NONRESIDENT
TRAINING
COURSE

August 1999

Illustrator Draftsman 3 & 2

Volume 2—Standard Drafting Practices and Theory

NAVEDTRA 14276

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.

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: In completing this nonresident training course, you will demonstrate a knowledge of the subject matter by correctly answering questions on the following subjects: composition, geometric construction, general drafting practices, technical drawings, perspective projections, and parallel projections.

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.

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Sailor's Creed

"I am a United States Sailor.

I will support and defend the Constitution of the United States of America and I will obey the orders of those appointed over me.

I represent the fighting spirit of the Navy and those who have gone before me to defend freedom and democracy around the world.

I proudly serve my country's Navy combat team with honor, courage and commitment.

I am committed to excellence and the fair treatment of all."

CONTENTS

ILLUSTRATOR DRAFTSMAN (DM) TRAINING SERIES

The following volumes in the DM Training Series are available or planned:

DM, Vol. 1, NAVEDTRA 12720

Equipment. This is an overview of general shop administration, available equipment, required operator adjustments, and equipment maintenance. Knowing the capabilities and limitations of the equipment before creating artwork is essential.

DM, Vol. 2, NAVEDTRA 12721

Standard Drafting Practices And Theory. Industry standards for composition, geometric construction, general drafting practices, technical drawings, perspective projections, and parallel projections are foundational material on which all executionable practices rely.

DM, Vol. 3, NAVEDTRA 12722

Executionable Practices. These chapters cover the theory of color, photography, computer-generated art, figure drawing, cartooning, animation, mediums, lettering, and airbrush. These are the skills a successful DM must master.

DM, Vol. 4, NAVEDTRA 12723-A

Presentations Graphics. Copy preparation, audio-viusal presentations, television graphics, and displays and exhibits are end products and will influence the how and why DMs do business.

Nonresident Training Courses (NRTC)

Nonresident Training Courses for the Illustrator Draftsman (DM) TRAMAN:

Paygrade	Volume	NRTC
E4/E5	Volume 1 Volume 2 Volume 3 Volume 4	NAVEDTRA 72720 NAVEDTRA 72721 NAVEDTRA 72722 NAVEDTRA 72723
E6/E7	Volume 1 Volume 3 Volume 4	NAVEDTRA 82720 NAVEDTRA 82722 NAVEDTRA 82723

NOTE: Check the Naval Education and Training Professional Development and Technology Center home page for advancement requirements (http://www.cnet.navy.mil/netpdtc/netpdtc.htm.) and the *Catalog of Nonresident Training Courses*, NAVEDTRA 12061, for ordering information.

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: n313.products@cnet.navy.mil
Phone: Comm: (850) 452-1001, Ext. 2167
DSN: 922-1001, Ext. 2167
FAX: (850) 452-1370
(Do not fax answer sheets.)
Address: COMMANDING OFFICER
NETPDTC N313
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 9 points. (Refer to *Administrative Procedures for Naval Reservists on Inactive Duty*, BUPERSINST 1001.39, for more information about retirement points.)

Student Comments

Course Title: *Illustrator Draftsman 3&2, Volume 2—Standard Drafting Practices and Theory*

NAVEDTRA: 14276 **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

COMPOSITION

Overview

Introduction

The greatest power of visual language lies in its immediacy. You see content and form simultaneously. Properly developed and composed, visual messages enter the brain directly without conscious decoding, translating, or delay. The message conveyed is not only a direct result of your ability to orderly arrange the elements or visual syntax in a composition, but also the receiver's ability to perceive, or his level of visual literacy. Your manipulation of negative and positive space, tonal patterns, and implied spatial relationships as elements on a page is an intellectual problem-solving process. The cerebral process of generalities without concrete rules that compose abstract visual syntax is a uniquely human ability the computer has not yet mastered. Effective compositions require understanding the dynamics of visual patterns and how we see, organize, and define those elements intellectually, emotionally, and mechanically.

Objectives

The material in this chapter enables you to do the following:

- Understand the importance of developing comprehensive thumbnail sketches.
- Differentiate between formal and informal arrangements.
- Use the elements of design to create disturbing or discordant compositions.
- Use the elements of design to create balanced and pleasing compositions.
- Understand the difference between color and tonal compositions.
- Recognize the implications of the compositional elements of one-, two-, and three-point perspective drawings.
- Use composition advantageously in technical drawings or blueprints.

Continued on next page

Overview, Continued

Acronyms

The following table contains a list of acronyms you must know to understand the material in this chapter:

Acronym	Meaning
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
CAD	Computer-Aided Drafting
DOD	Department of Defense
LH	Left Hand
MIL-STD	Military Standard
NEXT ASS'Y	Next Assembly
RH	Right Hand

In this chapter

This chapter covers the following topics:

Preliminary Information

Introduction

Before beginning new projects, gather all pertinent information. Weed through the data to eliminate nonessential items. Determine the main message and focus all other material in the composition to reenforce that message.

KISS

KISS is the acronym for keep it simple, stupid. We call this the principle of simplicity and clarity. Picasso epitomized the search for simplistic communication in twentieth century art. Because he was a contemporary and prolific multi-media artist, you can trace the evolution of Picasso's struggle for simplicity. Study Picasso's early work and you will find a traditional academic art foundation. In his later work you will find his technique is simplistic yet sophisticated. Use the KISS principle to pare down information to the basic intended message.

Incidental material

Once you select the subject for a picture, choose all secondary elements based on how well they support the main topic. Limit your selection to those elements that contribute the most to understanding the subject.

Attitude or impression

Know the attitude or impression the originator wants to convey. Dynamic compositions are inappropriate for funerals and weddings. Solemn compositions are not effective in festive applications. Some originators want to impress potential clients with their elegance, others like crass or brusque designs. Attitude affects composition. Decisions regarding object size, location, and arrangement, color, texture, and perspective should be made in the preliminary composition, before beginning the final artwork. This strategy allows you to anticipate and compensate for any unexpected impediments before committing man-hours and materials.

Text

Consider text or lettering as an integral part of design. Lettering is part of an overall composition and should be planned as carefully as you plan the composition.

End product

Consider how the product will be presented to an audience. Will the image be a painting, photograph, printed material, poster, slide, or flyer? The final form of an image determines to a large extent how you create it.

Thumbnail Sketches

Introduction

Thumbnail sketches are small, roughly drawn images quickly committed to paper. Drawn effortlessly and in rapid succession, they appear as nothing more than doodles to untrained eyes. Thumbnail sketches are, in fact, the most efficient mode of illustrative brainstorming and a source of potentially rich fodder for subsequent finished imagery. Thumbnail sketches are referred to throughout each volume in the Illustrator Draftsman (DM) training series.

The purpose of thumbnail sketches

Use thumbnail sketches to develop the most effective layout, balance, tone, shading, and color palettes. Working out image tonal areas, color, and shadings before committing yourself to finished media saves time and materials.

Before the thumbnail sketch

Before you can begin thumbnail sketching, assemble the information that applies to the finished illustration. Have the job order handy and refresh your memory on the originators intended message or impression. If sketching out personal creative endeavors, think about what you want the images to say. Clarify the intended message and select the best way of saying it.

Making thumbnail sketches

With a pencil, lay out several squares approximating the desired proportions of the finished image. Use the principles of composition covered in this chapter to lay out a series of drawings. Experiment with different placements of the elements, patterns, tones, and colors. Select the most successful thumbnail sketch to base the layout of the final illustration.

Figure 1-1 shows a series of thumbnail sketches.

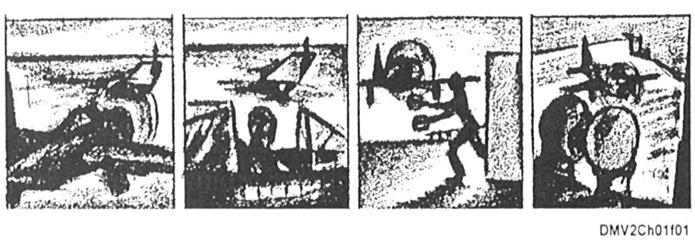

Figure 1-1.-Thumbnail sketches.

Compositional Elements

Introduction

A synergetic combination of compositional elements produces images that communicate volumes without written words. Images that fail to elicit appropriate responses usually lack some element of composition. Although there are no absolute rules on composition, we can generalize regarding psychophysiological reactions of perception to combinations of compositional elements.

Compositional elements

The basic elements of good composition include the picture area, picture depth, line movement, value, proportion, balance, unity, and clarity.

Picture area or picture plane

The picture area or picture plane is the amount of surface available to hold an image. The picture area is also synonymous with image area, the area enclosed by the edges of the paper or substrate surface. The size of the picture area influences the size of the objects you depict in the image. You can use size or relative size and location, as well as the overlapping of objects in the picture area to emphasize or subdue importance. Large objects or objects placed in the foreground tend to become more important. Similarly sized and placed objects become monotonous. Overlapping emphasizes main objects while partially obscuring secondary objects.

Figure 1-2 shows three objects in three different compositions.

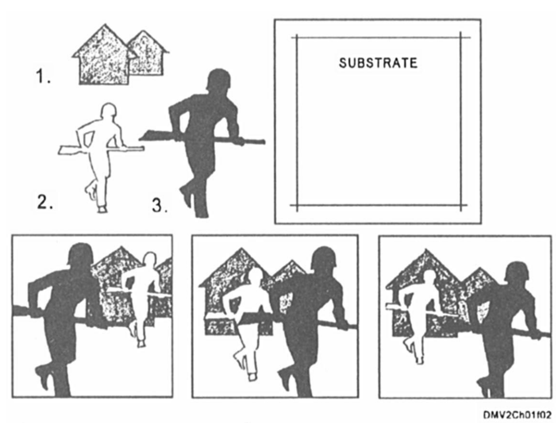

Figure 1-2.—Three objects in three different compositions.

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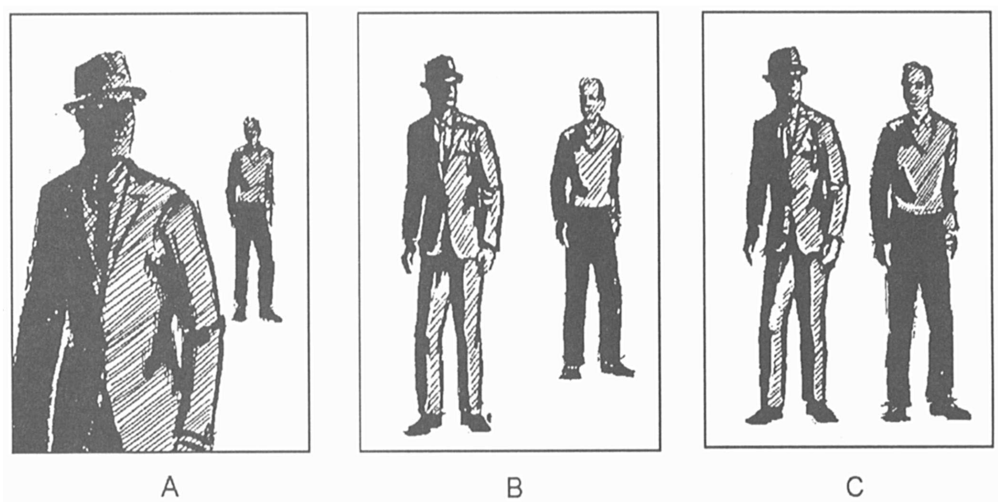
Picture area or picture plane (Continued)

Figure 1-3 shows relative sizes of figures in a picture area.



A. FIGURE IN FOREGROUND COMPLETELY OVERWHELMS DISTANT FIGURE.
B. THOUGH NOT SO GREAT A DISTANCE BETWEEN FIGURES, FIGURE IN FOREGROUND STILL DOMINATES PICTURE AREA.
C. HERE NEITHER FIGURE IS DOMINANT BECAUSE OF DISTANCE, BUT FIGURES THE SAME SIZE SHOULD BE USED ONLY IF SITUATION PERMITS: THIS ARRANGEMENT COULD BECOME MONOTONOUS.

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Figure 1-3.—Relative figural size.

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Picture area or picture plane (Continued)

Space inside the picture area exists as positive or negative space. Objects that dominate the eye occupy positive space. The space remaining is negative space. Most pictures offer a primary object as a positive subject presenting a complimentary design. Positive and negative space have nothing to do with darkness or lightness or mirror images as they do in photographic media. Beginning DMs usually concentrate on positive space and neglect negative space. Failure to understand the terms positive and negative space results in overcrowded, confusing images.

Figure 1-4 shows an example of positive and negative space. Is the image you initially see profiles or a goblet?

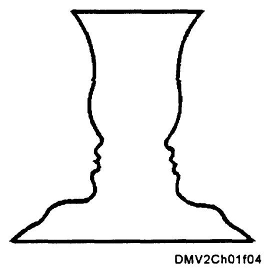

Figure 1-4. —Positive and negative space.

Equal areas of positive and negative spaces create ambiguity. This contrast competes for dominance and presents an unresolved visual state or conflict.

Figure 1-5 show the Chinese symbol, yin-yang. The symbol, a close balance of a positive-negative visual state, is unresolved, leaving the impression of constant moving or fluidity.

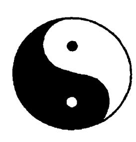

Figure 1-5. —The Chinese symbol of yin-yang.

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Picture depth or perspective

Picture depth or perspective is the assimilation of three-dimensions on a two-dimensional plane (paper or substrate). The suggestion of depth makes scenes appear more realistic. You can control the illusion of depth in picture areas by overlapping objects, using different sized objects, cropping closely into scenes, or by using common props and directional lines to direct viewers into the image. Linear and aerial (one-, two-, and three-point) perspective are covered later in this volume. All of these methods should compliment each other to form interesting compositions. Unless there is special reason - for doing so, never place objects in a line or row, crowd them into a half or a quarter of the picture area, or regularly arrange different illustrations in the same design. Placing objects in varied and interesting patterns prevents compositions from becoming stale and monotonous.

Figure 1-6 illustrates the use of a prop to create picture depth.

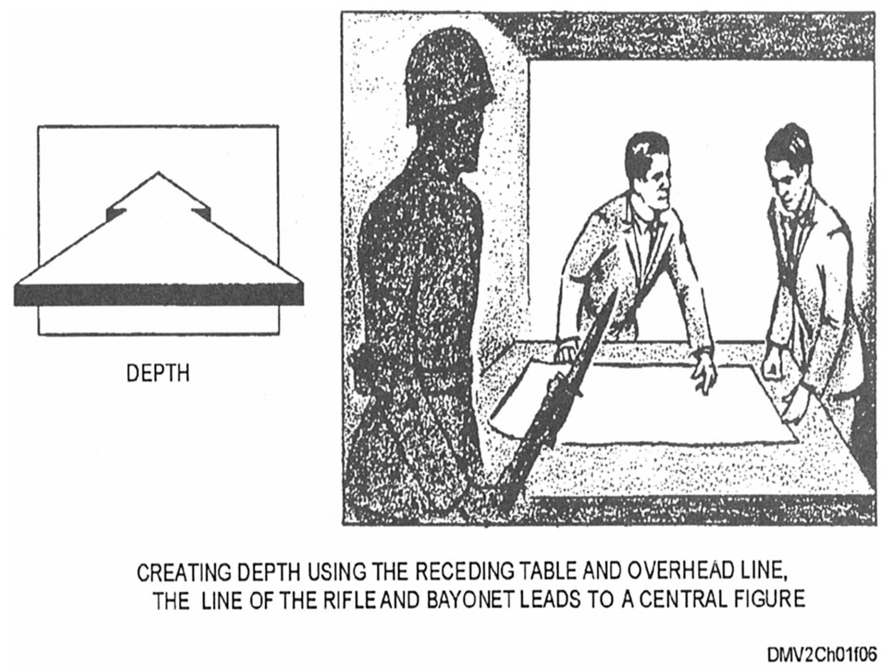

Figure 1-6.—Creating depth using props.

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Line movement The term “line movement” refers to the direction that the viewer’s eyes move within the picture area, called *directional lines,* and lines that suggest attitudes or emotion, *emotive lines.*

DIRECTIONAL LINES: Directional lines should always lead the viewer to see what you want him to see. Directional lines are created by arranging objects so that the outlines of the main objects lead to the intended action or center of interest. Directional lines may move smoothly and rhythmetically from one object to another, grouping and relating objects that belong together. The movement could also be abrupt, creating lines that clash. This latter method is appropriate when drawing scenes of violence, conflict, or stress. Review your thumbnail sketches. Evaluate which of the sketches have directional lines that successfully lead the viewer into the picture area. Do not allow linear backgrounds or foregrounds to compete or interfere with the center of interest. Avoid crowding lines or having lines spaced at equal intervals.

Figure 1-7 shows directional lines.

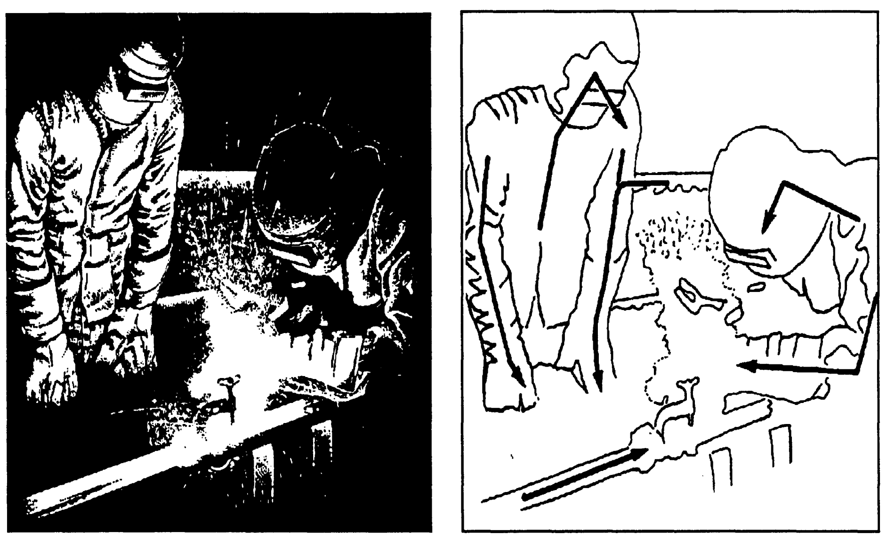

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Figure 1-7.—Directional lines.

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Line movement (Continued)

EMOTIVE LINES: Emotive lines are lines in the picture area that suggest emotions or attitudes. Vertical, diagonal, horizontal, and curved lines create different moods. Vertical lines suggest strength, rigidity, and power. Horizontal lines are associated with peace, tranquility, and quietness, while diagonal lines represent movement, action, and speed. Closely associated with figures and objects in the picture area, emotive lines provoke an overall mood to images. Do not confuse the purpose of directional and emotive lines.

Use vertical picture area formats for images containing predominantly vertical lines. Horizontal formats are best used for images containing predominantly horizontal lines.

Figure 1-8 shows the use of emotive lines.

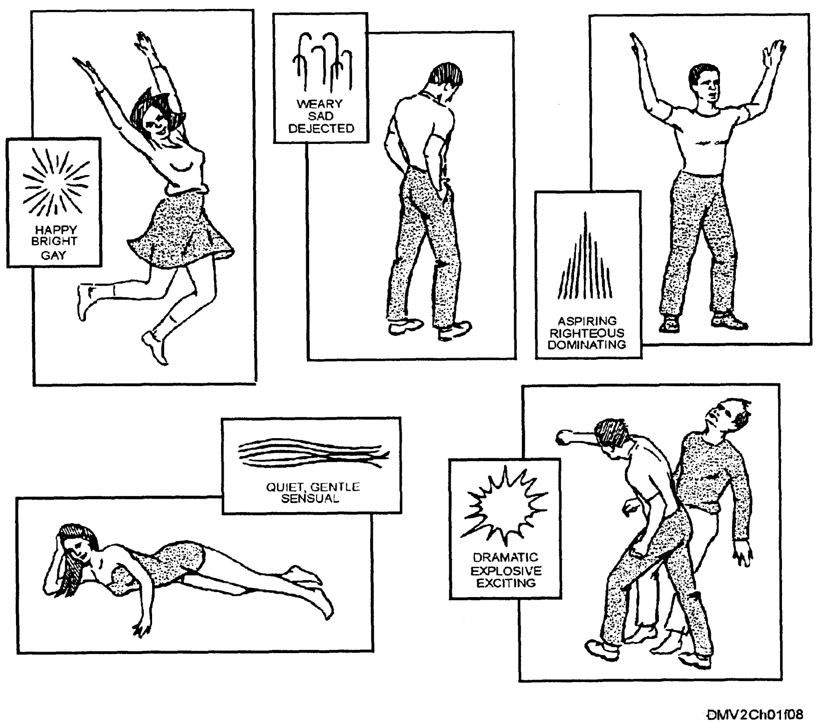

Figure 1-8.—Emotive lines.

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Value

Value is the overall pattern of lightness or darkness in pictures. Value within a picture should be consistent. Viewers are attracted to areas with the greatest contrast in values. If an object is surrounded by values that are nearly the same as its own value, the object will not attract much attention. The basic value patterns of most pictures fit one of the following four patterns: (1) light against dark, (2) dark against light, (3) dark and halftone against light, and (4) light and dark against halftone. Decide on a value pattern before making thumbnail sketches. If you change value patterns, do another thumbnail sketch and select the one that offers the best value composition.

Figure 1-9 displays the four basic value patterns.

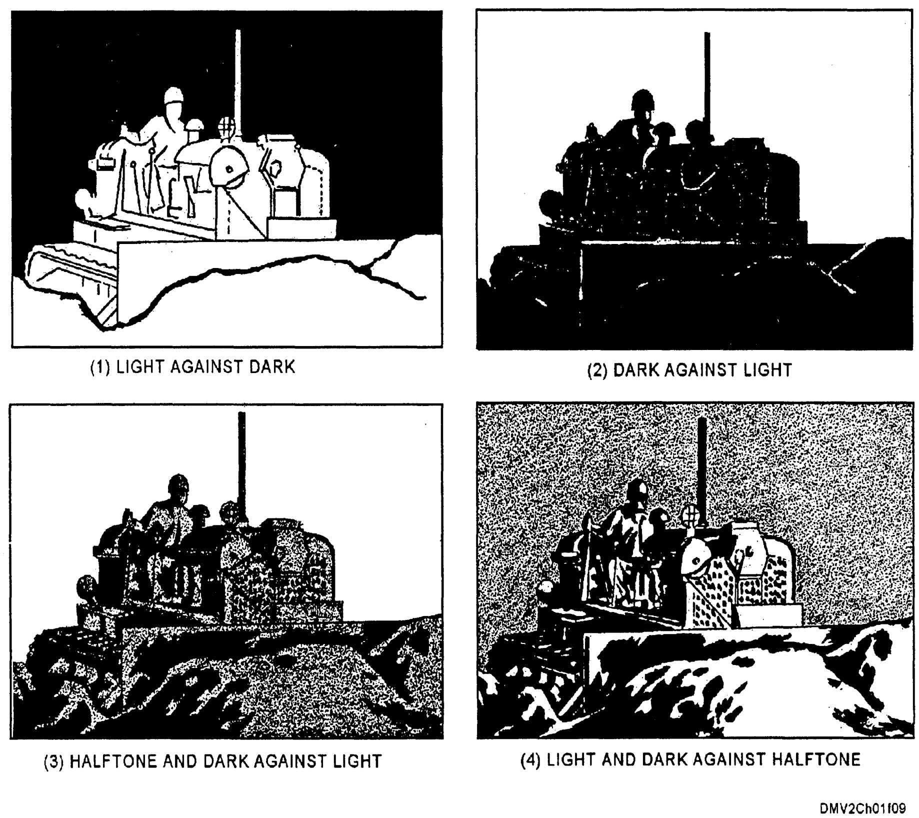

Figure 1-9.—Basic value patterns.

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Value (Continued)

Within the value pattern of a picture area, objects and their surroundings have individual values that contribute to moods or atmosphere. When scenes contain predominantly dark tones or colors, it is called *low key*. Low-key imagery suggests seriousness, drama, and mystery and is often used in pictures of horror. Scenes containing mostly light tones are called *high key*. High-key imagery creates feelings of delicacy or lightness.

Figure 1-10 is a low-key image.

Figure 1-10.—A low-key image.

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Value (Continued)

Figure 1-11 is a high-key image.

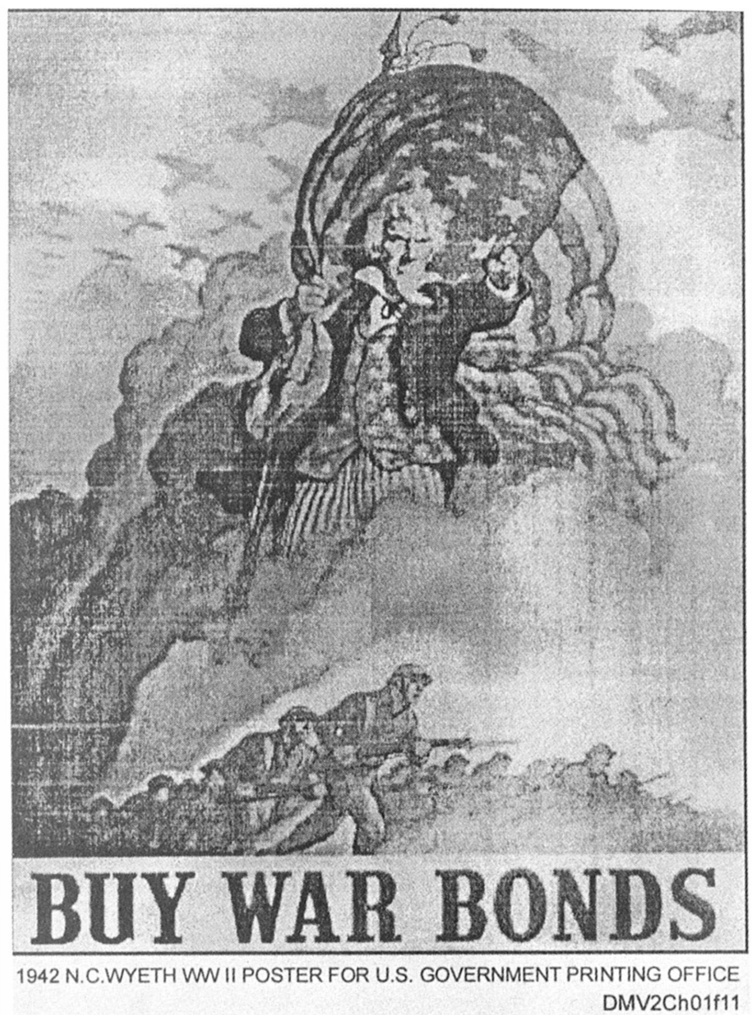

Figure 1-11.—A high-key image.

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Value (Continued)

Textures possess value and enhance emotional expression. Loosely drawn textures have a lighter overall value than dense textures. We equate certain textural appearances with tactile sensations. Texture can also imply picture depth. Fine details suggest nearness, while blurred textures denote distance. Texture can be actual, simulated, or abstract and used to describe objects, stimulate tactile responses, clarify spatial relationships, affect object dominance, and enrich the picture areas.

Figure 1-12 shows how the density of a textural area determines its value.

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Figure 1-12.—Value determined by texture.

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Value (Continued)

Figure 1-13 is an image based primarily on texture.

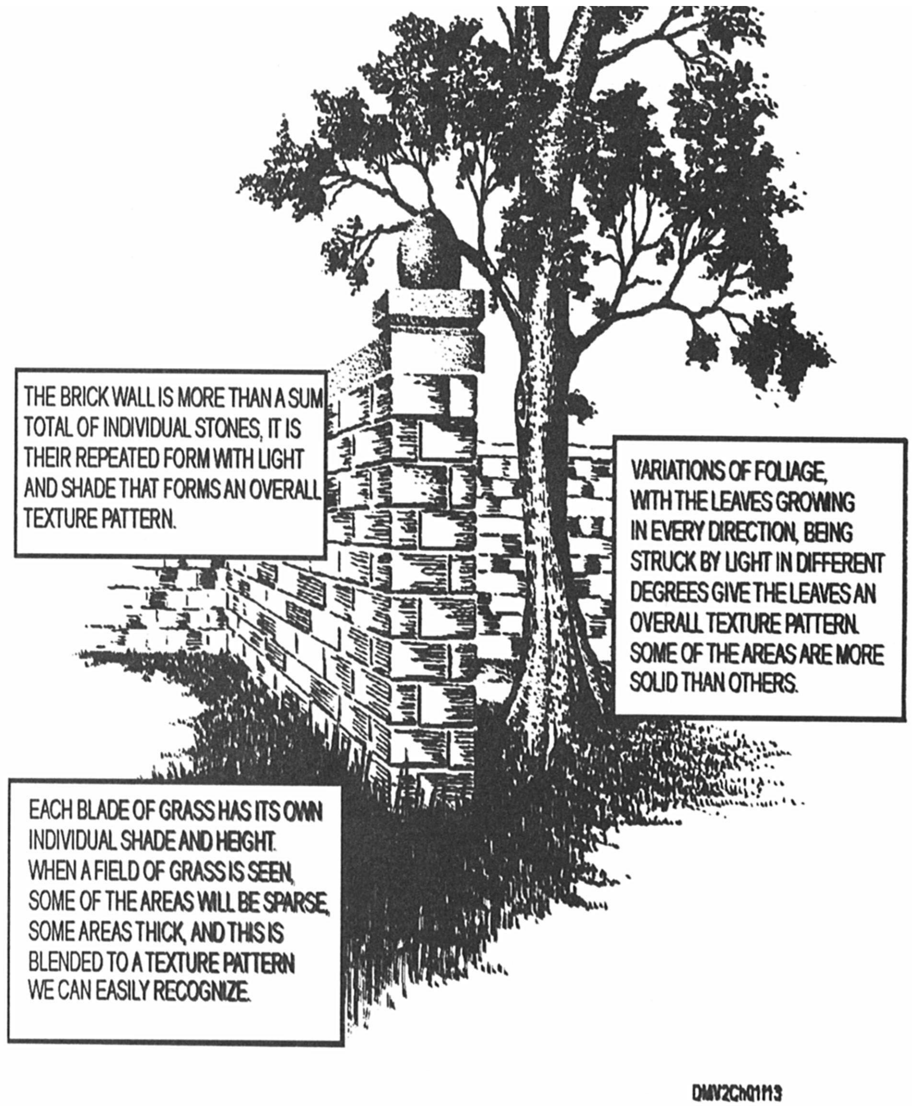

Figure 1-13.—Texture used to imply imagery.

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Value (Continued)

Color contrast is an effective compositional element just as tone is in black-and-white compositions. Colors with opposite characteristics contrast strongly when placed together. Each contrasting color accentuates the qualities of the other and makes images stand out dramatically. You can enhance the effects of color contrast by contrasting detail against mass.

Unfortunately, color also deceives. People gravitate toward color and relate to color more easily than black-and-white. Colors may have different hues but same or similar tonal values. Same or similar tonal values blend together in subsequent black-and-white reproduction, rendering the hues indistinguishable.

To evaluate the effectiveness of color compositions, imagine the image in black-and-white and apply the general rules of composition. Here are some general guidelines regarding color in compositions:

- Cool colors (bluish) and warm colors (reddish) almost always contrast.
- Cool colors recede, warm colors advance.
- Light colors contrast against dark colors.
- Bold colors offset weak colors.
- Colors may be different in hue but the same in tonal representation.
- Colors may be different in hue but the same in intensity.
- Color intensity or saturation determines tonal representations.
- Colors may be of the same hue but different in intensity and tonal representation.

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Proportion

Proportion in composition involves the division of information into units within the picture area. For example, rectangular picture areas can be divided into different segments to lend more interest to compositions. Some segments may contain illustrations, other segments may contain text. Notice that dividing a picture area into equal segments is less interesting than those segments of unequal area.

Figure 1-14 shows a rectangular picture area divided into segments.

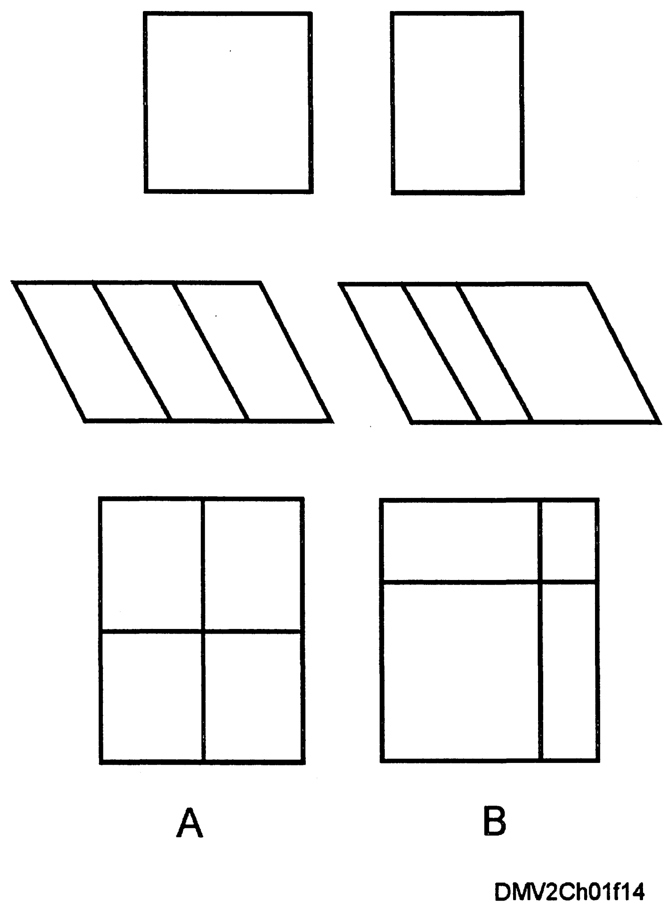

Figure 1-14.—Proportional divisions of a: A. Square; and B. Rectangle.

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Balance

Balance is the visual perception of how information sits on a page. Images should have balance in shapes, masses, tonal areas, and colors. Combinations of these elements imply a visual weight that anchors your attention. Disproportionately weighted images leave veiwers feeling off balanced. A balanced picture area presents information without creating discord. Unbalanced presentations leave the viewer feeling as if something is wrong in the image. Three general classifications of balance are symmetrical and asymmetrical, commonly referred to as formal and informal balance respectively, and radial balance.

FORMAL BALANCE: Formal or symmetrical balance results when each object is placed squarely on an imaginary vertical centerline, or by duplicating on one side each mass, shape, or line that appears on the other side of an imaginary vertical centerline. Formal balance is also the result of structuring the elements in the picture area to resemble a pyramid or inverted pyramid. In formal balance, the weight on the left side of the picture area should balance the weight on the right side and the bottom half should balance the top half.

Figure 1-15 shows examples of formal balance structures.

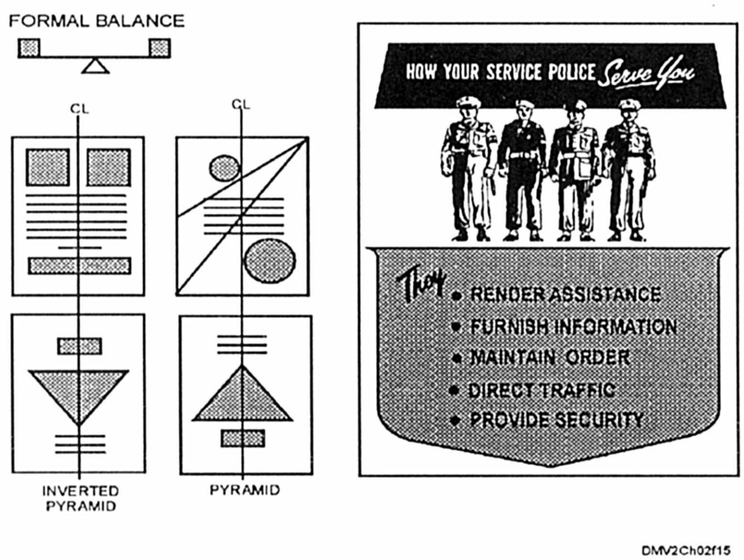

Figure 1-15.—Examples of formal balance.

Continued on next page

Balance (Continued)

INFORMAL BALANCE: Informal balance or asymmetrical balance is the placing of unlike elements on either side of an imaginary vertical centerline in an asymmetrical manner that results in each side of the picture area visually appearing equally weighted. The use of informal balance permits greater variety and design; however, the problem of balance becomes more complex. The left side of the picture area should still balance the right side and the bottom half should still balance the top half. When using informal balance, no mathematical rules apply, you must use your instincts.

Figure 1-16 is an example of informal balance.

Figure 1-16.—Informal balance.

Continued on next page

Balance (Continued)

RADIAL BALANCE: Radial balance is a circular arrangement of two or more elements around a center point. Radial balance is a modified form of symmetrical balance. When placed around a common center point, elements of equal strength or weight appear balanced and create a visual illusion of circular movement. Repetition is a key element to successful radial balance, which is used mostly in commercial decorative patterns.

Figure 1-17 is an example of radial balance.

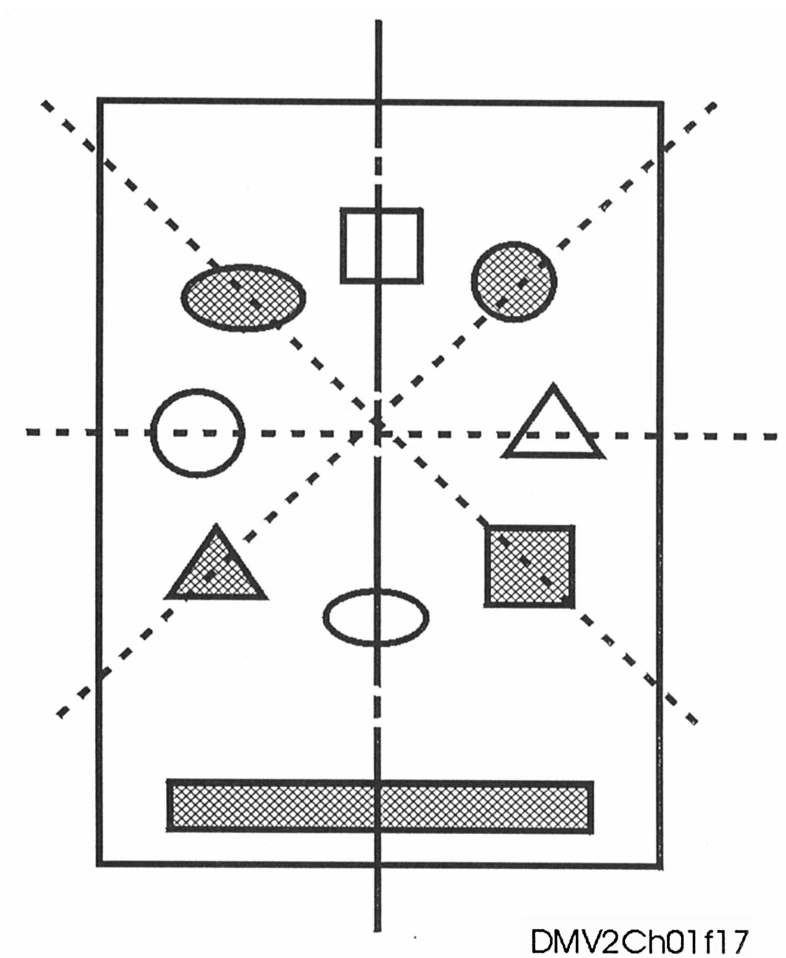

Figure 1-17.—Radial balance.

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Balance (Continued)

You must consider many factors to make pictures appear balanced. Some of these factors are as follows:

- Objects placed dead center (mathematical center) in the picture area appear unbalanced.
- Objects placed at the optical center (1/10th page size above mathematical center) appear balanced.
- Objects far from the center of the picture seem to have more weight than ones near the center.
- Objects in the upper half of a picture area seem heavier than objects of the same size in the lower half of the picture area.
- Isolation seems to increase the weight of an object.
- Interesting objects seem to have more compositional weight.
- Regular shapes seem to have more weight than irregular shapes.
- Elements on the right side of a picture area appear to have more weight than elements of the same size on the left side of a picture area.
- The direction in which figures, lines, and shapes appear to be moving within the picture area may affect the perception of balance.

Continued on next page

Unity

Unity in composition is the combining of elements in an organized pattern to solidify the elements into a unified whole. Unity depends heavily upon a balance of harmony, variety, and your personal sense of proportion. A composition without unity appears to be falling apart and produces a disturbing effect.

HARMONY: Harmony results from the use of rhythm and repetition. Rhythm is a measured flow of elements within an image. Rhythm may be a simple or complex variation within a theme (motif) or a reoccurring sequence of line (pattern). Repetition of a motif or pattern results in rhythm.

VARIETY: The opposite of compositional harmony is variety. You can create variety by contrasting unlike elements or by elaborating on like or equal elements. Irregularly grouping elements produces interest and variety by allowing more white space around the outside edges of an arranged group of elements rather than between each individual element. The white border acts as a frame.

Figure 1-18 shows an example of unity.

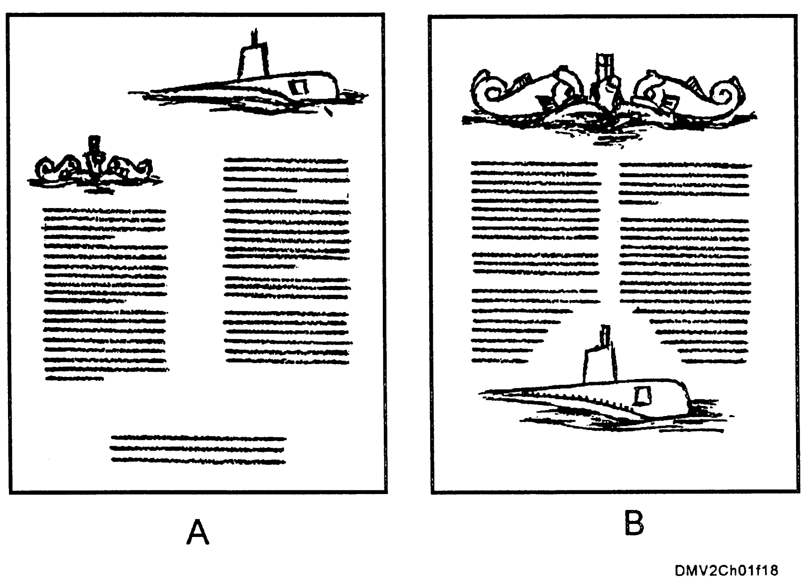

Figure 1-18.—Unity.

Continued on next page

Clarity

Clarity defines elements and guards against blending elements that can confuse the viewer. It is important to maintain legibility in lettering and definitiveness in composition. For example, overlapping objects in the picture area to obscure secondary objects beyond the point of recognition reduces the clarity of the message you are trying to convey. Use contrasting tones when lettering over objects to avoid blending similar tonal areas in subsequent reproductions. Examine your thumbnail sketches for clarity before laying out finished drawings.

Figure 1-19 is an example of clarity.

WW II POSTER FOR U.S. GOVERNMENT PRINTING OFFICE

Figure 1-19. —Clarity. DMV2Ch01f19

Pictorial Compositions

Introduction

As an artist or illustrator, you exercise total control over a picture area by using the basic principles of composition and dot, line, tone, direction, shapes, motion, color, texture, and scale. No other format offers such limitless control of content.

Picture depth in pictorial compositions

It is impossible to include in a flat two-dimensional picture all you can perceive about an object. When working in pictorial compositions, each two-dimensional representational image is the result of many decisions. One of the early decisions to make before beginning final artwork is whether or not to portray an object in two or more dimensions. Study the works of M. C. Escher, a master mathematician and draftsman. No other twentieth-century artist displays such mastery of image interdimensionally and illusion.

TWO DIMENSIONAL: Two-dimensional images have height and width but no depth. Two-dimensional images are often called *decorative* images. The images float superficially on the substrate surface and do not invite the viewer inside.

THREE DIMENSIONAL: Three-dimensional images have height, width, and depth. Referred to as *plastic* representations, shapes in three dimensions appear to be in-the-round. The viewer perceives three-dimensional images as more realistic.

FOUR DIMENSIONAL: Four dimensional imagery contains height, width, depth, and the element of time. Computer-generated imagery may incorporate time as an element in image creation or image evolution.

INFINITE DIMENSION: Images drawn in infinite dimension appear endless. The picture plane acts as a window through which the viewer observes the subject.

SHALLOW: Shallow images are sometimes called *Limited depth* images because you can control the visual elements and limit the amount of depth in the picture area.

Continued on next page

Proportion in pictorial compositions

By using the basic principles of composition to divide a picture area, the artist has total control over the proportion of the picture area. Since the scene does not already exist, as it does in photography, fragmentation of the picture area is an arbitrary decision left to the illustrator. Study the works of Mark Rotho and Piet Modrian, non-representational painters who successfully divide the picture plane into rectilinear elements. Evaluate your thumbnail sketches to determine their proportions. The following figure illustrates some proportional divisions found to be more pleasing to a viewer than others.

Figure 1-20 shows examples of proportional divisions of picture planes.

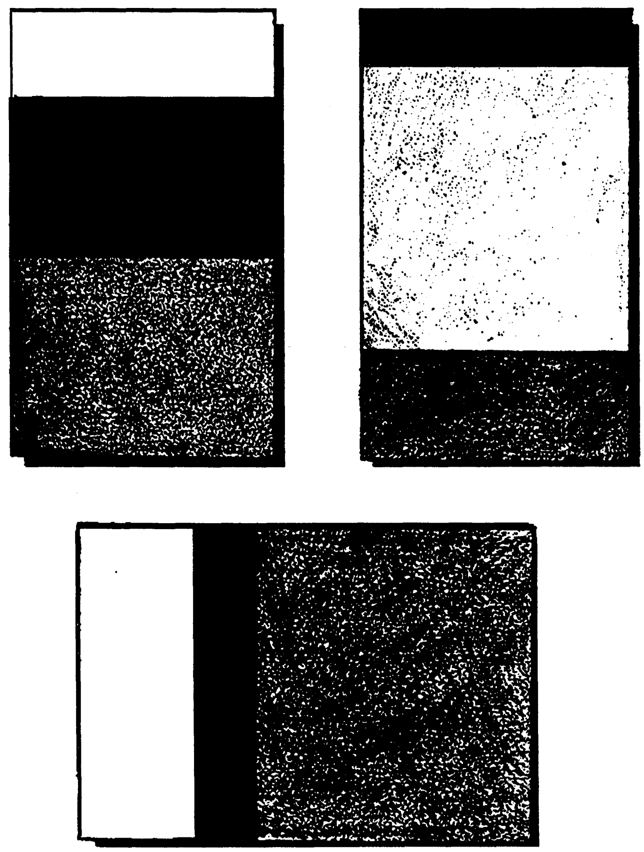

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Figure 1-20.—Proportional divisions of picture planes.

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Figures, props, and borders

The inclusion and placement of figures, props, and borders are also left to the discretion of the artist in pictorial compositions.

Figures

For figures to appear realistic, they must have emotions or feelings. In pictures, you communicate an emotion or feelings you want the figure to portray by expression, gesture, posture, and positioning. To simplify the descision process in determining the gesture, posture, or position of figures, imagine the figure in silhouette. Experiment with different positions until you find one that is successful. The meaning of a picture changes as attitudes or gestures of the figures change. Two or more figures in the same picture may change the attitude of the picture depending on how the figures relate to each other. Since the human figure is a dynamic form, viewers are naturally drawn to it. Figures reenforce the main message in pictures in a way no inanimate object can.

Figure 1-21 shows how reducing figures to silhouettes helps to simplify the selection of gestures, posture, and positioning.

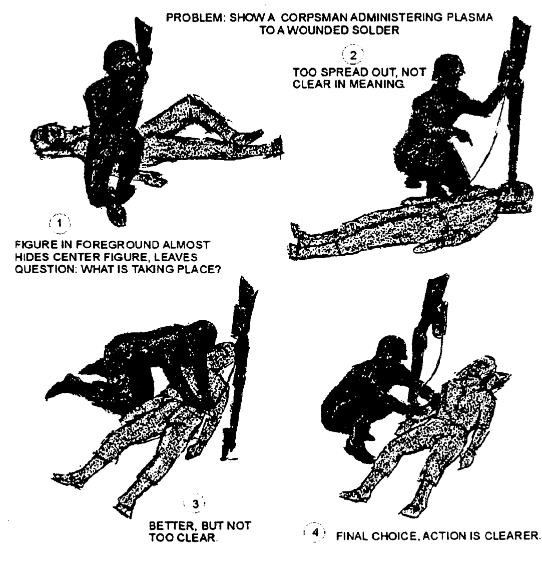

Figure 1-21.—Reduce figures to silhouettes to simplify effective positioning in the picture plane.

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Props

You should use props and settings that contribute to the mood and action in a picture. Props and settings should compliment figures, not compete or overpower them. Size, position, value, and contrast are the most effective means to keep scenes from overwhelming figures. If the purpose of the picture is the setting, give the setting the prominence it deserves.

Figure 1-22 shows the evolution of a simple setting.

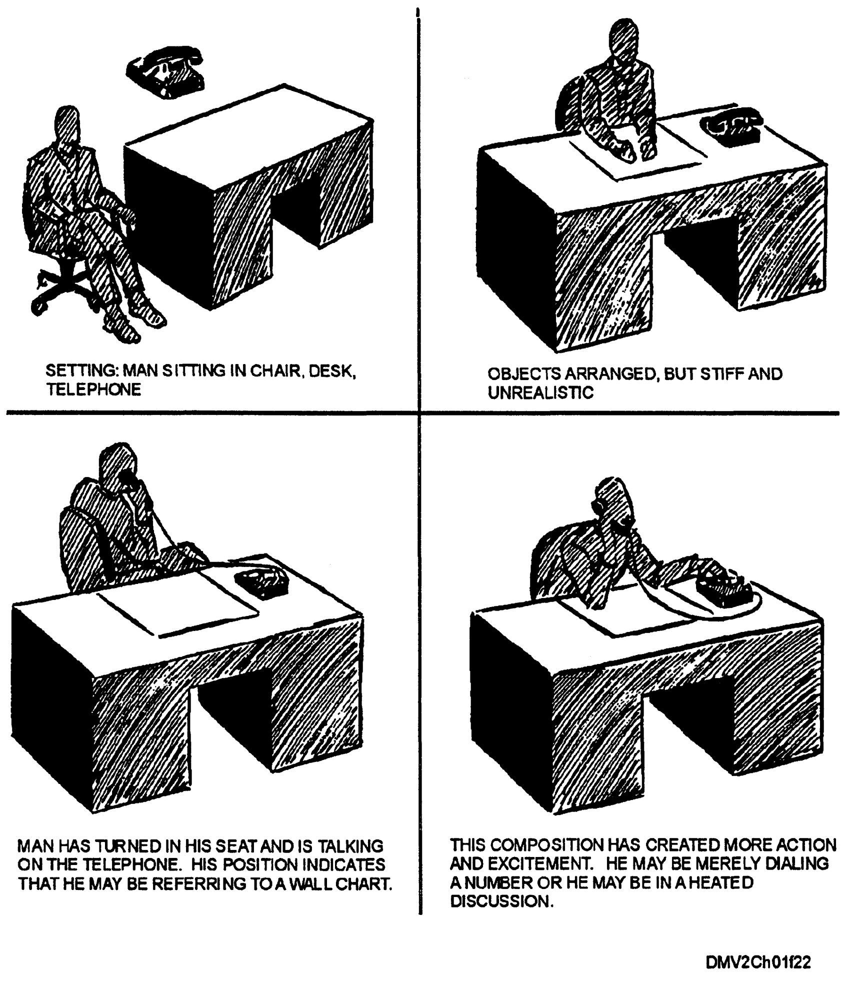

Figure 1-22.—The evolution of a simple setting.

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Pictorial Compositions, Continued

Borders

Borders outline picture areas. You should consider borders as part of the picture area because they link the picture to the real world. Borders can define or confuse viewers depending on your placement of objects inside the picture area. Figures, particularly, can affect the overall perception of border areas. For example, a figure can obscure a scene if placed too close to the border; the viewer's attention is directed by the figure to look at the border, not the scene. Even when the figure does not touch the border, the figure's gestures direct viewers to the border. Figures placed nearer one border than the other attract attention to the nearest border. To avoid this, leave more space between the figure and the border.

Figure 1-23 shows the affect of a figure on the perceptions of the borders.

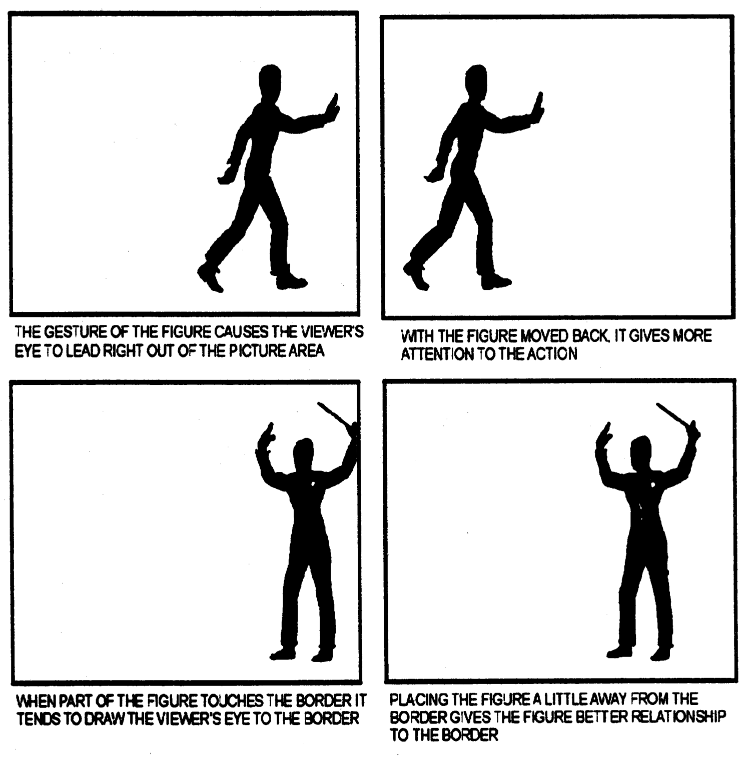

Figure 1-23.—Effects of a figure on borders.

Photographic Compositions

Introduction

Many people believe that photography is the most truthful and accurate representation of three-dimensional objects on a two-dimensional field. Anyone can learn how to take photographs; so what makes a photograph a successful image? You must understand the basic principles of photographic composition to evaluate and select images for use in commanding officer's biographies, web pages, change of command brochures, cruise books, and newsletters.

Photographic compositions

There are no thumbnail sketches in photographic compositions unless you are working in a controlled studio atmosphere. In studio environments you control factors affecting good composition.

In photographic compositions out of the studio area, the scene already exists. Photographic compositional decisions may have already been made for you by the environment and your remaining choices may be limited.

Photographic compositions involve manipulation of the following principles and elements: center of interest, subject placement, simplicity, viewpoint and camera angle, balance, shapes and lines, pattern, volume, lighting, texture, tone, contrast, framing, foreground, background, and perspective. Most of these elements are the same as pictorial compositions, with the exception of center of interest, subject placement, viewpoint, and camera angle.

Center of interest

Each picture should have one principal idea or subject that is called the *center of interest.* Subordinate elements must support, define, and focus attention on the center of interest. The center of interest should not be located in the center of the picture area.

Subject placement

Subject placement is the positioning of subjects or the center of interest in the picture area. In pictorial composition, subject placement relates most closely with proportion, the division of the picture plane into balanced segments. - In photographic compositions, there are two formulas for determining subject placement: the principles of thirds and dynamic symmetry.

Continued on next page

Subject placement (Continued)

The PRINCIPLE OF THIRDS: The principle of thirds refers to the intersection of vertical and horizontal lines that divide the picture area into thirds. The point of each intersection is marked with an "O." These intersections are good locations for the center of interest.

Figure 1-24 shows the principle of thirds for subject placement.

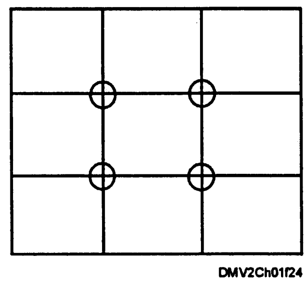

Figure 1-24.—The principle of thirds.

DYNAMIC SYMMETRY: The principle of dynamic symmetry locates the center of interest by drawing an imaginary diagonal line from one corner of the picture plane to the opposing corner. Another diagonal line drawn from a third corner perpendicular to and intersecting the first diagonal locates the center of interest.

Figure 1-25 shows the principle of dynamic symmetry.

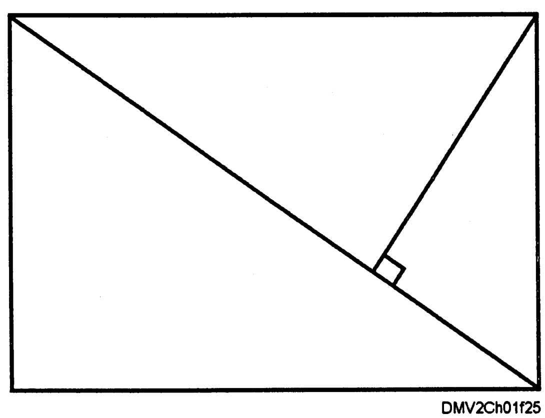

Figure 1-25.—The principle of dynamic symmetry.

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Viewpoint and camera angle

Viewpoint is the camera position in relation to the subject. *Camera angle* is the angle in which the camera is tilted. The terms "viewpoint" and "camera angle" are often used in conjunction with one another and sometimes are used interchangeably. They can also have different meanings depending on how you apply them. Repositioning subjects within the viewfinder and changing the camera angle are two simple ways to control composition.

Photographs made from ground level with the camera held horizontal to the ground is referred to as a *low viewpoint* (camera position); however, the same picture made from ground level with the camera tilted up may be referred to as a *low-camera angle.* Low viewpoints and low-camera angles can add emphasis and interest to many otherwise ordinary scenes. This type of photograph is useful in separating subjects from backgrounds, eliminating backgrounds and foregrounds, distorting scale, adding strength, and for creating the illusion of greater size and speed.

A picture made from a high or elevated position with the camera held horizontal with reference to the ground is referred to as a *high viewpoint;* however, if the camera is pointed down at some angle between horizontal and vertical, the camera position is referred to as a *high-camera angle.* High viewpoints and high camera angles help orient the viewer by showing relationships among all elements within a picture area. High viewpoints and camera angles also minimize apparent strength and size of subjects.

Horizontally held, eye-level photographs are usually taken at a height of 5 ½ feet. With the camera tilted up or down, you have either a high- or low-camera angle, respectively.

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Viewpoint and camera angle (Continued)

Figure 1-26 shows a comparison between camera angles and viewpoints.

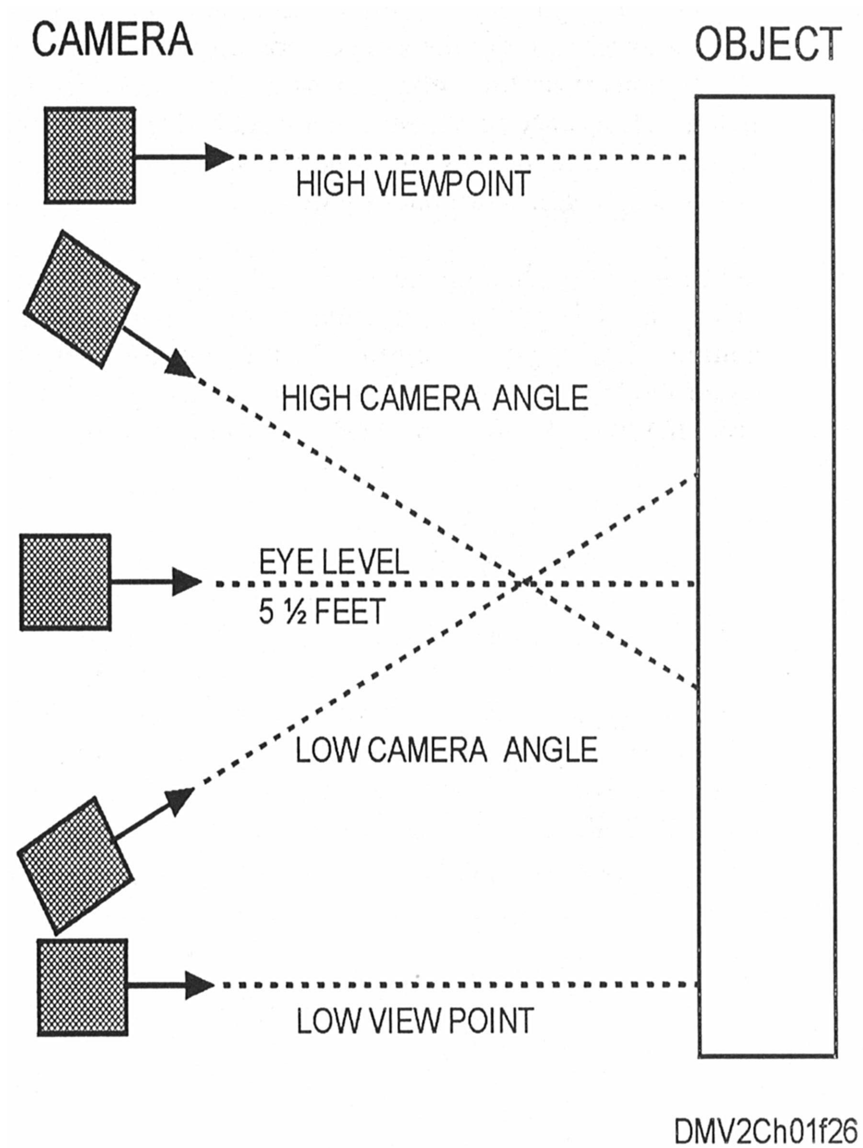

Figure 1-26.—Camera angles and viewpoints.

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Viewpoint and camera angle (Continued)

When selecting or taking photographs of people, particularly commanding officers, executive officers, command master chiefs, and visiting dignitaries, avoid unflattering camera angles and viewpoints. Eliminate images shot at extremely low-camera angles that emphasize double chins, excess weight, and nostrils. To subdue chubby cheeks and double chins, shoot from a high-camera angle to make the subject look up toward you. Because of Navy Regulations regarding eating, drinking, and smoking in uniform, eliminate all images of military personnel in uniform eating, drinking, or smoking. Images are acceptable if the subject is at an informal picnic or social occasion where the members are out of uniform.

When selecting photographs taken on base, onboard ship, or in classified areas, carefully review every element in the picture area for potential compromise. If you are unsure about an image, refer the photograph to the command Photographic Officer before releasing or reproducing it. Simple cropping may eliminate the need to reshoot an image.

Continued on next page

Viewpoint and camera angle (Continued)

Figure 1-27 is a photographic image after the classified areas have been cropped out.

Figure 1-27.—Crop out classified area.

Textural Compositions

Introduction

Compositions containing only text present a different set of problems to the DM. You should understand the impact of text and illustration in compositions. Plan textural compositions as carefully as you plan pictorial presentations.

Textural compositions

You should approach textural compositions using the guidelines for general compositions; however, with text the eye moves most naturally from left to right, up to down and ending in the lower-right corner of a page. Space, around and within type, called *white space,* is as important as printed space. Excessive white space fragments the visual impact of lettering. You can control white space by setting margins, text justification, adding or subtracting leading, and letterspacing.

Figure 1-28 are examples of manipulating white space.

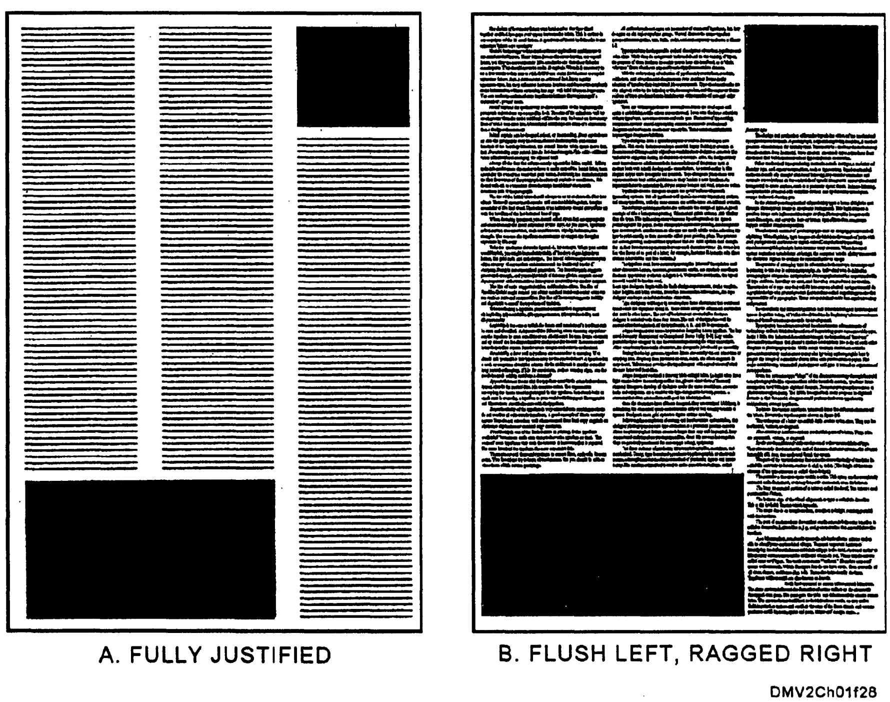

Figure 1-28.—Manipulating white space by setting text: A. Fully justified; or B. Flush left ragged right.

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Textural composition (Continued)

In addition to formal and informal balance, you can manipulate text for expressive representations.

Figure 1-29 is an example of text manipulated to form a pyramid, an inverted pyramid, and a bell shape.

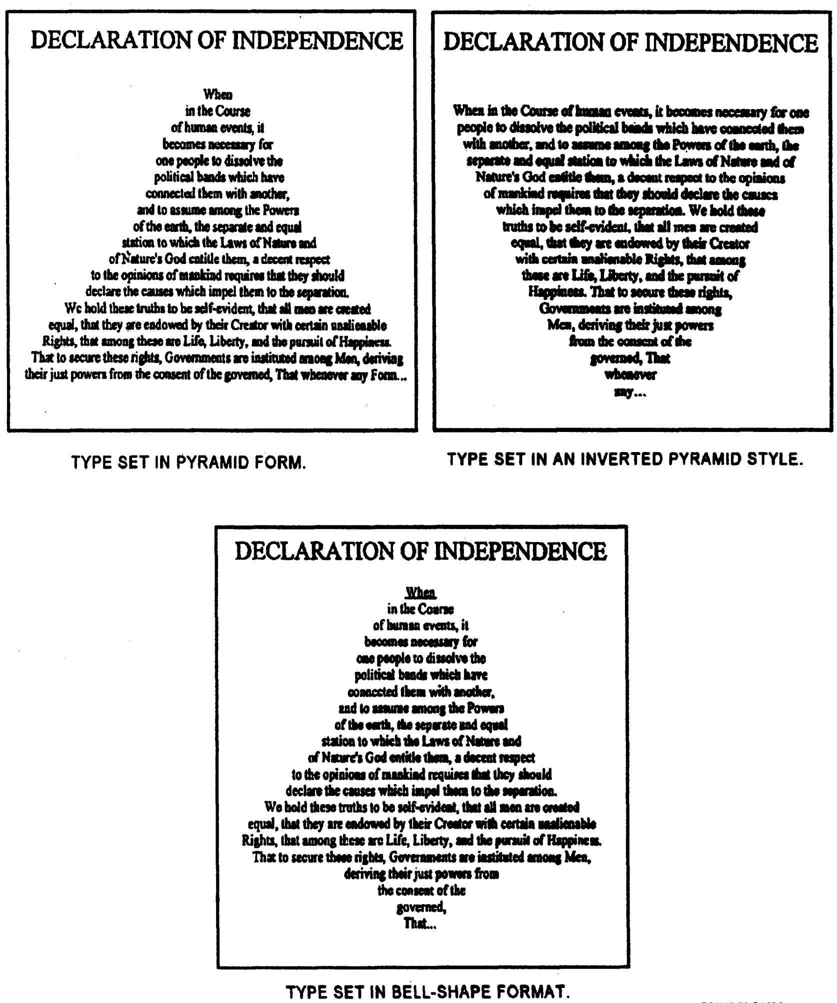

Figure 1-29.—Text manipulation.

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Textural compositions (Continued)

When text dominates compositions, consider the visual impact of each aspect of lettering.

Figure 1-30 shows ways to emphasize type.

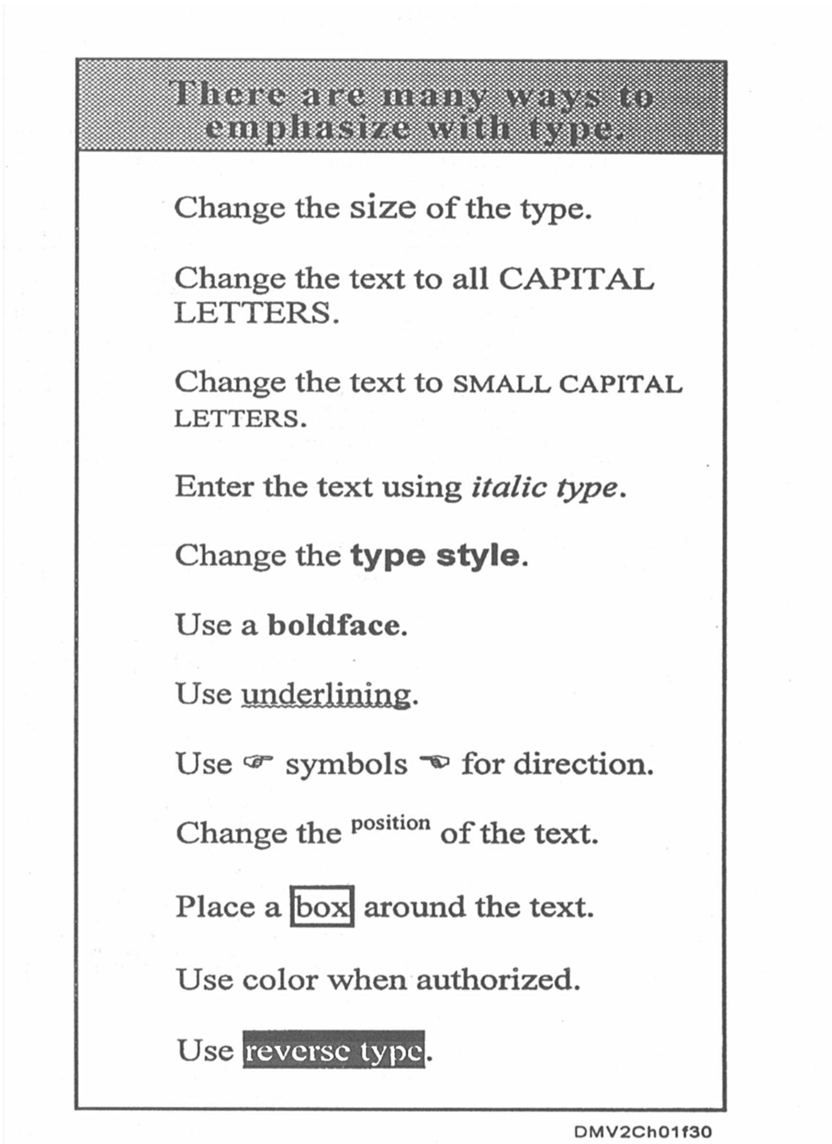

Figure 1-30.—Emphasizing type.

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Textural Compositions, Continued

Textural compositions (Continued)

Figure 1-31 shows a composition where text dominates the image.

Copy preparation is the planning and preparation that go into predominantly textural compositions if subsequent printing results. Copy preparation includes preparing layouts, making a dummy, selecting type styles, composing the type, and preparing the original artwork.

Preliminary information for textural compositions

In addition to the preliminary information you gather for pictorial compositions, you should make several additional decisions. The final size of the finished product, any special handling of photographic effects such as dropouts and reversals, and the location of illustrations and photographs affect the overall composition.

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Textural compositions (Continued)

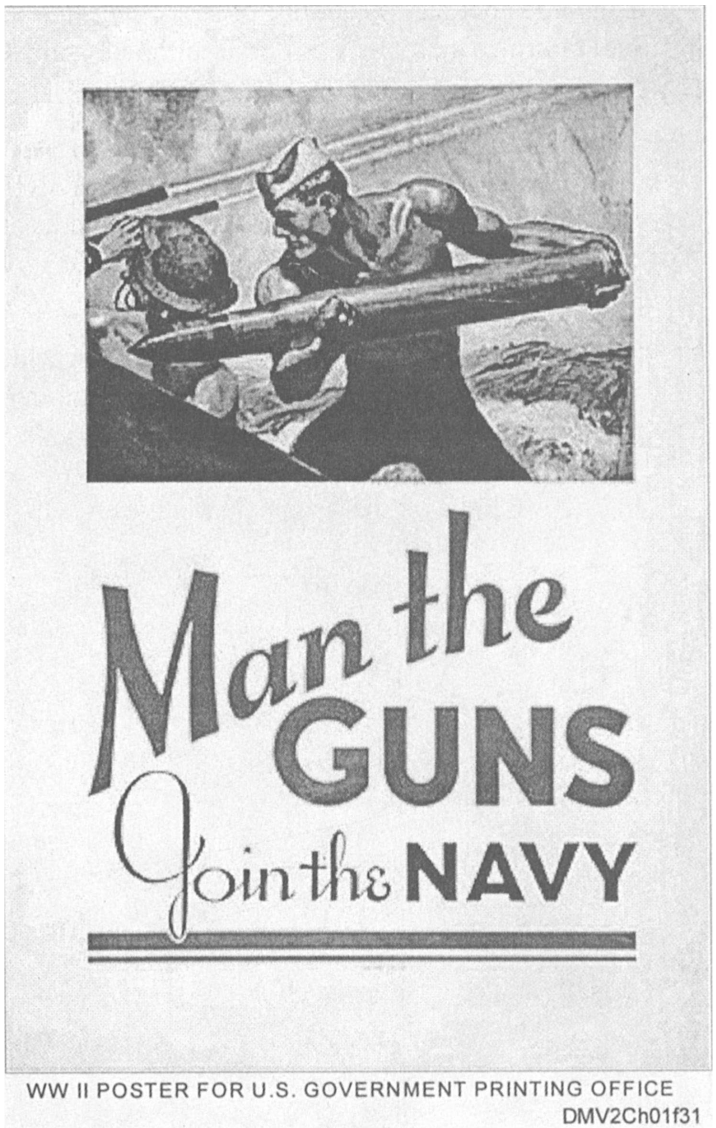

Figure 1-31.—Dominant text.

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Final size

Selecting a final size for the printed product affects not only the size of the page but page proportion. In determining final product size, consider the size of stock available, the limitations and capability of the reproduction equipment you intend to use, and the finished binding operations. Select a page size that can be cut out of stock sheets with the least amount of waste and conforms, as often as possible, to standard sheet sizes.

Standard sheet sizes

Several standard sheet sizes are used throughout the industry and the Navy. The most common standard sized sheet is 8 ½ by 11 inches. Index card applications are 3 by 5 and 5 by 8 inches. Photographic standards are 5 by 7 or 8 by 10 inches.

Proportion

Size affects the proportion or the ratio from width to height. Placing the above standard sheet sizes with their bottom and left edges together shows the relationship between proportions.

Figure 1-32 shows the proportion between standard sized sheets.

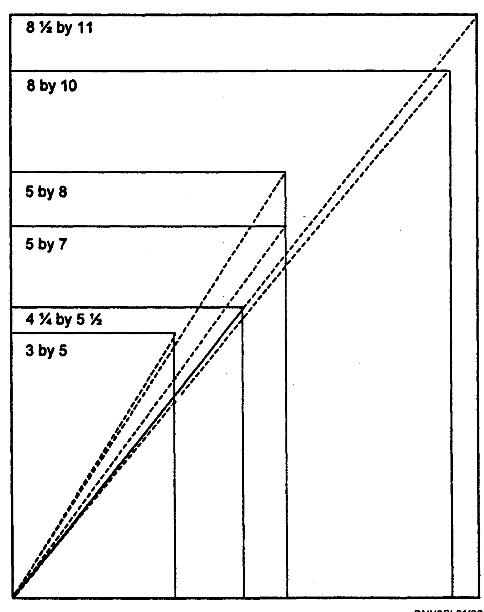

Figure 1-32.—Proportions between standard sheet sizes.

Continued on next page

Proportion (Continued)

To decide on practical and attractive page layouts, determine the amount of copy required and the objective of the final product. Some rectangular forms are more pleasing than others. The three most common rectangular page layouts are the hypotenuse rectangle with a width to height ratio of 5:7, the regular rectangle (2:3), and the Golden Mean rectangle (3:5).

Figure 1-33 shows the three rectangular forms most pleasing to the eye.

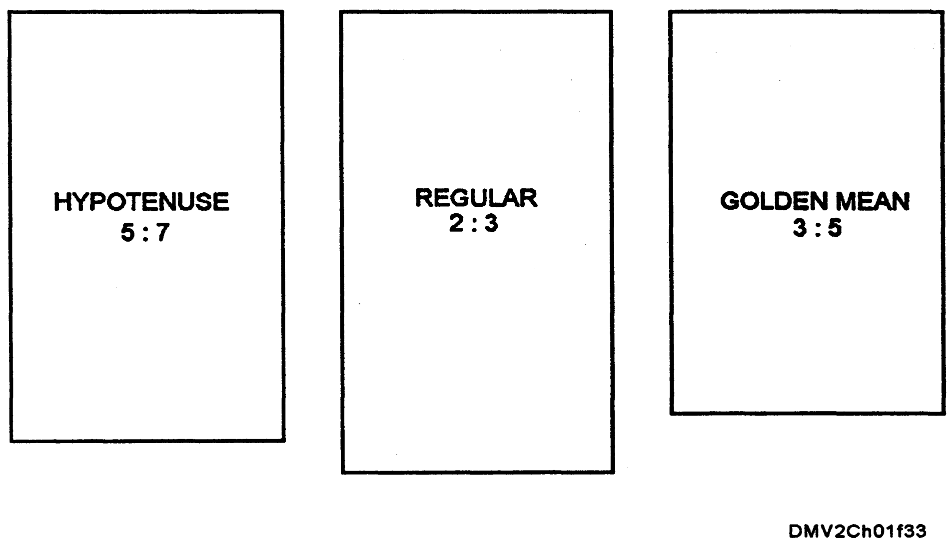

Figure 1-33.—Pleasing rectangular formats.

Continued on next page

Thumbnail sketches

Begin each project with thumbnail sketches. Make sure that all notes, instructions, and sketches stay with the copy to create a paper trail for reference if questions arise. Use lines or "Xs" to indicate lines of type vice actual type. Use sketches to represent illustrations and boxes to indicate photographs.

To prepare thumbnail sketches of textural layouts:

Step	Action
1	Prepare a list of the copy or text.
2	Use a gridded paper and mark the area of the printed product in one-quarter size.
3	Identify copy elements that require emphasis and use block shapes and shading to indicate the main elements on the thumbnail sketch.
4	Use straight lines to represent type that is 12 point or smaller.
5	Outline space for illustrations or photographs. Sketch illustrations or photographic content. Show only enough outline or shape to get an idea of the image.

Rough layout

A rough layout is a refinement of the thumbnail sketch selected by the customer. Rough layouts afford you the opportunity to combine images from the thumbnail sketches, study the designs for changes, and refine the final idea. Rough layouts have more detail than thumbnail sketches. If you must change a layout, the rough layout stage is where it is easiest to make modifications. The rough layout should give you an idea of what the finished product looks like.

Continued on next page

Comprehensive layouts

A comprehensive layout shows how the final product should look. It shows color and shading, illustration placement, and text.

To make a comprehensive layout:

Step	Action
1	Review the rough layout.
2	If the job requires two or more colors, select the colors and use a felt-tipped marker or colored pencils to color each element.
3	Position and letter all display type that is 14 point or larger.
4	Show the position of body type.
5	Sketch illustrations in their correct positions.
6	Box off areas for photographic placement.
7	Prepare overlay sheets if required.
8	Review layout and overlay sheet for correctness.

Figure 1-34 shows a comprehensive layout.

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Figure 1-34.—A comprehensive layout.

Continued on next page

Textural Compositions, Continued

Overlays

Overlays are sheets of paper or acetate containing all the information production personnel need to produce the final product. If an overlay sheet is incorrect, the final product will be incorrect also. The type of information on overlay sheets includes the kind, size, and style of type for each group or part of the layout, specific margins or line lengths, information about illustrations and photographs, colors of ink required with each element marked with each color, paper specifications for the kind, finish, weight, color, and size, the number of copies required, and the reproduction process, if known.

Mechanicals

Mechanicals are camera-ready layouts. Mechanicals are produced after the comprehensive layout and the final decisions are made regarding the end product.

Dummies

Layouts for booklets and pamphlets are called dummies. There are two types of dummies: preliminary dummies and paste-up dummies. Preliminary dummies are made before the type is set. Paste-up dummies are those made from proofs after the composition is complete. Refer to *Illustrator Draftsman Volume* 4, chapter 1, for more complete instructions regarding layout dummies.

BlueprintCompositions

Introduction

Blueprints and technical drawings have very specific formats for composition based on logic and industry standards. Learn blueprint terminology and standards. Do not deviate from the established industry format.

Blueprint compositions

Blueprints are copies of engineering drawings used as plans to construct or fabricate objects and machines. One of the first processes developed to duplicate tracings produced white lines on a blue background; hence the name *blueprint.* Today, other methods are available to reproduce copies and the final images may be brown, blue, black, grey, or maroon. Original drawings are referred to as the *master copy.*

Master copy

Master copies are the original engineering drawings drawn on translucent paper, cloth, or Mylar in pencil, ink, or computer-aided drafting (CAD) systems. Compositional elements in master copies are placed in standardized locations and in very specific ways. Sheet sizes, margins, and the locations of title blocks, revision blocks, drawing numbers, legends, and the associated materials blocks are some of the elements that must be preset in the composition.

Standards

Prescribed standards and procedures for military engineering drawings 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 and is updated yearly. Sometimes standards are referred to as Department of Defense Standards (DOD-STD). The MIL-STD you need most often is MIL-STD-100A. Obtain a copy of the standards for the shop and make sure you refer to the most current copy.

Continued on next page

Standards (Continued)

The following list contains common MIL-STD and ANSI standards.

Number	Title
MIL-STD-100A	Engineering Drawing Practices
ANSI Yl4.5M-1982	Dimensioning and Tolerances
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 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

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Sheet sizes

Drawing sheet sizes are standardized by the American Society of Mechanical Engineers (ASME) and the American National Standards Institute (ANSI). Sheet sizes are designated by letter. These standards are published in MIL-STD-100A. The drawing sheet sizes you use are determined by the needs of your command and your need to economically lay out required information

Figure 1-35 lists drawing sheet sizes and the associated letter designators.

FLAT SIZES				ROLL SIZES				
SIZE DES (LTR)	X (WIDTH)	Y (LENGTH)	Z (MARGIN)	SIZE DES (LTR)	X (WIDTH)	Y MIN (LENGTH)	Y MAX (LENGTH)	Z (MARGIN)
A(HORIZ)	8.50	11	.25&.38*	G	11	42	144	.38
A(VERT)	11	8.50	.25&.38*	H	28	48	144	.50
B	11	17	.38	J	34	48	144	.50
C	17	22	.50	K	40	48	144	.50
D	22	34	.50					
E	34	44	.50					
F	28	40	.50					

* HORIZONTAL MARGINS .38-INCH; VERTICAL MARGIN .25-INCH, ON "A" SIZE DRAWINGS

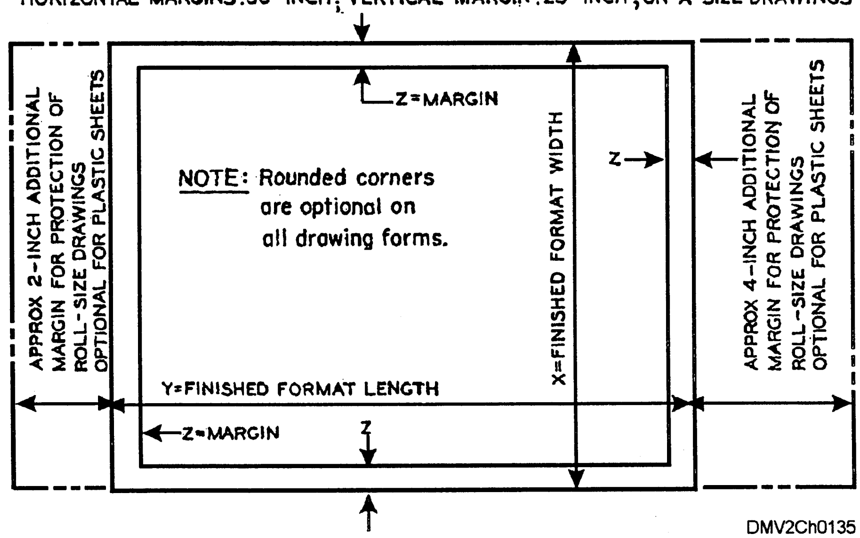

Figure 1-35.—Drawing sheet sizes and associated margin widths.

