate the final ship and system arrangement, fabrication, and installation.

1. E
2. F
3. G
4. H

1-24. What publication contains the letters to be used to designate the size of a blueprint?

1. Naval Ships' Technical Manual
2. ANSI 27.2Y
3. MIL-STD 100
4. Consolidated Index of Drawing

1-25. In the current blueprint numbering plan, the activity that designed the object to be built is identified in which of the following positions?

1. Federal Supply Code Identification Number
2. System Command Number, Part 1
3. System Command Number, Part 2
4. Revision Letter

1-26. What is the major difference in the old and new shipboard numbering systems?

1. The federal supply code identification number
2. The serial and file number
3. The Naval Facilities Engineering Code Identification number
4. The group numbers in block two

1-27. Which of the following is a necessary practice in caring for blueprints?

1. Make all corrections in ink
2. Allow them to dry out completely before restoring them
3. Properly fold and file them
4. Be sure all erasures are complete

1-28. When a plan is revised, what is the disposition of the old plan?

1. It is retained in a special file
2. It is attached to the back of the new copy
3. It is removed and sent to Naval Archives
4. It is removed and destroyed when replaced by the revised plan

1-29. On most ships, personnel in which of the following areas maintain the ship plans?

1. Engineering logroom
2. Ship's library
3. Repair division
4. Supply department

1-30. Which of the following codes identifies the harder grade of pencil lead?

1. 9H
2. 5H
3. 2H
4. 6B

1-31. When using needle-in-tube pens, you produce different line widths by what means?

1. Bear down firmly on the pen head
2. Change the needle points
3. Draw double lines
4. Hold the pen at 90° to the drawing surface

1-32. What instrument is used to produce irregular curves?

1. A protractor
2. Multiple combination triangles
3. A set of French curves
4. An adjustable triangle

A.	Visible
B.	Hidden
C.	Symmetry
D.	Extension and dimension
E.	Cutting plane
F.	Section
G.	Viewing
H.	Phantom
I.	Leader
J.	Center
K.	Break
L.	Stitch
M.	Chain

Figure 1C

IN ANSWERING QUESTIONS l-33 THROUGH 1-43, SELECT FROM FIGURE 1C THE TYPE OF LINE DESCRIBED IN THE QUESTION.

1-33. Lines used to indicate the part of a drawing to which a note refers.

1. B
2. C
3. I
4. J

1-34. Lines with alternating long and short dashes.

1. D
2. F
3. J
4. K

1-35. Lines used to shorten the view of long, uniform surfaces.

1. B
2. E
3. G
4. K

1-36. Lines used to indicate the surface in the section view imagined to have been cut along the cutting plane line.

1. E
2. F
3. G
4. H

1-37. Lines used to dimension an object.

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

1-38. Lines used to designate where an imaginary cutting took place.

1. E
2. F
3. G
4. H

1-39. Lines used to show surfaces, edges, or corners of an object that are hidden from sight.

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

1-40 Thick, alternating lines made of long and short dashes.

1. E
2. G
3. L
4. M

1-41. Lines that should stand out clearly in contrast to all other lines so that the shape of the object is apparent to the eye.

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

1-42. Lines used to indicate alternate and adjacent positions of moving parts, adjacent positions of related parts, and repetitive detail.

1. E
2. F
3. G
4. H

1-43. Lines used when drawing partial views of symmetrical parts.

1. C
2. D
3. E
4. F

1-44 Which of the following forms contains a curve that does not follow a constant arc?

1. Circle
2. Ellipse
3. Irregular curve
4. Ogee

1-45 Computer-aided drafting (CAD) helps a draftsman save considerable drawing time by which of the following means?

1. Its re-drawing capability
2. Its disk storage capability
3. Its lack of need for hand-held instruments
4. All of the above

1-46 Which of the following CAD components allows the draftsman to move from one command to another without the use of the function keys?

1. The plotter
2. The digitizer tablet
3. The printer
4. The computer program

1-47 Which of the following is a disadvantage of reproducing prints on a printer?

1. You cannot produce drawings on standard paper used for blueprints
2. You cannot do a quick review of the print at the design phase
3. You cannot copy complex graphic screen displays
4. You cannot get the quality from a printer that you can get from a pin plotter

1-48. What CAD component(s) produce(s) the drawing after it has been completed on the computer screen?

1. The plotter only
2. The digitizer only
3. The plotter and digitizer
4. The printer and digitizer

1-49. What is the main advantage of using numerical control machines rather than manually operated machines?

1. They can be used in mass production
2. They cost less to operate
3. They allow faster production
4. They can be operated by untrained machinists

1-50. Which of the following best describes direct numerical control (DNC)?

1. It allows the draftsman to program the computer to operate various machines used to produce the final print
2. It provides instructions that can be stored in a central computer memory, or on disk, for direct transfer to one or more machines that will make the part
3. It provides more rapid and precise manufacturing of parts
4. It acts as a central file where all drawings may be stored without having to store a large number of prints

1-51. What types of training are required to operate CAD and computer-aided manufacturing (CAM) systems?

1. Specialized and formal
2. Correspondence courses provided by the manufacturer of the system
3. Formal and on-the-job (OJT)
4. OJT and correspondence courses

1-52. Which of the following best describes the CAD/CAM systems used in manufacturing?

1. CAD draws the part and defines the tool path; CAM converts the tool path into codes the machine's computer understands
2. CAD controls the machine used to make the part; CAM is the drawing medium used to convert instructions to the machine making the part
3. 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
4. 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

1-53. The view of an object is technically known by what term?

1. Projection
2. Extensions
3. Extenders
4. Parallelism

1-54. To visualize the object to be made from a blueprint, you should take what step first?

1. Look at the front view only
2. Interpret each line on the adjacent view
3. Study all views
4. Look at the top and side views only

1-55. Why are central projections seldom used?

1. They vary with the distance between the observer and the plane of projection
2. They vary with the distance between the observer and the object
3. They vary in size according to the relative positions of the object and the plane of projection
4. All of the above

1-56. Oblique and axonometric projections show which of the following dimensions?