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Margins

Margins are the distance between the cut line or paper edge and the border. Like drawing sheet sizes, margins are predetermined. Notice that for "A"-size drawings, the margins are not equal.

Figure 1-36 shows margin sizes and placement on "A"-size drawings..

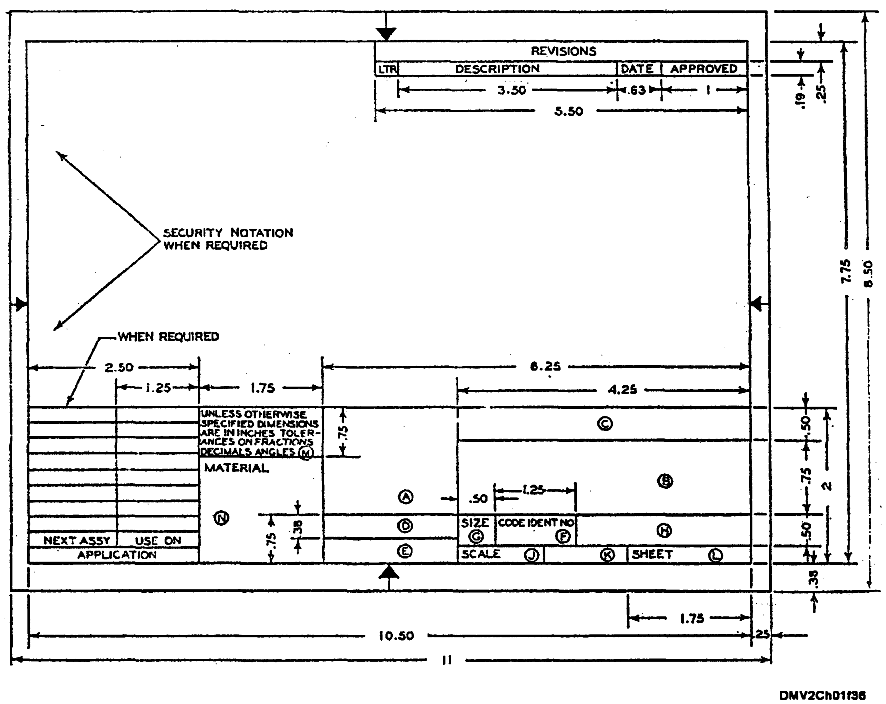

Figure 1-36.—Margins for an "A" -size drawing.

Information blocks

Information blocks provide information on material, composition, scale, dimensional notes, tolerances, surface finish, previous or related drawings, activity identification and approval, and classification level pertaining to fabrication or construction. You may leave some blocks blank if the information is not needed.

Continued on next page

Title block

Title blocks contain the name of the drawn object, drawing number, and all information required to identify the part or assembly. It also includes the name and address of the government agency or command preparing the drawing, scale, drafting record, authentication and date. Locate the title block in the lower-right corner of the drawing.

Figure 1-37 are examples of title blocks.

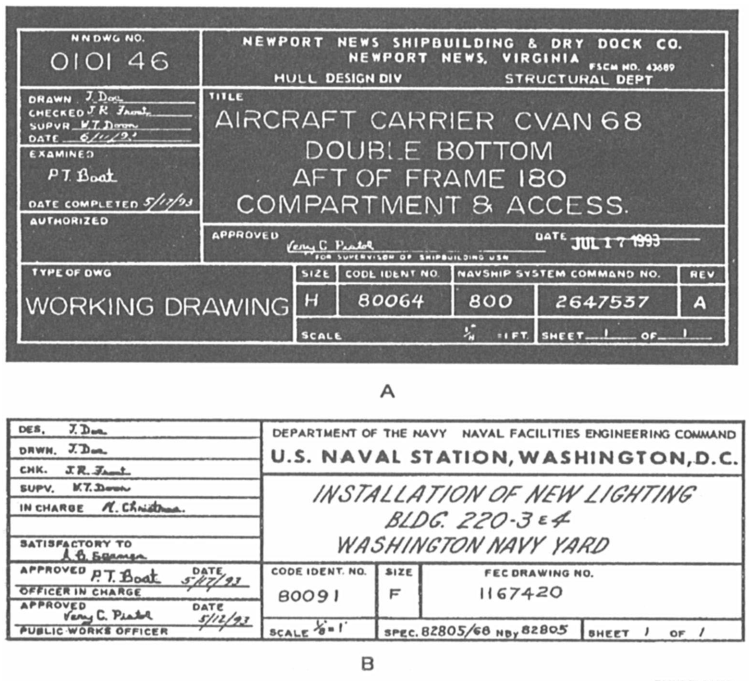

Figure 1-37.—Blueprint title blocks: A. Naval Ship Systems Command; B. Naval Facilities Engineering Command.

Drawing number

A drawing number appears on each drawing. On drawings with more than one sheet, the drawing number block shows the sheet number and the number of sheets in the series. The drawing number appears in the lower-right corner of the title block and may appear near the top border line in the upper corner or on the reverse side at the other end so it is visible when the drawing is rolled.

Continued on next page

Reference numbers

Reference numbers refer to numbers of other drawings. A dash and a number show that more than one detail is shown on a drawing. When two parts are shown in the detail drawing, the print has the drawing number plus a dash and an individual number. Dashes and numbers identify changed or improved parts and right- or left-hand parts. Left-hand parts are usually depicted in drawings. Some drawings use RH or LH for right- or left-hand parts. Others use even numbers for right-hand drawings and odd numbers for left-hand drawings. Reference numbers appear in the title block and they may also appear within the drawing near the parts they identify. Some reference numbers use a leader line to show the drawing and dash number of the part. Others use a 3/8-inch diameter circle around a dash number with a leader line to the part.

Figure 1-38 is an example of reference numbers.

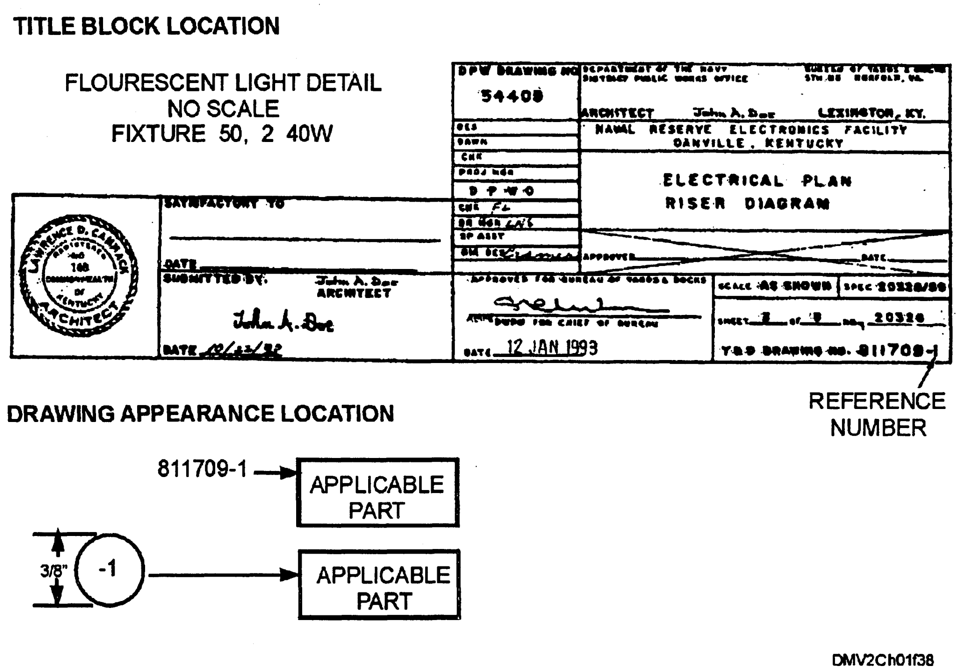

Figure 1-38.—Reference number location.

Continued on next page

Scale

The scale block shows the-size of the drawing compared to the actual size of the part or assembly. Choose the scale to fit the object and the space available on the sheet of drawing paper. Never measure from drawings; always use stated dimensions. Scale usually appears as part of the title block. Indicate scale using the fractional method where the drawing unit is the denominator and the object is the numerator, the equation method where scale is indicated in feet (’) and inches (”), or the graphical method with a primary scale to the right of the 0 and a subdivided scale to the left of the 0. Graphical scales are reserved primarily for maps.

Figure 1-39 illustrates the three ways of indicating scale on drawings.

FRACTIONAL METHOD		EQUATION METHOD
1/1	FULL SCALE	12" = 1'-0"
2/1	ENLARGE SCALE	24" =1'-0"
1/2	REDUCED SCALE	1/2" = 1'-0"

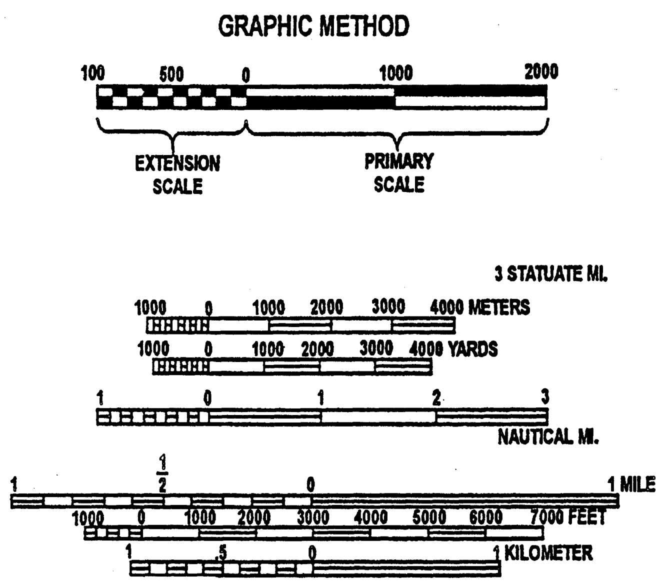

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Figure 1-39.—Indicating scale.

Continued on next page

Blueprint Compositions, Continued

Revision blocks Revision blocks are only needed on drawings if changes or improvements are made to the original part or assembly. The addition of a letter to the original number and a brief description of the revision in the revision block show that a drawing is revised. Subsequent revisions replace the previous letter with the next letter of the alphabet. Locate revision blocks above the title block on drawings larger than “A” size. On “A”-sized drawings, locate the revision block in the upper-right corner.

Figure 1-40 illustrates how revision blocks on drawings append to the title block.

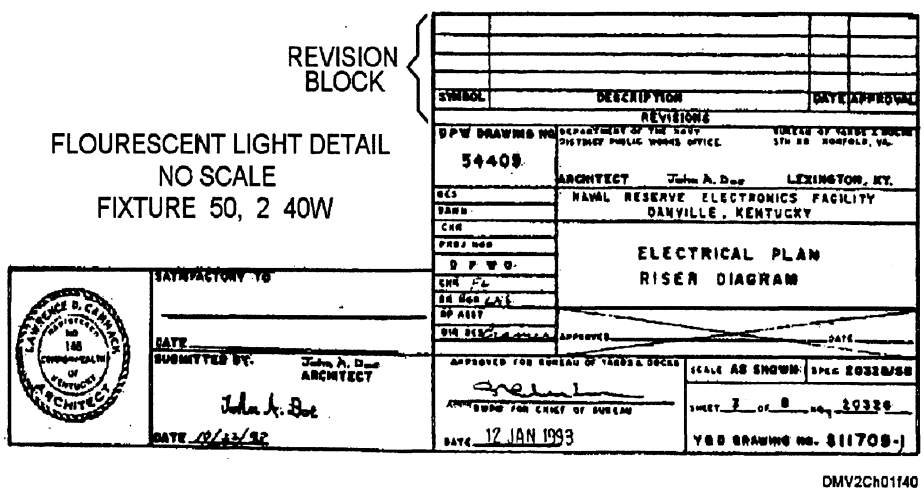


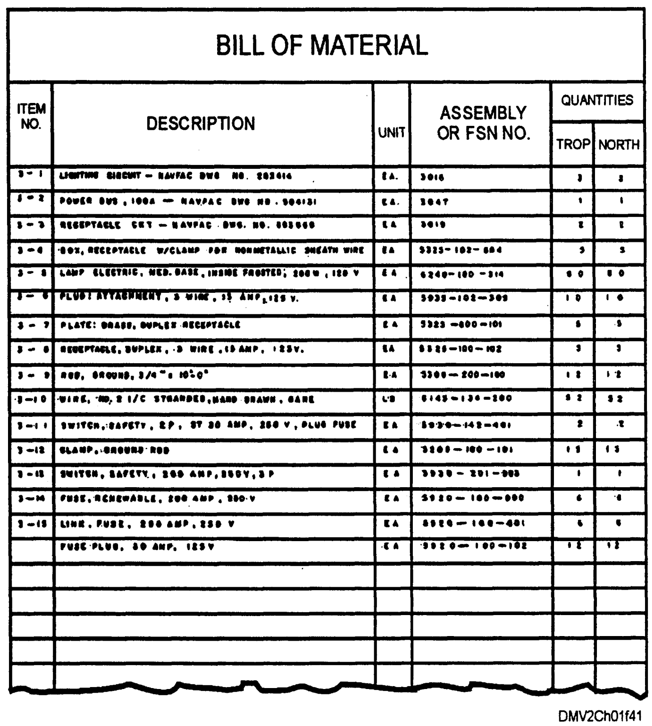
Figure 1-40.—Revision block appended to a title block.

Application blocks Application blocks identify directly or by reference the larger unit that contains the part or assembly on the drawing. The next assembly (NEXT-ASS’Y) column contains the drawing number or model of the next larger assembly. The used on column shows the model number or equivalent designations of the assembled units part. Locate application blocks appended to the far left side of title blocks.

Continued on next page

Bill of materials The bill of materials 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 the quantities required. The bill of materials often contains a list of standard parts known as a parts list or schedule. Locate a bill of materials on the right-side of the drawing.

Figure 1-41 is an example of a bill of materials.



BILL OF MATERIAL

ITEM NO.	DESCRIPTION	UNIT	ASSEMBLY OR FSN NO.	QUANTITIES	
				TROP	NORTH
3-1	LIGHTING CIRCUIT — NAVFAC DWG NO. 282414	EA.	3016	3	3
3-2	POWER BUS, 100A — NAVFAC DWG NO. 304131	EA.	3047	1	1
3-3	RECEPTACLE CKT — NAVFAC DWG. NO. [illegible]	EA	3019	2	2
3-4	BOX, RECEPTACLE W/CLAMP FOR NONMETALLIC SHEATH WIRE	EA	5325-102-504	5	5
3-5	LAMP ELECTRIC, MED. BASE, INSIDE FROSTED; 200W, 120 V	EA	6240-100-314	50	50
3-6	PLUG: ATTACHMENT, 3 WIRE, 15 AMP, 125 V.	EA	5935-102-309	10	10
3-7	PLATE: BRASS, DUPLEX RECEPTACLE	EA	5325-600-101	5	5
3-8	RECEPTACLE, DUPLEX, 3 WIRE, 15 AMP, 125V.	EA	5325-100-102	3	3
3-9	ROD, GROUND, 3/4" x 10'-0"	EA	5300-200-100	12	12
3-10	WIRE, NO. 2 1/C STRANDED, HARD DRAWN, BARE	LB	6145-130-200	32	32
3-11	SWITCH, SAFETY, 2P, ST 30 AMP, 250 V, PLUG FUSE	EA	5930-142-401	2	2
3-12	CLAMP, GROUND ROD	EA	5200-100-101	13	13
3-13	SWITCH, SAFETY, 200 AMP, 250V, 3P	EA	5930-201-303	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	5920-100-401	6	6
	FUSE PLUG, 30 AMP, 125V	EA	5920-100-102	12	12

Figure 1-41.—Bill of materials.

Zone numbers Zone numbers help locate particular points or parts on a drawing. Similar to numbers used on maps, specific locations designated by letters and numbers serve to pinpoint locations. Mentally draw invisible horizontal and vertical lines to the point of intersection. Zone numbers are read from left to right and from top to bottom, and are located in the margin or border areas of drawings.

Continued on next gage

Station numbers

Station points or station markings are a location system for aircraft. Some manufacturers, particularly in the aircraft industry, use station points to locate parts or assemblies. The centerline at the center of the part or assembly is designated by a zero. Incrementally numbered ribs to the left and right of the centerline serve as station markings to locate details. Station points appear on the actual drawing of the part or assembly.

Figure 1-42 illustrates the use of station points in aircraft drawings.

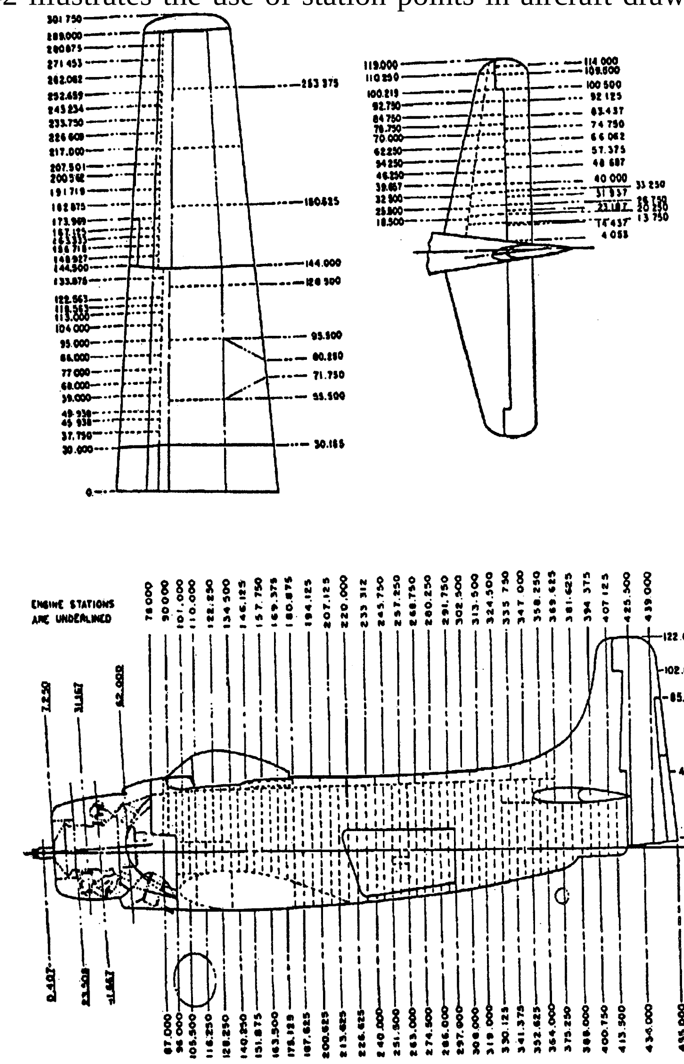


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Figure 1-42.—Aircraft station points.

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Finish marks

Finish marks show part surfaces that require finishing by machine. Machining provides a better surface appearance and a better fit with closely mated parts. Machine finishes are not the same as finishes of paint, enamel, grease, chromium plating, and similar coatings. Finish marks appear on the drawing near the surfaces to which they apply.

Notes and specifications

Additional information that does not belong in a regimented information block is included on drawings as notes and specifications. Place notes giving clarifying information directly on the drawing with a leader line that ties into the affected part or assembly. Specifications are statements containing a description such as the terms of a contract or details of an object not shown. Specifications provide additional information to show that the item conforms to the description and that it can be made without the need for further research, development, or design engineering.

Legends and symbols

Legends and symbols explain and define special marks placed on the drawing. Legends, if used, appear in the upper-right corner of drawings under the revision block

Figure 1-43 is an example of a legend.

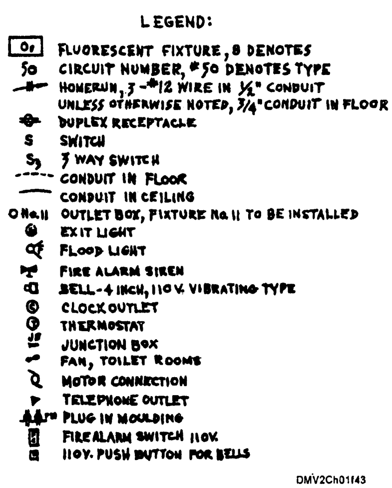

Figure 1-43.—A legend.

Summary

Review

This chapter introduces the concepts of composition, general compositional elements and their effects, and the differences in compositions between pictures, photographs, text pages, and engineering drawings. The success of imagery in all methods and media depends upon strong composition. No hard and fast rules direct what combination of compositional elements works for each situation.

Comments

Composition is one of the most important aspects of the DM rate. All of the talent in the world cannot compensate for poorly designed drawings. Poor compositions fail to communicate or, worse yet, miscommunicate. In today's electronic age, computers do not possess human-like perception in aesthetics. As yet, fundamentals of composition cannot be digitized into cookbook formulas and programmed into a microchip for computer emulation. High-end computer graphics systems still require input from a human with knowledge of compositional principles. It is important to learn the subtle differences between media formats and compositional presentations.

CHAPTER 2

GEOMETRIC CONSTRUCTION

Overview

Introduction

Familiarity with the step-by-step methods used for constructing geometric figures and knowing related definition of terms help you understand the practical applications of geometric construction to problem solving. Simplified- or preferred methods of geometric construction, as well as alternate methods, are valuable knowledge factors when used with drafting instruments to create accurate drawings. Geometric construction applies equally to computer-generated drawings as it does to more traditional instrumental drawings using triangles, compasses, protractors, and straightedges.

Objectives

The material in this chapter enables you to do the following:

- Identify angles as acute, obtuse, complimentary, or supplemental.
- Inscribe and circumscribe geometric figures.
- Calculate the degrees in an angle of a regular polygon.
- Identify quadrilaterals.
- Bisect lines, angles, and circles.
- Create an ellipse using the trammel or foci method.

Continued on next page

Acronyms

The following table contains a list of acronyms you must know to understand the material in this chapter:

Acronym	Meaning
DIA	Diameter
PI or π	3.1416
RAD or R	Radius

In this chapter

This chapter covers the following topics:

Definition of Terms

Introduction

Knowing the professional terminology used in a selected field is imperative for any degree of success. Illustrator Draftsman is no different. Without a solid knowledge of the definition of terms used in this field, you will be lost. Make sure you understand this chapter before you skip ahead to other chapters in this training manual.

Points and lines

This basic discussion on points and lines is to make sure you understand their definition and representation. If you do not understand how to succinctly draw a point or line, a viewer will not know how to interpret them.

POINT: A point is a location in space. It has no height, width, or depth. Represent a point of intersection on lines with short crossbars or between two lines with short cross hairs. Do not represent a point with a mere dot on paper.

Figure 2-1 shows how to represent points on paper.

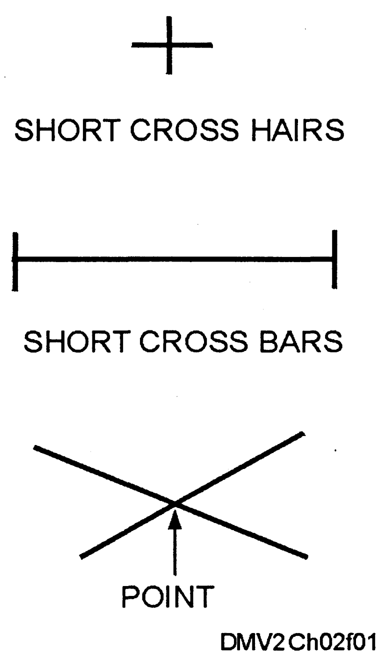

Figure 2-1.—Points.

Continued on next page

Points and lines (Continued)

LINE: A *straight line* is the shortest distance between two points and is often referred to simply as a line. If the length of a line is indefinite or without fixed endpoints, its length is any distance you select. If the line has fixed endpoints, mark them with small mechanically drawn cross hairs. Straight or curved lines are *parallel* if the shortest distance between them remains constant throughout their length. If a line is parallel to another line, use the common symbol for parallelism (||). Lines that intersect at right angles (90°) to each other are referred to as *perpendicular*. Indicate perpendicularity with short lines intersecting at right angles (⊥ (singular) or ⊥s (plural)) or a small square box at the apex (⊾) of the intersection.

Figure 2-2 shows common line terminology.

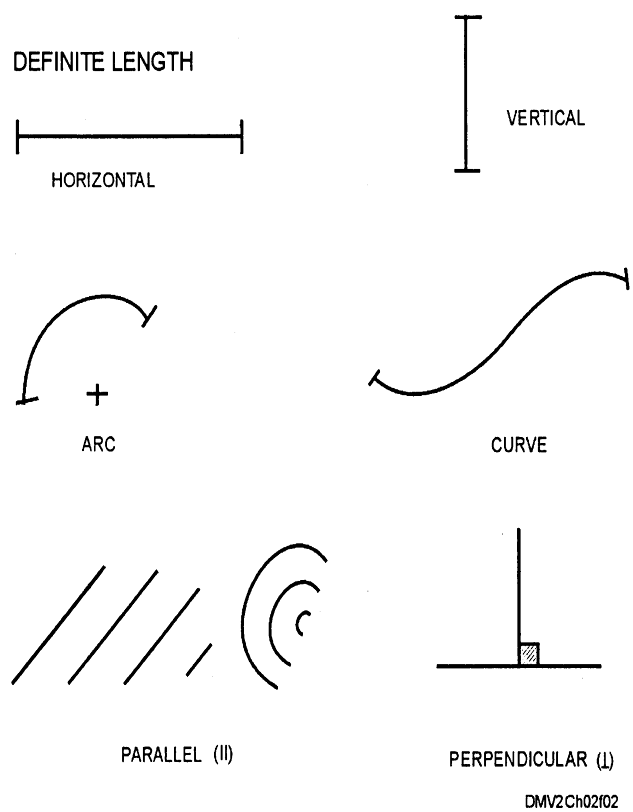

Figure 2-2. —Lines.

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Angles

Angles form when two lines intersect. The symbols for angularity are ∠ (singular) or ∠s (plural). There are a maximum of 180 possible degrees to an angle. A *straight angle* is an angle of 180° and appears as a straight line. *Obtuse angles* are angles less than 180° but more than 90°. An angle of 90° is referred to as a *right angle* because of the relationship between the two intersecting lines. *Acute angles* are angles less than 90°. When two angles are combined to total 90°, they are referred to as *complimentary angles. Supplementary angles* form when two angles combine to total 180°. You may draw angles at any degree of angularity using triangles or a protractor. To increase accuracy, use a vernier protractor or construct angles using the tangent, sine, or chord methods.

Figure 2-3 illustrates the different degrees of standard angularity.

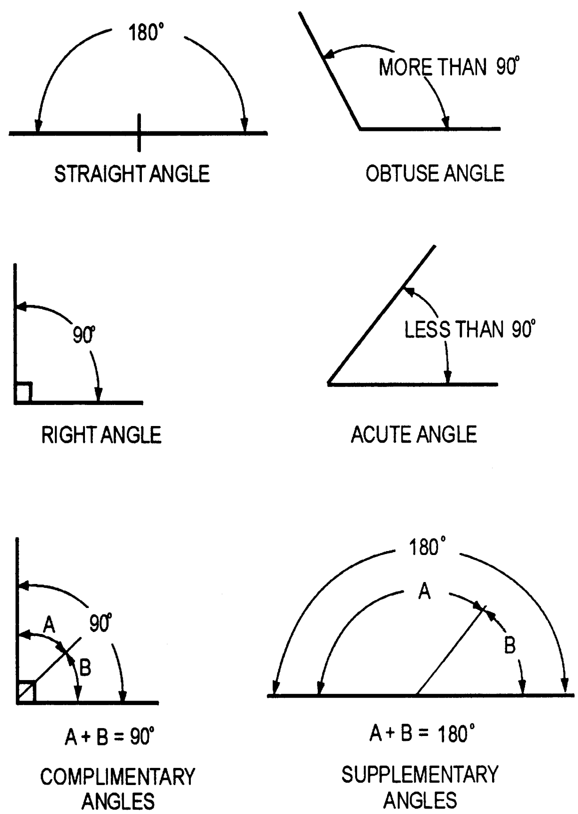

Figure 2-3.—Angles.

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Triangles

A *triangle* is a plane figure bound by three straight sides, which form three interior angles. The top of the triangle is the *vertex.* The height of a triangle is referred to as the *altitude.* The bottom of a triangle is its *base.* The sum of the three interior angles is always 180°. When all sides and all interior angles (60°) are equal, the triangle is referred to as an *equilateral triangle.* When two sides and two angles are equal, the triangle is an *isosceles triangle.* A *scalene triangle* does not have any equal sides or angles. A *right triangle* has one angle equal to 90° and the long side opposing that angle is called the *hypotenuse.*

Figure 2-4 shows triangles.

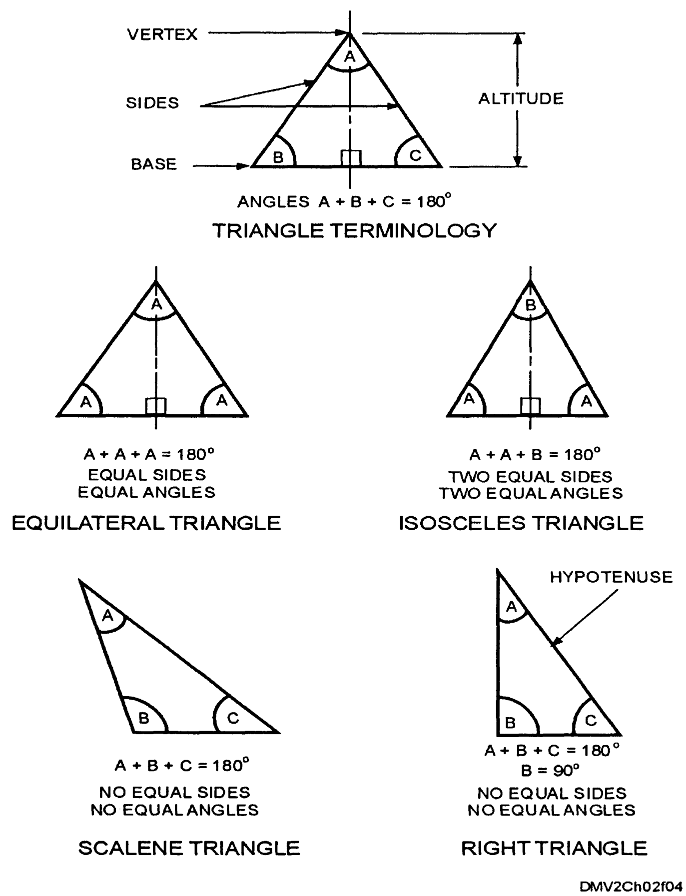

Figure 2-4.—Triangles.

Continued on next page

Quadrilaterals

Quadrilaterals are plane figures bound by four straight sides. Four-sided figures with parallel opposing sides are further classified as *parallelograms.* A parallelogram having four equal sides and equal angles is called a *square.* A *rhombus* has four equal sides and equal opposing angles. A figure with equal opposing sides and equal angles is a *rectangle.* A figure with equal opposing sides and equal opposing angles is a *rhomboid.* Quadrilaterals with only two parallel sides and no angles equal are *trapezoids.* If no sides and no angles are equal or parallel, the figure is called a *trapezium.* Trapezoids and trapeziums are quadrilaterals but are not parallelograms.

Figure 2-5 shows the six different types of quadrilaterals.

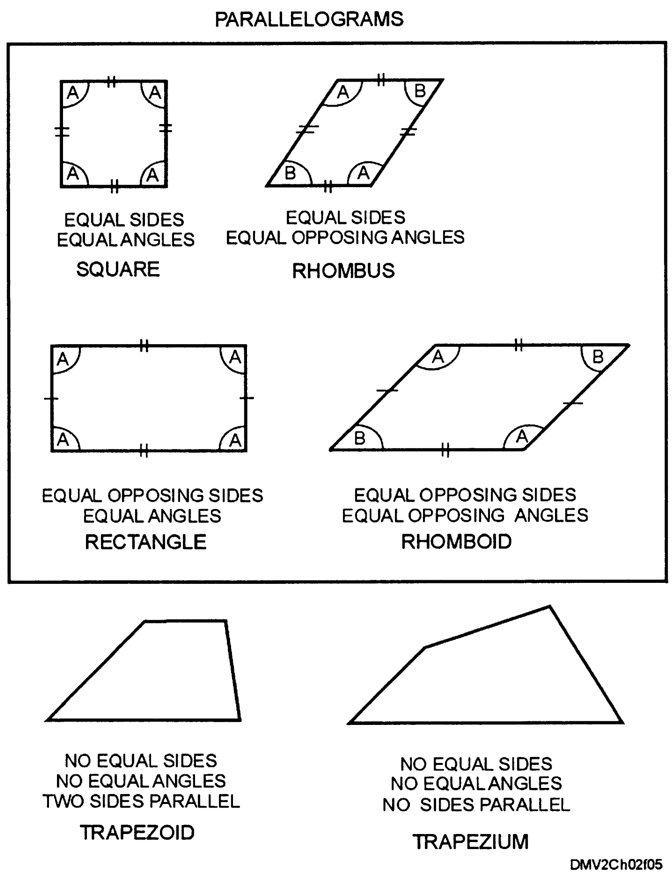

Figure 2-5.—Quadrilaterals.

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Polygons

Any plane figure bound by straight sides is a *polygon.* This definition includes triangles and quadrilaterals. Polygons having equal sides and equal angles are called *regular polygons* (including equilateral triangles and squares) and can be constructed by inscribing in or circumscribing around a circle or square, a technique covered later in this chapter. The following list shows how the names of the regular polygons change with the number of sides:

Sides	Name
3	Triangle
4	Square
5	Pentagon
6	Hexagon
7	Heptagon
8	Octagon
9	Nonagon
10	Decagon
12	Dodecagon

Figure 2-6 shows regular polygons.

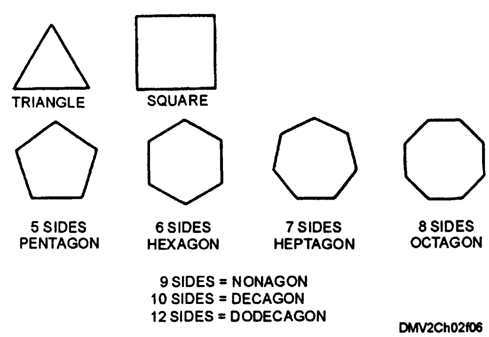

Figure 2-6.—Regular polygons.

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Definition of Terms, Continued

Circles

A *circle* is a closed curve in which all points along the curve are equidistant from the center. The distance from the center point to any point along the circle edge is called a *radius* (RAD or R). The distance from one side of the circle through the center point to the opposing side of the circle is the circle *diameter* (DIA). Half of the distance around a circle is called a *semicircle. Circumference* refers to the total distance around the circle. Calculate the circumference of a circle by multiplying the diameter of the circle by 3.1416 or π (pronounced pi). A *chord* is a straight line joining two points on a curve. A *segment* is the section of the curve cut off by the line or chord. *Quadrants* result from the intersection of two radii at 90° including the portion of the circle between the radii. *Sectors* are the part of the circle bound by two radii at other than right angles including the bound portion of the circle. *Angles* are formed by the intersection of radii but do not include the bound portion of the circle. An *arc* is a segment of the curved portion of the circle bound by the intersection of two radii but does not include the radii. A straight line that intersects and passes through two points on the circle is called a *secant.* Straight lines that touch but do not intersect at one point on a circle are said to be *tangent.* Multiple circles sharing a common center point are called *concentric circles.* Multiple circles that do not share a common center point are referred to as *eccentric circles.* Eccentric circles are most common in depicting reciprocal relationships such as in the camshaft of an engine.

Figure 2-7 illustrates circle terminology.

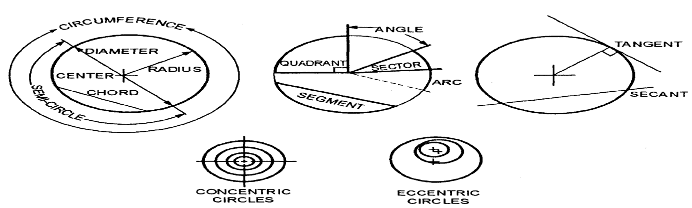

Figure 2-7.—Circle terminology.

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Circles (Continued)

Circles are also used to construct curves. The *Spiral of Archimedes* is a curve that forms at a fixed point in the center of the circle and rotates through geometrically determined points or locus. As the locus uniformly increase or decrease their distance from the center, the spiral emerges.

Figure 2-8 shows a Spiral of Archimedes.

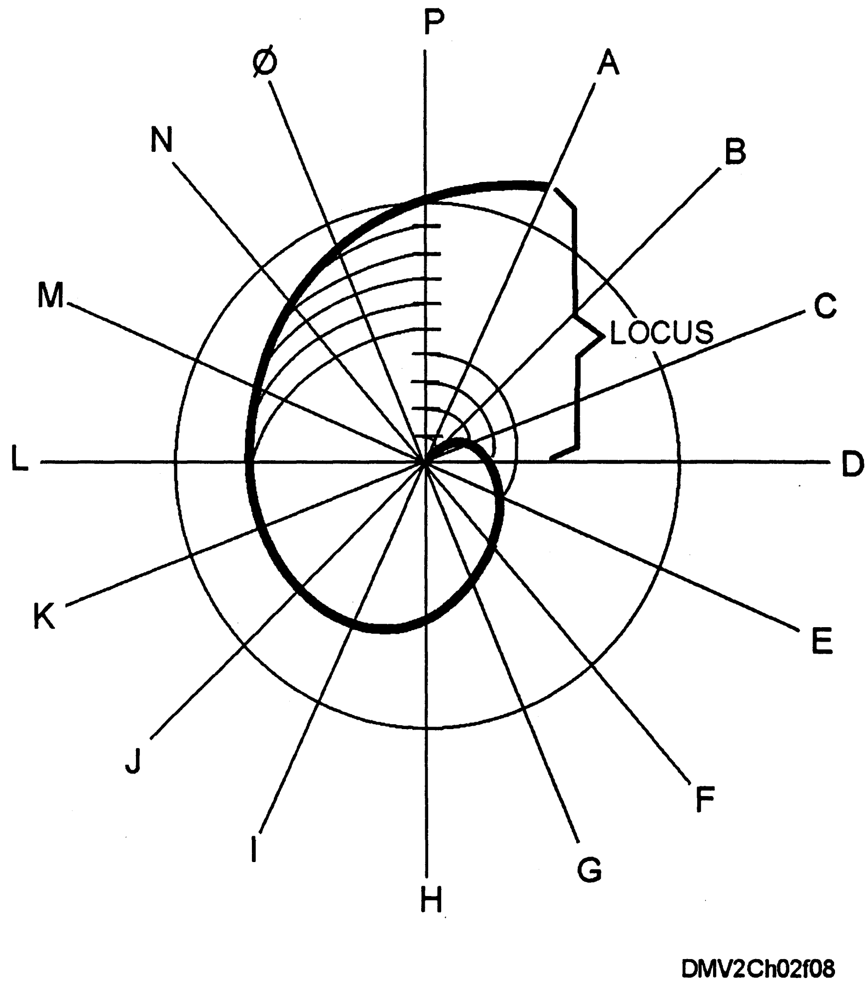

Figure 2-8.—The Spiral of Archimedes.

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Definition of Terms, Continued

Circles (Continued)

Points along the circumference of a circle rolling on a straight line are known as cycloidal or *cycloids.* Points along the circumference of a circle rolling on the convex side or outside edge of an equal or larger circle are called *epicycloid.* If the circumference of a circle rolls along the concave side or inside edge of a larger circle, the resulting curve is a *hypocycloid.*

Figure 2-9 illustrates the formation of a cycloid, epicycloid, and hypocycloid.

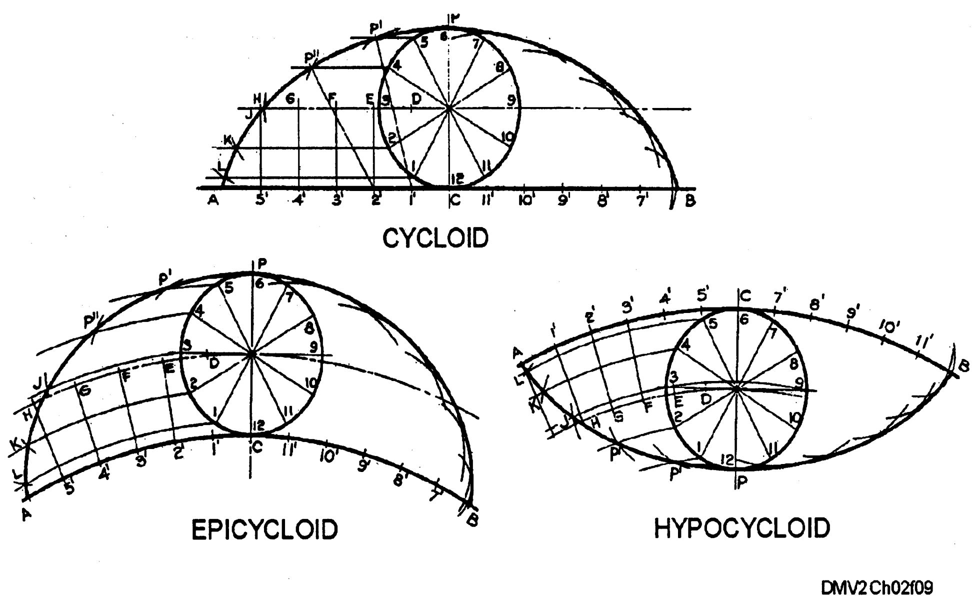

Figure 2-9.—Cycloids, epicycloids, and hypocycloids.

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Solids

Solids are figures having the three dimensions of length, width, and depth bounded by plane surfaces. Solids may also be known as *polyhedra*. The plane surfaces of polyhedra are called *faces* and if the faces are regular polygons, the solids are *regular polyhedra*.

Figure 2-10 shows regular polyhedra or solids.

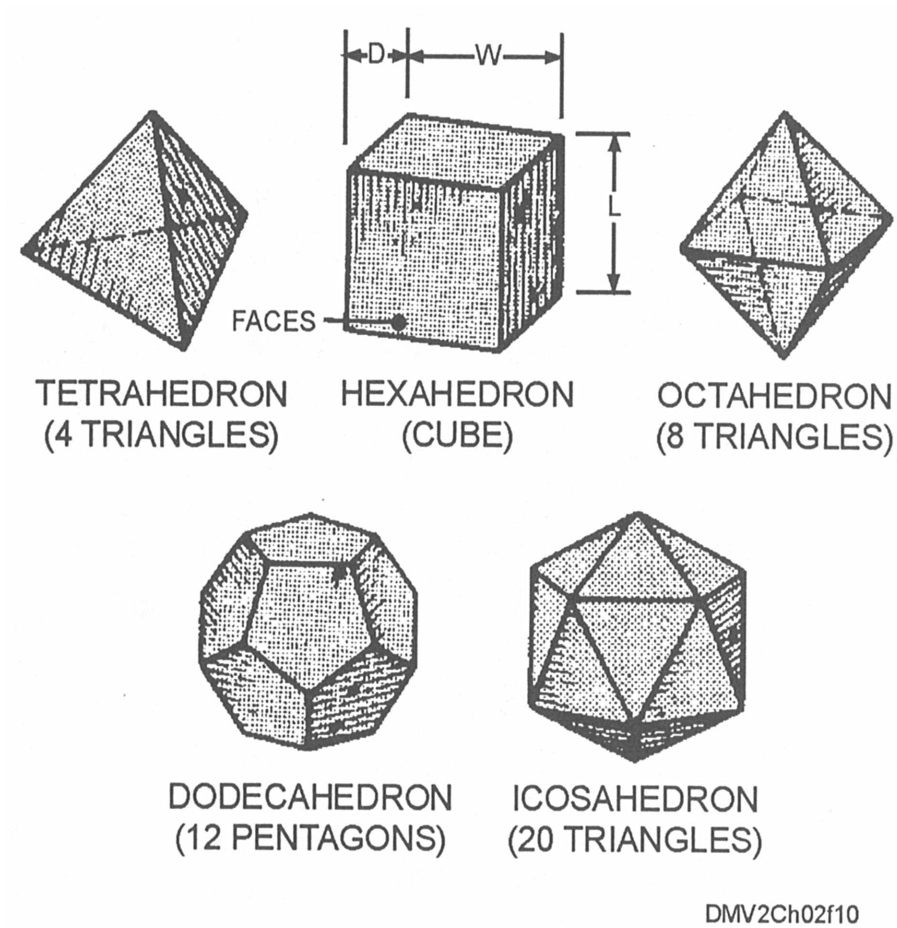

Figure 2-10.—Regular polyhedra.

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Solids (Continued)

A *prism* is a solid with two bases (top and bottom) that are equal regular polygons and three or more lateral faces that are parallelograms. If the bases are also parallelograms, the prism is a *parallelepiped.* A *right prism* has faces and lateral edges that are perpendicular to the bases. *Oblique prisms* have faces and lateral edges oblique to the bases.

Figure 2-11 illustrates prism configurations.

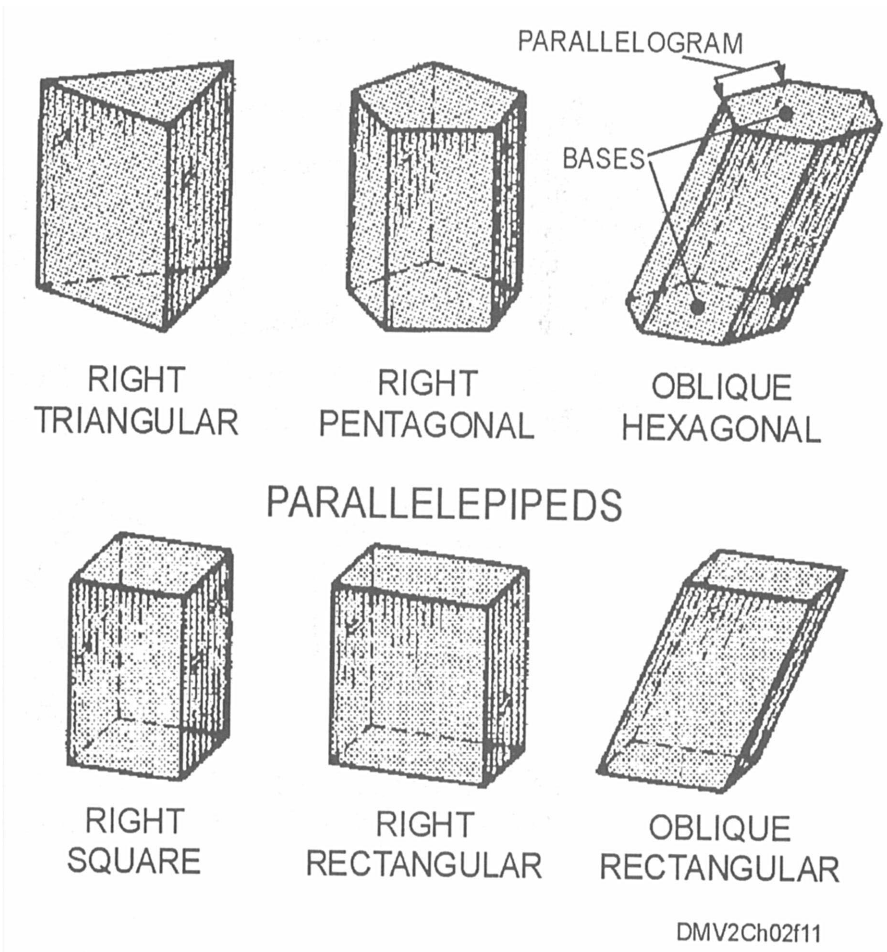

Figure 2-11.—Prisms.

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Solids (Continued)

Cylinders are two parallel bases formed by a fixed curve or *directrix* revolving around a straight line or *generatrix* at the center. The generatrix at the center of the cylinder is also called an *axis.* The height of the cylinder is called the altitude. Any point along the edges of the cylinder is referred to as an *element. Right circular* cylinders have lateral edges perpendicular to the bases and *oblique circular* cylinders have lateral edges oblique to the bases. Moving a point around and along the surface of a cylinder with uniform angular velocity to the axis and with a uniform linear velocity in the direction of the axis produces a *helix.* You may construct a helix using a cylinder or cone.

Figure 2-12 show examples of cylinders and a helix.

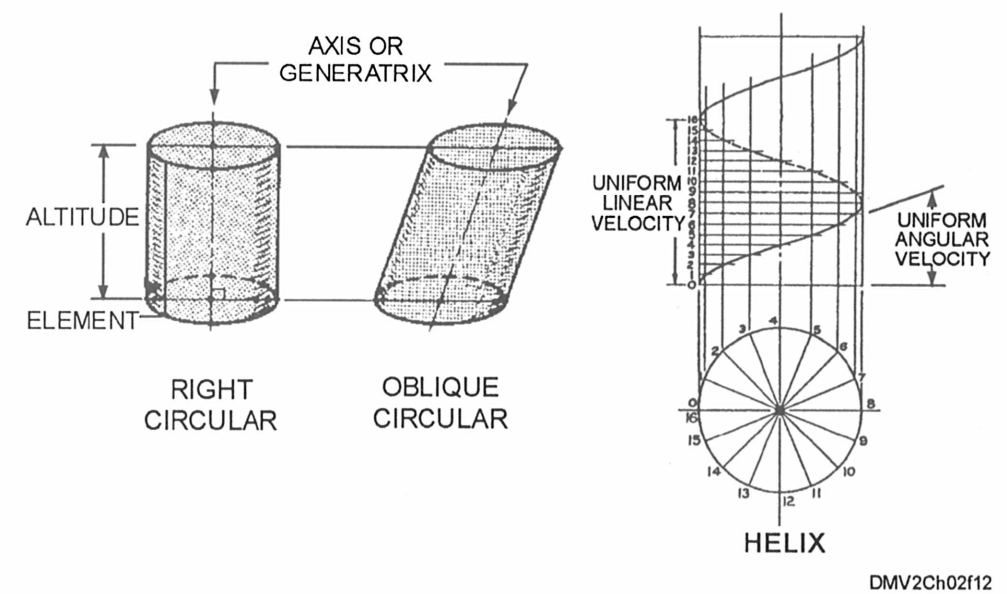

Figure 2-12.—Cylinders and a helix.

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Solids (Continued)

Pyramids have polygons for a base and triangular lateral faces that intersect at the vertex or top of the pyramid. A centerline from the vertex to the center of the base is known as the axis and its height is called the altitude. If the axis is perpendicular to the base, the pyramid is a *right pyramid.* All other pyramids are *oblique pyramids.* A pyramid that has been cut off near the vertex oblique to the base is said to be *truncated;* if the pyramid is cut off parallel to the base, the cut plane is known as a *frustum.*

Figure 2-13 illustrates pyramid terminology.

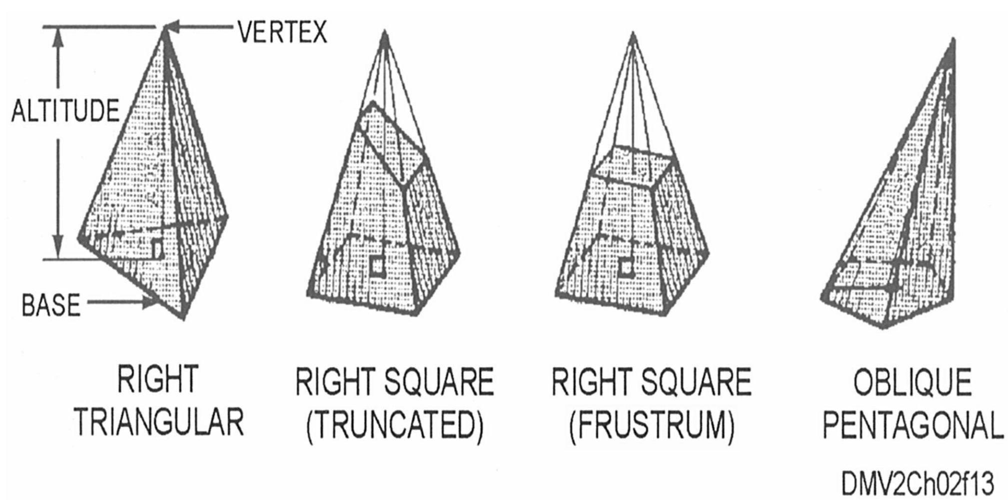

Figure 2-13.—Pyramids.

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Solids (Continued)

Cones have a generatrix that terminates in a fixed point at a vertex around which revolves a directrix or closed curve base. The generatrix is also known as the axis whose height is referred to as altitude. Any point around the cone from the base to the vertex is called an element. A cone whose axis is perpendicular to its base is a *right cone.* Planes intersecting a cone will make the cone appear truncated or frustum. Planes intersecting a right cone produce *conic sections.* Conic sections appear as curves. A conic section perpendicular to the axis appears as a circle at the plane of intersection. A conic section with a cutting plane oblique to the axis but making a greater angle with the axis than the elements appears as an ellipse. When the plane of intersection is oblique to the axis and at the same angle to the axis as the elements, the curves is referred to as a *parabola.* An oblique plane of intersection that makes a smaller angle to the axis than the elements is known as a *hyperbola.* Cones may also be used to construct helixes.

Figure 2-14 shows cones.

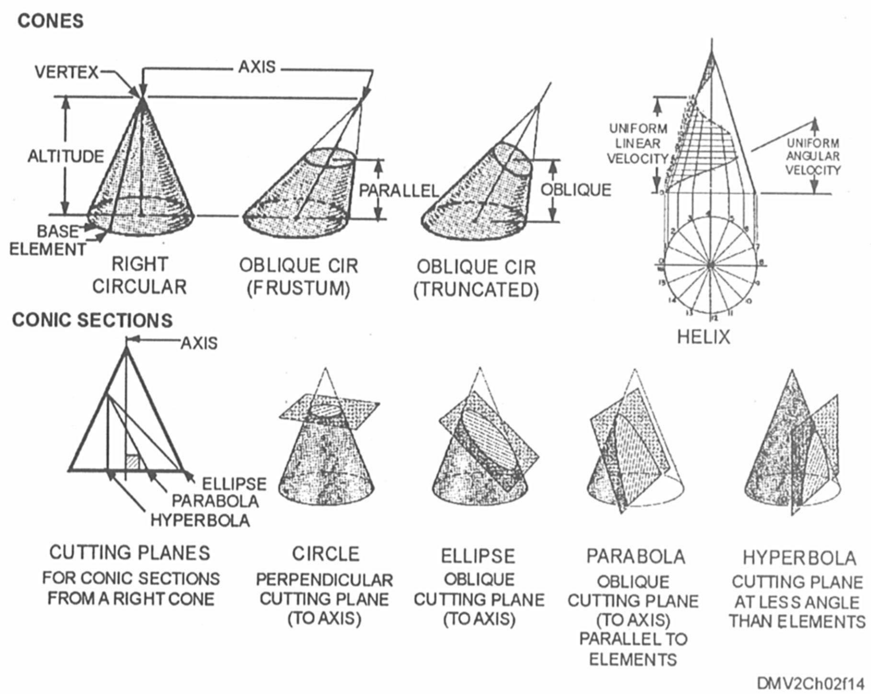

Figure 2-14.—Cone terminology.

Continued on next page

Solids (Continued)

Spheres are formed by a circle revolving around its diameter. The diameter of the circle then becomes the axis and the ends of the axis are known as *poles*.

Figure 2-15 shows a sphere, its axis, and its poles.

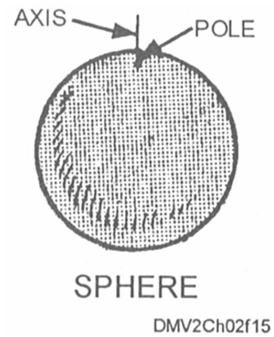

Figure 2-15.—A sphere.

A *torus* or *toroid* is formed by a circle or curve revolving around but not intersecting or containing an axis in its own plane. The axis of a torus is eccentric to the diameter of the circle or curve.

Figure 2-16 is an example of a torus.

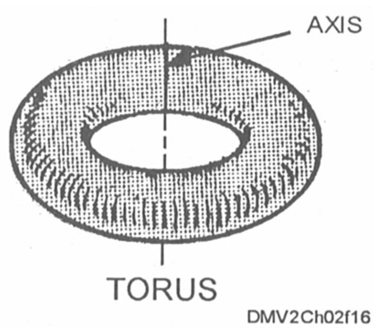

Figure 2-16.—A torus.

Continued on next page

Solids (Continued)

Ellipsoids are geometric surfaces whose plane sections are all ellipses or circles. *Oblate ellipsoids* have flattened surfaces at the poles. Ellipsoids flattened so that the altitude of the polar axis exceeds the equatorial diameter are called *prolate ellipsoids.*

Figure 2-17 shows the polar distortions of ellipsoids.

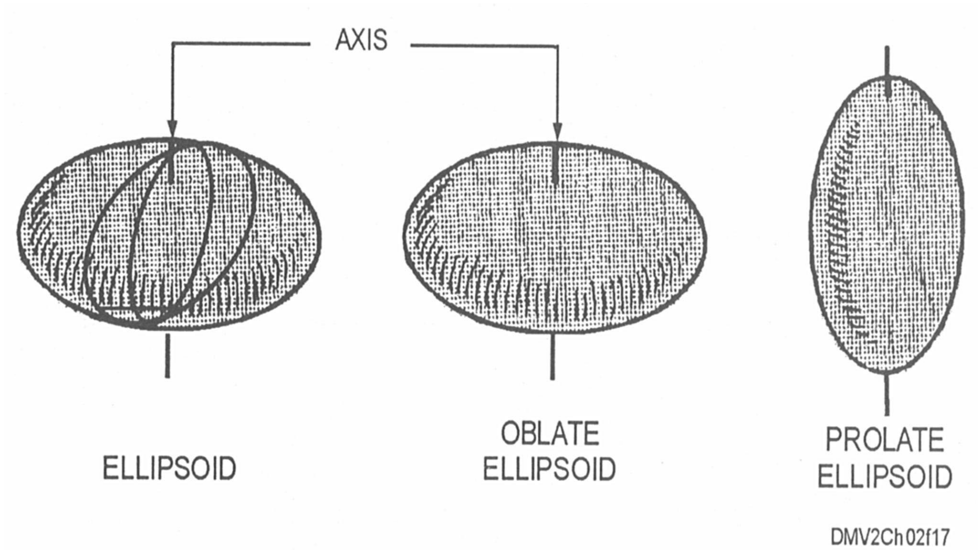

Figure 2-17.—Ellipsoids.

Bisection

Introduction

Problem solving with geometric constructions often involves dividing a given entity. Dividing geometric figures into two equal parts is called *bisecting*. The line that bisects the figure is known as a *bisector*. *You* should know how to bisect different geometric figures to accurately solve drafting problems.

Bisecting lines or circular arcs

To bisect a line or arc, use this table:

Step	Action
1	With a given arc or line (AB), use a compass set at a distance greater than half the distance of the given line and draw equal arcs above and below the given line.
2	Use a straightedge to join the intersections of the arcs. This straight line locates the center of the given line or arc.

Figure 2-18 shows how to bisect a line or arc.

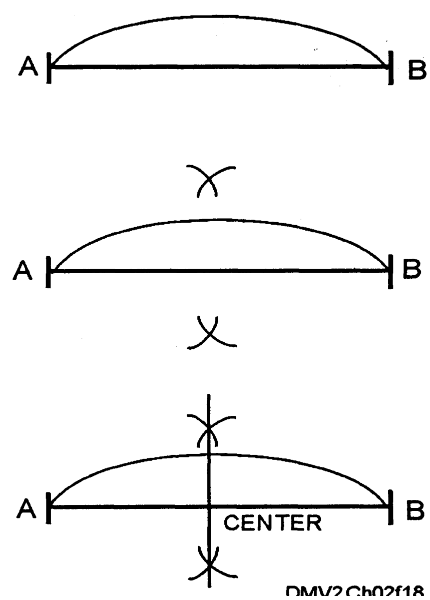

Figure 2-18.—Bisecting a line or arc.

Continued on next page

Bisecting angles To bisect an angle, use this table:

Step	Action
1	Given angle ABC, use a compass to draw an arc at any convenient radius from the apex.
2	Using the compass set at slightly more than half the distance from A to C and with the compass points at the intersections of the arc and angle legs (E and F), draw two short arcs that intersect at D.
3	Draw a straight line from A to D. This bisector divides the original given angle into two equal angles.

Figure 2-19 shows how to bisect an angle.

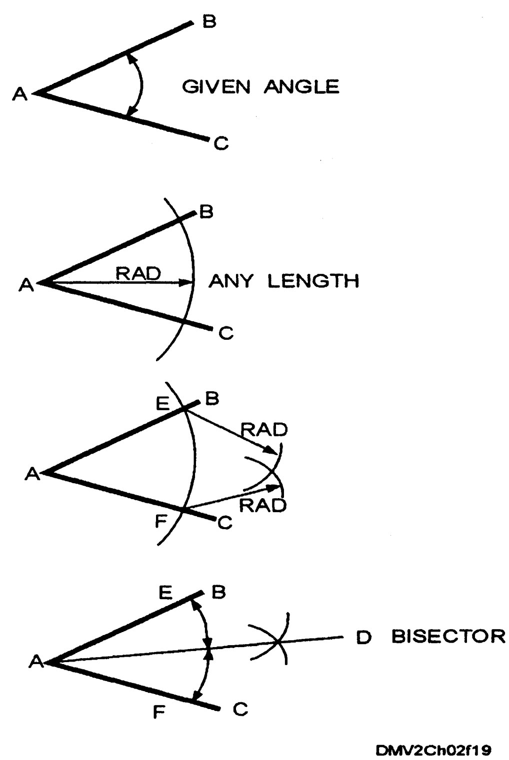

Figure 2-19.—Bisecting angles.

Division

Introduction

When you want two unequal portions or more than two equal portions of a line, you are dividing not bisecting. One of the most frequently executed geometric constructions is dividing a line into multiple equal or proportional parts.

Preferred method for dividing lines into equal parts

To divide a line into equal parts, use this table:

Step	Action
1	Given line AB, draw a perpendicular line (BC).
2	Place a scale or ruler with the first increment (0) at A.
3	Place the desired increment on the scale at the termination point of the perpendicular line (BC).
4	Make tiny pencil marks indicating the desired measurements along the scale.
5	Draw vertical construction lines perpendicular to the given line and parallel to each other. This divides the line into multiple equal increments.

Figure 2-20 shows the steps for the preferred method of dividing a line into multiple equal increments.

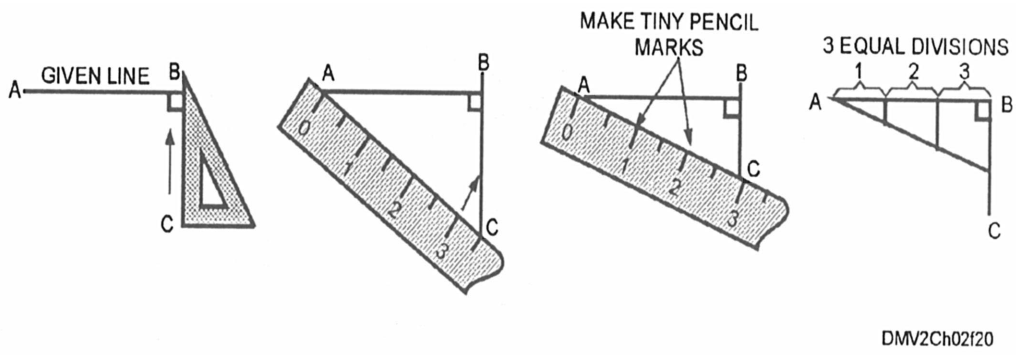

Figure 2-20.—Dividing a line into equal parts.

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Alternate method for dividing lines into equal parts

For an alternate method of dividing a line into equal parts, use this table:

Step	Action
1	Given line AB, draw a light line at any convenient acute angle from A.
2	Set off as many equal divisions as you require along the angled line with a scale or with a pair of dividers.
3	Connect the last increment with the end of the given line (B) with a triangle.
4	Using the same triangle, draw lines from the incremental points to the given line keeping all lines parallel to each other.

Figure 2-21 shows an alternate method for dividing lines into equal segments.

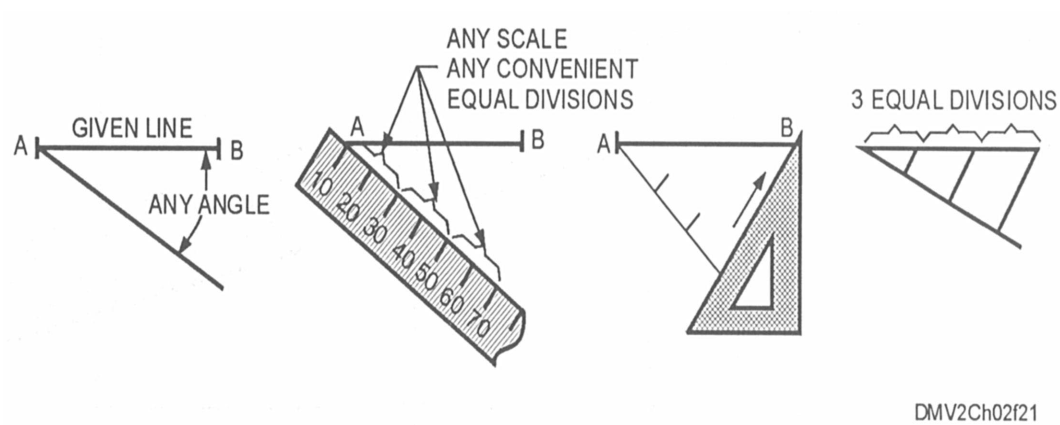

Figure 2-21.—An alternate method of dividing lines.

Continued on next page

Preferred method for dividing lines into proportional parts

To divide a line into proportional parts, use this table:

Step	Action
1	Given line AB, draw a perpendicular line at B.
2	Select any scale and set the first increment (0) at A.
3	Position the scale so that the total number of increments aligns with the perpendicular line at B.
4	Set off the desired increments with tiny pencil marks. In this case 2, 3, and 4 units are marked.
5	Draw vertical lines through these points to the given line.

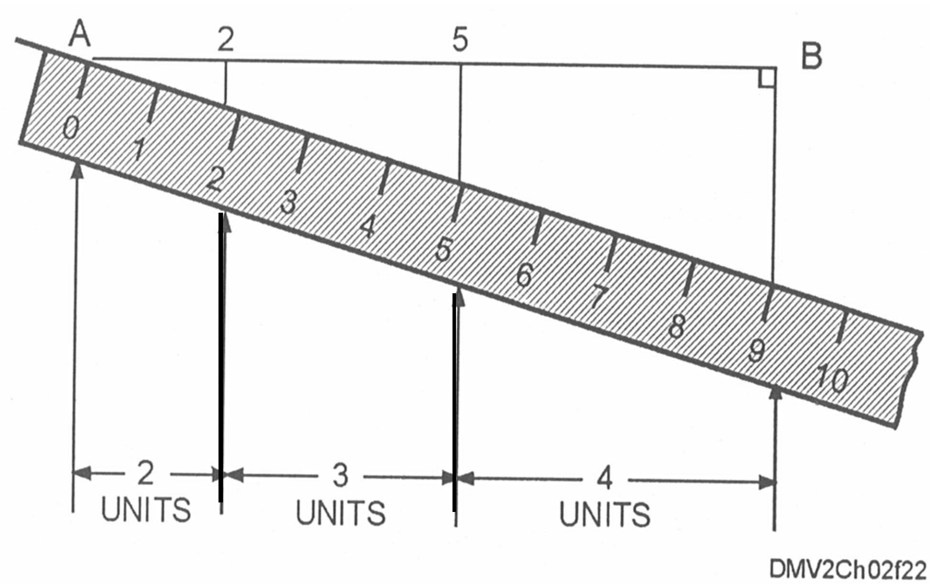

Figure 2-22.—Dividing lines proportionately.

Continued on next page

An alternate method of proportionally dividing lines into parts

For an alternate method of proportionally dividing lines, use this table:

Step	Action
1	Given line AB, draw another line (CD) at any distance below and parallel to the given line.
2	Set your scale along CD with 0 at endpoint C and set off the desired number of increments. Here the increments are 0, 2, 5, and 9.
3	With a straightedge, draw lines through endpoints A and C (0) and B and D(9) to intersect (0) any distance above AB.
4	Using your straightedge, connect lines 2 and 5 to 0.

Figure 2-23 is an alternate method for proportionally dividing lines.

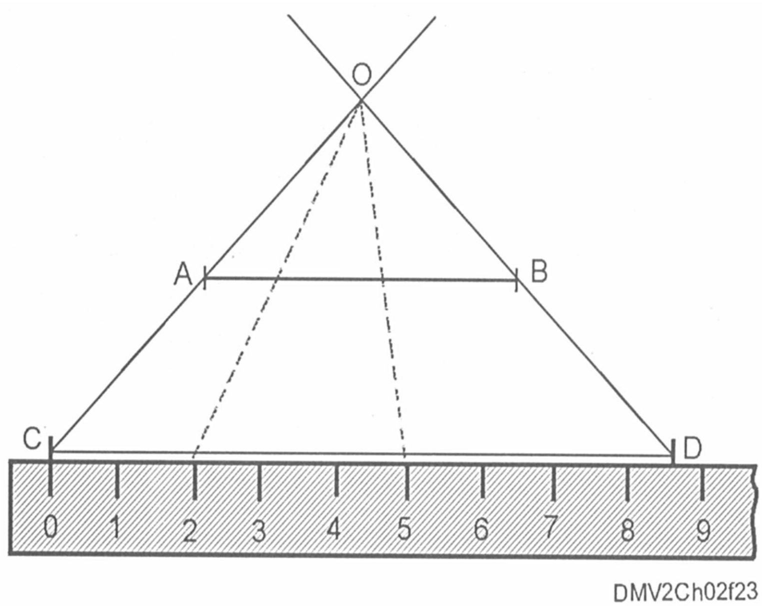

Figure 2-23.—An alternate method of dividing a line proportionately.

Transference

Introduction

At times you may need to move a geometric figure from one location to another on the same or different drawing paper. Transfer polygons, and irregular figures by first drawing a triangle, square, rectangle, or circle around the figure. You should know how to accurately transfer figures.

Transferring angles

To transfer an angle, use this table:

Step	Action
1	Given angle ABC, lay off a line equal to line AB at the new location on the same or different drawing paper (A’, B’).
2	Use any convenient radius (R, R’) and draw arcs using A and A’ as centers.
3	Where the arcs intersect lines AB and A’B’, draw two arcs (r, r’) equal to the distance between A and C.
4	Draw a straight line from A and A’ to the intersection of the two arcs R’ and r’.

Figure 2-24 illustrates how to transfer angles.

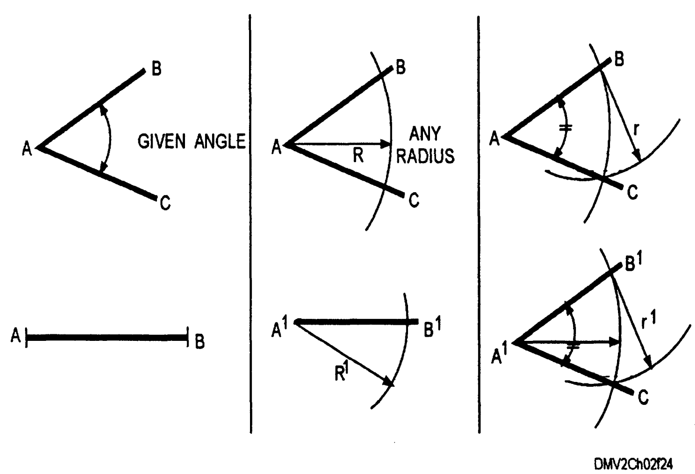

Figure 2-24.—Transferring angles.

Continued on next page

Transferring triangles

To transfer triangles to another location or drawing surface, use this table:

Step	Action
1	Given triangle ABC, set off any side (A’B’) in the new location.
2	Set the compass to the distance of line AC. Place your compass point at A’ and strike an arc.
3	Set the compass for the distance between AB. Place your compass point at B and strike an arc to intersect with the arc drawn from C’.
4	Draw straight lines from A’ to C’ and B’ to C’.

Figure 2-25 shows how to transfer a triangle.

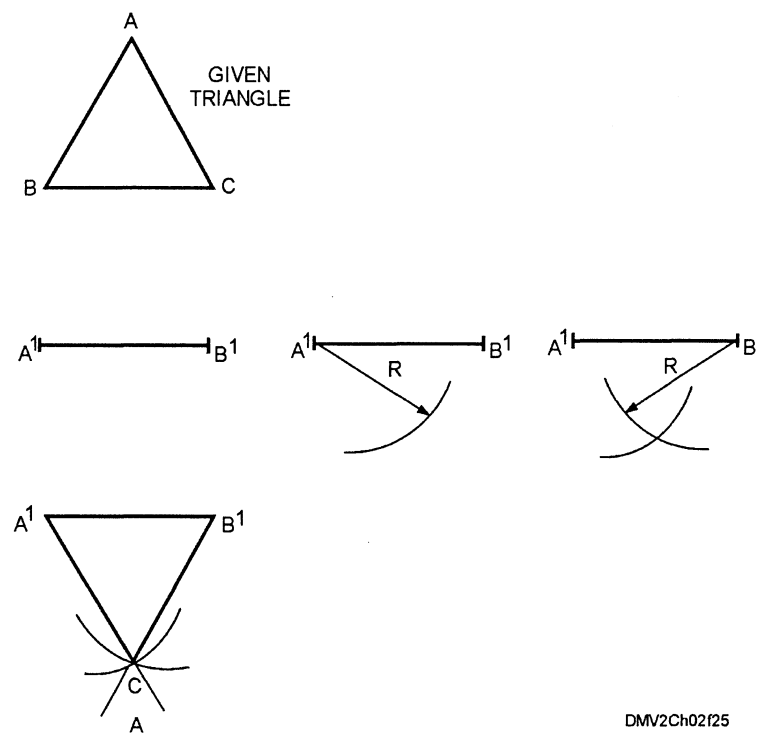

Figure 2-25.—Transferring triangles.

Tangency

Introduction

Tangent lines, arcs, circles, or surfaces are lines, arcs, circles, or surfaces that touch but do not intersect. When drawing irregular or noncircular curves with french curves, you plot a series of tangent arcs. When you indicate round corners on an otherwise straight plane, you are working with an arc that is tangent to two lines at right angles. Make sure all points of tangency are clearly defined before you begin inking.

To draw a circle tangent to a line

To draw a circle tangent to a line at a given point, follow this table:

Step	Action
1	Given line AB with point P representing the point of tangency, erect a perpendicular.
2	Set off the length of the radius of the required circle as a point on the perpendicular and mark it C.
3	Draw the circle using C as the center point and CP as the radius.

Figure 2-26 shows how to draw a circle tangent to a line.

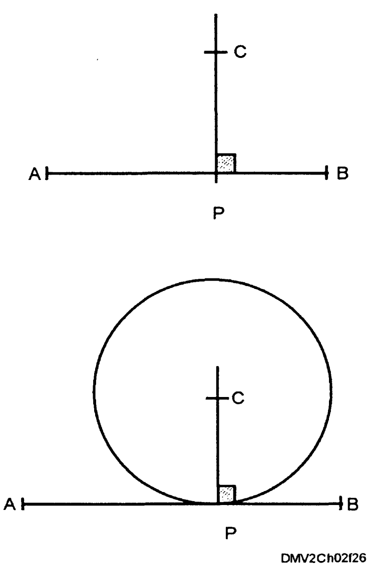

Figure 2-26.—A circle tangent to a line.

Continued on next page

To draw a line tangent to a circle through a point

To draw a tangent to a circle through a point. follow this table:

Step	Action
1	Given a circle with the intended point of tangency at P, move a triangle to a position where one side passes through the center of the circle and point P.
2	Slide the triangle across the straightedge until the opposite side of the triangle touches the circumference at P. If P is outside of the circle, place the triangle with one straight side passing from P to the circumference of the circle. Move the triangle over so that the opposing straight side passes through the center of the circle and intersects the circumference of the circle. Mark this T for point of tangency. Return the triangle to the first position.
2	Draw the required tangent.

Figure 2-27 shows the process for drawing a line tangent to a circle through a given point.

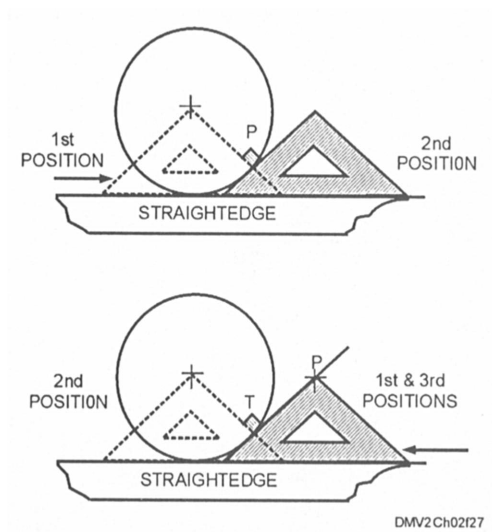

Figure 2-27.—A line tangent to a circle.

Continued on next page

To draw tangents to two circles

To draw tangents to two circles, follow this table:

Step	Action
1	Given two circles with centers marked C1 and C2, move a triangle or straightedge to connect the centerlines.
2	Place a triangle at the upper arcs of the circles until one side of the triangle touches both circles C1 and C2. Draw a line tangent to the circles.
3	Draw a perpendicular line from the points of tangency to the centerlines of the circles.
4	Repeat this procedure for the bottom arcs of the two circles.

Figure 2-28 shows how to draw tangents to two circles.

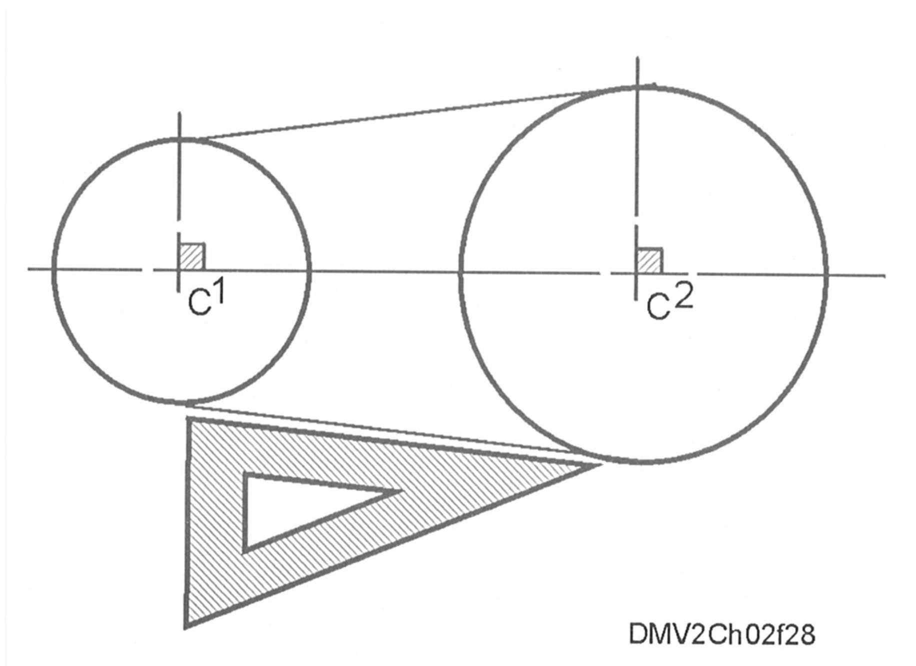

Figure 2-28.—Drawing tangents to two circles.

Continued on next page

To draw an arc tangent to two lines at right angles

It is impractical to draw small radii arcs by tangency construction. For small radii or radii up to 5/8ths inch, draw a 45° bisector of the angle and locate the arc by trial and error. You may also use a circle template so long as the diameter of the circle precisely equals twice the required radius.

To draw an arc tangent to two lines at right angles. follow this table:

Step	Action
1	Given two lines at right angles to each other, strike an arc at a selected radius intersecting the lines at tangent points T.
2	With the same selected radius and using points T as centers, strike another arc to intersect at a point C.
3	With C as a center, use the selected radius to draw the required tangent arc.

Figure 2-29 shows the process for drawing an arc tangent to two lines at right angles.

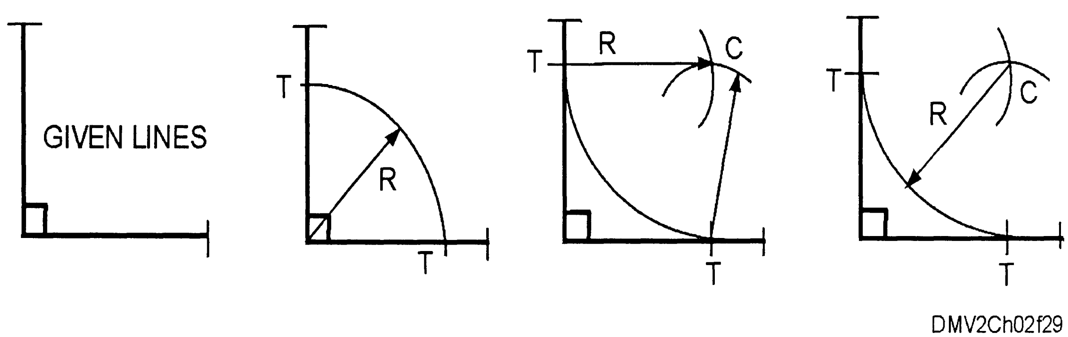

Figure 2-29.—Drawing an arc tangent to a right angle.

Continued on next page

To draw an arc tangent to two lines at acute or obtuse angles

To draw an arc tangent to two lines at acute or obtuse angles, follow this table:

Step	Action
1	Given two lines not at right angles (either greater than (obtuse) or less than (acute) 90°), draw lines parallel to the given lines at a distance that equals the desired radius of the required arc.
2	At the intersection of the parallel lines (C), draw perpendicular lines to locate tangent points T.
3	With C as the center and R as the radius of the required arc, draw the required arc between the points of tangency.

Figure 2-30 shows a tangent arc between acute and obtuse angles.

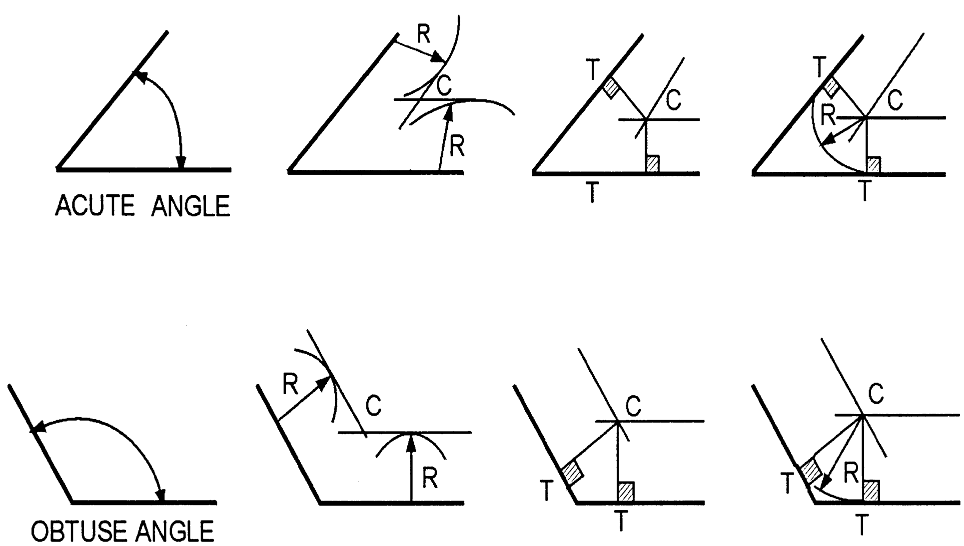

Figure 2-30.—Tangent arcs for acute and obtuse angles.

Continued on next page

To draw an arc tangent to two arcs

To draw an arc tangent to two arcs, follow this table:

Step	Action
1	Given arcs with centers A and B, and a required radius R, draw arcs parallel to the given arcs and at a distance that equals R.
2	Label the intersection of these arcs C since this is the center of the required tangent arc.
3	Draw lines from the centers A and B to C to locate points of tangency T.
4	Draw the required arc with a radius of R to the points of tangency.

Figure 2-31 shows the process of drawing a tangent arc to two arcs.

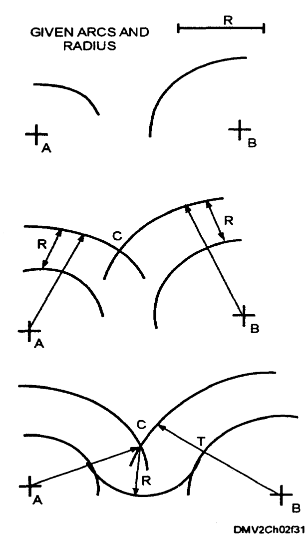

Figure 2-31. —Drawing an arc tangent to two arcs.

Clearly this section does not cover all situations of tangency but shows that the problems have mathematical solutions. Refer to texts in basic drafting for more complete coverage of tangential problem solving.

Polygonal Construction

Introduction

Polygons are the most common geometric constructions. A thorough understanding of these basic constructions enhances the novice draftsman's ability to draw accurately and to become more familiar with drafting instruments. Before beginning to draw polygons, you must understand the circumscribed and inscribed methods of drawing geometric constructions.

Circumscribed method

The *circumscribed method* of drawing polygonal constructions is a process by which the geometric figure is drawn inside a circle. The circle surrounds and defines the figure. The measurements for various planes or surfaces of the geometric figure are drawn *across the corners* or horizontal diameter of the circle.

Figure 2-32 is a square circumscribed by a circle.

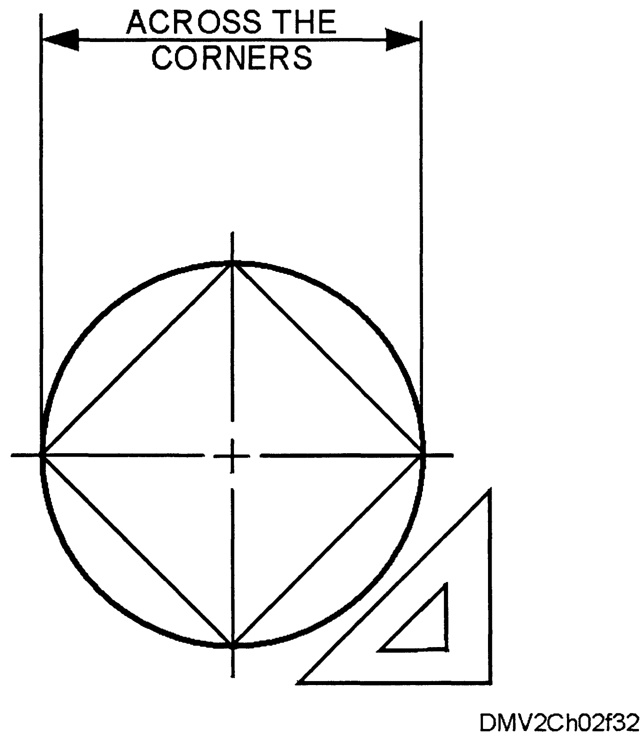

Figure 2-32.—A square circumscribed by a circle.

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Inscribed method

Drawing geometric figures around a circle is known as the *inscribed method* of polygonal construction. The circle is inside the figure and the sides of the geometric figure are tangential to the circle circumference. The diameter of the circle is measured at a 45° angle to the horizontal. Measurements for figure construction is made from the diameter or *across the flats.*

Figure 2-33 shows the construction of a square using the inscribed method.

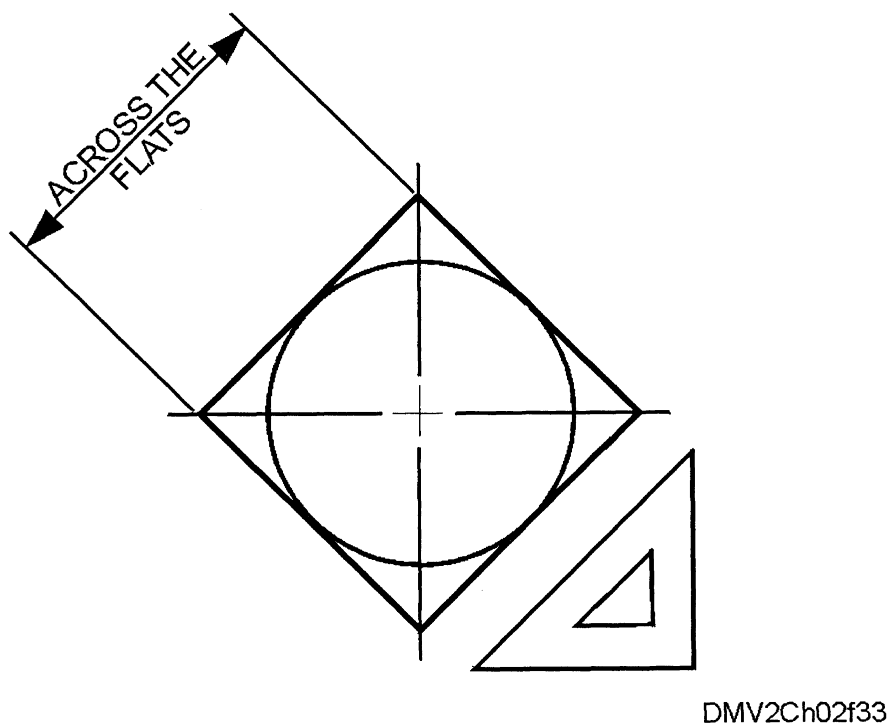

Figure 2-33.—A circle inscribed by a square.

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Angles

The most convenient method of laying out an angle is by using a triangle or a protractor. When absolute accuracy is important, use the tangent, sine, or chord method. A table of trigonometric tables listing tangent, sine, and chord values is located in the back of this book.

TANGENT METHOD: The *tangent method* of angle construction is a trigonometric function of an acute angle to find the ratio of the length of the side opposing the angle to the length of the side adjacent to the angle. In figure 2-34, the tangent of angle ∅ is y/x, and $y=x$ tan ∅ . To construct the angle, assign a simple value to x, in this case 10. The larger the number, the more accurate the construction. Find the tangent of angle ∅ in a table of natural tangents, multiply by 10 and set off y = 10 tan ∅.

Figure 2-34 is an angle constructed by the tangent method.

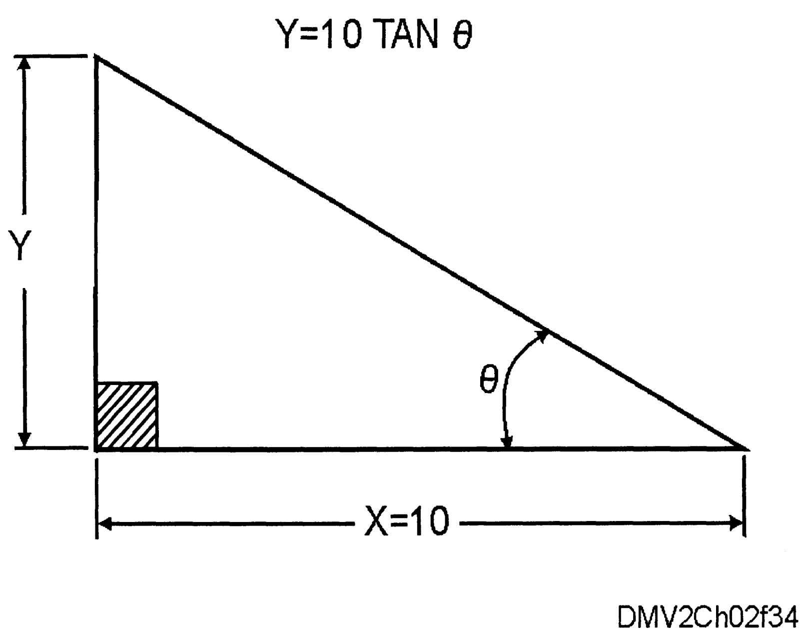

Figure 2-34.—The tangent method of angle construction.

Continued on next page

Angles (Continued)

SINE METHOD: The *sine method* of angle construction is another trigonometric function of the acute angle that is the ratio of the opposite side to the hypotenuse of a right triangle. Draw line *x* to any convenient length, again we will use 10. Find the sine of angle ∅ in a table of natural sines, multiply by 10, and strike *R*= 10 sin ∅. Draw the other side of the angle tangent to the arc.

Figure 2-35 is an angle drawn by the sine method.

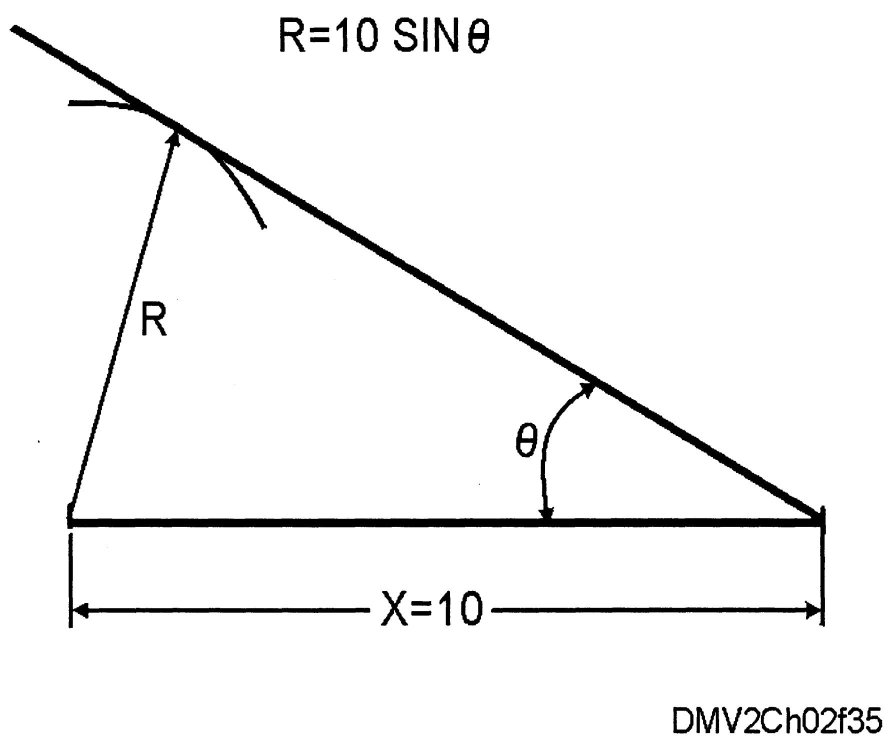

Figure 2-35.—The sine method of angle construction.

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Angles (Continued)

CHORD METHOD: The *chord method* of angle construction refers to the joining of two points on a curve by a line. Draw line x at any length and draw an arc at any radius, again let R= 10. Find chordal length C in the table of chords and multiply the value by 10. If a table is not available, calculate chordal value with the formula C = 2 sin ∅/2.

Figure 2-36 is an angle drawn by the chord method.

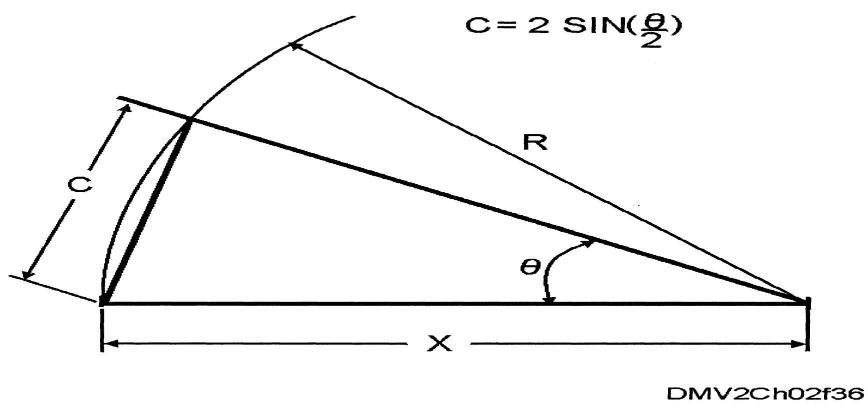

Figure 2-36.—The chord method of angle construction.

Continued on next page

Triangles

The preferred method of drawing triangles is with triangles or a protractor.

To draw triangles using triangles, use this table:

Step	Action
1	Select a triangle that contains the angles required to draw the triangle. For example, select a 30/60/90° triangle to draw an equilateral triangle where each angle equals 60°.
2	Draw a perpendicular line to the center of AB.
2	With given horizontal line AB, place the triangle base edge against the straightedge of your drafting table with the 60° angle at A.
3	Draw line AC to the perpendicular line.
4	Flip the triangle over to place the 60° angle at the base of the triangle at B and against the straightedge of your table.
5	Draw line BC. Lines AC and BC should intersect above the center of line AB and form a 60° angle to complete the equilateral triangle.

Figure 2-37 shows the construction of an equilateral triangle using a 30°/60°/90° triangle.

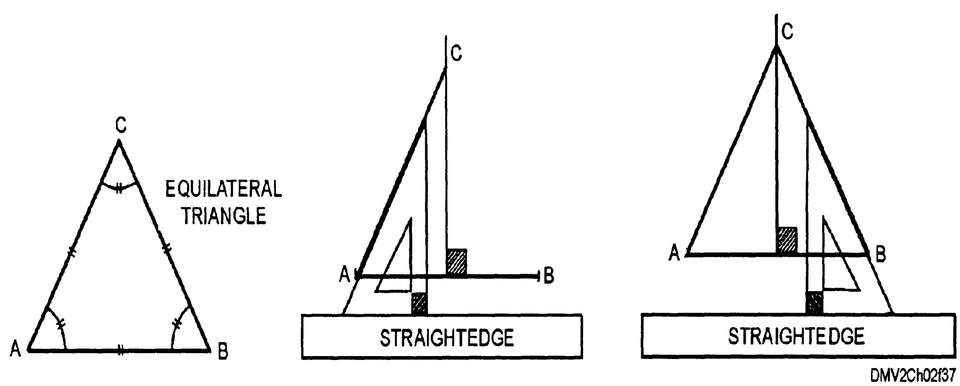

Figure 2-37.—Constructing an equilateral triangle.

Continued on next page

Triangles (Continued)

You may also use a protractor to construct triangles.

To use a protractor or semicircular protractor to construct an equilateral triangle, use this table:

Step	Action
1	With a straightedge, draw a line (AB) at any convenient length and a perpendicular line at the center.
2	Place the center of the protractor (usually marked 0) at A, align the protractor with the line AB.
3	Locate the 60° increment on the protractor and lightly mark your paper. If using a full circular protractor, you can increase accuracy by also locating and marking the opposing angle. This allows you to use the four-point reference system (*DM Volume 1,* chapter 2).
4	Move the protractor to B on line AB. Locate and mark the drawing at the 60° increment. Also mark the opposing angle , if possible.
5	Draw straight lines through the marked increments terminating at the perpendicular line. These lines should intersect forming an equilateral triangle.

Figure 2-38 shows an equilateral triangle constructed by using a protractor.

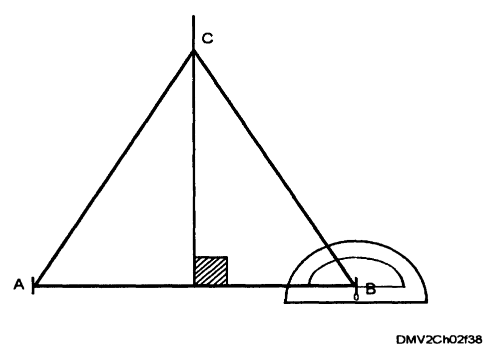

Figure 2-38.—Constructing an equilateral triangle with a protractor.

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Triangles (Continued)

You may use an alternate method of constructing triangles if triangles and protractors are not available.

To draw an equilateral triangle using an alternate method of construction, use this table:

Step	Action
1	Draw straight line AB the length of the base of your equilateral triangle.
2	Using the length of AB as a radius, strike an arc with A and with B as a center.
3	These arcs will intersect at C.
4	Draw straight lines from A to C and B to C to complete the triangle.

Figure 2-39 illustrates the process for constructing an equilateral triangle with an alternate method.

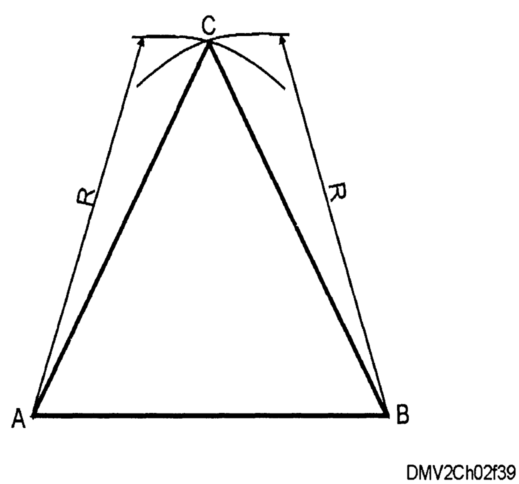

Figure 2-39.—Using a compass to construct an equalateral triangle.

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Squares

You may use triangles or protractors to construct squares. You may also construct a square using the circumscribed or inscribed method of construction.

To construct squares using the circumscribed method, use this table:

Step	Action
1	Draw horizontal and vertical lines intersecting at right angles to each other.
2	Using the intersection of these lines as a center, draw a circle of a diameter that equals the distance from one corner of the square to the opposing corner.
3	Where the circle intersects the horizontal and vertical centerlines, use a 45° triangle to draw connecting lines to form the square.

Figure 2-40 shows a square constructed using the circumscribed circle method.

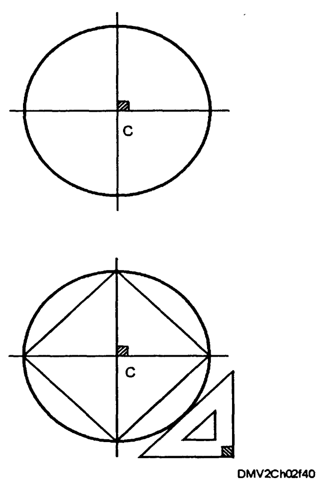

Figure 2-40. —Constructing a square using the circumscribed method.

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Squares (Continued)

To construct a square using the inscribed circle method, use this table:

Step	Action
1	Draw horizontal and vertical lines intersecting at right angles to each other.
2	Using the intersection of these lines as a centerline, draw a circle with a diameter equal to the distance between two opposing sides of the square.
3	Use a 45° triangle to draw straight lines tangent to the circumference of the circle and intersecting each other at 90°.

Figure 2-41 shows the construction of a square using an inscribed circle.

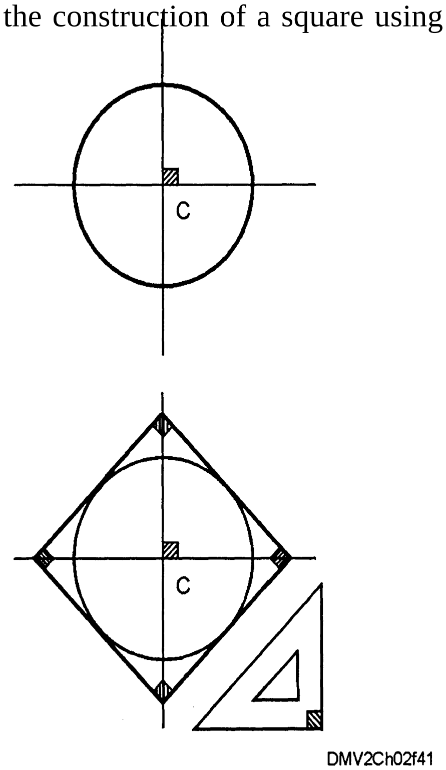

Figure 2-41.—Constructing a square using the inscribed method.

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Polygons composed of five or more sides

You can construct polygons composed of more than five sides using combinations of triangles, a pair of dividers, or a protractor. You may also circumscribe or inscribe multisided polygons in a square or circle. Always draw horizontal and vertical lines intersecting at right angles to each other first. Use the intersection of these lines as a center point for drawing circles or squares. The method for constructing multisided polygons with a pair of dividers is least accurate. The process requires you to estimate and lay out by trial and error equal portions along the circumference of the circle.

Figure 2-42 shows a pentagon constructed using a pair of dividers.

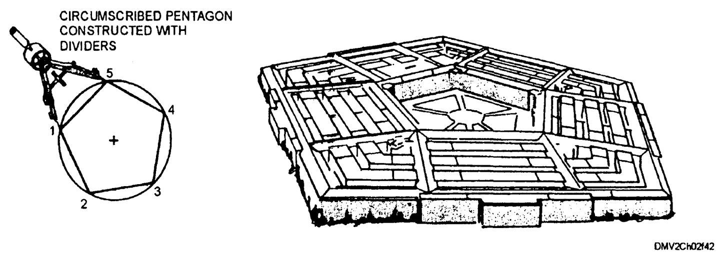

Figure 2-42.—The pentagon.

When using triangles to construct multisided polygons, you are limited to geometric figures that can be divided into angles that correspond to one of the 11 angles measurable by a triangle or combination of triangles such as hexagons (60°) and octagons (45°).

Figure 2-43 illustrates how to use triangles to construct a hexagon.

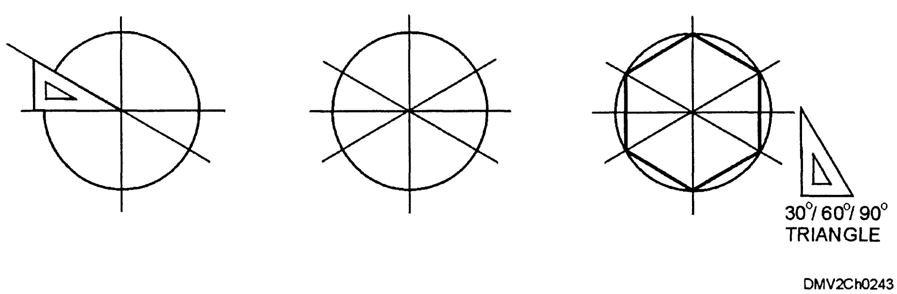

Figure 4-43.—A hexagon.

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Polygons composed of five or more sides (Continued)

Using a protractor to construct multisided polygonal figures requires you to mathematically compute the common angle using a formula. The formula divides the 360° of a circle by how ever many sides the polygon requires. For example, a heptagon or seven-sided polygonal figure requires a common angle of 51.3° (360° ÷ 7 = 51.3°).

Figure 2-44 shows a nine-sided (360° ÷ 9 = 40°) polygon.

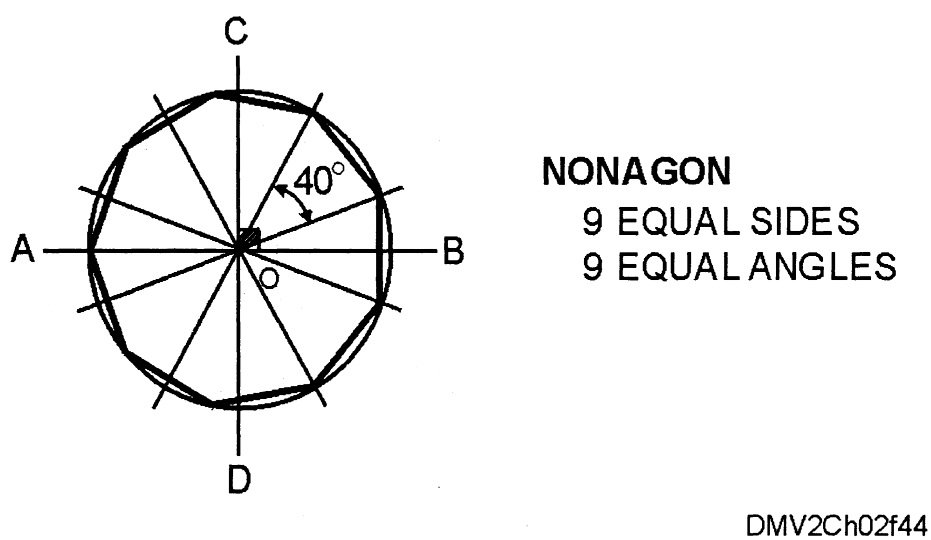

Figure 2-44.—A nongon.

Ellipse Construction

Introduction

Although ellipse templates greatly reduce construction time for an ellipse, you should know how to construct an ellipse using other methods. You may use the foci, trammel, concentric diameter, conjugate diameter, or circumscribed parallelogram method of ellipse construction.

Ellipses

An ellipse is created by moving a point so that the sum of its distances from two points (the foci) is constant and equal to the major axis. The foci serve as focal points for the rotation of the circumferential points. The major axis is its longest diameter. The shortest diameter is the minor axis. The ellipses formed is a basic, uniform, noncircular, closed curve. An ellipse may also be a conic section if formed by an oblique cutting plane on a solid.

Figure 2-45 shows ellipse terminology.

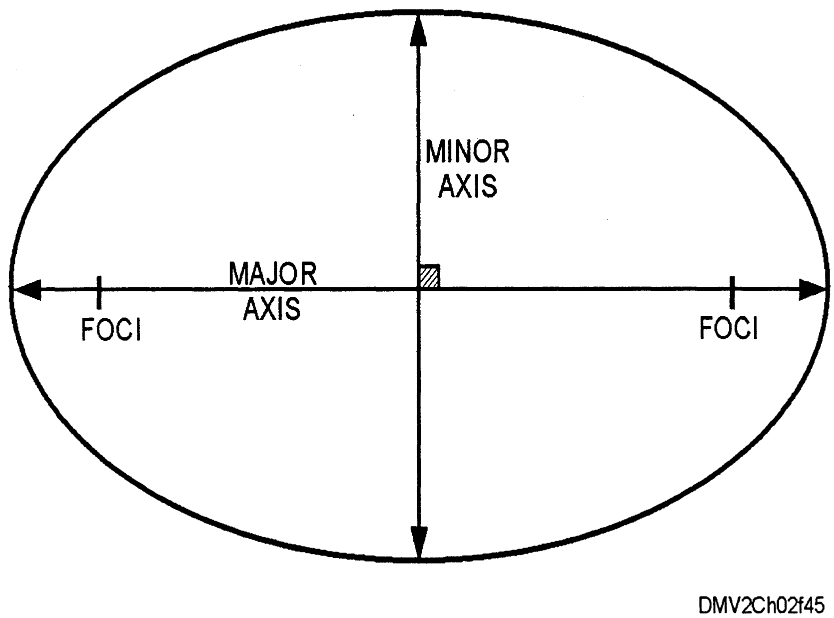

Figure 2-45.—Ellipse terminology.

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Determining foci

To determine the foci of an ellipse, strike arcs with a radius equal to half the major axis and with the center at the end of the minor axis. Another method is to draw a semicircle with the diameter equal to the major axis of the ellipse. Then draw GH parallel to the major axis. Draw GE and HF parallel to the minor axis.

Figure 2-46 show how to determine foci.

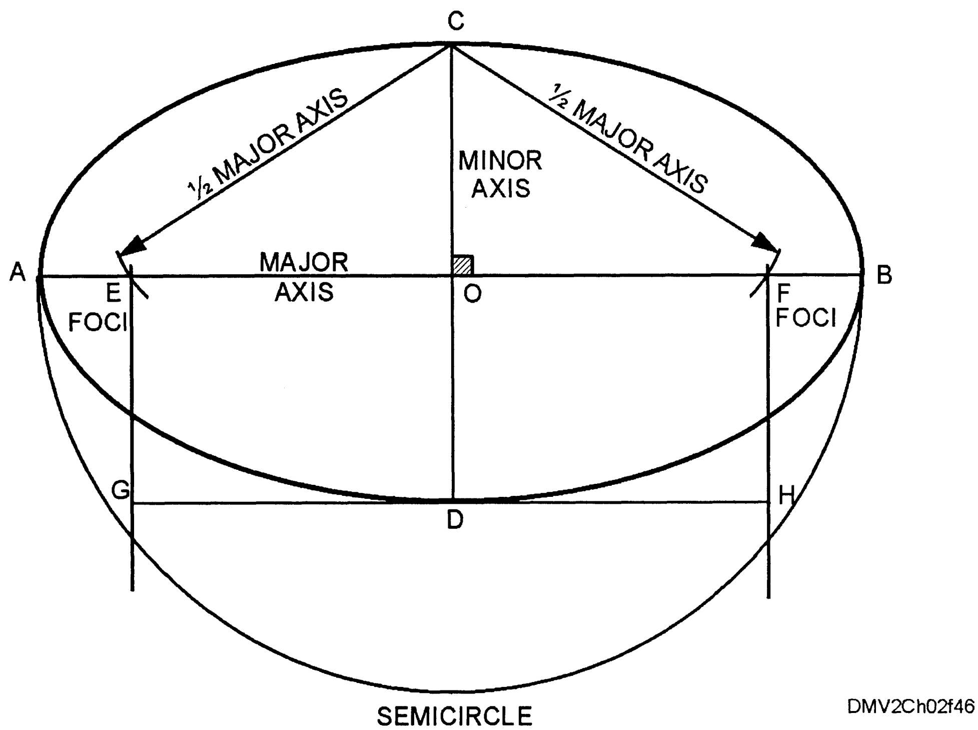

Figure 2-46.—Determining foci.

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Foci method

The *foci method* of ellipse construction involves plotting a series of points along the circumference of the ellipse by drawing a series of intersecting arcs using the foci on the major axis as centers.

To construct an ellipse using the foci method, use this table:

Step	Action
1	Lay out horizontal (AB) and vertical axes (CD) that intersect at right angles (0).
2	Locate the foci (F, F') by setting the compass to one half distance of the major axis AB and striking arcs along AB using C as the center.
3	Mark a minimum of five equal distances between F and 0. The more distances marked, the more accurate the ellipse construction.
4	Set the compass for the distance from A to 1. Strike arcs above and below line AB using 1 and F' as centers.
5	Set the compass for the distance A to 2. Strike arcs above and below AB using 2 and F' as centers. Continue plotting points this way until all five points form an ellipse circumference between CB and BD.
6	Mark a minimum of five equal distances between 0 and B.
7	Plot the five points forming an ellipse circumference between CA and AD using the same previous procedure but in reverse using F as the center.
8	Once all points are plotted, connect the points using french curves.

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Foci method (Continued)

Figure 2-47 illustrates the procedure for constructing an ellipse using the foci method.

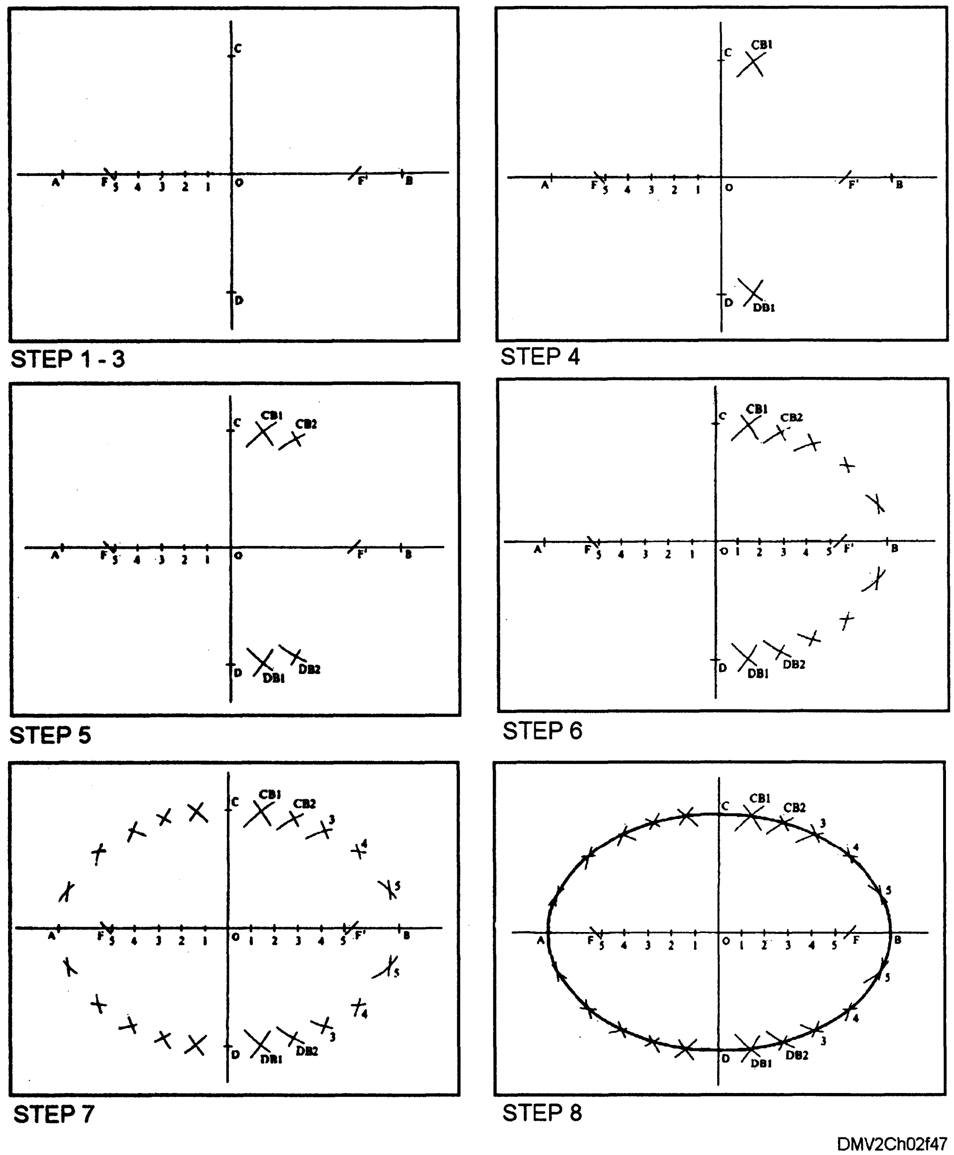

Figure 2-47.—Creating an ellipse by the foci method.

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The trammel method

The *trammel method* of ellipse construction involves plotting a series of points by using a strip of paper, cardboard, plastic, or straightedge marked with two foci and rotating the strip up, down, and around horizontal and vertical axes. The strip or length of paper or cardstock is a *trammel.* The trammel has three marks, two representing the foci and one representing the ellipse circumference.

To construct an ellipse using the trammel method, use this table:

Step	Action
1	Lay out horizontal (AB) and vertical (CD) axes that intersect at right angles (0).
2	Determine the minor and major axes and the foci of the intended ellipse.
3	On a strip of paper or cardstock, lay off distance GE representing half the length of the minor axis and GF representing half the length of the major axis.
4	Set the trammel on the drawing so that E is always traversing AB and F is moving along CD.
5	As you move the trammel, plot points at G which will always indicate the circumference of the ellipse.

Figure 2-48 shows the position of a trammel as you construct an ellipse.

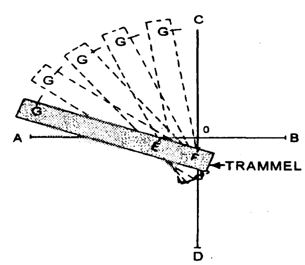

Figure 2-48.—The trammel method ellipse construction.

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Concentric diameters method

In the *concentric diameters method* of ellipse construction, you use the major and minor axes as diameters for concentric circles on a common horizontal and vertical axis intersecting at right angles. By drawing a diagonal across both circles and plotting subsequent points, you can construct an ellipse.

To construct an ellipse using the concentric diameters method, use this table:

Step	Action
1	Draw horizontal (AB) and vertical (CD) axes that intersect at right angles (0).
2	Using the length of the major and minor axes as diameters, lay out two concentric circles with 0 as a common center.
3	Draw a diagonal (XX) at any common angle through the circumferences of both circles passing through 0. Every diagonal drawn provides you with four points along the circumference of the ellipse.
4	From points X, draw lines XS parallel to CD and perpendicular to AB.
5	Where XX intersects the smaller circle, draw HE parallel to AB and perpendicular to CD.
6	Draw as many diagonals you feel necessary to adequately define the ellipse.
7	Lightly sketch the ellipse through the points. Darken the outline of the ellipse using french curves.

Continued on next page

Conjugate diameter method (Continued)

Figure 2-49 illustrate the concentric circle method of ellipse construction.

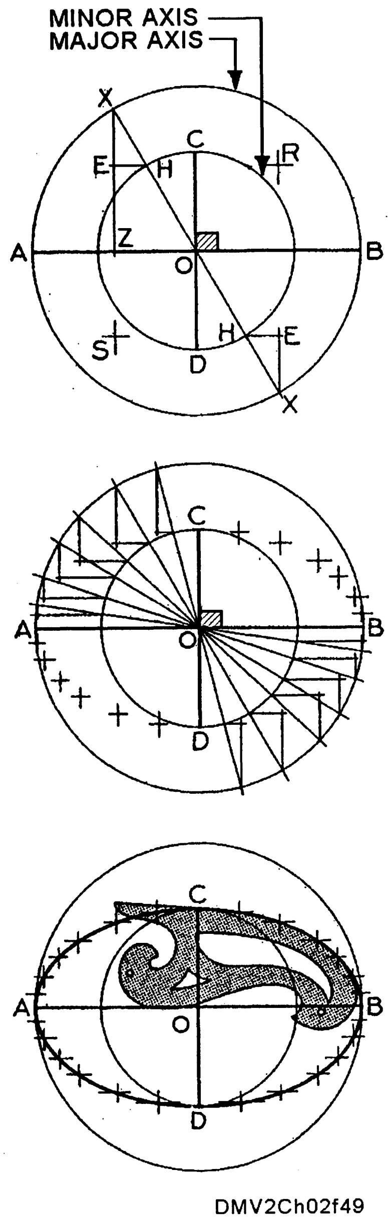

Figure 2-49.—Concentric circle method of ellipse construction.

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Conjugate diameter method

The *conjugate diameter method* of ellipse construction uses conjugate diameters to project a circle and through a series of tangents, plot points on the circumference of the ellipse.

To construct an ellipse using conjugate diameters, use this table;

Step	Action
1	Given two conjugate diameters (AB and DE) with C as a center, use the distance from C to A as a radius to draw a circle with C as the center.
2	Draw line (GF) perpendicular to AB and passing through C.
3	Draw lines connecting points D and F and points G and E.
4	Select any point (X) along AB and draw a line (PQ) parallel to DE and RS parallel to FG.
5	Determine at least five points to each quadrant. For larger ellipses, plot more points. The more points plotted the more accurate the ellipse circumference.
6	Lightly sketch the outline of the ellipse. Darken the ellipse using french curves.

Figure 2-50 illustrates the conjugate diameter method of ellipse construction.

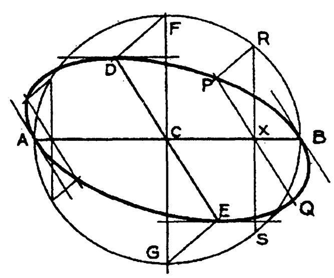

Figure 2-50.—The conjugate diameter method.

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Parallelogram ellipses

The *parallelogram method* of constructing ellipses inscribes the ellipse within a parallelogram. You may use conjugate diameters or the major and minor axes to formulate the parallelogram so long as the sides of the parallelogram are parallel to the diameters or axes.

To draw an ellipse by the parallelogram method, use this table;

Step	Action
1	Given the major and minor axes or the conjugate diameters AB and CD, draw a rectangle or parallelogram . Make sure all sides are parallel to their respective sides.
2	Divide the distance between AO and AJ into the same number of equal parts.
3	Starting at the ends of the minor axis CD, lightly draw straight lines through each point. The lines intersect forming the circumference of the ellipse.
4	Lightly sketch the outline of the ellipse. Darken the outline using french curves.

Figure 2-51 illustrates the procedure for drawing an ellipse inscribed within a parallelogram.

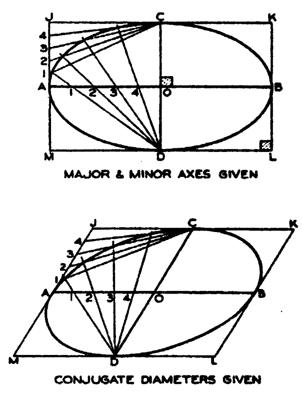

Figure 2-51.—The parallelogram method.

Involutes

Introduction

Some geometric figures are not bound by straight lines and arcs. They have no closed form but continue to spiral. This type of geometric figure is called an involute. Gear teeth and interlocking mechanisms are often depicted using this type of figure.

Involutes

An *involute* is the path of a point on a string as it unwinds from a line, polygon, or circle. Involutes are compound tangential arcs and semicircles of increasing larger diameters formed by lines, triangles, squares, and circles.

Involute of a line

To draw an involute of a line, use this table:

Step	Action
1	Given line AB, use line AB as a radius and B as a center to draw a semicircle AC.
2	Use AC as a radius and A as a center to draw another semicircle CD.
3	With BD as a radius and B as a center, draw semicircle DE.
4	Continue to repeat this pattern until the drawing is complete. Darken all outlines.

Figure 2-52 is an example of an involute of a line.

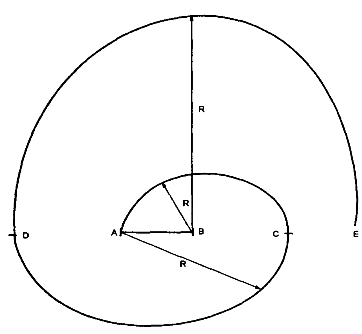

Figure 2-52.—The involute of a line.

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Involute of a triangle

To draw an involute of a triangle, use this table:

Step	Action
1	Given triangle ABC, extend the sides of the triangle to any convenient length.
2	Using CA as a radius and C as a center, strike arc AD terminating at the intersection of the extension BD.
3	With BD as a radius and B as a center, strike arc DE.
4	With AE as a radius and A as a center , strike arc EF.
5	Repeat this procedure until you reach a figure of the desired size.

Figure 2-53 is an example of an involute of a triangle.

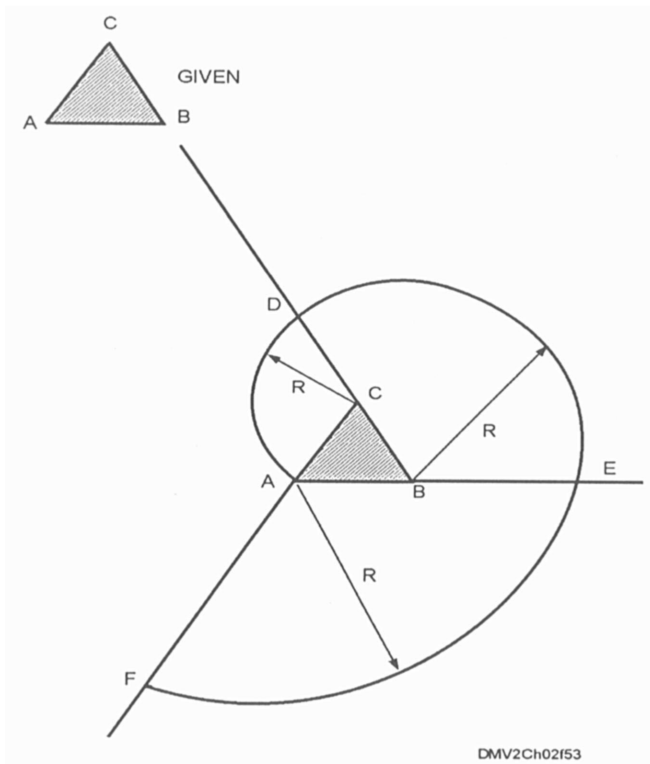

Figure 2-53.—The involute of a triangle.

Continued on next page

Involute of a square

To draw an involute of a square, use this table:

Step	Action
1	Given square ABCD, extend all sides any convenient length.
2	With CA as a radius and C as a center, draw arc AE.
3	With DE as a radius and D as a center, draw arc EF.
4	Repeat this procedure until you complete a figure of the desired size.

Figure 2-54 is an example of an involute of a square.

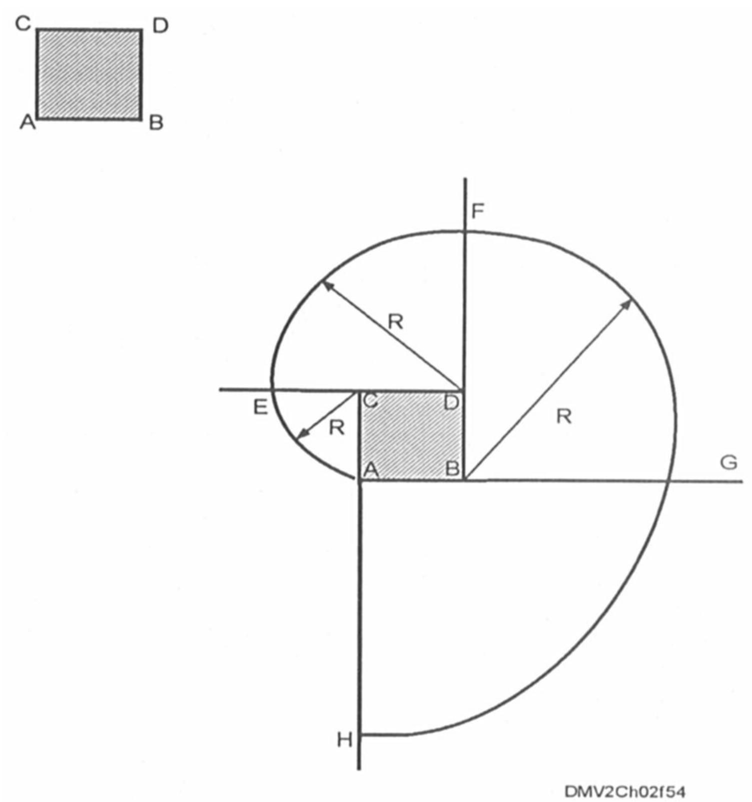

Figure 2-54.—An involute of a square.

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Summary, Continued

Review

This chapter begins with basic definitions of geometric figures. Explanations in the terminology and construction of two-dimensional figures such as lines, points, angles, triangles, quadrilaterals, and polygons form the foundation to understanding more the advanced geometric constructions of polyhedrons and solids. Bisection, division, transference, and tangency are all problem solving techniques that help you in advanced drafting situations. Polygonal, ellipse, and involute construction techniques should help to simplify geometric figure construction.

Comments

Geometric Construction is all about definitions. If you do not know the definitions in this chapter, study this chapter carefully and understand the terminology before you proceed into other chapters.

Once past the definitions, actual construction of geometric figures are simply, logically, and mathematically solvable. Geometric figure construction exercises your abilities to mentally solve problems and physically use drafting instruments to draw the solutions to problems on paper in a universally understood graphic language.

Geometric constructions are equally valid concepts whether you are drawing in pencil on paper or sitting at a computer drawing on a monitor screen.

CHAPTER 3

GENERAL DRAFTING PRACTICES

Overview

Introduction

Before 1955, Navy draftsmen were divided into six specialties: mechanical (DMM), structural (DMS), electrical (DME), topographical (DMT), lithographic (DML), and illustrative (DMI). Over the years, lithographic draftsmen became Lithographer's Mates (LI) and the draftsman rating polarized into two distinct camps referred to as straight-line draftsmen and illustrative draftsmen. Straight-line draftsmen formed the construction rating Engineering Aid (EA) and artists formed the Illustrator Draftsman (DM) rating. DMs maintain strong ties to their mechanical/mathematical foundations even today. Because a good draftsman is rarely unemployed, you should learn the fundamentals of drafting to improve your skills and marketability.

Objectives

The material in this chapter enables you to do the following:

- Define standard drafting terminology.
- Identify drafting standards and practices.
- Follow the standard order of inking.
- Identify common line conventions.
- Differentiate between line resolutions.
- Correctly dimension drawings with multiple parallel dimensions.
- Dimension radii and other rounded surfaces.
- Define tolerance and the differences between size, allowance, and fit.
- Understand the basic hole and basic shaft theory.
- Select regular and necessary views.

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Acronyms

The following table contains a list of acronyms you must know to understand the material in this chapter:

Acronym	Meaning
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
CAD	Computer-Aided Drafting
CADD	Computer-Aided Design Drafting
CAM	Computer-Aided Mechanical Drafting
CBORE	Counterbore
CDRILL	Counterdrill
CSK	Countersink
DOD-STD	Department of Defense Standards
DIA	Diameter
MIL-STD	Military Standards
PLS	Places
RAD or R	Radius
REF	Reference
SECT	Section
SF	Spotface
THRU	Through
TYP	Typical

Continued on next page

Overview, Continued

In this chapter

This chapter covers the following topics:

Drafting Definitions

Introduction

You should understand the definitions of a few terms before continuing.

Definitions

Most drawings fall into one of six basic categories, which include instrumental or mechanical drawings, computer-aided drafting or computer-aided design and drafting, engineering drawings and engineering drafting, engineering graphics or engineering design graphics, technical drawings, and technical sketching.

INSTRUMENTAL OR MECHANICAL DRAWINGS: The category of instrumental or mechanical drawings applies only to drawings made in whole or in part with drawing instruments.

COMPUTER-AIDED DRAFTING (CAD) and COMPUTER-AIDED DESIGN AND DRAFTING (CADD): Using computer techniques with the aid of graphic data processing systems to graphically express or solve technical equations is called CAD or CADD.

ENGINEERING DRAWINGS and ENGINEERING DRAFTING: Drawings used in technical work or industrial production are referred to as engineering drawings. The terms *working drawings* and *machine drawings* are also used in reference to engineering drawings.

ENGINEERING GRAPHICS or ENGINEERING DESIGN GRAPHICS: Engineering graphics or engineering design graphics refers to the design and specifications for physical objects and data relationships as in engineering and science.

TECHNICAL DRAWING: Any drawing that expresses technical ideas is a technical drawing and may also be called working or machine drawings.

TECHNICAL SKETCHING: Technical sketching is freehand drawing.

Another term you should be familiar with is *blueprint reading.* Blueprint reading is reading and interpreting a graphic language through symbology used to express technical ideas or mechanical solutions. Regardless of whether the drawing is on paper, film, computer monitor, or a table napkin, the graphic language should be the same.

Drafting Standards

Introduction

Drawings for Department of Defense (DOD) use must follow prescribed standards. Paper size, format, and symbology are but a few of the standardized practices used in government facilities. Compile a list of standards and familiarize yourself with their content.

Drawing standards

The policy of the Department of Defense (DOD) is to use to the maximum degree possible nongovernmental standards that fully satisfy the needs of the military with respect to their technical sufficiency. The American Society of Mechanical Engineers (ASME) and the American National Standards Institute (ANSI) publish standards of particular interest to draftsmen. Unclassified specifications, standards, and related standardization documents and those industrial documents coordinated for DOD use are published by the Assistant Secretary of Defense (Supply and Logistics), Office of Standardization.

DOD drawing standards are constantly updated and are identified by the terms *DOD-STD (Department of Defense Standard)* or *MIL-STD (Military Standard)* followed by a number. When starting a new project, make sure you have current standards. Check for the latest editions in the *Department of Defense Index of Specifications and Standards,* issued annually. Also check for supplements to the Index that are issued every 2 months. The Index and its supplements appear in two-part format: (1) an alphabetical listing by subject and (2) a numerical listing. DOD-STD-100 is the listing of standards you will require most often. To electronically download DOD specifications and standards, visit url http://dodssp.daps.mil/ (internet website).

Determining standards

Many of the drawings you work with have been in use for years. These old drawings may contain many obsolete symbols and markings. Also many architectural and engineering consulting firms who prepare drawings for DOD do not closely adhere to DOD- and MIL-STD symbols. For this reason, always look for a legend on the drawing. A legend helps you interpret any symbols unfamiliar to you . If there is no legend, study the drawings carefully to find the meaning of unfamiliar symbols and abbreviations. As more work is reallocated and contracted out, your vigilance as a DM and proficiency in drawing and drafting standards are an invaluable safeguard against costly wastes in time and material.

Drafting Techniques

Introduction

You should know the techniques of pencil drawing, tracings, and ink tracing before you attempt to create or revise technical drawings.

Pencil drawings

By far the greater part of all drafting is done in pencil. Most prints or photocopies are made from pencil tracings; all ink tracings are made from pencil drawings. There are two types of pencils: those with conventional wood-bonded cases known as *wooden pencils* and those with metal or plastic cases known as *mechanical pencils.*

Figure 3-1 shows an example of a conventional and mechanical pencils.

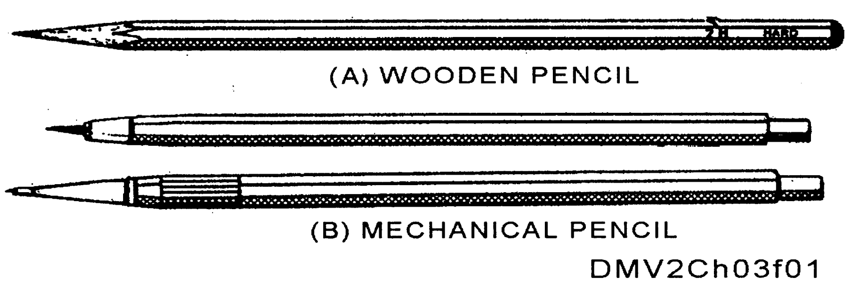

Figure 3-1.—Conventional and mechanical pencils.

Pencil manufacturers market three types of lead used to produce engineering drawings; graphite, plastic, and plastic-graphite.

GRAPHITE: Graphite is conventional lead composed of graphite, clay, and resins. It is available in varying degrees of hardness. The hardest grades are 9H, 8H, 7H, and 6H. Mediums grades are 5H, 4H, 3H, and 2H. Medium soft grades are H and F. The soft grades are HB, H, and 2B; and the softest grades are 6B, 5B, 4B, and 3B. The softer grades are not suitable for precise technical drawing or drafting, but may suffice for freehand technical sketches.

PLASTIC: Plastic lead was developed particularly for drawing or drafting on drafting films such as Mylar or vellums. They are available in a limited number of grades, which do not closely correspond to the degrees of hardness in conventional graphite leads. Plastic lead has good microform reproduction characteristics.

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Pencil drawings (Continued)

PLASTIC-GRAPHITE: Plastic-graphite leads are similar to plastic leads but are produced differently. The two types of plastic-graphite leads are fired and extruded. Plastic-graphite leads produce good opaque lines suitable for microform reproduction. They do not smear easily and also erase well.Line resolution is of paramount importance. Crisp, black line work and lettering indicate good pencil technique.

Figure 3-2 illustrates good pencil techniques.

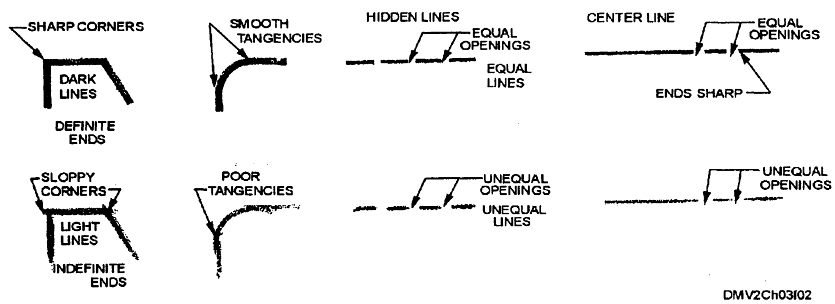

Figure 3-2.—Pencil techniques.

Pens

You may use any type of pen to ink over pencil tracings. The most common types in use are the ruling pen with an adjustable blade and the technical reservoir pen. Reservoir pens are gaining in popularity because you can connect them to compass legs to draw circles.

Figure 3-3 is a compass attachment for a reservoir pen.

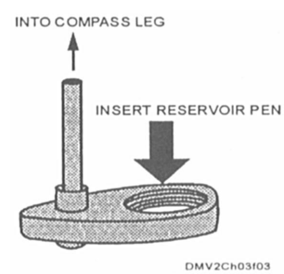

Figure 3-3.—A compass attachment to hold reservoir pens.

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Drawing aids

Some of the most common drawing aids are protractors, triangles, templates, and french curves.

Papers

Most drawings today are made directly on tracing papers, cloth, films, or vellum. Drawings on tracing papers are not actually tracings but original drawings. Should drawings require extensive revision, you may place the drawing under a sheet of tracing paper and make the revisions on this second-sheet.

When using translucent drawing or drafting mediums, place a sheet of white paper or illustration board underneath the drafting paper. The white color of the board improves visibility of your lines and the additional support under the drawing allows you to exert more pressure on the pencil lead to produce dense, black lines without excessive scoring of the paper.

Ink drawing

Drawing or tracing pencil drawings with ink takes precision and caution. You must distinguish between fine variations in line thickness and also acquire skill in drawing lines of desired widths. Controlling the thickness of the various lines you use for inked drawings requires a trained eye. You must also control the pressure of your hand on the pen as you press against the paper to prevent undesirable scoring of the paper surface.

Most Navy shops use technical reservoir pens. Technical pens come in a variety of line thicknesses. The pens are color coded on the cap or barrel to indicate the thickness of the line the nib produces. Before drawing a line on the drawing, test the line width on a scrap sheet of paper. Keep a soft cloth or tissue nearby to keep clean the pen nib of fiber and debris as you work.

In inking technical drawings, you will usually use three line thicknesses. In general, thick lines define the outline of the object, medium weight lines detail the object, and fine lines indicate leader lines, dimension lines, and centerlines.

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Inking techniques

When inking or tracing over pencil lines, center the ink line over the pencil line. If done correctly, the line thickness will overlap at points of tangency producing a smooth transition from straight to curved lines. When drawing intersecting lines, allow previous ink lines to dry before drawing the intersecting lines to prevent teardrop-shaped ends and rounded corners. If the drawing paper is excessively dirty or the pencil lead has a wax-based resin, ink may crawl producing ragged edges. Papers may absorb hand oils with excessive handling. Use a slip sheet of clean white paper under your hands to protect the paper surface. Factors that make lines heavier include slow movement of the pen, caked particles of ink in the reservoir, leaning the pen in any direction (not maintain perpendicularity), or a soft or humidity-affected working surface. Lines may become finer under the following conditions: rapid movement of the pen, an insufficient amount of ink in the reservoir, fresh ink in a clean pen, holding the pen perpendicular to the paper surface, or a hard or high paper surface.

Figure 3-4 illustrates correct and incorrect inking techniques.

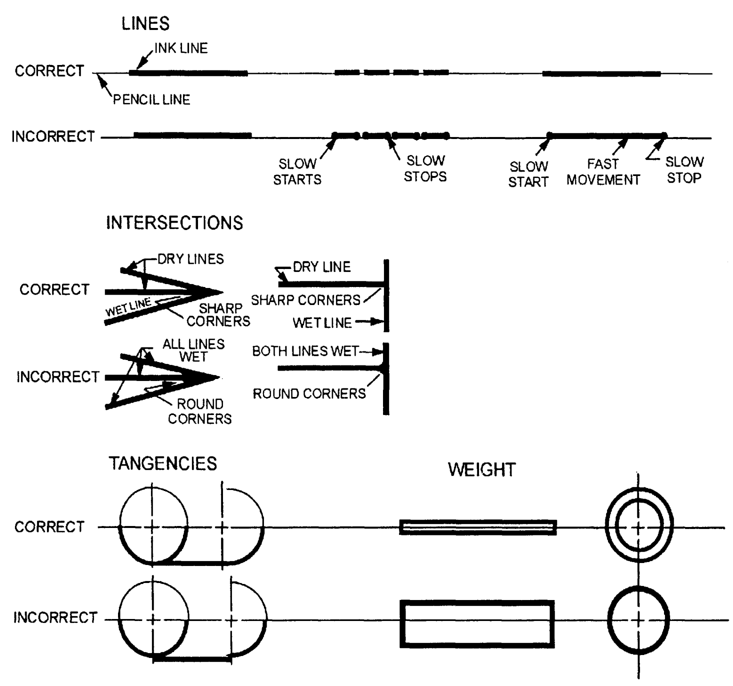

Figure 3-4.—Inking techniques.

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Inking order

The order in which you ink your drawings can make the drawings easier to execute. The first lines inked are circles and arcs followed by straight lines, then center, dimension, extension lines, and finally arrowheads and lettering. Some draftsmen prefer to ink centerlines before using a compass to ink circles because the ink may bleed through the hole in the paper caused by the compass needle.

This table lists the preferred order of inking:

Step	Action
1	Circles and arcs • Mark all tangent points in pencil directly on drawing • Indent all compass centers • Ink visible circles and arcs • Ink hidden circles and arcs • Ink irregular curves
2	Straight lines • Ink horizontal lines first, then vertical and inclined lines • Ink visible straight lines • Ink hidden straight lines
3	Center, dimension, and extension lines • Ink horizontal lines first, then vertical and inclined lines • Ink leader lines and section lines
4	Arrowheads, numbers, and lettering • Place light pencil guidelines directly on the drawing

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Inking order (Continued)

Figure 3-5 illustrates the order of inking.

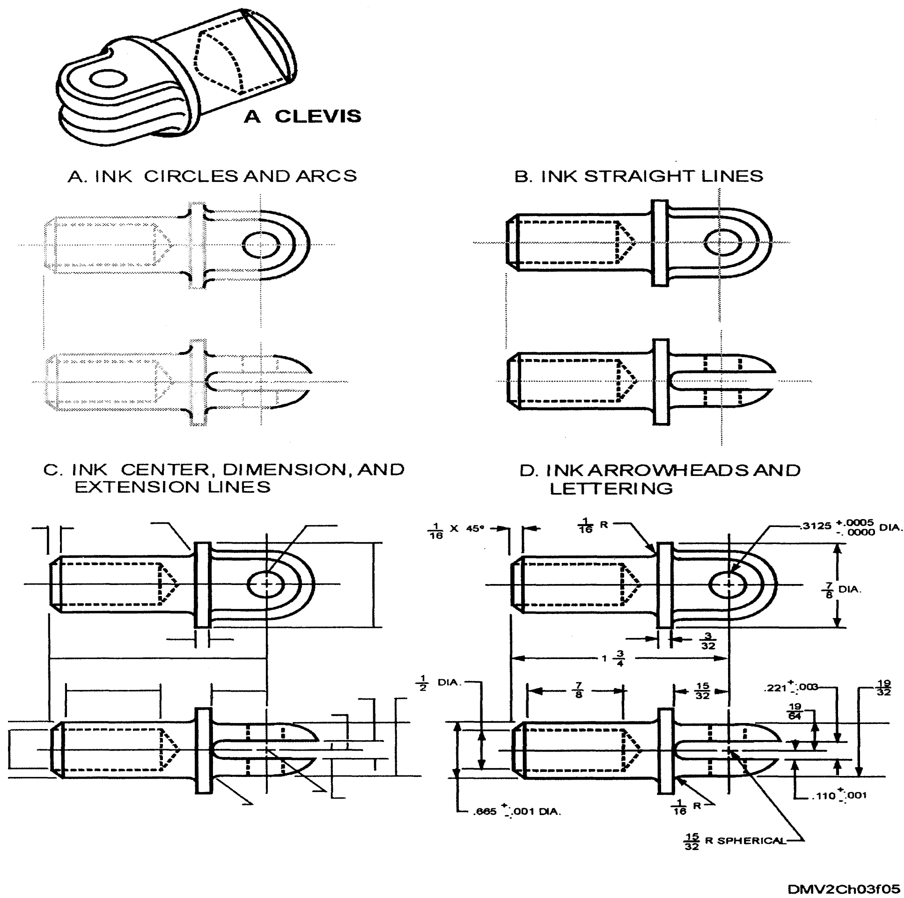

Figure 3-5.—The order of inking.

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Erasing in ink

Many people erroneously conclude that ink lines are not erasable. However, an erasure is negligibly visable if you erase ink carefully. For the best result in erasing an ink error, place a smooth hard surface under the error before you erase. Use an electric eraser with a medium-hard eraser bit (these are generally pink in color) and rotate the eraser in a circular motion over the affected area. Brush away any eraser particles.

If an ink blot occurs, soak up the excess ink with your tissue or another scrap of paper. This prevents the ink from seeping into the paper fibers. Allow the ink blot to dry thoroughly before erasing.

After erasure, gaps may appear in lines that require filling or touching up. Use a pen with a smaller diameter than the initial ink line to build consecutive strokes to the correct line width. Trying to match pen diameters to the thicker width is difficult and may incur additional erasures.

Excessive erasing may cause a weakening or hole in the paper. If this occurs, cut out the affected area with a sharp blade and patch in paper of the same type. Use translucent or transparent matt-surfaced adhesive tape to secure the patch in place from the reverse side of the paper. Ink carefully around the patch because blots and seepage is more likely to occur where paper fibers are cut.

Line Conventions

Introduction

The widths and construction of the lines you use in making a drawing are important to interpreting the drawing. DOD-STD-100 series states that on drawings, the actual widths of each type of line is governed by the size and style of the drawing. Good resolution for each type of line is important for maximum reproductive clarity.

Line conventions

Line configurations and the meanings assigned to these configurations are known as *line conventions.* Line conventions convey information as succinctly as a physical example of the object itself. The appropriate use of standard line conventions enables fabricators to replicate objects based solely on your drawing.

Centerlines

Lines that indicate the center of an object or shape are called *centerlines.* Centerlines are often the first lines drawn and serve to position images on paper. Sometimes, measurements use centerlines as a common point of reference. Centerlines may also indicate the travel of a moving center.

Centerlines are drawn by alternating evenly-spaced long and short dashes. They extend a minimum of 1/4" beyond the object outline. At points of intersection, they appear as short dashes. If there is no possibility of confusion, you may draw only the short centerlines (a single dash) rather than the entire length of the line.

Figure 3-6 shows examples of centerlines.

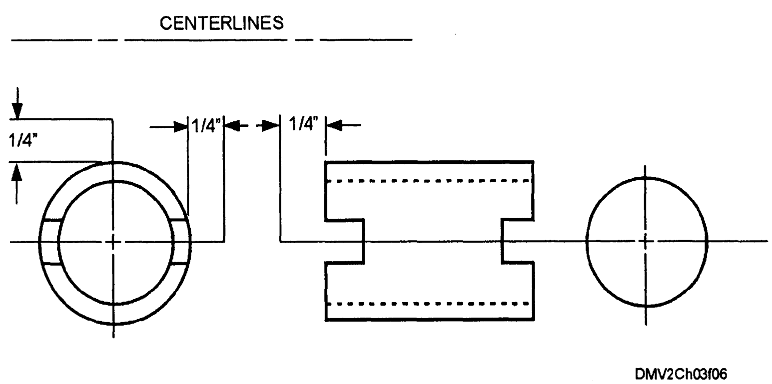

Figure 3-6.—Centerlines.

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Visible lines

Any lines visible in a view that define edges or outlines of objects are drawn with lines referred to as *visible lines.* Visible lines are drawn as solid, thick lines. In drawings that do not have cutting planes, visible lines will be the thickest lines drawn.

Figure 3-7 shows the use of visible lines.

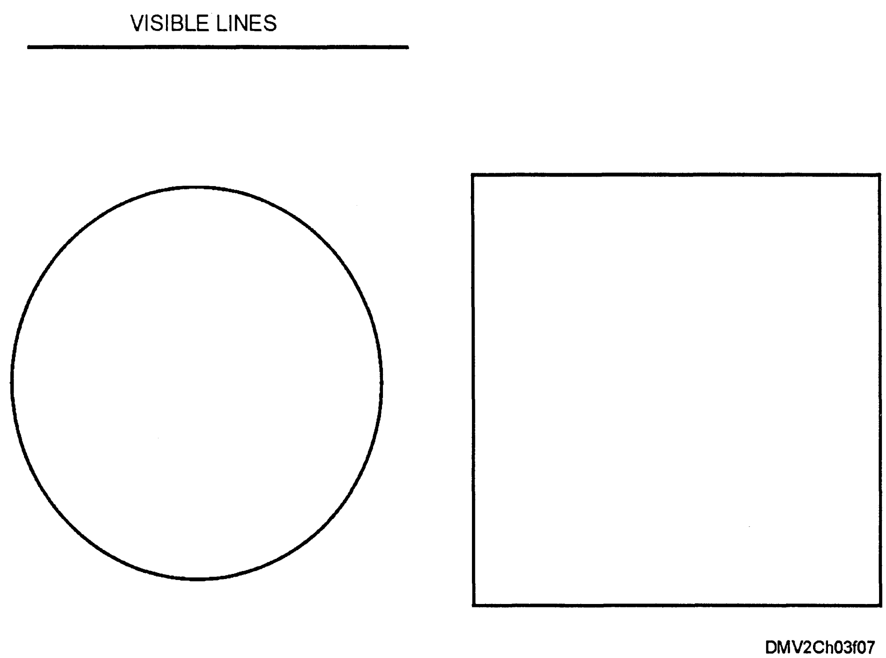

Figure 3-7.—Visible lines.

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Line Conventions, Continued

Hidden lines

Lines not readily apparent in a view of an object are *hidden lines.* Hidden lines are evenly-spaced, short dashes that begin and end as a dash in contact with the line from which it starts and stops. The exception being when it is a continuation of an unbroken line.

Figure 3-8 shows hidden lines.

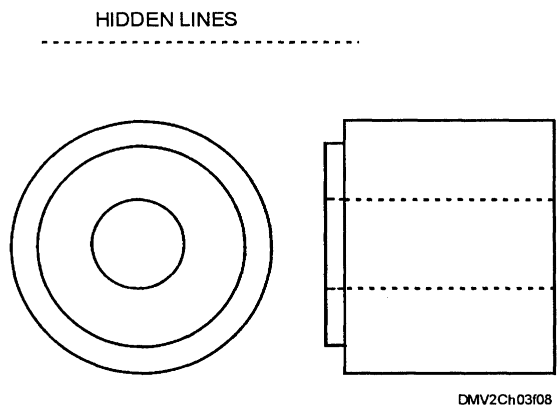

Figure 3-8.—Hidden lines.

Hidden lines that join visible lines or another hidden line must contact the line.

Figure 3-9 illustrates the correct and incorrect procedures for drawing adjoining hidden lines.

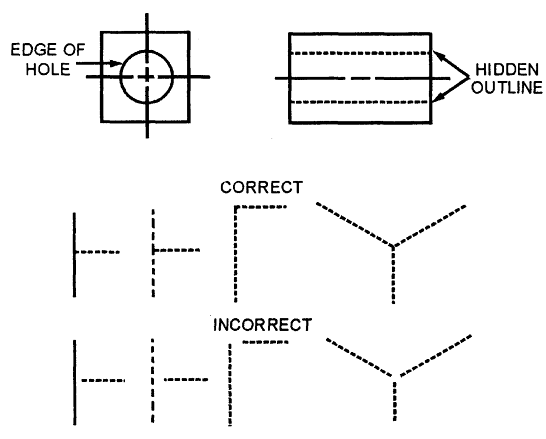

Figure 3-9.—Drawing hidden lines.

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Hidden lines (Continued)

At the intersection of a hidden and visible line, the hidden line will straddle the visible line. If you draw the hidden line in contact with the visible line, it implies that the hidden line is above, rather than below the visible line.

Figure 3-10 illustrates correct and incorrect procedures for drawing intersecting lines.

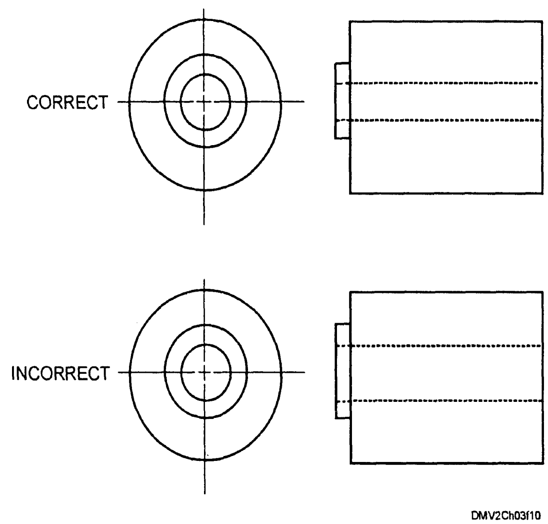

Figure 3-10.—Drawing intersecting hidden lines.

When drawing the intersection of two hidden lines at different levels, the hidden line representing the uppermost edge remains intact and the hidden line representing the lowermost edge is split by the upper hidden line.

Figure 3-11 illustrates hidden edges at different levels.

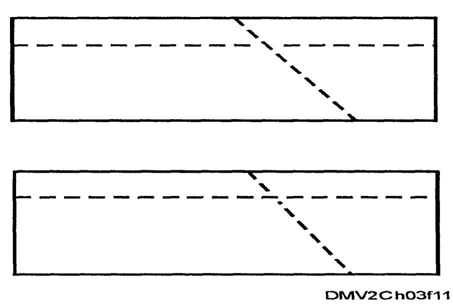

Figure 3-11.—Hidden edges at different levels.

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Extension lines

Extension lines are thin lines that extend from the object outline or point on the object to a place outside the image area. Extension lines define areas for dimensions. You should leave a 1/16" gap between the object outline or point on the object and the beginning of the extension line. Extension lines project 1/8" beyond the outermost dimension line. Extension and dimension lines are drawn at right angles to each other.

Figure 3-12 shows extension and dimension lines.

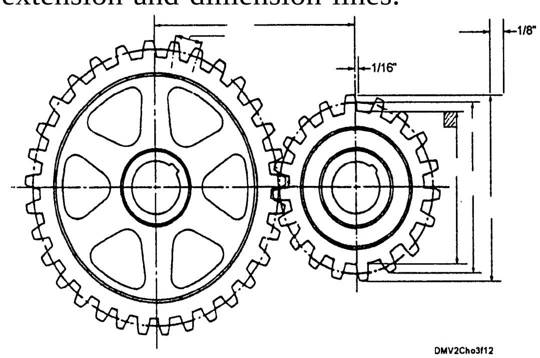

Figure 3-12.—Extension and dimension lines.

When extension lines must cross each other or object outlines, break the extension lines.

Figure 3-13 illustrates the correct and incorrect use of extension lines.

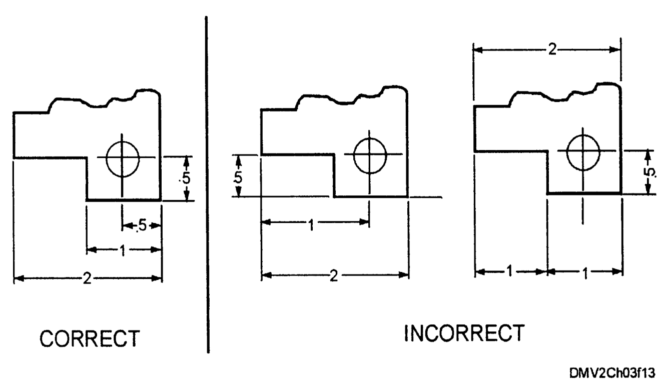

Figure 3-13.—Extension lines drawn correctly and incorrectly.

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Dimension lines

Lines that define the parameters of a dimension are called *dimension lines.* Dimension lines are thin lines terminating in arrowheads. Place dimension lines no closer than 3/8" from the object outline. Parallel dimension lines should be a minimum of 1/4" apart. You may place parallel dimension lines more than 1/4" apart so long as the spacing between dimension lines is uniform throughout the drawing. Dimension lines are generally broken in the center of the line to provide a space for the dimension figure. Dimension figures for parallel dimension lines are staggered. In some structural or architectural drawings, you may find dimension figures placed above the dimension line.

Figure 3-14 illustrates dimension lines.

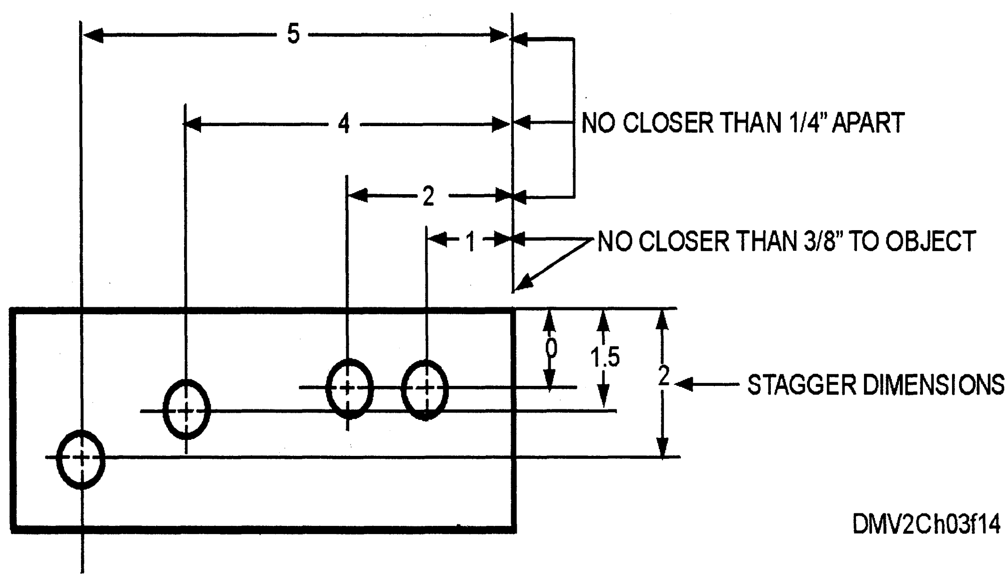

Figure 3-14.—Dimension lines.

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Dimension lines (Continued)

When indicating the radius of an arc or circle, place the arrowhead at the end of the dimension line that touches the object outline. The end of the dimension line terminates at the centerline of the arc or circle.

Figure 3-15 illustrates the dimensioning of arcs and circles.

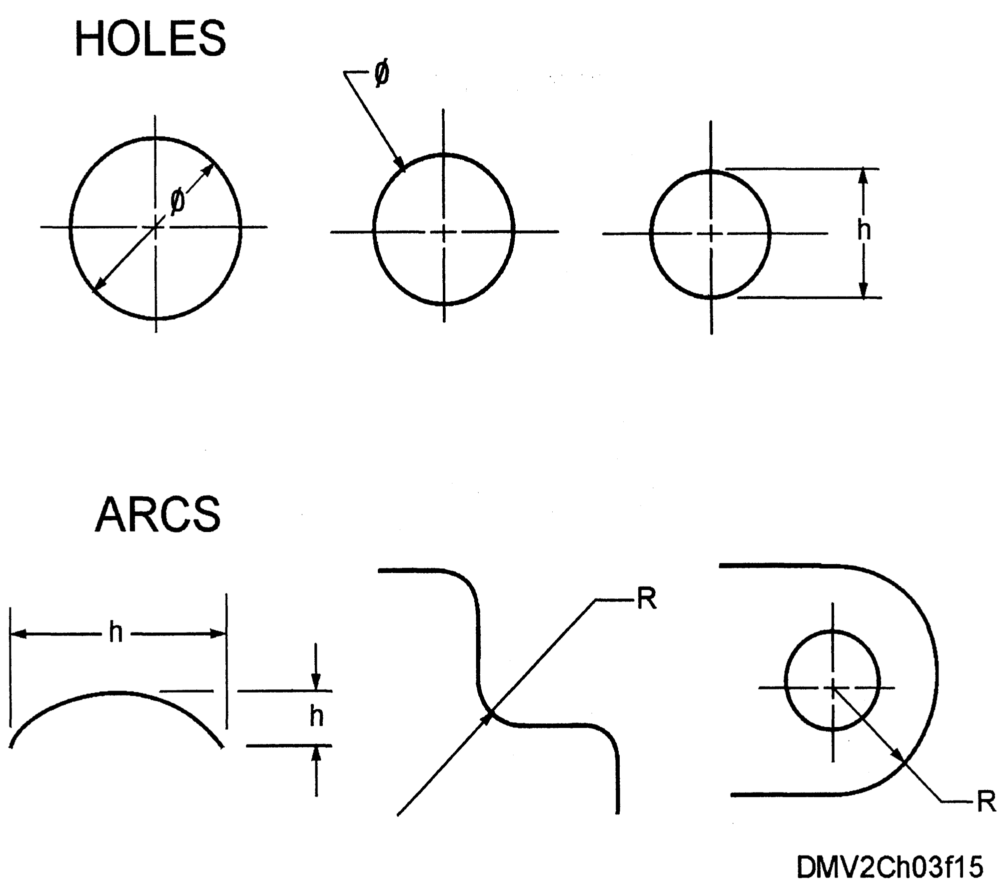

Figure 3-15.—Dimensioning arcs and circles.

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Arrowheads

Arrowheads indicate the extent of the dimension. All arrowheads on a drawing should be uniform in size and style. Arrowheads are usually solid and are from 1/8" to 1/4" long. Their length is approximately three times their width. Although many draftsmen recommend using templates to draw arrowheads, you should be able to draw them freehand. Carelessly drawn arrowheads make drawings look unfinished and unprofessional.

Figure 3-16 illustrates the proper construction of arrowheads.

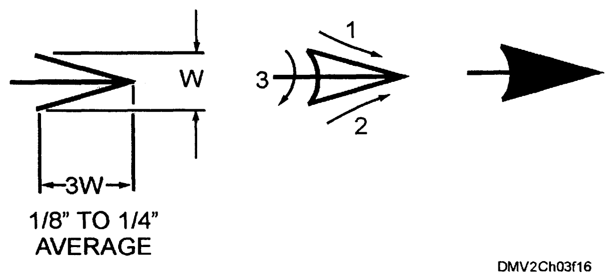

Figure 3-16.—Constructing arrowheads.

Leader lines

Notes or dimensions that pertain to surfaces or parts are lead to that surface or part by *leader lines.* Leader lines are thin, solid lines that terminate in an arrowhead or dot. Use arrowheads when leader lines terminate at the outline of an object. Use dots when leader lines terminate within the outline of the object or on the surface of the object.

Figure 3-17 shows examples of properly used leader lines.

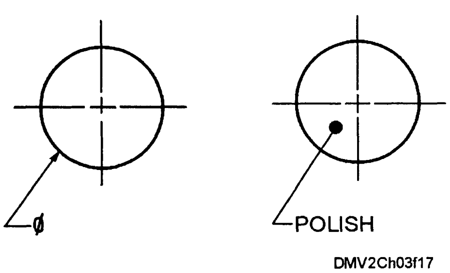

Figure 3-17.—Leader lines referring to: A. Dimensions, and B. Surface finish.

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Break lines

When an extended part of an object has a continuous shape and size, you can save space by abbreviating the object using zigzag or wavy lines. These zigzag or wavy lines are called *break lines* because you figuratively break away an unimportant segment of an object. The two types of break lines are *long break lines* and *short break lines.*

LONG BREAK LINES: Long break lines are ruled lines with freehand zigzags that reduce the size of the drawing required to delineate an object and reduce detail.

SHORT BREAK LINES: To indicate a short break in an object, use thick, solid, wavy freehand lines.

Rods, tubes, and bars have additional conventions that not only break their length but also imply the material or texture of the object.

Figure 3-18 illustrates how line conventions may indicate composition or texture.