1. Height and width only
2. Length only
3. Width only
4. Height, width, and length

1-57. Which of the following best describes an axonometric projection?

1. An orthographic projection in which the projectors are parallel to the object
2. A form of isometric projection in which the object is perpendicular to the viewing plane
3. A form of orthographic projection in which the projectors are perpendicular to the plane of projection and the object is angled to the plane of projection
4. A projection in which all views are drawn to the exact size and shape of the object

1-58. Conventional 3-view drawings are drawn by eliminating which of the following views from the third-angle orthographic projection?

1. Right side, bottom, and rear
2. Left side, top and bottom
3. Left side, rear, and top
4. Left side, bottom, and rear

1-59. Complex multiview drawings normally have how many views?

1. Two
2. Four
3. Six
4. Eight

1-60. When drawing a 3-view orthographic projection, the side and top views are drawn by extending lines in what direction(s)?

1. To the left and bottom of the front view
2. Horizontally to the right and vertically from the front view
3. From the bottom of the front view
4. Upward from the front view

1-61. Which of the following views shows the most characteristic features of an object?

1. Front
2. Top
3. Side
4. Bottom

1-62. What is the main purpose of a perspective drawing?

1. To show the object becoming proportionally smaller--a true picture of the object as the eyes see it
2. To show all views of the object in their true shape and size
3. To help the engineer design the object
4. To give the craftsman a clear picture to manufacture the part

1-63. Draftsmen use special views to give engineers and craftsmen a clear view of the object to be constructed.

1. True
2. False

A.	Auxiliary view
B.	Section view
C.	Offset section
D.	Half section
E.	Revolved section
F.	Removed section
G.	Broken-out section
H.	Aligned section
I.	Exploded view

Figure 1D

IN ANSWERING QUESTIONS 1-64 THROUGH 1-74, CHOOSE FROM FIGURE 1D THE VIEW DESCRIBED IN THE QUESTION. SOME ANSWERS MAY BE USED MORE THAN ONCE.

1-64. A view that gives a clearer view of the interior or hidden features of an object that normally are not seen in other views.

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

1-65. A view that shows the true shape and size of the inclined face of an object.

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

1-66. A view that shows an object that is symmetrical in both outside and inside detail.

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

1-67. A view that shows the inner structure of a small area by peeling back or removing the outside surface.

1. F
2. G
3. H
4. I

1-68. A view that shows the relative locations of parts when you assemble an object.

1. F
2. G
3. H
4. I

1-69. A view that shows particular parts of an object.

1. F
2. G
3. H
4. I

1-70. A view that is used when the true sectional view might be misleading as with ribs and spokes.

1. F
2. G
3. H
4. I

1-71. A view that eliminates the need to draw extra views of rolled shapes, ribs, and similar forms.

1. E
2. F
3. G
4. H

1-72. A view that shows the cutting plane changing direction backward and forward to pass through features that are important to show.

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

1-73. A view that is made by visually cutting away a part of an object to show the shape and construction at the cutting plane and that is indicated by diagonal parallel lines.

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

1-74. A view that removes a portion of an object so the viewer can see inside.

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

1-75. A detail drawing has which of the following characteristics not found in a detail view?

1. It shows only part of the object.
2. It shows shape, exact size, finish, and tolerance for each part
3. It is drawn on the opposite plane of the detail view
4. It shows multiple components or parts

ASSIGNMENT 2

Textbook Assignment: "Machine Drawings" and "Piping Systems," chapters 4 and 5.

2-1. What method of indicating tolerance allows a variation from design specifications in one direction only?

1. Unilateral
2. Bilateral
3. Limited dimension
4. Minimum value

2-2. What letters of the alphabet may NOT be used in a datum reference?

1. A, C, D
2. F, I, O
3. I, O, P
4. I, O, Q

2-3. The permissible variation of a part is known as

1. limited dimensioning
2. tolerance
3. geometrical characteristic
4. a datum reference

2-4. View B of figure 4-1 in the textbook indicates what method of showing tolerance?

1. Limited dimensioning
2. Unilateral
3. Bilateral
4. Geometrical tolerance

2-5. Terms such as roundness, flatness, symmetry, and true position describe the geometrical characteristics of

1. surfaces
2. angles
3. reference points
4. a feature control frame

2-6. Fillets are used to prevent chipping and sharp edges.

1. True
2. False

IN ANSWERING QUESTIONS 2-7 THROUGH 2-12, SELECT FROM THE FOLLOWING LIST THE TERM THAT IS DESCRIBED IN THE QUESTION.

A. Fillets
B. Rounds
C. Slots and slides
D. Key
E. Keyway
F. Keyseat

2-7. A slot or groove on the outside of a part into which the key fits.

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

2-8. Specially shaped parts mated together but still movable.

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

2-9. An item placed in a groove or slot between a shaft and a hub to prevent slippage.

1. C
2. D
3. E
4. F

2-10. A slot or groove on the inside of a cylinder, tube, or pipe.

1. C
2. D
3. E
4. F

2-11. Items normally used to increase the strength of a metal corner and to reduce the possibility of a break.

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

2-12. Edges or outside corners machined to prevent chipping and to avoid sharp edges.

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

2-13. Classes of threads are different from each other in which of the following characteristics?

1. Specified tolerance and/or allowance
2. Minimum and maximum pitch
3. Major diameter only
4. Major diameter and root clearance

2-14 What part of a thread designator number identifies the nominal or outside diameter of a thread?

1. The first
2. The second
3. The fourth
4. The letter designator

2-15 Which of the following thread dimensions shows a 1/4-20 left-hand National course screw with a tolerance or fit of 2?

1. 1/4-20 UNC
2. 1/4-20-RH-UNC
3. 1/4-20 UNC-2 LH
4. 1/4-20

2-16 Which of the following National Form threads are most commonly used?

1. National course (NC) and pipe.
2. National fine (NF) and press fit
3. National fine (NF) and National course (NC)
4. Metric and National fine (NF)

IN ANSWERING QUESTIONS 2-17 THROUGH 2-22, REFER TO FIGURE 4-13 IN THE TEXTBOOK.

2-17. The thread on the outside of a bolt is an example of what type of thread?