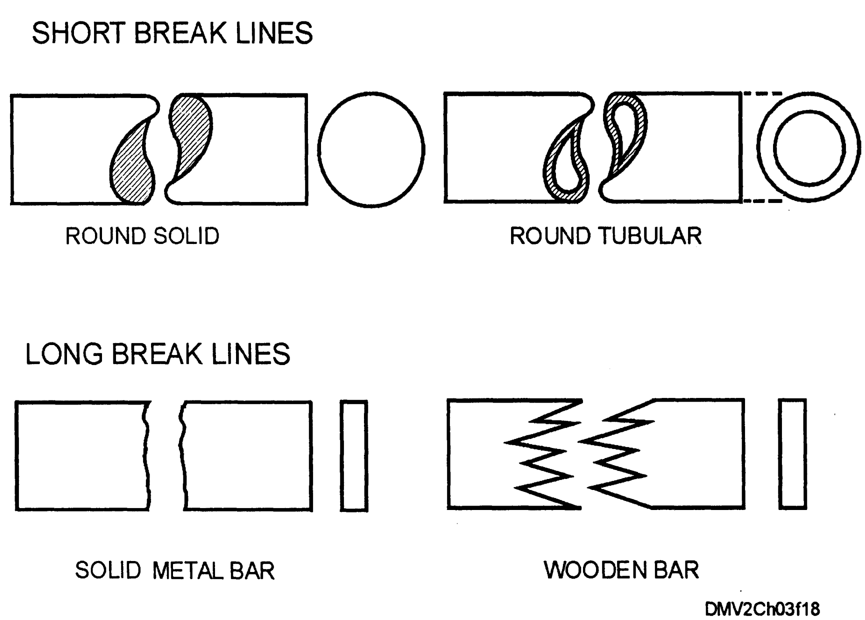

Figure 3-18.—Conventional breaks.

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Phantom or datum lines

To indicate alternate positions of parts, repeated detail, or to indicate a datum plane, use *phantom* or *datum lines.* Phantom or datum lines consist of a medium weight series of one long dash and two short dashes evenly spaced and terminating in a long dash.

Figure 3-19 is an example of a phantom line.

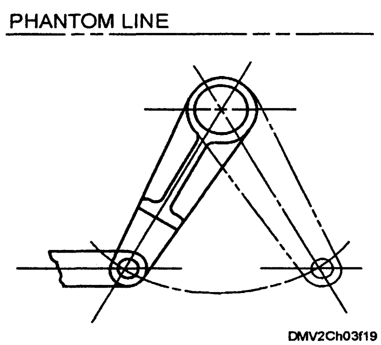

Figure 3-19.—Showing alternate lever positions with phantom lines.

Stitch lines

Depict stitching or sewing on an object with medium-weight, short dashes evenly spaced and labeled as stitching or sewing. These lines are called *stitch lines.*

Figure 3-20 is an example of stitch lines.

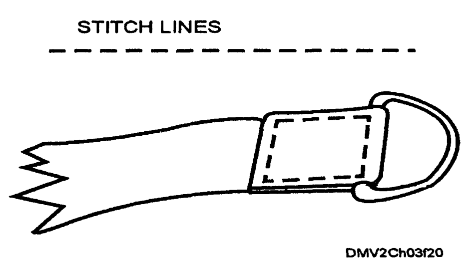

Figure 3-20.—Stitch lines showing the reenforcement of a d-ring on a strap.

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Viewing or cutting plane lines

To give a clearer view of obscure or oblique planes and interior or hidden features of an object that cannot be clearly observed in a conventional outside view, use *viewing* or *cutting plane lines* respectively. Viewing or cutting plane lines are the thickest of all lines. Viewing or cutting plane lines are solid lines. Only when the cutting plane line is offset does the line appear as thick, short dashes.

VIEWING PLANE LINES: Viewing plane lines indicate the plane or planes from which a surface or several surfaces are viewed.

CUTTING PLANE LINES: Cutting plane lines indicate a plane or planes exposed by cutting and removing an imaginary section of the object. The exposed plane is called the *sectional view* and the line used to cut the object is referred to as the *cutting plane line.* Hidden lines behind the plane of projection are customarily omitted, while lines visible behind the plane of projection must be included in the sectional view.

Figure 3-21 illustrates a cutting plane line.

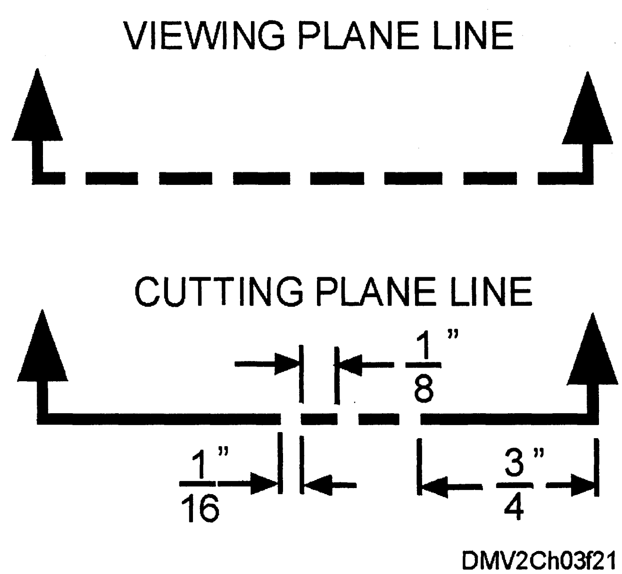

Figure 3-21.—Viewing and cutting plane lines.

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Viewing or cutting plane lines (Continued)

Cutting plane lines, together with arrowheads and letters, make up the *cutting plane indications.* Arrowheads at the end of cutting plane lines indicate the direction from which you view the section. The cutting plane may be a simple, continuous plane, or it may be offset to show the interior detail to better advantage. Identify all cutting plane indications by the use of *reference letters* placed at the point of the arrowheads. Where a change in the direction of the cutting plane is not clear, place reference letters at each change of direction. Where more than one sectional view appears on a drawing, letter the cutting plane indications alphabetically preceded by the word SECTION or abbreviation SECT. Place the title directly under the section drawing. If you exhaust the single letter alphabet, use multiples of letters.

Figure 3-22 shows simple and offset sectional views.

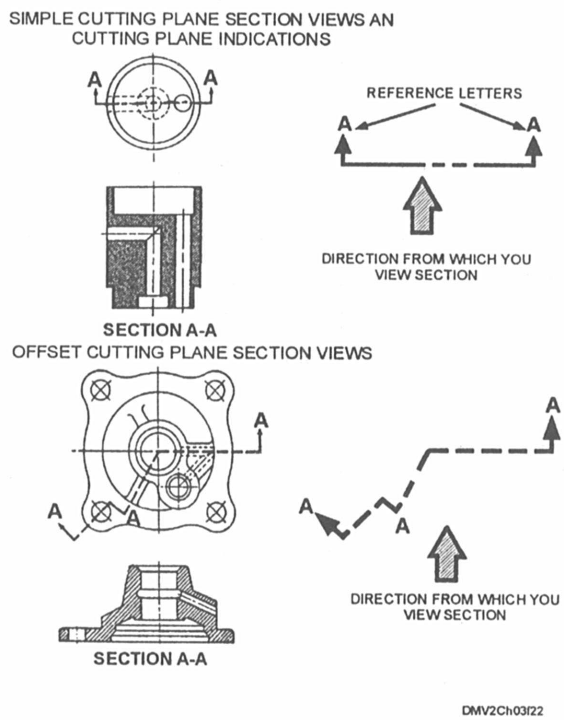

Figure 3-22.—Simple and offset sectional views.

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Line Conventions, Continued

Chart of line conventions

Keep a chart of line conventions handy. Use it often.

Figure 3-23 is a chart of industry accepted line conventions.

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 AND 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	¼ x 20 UNC-28 THD.

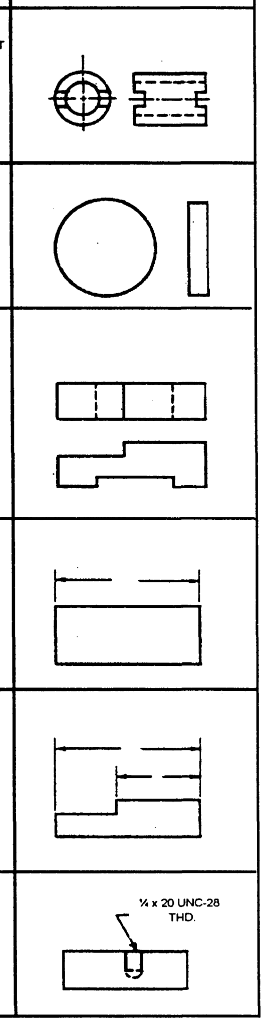

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Figure 3-23.—Line conventions.

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Chart of line conventions (Continued)

Line convention chart continued.

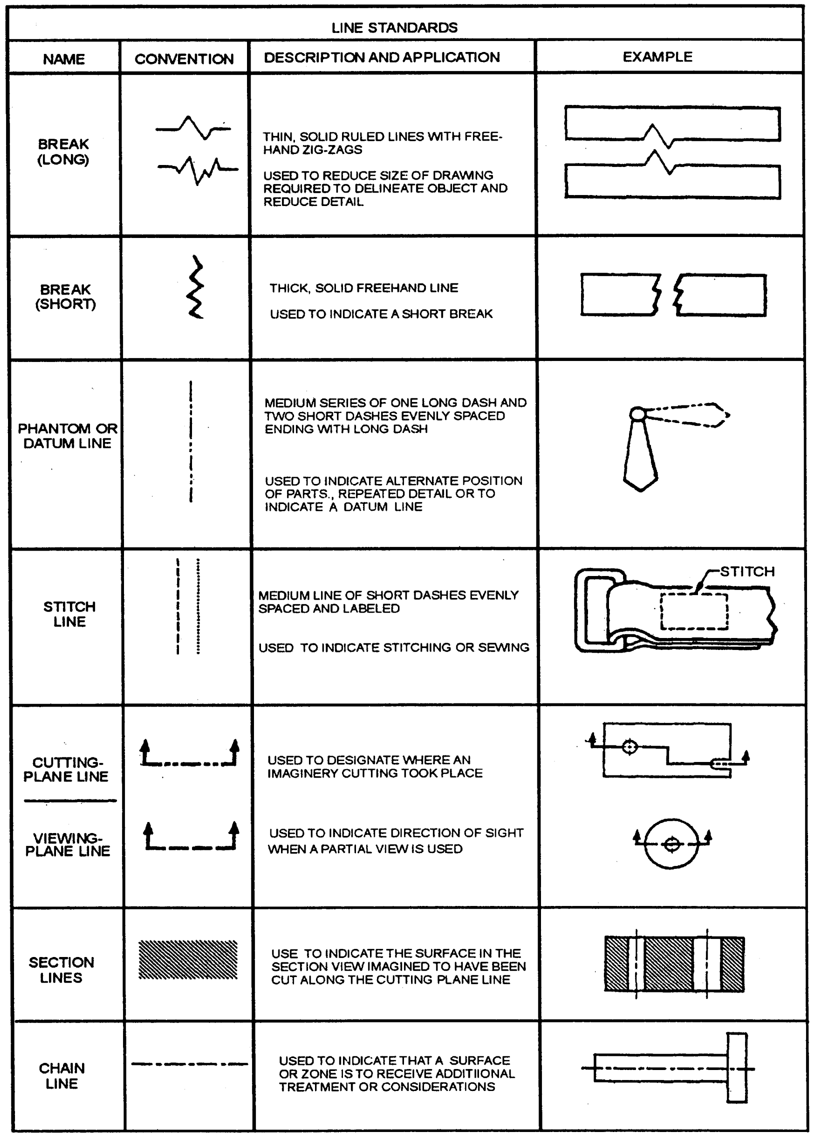

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Figure 3-23.—Line conventions (continued).

Dimensioning

Introduction

Not only do you need to describe the shape of an object, but also you must give the design a complete size description; you must give it dimensions,

Dimensions

Always give dimensions that are convenient for the shop worker or production manager. Work should never stop for mathematical computations that should have been on the drawing. Make dimensions clear and concise without duplication or the necessity to calculate, scale, or assume.

Types of dimensions

Two general types of dimensions are *size dimensions* and *location dimensions.* Size dimensions define the size of the simple geometric shapes within a part. An example of a size dimension is the diameter of a hole or the width of a slot. Location dimensions define the location of these geometric shapes in relation to each other. An example of location dimensions is how far apart holes or slots are from each other.

Dimensioning procedure

Dimension your drawings by first geometrically analyzing the object and then reviewing the procedures by which the object will be made and surfaced.

To analyze a dimension problem, follow this table:

Step	Action
1	Mentally divide the object into component geometric shapes.
2	Place size dimensions on each component part where they best describe the object.
3	Select a locating centerline.
4	Place location dimensions so that each geometric shape relates to a centerline or finished surface.
5	Add overall dimensions (length, width, and height).
6	Add all notes required to complete the description of the object.

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Dimension figures

Two ANSI approved systems indicate dimensions on drawings: the *aligned dimension* and the *unidirectional dimension system.* Select one system of dimensioning to use throughout the drawing. You may show dimensions with either whole numbers and fractions, decimals, or metric units of measure.

ALIGNED DIMENSIONS: Drawings made with aligned dimensions have all figures and notes aligned with a dimension line so that all read from the sides or edges of a drawing. The most common are read from the bottom and right side. Aligned dimensions are sometimes referred to as pictorial dimensions.

Figure 3-24 is an example of aligned dimensions.

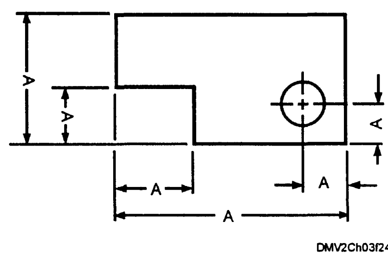

Figure 3-24.—Aligned dimensions.

UNIDIRECTIONAL DIMENSIONS: In the unidirectional dimension system, all dimension figures and notes are lettered horizontally and are read from the bottom of the drawing. The unidirectional dimension system is preferred over the aligned system because it is easier to read and understand.

Figure 3-25 is an example of the unidirectional dimension system.

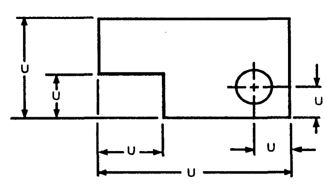

Figure 3-25.—Unidirectional dimensions.

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Dimension techniques

All dimension lines and arrowheads must lie in the planes of the object to which they apply. Align dimensions and notes shown with leaders to the bottom of the drawing. Notes without leaders should also align with the bottom of the drawing. Use single-stroke gothic letters for dimensions and lettering on drawings.

For clear dimensions, follow these general rules:

- Show sufficient dimensions to define size, shape, and position of each feature.
- Place dimensions on the view that most clearly represents the form of the geometric component of the part.
- Express each dimension so that it can be interpreted in only one way.
- Place dimensions outside of the object outline except when it helps to clarify.
- Never use centerlines, object lines, or extension lines as dimension lines.
- Select and arrange dimensions to minimize the accumulation of tolerances between related features.
- Do not double dimension. Do not locate a feature by more than one tolerance dimension in any one direction.
- Never cross dimension, extension, and leader lines unless absolutely necessary.
- Never break a dimension line except for inserting dimensions.
- Never run an extension or leader line through a dimension line or break it except where it passes through or is adjacent to arrowheads.
- Avoid dimensioning to hidden lines.
- Express angular dimensions in degrees (°), in minutes (′) and seconds (″), or in decimal parts of a degree.
- Do not use zeros before the decimal point for values less than 1 inch.
- Enclose dimensions in. parentheses or mark “REF” when it is (1) repeated on the same drawing, (2) specified on subordinate documents, (3) an accumulation of other dimensions, or (4) shown for information only.
- Do not use the word “TYPICAL” or the abbreviation “TYP.” Instead, indicate (in parentheses) the number of places to which the dimension applies (2 PLS).

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Unique methods of dimensioning

Various characteristics and features of parts require unique methods of dimensioning. These special situations include diameters, radii, rounded corners and ends, round, slotted, counterbored, countersunk, and counterdrilled holes, spot-facing, and chamfers.

Diameters

When indicating the diameter of a circular shape, the diameter symbol (∅) precedes all diametral values. When you must show the diameters of a number of concentric or eccentric cylindrical features, dimension them in a longitudinal or front view.

Figure 3-26 shows diametral values.

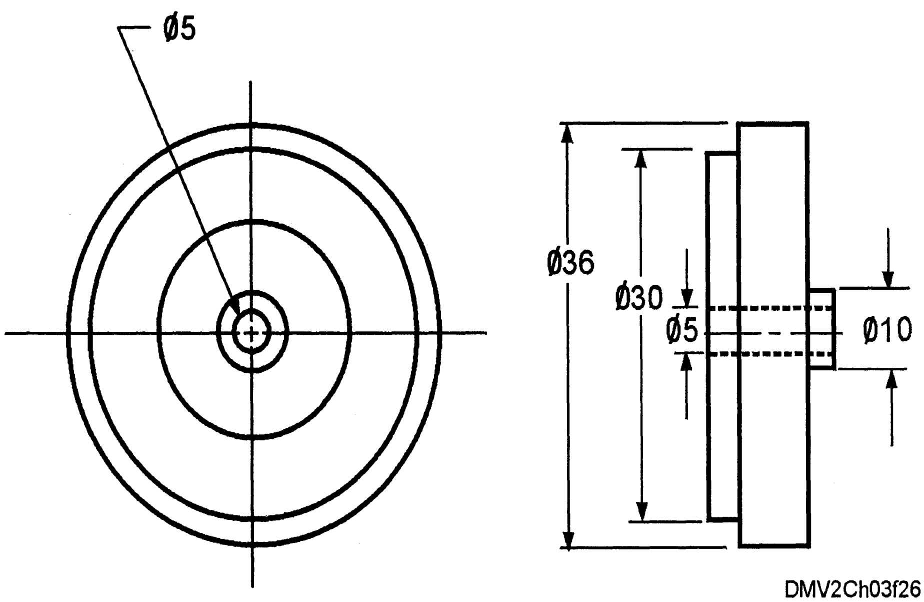

Figure 3-26.—Dimensioning diametral values.

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Radii

A radius is the distance between an arc and its center point. Indicate this distance with a radius dimension line. A radius dimension line uses one arrowhead at the arc end. Never use an arrowhead at the radius center.

Where location of the center is important and space permits, draw a dimension line from the radius center with the arrowhead touching the arc. Place the dimension between the arrowhead and the center. In limited space, extend the dimension line through the radius center. If you cannot place the arrowhead between the radius center and the arc, place it outside the arc with a leader. Where the center of a radius is not dimensionally located, do not indicate the center.

Where a dimension is given to the center of a radius, draw a small cross at the center. Where location of the center is unimportant, the drawing must clearly show that other dimensional features (such as tangent surfaces) control the arc location.

Figure 3-27 illustrates correctly dimensioned radii.

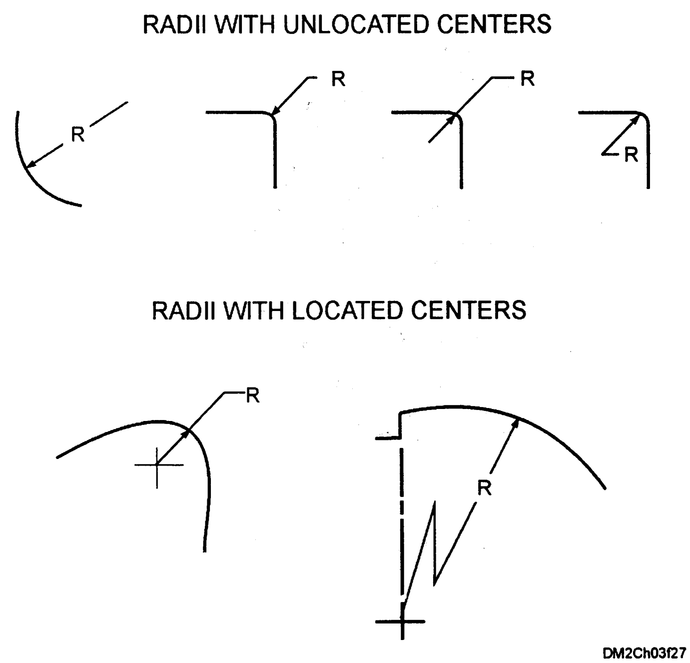

Figure 3-27.—Dimensioning radii.

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Rounded ends

When drawing parts with rounded ends, use overall dimensions. For fully rounded ends, indicate the radii but do not dimension them. For parts with partially rounded ends, extend the arc of the radii and dimension to the extension.

Figure 3-28 shows the dimensioning of rounded ends.

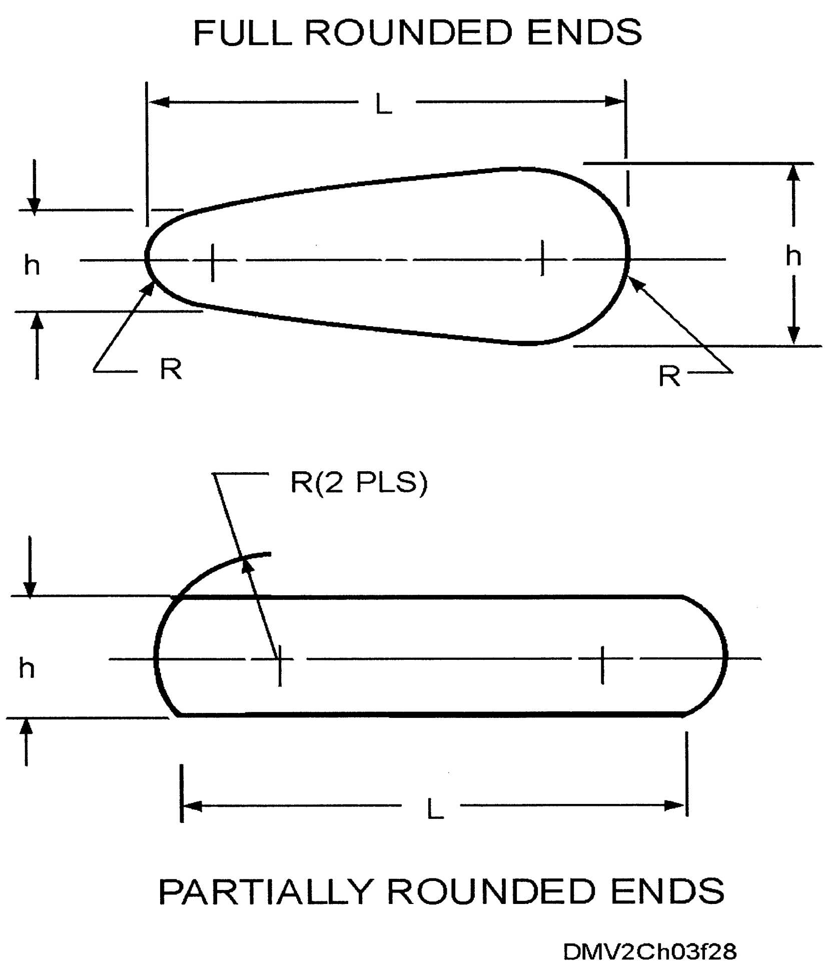

Figure 3-28.—Dimensioning rounded ends.

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Rounded corners

Where corners are rounded, dimensions define the edges and the arcs that are tangent.

Figure 3-29 is an example of a rounded corner.

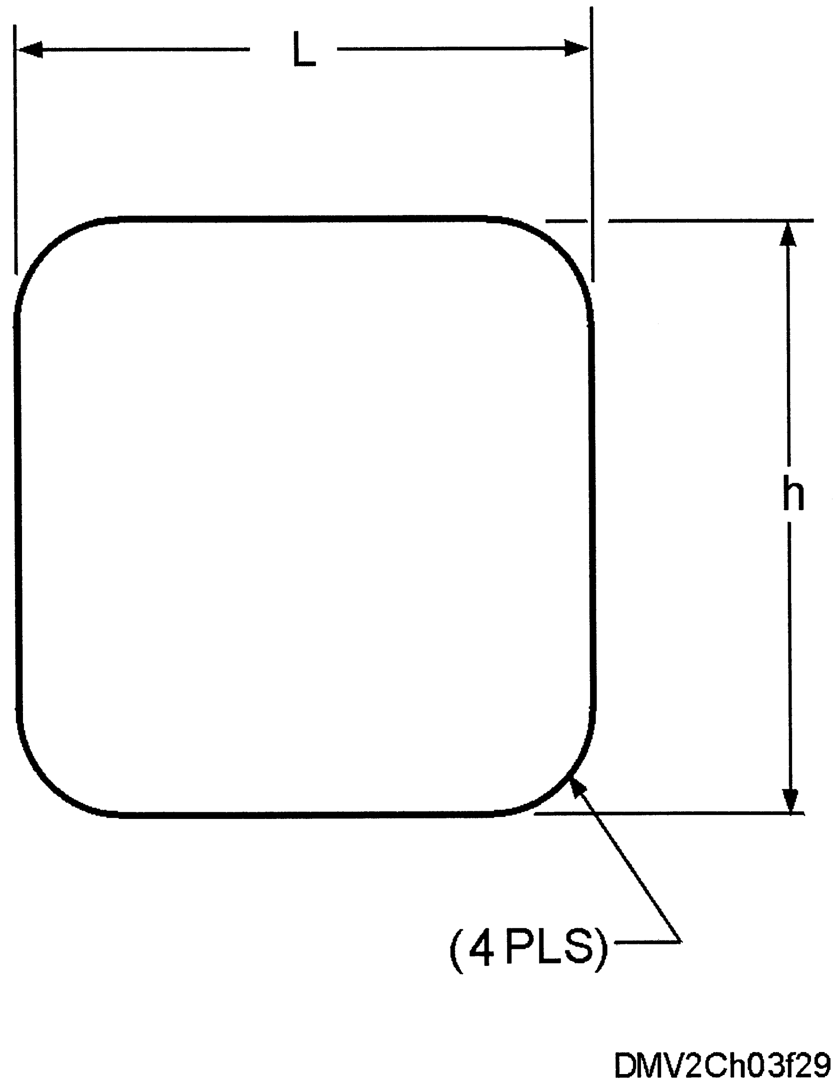

Figure 3-29.—Dimensioning rounded corners.

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Rounded holes

Where it is not clear that a hole goes through an object, the abbreviation "THRU" follows the dimension. A *blind hole* is a hole that does not pass completely through the object. The depth dimension of a blind hole is the depth of the full diameter from the surface of the part. Where a blind hole is also counterbored or counterdrilled, the depth dimension applies from the outer surface.

Figure 3-30 shows how to correctly dimension round holes.

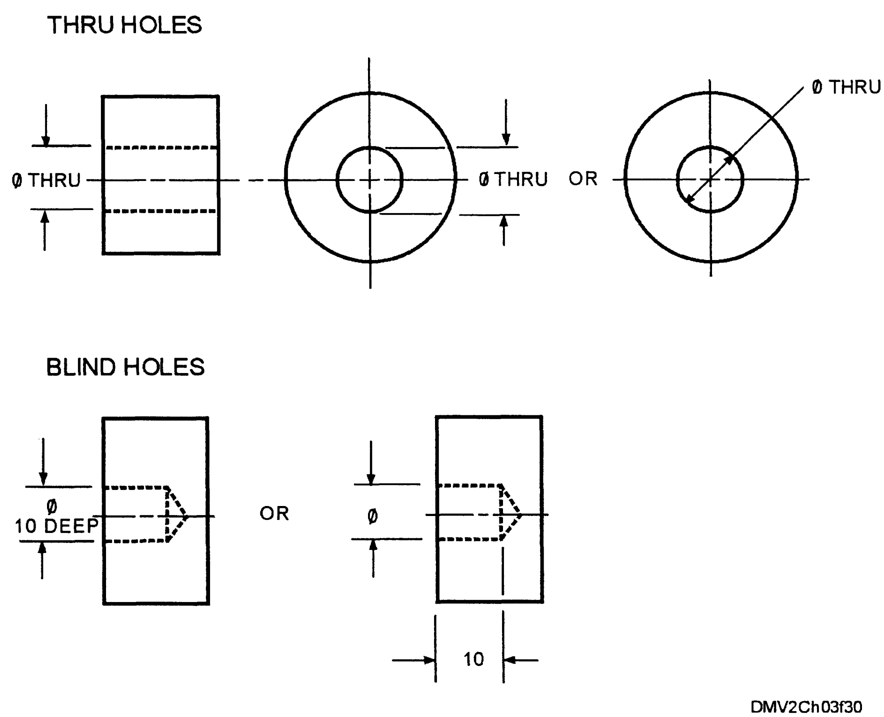

Figure 3-30.—Dimensioning rounded holes.

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Slotted holes

Dimension slotted holes by width, length, or center points. Indicate the end radii but do not dimension them.

Figure 3-31 illustrates three different methods for dimensioning slotted holes.

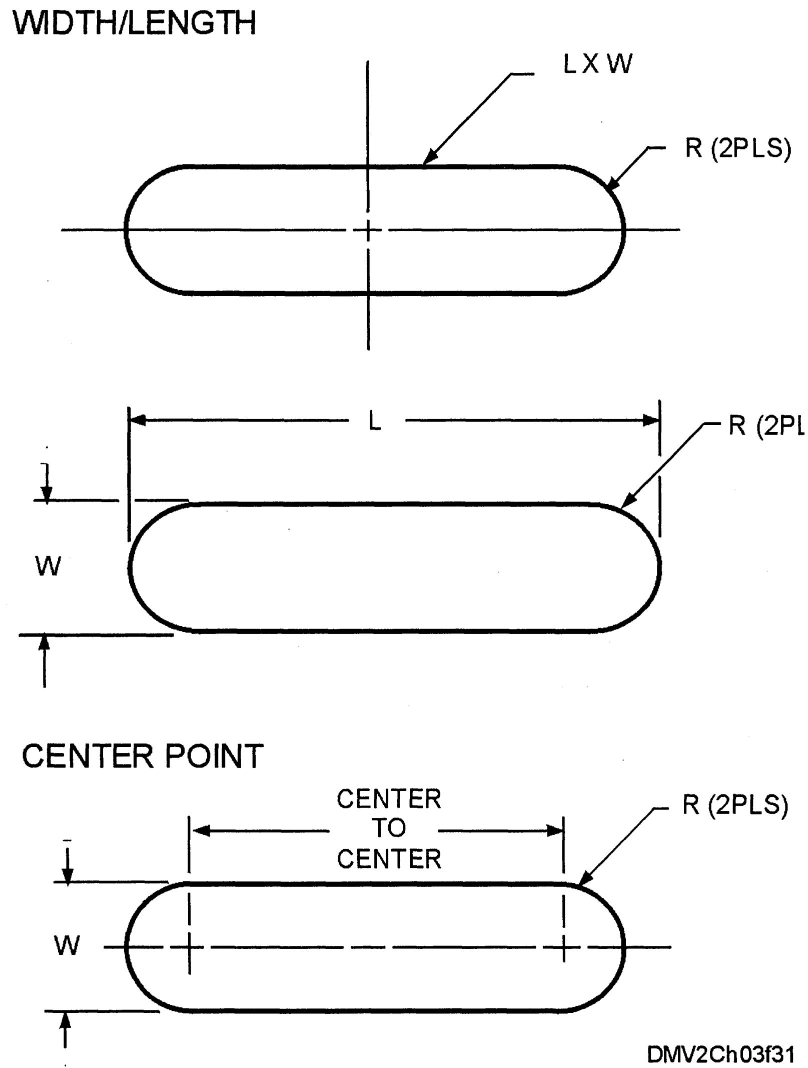

Figure 3-31.—Dimensioning slotted holes.

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Counterbored holes

Counterbored holes (CBORE) are holes of different depths that share concentric centers. There is no angularity in the larger bore. Dimension counterbored holes as two concentric diameters and a depth. Where the thickness of the remaining material has significance, dimension the thickness rather than the depth of the hole.

Figure 3-32 illustrates counterbored dimensioning.

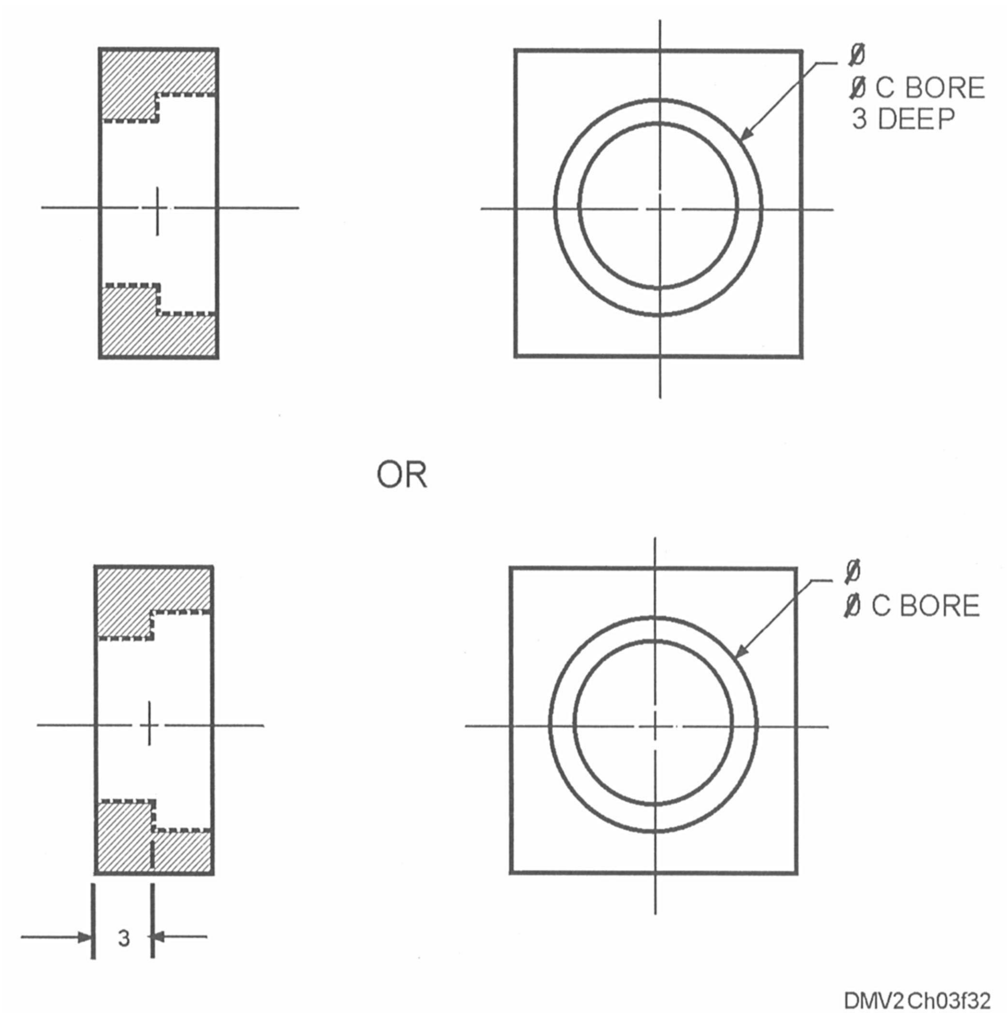

Figure 3-32.—Counterbore dimensions.

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Countersunk and counterdrilled holes

Countersunk (CSK) and *counterdrilled holes* (CDRILL) are two holes drilled at different depths that share a common center. For countersunk holes, specify the diameter and the included angle of the countersink. There is no depth to the larger hole since it only creates a bevel at the opening of the smaller hole. For counterdrilled holes, specify the diameter and the depth of the counterdrill. The larger diameter hole automatically creates a bevel determined by the angle of the drill bit; therefore, specifying the included angle of the counterdrill is optional. The depth dimension is the depth of the full diameter of the counterdrill from the outer surface of the part.

Figure 3-33 shows the dimensioning of countersunk and counterdrilled holes.

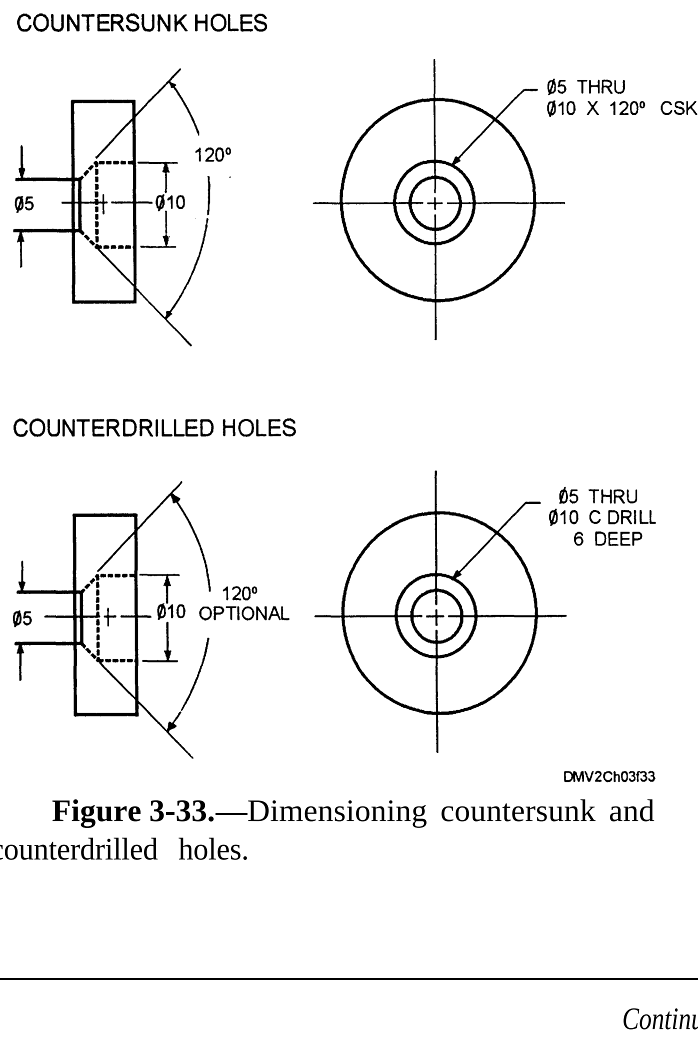

Figure 3-33.—Dimensioning countersunk and counterdrilled holes.

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Spot-facing

Spot-facing (SF) holes produce a round spot or surface around the top of another hole typically at 1/16-inch depth. This is often done to provide a bearing surface or to embed washers or t-nuts. Specify the spot-faced area. Identify the diameter of the spot-faced hole. Hole depth is often left to the discretion of the worker, but -you may specify either the depth or remaining thickness of the material.

Figure 3-34 is an example of a spot-faced hole.

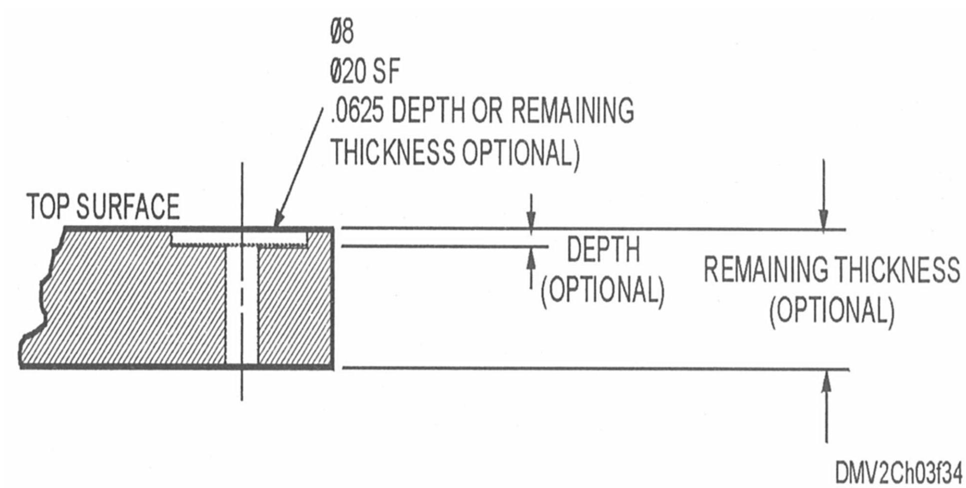

Figure 3-34.—Dimensioning spot-faced holes.

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Chamfers

Chamfers are bevels. *External chamfers* are bevels at the end of a dowel or shaft. *Internal chamfers* are bevels placed on the edges of a hole in an object. Dimension chamfers by angle and a linear dimension or by two linear dimensions. When specifying an angle and linear dimension, the linear dimension is the distance from the indicated surface of the part to the start of the chamfer.

Use a note to specify 45° chamfers. Use this method only with 45° chamfers as the linear value applies in either the longitudinal (internal) or radial (external) direction.

When depicting a chamfer of a round hole, follow the practice of dimensioning as shown (figure 3-35, view C) except where the chamfer diameter requires dimensional control. Also, apply this type of control to the chamfer diameter on a shaft.

Figure 3-35 illustrates dimensioning chamfers, 45° chamfers, and internal chamfers.

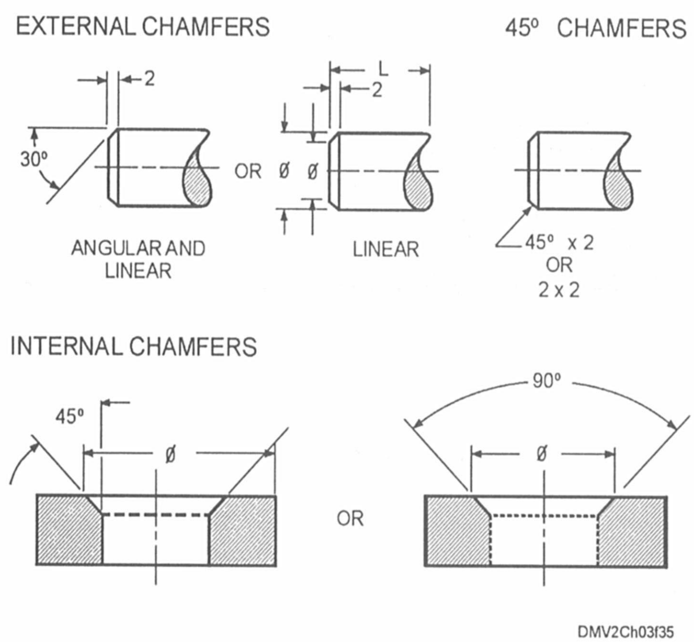

Figure 3-35.—Dimensioning chamfers.

Tolerances

Introduction

Quality and accuracy are major considerations in making machine parts or structures. Interchangeable parts require a high degree of accuracy to fit together. Dimensions of parts given on blueprints and manufactured to those dimensions should be exactly alike and fit properly. Unfortunately, it is impossible to make things to an exact or dimension. Most dimensions have a varying degree of accuracy and a means of specifying acceptable limitations in dimensional variance that an object will tolerate and still function.

Tolerance

Tolerance is the total amount a specific dimension may vary stated as a minimum and maximum limitation.

Tolerancing definitions

To understand tolerances, you should understand some of the definitions associated with the determination of a tolerance. These definitions may be generally categorized as relating to size, allowance, or fit.

SIZE: The size of an object or its mate is known as nominal, basic, or design size.

ALLOWANCE: The maximum and minimum allowable dimensions are known as limit, allowance, unilateral, and bilateral tolerances.

FIT: Fit, clearance, interference, or transition fit refer to how the object fits an assembly.

Size

To specify the size of an object, you dimension it with a nominal size, basic size, or design size.

NOMINAL SIZE: Nominal size generally identifies the overall size of an object.

BASIC SIZE: The basic size is the decimal equivalent of a nominal or numerically stated size. It is the dimension from which you derive the limits of size by the application of allowances and tolerances.

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Size, (Continued)

DESIGN SIZE: The size from which you derive the limits of size by the use of tolerances.

Figure 3-36 indicates object size.

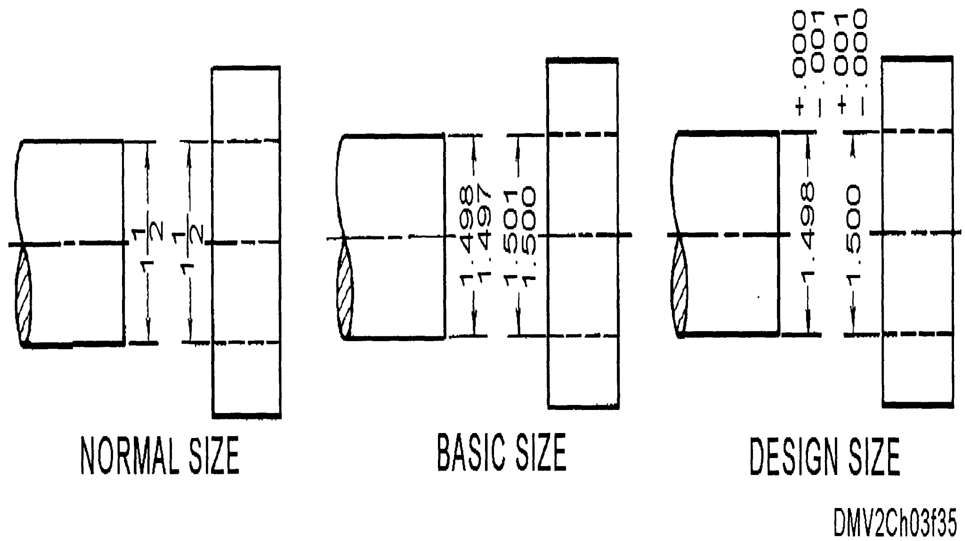

Figure 3-36.—Indicating object size.

Allowance

Limits, allowance, unilateral tolerance, and bilateral tolerance refer to size allowable variations.

LIMITS: The maximum and minimum sizes indicated by a toleranced dimension. For example, the limits for a hole are 1.500 and 1.501 inches and for a shaft 1.498 and 1.497 inches.

ALLOWANCE: The intentional difference between the maximum material limits of mating parts. This is a minimum clearance (positive allowance) or maximum interference (negative allowance) between mating parts.

UNILATERAL TOLERANCE: Unilateral tolerances indicate variation from the design size in one direction.

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Allowance (Continued)

BILATERAL TOLERANCES: Bilateral tolerances indicate variation from the design size in both directions. The actual size of the object may be larger or smaller than the stated size limitation if there can be equal variation in both directions. The plus and minus limitations combine to form a single value.

Figure 3-37 indicates tolerance.

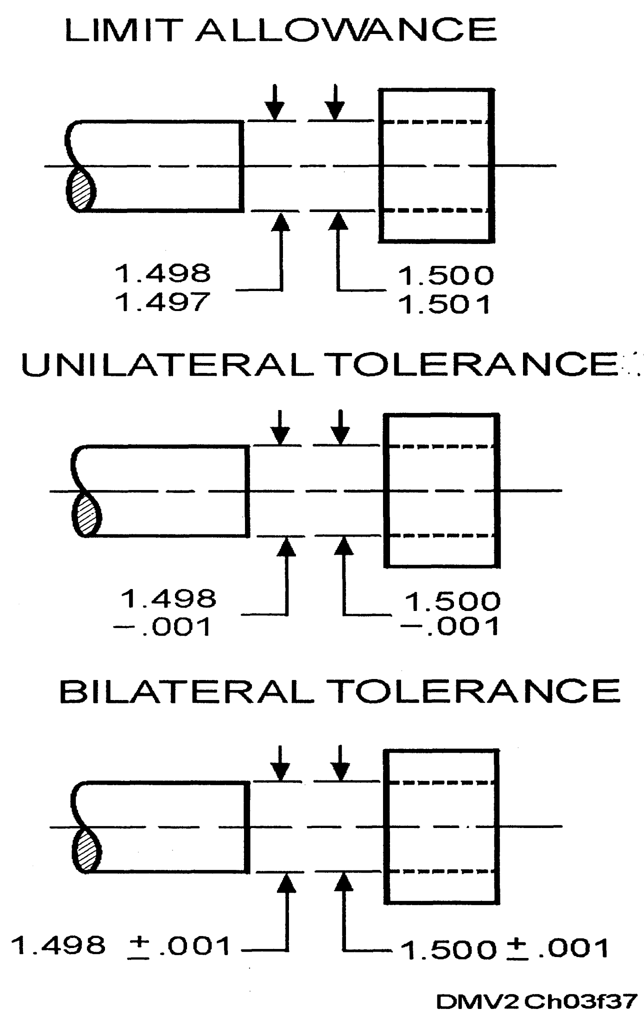

Figure 3-37.—Indicating tolerance.

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Fit

How mating parts or assemblies fit together with component parts is referred to as fit, clearance fit, interference fit, or transition fit.

FIT: Fit is the general range of tightness resulting from the application of a specific combination of allowance and tolerances in the design of mating parts.

CLEARANCE FIT: When a clearance results while you are assembling mating parts, the limits in size produced by that clearance is called the clearance fit.

INTERFERENCE FIT: When an interference results while you are assembling mating parts, the limits in size inferred by that interference is called the interference fit.

TRANSITION FIT: The limits in size resulting from a clearance or interference that results when assembling mating parts.

Figure 3-38 illustrates the differences between fits.

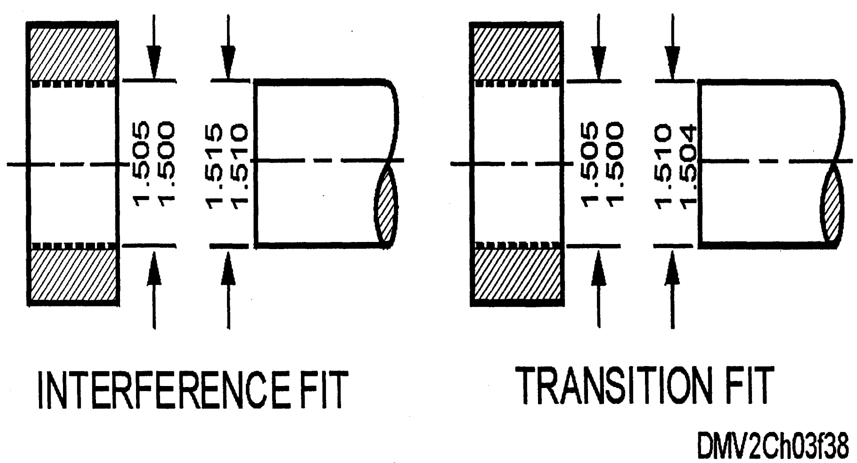

Figure 3-38.—The difference between: A. An interference fit, and B. A transition fit.

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Basic hole system

The basic hole system is a system of fits in which the design of the hole is the basic size and the allowance applies to the shaft.

When specifying the tolerances for a hole and cylinder and determining their dimensions, you should begin calculating by assuming either the minimum (smallest) hole or the maximum (largest) shaft size if they are to fit together well.

Figure 3-39 illustrates the basic hole system.

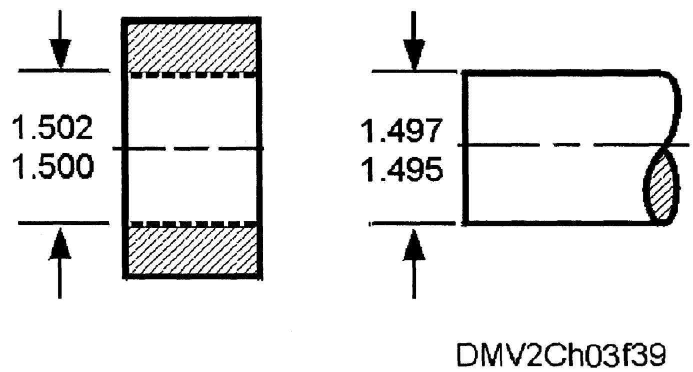

Figure 3-39.—The basic hole system.

In the illustration, the minimum hole size is the basic size. To calculate the maximum diameter of the shaft, assume an allowance of .003 inch and subtract that from the basic hole size.

Arbitrarily selecting a tolerance of .002 inch, apply the tolerance to both the hole and the shaft. This give a maximum hole (1.502 inches) and minimum shaft (1.495 inches). The minimum clearance fit is the difference between the smallest hole (1.500 inches) and the largest shaft (1.497 inches) or .003 inch. The maximum clearance fit is the difference between the largest hole (1.502 inches) and the smallest shaft (1.495 inches) or .007 inch.

Determine the maximum shaft size of an interference fit by adding the allowance (.003 inch) to the basic hole size (1.500 inches) or 1.503 inches.

To convert basic hole size to basic shaft size, subtract the allowance for a clearance fit or add it for an interference fit.

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Basic shaft system

The basic shaft system is a system of fits in which the design size of the shaft is the basic size and the allowance applies to the hole.

Figure 3-40 illustrates the basic shaft system.

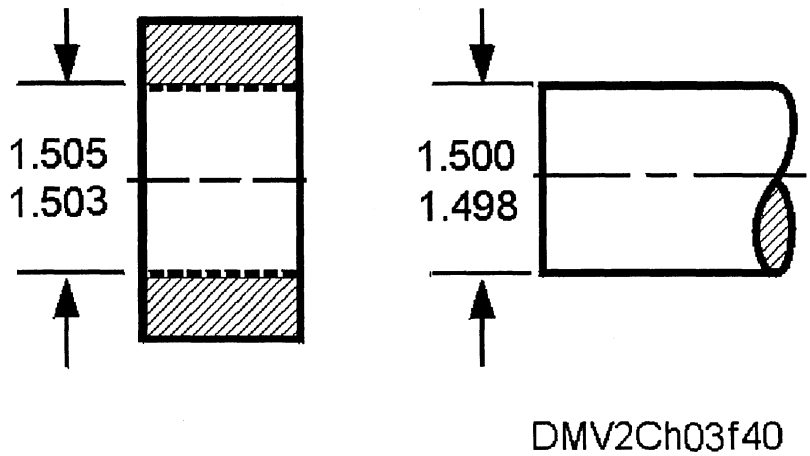

Figure 3-40.—The basic shaft system.

In the illustration, the maximum shaft size is the basic size. To obtain the minimum hole diameter, assume an allowance of .003 inch and add that to the basic shaft size.

Arbitrarily selecting a tolerance of .002 inch, add the tolerance to the hole and shaft to obtain the maximum hole (1.505 inches) and the minimum shaft (1.498 inches). The clearance fit is the difference between the smallest hole (1.503 inches) and the largest shaft (1.500 inches) or .003 inch. The maximum clearance fit is the difference between the largest hole (1.505 inches) and the smallest shaft (1.498 inches) or .007 inches.

Determine the minimum hole size of an interference fit by subtracting the allowance (.003 inch) from the basic shaft size (1.500 inches) or 1.497 inches).

To convert basic shaft size to basic hole size, add the allowance for a clearance fit or subtract it for an interference fit.

Views

Introduction

When drawing or projecting images on paper, you select a surface on the object and draw that surface parallel to the picture plane or paper surface. This creates a drawing with a limited amount of descriptive information. Technical drawings or blueprints must show a great deal more information and show it accurately. This often requires you to draw the same object as if you were looking from different viewpoints, bisecting piece parts, or exploding objects of complex design.

Views

A view is an image that results when an observer looks perpendicularly toward one face of an object and obtains a true view of the size and shape of that side. This one view provides only two of the three principal dimensions (width, height, and depth) of an object. You find the third dimension in an adjacent view. Some objects requiring only single view drawings to describe them are shafts, bolts, washers, and other similar items. More often than not, objects require two or multiple views to fully describe its features.

Multiview projection

Multiview projection is a systematically arranged set of views providing certain definite information about an object. You can view any object from six mutually perpendicular directions either by shifting the object with respect to the observer or by shifting the observer with respect to the object. The American National Standard arrangement of views vertically aligns the top, front, and bottom views and horizontally aligns the rear, left-side, front, and right-side views. Drawing a view out of place is a serious error, which can lead to confusion and wasted production hours.

Figure 3-41 shows the American National Standard for view arrangement.

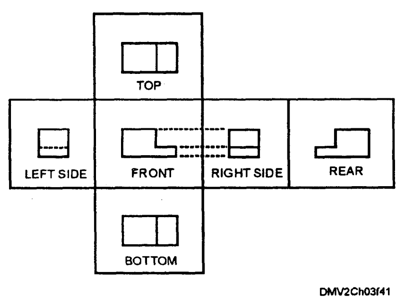

Figure 3-41.—View arrangement.

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Choice of views

Of these six possible views, the front, top, and right-side views are used most frequently. The plane of projection that provides the front view is called the *frontal plane,* the top view derives from the *horizontal plane,* and the plane that provides the side view is the *profile plane.* The front, top, and right-side views are called the *three regular views.* In architectural drawings, the top view is referred to by the term *plan,* and *elevation* refers to all views showing building height.

Figure 3-42 shows a plan and an elevation.

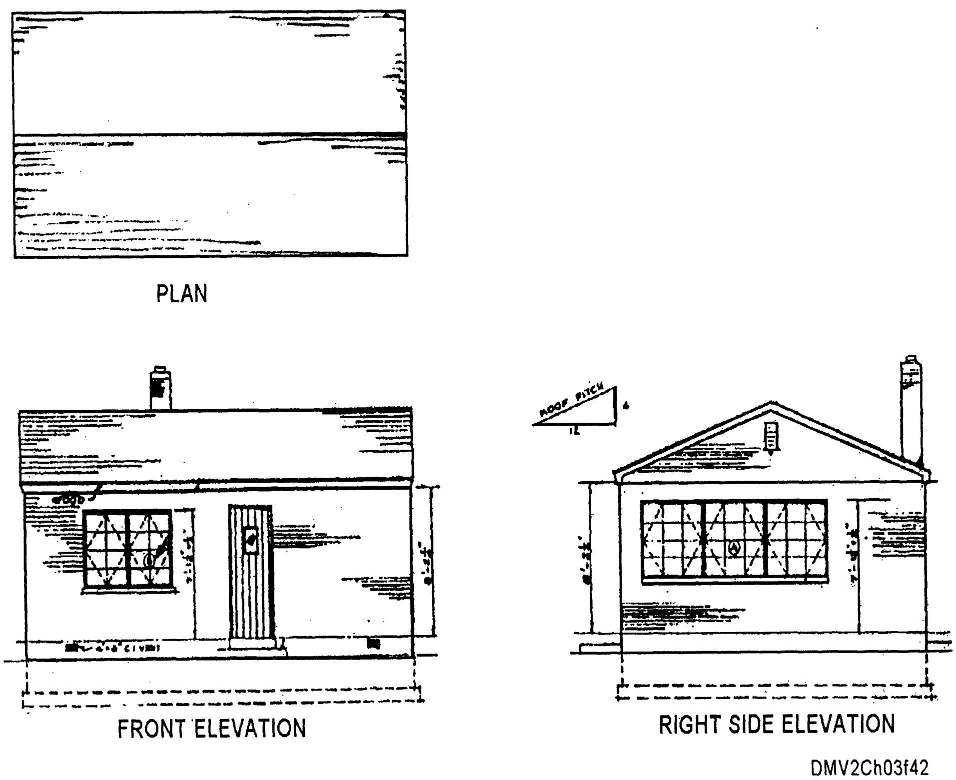

Figure 3-42.—A plan and elevation view.

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Choice of views (Continued)

Select only those views needed for a clear and concise description of an object, views that explain essential contours and contain the least number of hidden lines. When left- and right-side views are identical, use the right-side view. One way to determine which views to eliminate is to make thumbnail sketches of the object with all six views and eliminate those that show incomplete or redundant information. The minimum required number of views is referred to as necessary *views.*

Figure 3-43 illustrates the process of elimination in view selection.

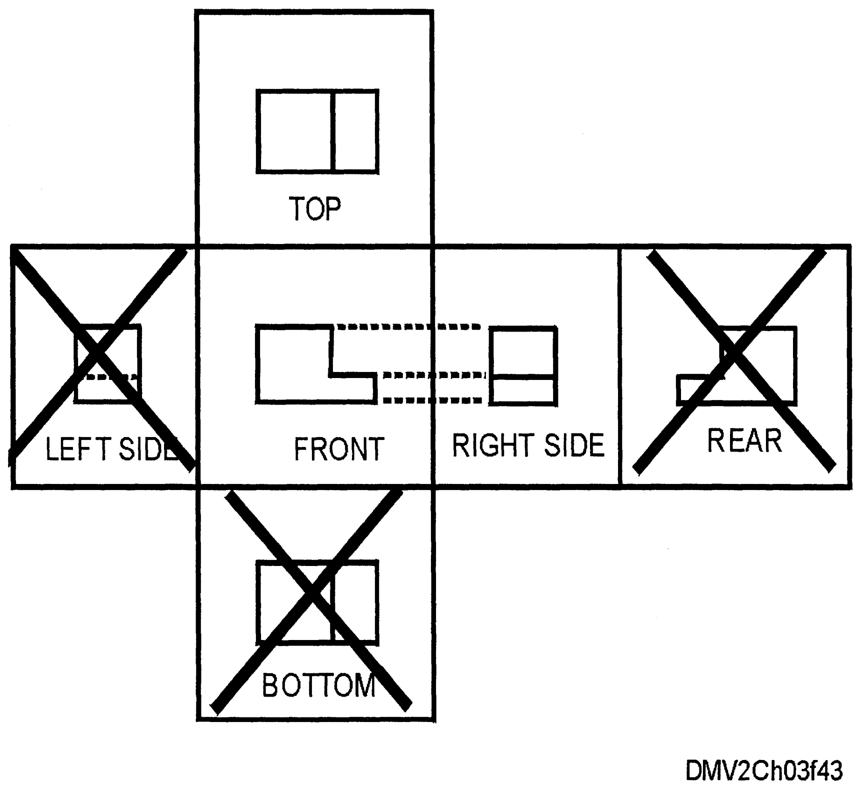

Figure 3-43.—Selecting necessary views.

Complicated objects may require more than three views or views on adjacent auxiliary planes.

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Auxiliary views

Any view not projected onto one of the principal planes is an *auxiliary view*. A *primary auxiliary view* is a view projected to a plane perpendicular to one of the three principal planes (top, front, or side) and inclined to the other two planes. A view projected from a primary auxiliary view on a plane inclined to all three principal planes of projection is referred to as a *secondary auxiliary view*. The purpose of an auxiliary view is to show the true shape and size of an inclined surface of an object since inclined surfaces are not parallel to any planes in multiview projections and appear foreshortened. The method of projecting the image of an object to an auxiliary plane is identical to the method used for projecting an image to one of the principal planes; that is, the projectors are parallel and the observer is positioned an infinite distance away from the object.

To draw a primary auxiliary view, follow this table:

Step	Action
1	Draw two adjacent principal views, one of which must show the inclined surface as an edge.
2	Lightly draw a reference line (AB) parallel to the edge view of the inclined plane.
3	Lightly draw a reference line (CD) between the two principal views. Use AB and CD to locate points in the auxiliary view.
4	Draw projectors from the inclined edge rotating reference line AB parallel with the inclined surface. These projectors are perpendicular to the inclined edge and the reference line as shown in figure 3-44.
5	Using a compass or dividers, transfer distances from reference line CD to the various points in the side view.
6	Darken all object outlines of the primary auxiliary view and erase all projectors and reference lines. The completed primary auxiliary view shows the true shape of the inclined surface.

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Auxiliary views (continued)

Figure 3-44 illustrates the steps in drawing auxiliary views.

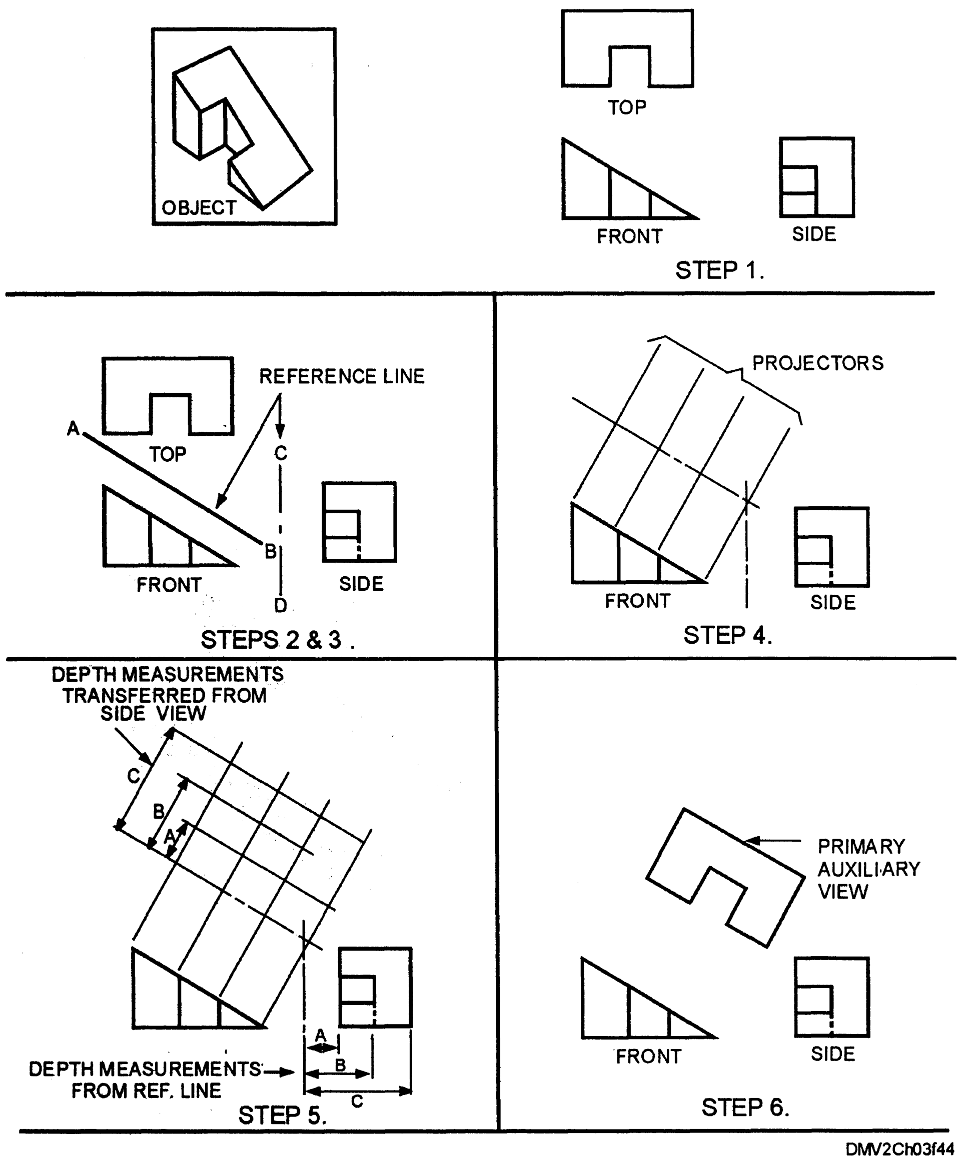

Figure 3-44.—Drawing an auxiliary view.

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Exploded views

Views that pictorially represent how objects and assemblies fit together are called *exploded views.* You may use any pictorial method including isometric and dimetric projection for exploded views with isometric representation the most common. Exploded views appear primarily in design presentations, catalogs, sales literature, and assembly instructions.

Figure 3-45 is an exploded view in isometric projection.

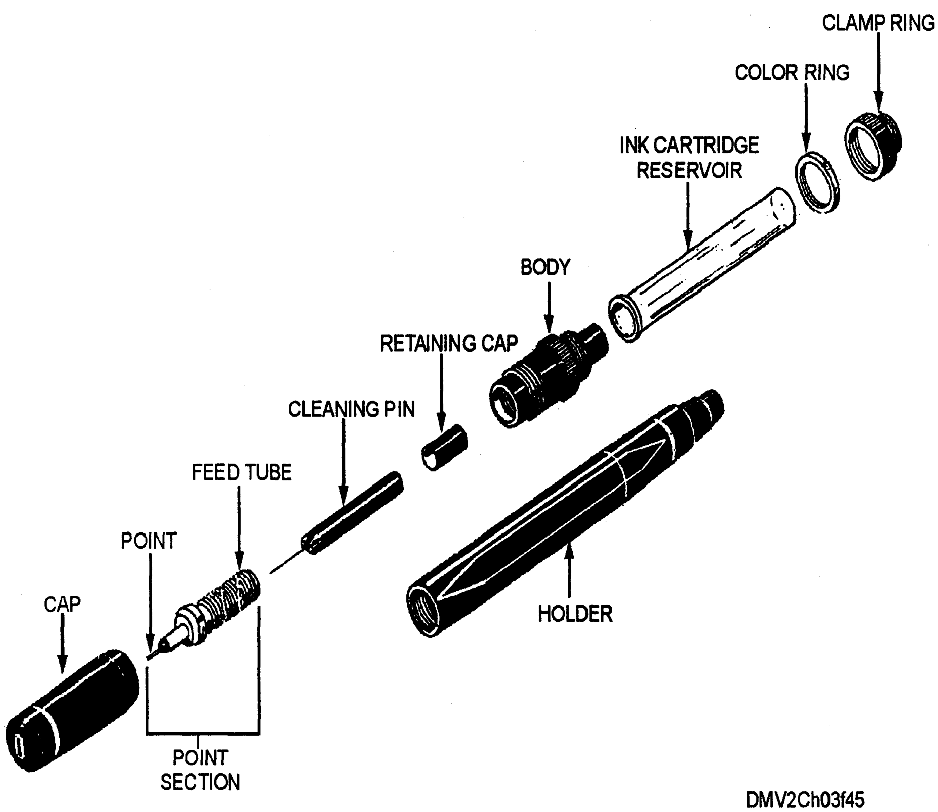

Figure 3-45.—An exploded view in isometric projection.

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Revolutions

A *revolution* is a view of an inclined surface obtained by revolving the object (not the observer as in auxiliary views) around an imaginary point until the desired surface appears in true shape and size. The imaginary point is the *axis of revolution.* Depending on the plane chosen, the axis is perpendicular to the plane of projection. Begin drawing revolutions by showing the object in its normal position, then revolving the object around the axis of revolution until the inclined surface is parallel to the plane of projection. Draw the plane of projection that is perpendicular to the axis first since it is the only view that remains unchanged in size and shape. You may revolve the object clockwise or counterclockwise. The first drawing of the revolved object is called the *primary revolution* and each view drawn in a new position using the primary revolution as a base is referred to as *successive revohtions.* Three other important rules to remember when drawing revolutions: (1) the revolved view always shows the axis as a point and this view does not change in size and shape, (2) in views where the axis appears as a line, dimensions parallel to the axis remains unchanged, and (3) lines that are parallel on the object are parallel in any view.

Figure 3-46 is a comparison of an auxiliary and a revolution view.

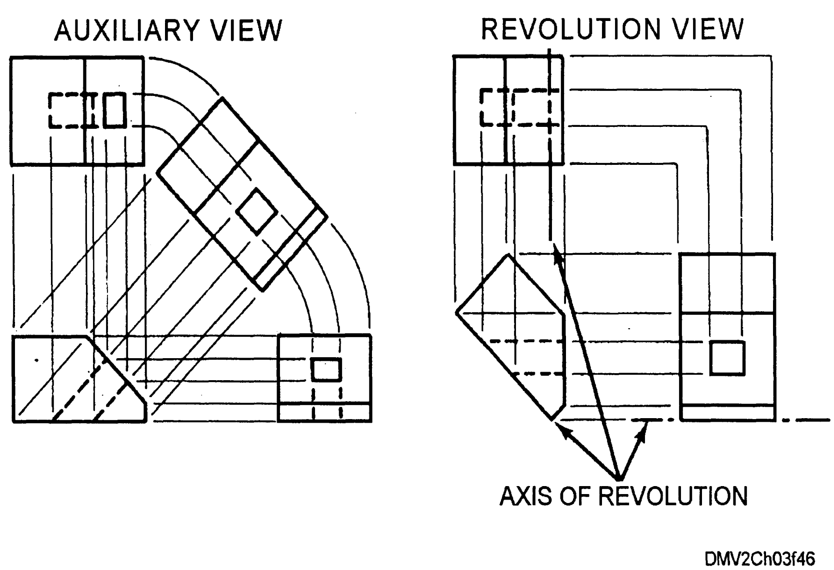

Figure 3-46.—Comparing an auxiliary and revolution view.

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Revolutions (Continued)

When revolving an object perpendicular to the front plane of projection, the depth dimensions in the top and side views remain true and the size and shape of the front view remain the same. The top and bottom views are now oblique to the horizontal plane of projection foreshortening the length dimensions. The side surfaces are now oblique to the profile plane causing vertical dimensions to foreshorten. The amount of foreshortening works itself out as you project the different views.

Figure 3-47 shows a 30-degree revolution perpendicular to the front plane of projection.

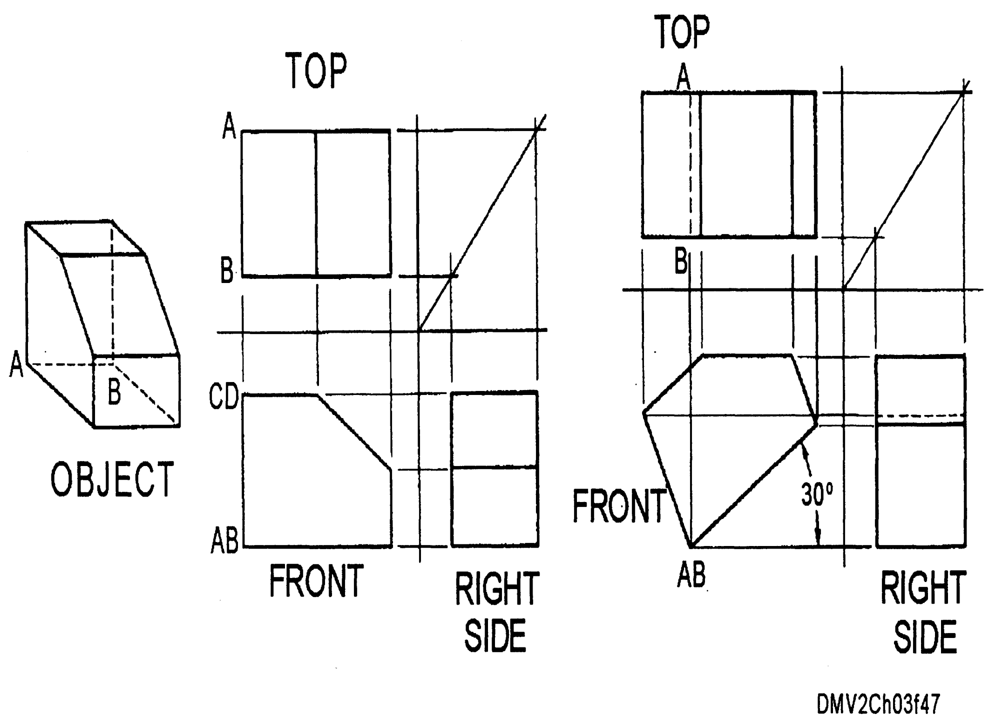

Figure 3-47.—Revolving the front plane of projection of an object 30 aegrees from the perpendicular.

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Revolutions (Continued)

When revolving objects perpendicular to the top plane of projection, height dimensions remain unchanged. Size and shape are unchanged. Transfer the revolved view from the orthographic view by means of dividers or a scale.

Figure 3-48 shows a 45-degree revolution perpendicular to the top plane of projection.

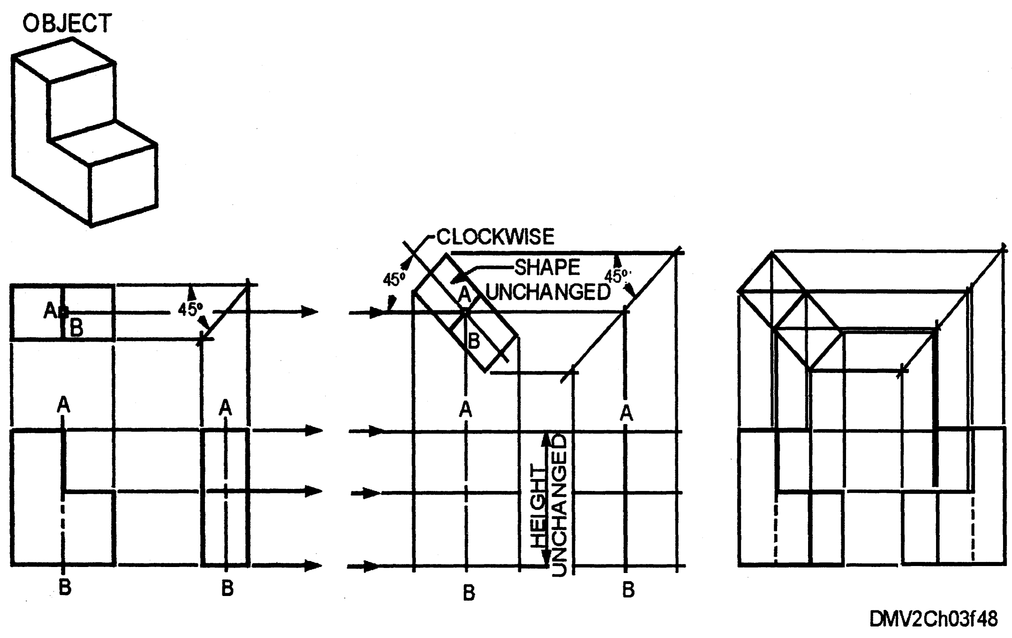

Figure 3-48.—A revolution perpendicular to the top plane of projection.

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Revolutions (Continued)

When you revolve a view perpendicular to the profile plane of projection, the axis appears as a point. The size and shape of the side view remain the same. The width of the object remains unchanged and you can transfer distances with a scale or dividers.

Figure 3-49 shows a 45-degree revolution perpendicular to the profile plane.

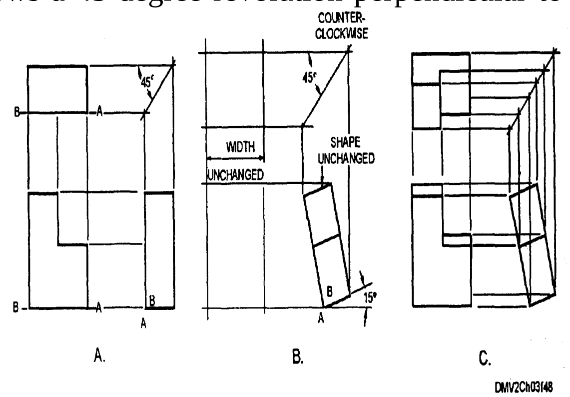

Figure 3-49.—A revolution 45 degrees to the profile plane.

You can find the true length of any line easily by means ‘of a revolution.

Figure 3-50 illustrates finding the true length of any line by revolution.

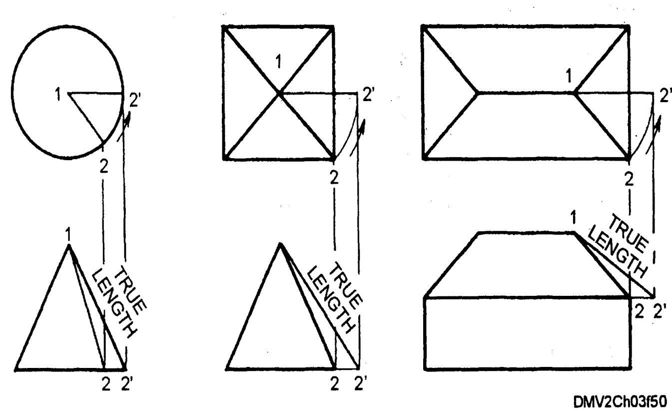

Figure 3-50.—The true length of any line in a revolution.

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Sectional views

To produce a sectional view, an imaginary plane, called the cutting plane, cuts through the object and the two halves are separated to expose the interior construction. The direction of sight may be toward the right or left half, while you disregard the portion of the object nearest the observer. Use a cutting plane line or viewing plane line to indicate the cutting plane and the direction of sight. Sectional views may be further classified as full, half, broken-out, revolved, removed, offset, aligned sections, and partial views.

Figure 3-51 shows an imaginary plane cutting through an object.

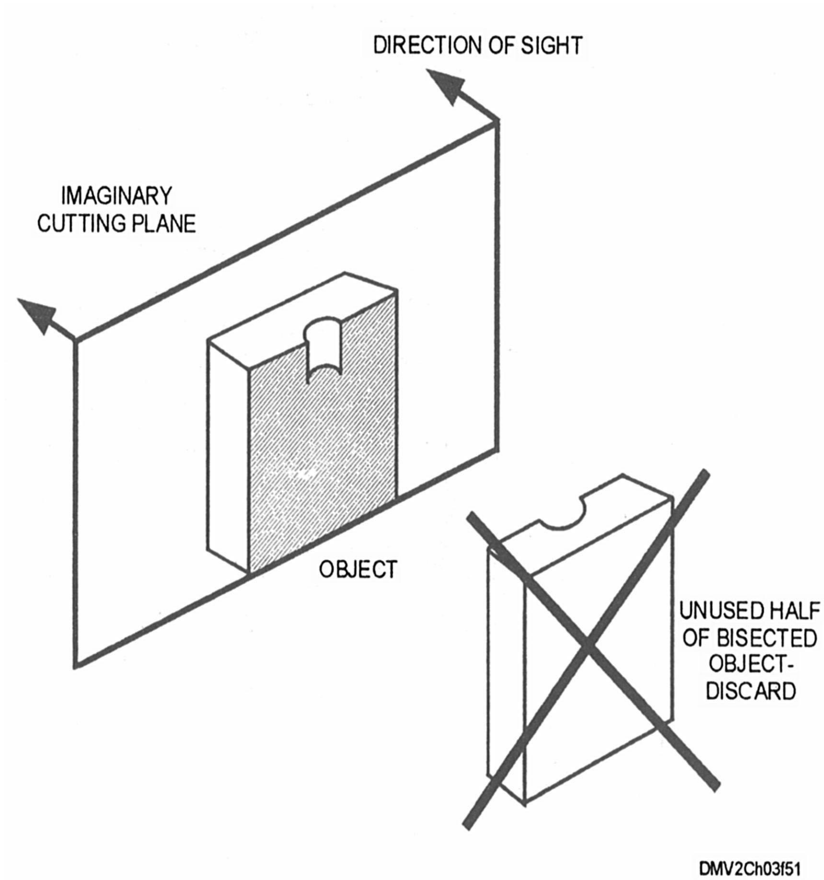

Figure 3-51.—Sectional views.

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Full sections

Passing the cutting plane completely through an object results in a full *section.* If the cutting plane is simple, it has the appearance of halving an object.

Figure 3-52 shows a full section.

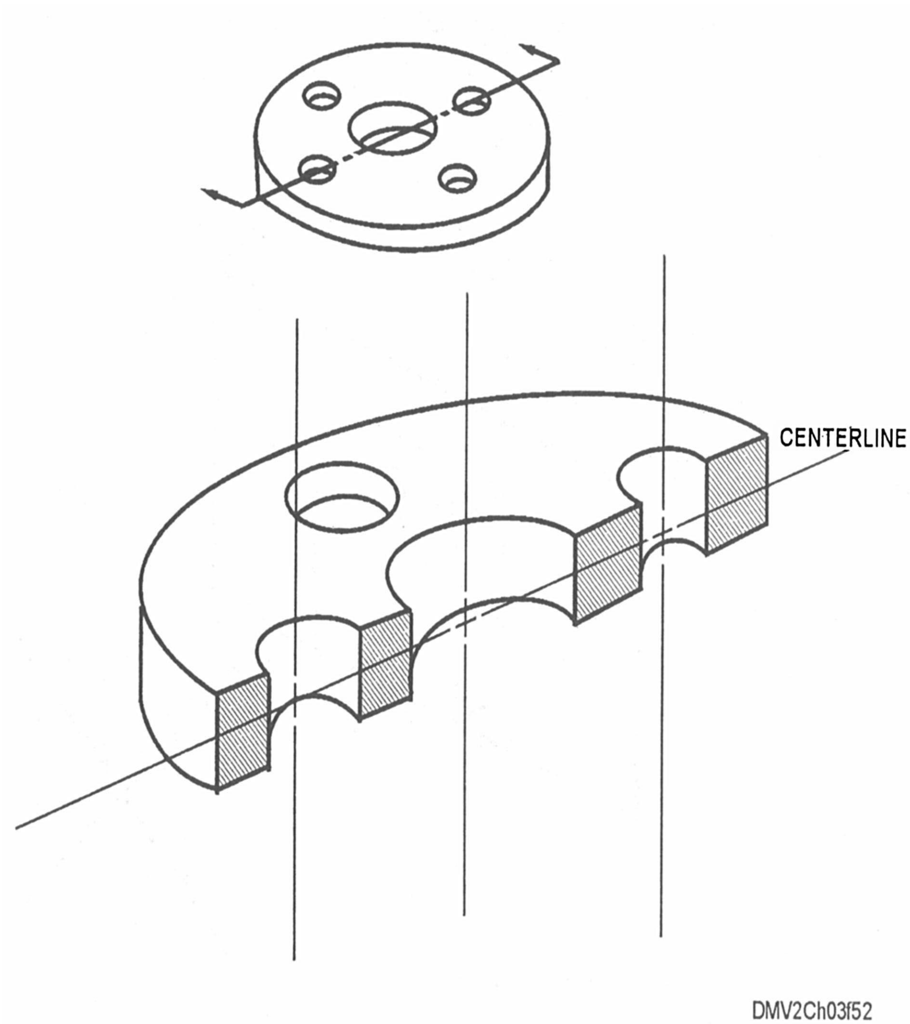

Figure 3-52.—A full section.

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Half sections

Cutting planes that pass halfway through an object result in a *half section.* The American National Standards Institute (ANSI) recommends using centerlines for the division line between the sectioned half and the unsectioned half of a half-section view. Notice that in fact, by using both centerlines you expose only one quarter of the object. Use a half-section view when you must show the interior of one half of the object while retaining the exterior of the other half. This limits the useful application of half-section views to symmetrically-shaped objects. Half sections are most useful when used in assembly drawings. Because half sections require symmetry and are difficult to dimension, they are not often used in detail drawings.

Figure 3-53 shows a half-section view.

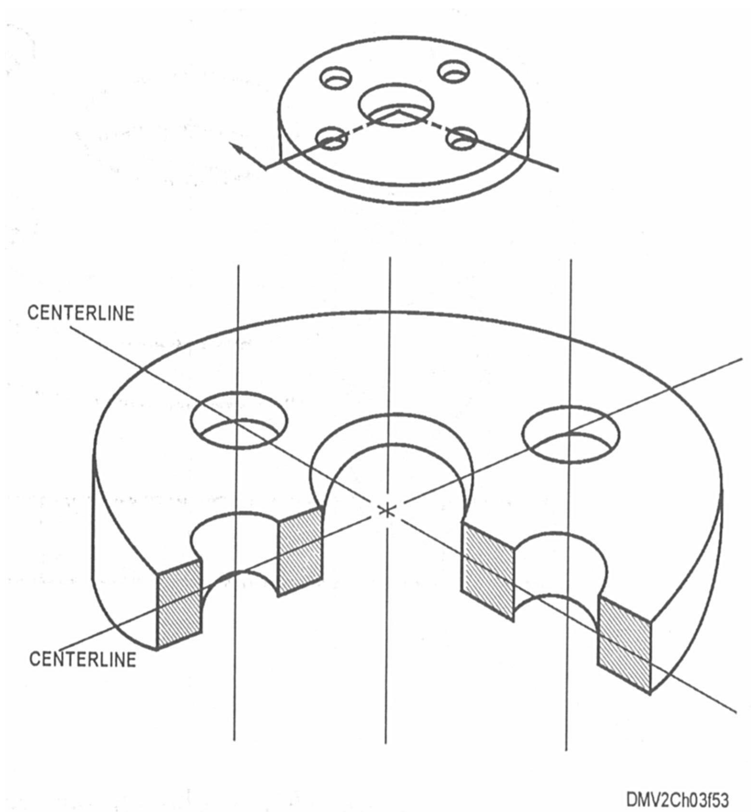

Figure 3-53.—A half section.

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Broken-out sections

When it is necessary to expose only a small portion of the internal shape of an object but not enough to warrant a full or half section, use a *broken-out section.* Define a broken-out section with a break line or a combination of a break line and a centerline.

Figure 3-54 shows a broken-out section using a break line.

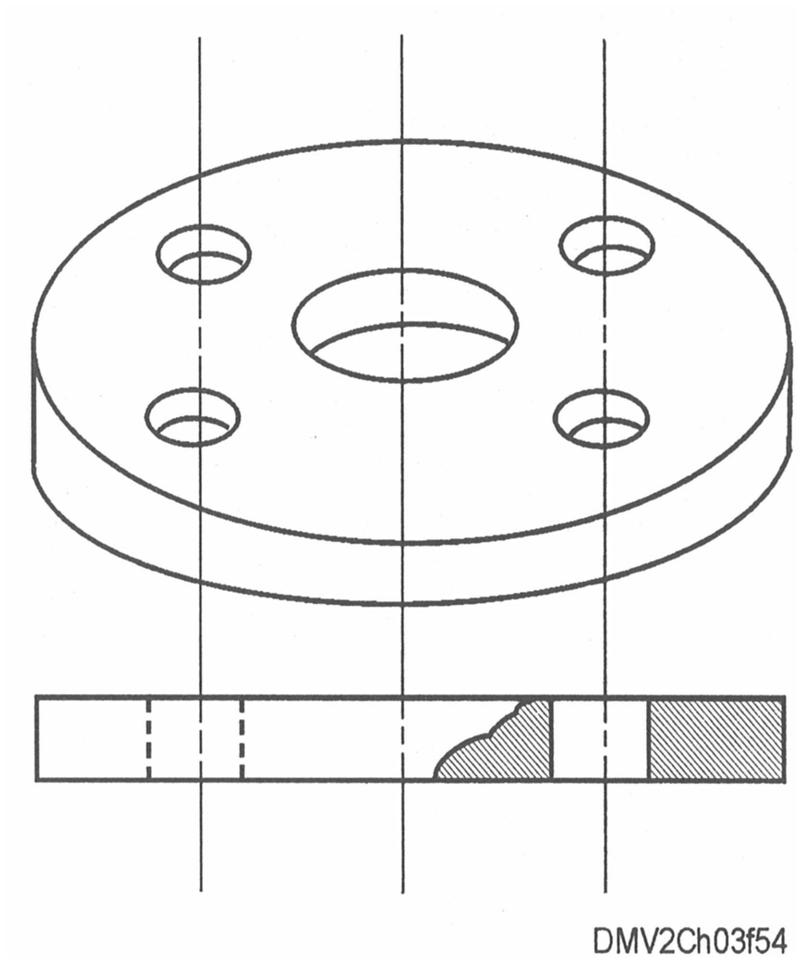

Figure 3-54.—A broken-out section.

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Revolved sections

Revolved sections are cross sections of an elongated form or object rotated toward the plane of projection to show its shape or contour. Drop a cutting plane perpendicular to the axis of the object and revolve the plane 90-degrees around a centerline and at a right angle to the axis. Retain the true shape of the revolved section regardless of the direction of the lines in the view. Superimpose the revolved section over the view and remove all original surface lines.

Figure 3-55 shows correct and incorrectly drawn revolved sections.

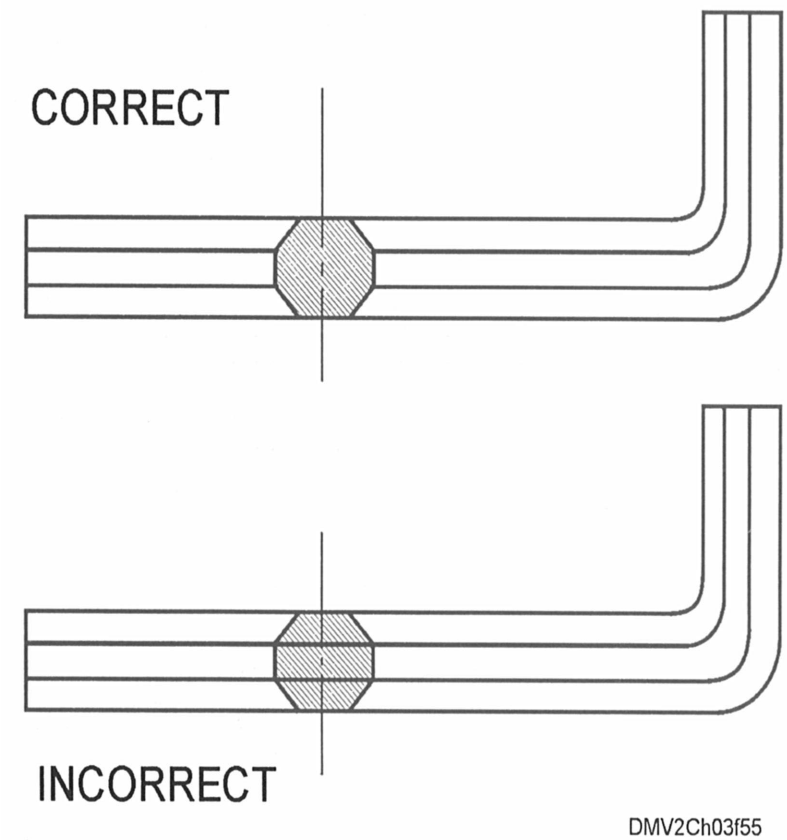

Figure 3-55.—A correct and incorrect revolved section of an allen wrench.

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Removed sections

A *removed section* is a section or partial section not directly projected from the view containing the cutting plane and not revolved or turned from its normal orientation. A removed section does not align with any other view, but, sometimes appears on centerlines extended from the section cuts. Use removed sections to show small details and to facilitate dimensioning. For this reason, they are often drawn in enlarged scale. Label removed sections alphabetically from left to right on the drawing and corresponding to the letters at the end of the cutting plane line. Precede the letters with the abbreviation SECT or SECTION. To avoid confusion, do not use the letters I, O, and Q. When you draw the removed section enlarged, indicate the larger scale beneath the section title.

Figure 3-56 shows removed sections.

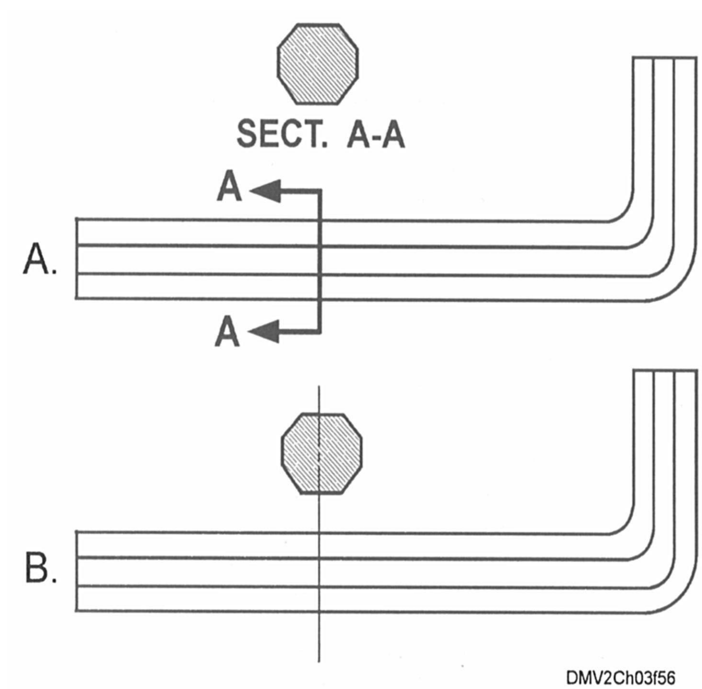

Figure 3-56.—Showing a removed section of an allen wrench using: A. The cutting plane, and B. The aligned section method.

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Offset sections

An *offset section* results when you bend the cutting plane to show internal features that are not in a straight line. The offsets or bends in the cutting plane never show in the sectional view. Cutting plane lines in an offset section appear as thick, dashed lines.

Figure 3-57 is an offset section.

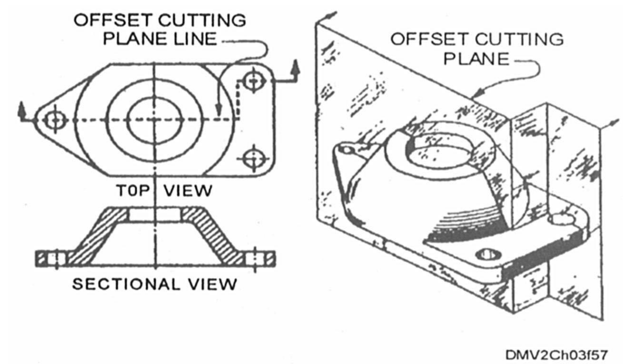

Figure 3-57.—An offset section.

Aligned sections

Aligned sections are sections where the cutting plane bends to pass through specific features of an object, then revolves 90-degrees to the plane of projection and aligns to a position across from the original view. Use aligned sections to give a clearer view and more complex description of objects.

Figure 3-58 shows an aligned section.

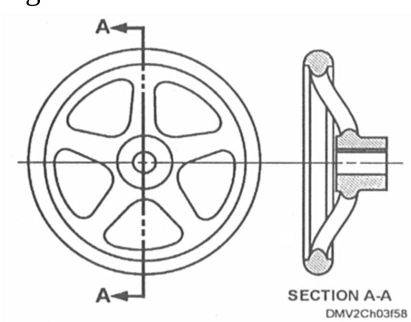

Figure 3-58.—An aligned section.

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Partial views

When objects are symmetrical and you are limited in the amount of space on the drawing or in drafting time, you may reduce an object image to only those features needed for minimum representation or a *partial view. You* may use partial views in conjunction with sectioning.

Figure 3-59 shows just how far you may take minimum representation.

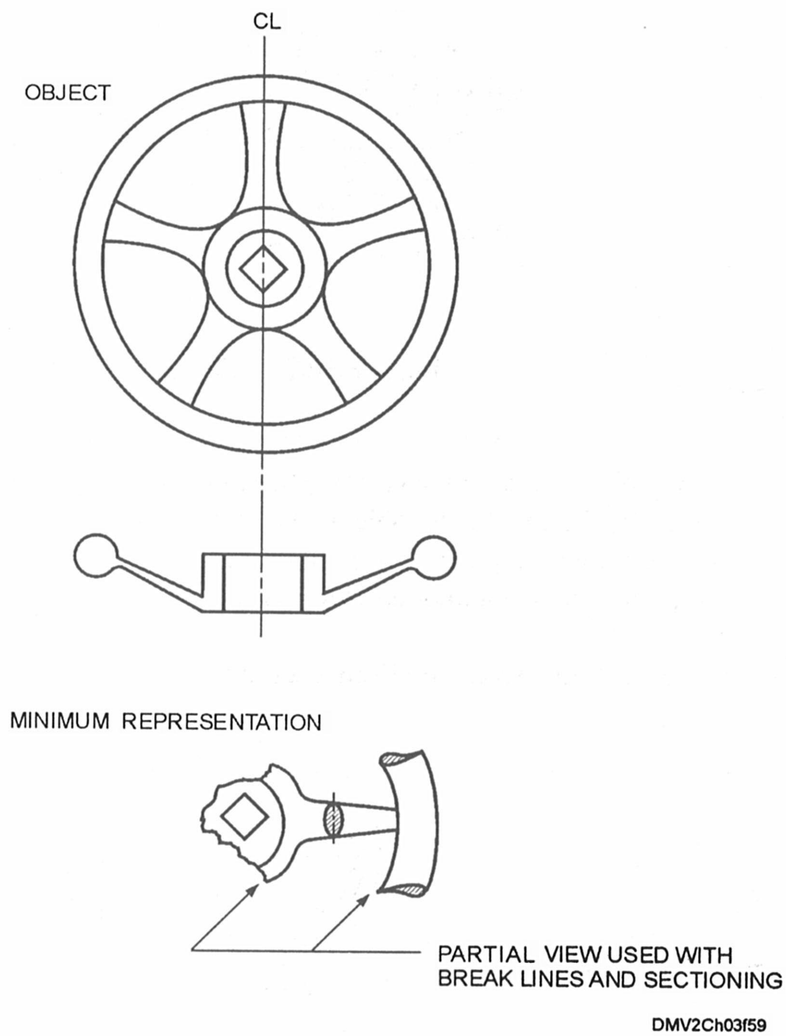

Figure 3-59.—Minimum representation of a symmetrical object.

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Conventional breaks

Use *conventional breaks*, often referred to as S-breaks, when elongated objects cannot fit on the drawing paper and you must figuratively remove a portion of the object. For this to work correctly, the object must maintain the same dimensions throughout its length or have a uniform taper. The break lines are usually drawn freehand; however, beginners may have more professional results if they use an irregular curve, compass, or s-break template.

Figure 3-60 illustrates conventional breaks in rods and tubing.

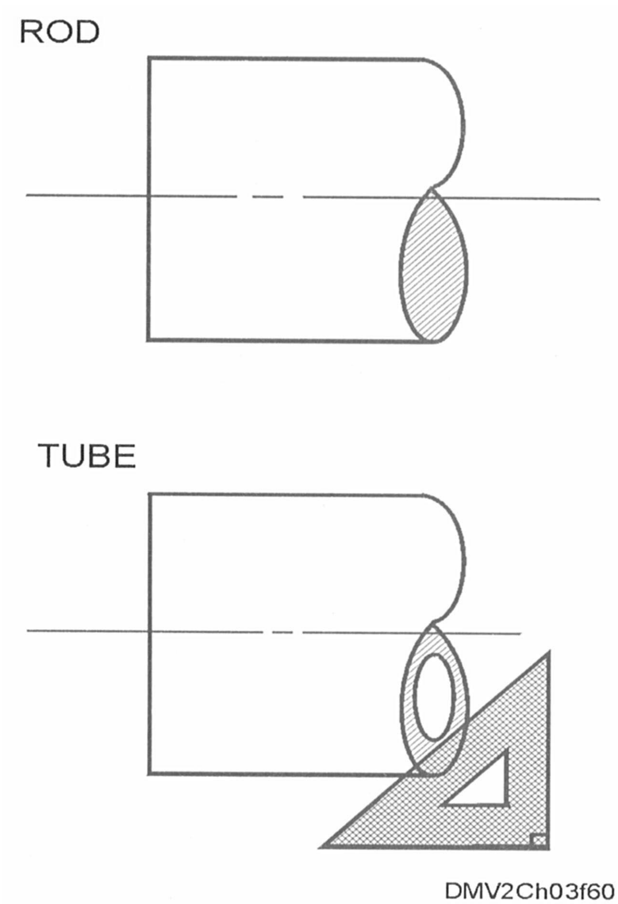

Figure 3-60.—Conventional breaks in rods and tubing.

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Conventional breaks (Continued)

Figure 3-61 is a table of industry accepted conventional break line conventions.

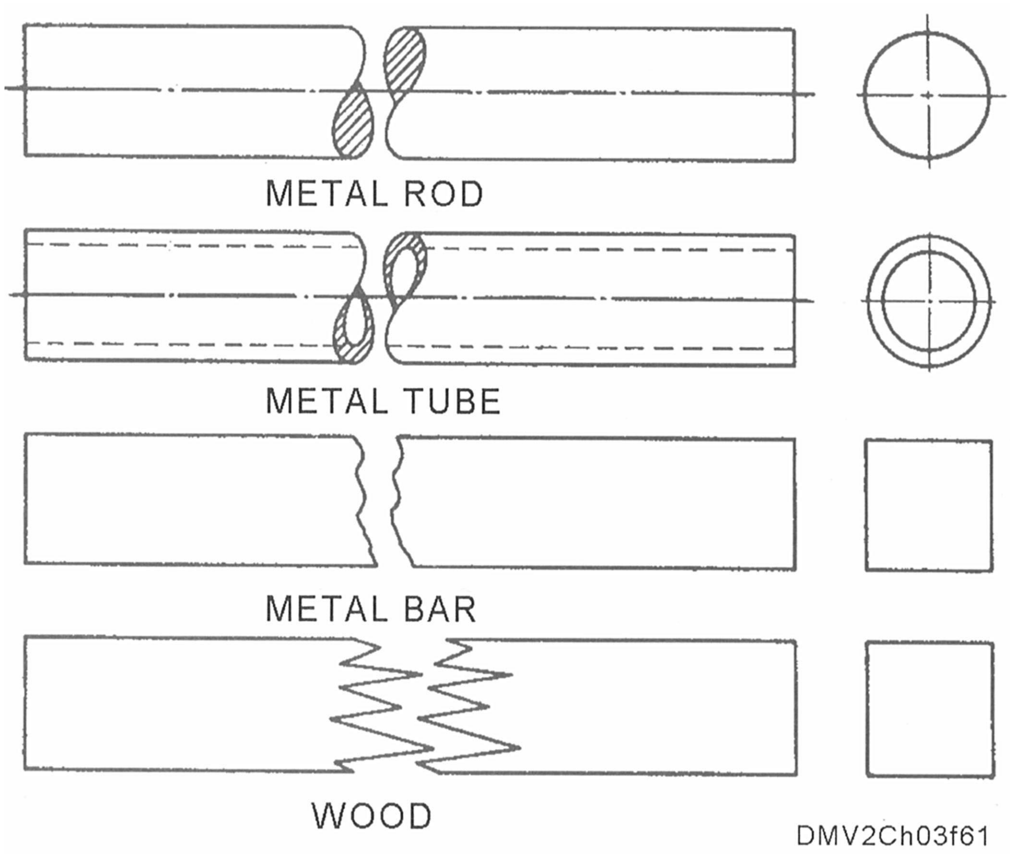

Figure 3-61.—Conventional break lines.

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Lines in sections

In section drawings, all visible edges and contours behind the cutting plane are shown. The exception is if the visible line or contour does not add to clarity in the representation. Since sectional views are meant to replace or define hidden lines, hidden lines should not appear in sectional views. The exception to this edict is when the hidden line is necessary for clarity and using it will allow you to omit a view.

Figure 3-62 illustrates correct and incorrect examples of lines in sectioning.

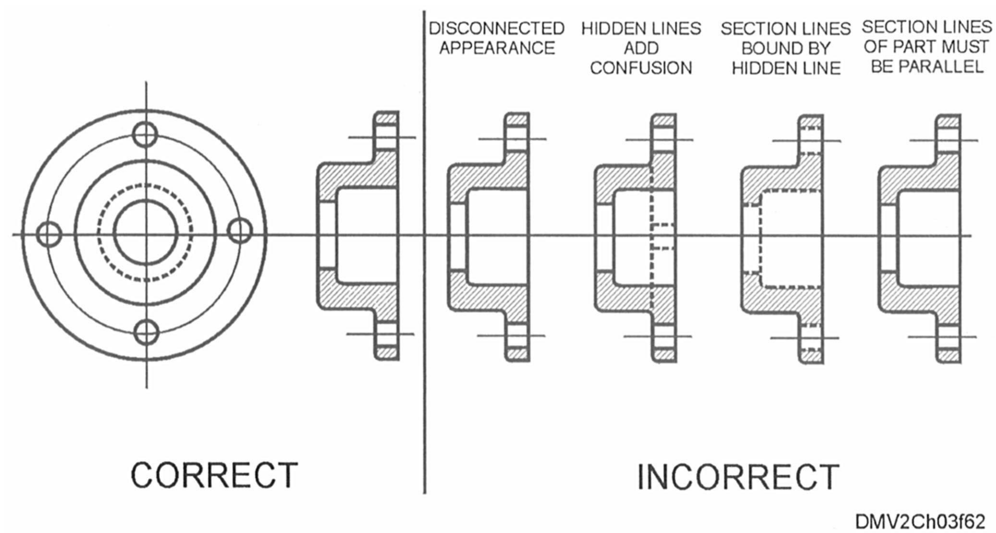

Figure 3-62.—Correct and incorrect lines in a sectional view.

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Section lining

Section lining is the symbolic representation of surfaces used to indicate the material used in producing the object or the finish given to the surface of the object. Additionally, you should notate detailed specifications on materials or surface finishes in text on the drawing in the title strip. Since there are many different section lining symbols, a general-purpose section lining (which normally represents cast iron) is often used in conjunction with specific notations to save time and effort.

Figure 3-63 lists common section linings.

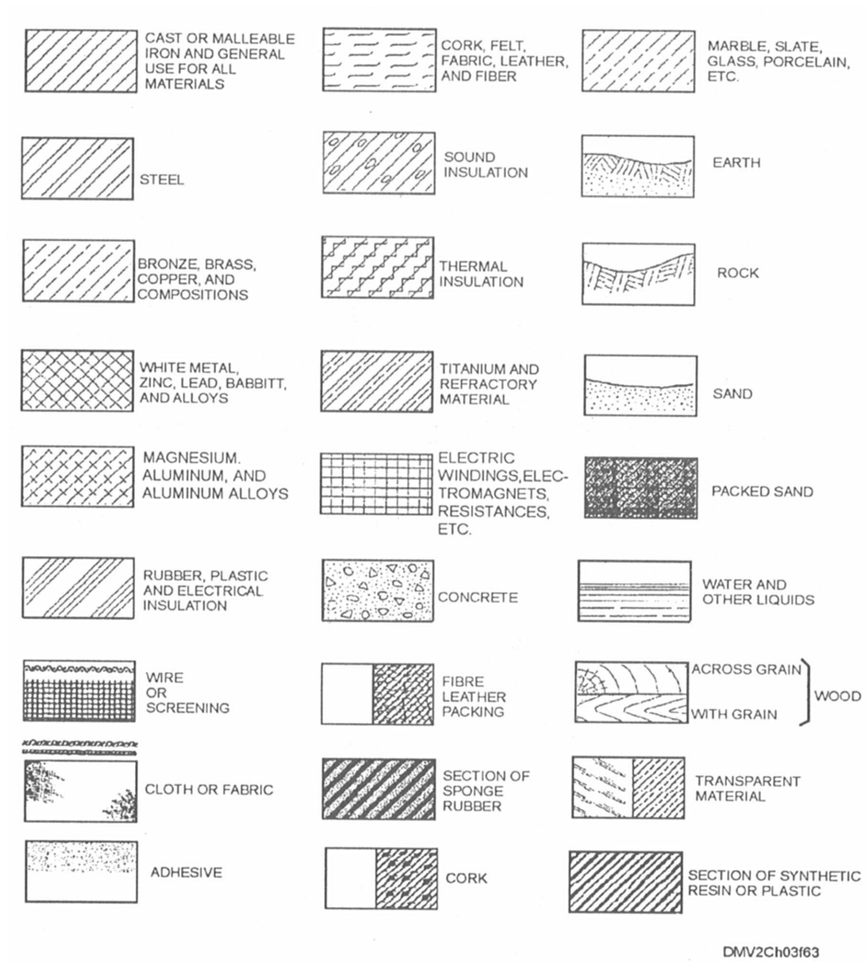

Figure 3-63.—Common section linings.

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Drawing section lines

There are several basic rules to drawing section linings that have a professional finished appearance.

To draw professional looking section linings. follow these rules:

- Section lining is always bound by visible lines.
- Do not overdraw section lines beyond visible lines.
- Visible lines never pass through an area of section lining.
- Section lines should be thinner than visible lines.
- Section lines should be uniformly thin, even in weight and with good resolution.
- Section lines within a sectioned area must be parallel.
- Uniformly space lines in section linings.
- Space section lines between 1/16- to 1/8-inch apart depending on the size of the drawing. For average section linings, space the section lines approximately 3/32-inch apart.
- Always draw section lines at 45 degrees to the horizontal.
- If section lines drawn appropriately at a 45-degree angle are or appear nearly parallel or perpendicular to a prominent visible outline, change the angle of the section lining to another easily drawn angle such as 30 or 45 degrees.
- Avoid dimensioning on sectioned areas and over section linings. When this is unavoidable, remove the section lining in the areas where the dimensions appear.
- When two or more parts in a section are adjacent, use section linings in opposing directions.
- You may limit drawing section lines to areas adjacent to the outline of sectioned areas, called *outline sectioning*, providing the drawing remains clear.

Figure 3-64 shows examples of correct and incorrect section lining.

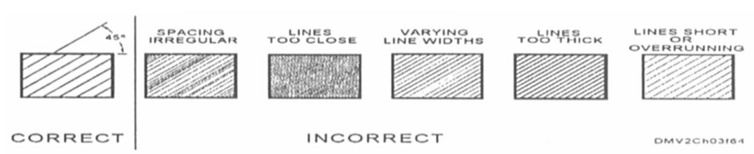

Figure 3-64.—Correct and incorrect section linings.

Summary

Review

This chapter introduces the novice draftsman to fundamental drafting terminology and practices by first defining general drafting categories and discussing DOD- and MIL-STDs. Good pencil technique and the order of inking lead the section on drafting techniques and set the criteria for line resolution. Industry-accepted line conventions, how and when to draw particular lines and their associated meanings precede the section on views, which covers regular, necessary, auxiliary, exploded, and partial views. Detailed coverage on sectional views, lines in a section, and section lining completes the chapter of general drafting practices.

Comment

As stated earlier, a good draftsman is never unemployed. Whether you work in applications drafting, piece part documentation, or research and design, you must know standard drafting terminology, standards, and practices. A computer is only a tool you, the draftsman, use to reduce board time and it cannot think for you. Learn correct drafting procedures. Nothing is more beautiful or satisfying to look at than a correctly executed ink drawing of a complex object. Drafting was and is an exciting and renumerative career. Computer-aided drafting is even more fascinating.

CHAPTER 4

TECHNICAL DRAWINGS

Overview

Introduction

In the United States, modern technical drawing can be traced to the year 1849 when a Baltimore, Maryland, schoolteacher published what is widely believed to be the first text on technical drawing. At that time, technical drawings were fine line drawings that resembled copperplate engravings. With the introduction of the blueprint process in 1876, fine line drawings became obsolete and modern technical drawings evolved. The Industrial Revolution in the early 1900s further refined, defined, and standardized technical drawing techniques, nomenclature, and symbology. The term *technical drawing* accurately suggests the broad scope of drawings for industry.

Objectives

The material in this chapter enables you to do the following:

- Identify the application of freehand drawing techniques in technical drawings.
- Describe freehand technical sketching techniques.
- Differentiate between technical sketching and technical drawings.
- Understand the importance of proportion and accuracy in technical drawing.
- Recognize graphic symbols for electrical and mechanical drawings.
- Recognize graphic symbols for structural drawings.
- Identify machine drawing screw thread technology.
- Interpret piping blueprints.

Continued on next page

Acronyms

The following table contains a list of acronyms you must know to understand the material in this chapter:

Acronym	Meaning
A	Addendum
AC	Addendum Circle
ANSI	American National Standards Institute
ASCE	American Society of Construction Engineers
ASME	American Society of Mechanical Engineers
C	Clearance
CAD	Computer Aided Drafting
CAM	Computer Aided Manufacturing
CP	Circular Pitch
D	Dedendum
DIA	Diameter
DP	Diametrial Pitch
DOD-STD	Department of Defense Standards
MIL-STD	Military Standards
N	Number of teeth
NC	National Course
NF	National Fine
OC	On Center
OD	Outside Diameter
PD	Pitch Diameter

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Acronyms (Continued)

Acronym	Meaning
PLS	Places
R	Radius
RD	Root Diameter
SECT	Section
TYP	Typical
UNC	Unified National Course
WD	Whole Depth

In this chapter

This chapter covers the following topics:

Technical Drawings and Sketches

Introduction

The entire world depends upon technical drawings to convey the ideas that feed today's industrialized society. Architectural, structural, electric, electronic, machine, plumbing, and piping drawings are all forms of mechanical/technical drawings. When rendering technical drawings, accuracy, neatness, technique, and speed in execution are essential. Inaccurate drawings could be worthless or lead to costly errors.

Technical drawings and sketches

Technical drawing is a necessarily broad term that applies to any drawing used to express technical ideas. Technical drawings are usually mechanically refined by using straightedges, triangles, and drafting instruments. Many of these drawings begin as a form of sketching. *Technical sketching* is a freehand sketch. The only equipment required to execute technical sketches are soft pencils in the F to HB range, paper, and an eraser. The novice sketcher may find paper that is cross sectioned with ruled lines beneficial in establishing and maintaining scale. There are gridded papers, isometric papers for isometric sketches, and perspective papers for sketches requiring perspective available. When selecting an eraser, chose a soft (pink) or artgum eraser.

Types of sketches

Since technical sketches and drawings represent three-dimensional objects, your sketches should conform to one of the four standard types of projection. The four major types of projection are (1) multiview, (2) axonometric, (3) oblique, and (4) perspective. Each type of projection is covered in detail in later chapters of this volume.

Figure 4-1 shows the four types of projections.

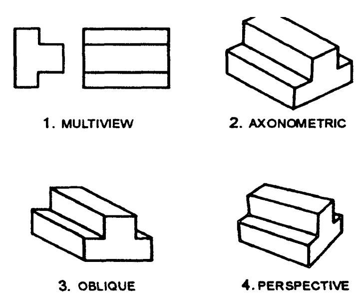

Figure 4-1.—The four types of projections.

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Scale

Technical sketches are not made to any scale. The size of your sketch depends upon the complexity of the object and the size of your paper. They are preludes to fabrication drawings (requiring precise measurements) and only meant to convey an overall idea. Using gridded or ruled sketching paper helps you to draw objects to size.

Figure 4-2 shows various types of ruled papers.

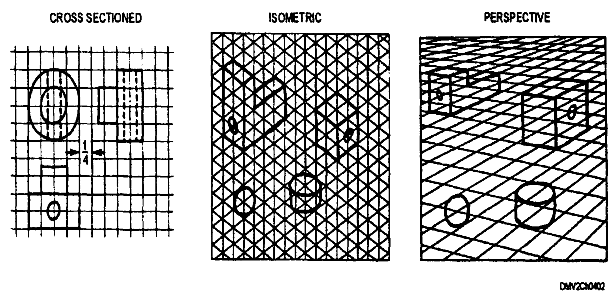

Figure 4-2.—Ruled sketch paper.

Proportion

Technical sketches must be proportional. No matter how much attention you pay to detail or how good your technique is, if the proportions are incorrect, the image is not successful. One method of establishing proportion is to use a small dowel or your pencil as a measuring stick representing an arbitrary unit of measure. Begin establishing proportion by comparing height-to-width ratios. Visually transpose that measurement to your paper. As you proceed with the sketch, continue to compare larger areas with smaller areas using the dowel or pencil as a ruler.

Figure 4-3 illustrates how to use a dowel or pencil as a unit of measure.

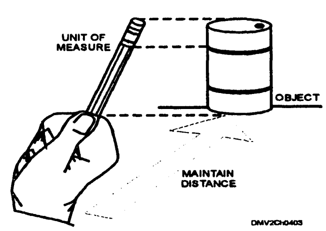

Figure 4-3.—Using a pencil as a unit of measure.

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Sharpening your sketch pencils

To maintain uniform pencil width and pinpoint accuracy, you should sharpen your pencil lead to a conical point. Standard office pencil sharpeners are fine for keeping the lead pointed. Also available are sharpeners that remove only the wooden encasement surrounding the graphite lead. These sharpeners require you to shape the lead by dragging the lead across a sandpaper pad while rotating the pencil simultaneously between your thumb and forefinger. For detailed instructions on sharpening pencil leads, see *DM, Volume I,* chapter 1.

Figure 4-4 shows how to point the pencil lead.

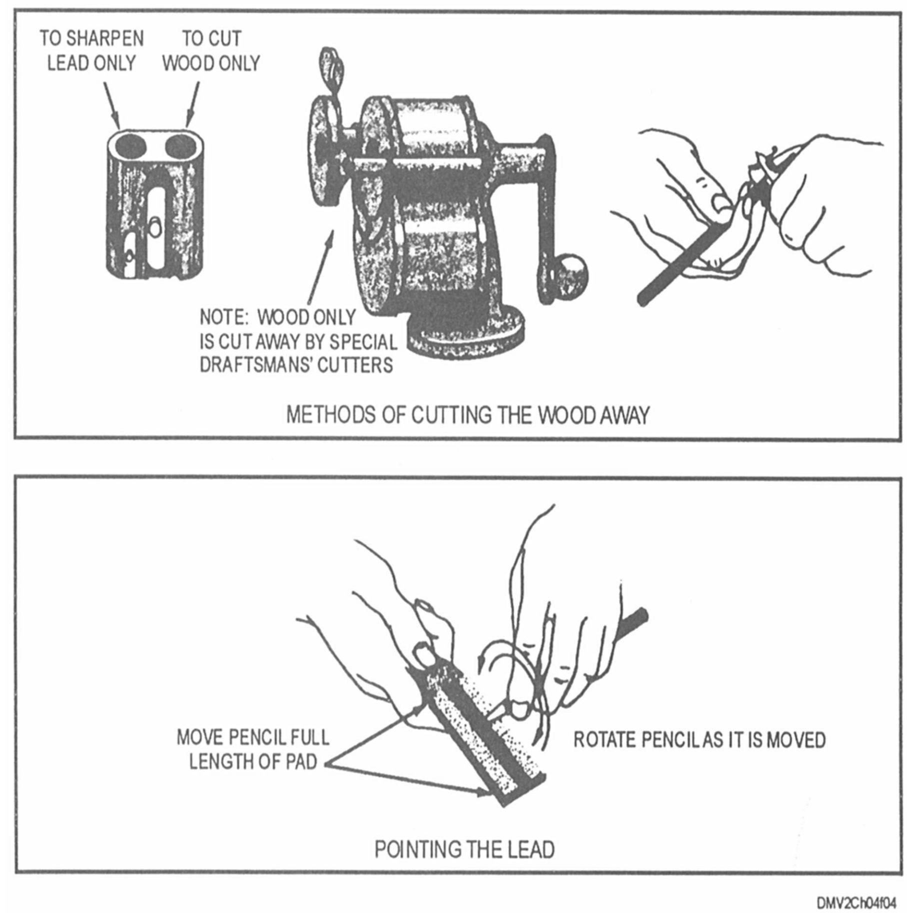

Figure 4-4.—Sharpening a pencil.

Continued on next page

Drawing straight lines

Pencil strokes are made by combined movements of your wrist and fingers. Sketch vertical and diagonal lines that slope to the left from top to bottom. Horizontal and diagonal lines that slope to the right are drawn from left to right. To help you become more proficient at sketching straight lines, place a series of dots approximately 1 inch apart and connect the dots with a series of short strokes. The better you become at sketching straight lines, the farther apart you should place the dots until the dots disappear altogether.

Figure 4-5 shows how to sketch straight lines.

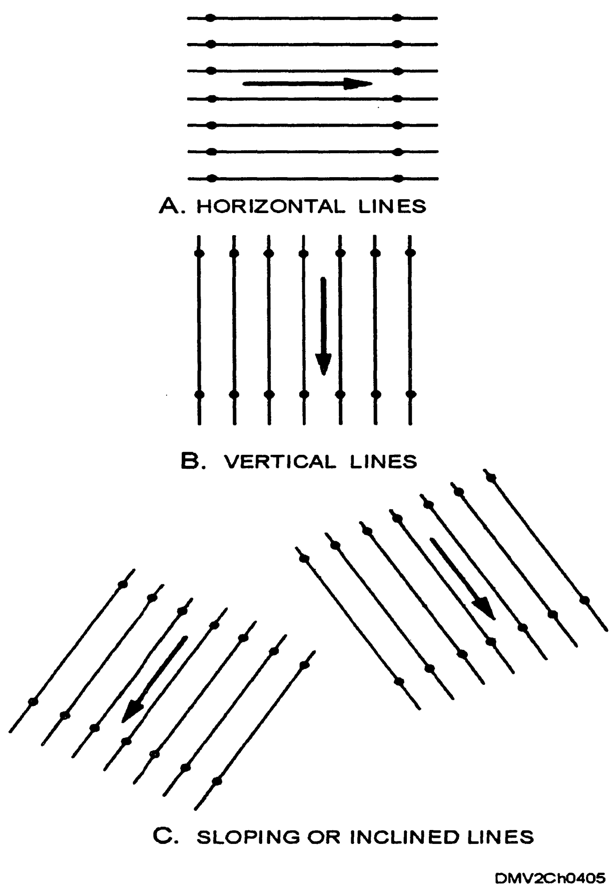

Figure 4-5.—Sketching straight lines.

Continued on next page

Sketching arcs, circles, and ellipses

Sketching arcs, circles, and ellipses are very similar processes. Lightly drawing a box to the proportion of the desired arc, circle, or ellipse will help in its construction. Using combined movements of your wrist and fingers, make short counterclockwise strokes. When you must join arcs to straight lines, draw the straight lines first to locate the ends of the arcs.

Figure 4-6 illustrates the sketching of arcs and circles within a box.

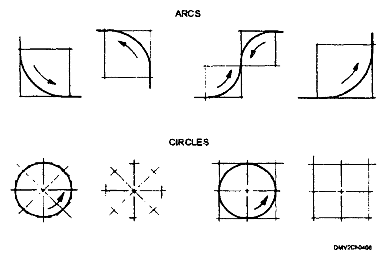

Figure 4-6.—Sketching arcs and circles.

You may also draw circles and ellipses using a trammel. A *trammel* is a length of cardboard or paper marked with both the major and minor axis of the desired ellipse. Place the trammel so that two of the points are on the respective axes. Mark the third point clearly since this point will form the curve on the paper. Place a dot periodically at the third point as you move the other two points along the axes. Place enough points to ensure a smooth and symmetrical ellipse. Sketch the ellipse lightly, then follow more heavily with the aid of irregular curves.

Figure 4-7 shows the use of a trammel.

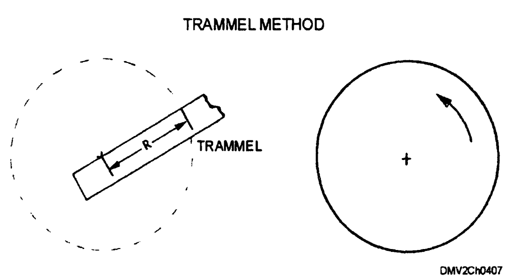

Figure 4-7.—Using a trammel to form a circle.

Continued on next page

Sketching arcs, circles, and ellipses (Continued)

To sketch ellipses freehand, hold the pencil naturally and rest the weight of your hand on the upper part of your other forearm. With your hand raised slightly above the paper, move the pencil rapidly in an approximate elliptical path. Once in motion, lower the pencil to lightly sketch overlapping ellipses.

Figure 4-8 illustrates the steps involved in freehand sketching an ellipse.

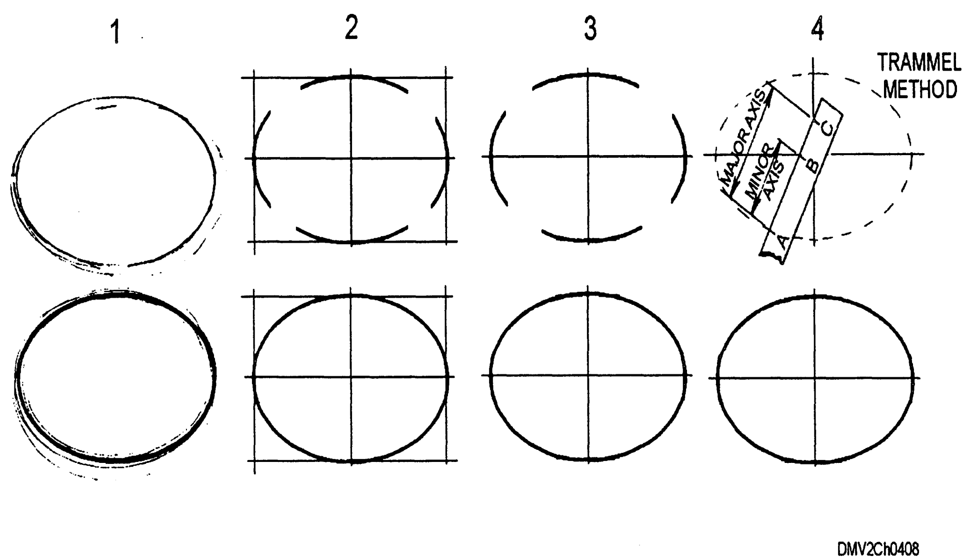

Figure 4-8.—Drawing ellipses.

Transferring or tracing images

When you need to transfer or trace images from one drawing to another or from one portion of a drawing to another location, you may transfer the image using a carbon or saral paper. When you have multiples of the same image and want to preserve some uniformity throughout their rendition, you will want to use this method. An easy way to transfer images when carbon or saral paper is not available is to color the backside of the paper or tracing with a contrasting color. Position the image into the new location and trace around its outline. The color on the reverse side of the image transfers the image to the paper.

Architectural/Structural Steel Drawings

Introduction

Architectural and structural drawings are drawings of steel, wood, concrete, and other materials used to construct buildings, ships, planes, bridges, towers, tanks, and so on. Building projects may be broadly divided into two major phases, the design phase and the construction phase. First, the architect conceives the project and sets the concept onto paper in the form of presentation drawings that are usually drawn in perspective by using pictorial drawing techniques. Next, the architect and engineer work together to decide upon construction materials and methods. The engineer determines the structural loads, mechanical, heating, lighting, and plumbing systems. The end result is the preparation of architectural and engineering design sketches that guide the draftsman who prepares the construction drawings. This section describes some common types of shapes and symbols used on architectural and structural drawings. For additional information in construction or building techniques, refer to the Seabee rate training manuals of *Engineeriing Aid* (EA), *Builder* (BU), and *Utilitiesman* (UT).

Shapes

Structural shapes common to construction materials are beams, channels, angles, tees, bearing piles, zees, plates, flat bars, and tie rod and pipe column. The American Society of Construction Engineers (ASCE) lists the symbols used to identify these shapes in bills of material, notes, or dimensions for military construction drawings in MIL-STD-18B.

BEAMS: A *beam* is a structural support. Beams are defined by their nominal depth in inches and weight per foot of length. There are wide-flange beams and I beams. The cross section of a wide-flange beam (WF) is in the form of the letter H and is the strongest most adaptable support structure. The cross section of I beams are in the shape of the letter I.

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Shapes (Continued)

Figure 4-9 shows the profile of a wide-flange beam.

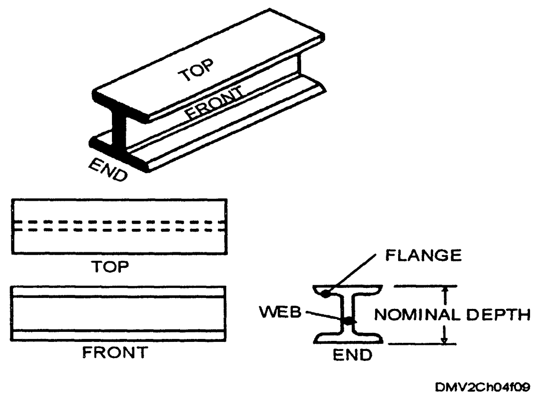

Figure 4-9.—The profile of a wide-flanged (H) beam.

CHANNELS: *Channels*, another structural support also defined by nominal depth and weight per foot, are principally used in locations where you need a single flat face without outstanding flanges on a side. A cross section of a channel is similar in shape to the squared letter C.

Figure 4-10 shows the profile of a channel.

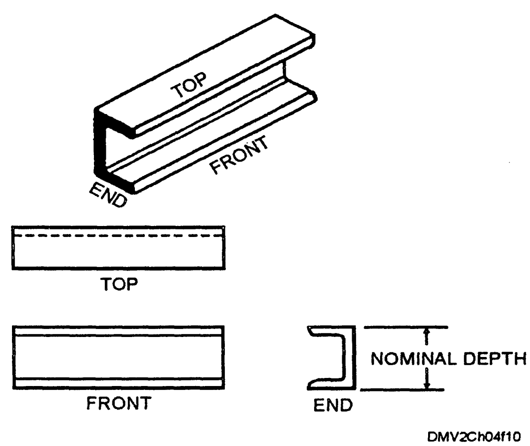

Figure 4-10.—The profile of a channel.

Continued on next page

Shapes (Continued0

ANGLES: *Angle* supports are measured in inches with the width of the longer leg given first. The third dimension is the thickness of the leg. You may use angles singly or in combinations of two or four angles to form members. You can also use angles to connect main members or parts of members together. The shape of a cross section of an angle is in the form of the letter L.

TEES: A structural tee is a standard I- or H-beam cut through the center of the web, thus forming two tee shapes from each beam. The dimensions of the tee are preceded by the letter T.

Figure 4-11 shows the profile of a tee.

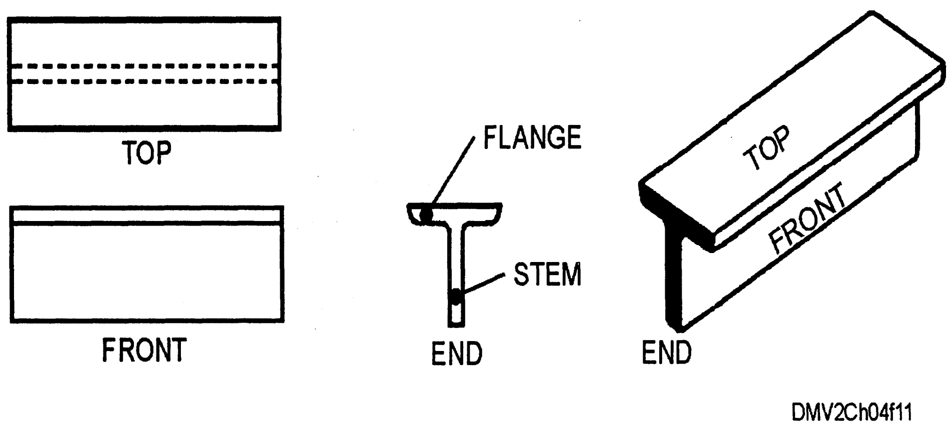

Figure 4-11.—The profile of a tee.

Continued on next page

Shapes (Continued)

BEARING PILES: Bearing piles are the same as wide-flange H-beams, but are much heavier per linear foot.

ZEE: These shapes are noted by depth, flange width, and weight per linear foot.

PLATES: Plates are noted by width, thickness, and length.

FLATBAR: Flat bars are similar to plates with edges rolled square. The dimensions are given for width and thickness.

TIE ROD AND PIPE COLUMN: Tie rods and pipe columns are designated by their outside diameters.

Members

The main parts of a structure are the load-bearing structural *members* that support and transfer loads on the structure while remaining in equilibrium with each other. The places where members connect 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 ability of the earth to support a load is called the *soil-bearing capacity.*

TOTAL DEAD LOAD: The *total dead load* is the total weight of the structure, which gradually increases as the structure rises and remains constant after the construction is completed.

TOTAL LIVE LOAD: The *total live load* is the total weight of moveable objects, such as people, furniture, and traffic that the structure supports at any particular time.

Continued on next page

Architectural/Structural Steel Drawings, Continued

Shape symbols The following list contains the symbols for single structural shapes.

Figure 4-12 lists common symbols for single structural shapes.

DESCRIPTION	PICTORIAL	MIL-STD SYMBOL	ILLUSTRATED USE	AISC SYMBOL	ILLUSTRATED USE
WIDE FLANGE SHAPE	FLANGE, WEB	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	NOMINAL DEPTH	M	8 X 8M 34.3	M	M8 X 34.3
CHANNELS				C	C9 X 13.4
AMERICAN STANDARD	DEPTH	⊔	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	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	FLANGE, WEB	BULB L	BULB L 6 X 3$\frac{1}{2}$ X 17.4		
TEES				WT	WT12 X 38
STRUCTURAL	FLANGE, STEM	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		O	O 6φ	⊕	pipe 4 std

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Figure 4-12.—Symbols for single structural shapes.

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Vertical members

Vertical structural members extend from footings or a foundation to the roof line. High strength vertical members are called *columns* or *pillars.* Short columns or *piers* rest directly on footings or may be set into the ground. On bridge structures, piers provide intermediate support for the bridge superstructure. In light-frame and wood constructions, vertical structural members are called studs. *Sills* or sole *plates* are horizontal members that support the bottom of studs on the foundations while *rafter plates*, *top plates* or *stud caps* anchor the top. Enlarged or combined studs at a corner position are referred to as *corner posts.*

Figure 4-13 shows light-frame vertical members.

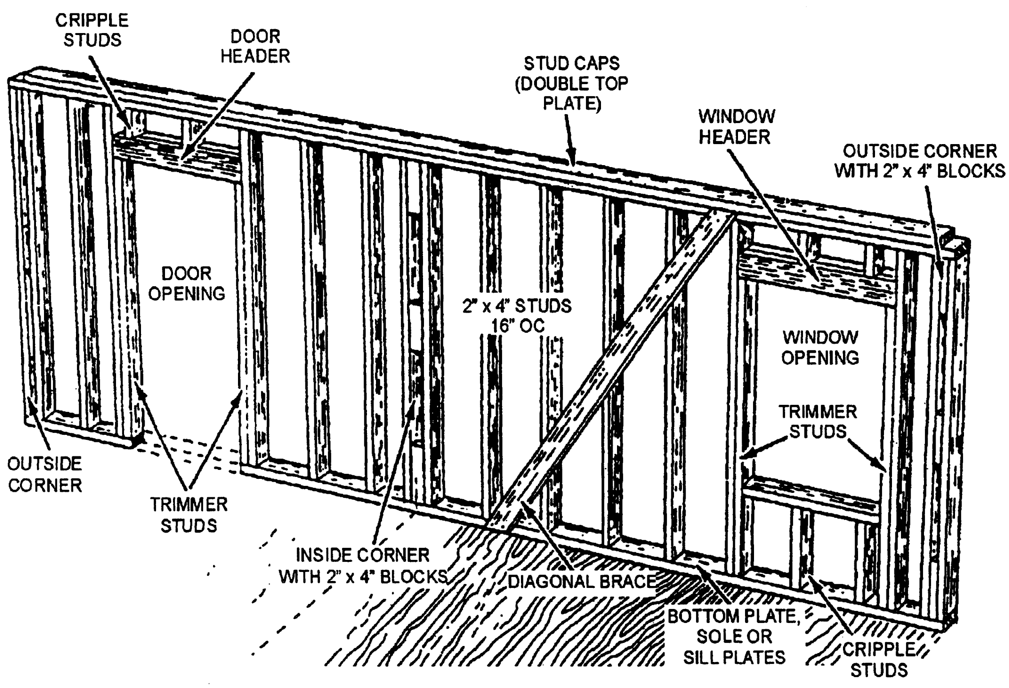

Figure 4-13.—Vertical members of a light-frame (wood) construction.

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Horizontal members

Beams are horizontal load-bearing members supported at both ends. When only one end is fixed, it is called a *cantilever.* Horizontal members that support the weight of concrete or masonry walls above door and window openings are called *lintels. Sills, girts,* or *girders* support the ends of floor beams in wood-construction. Sills, sole plates, stud caps, rafter plates, and top plates are horizontal members and were discussed in the previous paragraph.

Figure 4-14 show examples of a cantilever and a lintel.

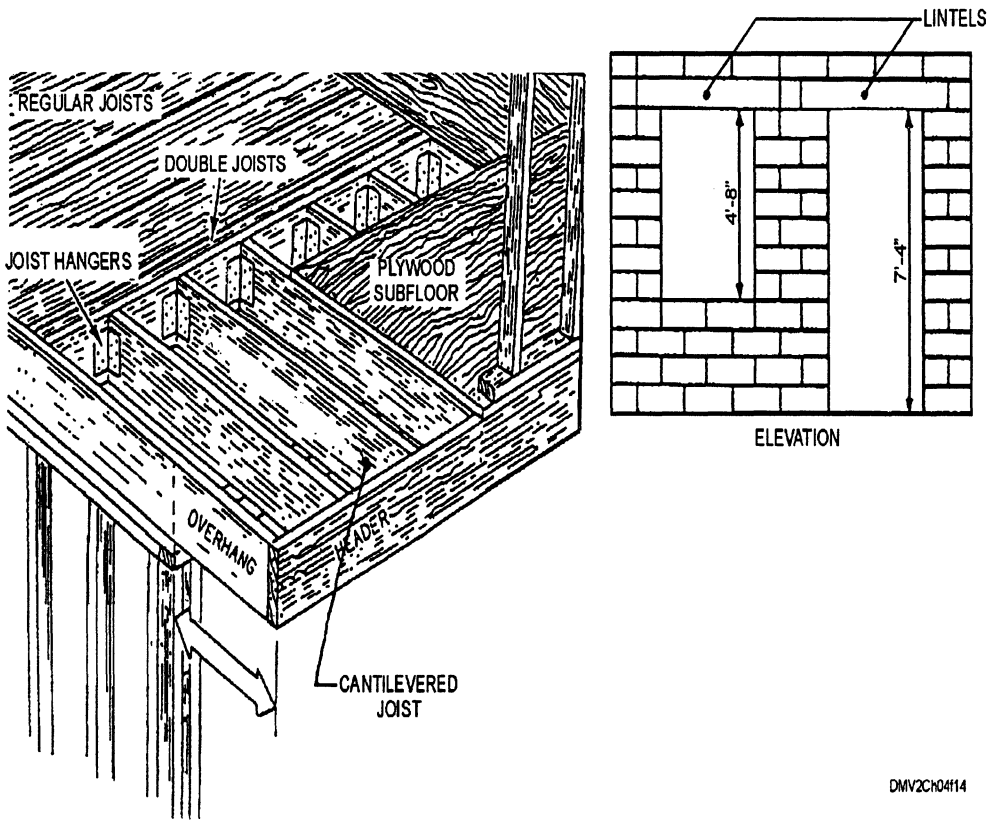

Figure 4-14.—Examples of joists: (A) A cantilever; and (B) A lintel.

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Trusses

A *truss* is framework consisting of two horizontal (or nearly horizontal) members joined by a number of vertical and/or inclined members to form a series of triangles. The horizontal members are called the *upper* or *top* and *bottom* or *lower chords.* The vertical and/or inclined members that connect the upper and lower chords are called *web members.* Use trusses when the maximum given load exceeds the rated strength of a beam.

Figure 4-15 illustrates the terminology of a truss.

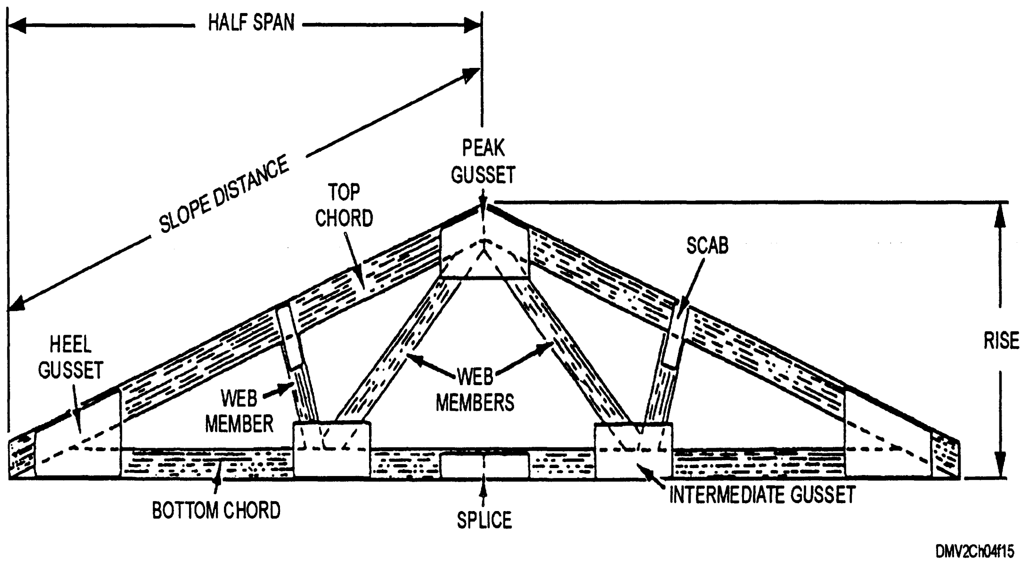

Figure 4-15.—Truss nomenclature.

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Steel truss construction

Steel structures use trusses that are either welded or riveted. Welded steel construction is more flexible than riveted construction. In both cases some welding or riveting is done in the shop and some in the field. Weld or rivet locations are premarked or predrilled. You should use standard welding or riveting symbols on your drawings.

Welding symbology

Eight elements comprise each welding symbol. The *reference line* or *base* (A) is the foundation for all other elements. The arrowhead (B) points to the location of the weld. Center the basic weld symbol (C) (a fillet weld in this case) on the base on the arrow side of the object being welded. The dimension and the length of the weld (D) appear near the weld. Supplementary symbols cap the basic weld symbol (E). This is the symbol for a convex weld and finish markings (F) indicate the degree of finish. The tail of the weld symbol (G) sets off symbols that show certain processes, specifications, or references. Omit the tail if no special instructions exists. Inside the tail, place the symbol or abbreviation (H) that represents the process, specification, or reference. This completes the eight elements of a basic welding symbol.

Figure 4-16 shows the elements of a basic weld symbol.

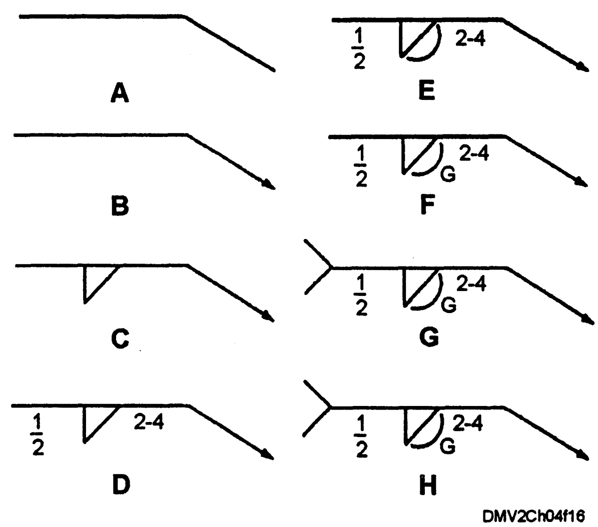

Figure 4-16.—The eight elements of a basic welding symbol.

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Welding symbology (Continued)

Figure 4-17 is a legend of standard location of elements and types of welding symbols.

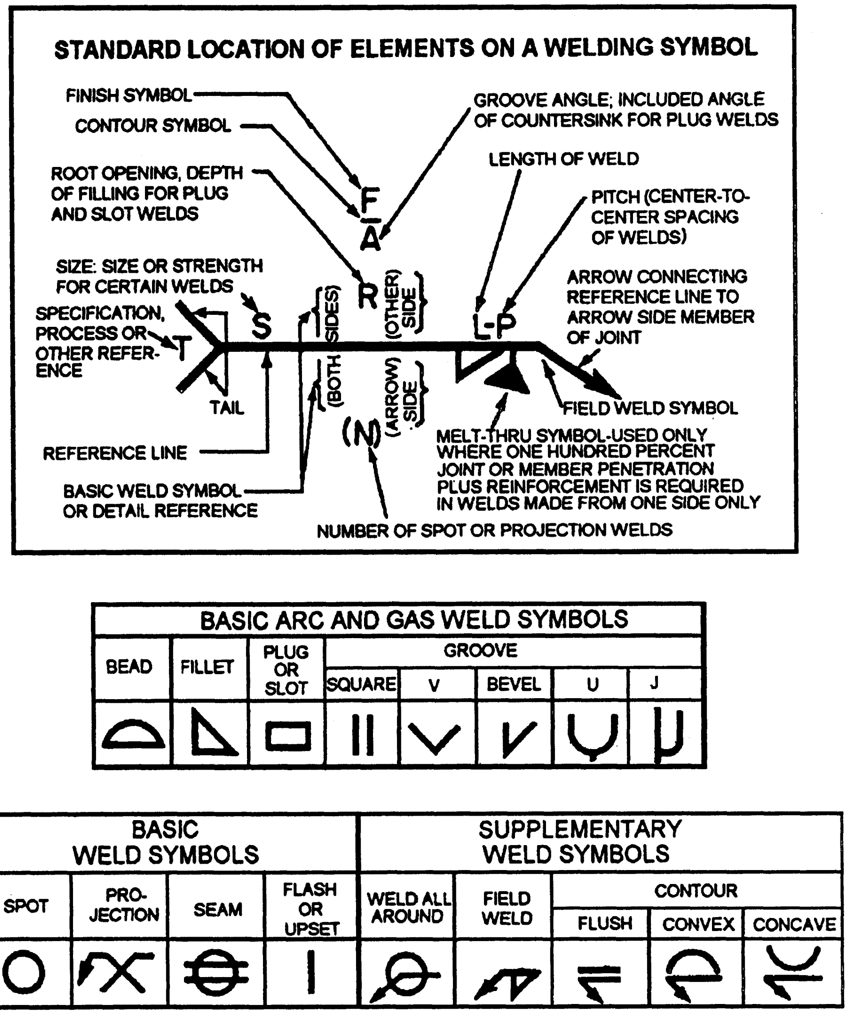

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Figure 4-17.—Standard locations of elements and types of welding symbols.

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Welding symbology (Continued)

Figure 4-18 is a chart showing the application of welding symbols.

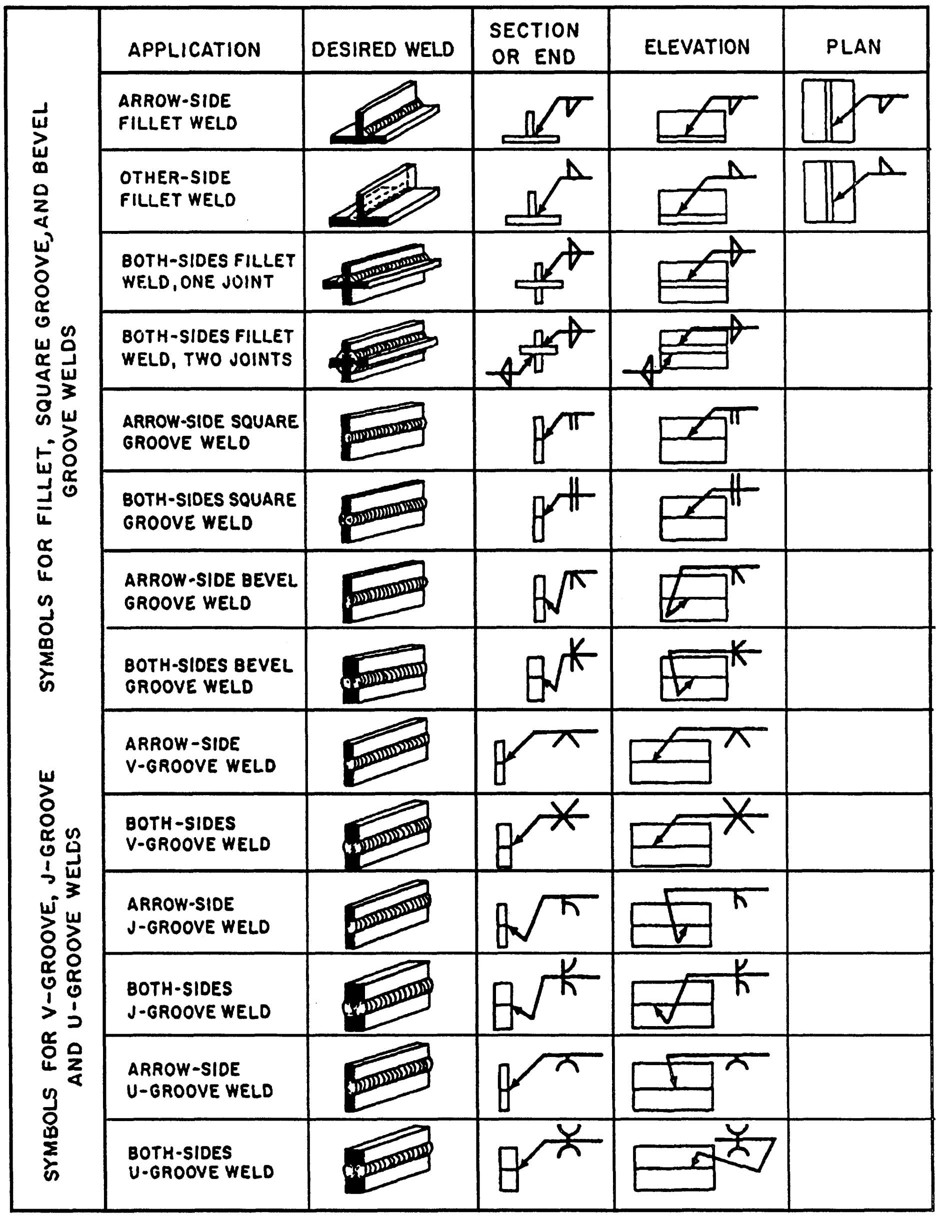

Figure 4-18.—The application of welding symbols.

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Architectural/Structural Steel Drawings, Continued

Rivet symbology

Rivet locations are predrilled or punched. Some rivet are driven at the shop, others are made at the jobsite. In either case, you should correctly locate and identify rivet connections on the fabrication drawings.

Figure 4-19 is a description and symbol for common rivet joints.

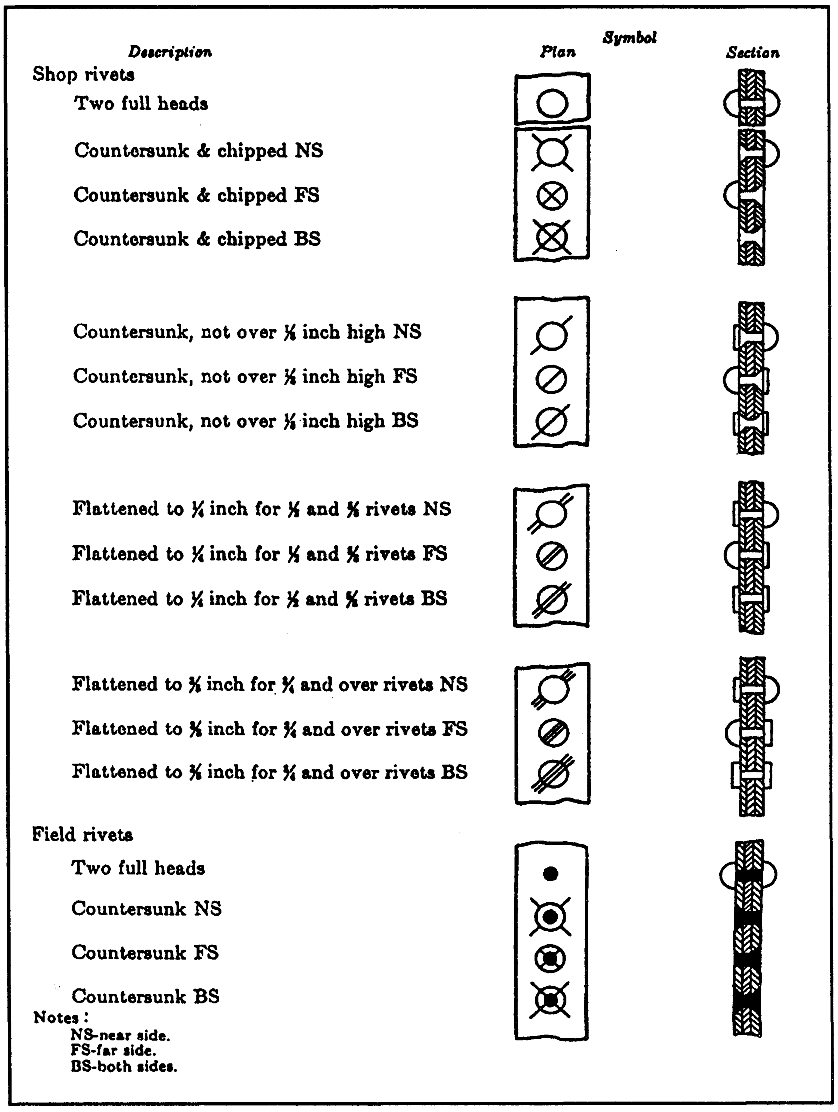

Figure 4-19.—Riveting symbols.

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Architectural/Structural Steel Drawings, Continued

Drawing steel structures

Blueprints used in the fabrication and erection of steel structures consist of a group of different types of drawings, such as layout, general, fabrication, erection, and falsework.

LAYOUT DRAWINGS: *Layout drawings,* often called *general plans* or *profile drawings,* provide information on the location, alignment, and elevation of a structure and its principal parts in relation to the ground site. They may also provide information on the nature of underlaying soil or the location of adjacent structures or roads. Written specifications usually supplement layout drawings.

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. They consist of plan views, elevations, and sections of the structure and its various parts.

FABRICATION DRAWINGS: *Fabrication* or *shop drawings* contain all the necessary information on the size, shape, material, and provisions for connection and attachments for each member. There is sufficient detail to order material and begin construction.

ERECTION DRAWINGS: *Erection drawings* or *erection diagrams* show the location and position of various members in the finished structure. They are particularly helpful in the field when they show the approximate weight of heavy pieces and the number of pieces.

FALSEWORK DRAWINGS: *Falsework drawings* are drawing that show temporary supportive construction necessary to the erection or construction of difficult or complicated structures.

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Construction drawings

Construction drawings are orthographic views that present as much information as possible graphically or by pictures. They consist of plan views, elevations, section views, details, and specifications all on a relatively large scale.

PLAN Views: *Plan views* are views of the structure as it would appear if projected onto a horizontal plane passed through or held above the structure area. The most common construction plans are plot plans (also called site plans), foundation plans, floor plans, and framing plans. *Plot or site plans* show the contours, boundaries, roads, utilities, trees, structures, and other significant physical features about structures on the site. *Foundation plans* are plan views of a structure projected on an imaginary horizontal plane passing through at the level of the tops of the foundation. The 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 length 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.

Figure 4-20 is an example of a floor plan.

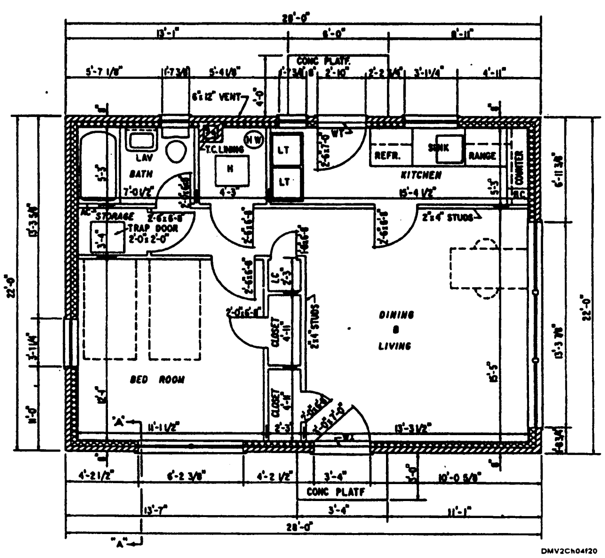

Figure 4-20.—A floor plan.

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Construction drawings (Continued)

Figure 4-21 shows graphic symbols used on architectural floor plans.

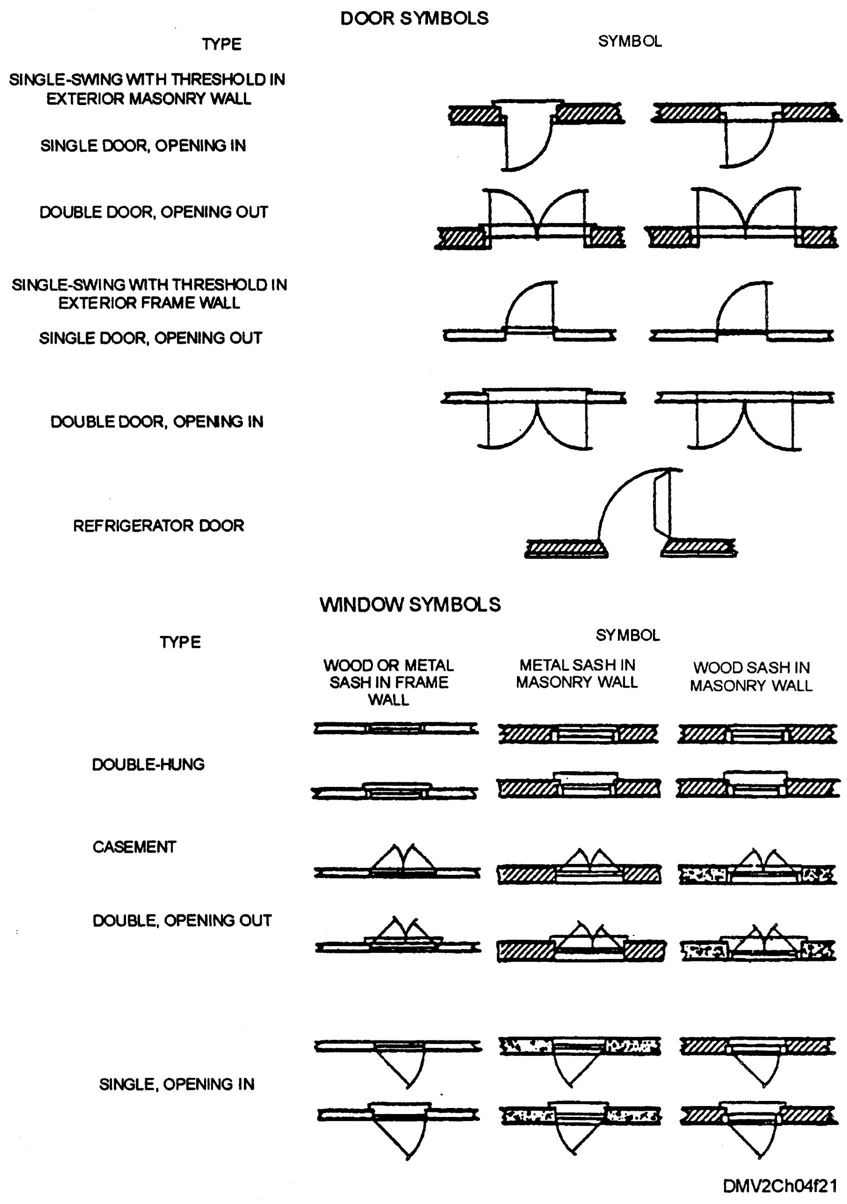

Figure 4-21.—Architectural symbols.

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Construction drawings (Continued)

ELEVATIONS: *Elevations* show the front, rear, and sides of a structure. Elevations give you important vertical distances such as the location and characteristics of doors and windows. Dimensions of window sashes and the dimensions and character of lintels are usually set forth in a window schedule.

SECTION VIEWS: A section view is a cross section of a structure usually confined to views cut by vertical planes.

Figure 4-22 is an example of a section view for a wall.

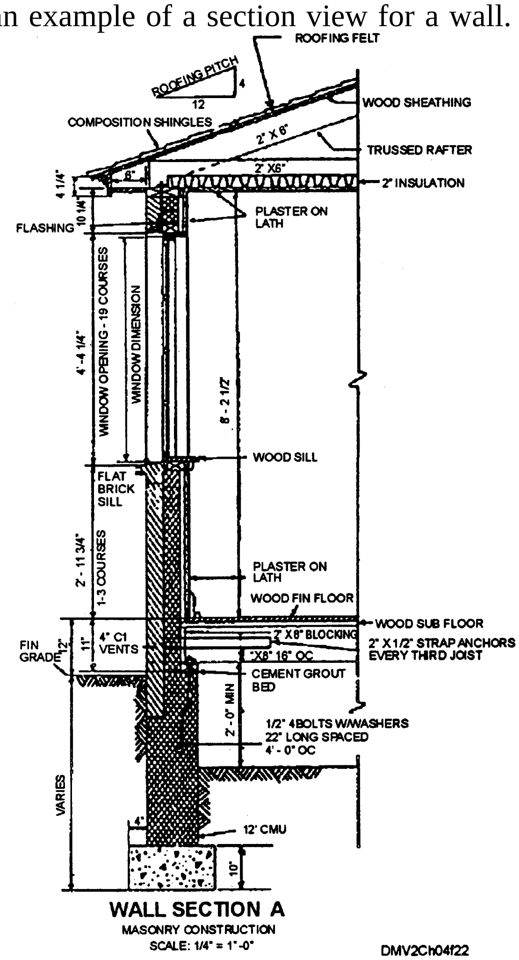

Figure 4-22.—A wall section.

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Architectural/Structural Steel Drawings, Continued

Construction drawings (Continued)

DETAIL DRAWINGS: *Detail drawings* show features that do not appear or appear too small on any other type of drawing. They are drawn at considerably larger scale than other drawings. Include detail drawings whenever the information given in the plans, elevations, and wall sections are insufficiently detailed to guide a craftsman on the job.

SPECIFICATION DRAWINGS: *Specification drawings* are not really drawings at all, but a list of written specifications. Specifications usually begin with a section on general conditions or description of the building including type of foundation, types of windows, character of framing, utilities installations, and so on. A list of definitions of terms used in the specs comes next, followed by certain routine declarations of responsibility.

Electrical/Electronic Drawings

Introduction

The major difference in electrical prints and electronic drawings is that electronic drawings are usually more difficult to read because they show more complex circuitry and systems. Interpreting either electronic or electrical prints requires you to recognize and understand the graphics symbols for electrical diagrams and the electrical wiring equipment symbols 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.

Electrical drawings

The Navy uses electrical drawings for shipboard electrical equipment and systems, shore-based power, lighting, and communications equipment, and aircraft electrical equipment and systems. Electrical drawings may be further divided into pictorial wiring diagrams, isometric wiring diagrams, single-line diagrams, schematic diagrams, elementary wiring diagrams, and block diagrams.

PICTORIAL WIRING DIAGRAMS: *Pictorial wiring diagrams* are pictorial sketches of various parts of an item of equipment and the electrical connections between the parts.

ISOMETRIC WIRING DIAGRAMS: 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.

SINGLE-LINE DIAGRAMS: Lines and graphic symbols simplify complex circuits or systems in a *single-line diagram.*

SCHEMATIC DIAGRAMS: A *schematic diagram* shows how a circuit functions electronically.

ELEMENTARY WIRING DIAGRAMS: *Elementary wiring diagrams* show in simplest form how each individual conductor connects to various connection boxes of an electrical circuit or system.

BLOCK DIAGRAMS: Major equipment components or systems reduced to simple geometric form and displayed in normal order of progression of signal or current flow by single lines comprise *block diagrams.*

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Shipboard electrical prints

To better understand electrical/electronic prints used on board Navy ships, you should first familiarize yourself with the numbering system for electrical units.

Numbering electrical units

All similar electrical units on a ship comprise a group. Each group has 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 similar 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 system continues until all similar units on the same level are numbered. It then begins again on another level until all levels are numbered. Additional general rules for numbering electrical units are as follow:

- Within a given compartment, 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 panel is normally accessible. 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.

- Main switchboards or switch gear groups supplied directly from ship's service generators are designated with the suffix S. For example 1S, 2S, and so forth.

- Switchboards supplied directly by emergency generators are designated 1E, 2E and so on.

- Switchboards for special frequencies (other than the frequency of the ship's service system) have alternating current (ac) generators designated 1SF, 2SF, and so on.

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Zone control numbers

Larger ships are numbered according to a zone control system. This system generally coincides with the fire zones prescribed by the ship's damage control plan. Load center switchboards distribute electrical power within each zone. Load center switchboards and miscellaneous switchboards on ships with zone control distribution are given identification numbers. The first number represents the zone, and the second number represents the switchboard within the zone.

Cable markings

Cable labels are metal tags embossed with identification numbers attached to cable wire as close as practical to each point of connection on both sides of decks, bulkheads, and barriers. There are two systems for marking electrical cables on ships. The old system of cable markings appear on ships built before 1949. The tags are red (vital), yellow (semivital), and grey (nonvital). Letter designators identify power and lighting cables for different services. The new cable tag system appears on ships built after 1949. The new system consists of three parts in sequence: source, voltage, and service. When practical, destination may also appear on the tag.

Figure 4-23 is an example of a marked cable tag.

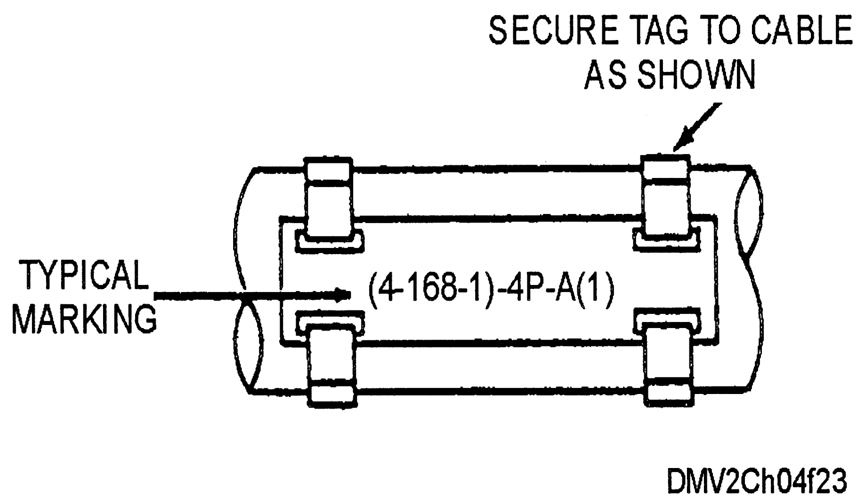

Figure 4-23.—A cable tag.