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

2-18. The largest diameter of an external or internal thread is known by what term?

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

2-19. The center line that runs lengthwise through a screw is known by what term?

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

2-20. The surface of the thread that corresponds to the major diameter of an external thread and the minor diameter of an internal thread is known by what term?

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

2-21. The surface of the thread that corresponds to the minor diameter of an external thread and the major diameter of an internal thread is known by what term?

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

2-22. The distance from a point on a screw thread to a corresponding point on the next thread, measured parallel to the axis is known by what term?

1. B
2. D
3. E
4. F

2-23. The distance from the root of a thread to the crest, measured perpendicularly to the axis, is known by what term?

1. Lead
2. Pitch
3. Depth
4. Major diameter

2-24. What is the definition of the term "lead"?

1. The distance a screw thread advances on one turn, parallel to the axis
2. The distance the thread is cut from the crest to its root
3. The distance from the thread's pitch to its root dimension
4. The distance between external threads

A. Pitch diameter
B. Outside diameter
C. Number of teeth
D. Addendum circle
E. Circular pitch
F. Addendum
G. Dedendum
H. Chordal pitch
I. Diametral pitch
J. Root diameter
K. Clearance
L. Whole depth
M. Face
N. Thickness
O. Pitch circle
P. Working depth
Q. Rack teeth

Figure 2A

IN ANSWERING QUESTIONS 2-25 THROUGH 2-41 SELECT FROM THE GEAR NOMENCLATURE IN FIGURE 2A THE TERM THAT IS DESCRIBED IN THE QUESTION.

2-25. The diameter of the pitch circle (or line) that equals the number of teeth on the gear divided by the diametral pitch.

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

2-26. The distance from center to center of teeth measured along a straight line or chord of the pitch circle.

1. F
2. G
3. H
4. I

2-27. The height of the tooth above the pitch circle or the radial distance between the pitch circle and the top of the tooth.

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

2-28. The circle over the tops of the teeth.

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

2-29. The number of teeth to each inch of the pitch diameter or the number of teeth on the gear divided by the pitch diameter.

1. I
2. J
3. K
4. L

2-30. The distance from top of the tooth to the bottom, including the clearance.

1. J
2. K
3. L
4. M

2-31. A gear that may be compared to a spur gear that has been straightened out.

1. M
2. O
3. P
4. Q

2-32. The working surface of the tooth over the pitch line.

1. L
2. M
3. N
4. O

2-33. The greatest depth to which a tooth of one gear extends into the tooth space of another gear.

1. N
2. O
3. P
4. Q

2-34. The diameter of the circle at the root of the teeth.

1. I
2. J
3. K
4. L

2-35 The distance between the bottom of a tooth and the top of a mating tooth.

1. H
2. I
3. J
4. K

2-36. The width of the tooth, taken as a chord of the pitch circle.

1. N
2. O
3. P
4. Q

2-37 The diameter of the addendum circle.

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

2-38 The length of the portion of the tooth from the pitch circle to the base of the tooth.

1. D
2. E
3. F
4. G

2-39. The circle having the pitch diameter.

1. N
2. O
3. P
4. Q

2-40. The diametral pitch multiplied by the diameter of the pitch circle.

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

2-41. The length of the arc of the pitch circle between the centers or corresponding points of adjacent teeth.

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

2-42. Helical springs are always identified by their classification and drawn to true shape.

1. True
2. False

2-43. Which of the following are three classifications of helical springs?

1. Contortion, extension, and compression
2. Extension, compression, and torsion
3. Combination extension and compression, torsion, and flex
4. Combination tension and compression, extension, and retracting

2-44. A number within the angle of a finish mark symbol provides what information?

1. The degree of finish
2. The roughness height in thousandths
3. The roughness height in one hundred thousandths
4. The ability to adhere to its mating part

2-45. When a part is to be finished all over, the finish mark is drawn on an extension line to the surface of the part to be machined.

1. True
2. False

2-46. The acceptable roughness of a part depends on which of the following requirements?

1. How the part will be used
2. The type of equipment used to make the finish
3. The method used to achieve the desired roughness
4. The designer's personal preference

2-47. What publication contains the standards for roughness?

1. MIL-STD. 46-1/C
2. ANSI 46.1-1962
3. NSTM 9730
4. MIL-STD 35-53

2-48. ANSI Y14.5M-1982 is the standard for all blueprints whether they are drawn by hand or on a computer.

1. True
2. False

2-49. Which of the following orthographic drawings are drawn on one plane only?

1. Mechanical
2. Single- and double-line pipe
3. Electrical
4. Electronic

2-50. A draftsman uses which of the following drawings to show the arrangement of pipes and fittings?

1. Double- and single-line orthographic
2. Single-line orthographic only
3. Single-line isometric
4. Double-line isometric

2-51. Which of the following types of drawings takes more time to draw and is used where visual presentation is more important than time?

1. Single-line orthographic
2. Double-line orthographic
3. Single-line isometric
4. Double-line isometric

2-52. What is the advantage of using single-line isometric drawings to lay out piping systems?

1. They take less time and show all information required
2. The information is of better graphic quality
3. They take less time and are shown on three planes of projection
4. They are cheaper to produce and easier to understand

2-53. A pipe connection is shown on a drawing by what means?

1. A break in the line
2. A general note specifying its location
3. A heavy dot and a note or specification to describe the type of connection
4. A leader line to the point of the connection and a note showing how the connection should be made

2-54. Detachable connections may be shown on a pipe drawing by which of the following means?

1. General notes
2. Specifications
3. A bill of material
4. All of the above

2-55. On a pipe drawing, one pipe is shown crossing in front of another by what means?

1. A heavy dot on the line represents one pipe passing in front of the other
2. The line representing the pipe farthest away has a break or interruption
3. The line representing the closest pipe has a break or interruption
4. The farthest line is drawn with a heavy, thick line

2-56. When an item is not covered by specific standards, what person or organization ensures that a suitable symbol is used?

1. The draftsman
2. The technician
3. The designer of the fitting
4. The responsible activity

2-57. When standard fittings are not used on a drawing, fittings such as tees, elbows, and crossings are shown by which of the following means?

1. Notes and specifications
2. Continuous lines
3. Circular symbols that show the direction of piping
4. Both 2 and 3 above

2-58. Piping system prints with more than one of the same piping systems are shown on a drawing by what means?

1. Additional letters added to the symbols
2. A print with several drawing numbers
3. A general note or specification
4. Heavier lines that differentiate between the systems

IN ANSWERING QUESTIONS 2-59 THROUGH 2-64, SELECT FROM THE FOLLOWING LIST THE COLOR ON THE PIPING SYSTEM THAT CARRIES THE MATERIAL IN THE QUESTION.

A. Yellow
B. Brown
C. Blue
D. Green
E. Gray
F. Red

2-59. Physically dangerous materials.

1. C
2. D
3. E
4. F

2-60 Toxic and poisonous materials.

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

2-61 Fire protection materials.

1. C
2. D
3. E
4. F

2-62. Anesthetics and harmful materials.

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

2-63. Flammable materials.

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

2-64. Oxidizing materials.

1. C
2. D
3. E
4. F

2-65. What is the hazard symbol for carbon dioxide?

1. FLAM
2. AAHM
3. TOXIC
4. PHDAN

2-66. Which of the following materials is not ordinarily dangerous in itself?

1. Trichloroethylene
2. Freon
3. Alcohol
4. Gasoline

2-67. Which of the following markings identifies materials that are extremely hazardous to life or health?

1. FLAM
2. TOXIC
3. AAHM
4. PHDAN

2-68. What publication lists standards for the marking of fluid lines in aircraft?

1. NSTM 3790
2. OPNAV 5100.1C
3. MIL-STD-1247C
4. NOSHA, Part 2

IN ANSWERING QUESTIONS 2-69 THROUGH 2-73, SELECT FROM THE FOLLOWING LIST THE TYPES OF HYDRAULIC LINES THAT ARE DESCRIBED IN THE QUESTION.

A. Supply lines
B. Pressure lines
C. Operating lines
D. Return lines
E. Vent lines

2-69. These lines carry only pressure from pumps to a pressure manifold, and on to various selector valves.

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

2-70. These lines carry excess fluid overboard or into another receptacle.

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

2-71. These lines alternately carry pressure to, and return fluid from, an actuating unit.

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

2-72. These lines carry fluid from the reservoir to the pumps.

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

2-73. Arrows printed on pipes show only the direction of fluid flow.

1. True
2. False

2-74. You will find standard piping symbols in what publication?

1. MIL-STD-17B, Parts 1 and 2
2. MIL-STD-14A
3. MIL-STD-35-35/2
4. MIL-STD-19B, Parts 1 and 2

2-75. In figure 5-23, assume the tee in the upper right corner has openings of A = 3 inches,
C = 1 inch. You should read them in what order?

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

ASSIGNMENT 3

Textbook Assignment, "Electrical and Electronics Prints," chapter 6.

● QUESTIONS 3-1 THROUGH 3-45 DEAL WITH ELECTRICAL PRINTS.

IN ANSWERING QUESTIONS 3-1 THROUGH 3-6, SELECT FROM THE FOLLOWING LIST THE WIRING DIAGRAM DESCRIBED IN THE QUESTION.

A Pictorial
B. Isometric
C. Schematic
D. Block
E. Single-line
F. Elementary

3-1. The outline of a ship or aircraft containing the general location of equipment.

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

3-2. Lines and graphic symbols that simplify complex circuits or systems.

1. C
2. D
3. E
4. F

3-3. Shows how each individual conductor is connected within the various connection boxes of an electrical circuit or system.

1. B
2. D
3. E
4. F

3-4. Made up of pictorial sketches of the various parts of an item of equipment and the electrical connections between the parts.

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

3-5. Graphic symbols that show how a circuit functions electrically.

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

3-6. Squares, rectangles, or other geometrical figures that represent major equipment components.

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

3-7. A series of consecutive numbers begins with the number 1 on a piece of equipment located in the lowest, foremost starboard compartment and continues on to similar pieces of equipment in the next compartment and so forth. This is a definition of what numbering term?

1. Form
2. Group
3. Type
4. Unit

3-8. When similar units are numbered within a compartment, what rule dictates the order of precedence?

1. Forward takes precedence over aft, port over starboard, and upper over lower
2. Lower takes precedence over upper, aft over forward, and starboard over port
3. Lower takes precedence over upper, forward over aft, and starboard over port
4. Lower takes precedence over forward, upper over aft, and port over starboard

3-9. A distribution panel is located on the second deck at frame 167 and is the first one on the port side of the compartment. It has what identification number?

1. 2-2-167
2. 167-2-1
3. 2-167-2
4. 2-l-167

3-10. The first number of a distribution panel provides what information about its location?

1. The horizontal position in relation to the center line
2. The vertical level by the deck or platform at which the unit is accessible
3. The vertical position in relation to the frame where it is located within the compartment
4. The horizontal and verticle location with relation to the center line

3-11. The identification number on a distribution panel provides what locations in its (a) second and (b) third positions

1. (a) Longitudinal, (b) transverse
2. (a) Deck, (b) frame
3. (a) Frame, (b) deck
4. (a) Deck, (b) platform

3-12. A ship that is divided into areas that coincide with fire zones prescribed by the ship's damage control plan has what type of numbering system?

1. Zone control
2. Fire control only
3. Damage control only
4. Both 2 and 3 above

3-13. In a zone control numbering system, the first and second digit on a switchboard number identifies the zone and the number of the switchboard within that zone.

1. True
2. False

3-14. Permanently installed shipboard electrical cables are identified by what means?

1. Numbers painted on the cable
2. Numbers painted on the bulkhead
3. Plastic tags
4. Metal tags

● QUESTIONS 3-15 THROUGH 3-22 DEAL WITH THE OLD SHIPBOARD CABLE TAG SYSTEM.

3-15. What color identifies a semivital cable?

1. Red
2. Gray
3. White
4. Yellow

3-16. What color identifies a vital cable?

1. Red
2. Gray
3. White
4. Yellow

3-17. The cable service letters FB identify a cable used for what purpose?