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Cable markings (Continued)

The following list shows new cable tag designators:

Letter	Function
C	Interior communications
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

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Isometric wiring diagrams (shipboard)	Isometric wiring diagrams show an entire circuit system layout. It shows each deck of the ship arranged in tiers, bulkheads and compartments, a marked centerline, frame numbers for every five frames, and the outer edge of each deck in a general outline of the ship. All athwartship lines make an angle of 30 degrees to the centerline and cables that run from one deck to another are drawn at right angles to the centerline. A single line represents a cable regardless of the number of connectors.
Single-line diagrams (shipboard)	Single-line diagrams show a general description of a system and how the system functions. More detailed than block diagrams, they require less supporting text.
Schematic diagrams (shipboard)	Electrical schematic diagrams describe 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 various components.
Elementary wiring diagrams (shipboard)	Elementary wiring diagrams show in detail each conductor, terminal, and connection in a circuit. It also shows conductor markings alongside each conductor and how they connect in a circuit. Elementary wiring diagrams are not drawn to any scale.
Wiring deck plan (shipboard)	Wiring deck plans are peculiar to ship electrical systems and show the actual installation diagram for the deck or decks shown in increments of 150 to 200 linear feet. Drawn to scale (usually 1/4 inch to the foot), they show the exact location of all fixtures. Wiring deck plans include a bill of material and a list of all necessary equipment to complete the job.
Equipment wiring diagram (shipboard)	Equipment wiring diagrams show relative positions of various components of equipment and how each individual conductor connects to the circuit. You will need wiring diagrams for various pieces of equipment in a system for troubleshooting electrical failures.
Block diagrams (shipboard)	Block diagrams of electrical systems show major units of the system in block form. Used with text material, they provide a general description of the system and its function.

Continued on next page

Aircraft electrical prints

Aircraft electrical prints include schematic diagrams and wiring diagrams. Similar to shipboard schematics, aircraft schematics show electrical operations. Aircraft wiring diagrams show detailed circuit information on all electrical systems. A master wiring diagram is a single diagram that shows all the wiring in the aircraft. Diagrams of major circuits generally include an isometric wiring diagram showing the location of equipment and the routing of interconnecting cables. The simplified wiring diagram details how each component connects to the system. Circuit wiring diagrams give equipment part numbers, wire numbers, and all terminal strips and plugs.

Aircraft wire identification coding

All aircraft wiring is identified on wiring diagrams exactly as it appears in the aircraft. A code identifies each wire combining letters and numerals imprinted at prescribed intervals along the wire run.

Figure 4-24 outlines the elements of aircraft wire identification designations.

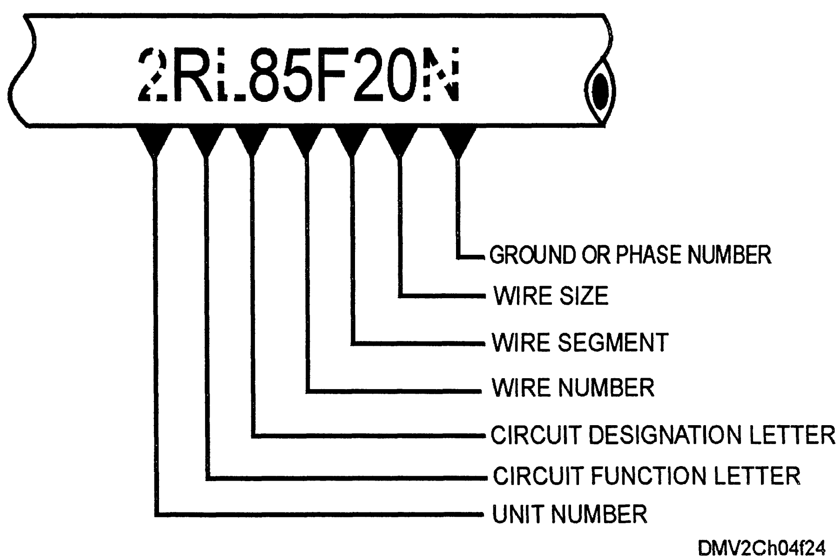

Figure 4-24.—Aircraft wire identification.

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Aircraft wire identification coding (Continued)

The following list shows circuit function codes for aircraft wiring:

Letter	Function
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- dc power or power control system
Q	Fuel and oil
R	Radio (navigation and communications), RN-navigation, RP-intercommunications, RZ-interphones, headphones
S	Radar, SA-altimeter, SN-navigation, SQ-track, SR-recorder, SS-search
T	Special electronic, TE-countermeasures, TN-navigation, TR-receivers, TX-television transmitters, TZ-computers

Continued on next page

Aircraft wiring identification coding (Continued)

Part	Function
V	DC power and dc control wires for ac systems
W	Warning and emergency
X	AC power
Y	Armament special systems

Electronic prints

Electronic prints include isometric wiring diagrams, elementary wiring diagrams, block diagrams, schematic diagrams, and interconnection diagrams. The functions of electronic prints and electrical prints are the same except that electronic prints are generally harder to read because they are more detailed and complex. Electronic prints often appear with color coded wiring as shown in the following list:

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
AC power lines	Grey
Miscellaneous, above or below ground returns	White

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Interconnection diagrams (shipboard)

Interconnection diagrams show cabling between electronic units and how the units interconnect. All terminal boards are assigned reference designation according to a unit numbering system.

Reference designations

A *reference designation* is a combination of letters and numbers used to identify the various parts and components on electronic drawings, diagrams, and parts lists. Reference designations are assigned beginning with the unit and continuing down to the lowest level (parts). Units begin with the number 1 and continue with consecutive numbers for all units of a set. Assemblies and subassemblies are assigned reference designators beginning with the unit number, the letter A to indicate an assembly or subassembly, and a specific number. Parts are assigned Reference designations for parts that consist of a unit and assembly or subassembly designation plus a letter or letters identifying the class to which the part belongs and a specific number. For each additional subassembly, another letter A and number are added to the part reference designationIn the prints you work with the drawings reference designation will comply with a system called the unit numbering system.

Unit numbering system

The *unit numbering system* is the reference designation system used to identify electronic systems that 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* is one or more units and the necessary assemblies, subassemblies, and parts connected or associated together to perform an operational function.

Figure 4-25 shows a five-unit set.

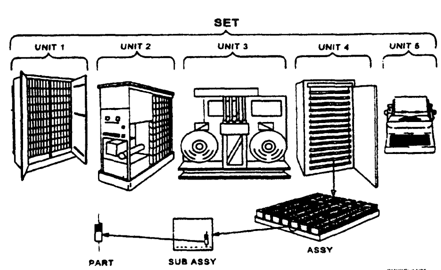

Figure 4-25.—A five-unit set.

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Aircraft electronic prints

Aircraft electronic prints include isometric wiring diagrams and block diagrams both simplified and detailed. The purpose and functions of these diagrams are similar to their shipboard counterpart. Aircraft electronic wiring diagrams fall into two basic classes: chassis wiring diagrams and interconnecting diagrams.

Electro-mechanical drawings

Electromechanical devices such as synchros, gyros, accelerometers, autotune systems, and analog computing elements are common in avionic systems. You need more than an electrical or electronic drawing to understand these systems; therefore, we use a combination of mechanical drawings and electronic or electrical drawings and call them *electromechanical drawings.* Electromechanical drawings show only those items essential to the operation of a particular piece of equipment or part.

Logic diagrams

Logic diagrams describe the operation and maintenance of digital computers. Simple logic operations used in digital computers are based on the theory in Boolean algebra that an element can be in only one of two possible states at any given time and that there are three basic operations, AND, OR, and NOT. The two states, represented by 0 and 1 respectively, correspond to the binary number systems consisting of the symbols 0 and 1. Computer operating terms NOR, NAND, INHIBIT, and EXCLUSIVE OR correspond to the basic AND, OR, and NOT.

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Logic diagrams (Continued)

Figure 4-26 is a table of logic operations comparisons and binary values.

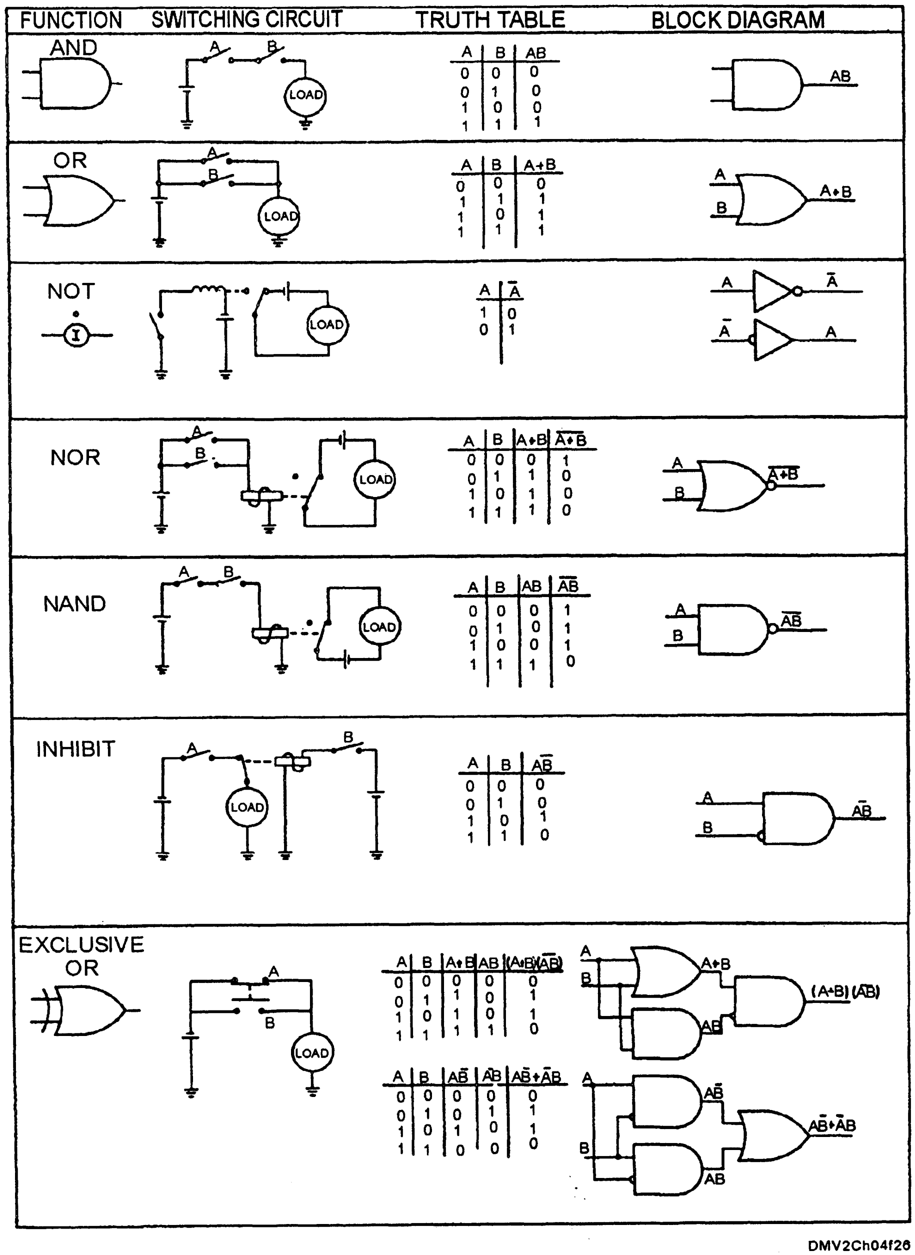

Figure 4-26.—Logic operations comparison chart.

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Basic logic diagrams

Basic logic diagrams show the operation of particular units or components. Show basic logic symbols in their proper relationship to show operation only in the most simplified form possible.

Figure 4-27 show a basic logic diagram.

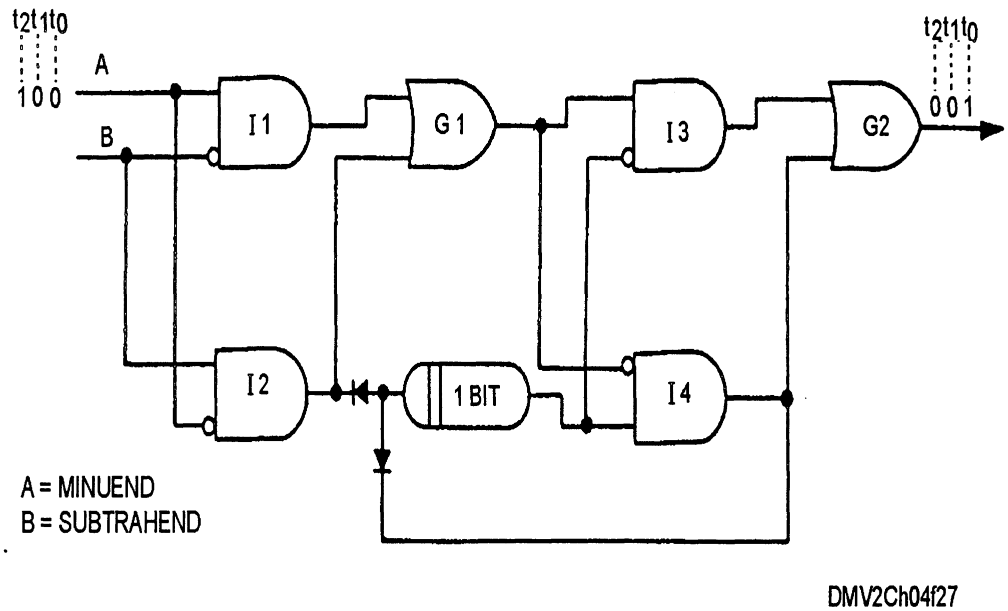

Figure 4-27.—A basic logic diagram.

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Detailed logic diagrams

Detailed logic diagrams show all logic functions of the concerned equipment. Additionally, they include information such as socket locations, pin numbers, and test points to help in troubleshooting. A detailed logic diagram may consist of many separate sheets.

Figure 4-28 is an example of a detailed logic diagram.

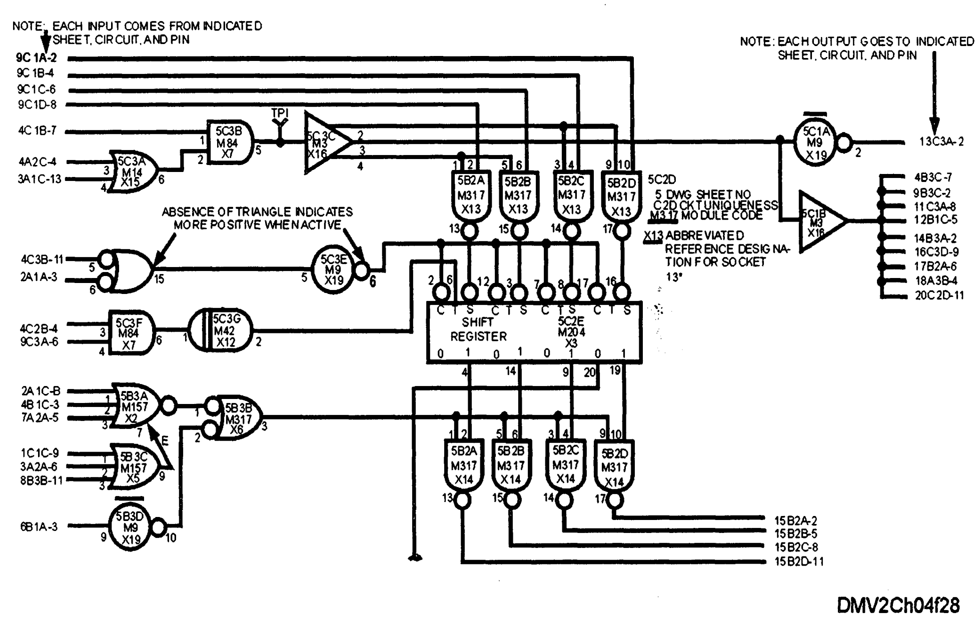

Figure 4-28.—A detailed logic diagram.

Machine Drawings

Introduction

In learning to draw and read machine drawings, you must first become familiar with common terms, symbols, and conventions. The following paragraphs cover common terms most used in all aspects of machine drawings.

Standards

American industry and the Department of Defense (DoD) follow the standard *Geometrical Dimensioning and Tolerancing,* ANSI Yl4.5M-1982. This is the standard used in all blueprint production whether the master drawings are drawn by human hand or by computer-aided drawing (CAD) equipment. It standardizes the production of prints from the simplest hand-made job on site to single or multiple-run items produced in a machine shop with computer-aided manufacturing (CAM). Refer to ANSI Y14.5M-1982 when creating or altering machine drawings. Also refer to MIL-STD-9A for *Screw Thread Conventions and Methods of Specifying,* ANSI 46.1 for *Surface Textures,* and MIL-STD-12C for *Abbreviations for Use On Drawings and In Technical-Type Publications.*

General terms

Tolerances, fillets and rounds, slots and slides, keys, keyseats, and keyways, screw threads, gears, helical springs, and finish marks present common problems to the draftsman. Standards offer uniform solutions to these problems.

TOLERANCES: *Tolerancing* is a method of indicating acceptable variations in size or surface and appears as a minus or plus a certain amount stated in fractions or decimals. The minus or plus figures are the minimum and/or maximum value prescribed for a specific dimension. The three ways of showing tolerances are the *unilateral method* used when variation in design is permissible in one direction only, the *bilateral method,* which shows the acceptable minus or plus variations, and the *limiting dimensioning method,* which states both the allowable minimum and maximum measurements.

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Gerneral terms (Continued)

Figure 4-29 shows the methods of indicating tolerances.

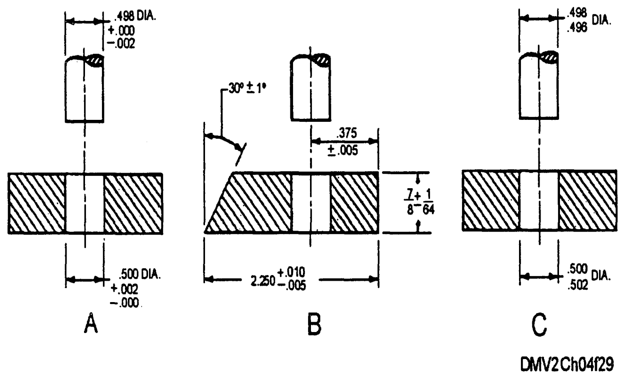

Figure 4-29.—Methods of indicating tolerance.

SURFACE TOLERANCES: Toleranced surfaces have certain geometric characteristics such as roundness or perpendicularity to other surfaces. A *feature control symbol* is made of geometric symbols and tolerances, which may include a datum reference and indicates surface tolerances. A *datum* is a surface, line, or point from which a geometric position is determined or from which a distance is measured.

Figure 4-30 illustrates a feature control frame indicating a datum reference.

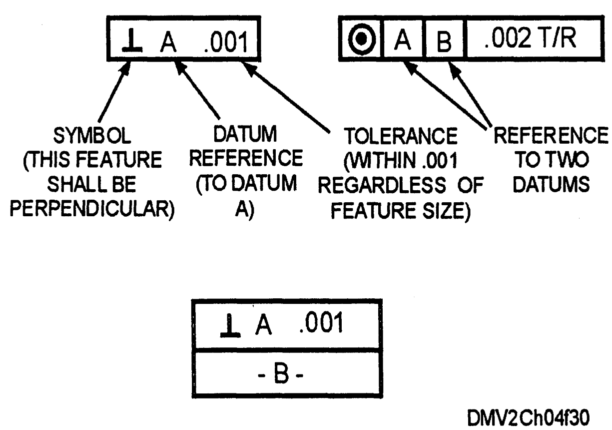

Figure 4-30.—Feature control frame indicating a datum reference.

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General terms (Continued)

Figure 4-31 is a chart of general geometric characteristic symbols.

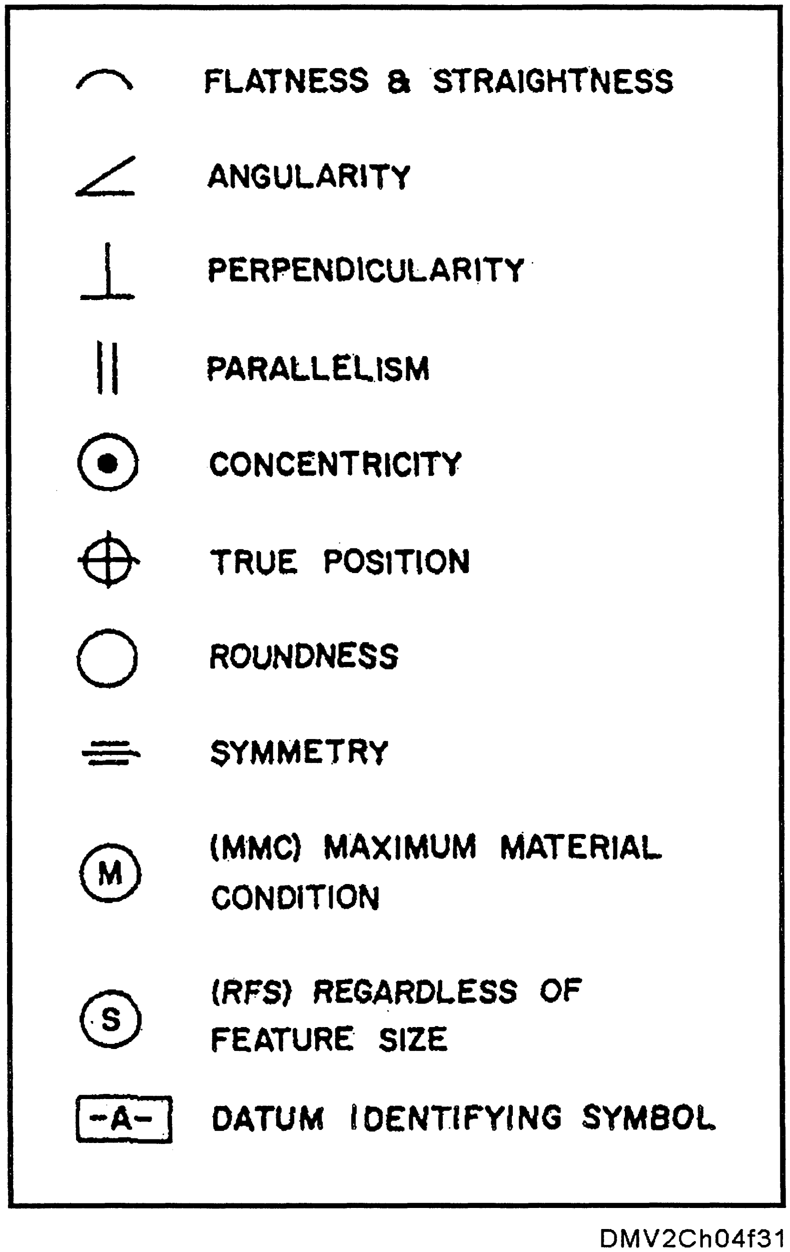

Figure 4-31.—Geometric characteristics symbols.

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General terms (Continued)

FILLETS AND ROUNDS: *Fillets* are concave metal (inside) corners. In cast objects, fillets strengthens the corners because they cool more evenly than sharp corners. *Rounds* are edges (outside corners) that are rounded to prevent chipping or sharp cutting edges.

Figure 4-32 shows examples of a fillet and a round.

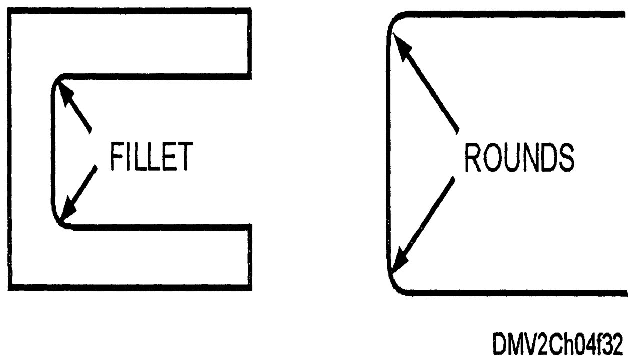

Figure 4-32.—A fillet and a round.

SLOTS AND SLIDES: *Slots* and *slides* are two specially shaped pieces of material formed to mate together and hold secure while allowing lateral or sliding movement. The two types of slots are tee slots and dovetail slots.

Figure 4-33 shows tee and dovetail slots and slides.

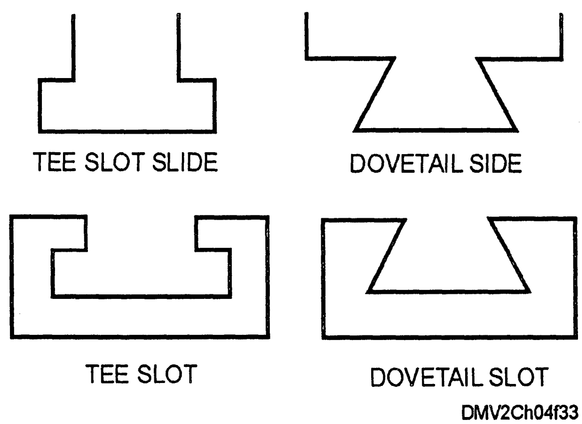

Figure 4-33.—Tee and dovetail slots and slides.

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General terms (Continued)

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. The three types of keys are the flat bottom, round bottom, and square. A *keyseat* is a groove into which a key fits. A *keyway* is an exterior sleeve surrounding the keyseat, which prevents movement of all parts.

Figure 4-34 shows keys, keyseats, and keyways.

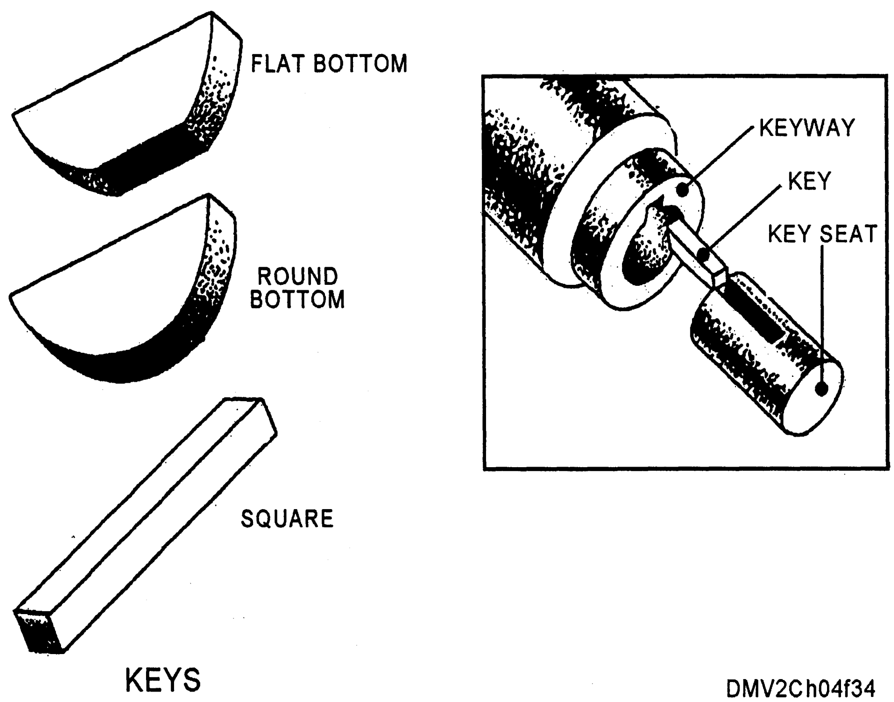

Figure 4-34.—Keys, keyseats, and keyways.

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General terms (Continued)

SCREW THREADS: Draftsmen use different methods to show threads on drawings. For some drawings, a simplified method of thread representation will suffice; for other drawings, you may have to represent thread by the schematic method or the detailed method.

Figure 4-35 shows the differences in thread representation.

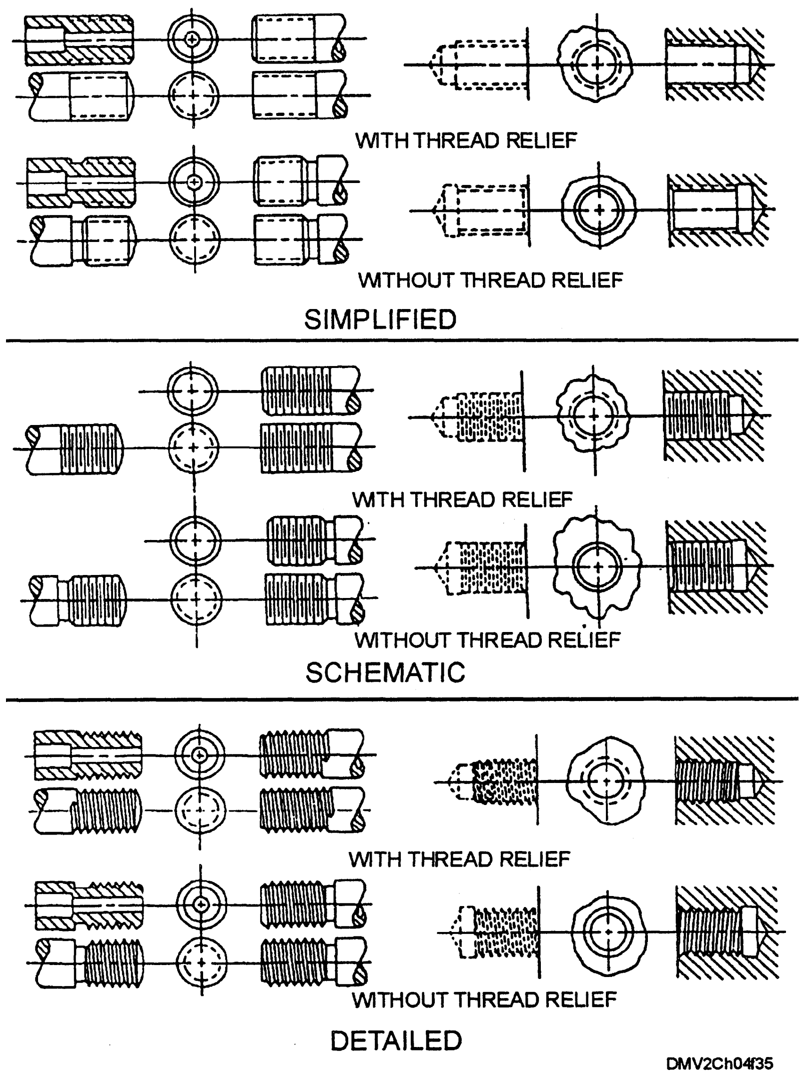

Figure 4-35.—Thread representation.

Continued on next page

General terms (Continued)

To save time, use symbols that are not drawn to scale. Show the dimensions on the threaded part and place other information on a note in the upper-left corner of the drawing. In our example, the note shows the thread designation of 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 Course. The last number identifies the class of thread and tolerance commonly called the fit. If it is a left-hand thread, a dash and the letters LH follow the class of thread. Threads without the LH are right-hand threads.

Specifications for the manufacture of screws include thread diameter, number of threads per inch, thread series, and class of thread. The two most common screw thread series are the Unified or National Form Threads, which are called National Course or NC and National Fine (NF threads). NF threads have more threads per inch of screw length than NC.

The amount of tolerance and/or specified allowance distinguishes between classes of threads. Formerly known as class of fit, a new term, *class of thread* is now in use by the National Bureau of Standards in the Screw-*Thread Standards for Federal Services*, Handbook H-28.

Figure 4-36 show thread designation for an external thread.

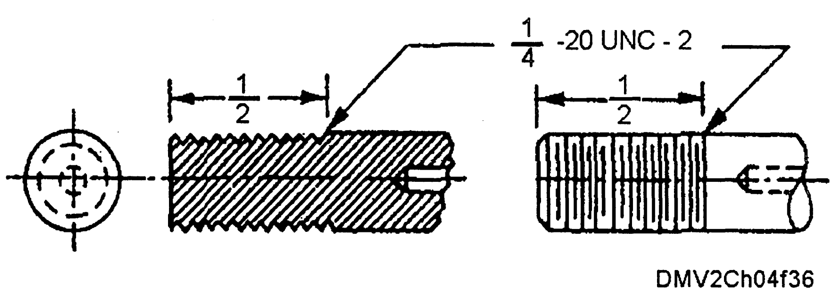

Figure 4-36.—External thread designations.

Continued on next page

General terms (Continued)

Terminology used to describe screw threads is a worldwide industry standard.

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

EXTERNAL THREAD: A thread on the outside.

INTERNAL THREAD: A thread on the inside.

MAJOR DIAMETER: The largest diameter of an external or internal thread.

AXIS: The centerline running lengthwise through a screw.

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

ROOT: The surface of a 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 as measured parallel to the axis.

LEAD: The distance a screw thread advances on one turn as 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.

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General terms (Continued)

Figure 4-37 shows screw thread terminology and locations.

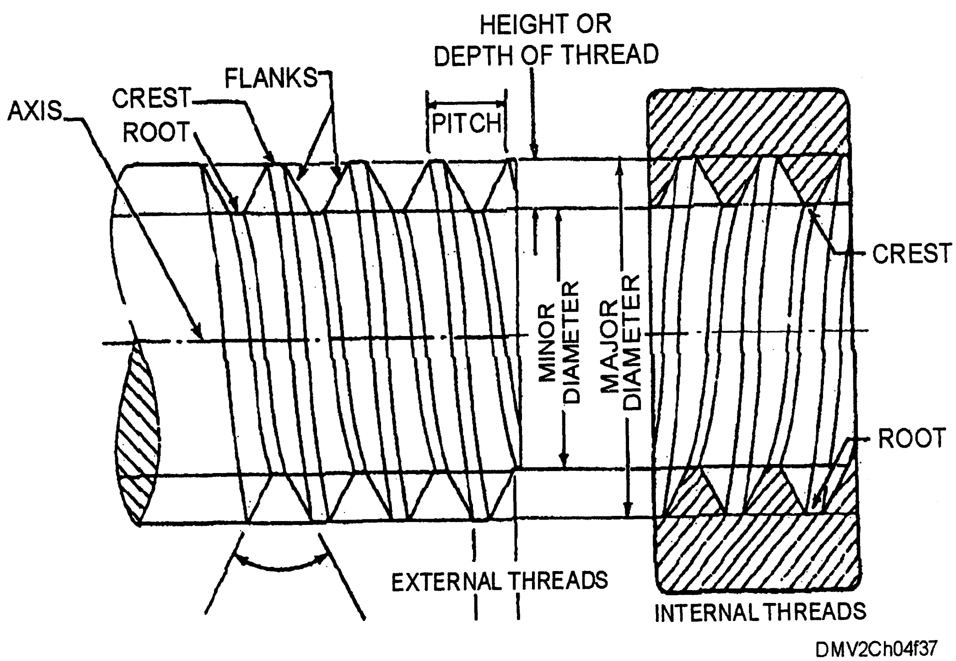

Figure 4-37.—Screw thread terminology.

Continued on next page

General terms (Continued)

GEARS: *Gears* transmit power and rotating or reciprocating motion from one machine part to another. When drawing gear teeth on machine drawings, draw only enough gear teeth to identify necessary dimensions.

Relate gear nomenclature with the terms in the figure.

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 simply as 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.

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 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.

CHORAL 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 the tooth and the top of a mating tooth.

Continued on next page

General terms (Continued)

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 the 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: Compare a rack to a spur gear that is straightened out, then the linear pitch of the rack teeth equals the circular pitch of the mating gear.

Figure 4-38 illustrates gear nomenclature.

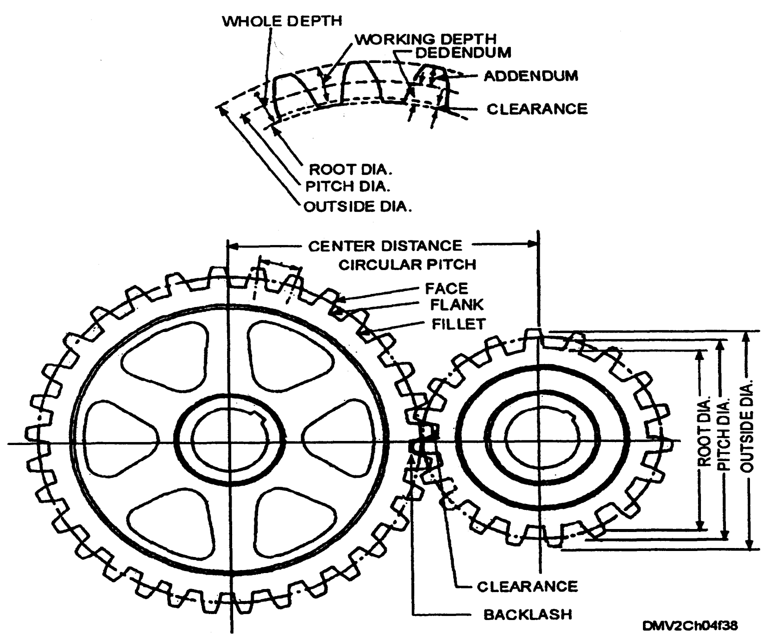

Figure 4-38.—Gear nomenclature.

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General terms (Continued)

HELICAL SPRINGS: *Helical springs* are mechanical devices designed to store energy by compression, extension, or torsion and return an equivalent amount of energy when released. Drawings seldom show a true representation of the helical shape. Draw helical springs on machine drawings with detailed or schematic (single-line) representation.

Figure 4-39 shows detailed and single-line representations of helical springs.

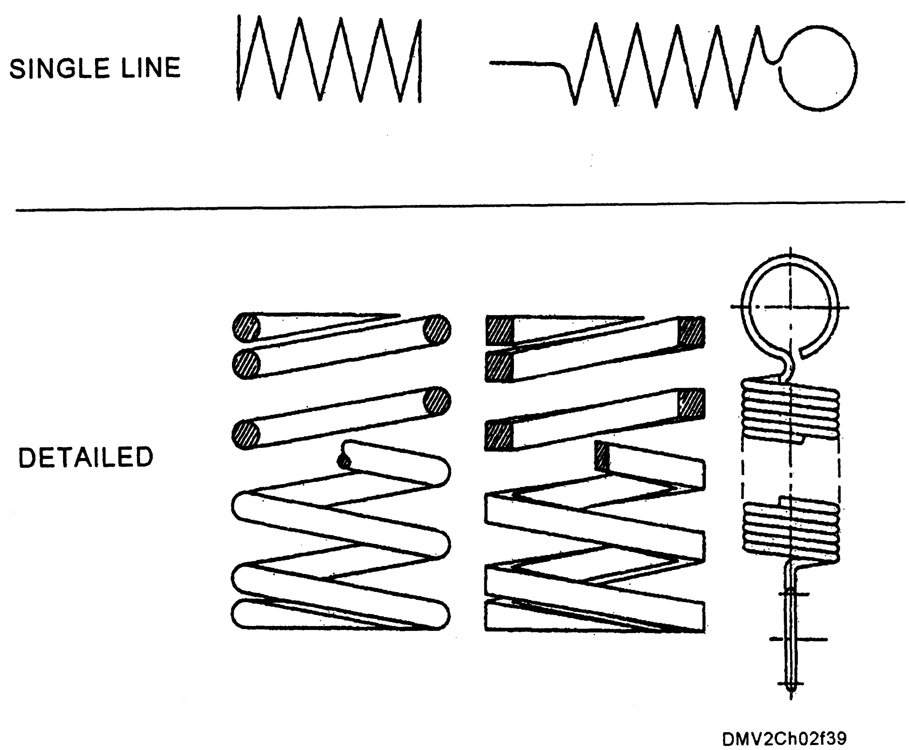

Figure 4-39.—Single-line and detailed representations of helical springs.

Continued on next page

General terms (Continued)

FINISH MARKS: *Finish marks* indicate the amount of acceptable surface abrasion in a finish. The purpose of the part determines what surfaces require finishes while others do not.

Indicate surface finishes by drawing a modified check mark and placing the degree of finish in the angle of the check mark.

Figure 4-40 shows the proportions for a basic finish mark.

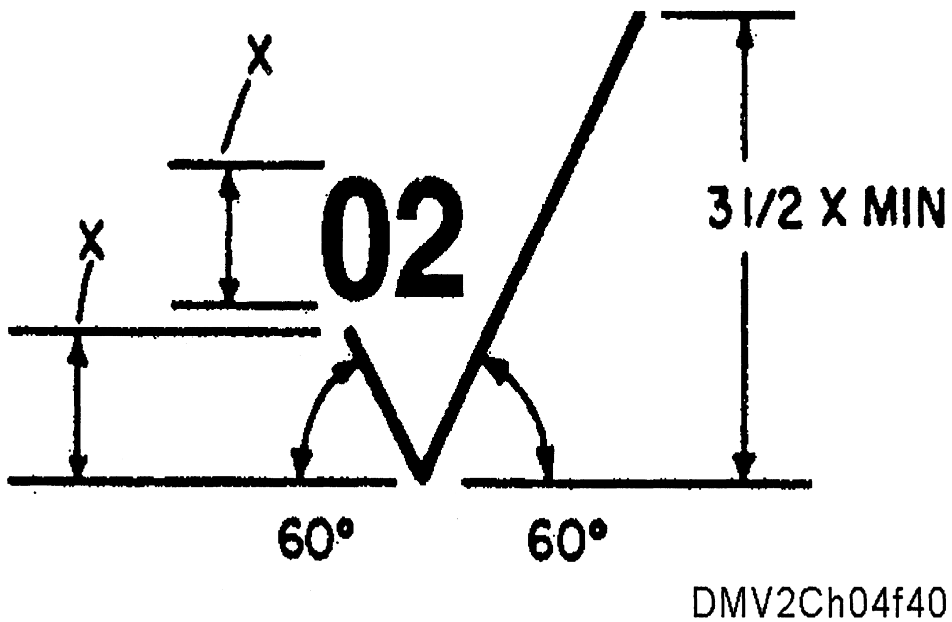

Figure 4-40.—Proportions for a basic finish mark.

Continued on next page

General terms (Continued)

When possible, draw the finish mark touching the surface to which it refers. In a limited space, draw the symbol on an extension line on that surface or on the tail of a leader line with an arrowhead touching the surface. When a part requires an all over finish, notate on the drawing “FINISH ALL OVER (degree).” When all but a few surfaces are similarly finish, place the finish marks at the appropriate locations and notate on the drawing “FINISH ALL OVER EXCEPT AS NOTED.”

Figure 4-41 shows how to place finish marks.

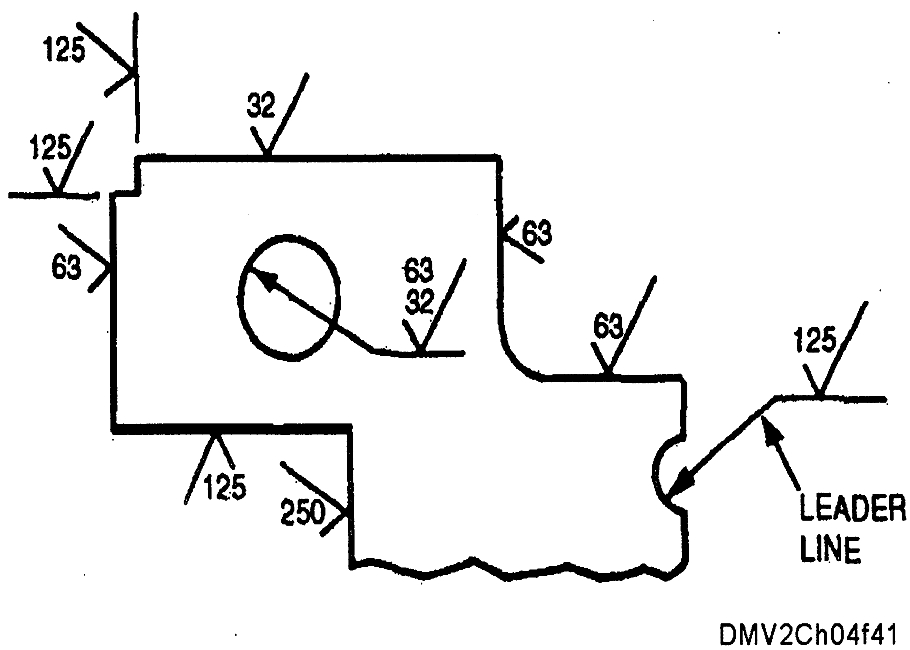

Figure 4-41.—Placing finish marks.

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General terms (Continued)

Figure 4-42 illustrates typical examples of symbol use.

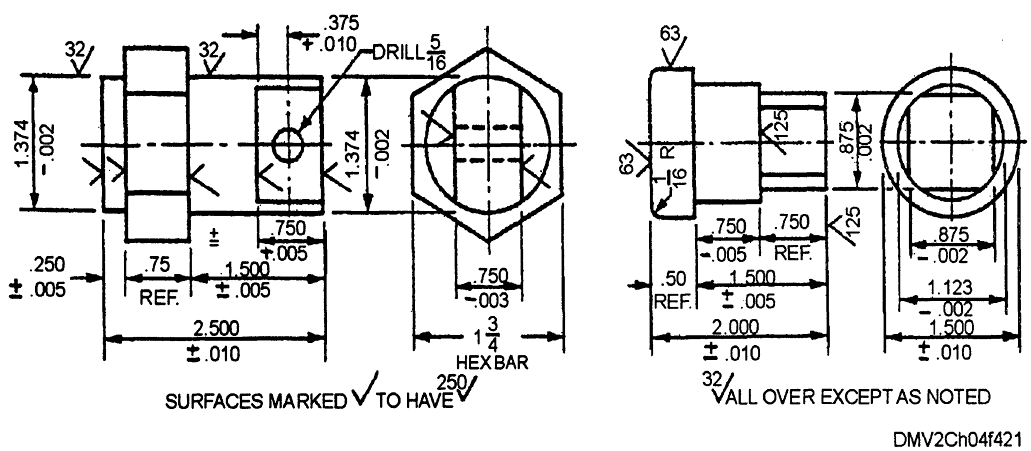

Figure 4-42.—Typical examples of symbol use.

Plumbing/Piping Drawings

Introduction

Almost every conceivable fluid is handled in pipes during its production, processing, transportation, and use. Piping is also used as a structural element in columns and handrails. For these reasons, DMs should become familiar with plumbing and piping drawings and the plumbing and piping symbols used to show the size and location of pipes, fittings, and valves. In this section little differentiation is made between plumbing and piping drawings.

Methods of projection

The two types of projection used in plumbing and piping diagrams are orthographic and isometric (pictorial).

ORTHOGRAPHIC PLUMBING OR PIPE DRAWINGS: Orthographic pipe drawings show single pipes either straight or bent in one plane only. Orthographic pipe drawings may be single-line drawings where you draw the center line of the pipe as a thick line and add valves and fittings, or double-line drawings where you draw each valve and fitting. Use the single-line method when speed is essential. Double-line drawings are generally used in applications, such as catalogs, where visual appearance is more important than drawing time. Orthographic pipe drawings are sometimes used on more complicated piping systems.

Figure 4-43 shows an example of a single- and a double-line orthographic piping drawing.

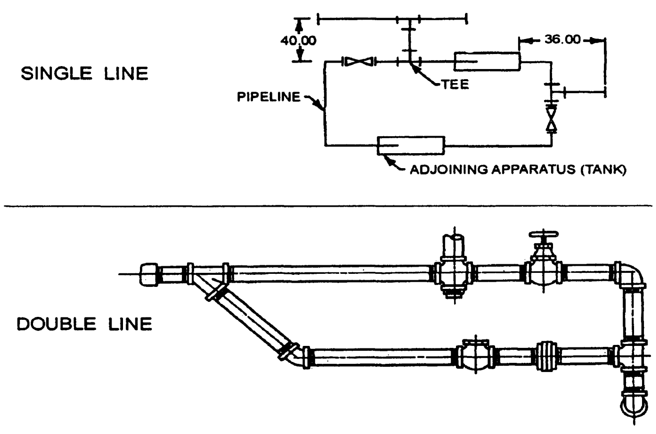

Figure 4-43.—Orthographic pipe drawings.

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Methods of projection (Continued)

ISOMETRIC (PICTORIAL) PLUMBING OR PIPE DRAWINGS: Use isometric pipe drawings for all pipes bent in more than one plane. You may use either the single-line or double-line method. The finished drawings are easier to understand in pictorial format than as orthographic line drawings.

Figure 4-44 is an example of a single-line isometric pipe drawing.

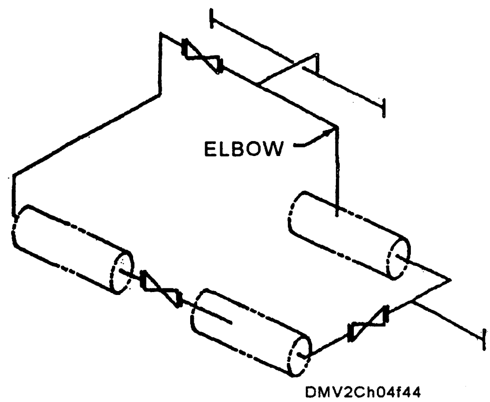

Figure 4-44.—A single-line isometric pipe drawing.

Figure 4-45 is an example of a double-line isometric pipe drawing.

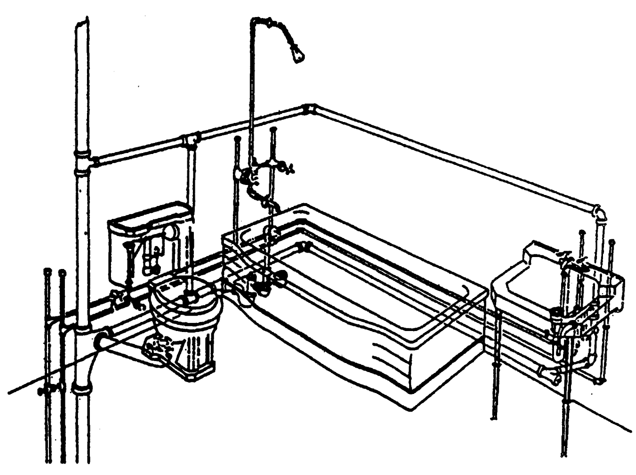

Figure 4-45.—A double-line isometric pipe drawing.

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Crossing pipes

To show pipes that cross each other without connection, draw lines without interruption. When it is important to show that one pipe passes behind another, break or interrupt the line representing the pipe fartherest from the viewer.

Figure 4-46 shows how to cross pipes.

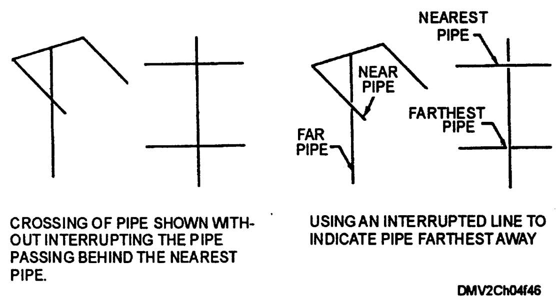

Figure 4-46.—Crossing pipes.

Connecting pipes

Show permanent connection of pipes, whether made by welding or other processes such as gluing or soldering, as a heavy dot with a general note or specification describing the type of connection. Show detachable connections between pipes as a thick single line and a general notation. The bill of material lists this type of connection as flanges, unions, or couplings and whether the fittings are flanged or threaded.

Figure 4-47 shows how to represent permanent and detachable connections.

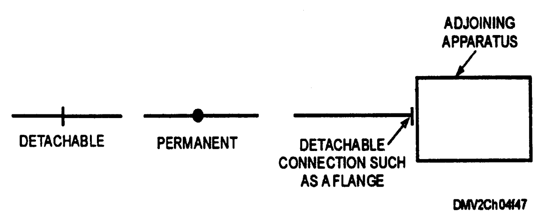

Figure 4-47.—Permanent and detachable connections.

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Fittings

Sometimes standard symbols for fittings like tees, elbows, crossings, and so forth, are not shown on drawings. Use the circular symbol for a tee or elbow when it is necessary to show piping coming toward or moving away from the viewer.

Figure 4-48 illustrates how to draw fitting coming toward or moving away from the viewer.

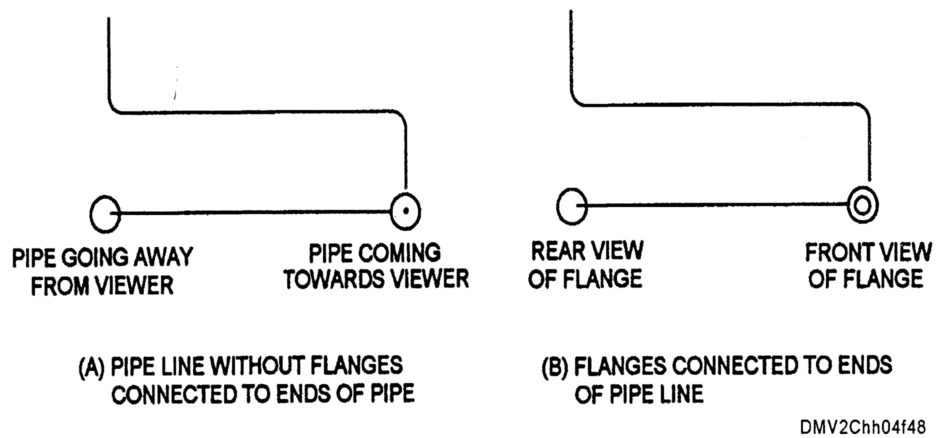

Figure 4-48.—Indicating the ends of pipe fittings.

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Plumbing/Pipe Drawings, Continued

Reading fittings Each opening on a fitting is identified with a letter. On crosses and elbows, you always read the largest opening first and then follow the alphabetical order in figure 4-49. On tees, 45-degree Y-bends or laterals, and double-branch elbows, read the largest opening first, the opposite opening next, and the outlet last.

Figure 4-49 show the order in which you read fittings.

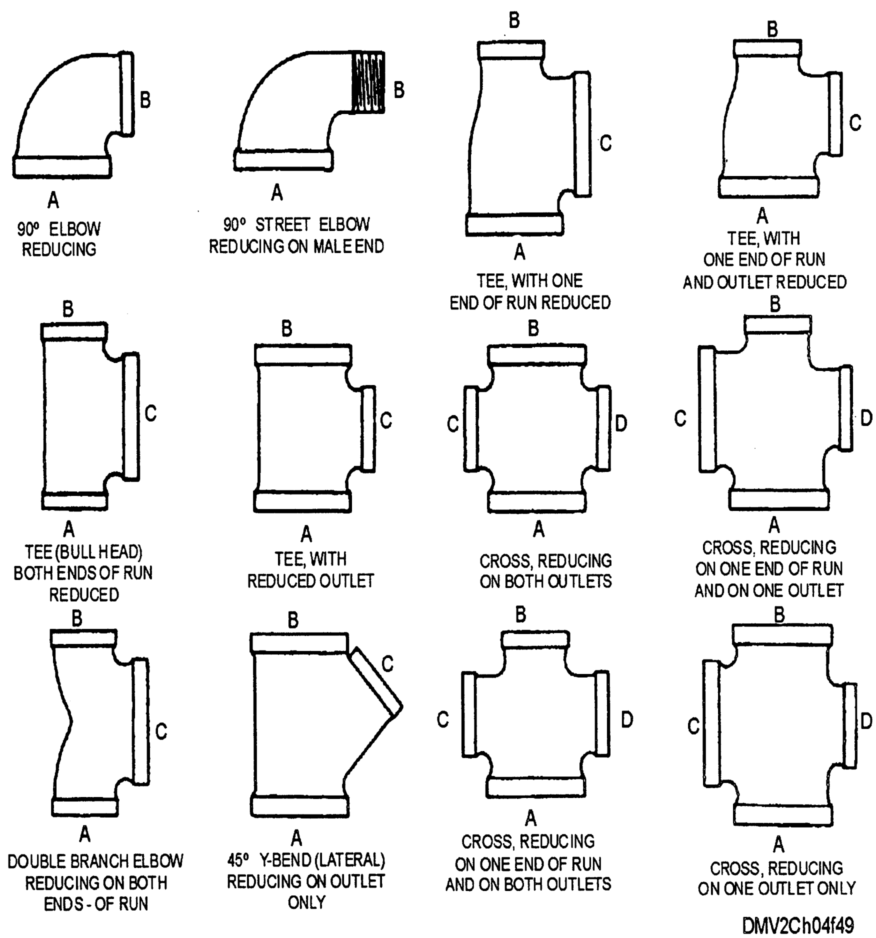

Figure 4-49.—Plumbing fittings

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Symbols and markings

MIL-STD-17B, part I, lists mechanical symbols used on piping prints other than those used for aeronautical, aerospacecraft, and spacecraft (listed in part II). When an item is not covered in the standards, the responsible or originating activity designs a suitable symbol and explains it in a note. When more than one piping system of the same kind appears on a print, use letters added to the symbols to differentiate between the systems.

Figure 4-50 is a list of common pipe line symbols.

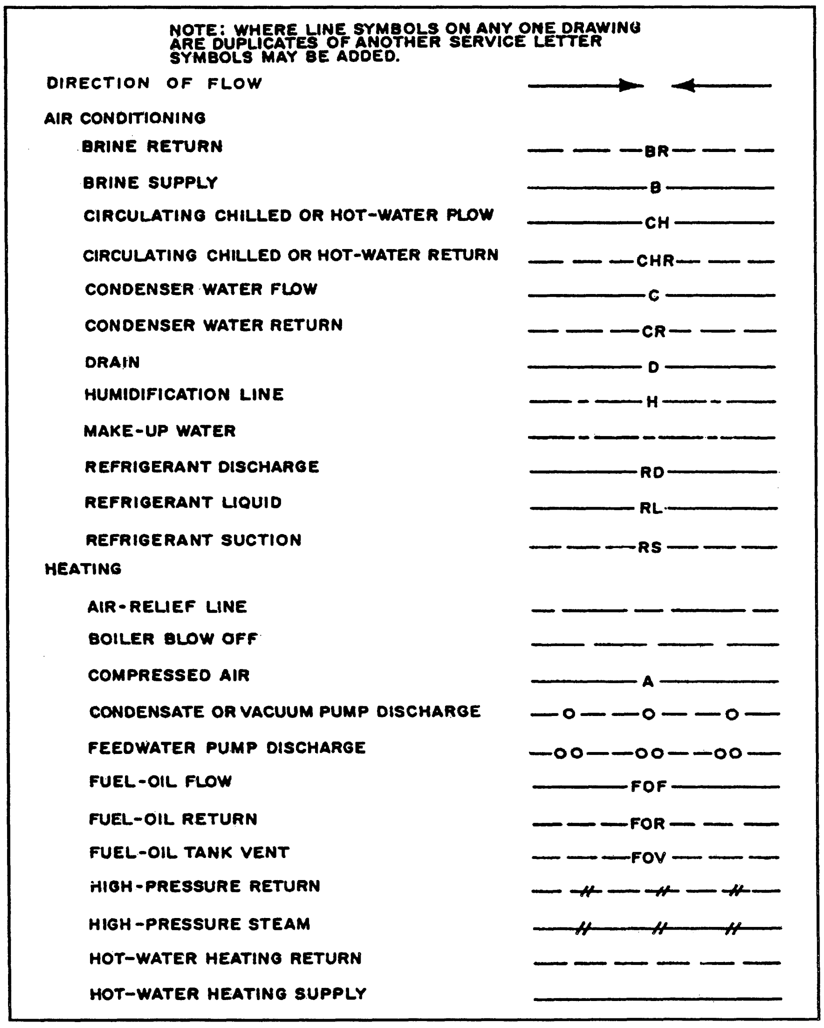

Figure 4-50.—Common pipe line symbols.

Continued on next page

Symbols and markings (Continued)

Figure 4-51 is a list of common piping symbols.

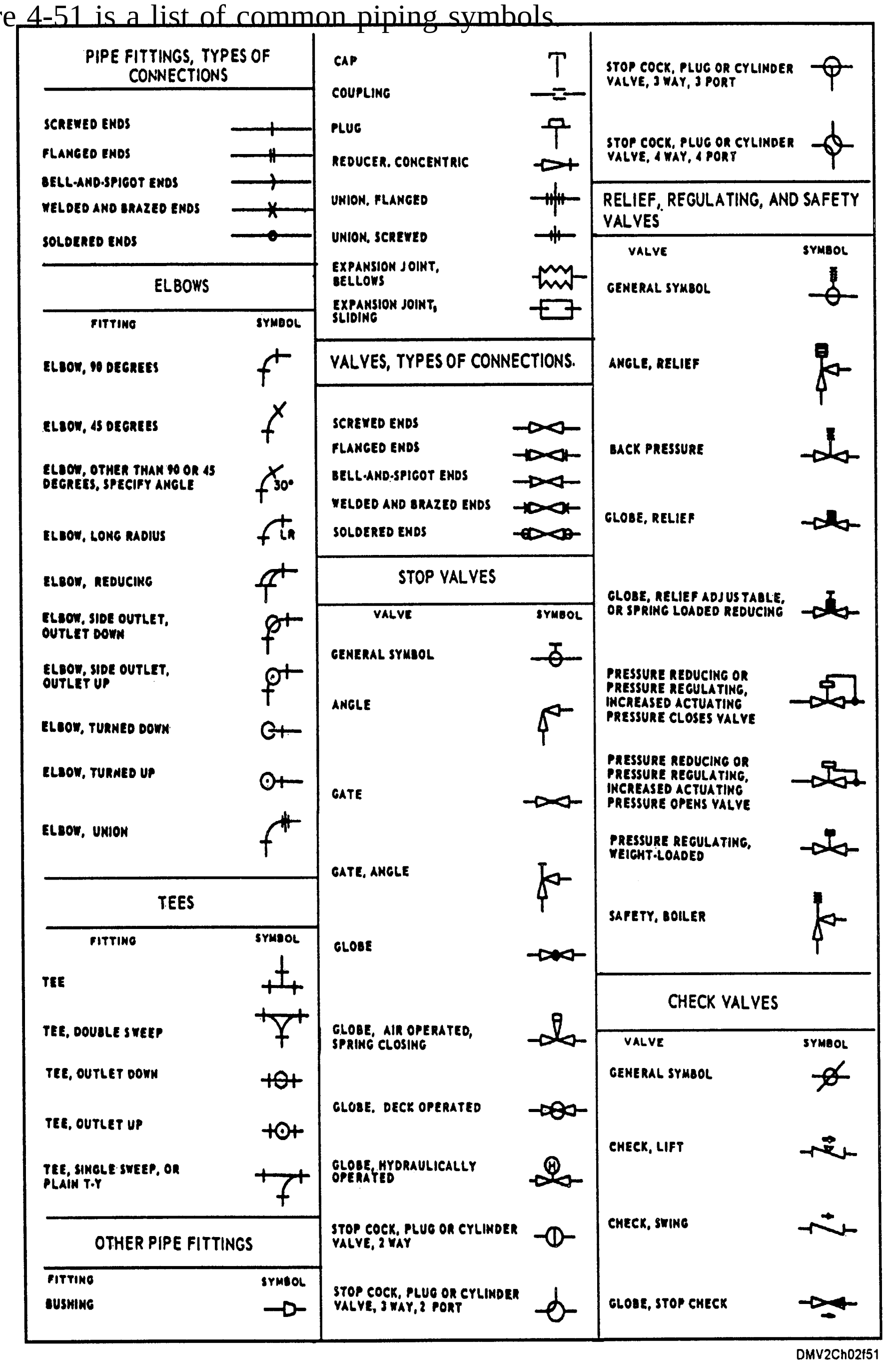

Figure 4-51.—Common piping symbols.

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Symbols and markings (Continued)

Figure 4-51 is a continuation of the list of common piping symbols.

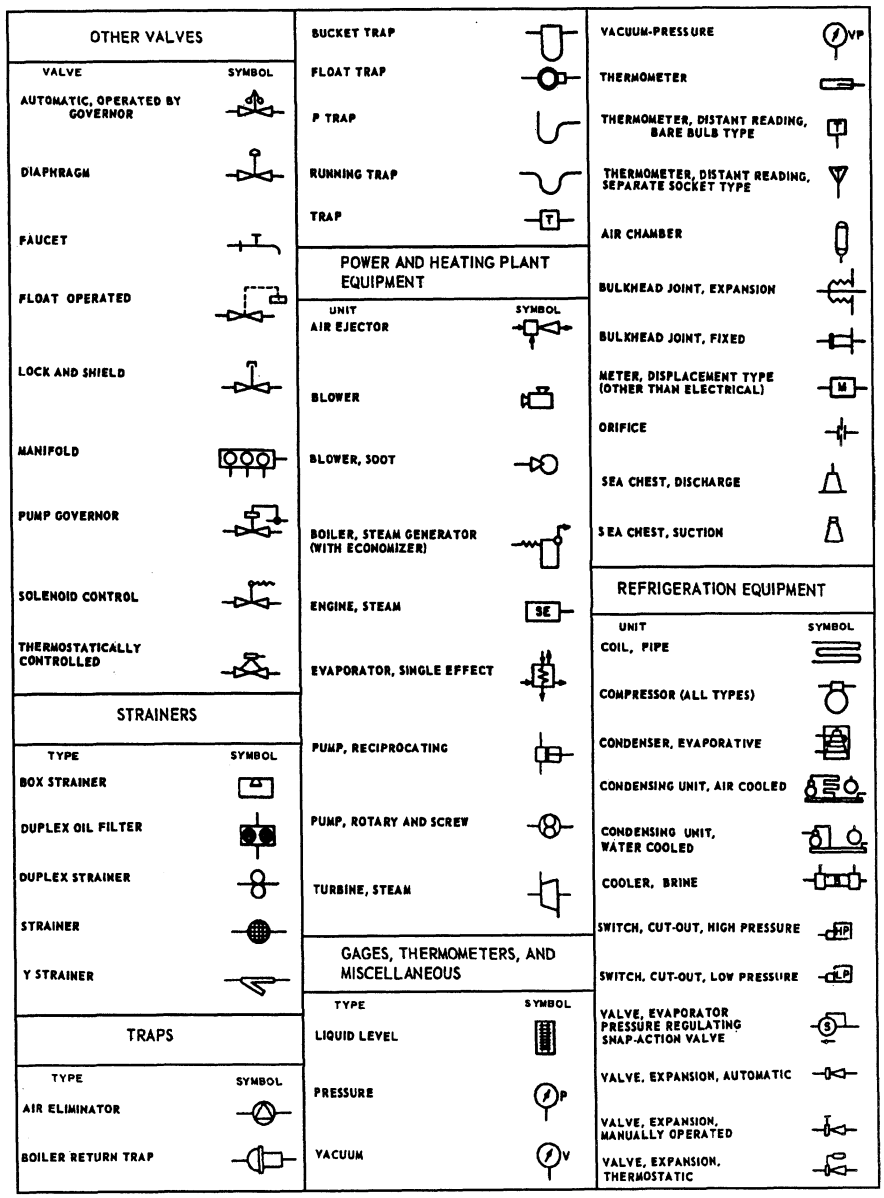

Figure 4-51.—Common piping symbols (continued).

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Symbols and markings (Continued)

Figure 4-52 is a list of common plumbing symbols.

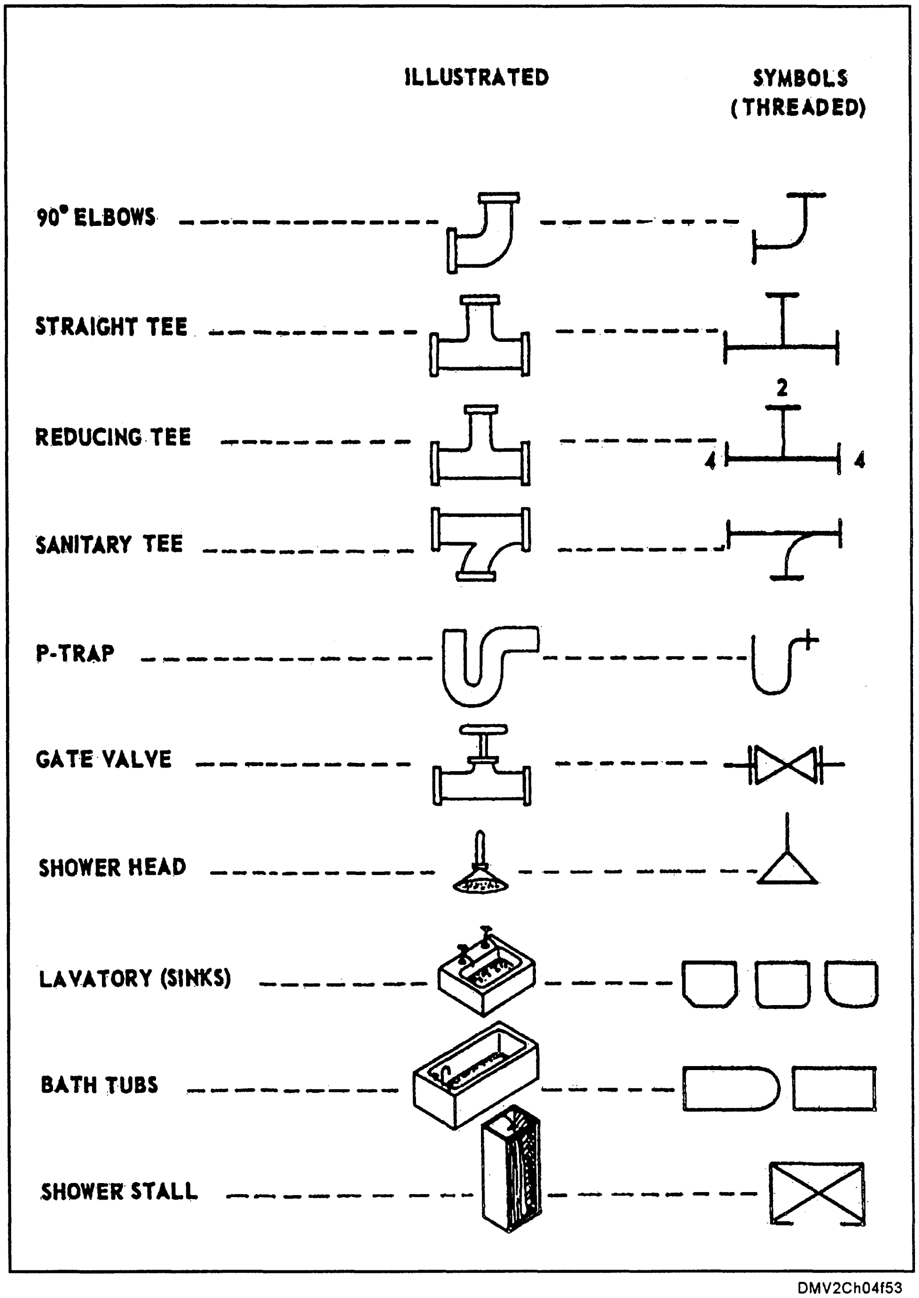

Figure 4-52.—Common plumbing symbols.

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Color codes

MIL-STD-101C establishes the color code used to identify piping carrying hazardous fluids. It applies to all piping installations in naval industrial plants and shore stations that use color coding. All valve wheels must be color coded. Color coding on pipes is optional.

This list outlines common color codes for fluid under MIL-STD-101C.

Part	Function
Yellow	Flammable materials
Brown	Toxic and poisonous materials
Blue	Anesthetics and harmful materials
Green	Oxidizing materials
Grey	Physically dangerous materials
Red	Fire protection materials

Fluid lines on aircraft are marked according to MIL-STD-1247C, *Markings, Functions, and Designations of Hoses, Piping, and Tube Lines for Aircraft, Missiles, and Space Systems.* Aircraft fluid lines are also marked with an arrow to show direction of flow and a hazard marking. The four general classes of hazards are FLAM for flammable or combustible materials, TOXIC for material extremely hazardous to life or health, AAHM for anesthetics, vaporous and nonvaporous that present dangers to life and health, and PHDAN for materials that by themselves are not dangerous but present the danger of asphyxiation. PHDAN material are often pressurized or temperature sensitive.

Continued on next page

Color codes (Continued)

Figure 4-53 lists color codes and symbols for aircraft fluid lines.

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	

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Figure 4-53.—Aircraft fluid line color codes and symbols.

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Fluid power symbols

Figure 4-54 is a list of common fluid power symbols.

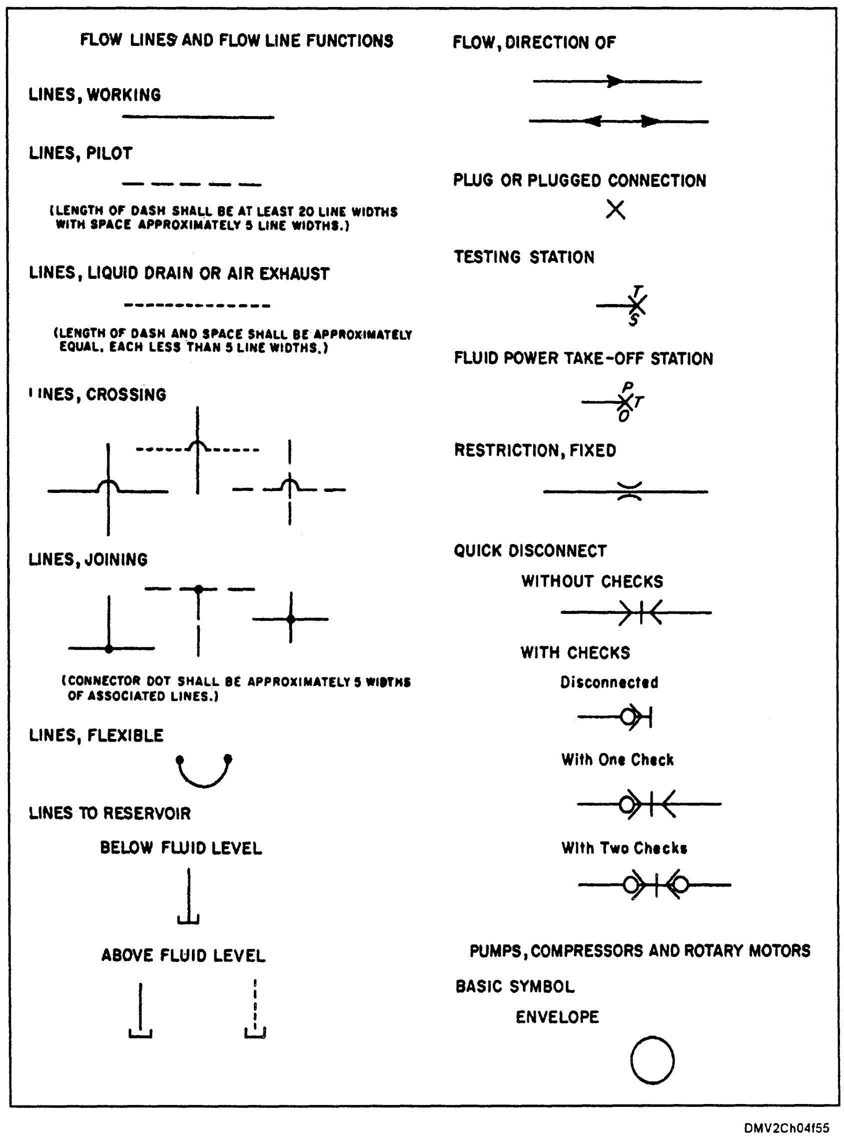

Figure 4-54.—Fluid power symbols.

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Shipboard piping prints

Standard piping symbols appear on shipboard piping prints with a symbol list. Sometimes symbol lists are left off the print; therefore, you must be familiar with standard symbols. Many operation and maintenance manuals do not use standard symbols because these systems are drawn in detail or pictorially.

Hydraulic prints

Hydraulic systems are on aircraft and on board ships activating weapons systems, navigational equipment, and remote controls of numerous mechanical devices. Shore stations use hydraulically driven maintenance and repair shop equipment. Hydraulic systems are also used in construction, automotive, and weight-handling equipment. In general hydraulic lines are designated as *supply lines*, which carry fluids from a reservoir to pumps, *pressure lines* that carry only pressure, *operating lines* that alternately carry pressure to and return fluids from an actuating unit, *return lines* return fluids to the reservoir, and *vent lines* that carry excess fluids overboard or into another receptacle. To distinguish one hydraulic line from another, the DM designates each line according to its function within the system. MIL-STD-17B, part II, lists symbols used on hydraulic systems. On drawings of hydraulic systems, basic symbols often show a cut-away section to clarify operation.

Figure 4-55 shows basic types of hydraulic symbols.

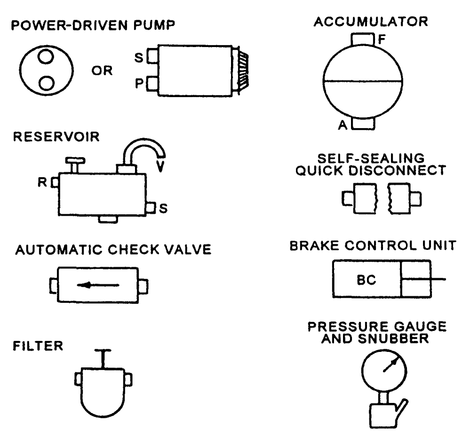

Figure 4-55.—Basic types of hydraulic symbols.

Summary

Review

This chapter introduces you to various types of technical drawings. Beginning with a brief description of technical sketching and technical drawing followed by architectural/structural drawings, electrical/electronic drawings, machine drawings, and, finally, plumbing/piping drawings. Each section has a vocabulary and symbology that is unique. There are superficial directions on how the DM should approach each type of technical drawing and the significance of different drawings within each type. The chapter ends with hydraulic systems.

Comments

This chapter is not meant to be your sole reference to technical drawings. Before plunging in to draw, revise, or interpret each type of technical drawing, pull the appropriate references and study the symbols. As an Illustrator Draftsman, you may or may not have an opportunity to work on each of these types of technical drawings. You should, however, be familiar with the various types of technical drawings and know where to look for guidance in the event you are required to draw, revise, or interpret one. Opportunity abounds for well-versed draftsmen in the civilian community especially if you can compliment your knowledge and abilities with computer savvy.

CHAPTER 5

PERSPECTIVE PROJECTIONS

Overview

Introduction

The principal device for spatial representation that creates the illusionistic third dimension on two-dimensional surfaces has been perspective. Refinements during the Renaissance and the subsequent development of photography in the nineteenth century reenforced perspective as the natural and standard method of representation. By the end of the nineteenth century, artists exposed to art from non-western cultures challenged the confinements of absolute perspective to develop abstract and expressive representations. An understanding of perspective helps you create more realistic imagery. Before you can coherently create abstract art, you should understand the principles of perspective. Study the works of Albrecht Dűrer for examples of superb draftsmanship and perspective representation. In contrast, study the work of Marcel Duchamp, whose expressive distortions of perspective and perception led into the Futurism movement in 1909.

Objectives

The material in this chapter enables you to do the following:

- Distinguish between parallel and perspective projection.
- Define one-point perspective.
- Define two-point perspective.
- Define three-point perspective.
- Recognize the differences in three-point perspective and isometric projection.
- Evaluate key features in drawings and check for technical accuracy and completeness.

Continued on next page

Acronyms

The following table contains a list of acronyms that you must know to understand the material in this chapter.

Acronym	Meaning
CL	Centerline
CV	Center of Vision
GL	Ground Line
HL	Horizon Line
SP	Station Point
PP	Picture Plane
VP	Vanishing Point

In this chapter

This chapter covers the following topics:

Perspective

Introduction

Two types of projections or methods of realistically representing objects on a page are parallel projection and perspective or central projection. Parallel projection is used for technical drawings and blueprints and is covered in the next chapter. Perspective or central projection is used in creative art or technical sketching but seldom in technical drawing.

Perspective or central projection

Perspective projection, sometimes called *central projection,* is the method by which artists realistically portray three-dimensional objects on a two-dimensional plane. Perspective or central projection is, in theory, where objects are drawn on a page 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. The resultant drawing is always called a central projection because the lines of sight or projectors meet at a central point -the eye of the observer. The projected view of the object may vary considerably in size according to the relative positions of the objects and the plane of projection. Varying from natural perspective distorts images into abstract or expressive representation. Perspective alone will not effectively create the illusion of three dimensions without tone or shading. In photography, perspective dominates. Although scene replication is almost exact, photography has crucial limitations regarding field of view. The human eye sees wide and far but the photographic lens has field of view limitations that even with corrective lenses results in distortion. Corrective wide-angle lenses typically result in distortion called *barrel distortion*, where the lines parallel to the sides of the picture frame bow inward at the center.

Figure 5-1 illustrates the effect of barrel distortion.

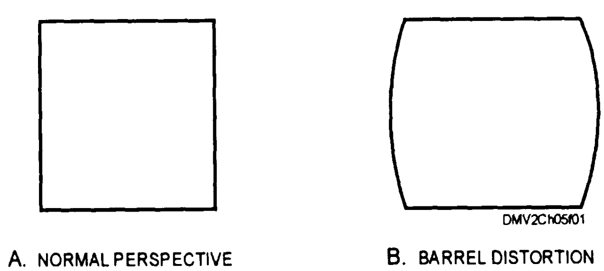

Figure 5-1.—Differences in a cube exhibiting:
A. Normal perspective, and B. Barrell distortion.

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General principles of perspective

Perspective involves four main elements; the observer's eye, the object being viewed, the plane of projection, and the projectors from the observer's eye to all points on the object. Other terms you should become familiar with are plan and elevation, picture plane, vanishing point, horizon line, ground line, and visual rays.

THE OBSERVER'S EYE: The observer's eye, also known as the *station point* (SP), represents the location of the eyes of the observer. You should direct the centerline (CL) of the cone of visual rays toward the center of interest. For small or medium-sized objects, place the station point slightly above the object. For large objects, place the station point at eye level or approximately 5 feet 6 inches above ground. The station point is the most influential element of perspective drawing because it affects location, viewpoint, and perspective.

Figure 5-2 shows the centerline of a cone of visual rays.

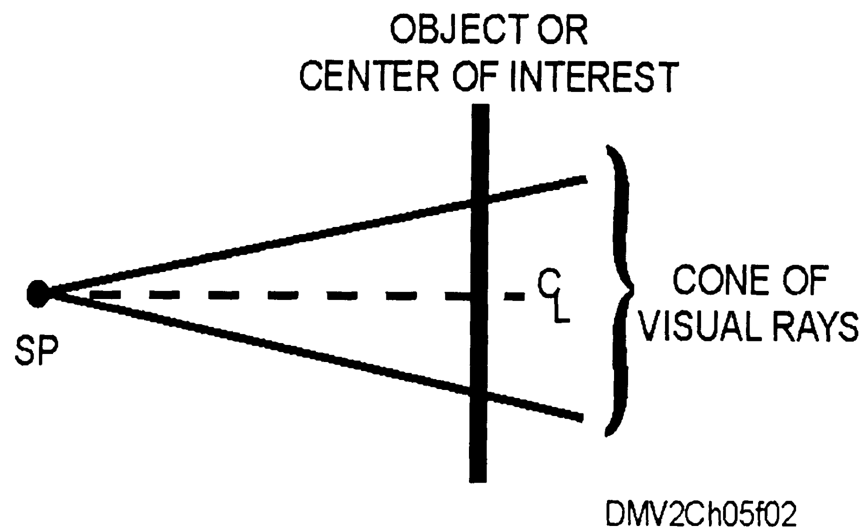

Figure 5-2.—The cone of visual rays.

Continued on next page

General principles of perspective (Continued)

THE OBJECT BEING VIEWED: The object being viewed is the object that attracts the observer's eye. With rare exceptions, the object being viewed appears behind the plane of projection. An object placed above the horizon line appears as if seen from below. An object placed below the horizon line appears as if seen from above.

Figure 5-3 shows a cube on, above, and below the horizon line as viewed from the same station point.