1. Interior communication
2. Battle power
3. Fire control
4. Sonar

IN ANSWERING QUESTIONS 3-18 THROUGH 3-22, REFER TO THE FOLLOWING CABLE TAG NUMBER.

1-FB-411-A1A

3-18. What numbers identify the main?

1. 1-FB
2. FB-411
3. 411-A1A
4. 1-FB-411

3-19. What numbers identify the submain?

1. 411
2. FB-411A
3. 1-FB-411A
4. 1-FB-411-A1

3-20. What numbers identify the branch?

1. FB-411
2. 1-FB
3. 1-FB-411
4. 1-FB-411-A1

3-21. What numbers identify a feeder?

1. FB
2. FB-411
3. 1-FB-411
4. 1-FB-411-A

3-22. What numbers identify a subbranch?

1. FB-411
2. 1-FB-411
3. 1-FB-411-A1
4. 1-FB-411-A1A

● QUESTIONS 3-23 THROUGH 3-28 DEAL WITH THE NEW SHIPBOARD CABLE TAG SYSTEM.

3-23 The new cable tag system numbers show which of the following parts in sequence?

1. Service, voltage, source
2. Voltage, service, source
3. Source, voltage, service
4. Source, service, voltage

3-24 The number 24 identifies what circuit voltage?

1. 2.4
2. 24
3. 240
4. 100 to 240

3-25. Cable voltages between 100 and 199 are identified by what means?

1. The letter A
2. The letter B
3. The number 1
4. The actual circuit voltage

3-26. When two or more generators service the same switchboard, the generators are marked by what means?

1. The first has the same number as the switchboard and the second will have that number followed by a letter
2. The first is marked with an A and the second with a B
3. They are numbered consecutively
4. Both have the switchboard number followed by consecutive numbers

3-27. On a cable marked with the number (1-143-3)-ZE-4P-A(2), the (2) provides what information about the cable?

1. Its location in the ship
2. Its location in the compartment
3. The section of the power main
4. The voltage in the circuit

3-28. In a three-phase ac system, a power cable with two conductors will be what colors for (a) B polarity and (b) C polarity?

1. (a) White, (b) black
2. (a) Black, (b) white
3. (a) Red, (b) black
4. (a) Red, (b) white

3-29. The symbols on an isometric wiring diagram that identify fixtures and fittings are found in what publication?

1. MIL-STD-15-2
2. Standard Electrical Symbol List, NAVSHIPS 0960-000-4000
3. ANSI Y32.7
4. Basic Military Requirements

3-30. A cable size of 9000 circular mils is identified in which of the following cable marking numbers?

1. (2-38-1)-L-A1-T-9
2. (3-12-9)-L-A1A-T-150
3. (9-124-4)-L-1A
4. (l-38-21-9

3-31. On an isometric wiring diagram, a single line represents cables with how many conductors?

1. One only
2. Two only
3. Three only
4. Any number

3-32. Which of the following plans shows the exact location of the cables aboard a ship?

1. Damage control plan
2. General plans
3. Wiring deck plan
4. Fire control plan

IN ANSWERING QUESTIONS 3-33 THROUGH 3-40, SELECT FROM THE FOLLOWING LIST THE DIAGRAM THAT IS DESCRIBED IN THE QUESTION.

A. Block diagram
B. Electrical system diagram
C. Elementary wiring diagram
D. Equipment wiring diagram
E. Isometric wiring diagram
F. Schematic diagram
G. Single-line diagram

3-33. Which diagram shows each conductor, terminal, and connection in the circuit?

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

3-34. Which diagram shows the ship's decks arranged in tiers?

1. A
2. C
3. E
4. F

3-35. Which diagram is used along with text material to show major units of the system in block form?

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

3-36. Which diagram is used to operate and maintain the various systems and components aboard ship?

1. A
2. B
3. E
4. G

3-37. Which diagram is illustrated in figure 6-3 in the textbook?

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

3-38. Which diagram shows the electrical operation of a particular piece of equipment, circuit, or system?

1. B
2. D
3. F
4. E

3-39. Which diagram shows the relative positions of various equipment components and the way individual conductors are connected in the circuit?

1. A
2. D
3. E
4. F

3-40. Which diagram shows a general description of a system and how it functions?

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

- QUESTIONS 3-41 THROUGH 3-45 DEAL WITH AIRCRAFT ELECTRICAL PRINTS.

3-41. All of the wiring in an aircraft is shown on which of the following prints?

1. A master wiring diagram
2. A master block diagram
3. A wiring plan
4. An isometric and schematic diagram

3-42. Equipment part numbers, wire numbers, and all terminal strips and plugs are shown in what type of wiring diagram?

1. Master
2. Circuit
3. Schematic
4. Isometric

3-43. In figure 6-7 in the textbook, the wire identification code shows what total number of identical units in the aircraft?

1. One
2. Two
3. Three
4. Four

3-44. A wire with the circuit function code 2RL 85F20N will be found in what circuit of an aircraft?

1. Radar
2. Engine control
3. Control surface
4. Radio

3-45. What is the wire number of an aircraft wire with the number 4SL 65F20N?

1. 4
2. 65
3. 20
4. 20N

- QUESTIONS 3-46 THROUGH 3-75 DEAL WITH ELECTRONICS PRINTS.

3-46. What types of electronics wiring diagrams show (a) the general location of electronics units, and (b) how individual cables are connected?

1. (a) Block, (b) isometric
2. (a) Isometric, (b) elementary
3. (a) Interconnection, (b) block
4. (a) Schematic, (b) elementary

3-47. A complete list of electronic cable designations may be found in what NAVSHIPS publication?

1. 0924-000-0140
2. 0945-001-1124
3. 0967-000-0140
4. 0932-101-1202

IN ANSWERING QUESTIONS 3-48 AND 3-49, SELECT FROM FIGURE 6-9 IN THE TEXTBOOK THE CIRCUIT OR SYSTEM DESIGNATION DESCRIBED IN THE QUESTION.

3-48. Aircraft early warning radar.

1. R-EA
2. R-EW
3. R-EZ
4. R-S

3-49. Height determining radar.