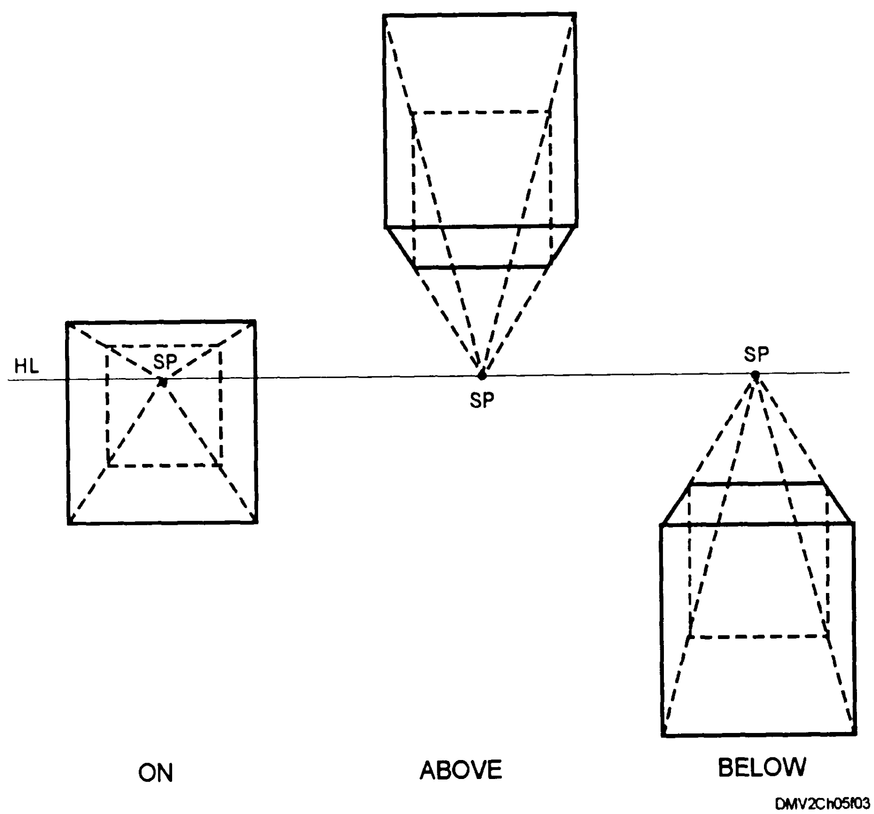

Figure 5-3.—Perspective changes as position relative to the horizon line changes.

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General principles of perspective (Continued)

THE PLANE OF PROJECTION: The plane of projection is the imaginary plane normally located between the observer and the object being drawn. The location of the plane of projection determines the size of the object on the picture plane. The points at which projectors intersect the picture plane are called *piercing points.* A collective of all of the piercing points produces perspective and are called *perspectives.*

THE PROJECTORS FROM THE OBSERVER'S EYE TO ALL POINTS ON THE OBJECT: The projectors are imaginary lines from the observer's eye to the object being drawn. Projectors are also called *visual rays.* The range of view of visual rays is called the *cone of vision.*

Figure 5-4 shows piercing points and visual rays.

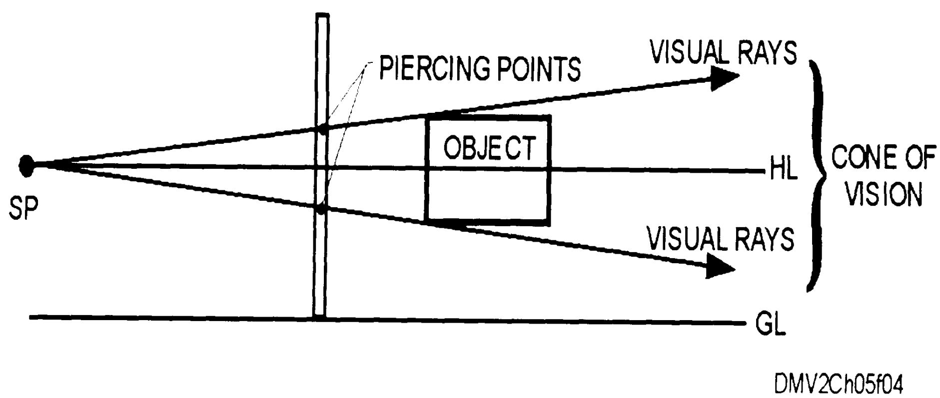

Figure 5-4.—Piercing points, visual rays. and cone of vision.

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General principles of perspective (Continued)

PLAN AND ELEVATION: Top views in perspective drawings are called *plan views* and the front and side views are called *front elevation* and *side elevation,* respectively.

Figure 5-5 shows a plane view and elevation.

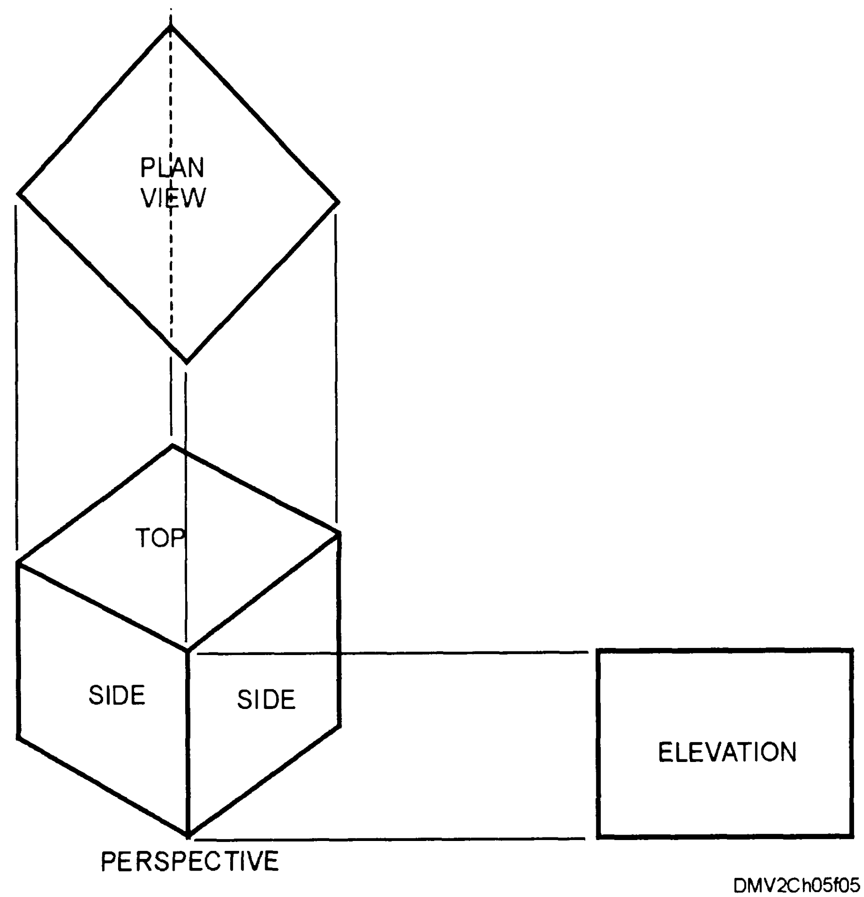

Figure 5-5.—A plan view and elevation.

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General principles of perspective (Continued)

PICTURE PLANE (PP): The picture plane (PP) is the imaginary vertical plane placed between the eye of the observer and the object being drawn. Although the usual position of the picture plane is between the station point and the object, you may also place the PP behind the object or behind the SP as it is in photography when the image strikes the film or focal plane. Moving the picture plane alters perspective or scale but not proportion. In general, the farther the plane is from the object, the smaller the perspective. A picture plane, plane of projection, and drawing surface may be the same.

Figure 5-6 shows possible locations for the picture plane.

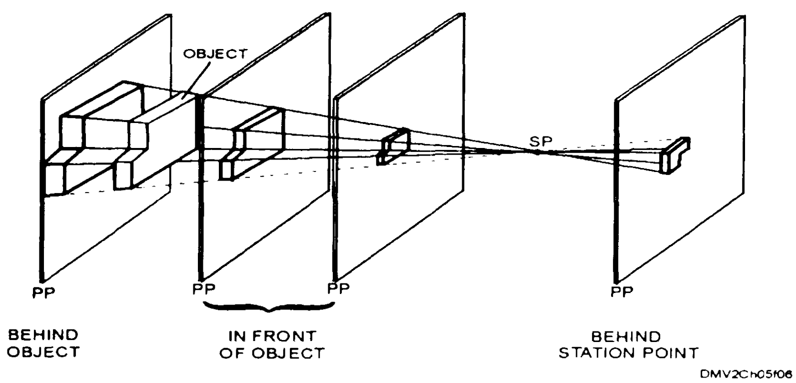

Figure 5-6.—Location of the picture plane.

VANISHING POINT (VP): Vanishing points (VP) are where parallel horizontal lines appear to converge. Vanishing points are also known as the *center of vision (CV).*

Figure 5-7 show how horizontal lines in perspective seem to converge into vanishing points.

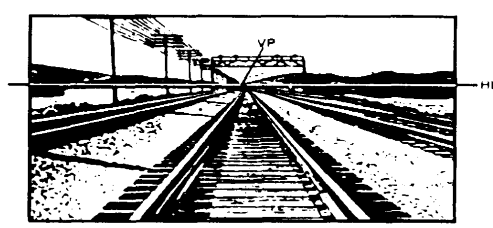

Figure 5-7.—Horizontal lines in perspective.

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General principles of perspective (Continued)

HORIZON LINE (HL): The horizon line is the position of the horizon that may or may not be visible on the picture plane depending on your angle of sight. The horizon line is also known as the eye level. Eye level is typically defined as 5 feet 6 inches above the ground.

GROUND LINE (GL): The ground line represents the edge of the ground plane on which the object rests. The ground line defines the lower limits of your drawing.

Figure 5-8 illustrates component parts of the principles of perspective.

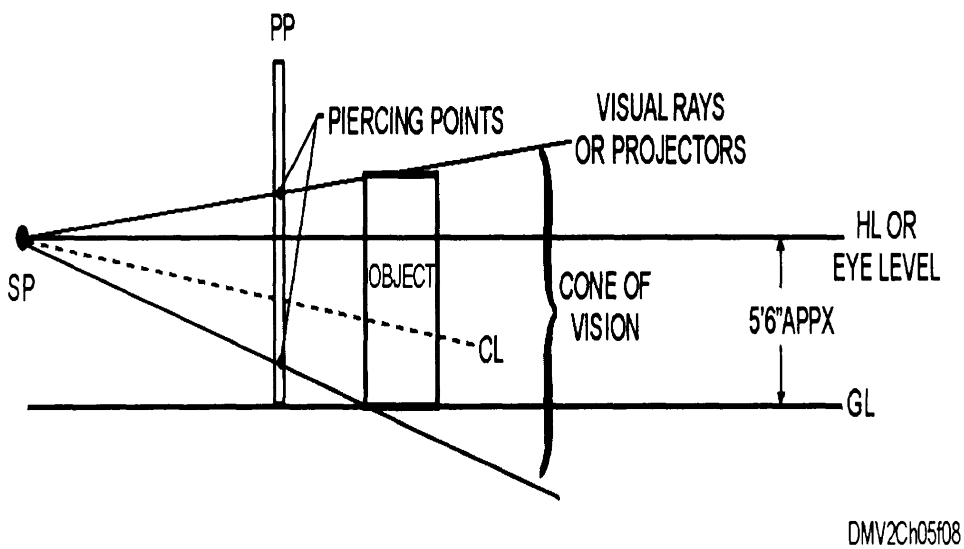

Figure 5-8.—Component parts in perspective.

Linear Perspective

Introduction

Linear perspective, aerial perspective, and shading are the prime methods for conveying a sense of natural space and three-dimensional form. In linear perspective, converging lines express the recession of parallel forms into space away from the observer. Linear perspective produces images that are accurate representations of real objects recognized and identified by artists and laymen alike.

Linear perspective

Linear perspective is a geometric system for depicting objects, planes, and volumes in space on a two-dimensional field. This precise mathematical interpretation is based on the location of the observer in reference to the objects drawn. This system uses size, position, and converging parallels to create a unified spatial order. Certain characteristics common to images drawn in linear perspective are vanishing points, horizon lines, ground lines, and picture planes. Linear perspective is the type of perspective most commonly used by draftsmen and artists.

Figure 5-9 is an example of linear perspective.

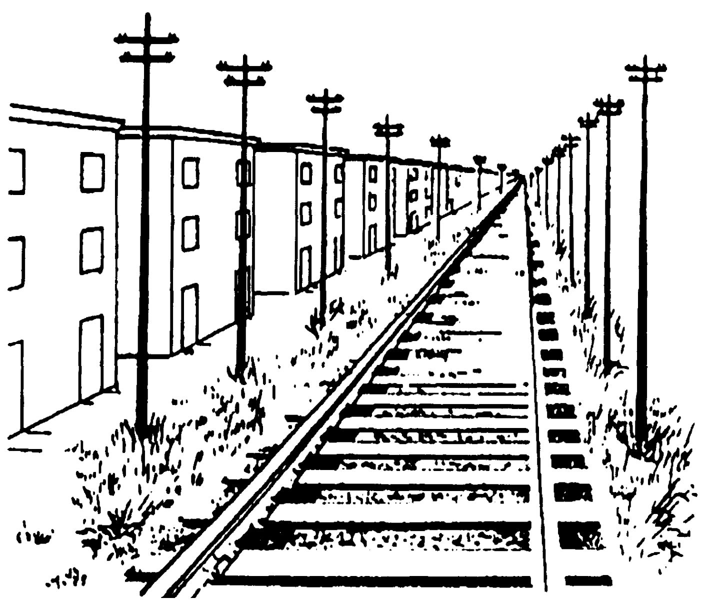

Figure 5-9.—Linear perspective.

Reverse Perspective

Introduction

Asian and eastern cultures approach perspective from an opposite philosophy. The traditional oriental artist believed that parallel lines converged as the lines approached the spectator. This belief involves the observer as an active participant in the image rather than a passive bystander. This philosophy or technique is known as *reverse perspective.* For further study in reverse perspective, study works before 1729, particularly those paintings executed by Japanese artist Kiyonobu, founder of the Torii school.

Reverse perspective

Reverse perspective is when parallel horizontal lines converge as they approach the observer. This technique requires the location of the picture plane behind the station point creating the illusion of enclosing or limited space that actively involves the observer in the image area. The observer sees the image as large, flat (in perspective), and detailed (without the affects of aerial perspective). The spatial panorama presented to the observer is rarely noticeably enclosed by an implied picture plane.

Figure 5-10 illustrates the location of the picture plane and a resultant perspective.

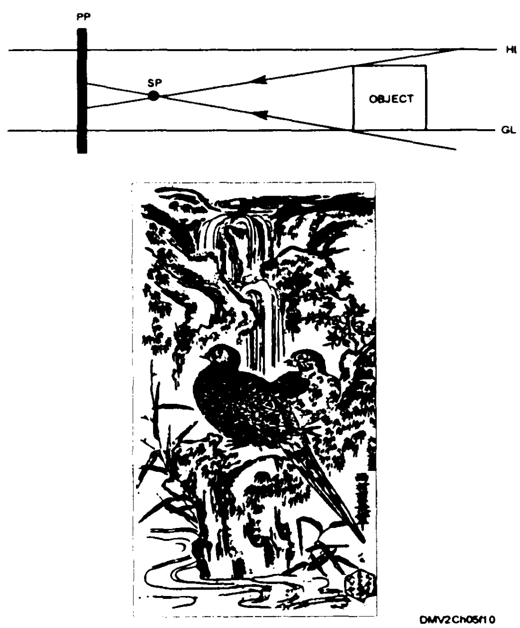

Figure 5-10.—Reverse perspective.

Aerial Perspective

Introduction

Aerial perspective creates the illusion of distance. Aerial perspective is sometimes referred to as *atmospheric perspective* because it attempts to replicate the natural muting effect of the atmosphere as distance increases between the station point, object, and horizon line.

Aerial perspective

Aerial perspective creates the illusion of distance in an image by lightening values, softening contours, reducing value contrasts, and neutralizing colors in objects approaching the horizon line. Details that are less crisp and colors that are less intense imply distance. Aerial perspective works in conjunction with linear perspective contributing to the overall success in portraying perspective within a scene.

Figure 5-11 illustrates how the principles of aerial perspective creates distance.

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Figure 5-11.—Aerial perspective.

One-Point Perspective

Introduction

One-point perspective is when an object is directly in front of an observer and not seen at an angle. The principal surface of an object is parallel to the picture plane and to the station point. The remaining structure of the object is perpendicular to the picture plane. For this reason, one-point perspective is also called *parallel perspective.* One of the most common uses of one-point perspective is in interior architectural illustrations. For interesting study on one-point perspective, study tromp-l'œil drawings and paintings.

One-point or parallel perspective

One-point or parallel perspective places two principal edges (height and width) of one surface of an object parallel to the picture plane. Height and width have no vanishing point and appear in true length since they are parallel to the picture plane. Only the depth dimension must be put in perspective, and this requires one vanishing point. The station point is in front and parallel to the object and the vanishing point is directly behind. To find the third dimension representing depth, project visual rays from the station point to the vanishing point. Changing the location of the vanishing point or raising and lowering the eye level affect perspective.

Figure 5-12 shows one-point perspective with vanishing points behind and above the cube or object.

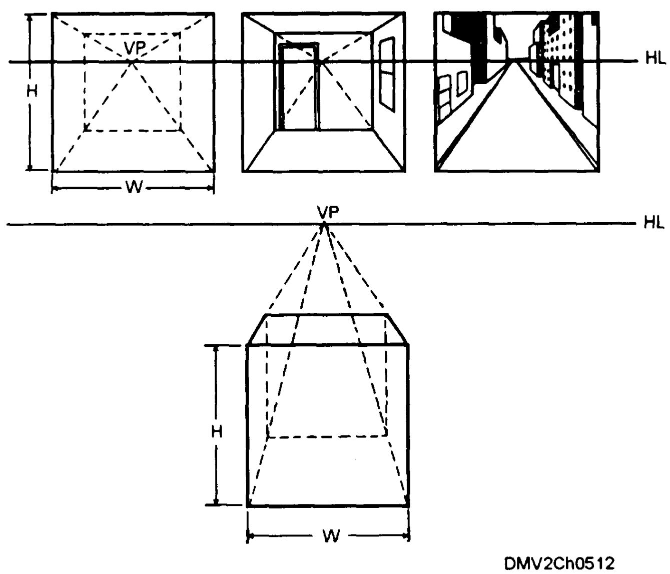

Figure 5-12.—One-point perspective.

Two-Point Perspective

Introduction

Two-point perspective is when objects are located at an angle to the picture plane but with vertical edges parallel to the picture plane   Two vanishing points are required to project the remaining dimensions. Two-point perspective is also called *angular perspective* because of the angular position of the object in relation to the picture plane. Two-point perspective is the most commonly used type of perspective in drawing and illustration.

Two-point or angular perspective

In two-point or angular perspective, an object is placed at an angle to the picture plane but with one set of vertical edges parallel to the picture plane. Place the object so that the angles created by the surface of the object to the picture plane are unequal. For convenience in drawing, the angles you select should equate to angles that a common 45° or 30/60/90° triangle or combination of the two triangles can easily replicate. The vertical parallel edge (height) appears in true length and does not require vanishing points. You may make direct measurements from this parallel vertical edge. You must use perspective to draw the remaining profile of the object. This will require two vanishing points (width and depth). The station point is located in front of and parallel to the picture plane. The object is at an angle to the picture plane and vanishing points are usually located to the left and right of the object. Visual rays projected from the station point to the vanishing point intersect the object at piercing points to form perspective. If available, you may use the plan and elevation of multiview drawings in the construction of the perspective drawings.

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Two-point or angular perspective (Continued)

Figure 5-13 shows the typical set up for two-point perspective.

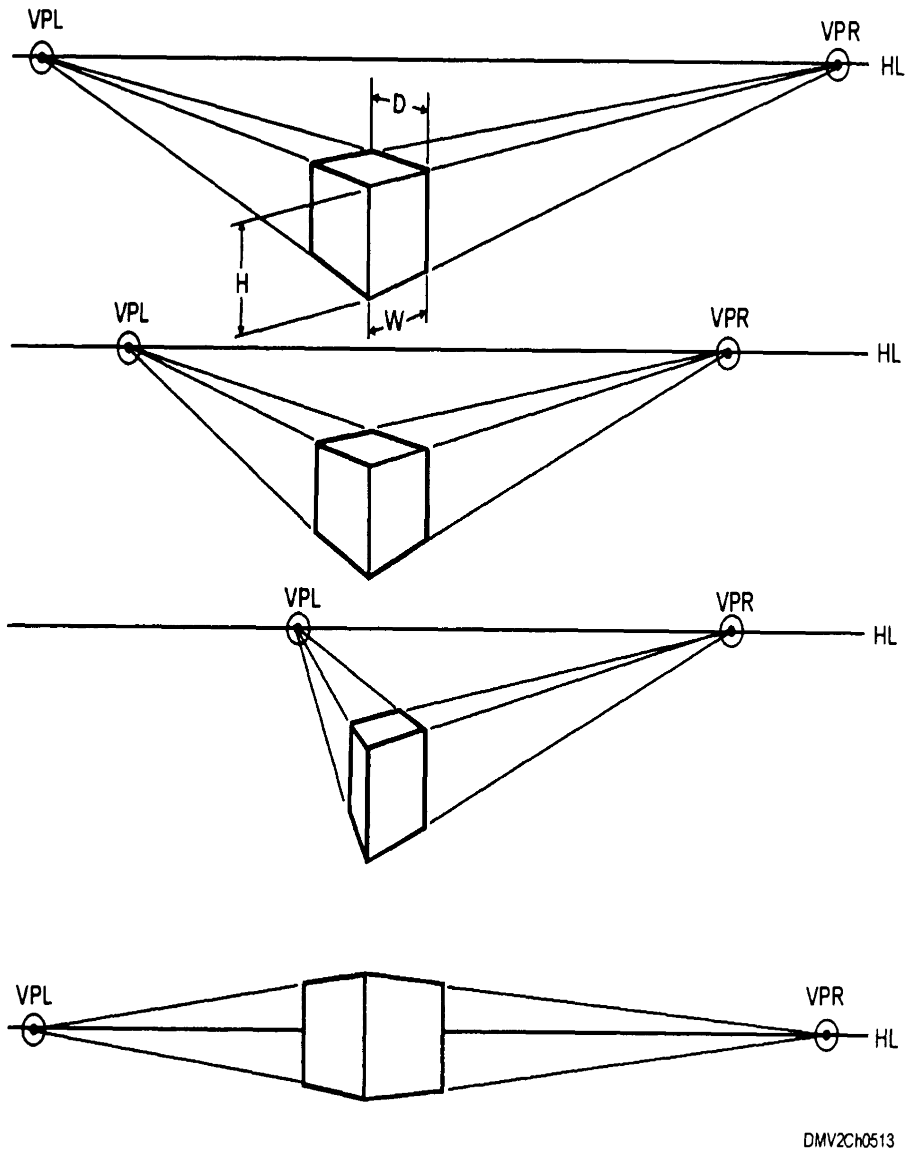

Figure 5-13.—Two-point perspective.

Three-Point Perspective

Introduction

Three-point perspective is when no edge of the object is parallel to the picture plane and all three dimensions (height, width, and depth) require vanishing points. Three-point perspective is also known as *oblique perspective.* You need a more sophisticated sense of perspective to successfully create illustrations in three-point perspective.

Three-point or oblique perspective

In three-point or oblique perspective, the object is placed so that none of the principal edges is parallel to the picture plane. All three edges require separate vanishing points to determine height, width, and depth. The station point is parallel to the picture plane and the cone of visual rays is perpendicular to the picture plane. The decision on the placement of the vanishing points is arbitrary and based purely on aesthetics. Here are two general rules to follow in placing vanishing points in three-point perspective: (1) separate vanishing points to make small objects look better and (2) place vanishing points closer together to emphasize the expanse or large size objects.

Figure 5-14 shows an object rendered in three-point perspective.

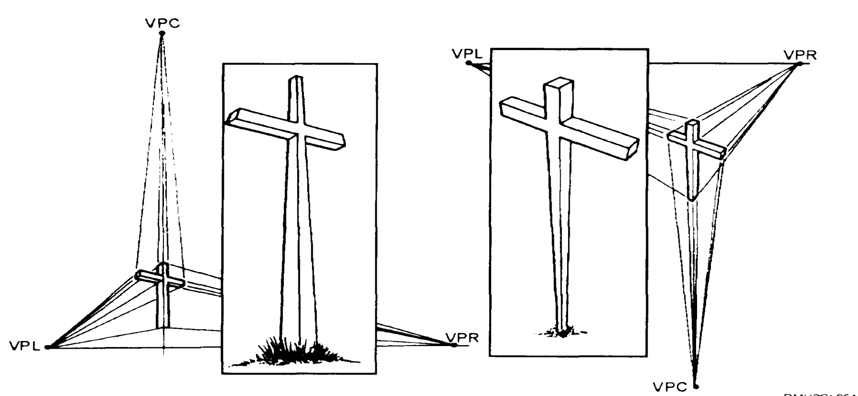

Figure 5-14.—Three-point perspective.

Perspective Practices

Introduction

As ethereal as perspective drawing may seem, there are some standard practices that help you construct believable perspective drawings.

Mechanical construction of perspective drawings

Two basic systems are used in the mechanical construction of accurate perspective drawings: the plan-view method and the measuring-line method. Many illustrators use a combination of both systems when using mechanical means to produce drawings in perspective.

Plan-view method in one-point perspective

The plan-view method of constructing one-point perspective drawings requires that you have copies of orthographic projection drawings drawn to scale.

To construct perspective drawings from a plan view, use this table:

Step	Action
1	Establish an arbitrary horizon line (HL) depending on the eye level you wish to portray (figure 5-15, view A).
2	Locate the picture plane (PP) so that it does not interfere with the drawing. Remember that the picture plane may be the same as the horizon line.
3	Draw the plan view. You may draw the plan view above or below the picture plane, but it is easier to draw it resting on top of the picture plane.
4	Draw the ground line (GL) in an arbitrary location below and parallel to the picture plane (figure 5-15, view B).
5	Locate the station point (SP) not less than twice the width of the object (obtained from the plan view) and directly in front of or to one side of the plan view. You may also place the SP two or three times the object's greatest length from the nearest point of the plan view but if placed any closer, distortion of the perspective will result.
6	Project the width of the plan view to the ground line.

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Plan-view method in one-point perspective (Continued)

Step	Action
7	Draw the front view of the object on the ground line. If the front view of the object is touching the picture plane. the front view is true in size. If the plan view is behind or in front of the picture plane, the front view of the object is smaller or larger, respectively (figure 5-15, view C).
8	Project a vertical line from the station point to the horizon line to locate the vanishing point (VP).
9	From the comers of the front view (D, E, G, and F), draw visual rays to the vanishing point.
10	line from point A of the plan view to the station point. This line intersects the picture plane at point H. Draw a perpendicular line from point H to intersect the visual rays (points J and K). This accurately locates the back corners and defines the depth of the object (figure 5-15, view D).
11	Darken the object outlines.

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Plan-view method in one-point perspective (Continued)

Figure 5-15 shows a simple one-point perspective of a cube constructed from a plan view.

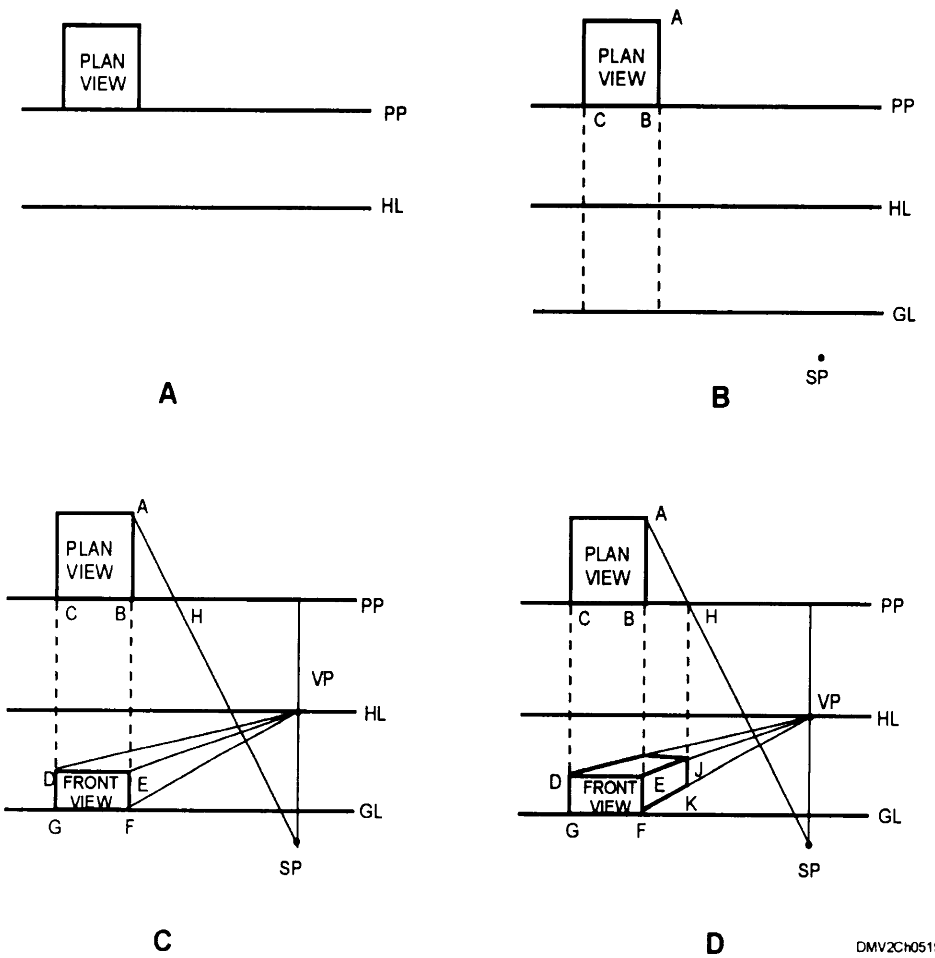

Figure 5-15.—The plan-view method of one-point perspective.

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Plan view method in two-point perspective

Two-point or angular perspective is the most common type of perspective drawing.

To construct two-point perspective drawings from a plan view, use this table:

Step	Action
1	Draw the horizon line and ground line (figure 5-16. view A).
2	Draw the picture plane line near the top of your paper so that it is out of the way of the perspective drawing.
3	Draw an arbitrary perpendicular line from the corner where the object touches the picture plane (point 0) to locate the station point. Place the station point at a distance not less than twice the total width of the object from point O (figure 5-16, view B).
4	Draw the plan view of the object.
5	Draw a line from the station point parallel to the side of the plan view where it intersects the picture plane (OB).
6	Draw a perpendicular line from 1 to the horizon line to locate the right vanishing point (VPR).
7	Draw a line from the station point parallel to the side (OA) of the plan view to where it intersects the picture plane at (2).
8	Draw a perpendicular line from 2 to the horizon line to locate the left vanishing point (VPL). The angle formed by the lines drawn from the station point to points 1 and 2 is equal to 90°.
9	Draw lines from the corners of the plan view (O, A. B, C) to the station point (figure 5-16, view C).
10	Project perpendicular lines from where these lines intersect the picture plane downward to the ground line.
11	From point Y, the intersection of line OSP, and the ground line. extend visual rays to both vanishing points to define the lower base of the object.

Continued on next page

Plan-view method in two-point perspective (Continued)

Step	Action
12	Taking dimensions from the orthographic views (the edge of the object that touches the picture plane), measure the vertical distance along line OY (figure 5-16, view D).
13	Project these points to the vanishing points.
14	The edges and comers of the object outline are defined where the visual rays intersect the perpendicular projectors.
15	Darken the object outlines.

Figure 5-16 shows the mechanical plan view method of constructing two-point perspectives.

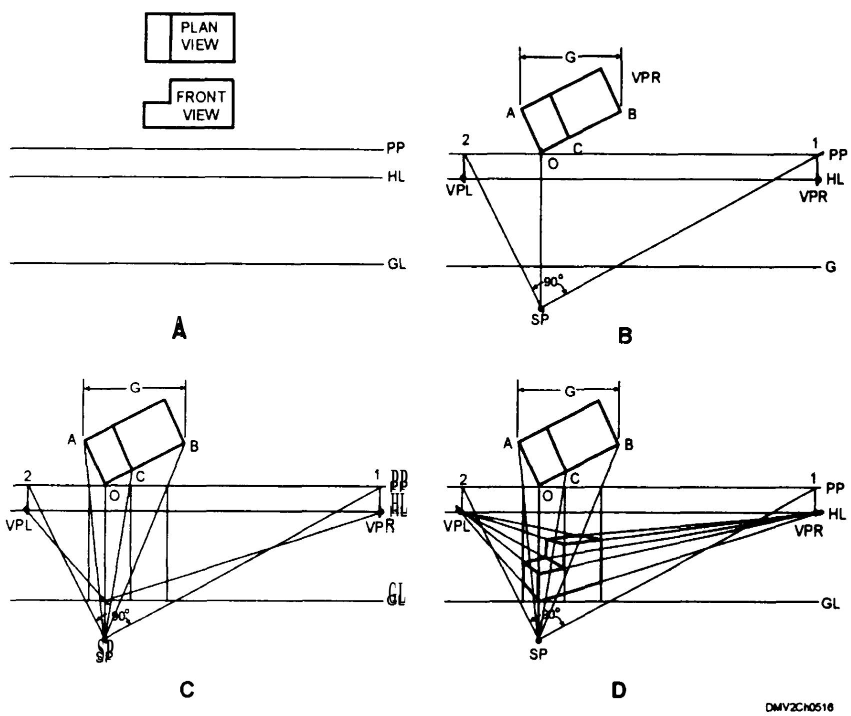

Figure 5-16.—The plan-view method of two-point perspective.

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Measuring-line method of perspective projection

The measuring-line method of constructing perspective drawings is used less than the plan view method. Use the measuring-line method of constructing perspective drawings when you do not have scaled orthographic drawings of the object. The measuring-line method works best when used in simple constructions of linear objects because of the amount of mathematical computations required to determine line lengths.

To construct perspective drawings using the line-measurement method, use this table:

Step	Action
1	Draw a horizon line and ground line.
2	Arbitrarily place two well-separated vanishing points, one on either side of the object (VPL and VPR).
3	Select a surface (A) and place it parallel (one-point perspective) or at an angle (two-point perspective) to the picture plane.
4	Extend visual rays from the station point to the vanishing points.
5	Measure height along the dimension that is parallel to the picture plane. This measurement will appear in true length.
6	Measure the dimensions of width and length against the GL. Draw perpendicular lines to intersect the receding lines leading to the vanishing points.
7	Darken all object outlines.

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Measuring-line method of perspective projection (Continued)

Figure 5-17 shows the line-measurement method of constructing perspective.

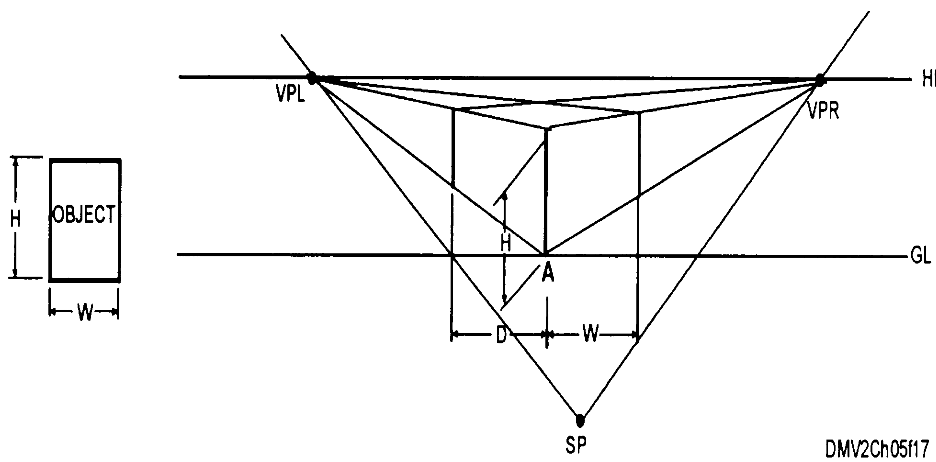

Figure 5-17.—The line-measurement method of constructing perspective drawings.

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Distortion

Distorted images appear when the object being drawn is too high or too low below the horizon line. Distortion also occurs when the station point is too close to the object. Moving the station point is the easiest and most used method for correcting distortion.

Figure 5-18 illustrates distortion caused by incorrect object placement.

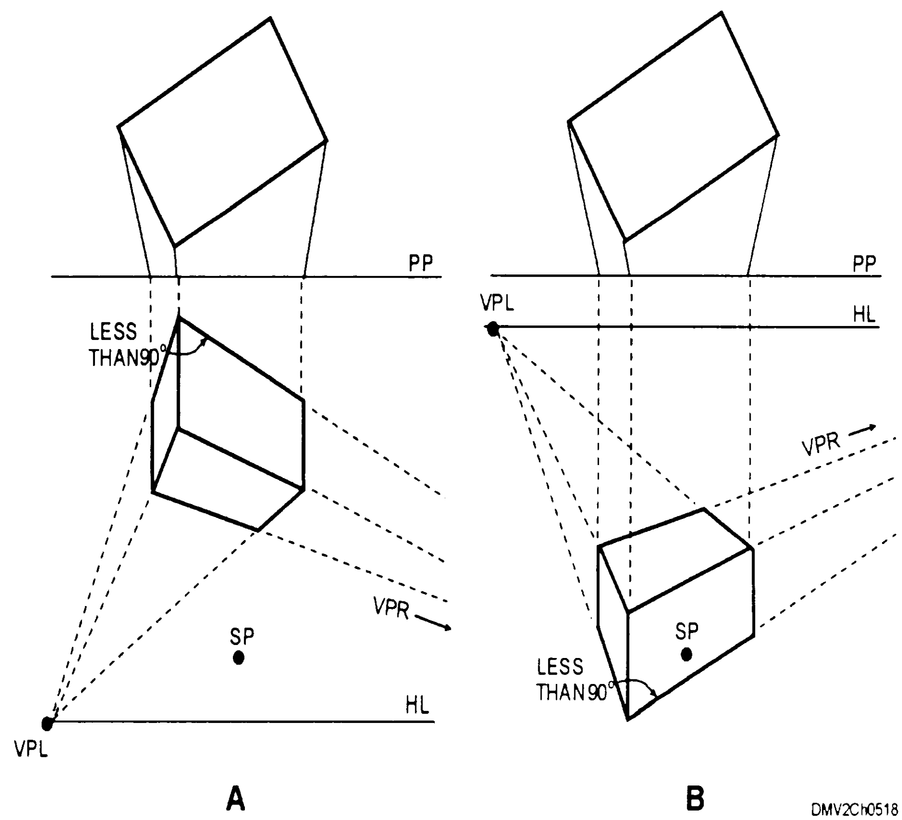

Figure 5-18.—Distortion caused by: A. Object placement too high, and B. Object placement too low in relation to the horizon line.

Measurements in perspective

All lines in the picture plane are shown in true length. All lines behind the picture plane are foreshortened. All lines and shapes parallel to the picture plane are shown in true size and shape.

Continued on next page

Inclined lines and planes

Lines and planes inclined toward or away from the picture plane have vanishing points similar to horizontal vanishing points. When constructing perspective drawings from plan and elevation views, locating the vanishing points for the inclined lines involves further preliminary projection.

To find the vanishing points of inclined lines in two-point perspective, use this table:

Step	Action
1	Place the picture plane, horizon line, and ground line as done previously in the mechanical construction of perspective drawings.
2	Extend the vertical lines AB and CD through the horizontal vanishing points (VPR and VPL). The vanishing points for inclined lines and surfaces will fall along these lines. Note that when you view an object, all inclined planes should project to the right. which means that all their vanishing points fall to the right of vertical line CD (figure 5-19, view A).
3	Using the line from the station point to where it intersects the picture plane (SPY), construct angle *a* equal to the angle made by the inclined plane 1234 and the picture plane in the elevation view. Extend this line beyond line CD (figure 5-19, view B).
4	Construct a perpendicular to this line intersecting CD at Y.
5	Using a compass or dividers, lay off this perpendicular distance on CD from the right vanishing point. This is VPRl for the inclined plane 1234.
6	Proceed with this method for the remaining inclined planes to obtain VPR2 and VPR3 (figure 5-19, view C).
7	Finish and darken the object outline.

You can find the perspectives of inclined lines without finding the vanishing points by finding the perspectives of the end points and joining them. You can determine the perspective of any point by finding the perspectives of any two lines intersecting at the point.

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Inclined lines and planes (Continued)

Figure 5-19 shows how to draw inclined lines and planes in two-point perspective.

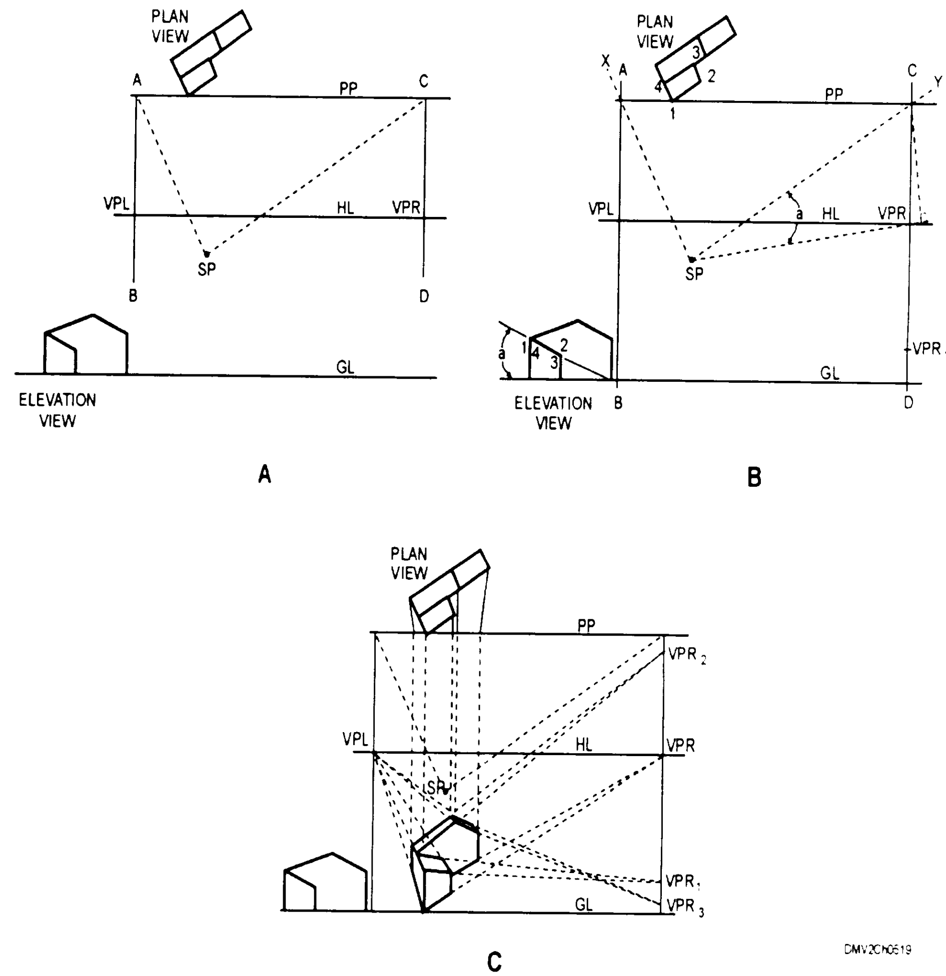

Figure 5-19.—Drawing inclined lines and planes in two-point perspective.

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Curves and circles in perspective

Curves and circles in perspective appear in true shape and size when the surface containing the curve or circle is parallel to the picture plane. Curves and circles on surfaces not parallel to the picture plane appear as ellipses. Ellipses have no direct transferable measurement; therefore you must place the circle within a square. By inscribing the circle within a square, the vanishing points and proportions of the curves are easily determined.

To lay out a circle in one-point perspective, use this table:

Step	Action
1	Draw a circle with the dimensions desired (figure 5-20, view A).
2	Draw a square circumscribing the circle. Construct center lines and diagonals inside the square. The intersections of the circle, the center lines, and the diagonals give you eight checkpoints for drawing the circle in perspective (figure 5-20, view B).
3	Draw the square in one-point perspective including the center lines and diagonals (figure 5-20, view C).
4	Draw in the circle through the eight checkpoints (figure 5-20, view D).

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Curves and circles in perspective (Continued)

Figure 5-20 shows the layout of a circle in one-point perspective.

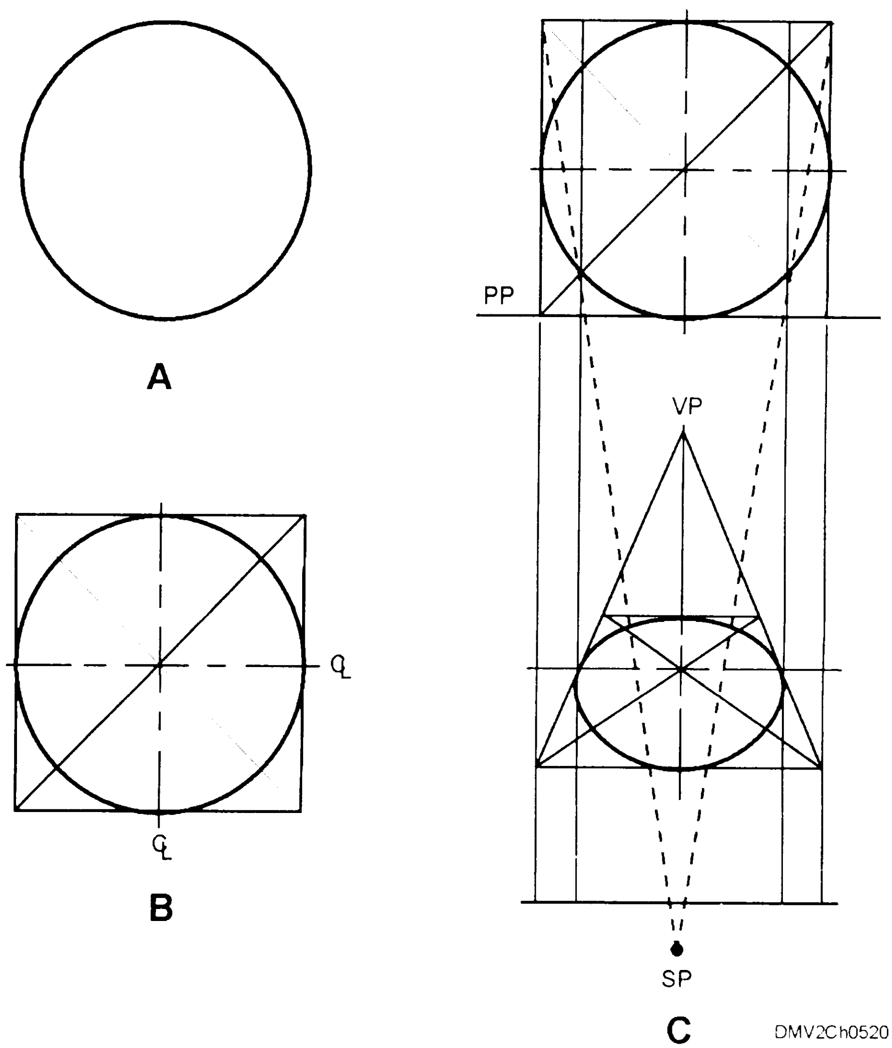

Figure 5-20.—The layout of a circle in one-point perspective.

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Curves and circles in perspective (Continued)

Drawing curves and circles in two-point perspective is similar to drawing in one-point perspective except for the additional vanishing point.

Figure 5-21 shows the circle in two-point perspective.

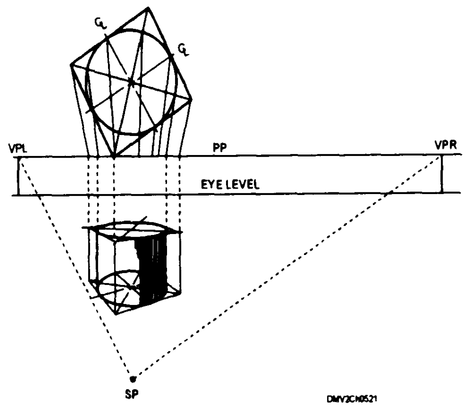

Figure 5-21.—The circle in two-point perspective.

Dividing lines or receding area into parts in perspective

Sometimes you need to divide a line or area into a number of parts. The key to most division of space problems in perspective is the vertical or horizontal line parallel to the picture plane.

To divide a receding plane into equal areas, use this table:

Step	Action
1	Divide the left vertical (AO) into equal parts with a ruler or scale.
2	From these points, draw lines to the vanishing point (figure 5-21, view A).
3	Draw a diagonal from point A to point B (figure 5-21, view B).
4	Where the diagonal and receding lines intersect, draw vertical lines. This divides the receding plane into equal units.

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Dividing lines or receding area into parts in perspective (Continued)

Figure 5-22 illustrates dividing a receding plane or surface.

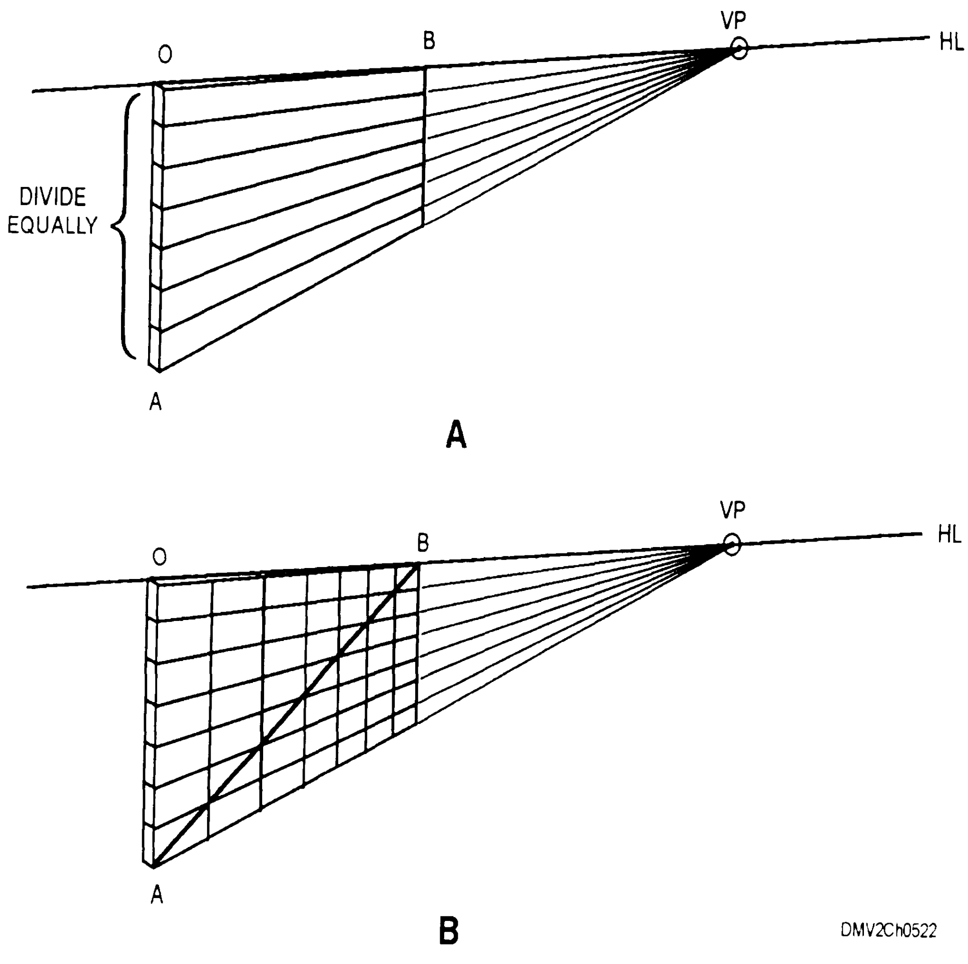

Figure 5-22.—Dividing a receding plane or surface into equal parts.

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Dividing lines or receding area into parts in perspective (Continued)

When the problem involves finding equal division points of a plane in perspective and the placement of these points is known, the problem can be solved as shown in figure 5-23. Since the points are parallel on the object, they have the same vanishing point.

To find incrementally placed horizontal points in perspective, use this table:

Step	Action
1	Locate a horizon line, ground line, and station point.
2	Place a vanishing point and draw a visual ray from the SP to the VP.
3	At the intersection of A and GL, measure and center the width of the first horizontal element.
4	Draw lines from each end of the first horizontal element to the VP.
5	Measure incrementally spaced horizontal elements along A to the intersection of HL.
6	Darken the outlines.

Figure 5-23 shows equally spaced horizontal points.

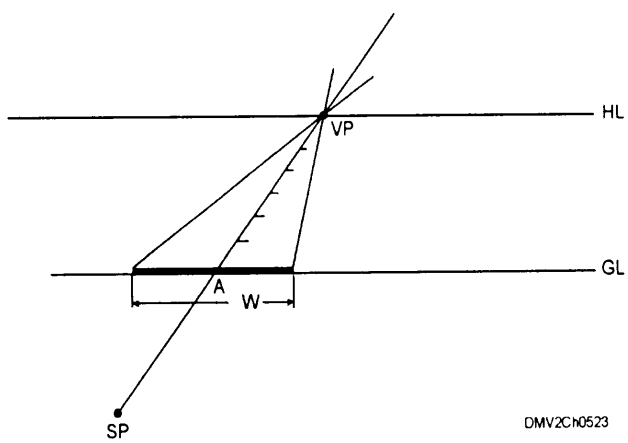

Figure 5-23.—Projecting horizontal points.

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Dividing lines or receding areas into parts in perspective (Continued)

When drawing vertical divisions in perspective, use this table and refer to figure 5-24.

Step	Action
1	Construct the first two points with the desired space in between them (A and B).
2	Locate a vanishing point (VP) and draw lines C and D from the original two objects. No part of the objects should extend above or below the receding lines.
3	Mark the center of the first post and draw a line (E to VP).
4	From the top of the first post, draw a diagonal line through the center of the second post. The third post will be located where the diagonal line intersects the line representing the receding group line (D to VP).
5	Repeat this procedure locating any number of members desired, drawing one at a time.

Figure 5-24 illustrates drawing vertical divisions in space.

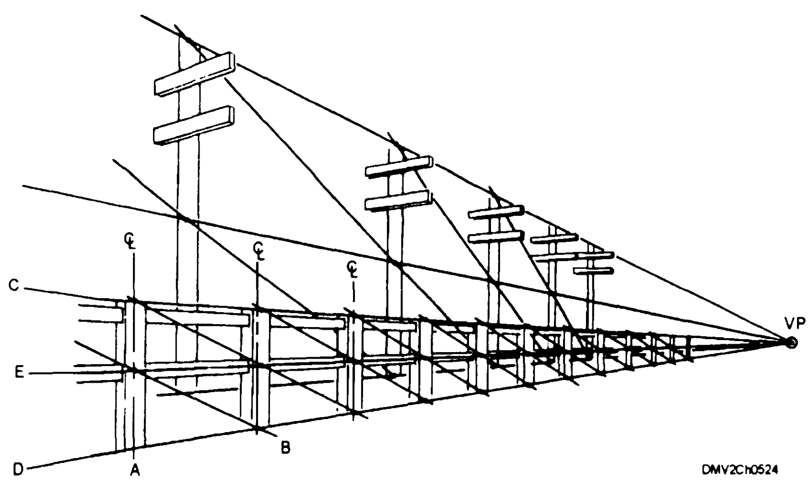

Figure 5-24.—Drawing vertical divisions in perspective.

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Reflections, shadows, and shade in perspective

Realistic perspective drawings drawn either mechanically or by freehand may require the use of reflections, shadows, or shading.

REFLECTIONS: Reflections occur when you view an object on or near glossy or shiny surfaces such as glass, polished metals, or water. Reflections appear not as a scene in reverse, but as though you were below the scene looking up. When drawing reflections, the station point and the horizon line are the same as the ones used to initially draw the object. Horizontal widths remain the same and project downward defining the width of the reflection. Vertical height is the only dimension left to calculate. To define heights in a reflection, revolve the object to reflect below a surface as far as it projects above it. When the object is close to the horizon, the reflection is nearly a duplicate of the original scene. When an object is set back from the horizon line, the scene appears abbreviated.

Figure 5-25 illustrates how the horizon line, station point, and vanishing points are the same for the object and the object in reflection.

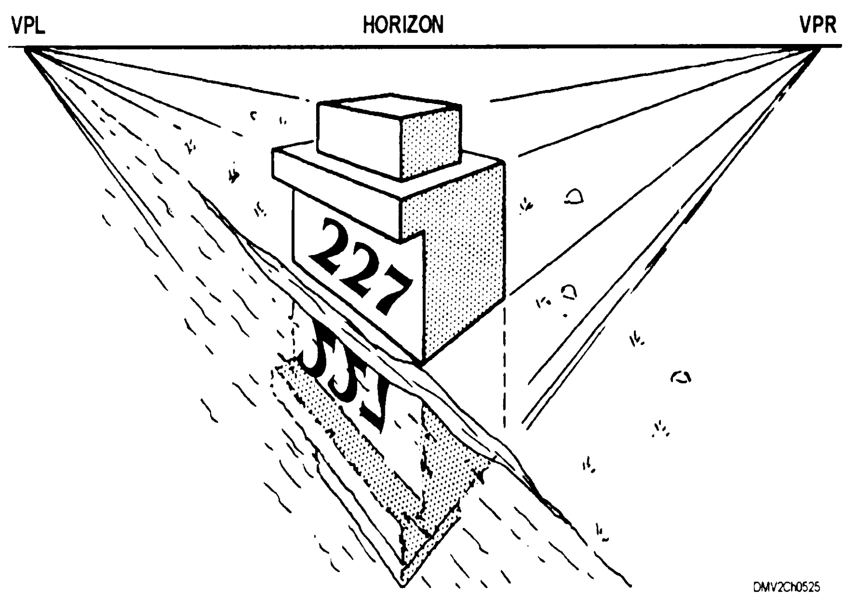

Figure 5-25.—Reflections in perspective.

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Reflections, shadows, and shade in perspective (Continued)

Figure 5-26 shows the affect on reflections of changing the objects position to the horizon line.

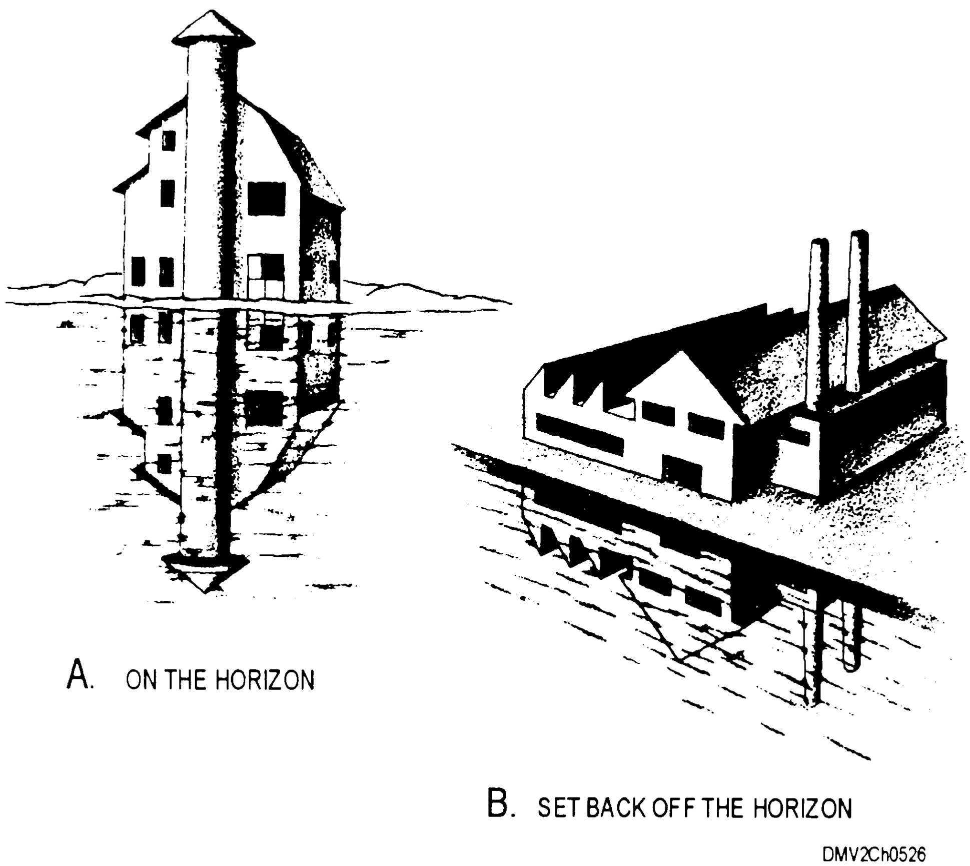

Figure 5-26.—Affects on reflections when objects are placed: A. On the horizon, and B. Set back off the horizon.

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Reflections shadows, and shade in perspective

SHADOW: Shadows in perspective necessitate your determining the position of a light source and a vanishing point for the shadow. Establish a light source either on or off your drawing paper. This is a simulated position and direction that indicates the location of a real light such as the sun or a light bulb. Locate a vanishing point for the shadow vertically below the light source on the horizon. Draw visual rays from the simulated light source to the corners of the object. Extend the rays to the plane on which the object rests. Draw lines from the vanishing point of the shadow to intersect the visual rays from the light source along the ground line. The shadows will follow the contour of the plane or object on which they fall.

Figure 5-27 shows the location of a light source, shadow vanishing point, and shadows in perspective.

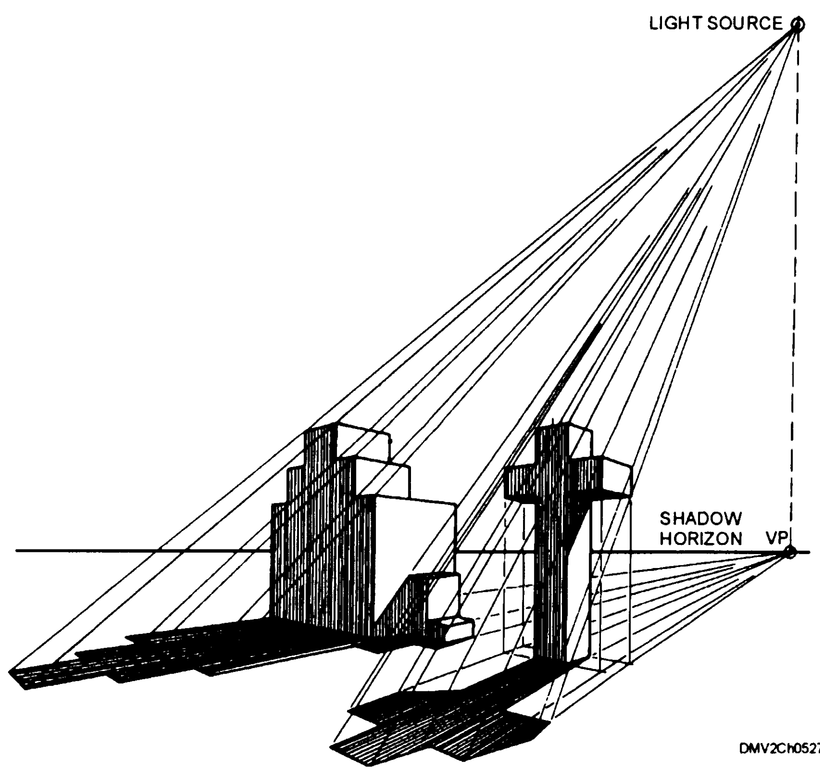

Figure 5-27.—Shadows in perspective.

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Reflections, shadows, and shading on perspective (Continued)

SHADING: Without shading perspective drawings fail to believably portray reality. Shading finishes and embellishes drawings. Shading helps to describe object outlines and simulate tactile surfaces. Shading on technical drawings should be kept simple and limited to clarifying an object or a picture. When done correctly, shading improves the presentation of display drawings, patent drawings, and industrial pictorial drawings. Working drawings are ordinarily not shaded.

Figure 5-28 shows various shadings on different objects.

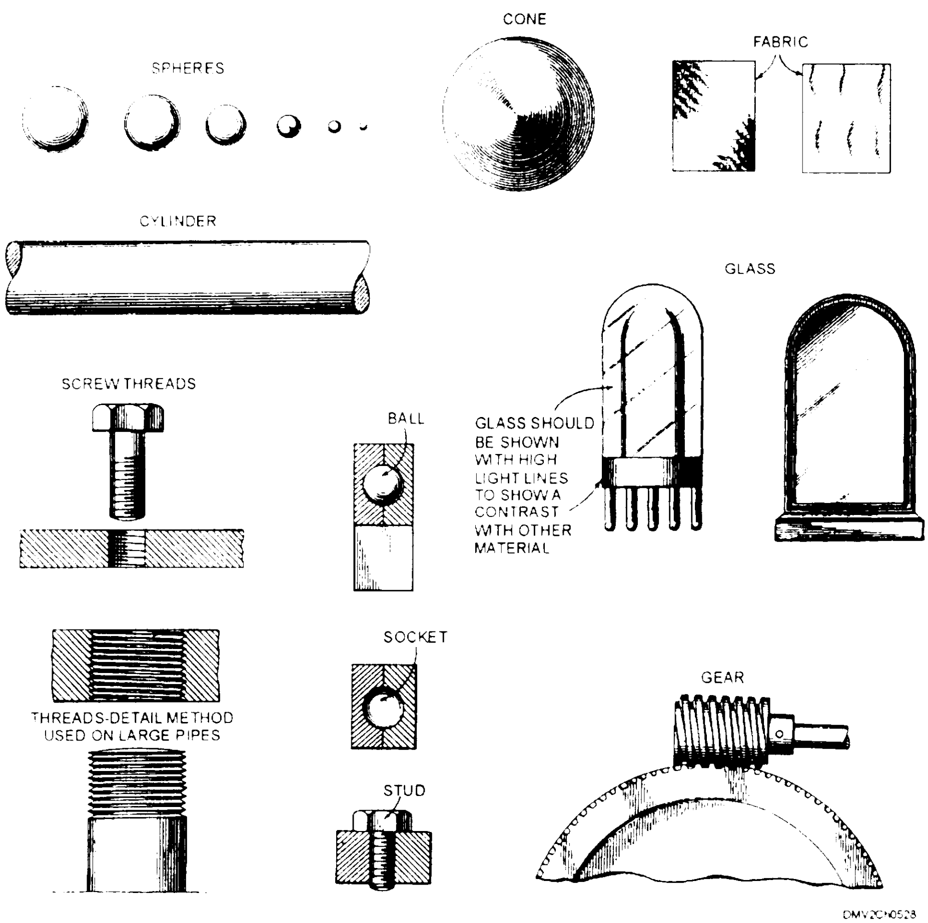

Figure 5-28.—Examples of how shading finishes a drawing.

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Summary, Continued

Review

This chapter covers the theory of perspective projections, the interrelationship of linear and aerial perspective, and the opposing principle of reverse perspective. Definitions of one-, two-, and three-point perspective should enable you to create perspective drawings. The procedures for mechanical construction of perspective drawings using the plan-view method are discussed as well as a brief description of line measurement. The section on general practices in constructing perspective drawings should simplify your task of creating realistic perspective drawings of any object in front of you.

Comments

Perspective is not the easiest part of the DM rating to learn. Perspective is the most telling feature of a drawing when assessing the talents of a DM. Each one of us has seen drawings that superficially appear well constructed. On closer inspection, certain details make us aware that the DM was not as talented as was first thought. The most tattle-tell element in a perspective drawing is the way a circle on a plane not parallel to the plane of projection is drawn. Pay close attention to the angle of the major to minor axis of an ellipse representing a circle in perspective. Strive to get the details right.

Perspective projections are often confused with parallel projections covered in the next chapter. Take the time to truly understand the material in this chapter before moving on to the next chapter.

CHAPTER 6

PARALLEL PROJECTIONS

Overview

Introduction

All objects that you as a Illustrator Draftsman draw are three dimensional. The problem facing you is presenting three dimensions (length, width, and depth) on a two-dimensional plane, which is your drawing surface. In the last chapter we discussed depicting length, width, and depth pictorially in perspective projections. In this chapter, three-dimensional objects drawn on two-dimensional surfaces in a way that exposes and explains each surface of the object is called parallel projections. Parallel projections are used in technical drawing and drafting applications.

Objectives

The material in this chapter enables you to do the following:

- Define and identify parallel projections.
- Recognize the characteristics of oblique parallel projections.
- Identify the primary difference between oblique cavalier and cabinet projections.
- Recognize the characteristics of orthographic parallel projections.
- Name the three types of axonometric projections.
- Identify predominant features in isometric projections.
- Recognize the differences between first- and third-angle projections.

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Overview, Continued

Acronyms

The following table contains a list of acronyms that you must know to understand the material in this chapter:

Acronym	Meaning
CL	Centerline
PP	Plane of Projection
SP	Station Point
VP	Vanishing Point

In this chapter

This chapter covers the following topics:

Parallel Projections

Introduction

A view of an object is known technically as a projection. Projection is done, in theory, by extending lines of sight called projectors or visual rays from the eye of the observer or station point (SP) through lines and points on the object to the plane of projection (PP). Projectors that appear to converge at a vanishing point (VP) are called *perspective projections* and are used in technical sketching. Projectors that remain parallel to the object and perpendicular to the picture plane are called *parallel projections* and are used in technical drawing and drafting applications.

Parallel projections

Parallel projections are projections where visual rays remain parallel to the object. Regardless of the relative positions of the object, the plane of projection, and the distance from the observer, parallel projections of objects have the same dimensions as the objects. Parallel projections may be further classified into oblique and orthographic projections.

Figure 6-1 shows the classification of major projections.

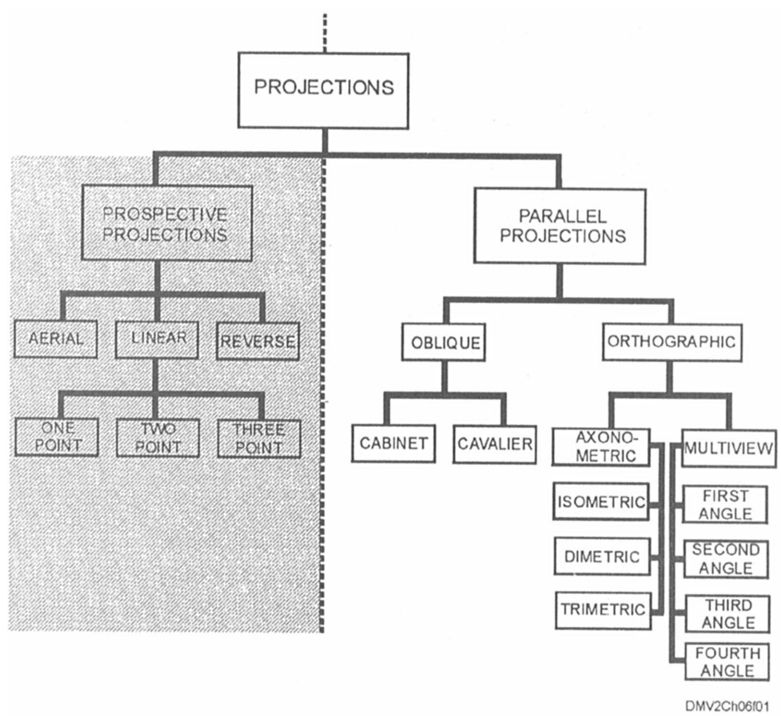

Figure 6-1.—Projections.

Oblique Projections

Introduction

An oblique projection is one of two major classifications of parallel projection.

Oblique projections

An oblique projection is the projection of an object in which the projectors are other than perpendicular to the plane of projection. An oblique projection shows front and top surfaces that include the three dimensions of height, width, and depth. The front or principal surface of an object (the surface toward the plane of projection) is parallel to the plane of projection. Surfaces oblique to the plane of projection are not shown in their true size. Oblique projections are superior to orthographic projections in pictorially representing objects.

Figure 6-2 illustrates the angle of the projectors in oblique projection.

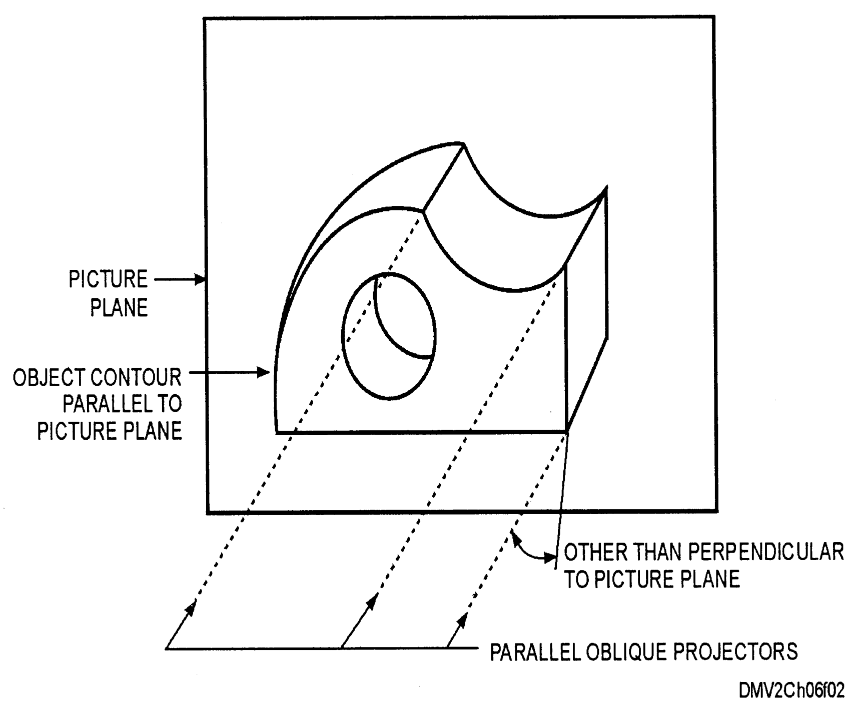

Figure 6-2.—Oblique projection.

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Selecting a surface

Only one surface of the object can be parallel to the picture plane and represented in its true size and shape. Place the surface with the irregular outline or contour (curved or circular features) parallel to the picture plane or place the longest dimension of the object parallel to the picture plane. If the object is such that the surface with the longest dimension conflicts with the irregular surface, always place the irregular surface parallel to the picture plane. This procedure minimizes distortion in the projected image.

Direction of the projectors and line length

Line lengths projected in oblique projection are determined by the angle of the projectors to the plane of projection. Projectors that angle 45° to the plane of projection project lines perpendicular to the plane of projection in true length. When the angle of the projectors is greater, the line projected is shorter. When the angle of the projectors is smaller, the projected line is longer. Theoretically, any line perpendicular to the plane of projection could project any length from zero to infinity. Any line parallel ‘to the plane of projection will project in true size.

Figure 6-3 shows line length relative to the angle of the projectors.

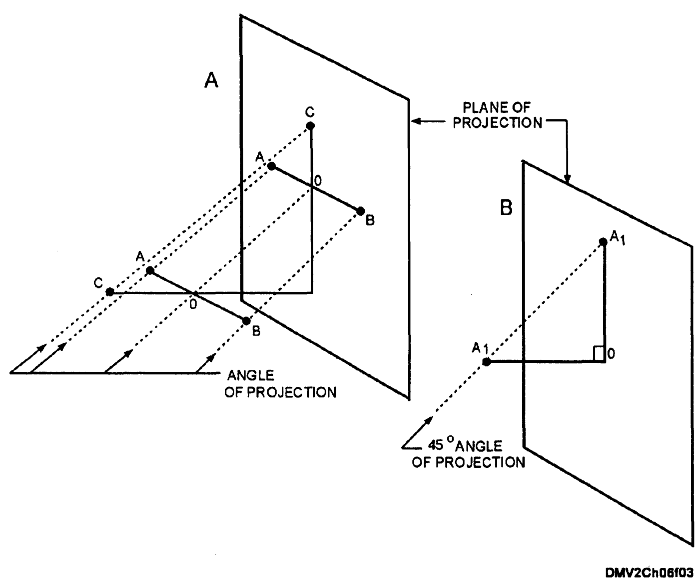

Figure 6-3.—Line length: A. Lines parallel, and B. Lines perpendicular to the plane of projection.

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Receding lines

Lines perpendicular to the plane of projection appear in oblique projection drawings as parallel inclined lines. These lines appear to recede but never to converge; hence the name, *receding lines.*

Angles of receding lines

You may draw receding lines at any convenient angle. The angle you select to draw receding lines depends on the shape of the object and the location of any significant surface features. Use a large angle to draw receding lines when you want a better view of the top of an object. Use a small angle when you want to show features on the side of an object. Choose angles easily drawn with 45° and 30°/60° triangles.

Length of receding lines

Oblique projections present an unnatural appearance to the eye because the receding lines do not converge into a vanishing point but remain parallel and seem to diverge in the distance. The length of the receding lines contributes to distortion. Receding lines drawn in full scale give the appearance of being too long and raising the back of the object higher than the top or front surface. For this reason, objects with great length should not be drawn in the oblique with the longest dimension perpendicular to the plane of projection. For the object to appear more natural, foreshorten the receding lines. Oblique projections with full scale receding lines are known as *cavalier projections.* Drawings where the receding lines are foreshortened by half are referred to as *cabinet projections.*

Figure 6-4 illustrates the difference in distortion between a cavalier and cabinet projection.

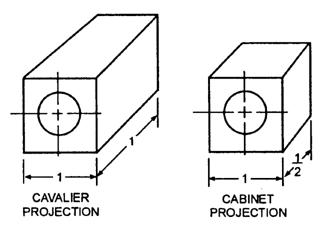

Figure 6-4.—A distorted cavalier projection and foreshortened cabinet projection of a cube.

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Cavalier projections

Cavalier projections are oblique projections where the front axes are always perpendicular to each other and the receding axis is drawn at any angle other than 90°. When the receding axis is drawn at an angle of 45° with the plane of projection, all edges are projected their true length. For this reason, most cavalier drawings use the 45° angle. Cavalier projections originated in the drawings of medieval fortifications and were made on the horizontal planes of projection. The central portions of these fortifications were higher than the rest and were called cavalier because of their commanding position.

Figure 6-5 shows an oblique projection of a bookshelf drawn in full scale with the receding axis at a 45° angle to the horizontal.

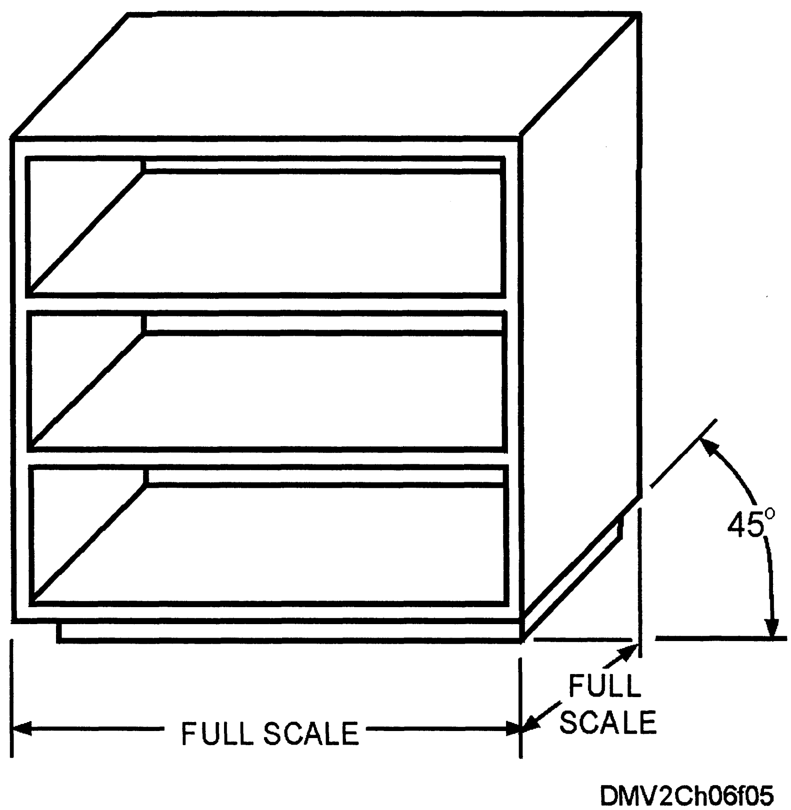

Figure 6-5.—A cavalier projection.

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Cabinet projection

Cabinet projections are oblique projections where the receding axes are drawn at any angle with the horizontal but usually drawn at 30° or 45°. The full scale of the receding axis distorts the projection and requires foreshortening to look more natural. You may use any oblique ratio (two to three or three to four) but a one to two (one half) ratio is more common. When you reduce the scale by half, it is called a *cabinet projection.* The term *cabinet drawing* comes from drawings in the furniture industry.

Figure 6-6 shows a bookcase with the receding axis reduced in scale by half.

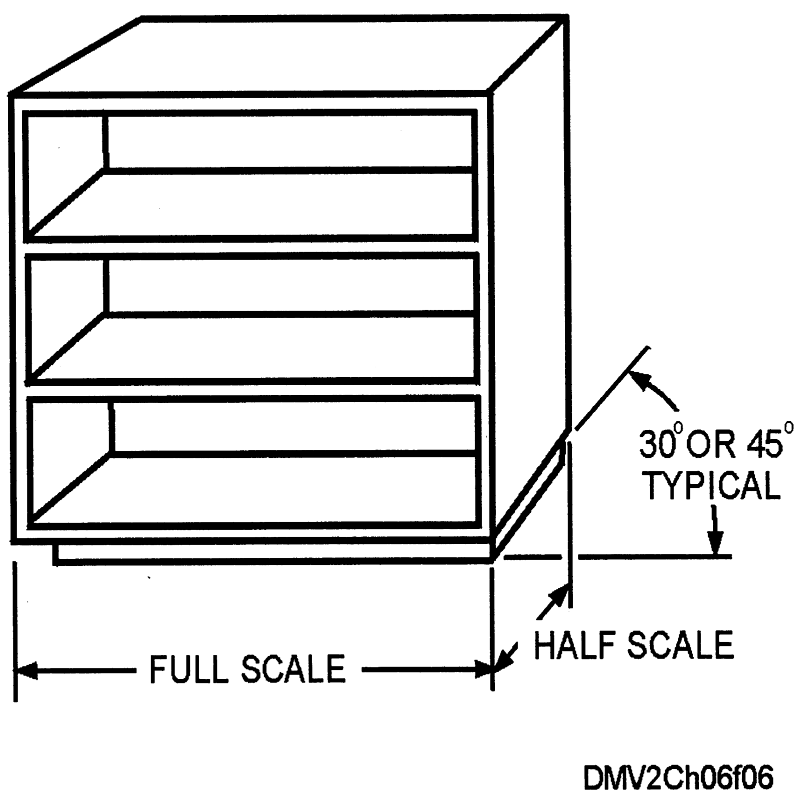

Figure 6-6.—A cabinet projection.

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Oblique drawing practices

In general, begin an oblique projection by drawing a centerline (CL) skeleton and building the drawing on these centerlines. Make sure to construct all points of tangency, particularly when you are planning to ink in the drawing.

Circles, arcs, and ellipses

Objects with surfaces parallel to the plane of projection that contain circles, arcs, and ellipses project in true size and shape. Circles not parallel to the plane. of projection project as ellipses. Circles, arcs, and ellipses have no transferable linear measurements and this requires you to inscribe the circle, arc, or ellipse in. an equilateral parallelogram or square. Draw perpendicular bisectors to the four sides of the parallelogram to locate the centers of the circle or arc. This method works best in cavalier drawings because the receding axis is drawn full scale. An alternate method of drawing a circle in an oblique cavalier projection is by the alternate four-center ellipse method.

To draw a circle in oblique projection by the four-center method, use this table:

Step	Action
1	Draw a vertical and horizontal centerline with the horizontal center line receding from the plane of projection.
2	Construct a circle equal in diameter to the actual circle using as a center the intersection of the vertical and horizontal centerlines.
3	The constructed circle will intersect each centerline at two points. From the two points on one centerline, draw two perpendiculars to the other centerline.
4	From the two points on the other centerline, draw two perpendiculars to the first centerline.
5	From the intersection of the four perpendiculars, draw four circular arcs.
6	Darken all outlines.