1. R-EF
2. R-EG
3. R-EW
4. R-EZ

3-50. A simplified block diagram is shown in which of the following figures in the textbook?

1. 6-10
2 6-11
3. 6-12
4. 6-13

3-51. On shipboard prints, what number or letter identifies the circuit differentiating portion of cable marking 2R-ET-3?

1. R
2. 2
3. 3
4. E

3-52. Block diagrams describe the functional operation of electronics systems in a different manner than they do in electrical systems.

1. True
2. False

3-53. Which of the following diagrams may be used to troubleshoot as well as identify function operations?

1. Detailed schematic block
2. Servicing block
3. Functional block
4. Both 2 and 3 above

3-54. Individual circuits and parts may be checked more easily by using which of the following diagrams?

1. Detailed schematic block
2. Servicing block
3. Schematic
4. Isometric

3-55. In detailed schematic diagrams, signal flow is shown moving in what direction?

1. Top to bottom
2. Right to left
3. Left to right
4. Bottom to top

3-56. In a wiring circuit diagram, grounds, grounded elements, and returns are identified by what color?

1. Orange
2. Brown
3. Black
4. Violet

3-57. The reference designations currently used to identify parts in electronic drawings are part of the block numbering system.

1. True
2. False

3-58. A system is defined as two or more sets and other assemblies, sub-assemblies, and parts necessary to perform an operational function in what numbering system?

1. Block
2. Reference
3. Unit
4. Group

3-59. What is the highest level in the assignment of reference designations for the current electronics designation system?

1. Set
2. Unit
3. Part
4. Assembly

3-60. Identify the following resister with the reference designation 2A11A4A1R3.

1. No. 3 resistor on No. 1 card of rack 4 in assembly 11 of unit 2
2. No. 3 resistor on No. 2 card of rack 4 in assembly 11 of unit 1
3. No. 1 resistor on No. 2 card of rack 3 in assembly 11 of unit 1
4. No. 1 resistor on No. 3 card of rack 2 in assembly 11 of unit 4

3-61. The spaghetti tags on the ends of a conductor provide what information?

1. The terminal board and terminal to which the marked end is connected
2. The abbreviated reference designation number
3. The terminal board and terminal to which the opposite end is connected
4. The complete reference designation number

3-62. A block diagram of a complicated aircraft system that contains details of signal paths, wave shapes, and so on is commonly known by what term?

1. Schematic diagram
2. Signal flow diagram
3. Flow path indicator
4. Reference chart

3-63. Aircraft electronic wiring diagrams fall into which of the following classes?

1. Diagnostic
2. Chassis
3. Interconnnecting
4. Both 2 and 3 above

3-64. What part of the aircraft electronics wire identification code designates the terminal connection?

1. First
2. Second
3. Third
4. Fourth

3-65. Drawings that are broken down and simplified both mechanically and electronically are known by what term?

1. Electromechanical drawings
2. Detailed electronic/mechanical drawings
3. Simplified electronic and mechanical drawings
4. Electronic and mechanical isometric drawings

● QUESTIONS 3-66 THROUGH 3-75 DEAL WITH COMPUTER LOGIC.

3-66. The operations of digital computers are expressed in

1. arithmetical expressions
2. algebraic equations
3. verbal reasoning
4. symbolic logic

3-67 Boolean algebra uses what three basic logic operations?

1. AND, OR, and NAND
2. NAND, INHIBIT, and NOR
3. AND, OR, and NOT
4. OR, NAND, and NOR

3-68 Boolean algebra is based upon elements having how many possible stable states?

1. Two
2. Four
3. As many as there are terms in an expression
4. An infinite number

3-69 What is the Boolean algebra expression for the OR operation?

1. AB
2. A
3. +
4. ●

IN ANSWERING QUESTIONS 3-70 THROUGH 3-73 SELECT FROM THE FOLLOWING LIST THE LOGIC OPERATION DESCRIBED IN THE QUESTION.

A. AND
B. OR
C. NOT
D. NOR
E. NAND
F. INHIBIT
G. EXCLUSIVE OR

3-70. Every input line must have a signal to produce an output.

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

3-71. A combination of an OR operation and a NOT operation.

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

3-72. An input signal produces no output, while a no-signal input state produces an output signal.

1. B
2. C
3. F
4. G

3-73. When a signal is present at every input terminal, no output is produced.

1. D
2. E
3. F
4. G

3-74. Basic logic diagrams have what purpose in computer logic?

1. To express the operation being used
2. To identify the algebraic expression
3. To show the operation of the unit or component
4. To troubleshoot and maintain the system

3-75. Detailed logic diagrams provide which of the following information?

1. All logic functions of the equipment
2. Socket locations
3. Test points for troubleshooting
4. All of the above

ASSIGNMENT 4

Textbook Assignment: "Structural and Architectural Drawings" and "Developments and Intersections," chapters 7 and 8.

- QUESTIONS 4-1 THROUGH 4-19 DEAL WITH STRUCTURAL SHAPES AND MEMBERS.

4-1. A building project is divided into what phases?

1. Design and production
2. Design and construction
3. Design, presentation, and construction
4. Presentation, construction, and approval

4-2. The structural load a proposed building will carry is decided by which of the following persons?

1. The draftsman
2. The engineer
3. The architect
4. Both 2 and 3 above

4-3. You can find information on structural shapes and symbols in which of the following publications?

1. ANSI 14.5/2 1982
2. MIL-STD-18B, part 4
3. American Society of Construction Engineers
4. Both 2 and 3 above

4-4. The dimension of the widest leg is always given first in the designation of what shape?

1. Channel
2. Angle
3. Tee
4. Tie rod

4-5. A zee shape that is 4 inches in depth, has a 3 1/2-inch flange, and weighs 10.2 lbs. per linear foot is described in which of the following dimensions?

1. Z 4 x 3 1/2 x 10.2
2. S 10.2 x 3 1/2 x 4
3. W 3 1/2 x 4 x 10.2
4. Z 3 1/2 x 4 x 10.2

4-6 Channel shapes are most commonly used in areas that require which of the following characteristics?

1. Additional strength
2. Built-up members
3. Reinforcement
4. A single flat face without outstanding flanges

4-7. An I beam shape with a dimension of 17 I 40.5 has what nominal depth?

1. 40.5
2. 57.5
3. 17
4. 17.5

4-8. Tie rod and pipe columns are designated by what measurement(s)?

1. Thickness
2. Outside diameter
3. Inside diameter
4. Thickness and outside diameter

4-9. The total weight of all people and movable objects that a structure supports at any one time is what type of load?

1. Dead
2. Live
3. Cumulative
4. Transfer

4-10. The total load supported by a structural member at a particular instant is equal to what two types of loads?

1. Transfer and cumulative
2. Transfer and live
3. Cumulative and dead
4. Dead and live

4-11. The soil bearing capacity is greatest when a structure has a wide foundation or footing.

1. True
2. False

A. Beam	H. Pillar
B. Cantilever	I. Rafter plate
C. Column	J. Sill
D. Girder	K. Sole plate
E. Girt	L. Stud
F. Lintel	M. Top plate
G. Pier	N. Truss

Figure 4A

IN ANSWERING QUESTIONS 4-12 THROUGH 4-19, CHOOSE FROM FIGURE 4A THE STRUCTURAL MEMBER DESCRIBED IN THE QUESTION. SOME CHOICES MAY NOT BE USED.

4-12 A horizontal load-bearing structure that spans a space and is supported at both ends.

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

4-13. Usually rests directly on footings.

1. C and H
2. E and F
3. H and K
4. J and L

4-14. The chief vertical structural member used in the construction of lightweight buildings.

1. C
2. E
3. G
4. L

4-15. Supports the ends of floor beams or joists in wood-frame construction.

1. D, E, and J
2. E, H, and L
3. F and G
4. H and J

4-16. A member that is fixed at one end.

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

4-17. Support the wall ends of rafters.

1. A and D
2. G and H
3. I and M
4. K and L

4-18. May rest directly on a footing, or may be set or driven into the ground.

1. C
2. G
3. H
4. L

4-19. Two horizontal members joined together by a number of vertical and/or inclined members.

1. B
2. D
3. L
4. N

4-20. The process of riveting steel structures has been replaced by welding because of its greater strength and reduction of stress applied to the connection.

1. True
2. False

● IN ANSWERING QUESTIONS 4-21 THROUGH 4-24, REFER TO THE WELD SYMBOL ELEMENTS IN FIGURE 7-4 IN THE TEXTBOOK.

4-21. What element shows the specification, process, or other reference as to the type of fabrication?

1. 5
2. 6
3. 7
4. 8

4-22. In part 6, the letter G provides what information about the weld?

1. It will be finished by filing
2. It will be finished by grinding
3. It is double welded and ground
4. It requires a 2-4 finish

4-23. In part 4, the symbols "1/2" and "2-4" show that the weld should be (a) how thick, (b) how long, and (c) have how much pitch?

1. (a) 2 inches, (b) 1/2 inch, (c) 4 inches
2. (a) 1/2 inch, (b) 4 inches, (c) 2 inches
3. (a) 4 inches, (b) 1/2 inch, (c) 2 inches
4. (a) 1/2 inch, (b) 2 inches, (c) 4 inches

4-24. In part 2, the arrow provides what information about the weld?

1. Location
2. Direction
3. Type
4. Degree of finish

4-25. When steel structures will be riveted, the rivet holes are always drilled during which of the following steps?

1. Fabrication
2. Assembly on site
3. Both 1 and 2 above
4. Erection

4-26. What field riveting symbol shows that the rivet should be countersunk on both sides?

1. 
2. 
3. 
4. 

4-27. The shop riveting symbol  shows that the rivet should be installed in what way?

1. Countersunk and chipped on the near side
2. Countersunk and chipped on both sides
3. Countersunk and chipped on the far side
4. Riveted with two full heads

4-28. What shop riveting symbol shows that the rivet should be countersunk and not over 1/8 inch high on the far side?

1. 
2. 
3. 
4. 

IN ANSWERING QUESTIONS 4-29 THROUGH 4-33, SELECT FROM THE FOLLOWING LIST THE TYPE OF DRAWING DESCRIBED IN THE QUESTION.

A. Layout
B. General
C. Fabrication
D. Erection
E. Falsework

4-29. These drawings show where temporary supports will be used in the erection of difficult structures.

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

4-30. The number of these drawings needed depends on the size and nature of the structure and the complexity of the operation.

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

4-31. These drawings provide information on the location, alignment, and elevation of the structure and principle parts in relation to the ground at the site.

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

4-32. These drawings contain necessary information on the size, shape, material, and provisions for connections and attachments for each member.

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

4-33. These drawings show the location of the various members in the finished structure.

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

4-34 Contours, boundaries, roads, utilities, trees, structures, and other physical features of a site are shown in what type of construction plan?

1. Framing
2. Floor
3. Plot
4. Site

4-35 What type of construction drawing shows plans and elevations on a small scale?

1. Plot
2. General
3. Detail
4. Site

● IN ANSWERING QUESTIONS 4-36 AND 4-37, REFER TO THE FOUNDATION PLAN IN FIGURE 7-9 IN THE TEXTBOOK.

4-36. The main foundation consists of what material(s)?

1. An 8-inch block wall on a 10-inch footing
2. An 8-inch block wall on a 12-inch footing
3. A 10-inch block wall on an 18-inch footing
4. A 10-inch block wall on an 18-inch footing

4-37. What are the dimensions of the piers?

1. 10 x 16 inches
2. 12 x 12 inches
3. 14 x 16 x 18 inches
4. 14 x 18 x 20 inches

4-38. The length, thickness, and character of walls on one floor are shown in what type of plan?

1. Foundation
2. Floor
3. Framing
4. Plot

4-39. The dimensions and arrangements of wood structural members are shown in what type of plan?

1. Floor
2. Plot
3. Utility
4. Framing

4-40. Information on studs, corner posts, bracing, sills, and plates is provided in what type of plan?

1. Floor
2. Plot
3. Utility
4. Framing

4-41. A builder decides where to leave openings for heating, electrical, and plumbing systems by using what type of plan?

1. Framing
2. Plot
3. Utility
4. Floor

4-42. An elevation drawing shows which of the following views?

1. A horizontal view of the foundation
2. A vertical view of doors and windows
3. A two-dimensional view of roof framing
4. A three-dimensional view of the location of utilities

4-43. When general plans of a given area such as a wall section contain insufficient information, the craftsman relies on what type of drawing?

1. Specification
2. Detail
3. Elevation
4. Sectional

4-44. When a craftsman finds a discrepancy between the drawings and specifications, the drawings take precedence.

1. True
2. False

4-45. What is the meaning of the term "sheet metal development?"

1. A three-dimensional object is formed on a flat piece of sheet metal
2. A three-dimensional object is unrolled or unfolded onto a flat plane through the medium of drawn lines
3. A pictorial drawing of an object is made from sheet metal in its true dimensions
4. A three-view orthographic projection is made on sheet metal

4-46. In figure 8-1 of the text, view A shows what type of bend used on sheet metal?

1. A joint
2. A seam
3. An edge
4. A rolled joint

4-47. Which of the following seams is the least difficult to make?

1. A flat lock seam
2. A lap seam
3. A cap strip connection
4. An S-hook slip joint

4-48. In bending sheet metal, the bend allowance is computed along what part of the bend?

1. The neutral line
2. The outside of the sheet metal as it is being stretched
3. The inside of the sheet metal as it is being compressed
4. The flat

A. Base measurement B. Bend allowance C. Bend tangent line D. Flange E. Flat F. Leg G. Mold line H. Radius I. Setback

Figure 4B

IN ANSWERING QUESTIONS 4-49 THROUGH 4-53, CHOOSE FROM THE METAL BENDING TERMS IN FIGURE 4B THE TERM DESCRIBED IN THE QUESTION. Some choices may not be used.

4-49. The outside diameter of the formed part.

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

4-50. The amount of metal used to make a bend.

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

4-51. A line formed by extending the outside surfaces of the leg and flange so they intersect?

1. B
2. C
3. G
4. H

4-52. The distance from the bend tangent line to the mold point.

1. C
2. D
3. G
4. I

4-53. The shorter part of a formed angle.

1. B
2. D
3. E
4. F

4-54. A surface is said to be developable if a thin sheet of flexible material can be wrapped smoothly about its surface.

1. True
2. False

4-55. What type of development refers to an object that has surfaces on a flat plane of projection?

1. Radial line
2. Straight line
3. Right pyramid
4. Oblique pyramid

4-56. In figure 8-9, part B, in the textbook, line E-l is the true length of what line(s)?

1. A-l
2. B-2 and D-4
3. C-3
4. 0-1 and 02

4-57. What type of pyramid has lateral edges of unequal length?

1. Right
2. Oblique
3. Orthographic
4. Isometric

4-58. In figure 8-11, view D, in the textbook, the true length of the truncated pyramid is represented by the point between what lines?

1. M-N
2. M-O
3. N-P
4. Y-Z

● QUESTIONS 4-59 THOUGH 4-61 DEAL WITH PARALLEL-LINE DEVELOPMENT AND FIGURES 8-12 AND 8-13 IN THE TEXTBOOK.

4-59 In figure 8-12, view A, the width of the cylinder is equal to what other of its measurements?

1. Height
2. Length
3. Height plus the seam allowance
4. Circumference

4-60 It is normal practice to place seams on the shortest side in sheet metal development. Which of the following forms is an exception?

1. Cylinder
2. Pyramid
3. Cone
4. Elbow

4-61. In figure 8-12, view B, points of intersection are established on the development for what purpose?

1. To determine its true length
2. To give it a curved shape
3. To determine its actual size
4. To ensure greater accuracy.

● QUESTIONS 4-62 THROUGH 4-69 DEAL WITH RADIAL-LINE DEVELOPMENT OF CONICAL SURFACES.

4-62. What two dimensions are necessary to construct a radial-line development of a conical surface?

1. The true length of the right angle and the diameter of its base
2. The slant height of the cone and the diameter of the base
3. The slant height of the cone and the circumference of the base
4. The true length of the slant height of the cone and the angle of the cone

4-63. The size of the sector is determined by what dimensions?

1. The radius of the circle
2. The height of the cone
3. The sector minus the height of the cone
4. The proportion of the height to the base diameter

4-64. When developing a regular cone, the element lines can be seen in their true length only under which of the following conditions?

1. The viewer is looking at them at right angles
2. The development is completed
3. A base line is established
4. There is a projection to an auxiliary view

4-65. If a regular cone is truncated at an angle to the base, the inside shape on the development no longer has a constant radius.

1. True
2. False

4-66. When developing a regular cone, the true length settings for each element are taken from what view(s)?

1. Top
2. Side
3. Front only
4. Front and side

4-67. When the development of the sloping surface of a truncated cone is required, what view shows its true shape?

1. Orthographic
2. Auxiliary
3. Detail
4. Isometric

4-68. Oblique cones are generally developed by using what method?

1. Straight-line development
2. Radial-line development
3. Triangulation
4. Approximation

4-69. On an oblique cone, you should draw a true length diagram adjacent to the front view under which of the following circumstances?

1. When it is necessary to find the true length of several edges or elements
2. When directed by notes and specifications
3. When drawing radial-line developments
4. When drawing straight-line developments

● QUESTIONS 4-70 THROUGH 4-73 DEAL WITH TRANSITION PIECES.

4-70. Nondevelopable surfaces require what type of development?

1. Straight line
2. Radial line
3. Triangulation
4. Approximation

4-71. When a surface is developed from a series of triangular pieces laid side-by-side, the procedure is known by what term?

1. Transitioning
2. Approximation
3. Paralleling
4. Triangulation

4-72. To develop a square-to-round transition piece, you should take what step first?

1. Draw a true length diagram
2. Draw the front view
3. Draw the top and side views
4. Develop the square piece

4-73. Rectangular-to-round transition pieces are developed in the same manner as square-to-round with which of the following exceptions?

1. All of the elements are centered on the same axis
2. The rectangular-to-round requires auxiliary views
3. All the elements are drawn to their true lengths
4. All the elements are of different lengths