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Circles, arcs, and ellipses (Continued)

Figure 6-7 illustrates the procedure for drawing the four-center method in oblique projection.

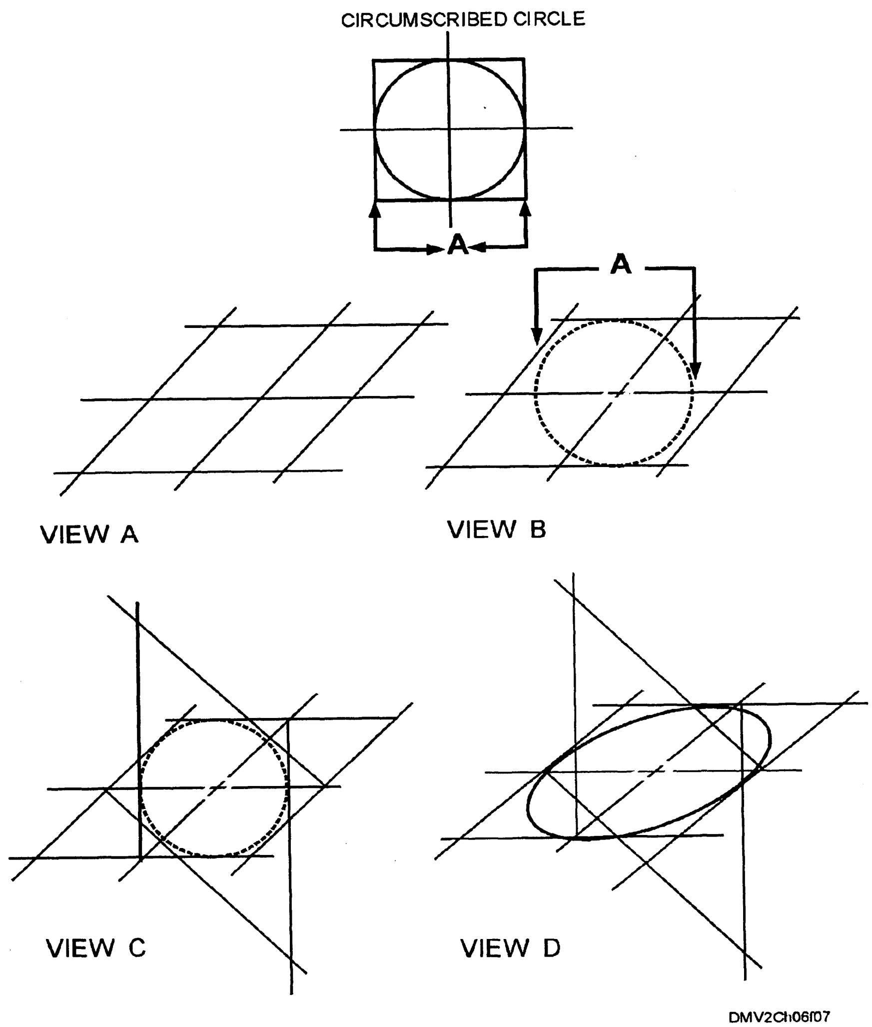

Figure 6-7.—The ellipse by the four-center method of construction in oblique projection.

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Circles, arcs, and ellipses (Continued)

If you are drawing circles, arcs, or ellipses in an oblique cabinet projection, remember that the receding axis is reduced and you must reduce all measurements along the receding axis by the same scale.

Figure 6-8 shows a circle drawn in a cabinet projection.

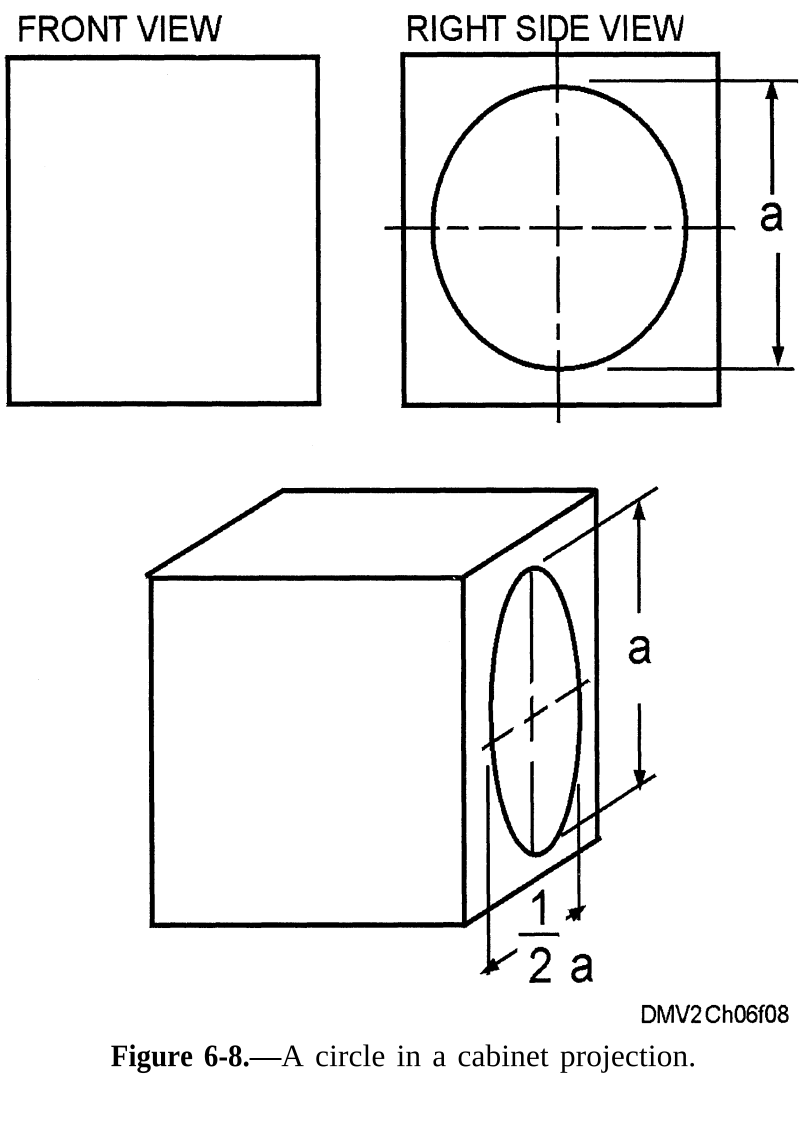

Figure 6-8.—A circle in a cabinet projection.

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Offset measurements

Offset measurements are measurements or locations that are parallel to certain edges on the main surface of the object and remain parallel to the same edges after projecting to another view. When an object is drawn as a cavalier projection, all offset measurements may be drawn full scale. If the object is drawn as a cabinet projection where the receding axis is drawn in reduced scale, measurements parallel to the receding axis must be drawn to the same reduced scale.

Figure 6-9 shows an object with offset measurements.

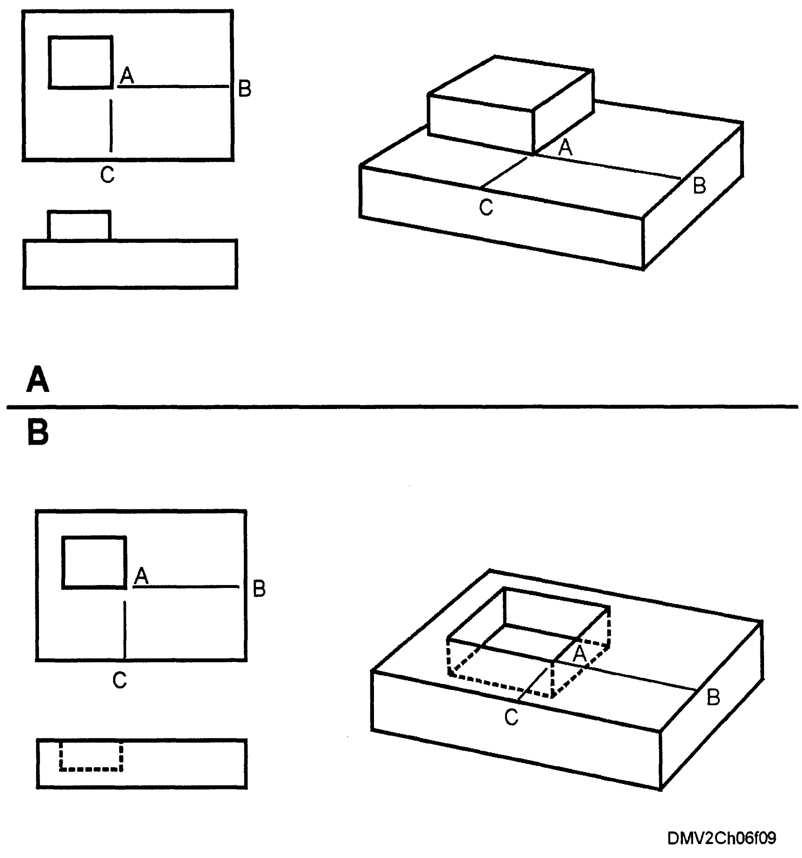

Figure 6-9.—Offset measurements: A. Raised features, and B. Recessed features.

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Angles

When an angle of a specific degree lies in a receding plane, you must covert the angle into linear measurements before drawing the angle in oblique projection. Remember that in a cabinet projection, you must reduce all receding dimensions by the same reduced scale.

Sections

Sections in oblique projections are often used to show interior or hidden shapes. Oblique half sections where you remove only a quarter of the object is the most common section used because it shows so much more of the interior surface. Oblique full sections where the plane of intersection passes completely through the object are seldom used. You may use all types of sectional views in an oblique projection.

Figure 6-10 shows a half and full section of an oblique projection.

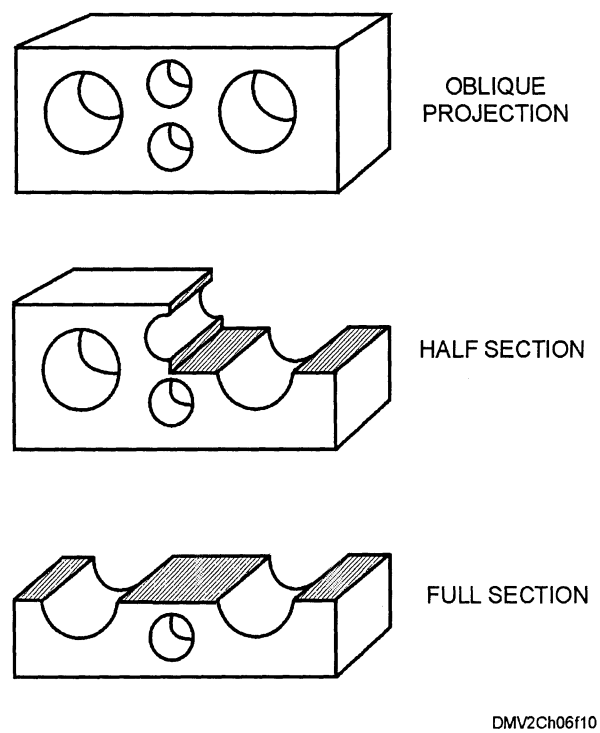

Figure 6-10.—An oblique projection with a half section and full section removed.

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Oblique dimensioning

All dimension lines, extension lines, and arrowheads must lie in the planes of the object to which they apply. Place dimensions outside the object outline except when it helps to clarify. Align dimensions and notes shown with leaders to the bottom of the drawing. Notes without leaders should also be aligned with the bottom of the drawing. There are two systems to indicate dimensions on drawings; the aligned dimension and the unidirectional dimension systems. Select one system of dimensioning to use throughout the drawing. You may show dimensions with either whole numbers and fractions, decimals, or metric units of measure.

ALIGNED DIMENSIONS: Drawings made with aligned dimensions have all figures and notes aligned with a dimension line so that all read from the sides or edges of the drawing. Aligned dimensions are sometimes referred to as pictorial dimensions.

UNIDIRECTIONAL DIMENSIONS: In the unidirectional dimension system, all dimension figures and notes are lettered horizontally and are read from the bottom of the drawing. The unidirectional dimension system is preferred over the aligned system because it is easier to read and understand.

Figure 6-11 are examples of both the aligned and unidirectional dimensioning systems.

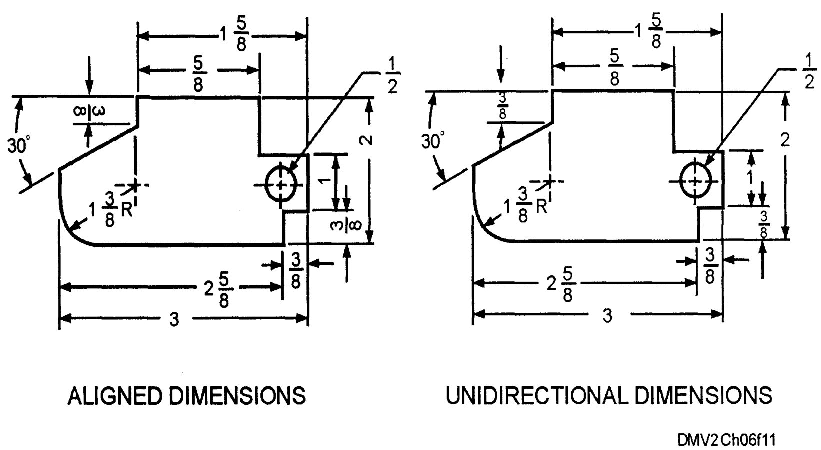

Figure 6-11.—Dimensioning.

Orthographic Projections

Introduction

The second major classification of parallel projections is orthographic projections.

Orthographic projections

Orthographic projections are drawings where the projectors originating from the observer or station point remain parallel to each other and perpendicular to the plane of projection. For accurate and scientifically correct presentations of objects, piping diagrams, machine, structural, architectural drawings, and furniture design that can be sufficiently understood and replicated by a craftsperson, use a form of orthographic projection. Orthographic projections are commonly referred to as *blueprints* because the method of reproduction, usually by the diazo process, renders the image with a blue line. Orthographic projections are further subdivided into axonometric projections and multiview projections.

Figure 6-12 shows an example of an orthographic projection.

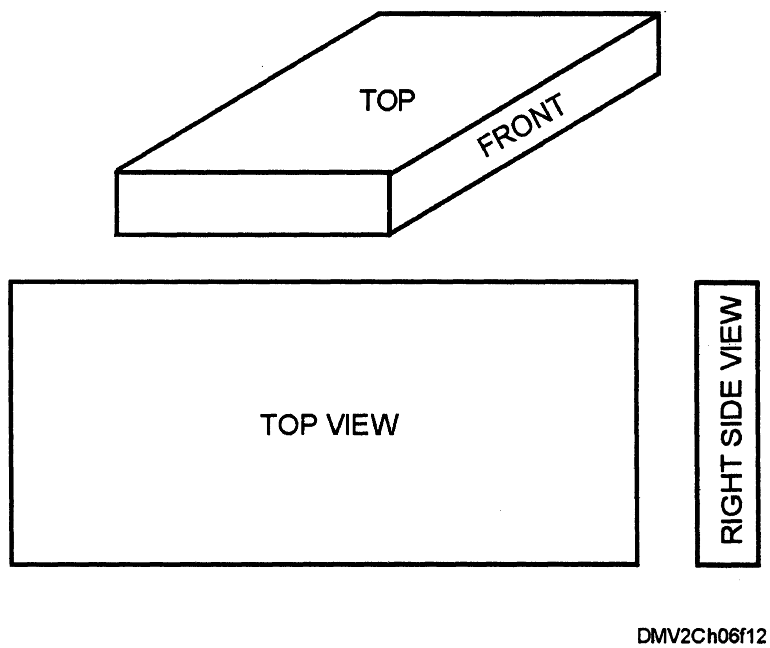

Figure 6-12.—An orthographic projection.

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Axonometric projections

In axonometric projections, the observer is located at infinity and the visual rays are parallel to each other and perpendicular to the plane of projection. A key feature of axonometric projections is that the object is inclined toward the plane of projection showing all three surfaces in one view. Since the principal edges and surfaces of the object are inclined toward the plane of projection, the length of the lines, sizes of the angles, and proportions of the object varies according to the amount of angle between the object and the plane of projection. The greater the angle to the plane of projection, the greater the amount of required foreshortening. The three edges that intersect nearest the location of the observer are known as the *axonometric axes (O).* Axonometric projections are further classified as isometric projections, dimetric projections, and trimetric projections.

Figure 6-13 shows an axonometric projection.

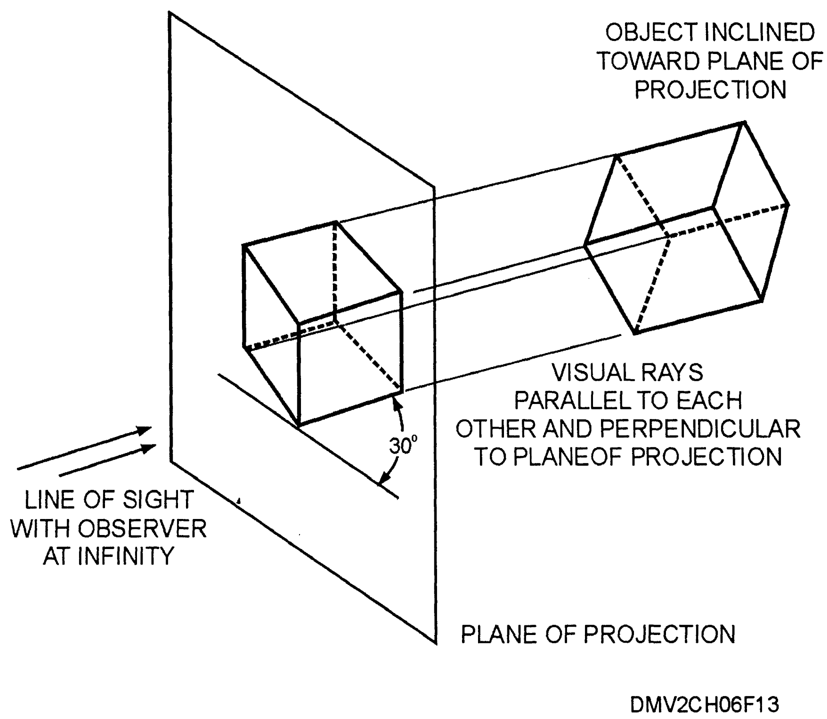

Figure 6-13.—An axonometric projection.

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Isometric projections

The term *isometric* means equal measure. When principal edges or axes make equal angles with the plane of projection and are equally foreshortened, the result is an isometric projection. Because all angles and lengths are equal, you can used the same scale for the entire layout. The three edges that intersect nearest the location of the observer are known as the *isometric axes* (O) and are 120° apart. The three surfaces shown are referred to as *isometric planes.* Lines parallel to the isometric axes are called *isometric lines.* Lines not parallel to the isometric axes are called *nonisometric lines.* You can generally draw isometric projections without additional auxiliary or revolved views. Most exploded views use isometric projection. Isometric axes and isometric lines are easily constructed with a 30°/60° triangle. Isometric projection is the most frequently used type of axonometric projection.

Figure 6-14 is a cube in isometric projection.

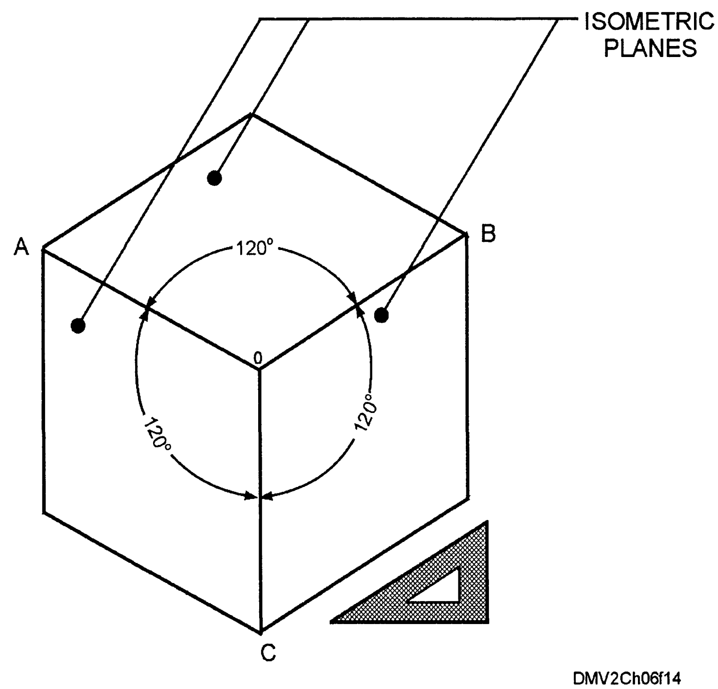

Figure 6-14.—An isometric projection of a cube.

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Isometric scale

An isometric scale measures foreshortened lines with uniform accuracy. Drawings made using an isometric scale create isometric projections by rendering the object exactly as seen on the plane of projection. You can make an isometric scale on paper or cardboard to aid you in laying out measurements. All distances in an isometric scale are 2/3 times true length or approximately 80 percent of true size.

To make an isometric scale, use this table:

Step	Action
1	Along a horizontal line, mark off equal increments with any standard scale (figure 6-15, view A).
2	Using a 45° triangle, lay off lines from each of the increments.
3	Using a 45° and a 30°/60° triangles, form a 75° angle with the horizontal and lay off a line intersecting the diagonal lines.
4	Align a piece of paper, acetate, or cardboard, with the 75° line indicating equal increments. These increments form the isometric scale.

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Isometric scale (Continued)

Figure 6-15 shows how to construct an isometric scale.

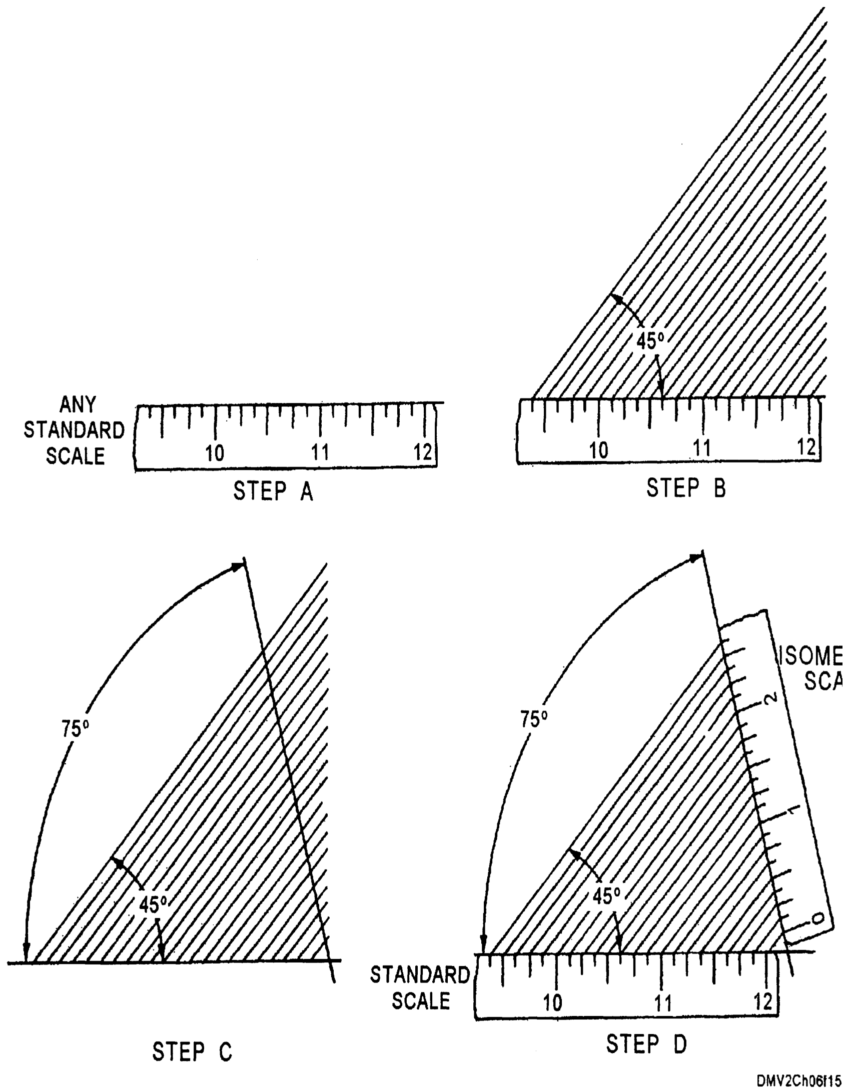

Figure 6-15.—Constructing an isometric scale.

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Isometric drawing

Isometric drawings are drawn using an ordinary scale (not an isometric scale) to lay out measurements. Images in isometric drawings are about 25 percent larger than if rendered as an isometric projection using an isometric scale. Proportion between the projection and drawing is the same. Pictorially, an isometric projection and an isometric drawing appear the same. However, a projection is foreshortened and the drawing is full scale, making it easier to create isometric drawings.

Isometric drawing practices

Begin an isometric drawing by locating the isometric axes. All remaining measurements are made parallel to the isometric axes. You cannot set off any measurements along diagonal or nonisometric lines. Use offset or coordinate measurements to lay out inclined or oblique surfaces or edges.

Position of the isometric axes

The position of the isometric axes depends on the position the object is normally viewed. You may position the isometric axes in any desired location so long as there remains 120° between the axes. Place the long axis horizontally for the best effect in drawing long objects.

Figure 6-16 shows how changing the position of the isometric axes changes the object view.

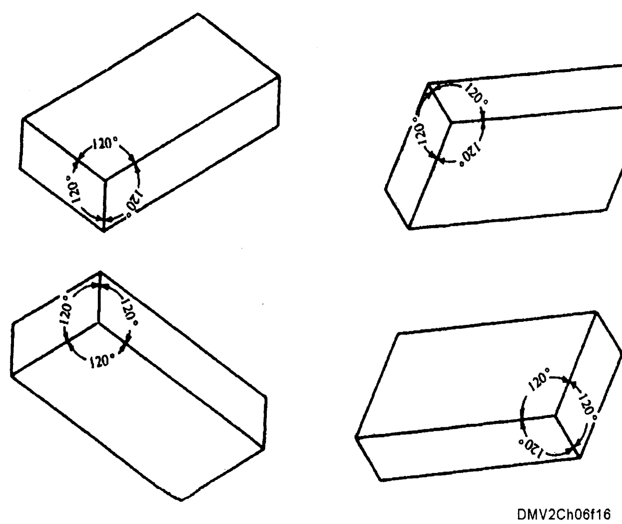

Figure 6-16.—Changing isometric axes.

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Circles, arcs, and ellipses

Circles, arcs, and ellipses do not appear in true size or shape in an isometric drawing or projection because all surfaces of the projected object are angled toward the plane of projection. To draw circles, arcs, and ellipses in isometric drawings and projections, you must use the offset measurement or four-center method. Make sure to draw enough points to accurately fix the path of the curve. The more points plotted, the greater the accuracy. Once you plot the points, lightly freehand sketch the curve and darken it with the aid of an irregular or french curve.

To draw circles, arcs, or ellipses by plotting a series of points, use this table:

Step	Action
1	Draw randomly spaced parallel lines across a circle projected in true size and shape on the plane of projection. To increase accuracy, plot more points using more parallel lines.
2	Transfer these lines from the circle to the isometric drawing or projection with a pair of dividers. To locate points in objects with some width, vertically extend the points a distance equal to the width of the object. Some of these points will appear as hidden points and lines.
3	Draw the final ellipse freehand and darken it with an irregular or french curve.

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Circles, arcs, and ellipses (Continued)

Figure 6-17 shows the construction of an ellipse in an isometric drawing.

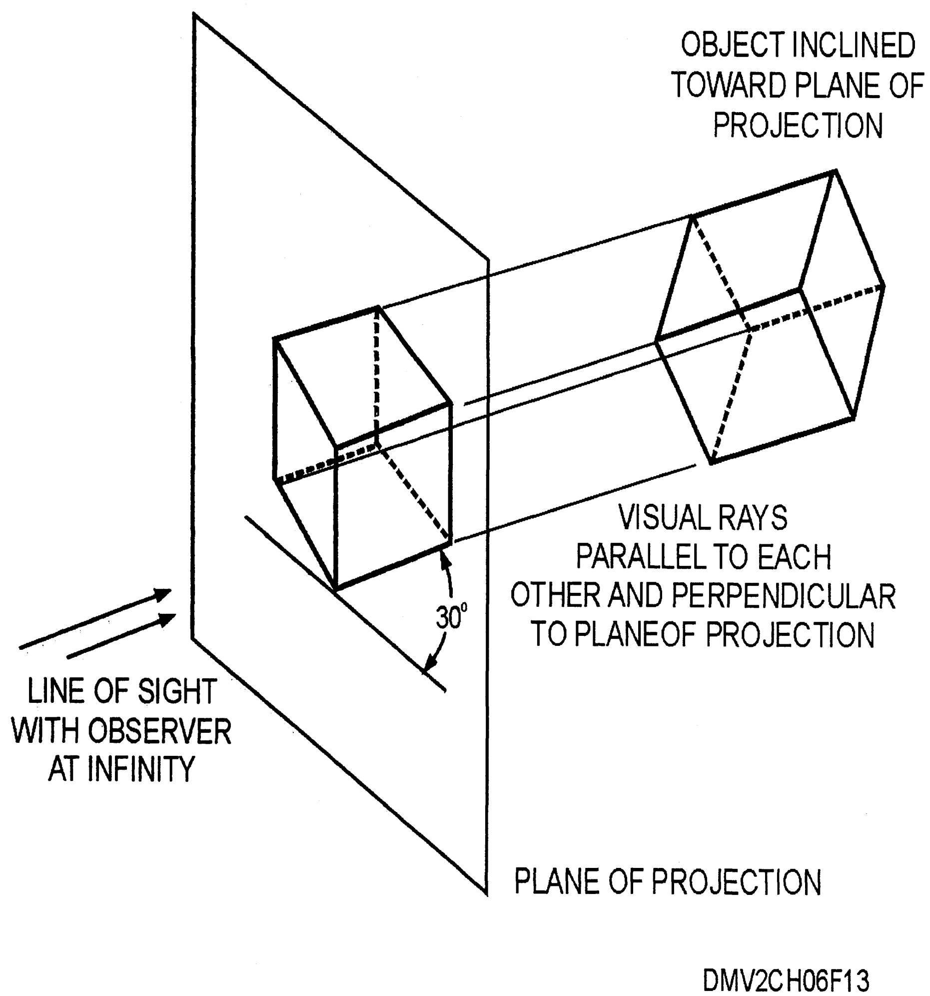

Figure 6-17.—Constructing an ellipse in isometric.

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Circles, arcs, and ellipses (Continued)

Ellipses have two axes, a *major axis* (long) and a *minor axis* (short). When the horizontal and vertical centerlines of a circle drawn parallel to the plane of projection is drawn in isometric and each has parallel tangents, they become *conjugate diameters* representing the major and minor axes, respectively. The two diameters of an ellipse are conjugate when each is parallel to the tangents at the ends of the other. One of a given pair of given conjugate diameters is, as a rule, not perpendicular to the other. In general, here are three rules to remember when drawing ellipses in isometric, (1) the major axis of an ellipse is equal to the diameter of the circle, (2) the major axis of the ellipse is always at right angles to the centerline of the circle, and (3) the minor axis is at right angles to the major axis, which coincides with the centerline of the circle. ‘Another way of drawing ellipses in isometric is to use an ellipse template. Ellipse templates are available in many different degrees with the major and minor axes marked on the template. Base your selection of the appropriate ellipse on the location and degree of the axes.

Figure 6-18 shows the relationship of the conjugate diameters of a circle to the major and minor axes of an ellipse.

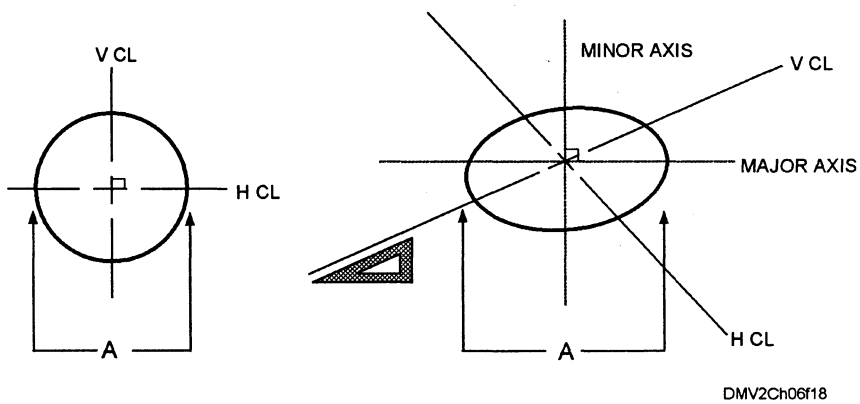

Figure 6-18.—Major and minor axes.

Offset measurements

Offset measurements are measurements used to locate features or edges with respect to the features and edges on the main surface of the object. Feature and edges parallel to edges of the main surface remain parallel in isometric drawings.

Continued on next page

Angles

Angles project in true size only when the plane of the angle is parallel to the plane of projection. Since the surfaces of an object are inclined toward the plane of projection, most angles will not project in true size. An angle may project larger or smaller than true size depending on its position to the plane of projection. Convert angular measurements into linear measurements before laying them out along isometric lines. You may also use an isometric protractor.

Sections

You may use all types of sectional views in isometric drawings and projections. Half sections are used most often because only a quarter of the object is removed, showing the relationship between the interior and exterior surfaces. When drawing a half section in isometric, draw the entire object first, then remove the half section. When drawing a full section where the cutting plane passes completely through the object in an isometric drawing, draw the cutting plane first, then draw the portion of the drawing behind the cutting plane.

Figure 6-19 shows a half and full section in isometric.

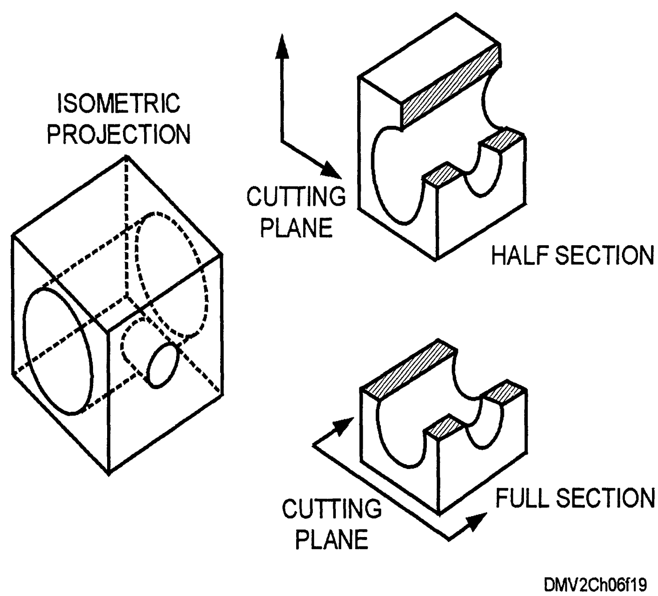

Figure 6-19.—A half and full section in isometric.

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Isometric dimensioning

Isometric dimensions are similar to dimensions in other types of projections. All dimension lines, extension lines, and arrowheads must lie in the planes of the object to which they apply. Place dimensions outside the object outline. Align dimensions and notes shown with leaders to the bottom of the drawing. Notes without leaders should also be aligned with the bottom of the drawing. You may use the aligned or unidirectional system of dimensioning. Select one method of dimensioning and use whole and fractional numbers, decimals, or metric units of measure. Remain consistent throughout the drawing.

Figure 6-20 shows isometric dimensioning.

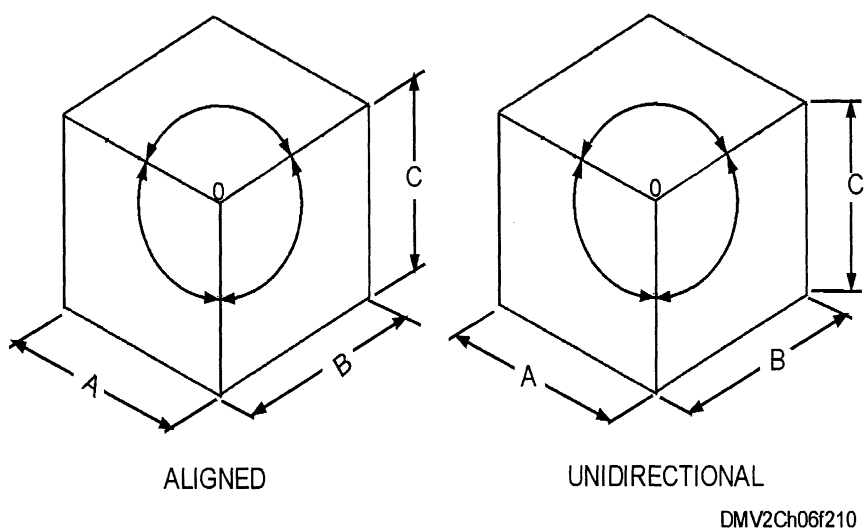

Figure 6-20.—Isometric dimensioning.

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Dimetric projections

A dimetric projection is an axonometric projection where two of an objects axes make equal angles with the plane of projection and the third angle is larger or smaller than the other two. You use one scale for the two equal axes and change scale to foreshorten the third axis in a different ratio. Do not confuse the angles between the projection of the axes and the angle the axes make with the plane of projection. Dimetric projections are used less often than isometric projections.

Figure 6-21 shows an example of dimetric projections.

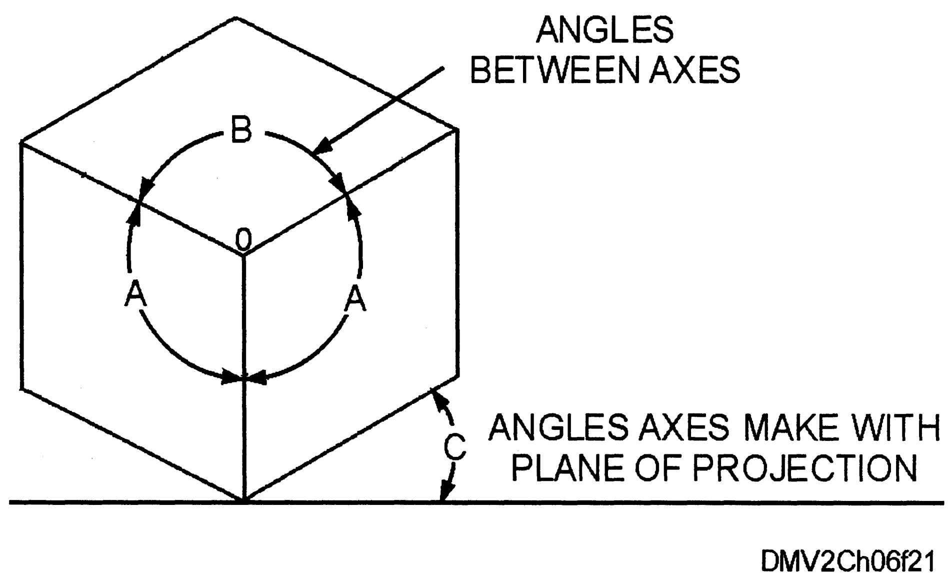

Figure 6-21.—A dimetric projection.

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Trimetric projections

A trimetric projection is an axonometric projection where no two axes form equal angles with the plane of projection. Each of the three axes and the lines parallel to them have different ratios for foreshortening. The object is projected so that no axis forms an angle less than 90° and three different trimetric scales must be used to lay out measurements along the axes.

Figure 6-22 is an example of a trimetric projection.

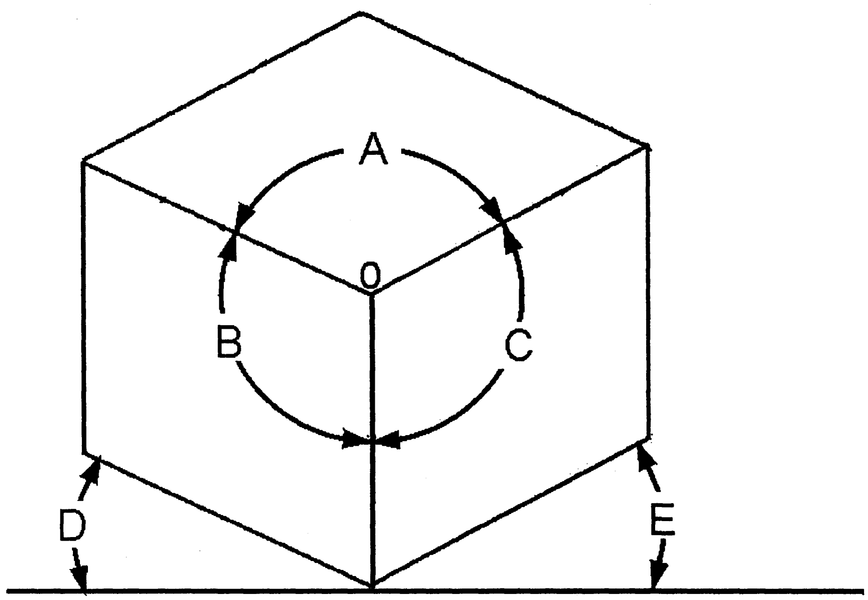

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Figure 6-22.—A trimetric projection.

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Multiview projections

Multiview projections are the second major subdivision of orthographic projections.

Principal views

There are six principal views in a multiview orthographic projection. These are the front, back, top, bottom, and left- and right-side views. Of these views or planes, three are referred to as primary planes of projection (vertical, horizontal, and profile). Most objects are adequately represented by the three primary planes.

Angles of projection

The primary planes intersect each other at right angles. The angles between the horizontal and vertical planes are described as first, second, third, and fourth angles of projection. In theory, you can place an object in any of these angles of projection and draw or project its image onto the projection planes, which in turn could be rotated onto the plane of your drawing paper. Only first- and third-angle projection have a practical application today.

Figure 6-23 shows the angles of projection in a multiview projection.

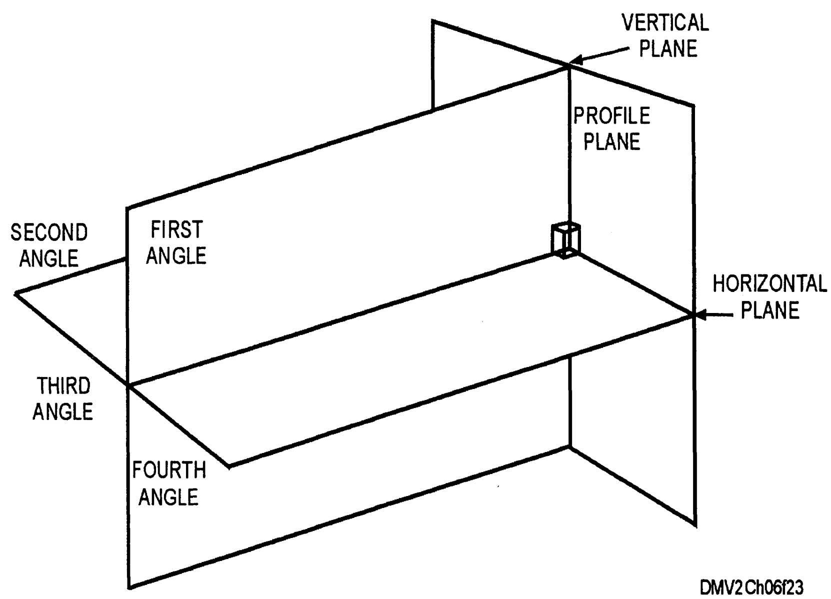

Figure 6-23.—Angles of projection in multiview projections.

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First-angle projections

First-angle projection places the object on the profile plane with the vertical plane on the left and the horizontal plane on the bottom and is used throughout Europe. This position locates the top view below the front view, the right-side view on the left side of the front view, and the bottom view above the front view. Because the positioning of the views initially seems illogical, first-angle projections is not taught or practiced in the United States.

Figure 6-24 shows how the principal views are hinged in first-angle projection.

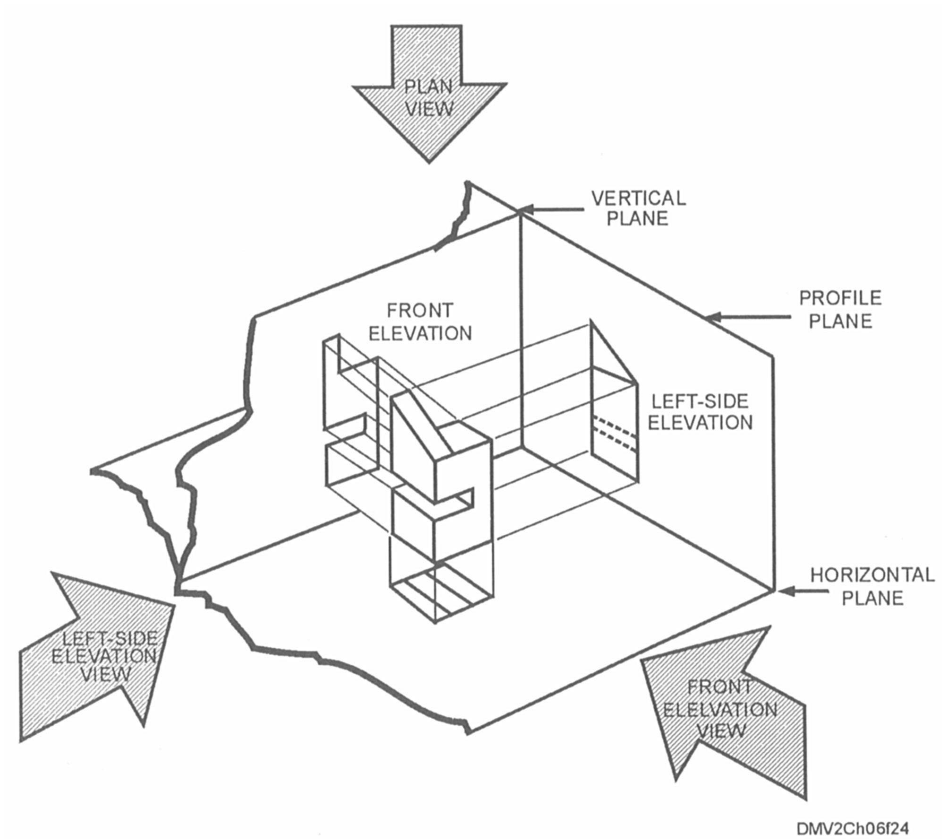

Figure 6-24.—Principal views in first-angle projection.

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Third-angle projections

Third-angle projection places the object with the front view projected onto the vertical plane, the top view onto the horizontal plane, and the right-side view onto the profile plane. The arrangement of the three views on paper is logically sequenced. Since the late 1800s, third-angle projection has been the American standard in drafting practice.

Figure 6-25 shows third-angle projection.

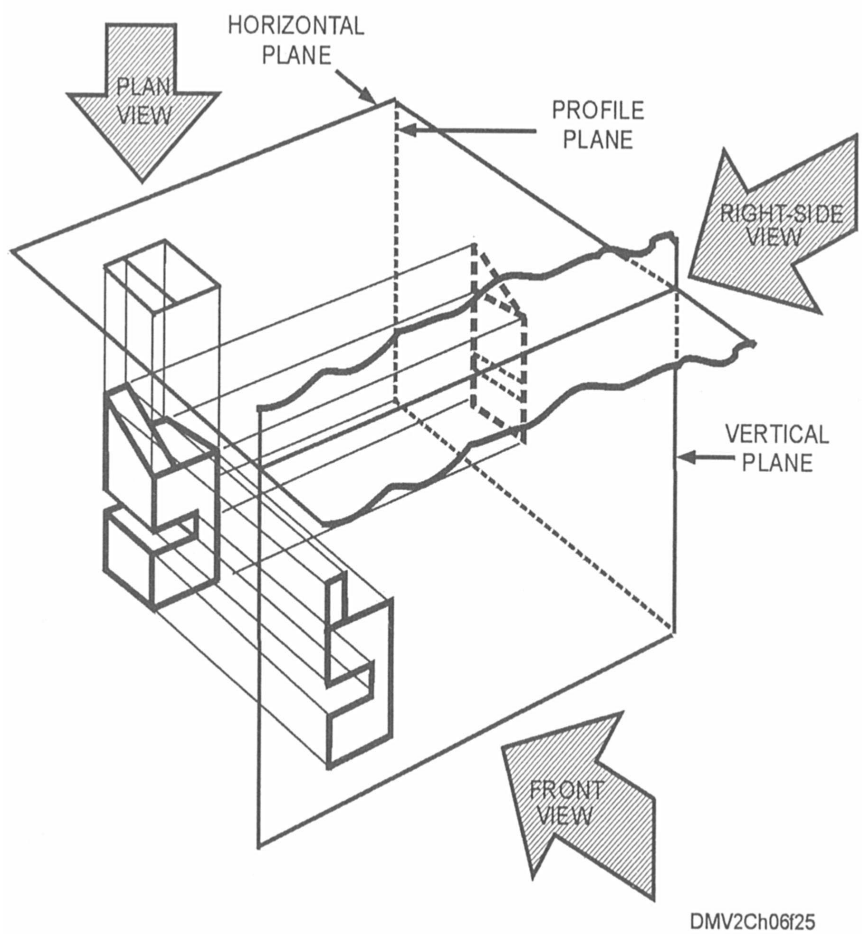

Figure 6-25.—Principal views in third-angle projection.

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Position of the principal views

When you see all six planes of projection with their respective images in space, they form a transparent, box-like structure in which the object itself appears suspended in air. In third-angle projection, as the box opens, all views rotate toward the observer as though they were hinged. The front view always lies in the plane of the drawing surface and does not rotate. Each view has two of the three common space dimensions of height, length, and depth and adjacent views supply the missing dimension. The relative positions of the six principal views and their relationship to each other are logically arranged on a drawing surface.

Figure 6-26 shows the revolution and eventual position of the six principal views in third-angle projection.

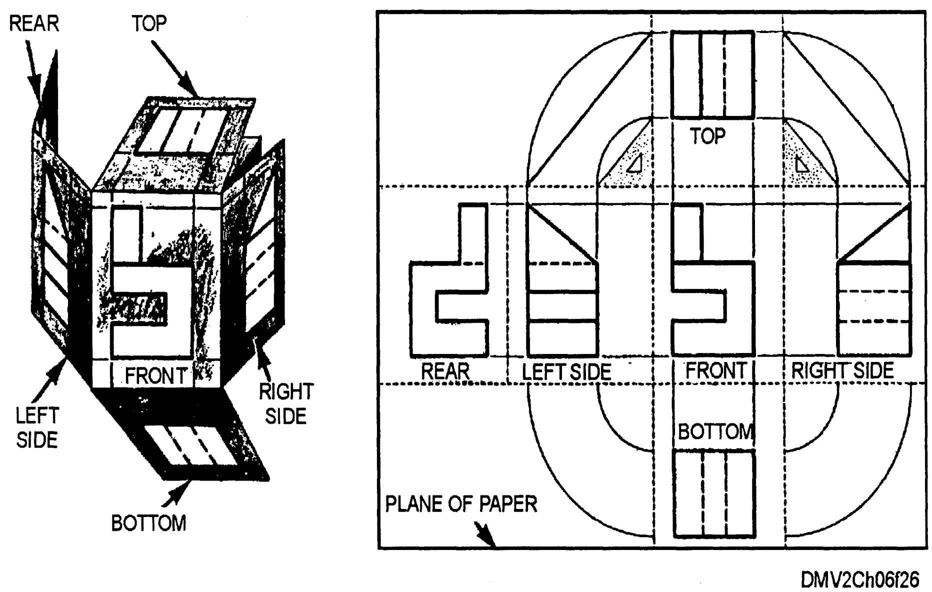

Figure 6-26.—Revolution and position of the six principal views in third-angle projection.

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Miter lines

Miter lines are a convenient method for laying out a third view when drawing the primary planes or views on paper. Any horizontal movement of the miter line to the left or right controls the distance between the views to allow space for dimensioning.

To use a miter line to draw a third view, use this table:

Step	Action
1	Place a horizontal and vertical centerline between the two views at any convenient distance (lines AB and CD).
2	Draw a miter line to the intersection of the horizontal and vertical centerlines (figure 6-27, view A).
3	Lightly draw projectors from the top view to the miter line (figure 6-27, view B).
4	Lightly draw vertical projectors from the points of intersection of the miter line and horizontal projectors.
5	Using the front view, draw horizontal projectors to the vertical projectors. The result is the outline and placement of the third view (figure 6-27, view D).

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Miter lines (Continued)

Figure 6-27 shows how to use a miter line.

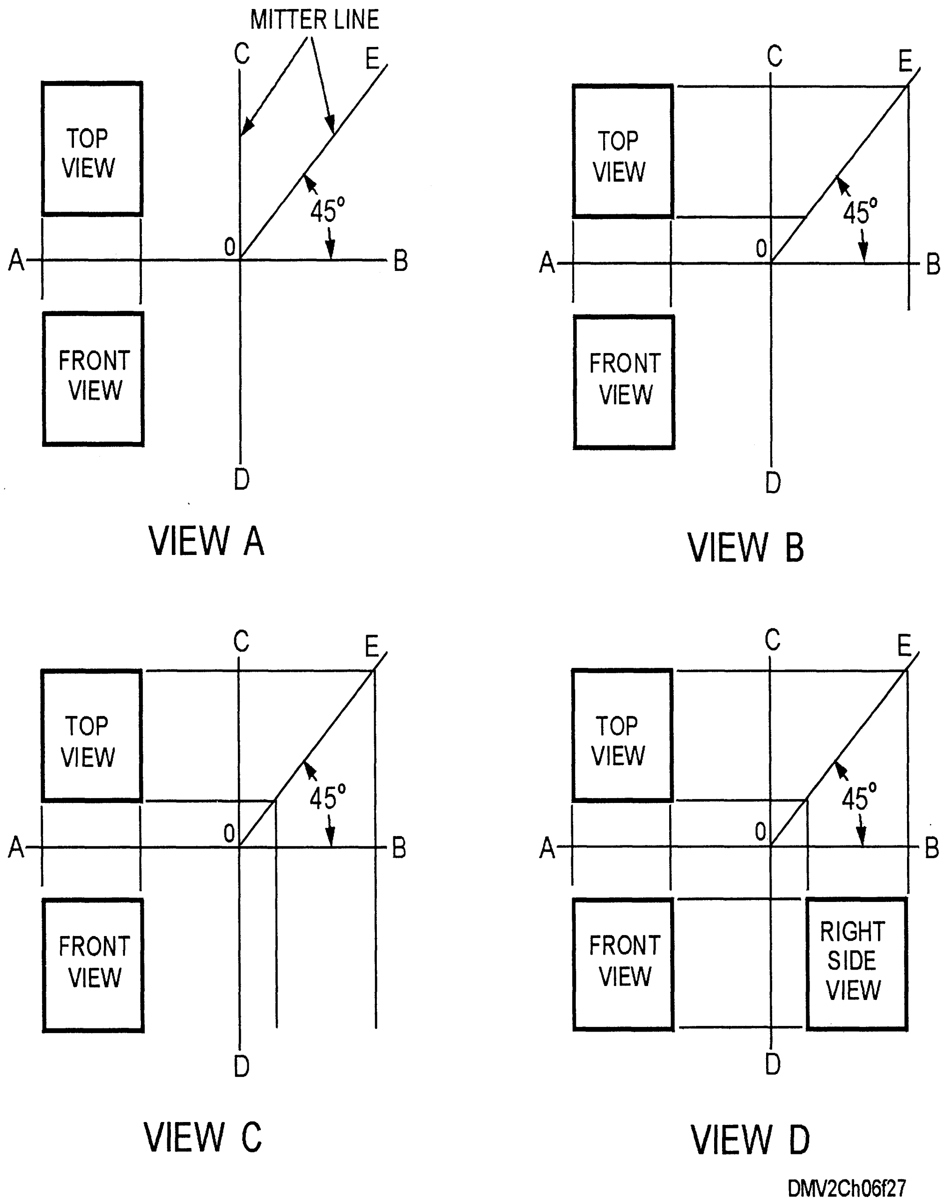

Figure 6-27.—Using a miter line.

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Proper spacing of views

Space views on your drawings to give the appearance of a balanced drawing. In general, the top and bottom margins are equal and the left and right margins are equal. Sometimes the spacing of the views is technically correct but the image interferes with the placement of the title block or appears off balance. If the object allows arbitrary choice with regard to the designation of views, you can improve the spacing by changing the designation. Spacing views in a drawing of a circular object is like spacing letters -you must try to equalize the areas of space around and between the views.

Figure 6-28 shows technically correct spacing and improved spacing for a three-view drawing of a rectangle.

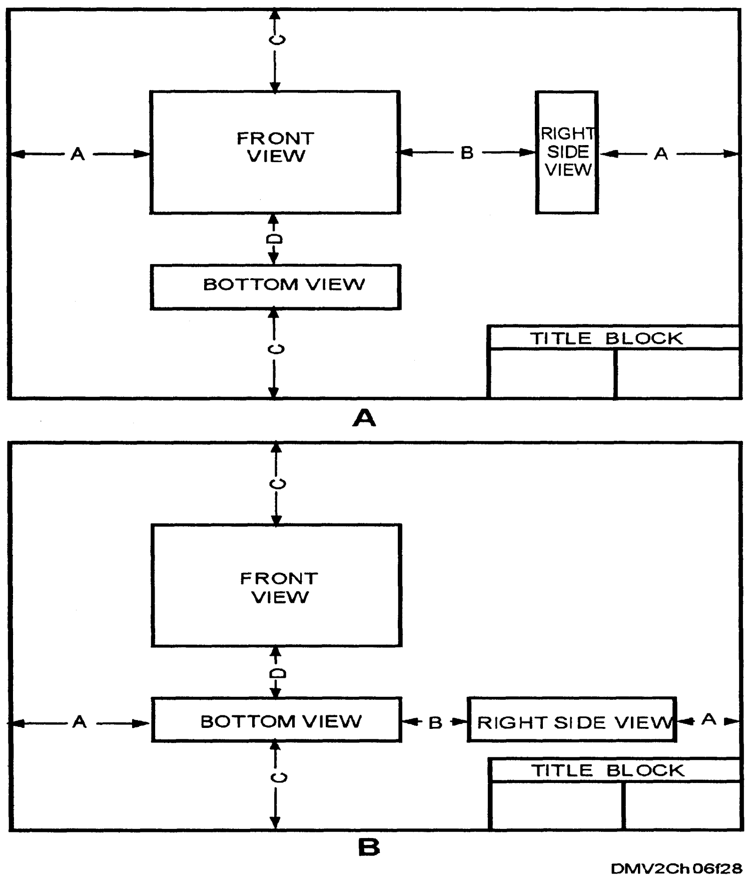

Figure 6-28.—The spacing of views: A. Technically correct, and B. Visually improved.

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Analyzing a multiview projection

In third-angle projection, the plane of projection is always presumed to be between the object and the observer regardless of which view you are considering. Each view of the surface of an object is a view of that surface as it would appear to an observer looking directly at it. You should be able to determine what each line in a particular view represents.

Choosing the necessary views

A multiview projection should contain only as many views required to describe the object fully. Most objects can be described in two or three views. One-view drawings are objects that can be completely defined by that view. Features such as thickness or length is listed as a dimension or note. Many objects have no definite top or bottom. With objects of this kind, select a surface and call it according to convenience. When eliminating views, here are four rules to remember, (1) show an object in the position it customarily occupies, (2) a top view is preferable to a bottom view, (3) a right-side view is preferable to a left-side view, and (4) a view with a visible line is preferable to a view with the same line shown as a hidden line.

Figure 6-29 show a one-view drawing of a washer.

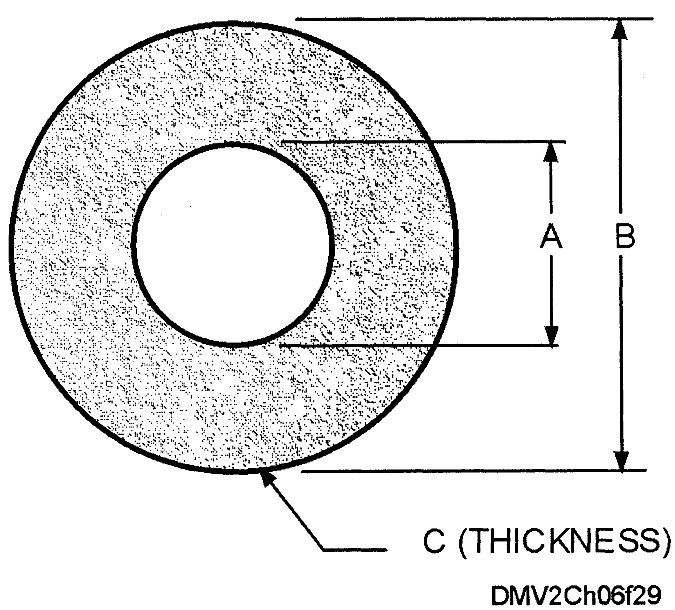

Figure 6-29.—A one-view drawing.

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Corner point numbering

To help understand the view of an object, you may assign a number to each of the corners. A corner point may be hidden or visible in a particular view of the object. Hidden corner points are numbered inside the object's outline; visible corner points are numbered outside the outline.

Figure 6-30 shows an object with a hidden and visible numbered corner point.

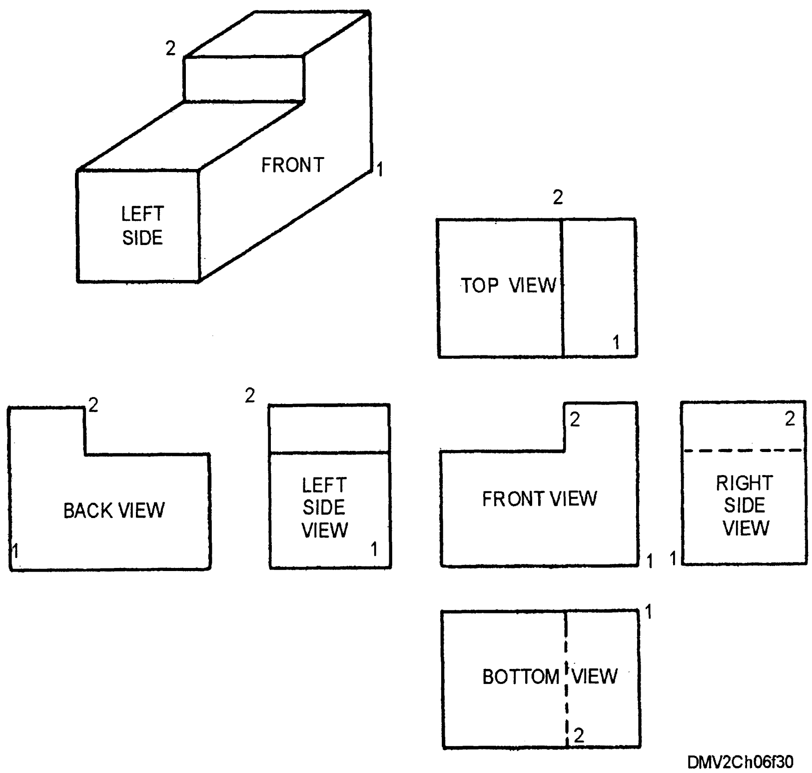

Figure 6-30.—Corner point numbering.

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Normal and oblique lines

A normal line in a multiview projection is parallel to two of the planes of ‘projection and perpendicular to the third. A line parallel to a plane of projection appears in true length depending on the scale of the drawing. A line perpendicular to a plane of projection appears on that plane as a point. A line perpendicular to one plane of projection must be parallel to the other two, but a line parallel to one plane of projection may be oblique to one or both of the others. This type of oblique line appears in true length in a view on the plane of projection to which it is parallel but appears foreshortened in all regular views of the object.

Figure 6-31 is a pictorial drawing of a block in the upper-left corner. Placing the front face parallel to the vertical plane in a multiview projection places the bottom face parallel to the horizontal plane and right-side face parallel to the profile plane. Line AB is parallel to the vertical plane but oblique to both the horizontal and the profile planes. Only in the front and back views is line AB shown in true length. In all other views AB is foreshortened.

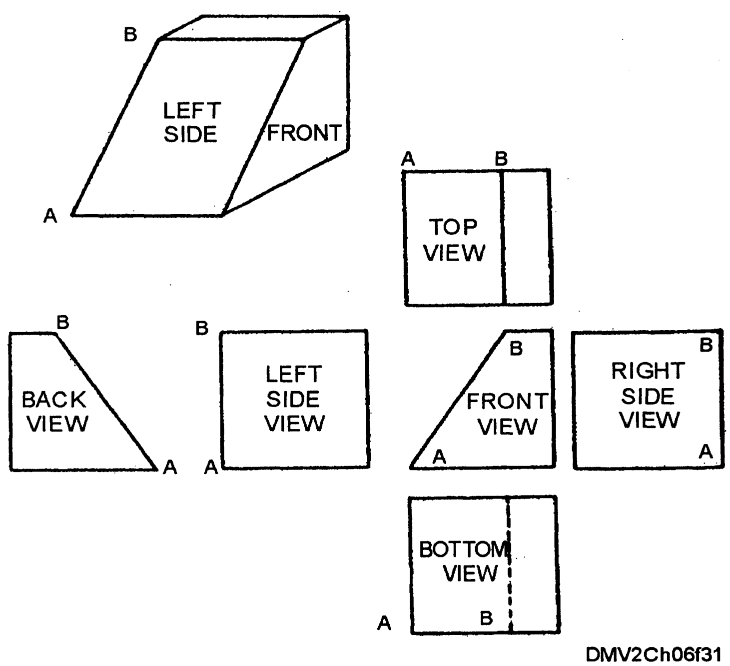

Figure 6-31.—Line AB in true length on the front and back view.

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Normal and oblique lines (Continued)

Figure 6-32 shows a pictorial drawing of a triangular object in the upper-left corner. The right side is presumed parallel to the profile plane of projection, the bottom view parallel to the horizontal plane, and the front view parallel to the vertical plane. The line AB is oblique to all three planes. The true length of AB is shown in the small triangle to the left of the single-view projection. It is the length of the hypotenuse of a triangle with the altitude equal to the length of AB as it appears in the top view of the multiview projection. AB is foreshortened in all of the orthographic views.

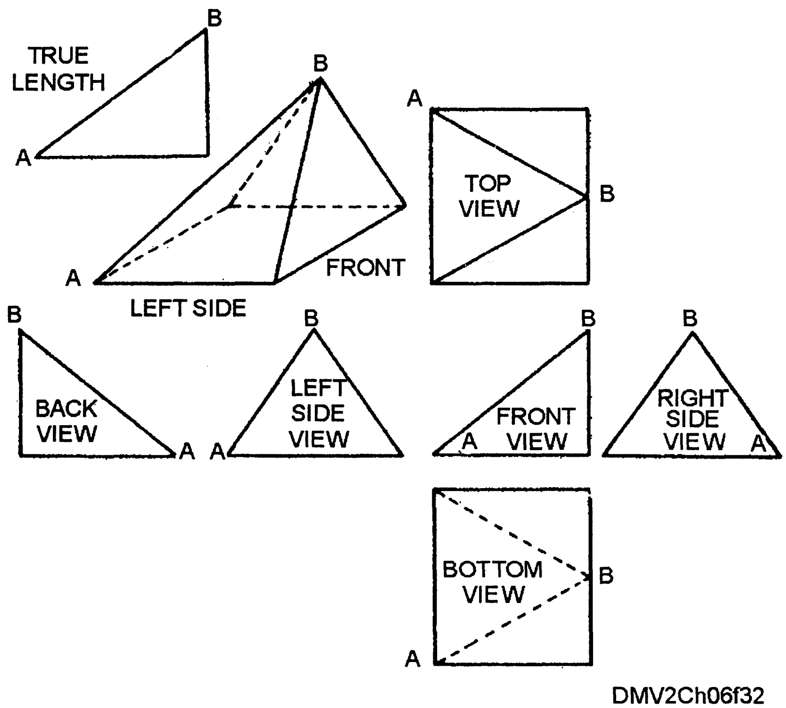

Figure 6-32.—Oblique lines foreshortened in all orthographic views.

Circles, arcs, and ellipses

In multiview projections, a circle on surfaces parallel to the plane of projection appears as a circle. A circle on a surface that is oblique to the plane of projection appears as an ellipse.

Parallel Practices

Introduction	Drawing practices for parallel projections are more standardized than for perspective projections. There is very little latitude for creative interpretation of an object and more use of drawing and drafting instruments. Parallel projections are working drawings or blueprints.
Mechanical construction	Use a scale, straightedge, triangles, and templates to mechanically construct accurate parallel projections.
Scale	Select a scale or ratio to represent the object on paper. Modify each measurement you make with the selected scale. Make note of the scale you select to enter in the appropriate space in the title block of the drawing.
Layout	All elements combined in a parallel projection drawing should present a balanced appearance. If you elect to draw your projection on standard drawing paper with preprinted information blocks and borders, consider the placement of views and the proximity of the information blocks. Make sure the drawing doesn't overcrowd or interfere with information blocks. Do not arbitrarily alter the relationship of adjacent views on the paper because you incorrectly spaced the views.
Measurements	All lines parallel to the picture plane project in true size or full scale. All lines perpendicular to the plane of projection project as a point. Oblique or inclined lines are foreshortened. Use offset measurements to locate surface characteristic that share common edges.
Circles, arcs, and ellipses	Circles, arcs, and ellipses parallel to the plane of projection appear in true size and shape. Circles not parallel to the plane of projection appear as ellipses. Use the system of plotted points or circumscribed circle method of projecting circles, arcs, and ellipses on surfaces not parallel to the plane of projection since these curves have no direct transferable measurements.
Reflections, shadows, and shade	Parallel projections generally do not contain reflections, shadows, and shading since this would interfere with any textural implications made by crosshatching, stipple, or other pattern.

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Parallel Practices, Continued

Partial views	Use a partial view if necessary to clarify the description of an object. Use a break line or the contour of the object itself to define the limitations of the partial view. Do not place break lines too near a visible or hidden line. For symmetrical objects, consider using a sectional view.
Sectional views	You may use any type of sectional view in a multiview projection so long as its purpose is to clarify the features of an object. A cutting-plane line indicates the part being viewed with the arrowhead showing the direction of sight.
Revolved or removed sections	You should use removed or revolved views on multiview projections to clarify an objects profile. Removed sections may be partially removed and rotated toward the plane of projection or they may be a separate revolution of the entire object aligned with the primary view as in an aligned section. Removed views are indicated by a viewing-plane line with arrowheads indicating the direction of sight. The viewing-plane shows a portion of the object as it would appear if removed from the object.
Angles	In multiview projections, angles on the surface of an object that is parallel to the plane of projection appear in true size and shape. Angles on surfaces not parallel to the plane of projection appear foreshortened. Convert angle into linear measurements before drawing.
Dimensioning	All dimension lines, extension lines, and arrowheads must lie in the planes of the object to which they apply. Place dimensions outside the object outline except when it helps to clarify. Align dimensions and notes shown with leaders to the bottom of the drawing. Notes without leaders should also be aligned with the bottom of the drawing. You may use either aligned or unidirectional methods of dimensioning. Use either whole numbers and fractions, decimal, or metric units of measure to mark dimensions on a drawing.
Lettering	Lettering on multiview projections is single-stroke gothic. Lettering is vertical in orientation.

Summary

Review

This chapter acquaints you with the various types of parallel projections. There are vast differences between oblique and orthographic projections. Oblique projections, particularly isometric projections are the most widely recognized because of their unique angular relationship to the plane of projection. Orthographic projections are most closely associated with blueprints or working drawings used for all types of construction. The chapter terminates with standard practices for rendering objects in parallel projection.

Comments

The theory and study of parallel projections develop your ability to think or visualize in three dimensions. Parallel projections are methodical, logical, mathematically correct representations of real objects or what could become real objects. Understanding parallel projections increases your ability to understand the mechanical interrelationship between parts from a wheel bearing on your automobile to the component parts of a Rubik's cube.

A suggestion for increasing your understanding of perspective and parallel projections is to look at the projection chart in the beginning of this chapter to get an overall feel for the subject. Select only one block (type of projection) and study it until you understand it. Then, return to an overall study of projections to fully grasp the relationship between the different types of projections.

APPENDIX I
GLOSSARY

Glossary

Introduction

One important key to success in any technical rate is mastery of the language associated with it. Learn the glossary as an integral part of your learning process. Use the terms other professionals are using in your field.

A

ACCENT LIGHT—A light that highlights or emphasizes the subject in a scene.

ACETATE—Tough, transparent, or semitransparent sheets available in various thicknesses used as overlays in color separation, friskets in retouching, cels for animated drawings, and displays. Treated acetate readily accepts ink and paint.

ACHROMATIC—Black, white, and the grays in between.

ACRYLIC PAINTS—*See* POLYMER.

ACTINIC LIGHT—The short waves of the light spectrum (green, blue, and ultraviolet) that cause chemical changes in light-sensitive photographic emulsions.

ACTION LINES—Extra lines drawn around or following a cartoon figure or object to emphasize motion.

ACTIVATOR—The solution or chemical that starts the reaction of the developing agent in a photosensitized emulsion.

ADDITIVE PROCESS—A process that produces white light by starting with darkness and combining colored light.

ADHESIVE—(1) A gelatin or casein used as a binder in pigment; (2) A chemical compound used as a glue.

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A (Continued)

ADVANCING COLORS—Colors that appear to come forward, such as red, yellow, and orange.

AESTHETIC—Pertaining to the beautiful, particularly in art.

AGATE—Type size of 5 ½ points.

AIRBRUSH—An atomizer that applies a fine spray of paint under pressure from a tank of compressed air or carbonic gas.

AIRBRUSHING—Using an airbrush to create art or improve the appearance of art.

ANALOGOUS COLORS—Colors closely related to one another on a color wheel, such as blue, blue-green, and green.

ANATOMY—The bone and muscle structure of humans and animals as it affects the appearance of surface forms and contours.

ANGLE—A figure formed by two lines or planes extending from, or diverging at, the same point.

ANHYDROUS AMMONIA SYSTEM—A system that uses a mixture of water and ammonia in the developing section of some whiteprint machines.

ANILINE COLORS—Brilliant colors derived from coal tar that tend to fade in time.

ANIMATED CARTOON—A cartoon drawn in a series of progressive actions to give the effect of continuous movement.

ANIMATION—Sequentially drawn pictures displaying a range of motion which, when viewed in rapid succession, appear to be moving.

ALIGNED SECTION—A sectional view that revolves some internal features into or out of the plane of view.

Continued on next page

A (Continued)

AMERICAN STANDARDS ASSOCIATION—*Also called* ASA. *See* ISO or EXPOSURE INDEX.

ANTIQUE STOCK—A rough-surfaced paper, such as wove or laid.

APERTURE—An opening behind the lens that allows exposure to one frame of film.

APPLICATION BLOCK—The part of a drawing of a subassembly, showing the reference number for the drawing of the assembly or adjacent subassembly.

ARC—A portion of a curved line.

ARC LAMP—A light source resulting from the application of current to two carbon electrodes that form an electric arc.

ARCHITECT'S SCALE—A scale used when dimensions or measurements represent feet and inches.

AREA (PICTURE)—The flat surface within the border of a picture.

ARROWHEAD—An indicator shaped like an elongated triangle used at the end of a lead line to direct attention to an object or a point of reference.

ART—Any copy other than text; any photograph, painting, or drawing in line, halftone, or continuous tone.

ART BRUSHES—*See* BRUSHES.

ART GUM—A soft, grit-free eraser used to clean drawings and remove unwanted pencil lines.

ARTIST'S BOARD—*See* ILLUSTRATION BOARD.

ARTWORK—Illustrations, drawings, photographs, renderings, paintings, sketches, and copy.

Continued on next page

A (Continued)

ASCENDERS—The part of lowercase letters that project above the main body waistline, such as h, d, and f.

ASPECT RATIO—The proportion of the media format that governs the size of the original artwork.

ASSEMBLE EDITING—Putting scenes in chronological or progressive order.

ASYMMETRICAL —An informal balance of objects or sections of equal mass and weight on each side of a center line.

ATTITUDE—A position or action of the body or part of the body that approximates an emotion, character, or personality.

ATTRIBUTES OF MEDIA—Specific characteristics of a chosen medium.

AUDIO—Sound that is heard.

AUDIO-TUTORIAL—*Also called* AT. Instructions given to a student that uses primarily sound.

AUDITABLE PICTURE ADVANCE SIGNAL—An auditable signal that indicates the moment to change the image to another.

AUTO-TRACE —A software option that allows the tracing of one image into another file option.

AUXILIARY VIEW—A drawing showing the true shape of objects that have features not parallel to the three principal planes of projection.

AXONOMETRIC PROJECTION—A drawing that shows the inclined position of an object in an isometric, dimetric, or trimetric format.

B

BACKGROUND ART—Design, texture, pattern, or other form of artwork used to create a background effect for type and illustration.

Continued on next page

B (Continued)

BACKUP—The registration of two sides of a printed sheet.

BALANCE—A harmonious arrangement of the various components in a picture plane in a symmetrical (formal) or asymmetrical (informal) format.

BALL-AND-SOCKET JOINT—A flexible joint that rotates in all directions.

BALLOON—(1) A space containing the words spoken by cartoon characters; (2) A distortable shape used as a base to draw a cartoon head.

BALLOON LETTERING—Informal, single-stroke lettering used in comic strip balloons.

BAR CHART—A graphic representation comparing numerical values by means of rectangles of equal width.

BASE ART—*Also called* BASIC ART and BLACK ART. *See* BLACK ART.

BEADED SCREEN—A screen comprised of glass or plastic beads that reflect light from a projected image.

BEAM COMPASS—A compass capable of drawing circles and arcs that exceed the limits of a standard compass.

BEND ALLOWANCE—An additional amount of metal used in a bend in metal fabrication.

BENDAY—Mechanical shading applied to artwork to give a variety of tones to line drawings. Benday is named for its inventor, Benjamin Day.

BÉLZIER CURVES—A computer tool that draws precise curves with great accuracy.

BILL OF MATERIALS—A list of standard parts or raw materials needed to fabricate items.

Continued on next page

B (Continued)

BINDER—An adhesive, coagulate, reducer, or extender added to pigments to maintain consistency, to promote adhesion, and to facilitate application.

BISECT—To divide into two equal parts.

BIT—The smallest unit of electronic information a computer can handle.

BIT MAP—*Also called* PIXEL MAP. A matrix of dots or pixels.

BLACK ART—*Also called* BASE ART. Art used in making process plates for illustrations of two or more colors.

BLACK-AND-WHITE—(1) Line art executed in a black-and-white medium only; (2) Continuous-tone art executed in black, white, and intermediate tones.

BLACK PATCH—A black masking patch pasted into the exact size and location on artwork where a photograph is to appear on the reproduction copy.

BLEED—The borders on the artwork and printing plate that extend beyond the final trimmed edge of the sheet.

BLENDING—Mixi.ng or incorporating one color or tone with another.

BLOCKING IN—Indicating the broad outline of objects or shapes in a picture using preliminary lines.

BLOCK OUT—Eliminating an unwanted section of a picture.

BLOWUP—An enlargement.

BLUEPRINT—A direct, positive print made on chemically treated paper from a translucent or transparent drawing.

BOARD—Any heavy material used for mounting art or making displays.

Continued on next page

B (Continued)

BOARD ART—Any artwork mounted on heavy board stock.

BODY TYPE—Type used for the main body of text in printed matter.

BOLDFACE—Type emphasized by darkening or increasing letter weight.

BOOKLET—A pamphlet bound within paper covers.

BOOT-UP—Start-up of the computer.

BONE—An instrument with a plastic, agate, or metal tip used for burnishing shading sheets, pressure-sensitive letters, and paste-ups.

BORDER AREA—The areas around a graphic that represents a protective perimeter.

BOUNCE LIGHT—Lighting set up to reflect from nearby surfaces onto a subject.

BOURGES PROCESS—A method of color separation using prepared colored or toned papers or acetate sheets.

BOW INSTRUMENTS—Drafting tools that draw circles and arcs less than one inch in diameter.

BOX—To enclose with borders or rules.

BREAK LINE—Lines to reduce the graphic size of an object, generally to conserve paper space.

BRIEFING CHART—*Also called* BRIEFING PAD. A visual aid that presents information on large paper or board.

BRIGHT—A short haired, flat, chisel-shaped brush.

BRISTLE.—A hog hair brush used primarily in oil painting.

Continued on next page

B (Continued)

BRISTOL BOARD—A drawing surface made of fine, tough, flexible cardboard available in several thicknesses and in a variety of surfaces.

BROADSIDE—*Also called* BROADSHEET. A large, folded advertising piece.

BROCHURE—A bound pamphlet.

BROKEN COLOR—Two or more colors applied simultaneously to artwork without prior mixing or blending.

BROKEN OUT SECTION—An auxiliary view used when a partial view of an internal feature is insufficient.

BROWNPRINT—A photographic print or silverprint that produces a brown image.

BRUSHES—A collection of bristles or hairs used to apply pigment and glues.

BULLET—A symbol (●) used to preface listed items.

BURNISH—The application of pressure to secure paste-ups, shading sheets, and lettering to artwork.

BURNISHER—Also *called* BONE. An instrument made of plastic, wood, glass, metal, stone, or ivory used to flatten, smooth, or polish a surface with hand pressure.

BUSY—Excessive or competing detail.

BUTTON BAR—*Also called* TOOL BOX. A program specific legend of options available to a computer user.

Continued on next page

C

CABINET PROJECTION—A type of oblique drawing with the angled receding lines drawn to one-half scale.

CALLOUT—To call attention to a part or item in an illustration.

CAMCORDER—A video camera and recorder in one unit.

CAMEO PAPER—Paper of a dull, smooth finish used frequently for carbon and graphite pencil drawings.

CAMERA LUCIDA—*Also called* LACEY LUCY. An instrument with prism lenses used for enlarging or reducing artwork.

CAMERA-READY COPY—*See* REPRODUCTION COPY.

CANVAS—A surface made of cloth, usually cotton or linen, for painting.

CANVAS BOARD—Cardboard covered with cotton or linen used as a surface for painting.

CANVASKIN—A paper with a textured surface resembling canvas.

CAPTION—Any descriptive heading or title for an illustration or table.

CARBON PENCIL—Pressed carbon in a wood casing.

CARICATURE—The deliberate exaggeration and distortion of prominent features or mannerisms.

CARPENTER'S PENCIL—A wide, flat lead pencil ideal for chisel point lettering or laying in broad tones.

CARTOON—A comic or satiric drawing.

CARTOUCHE—A scroll-like design used ornamentally in printing or hand lettering.

Continued on next page

C (Continued)

CASEIN—A curd of milk and lime used as a binder in tempura paint.

CAVALIER PROJECTION—A form of oblique drawing with the receding lines drawn full scale at 45° to the orthographic front view.

CD—*See* COMPACT DISK.

CD ROM—*See* COMPACT DISK READ-ONLY MEMORY.

CEL—Acetate overlays used in television art and animation.

CEL LEVEL—The number of cels placed one over another on the same background and photographed at the same time.

CENTER DISK—A drafting instrument that protects the paper surface from damage when drawing multiple concentric circles with a compass.

CENTER OF INTEREST—The part of the picture that attracts the most attention.

CENTER LINE—Lines that indicate the center consisting of alternating long and short dashed evenly spaced.

CENTER SPREAD—Two facing pages formed by one folded sheet of paper.

CENTRAL PROCESSING UNIT—Also *called* CPU. The integrated circuit (IC) chip that controls the speed and processing power of the computer.

CHAIN or CIVIL ENGINEER'S SCALE—A scale, generally triangular, divided in decimal units or units of 10.

CHARACTER—Any letter, number, punctuation mark, or space in printed matter.

Continued on next page

C (Continued)

CHARACTER GENERATOR—A computer hardware or software device that provides a means for formulating a character font and as a controlling function during printing.

CHARCOAL—Specially charred willow sticks used for drawing on a paper with tooth.

CHARCOAL DRAWING—A drawing made with charcoal.

CHARCOAL PENCILS—Charred willow sticks encased in wood for strength.

CHIAROSCURO—Rendering forms using a balanced contrast between pronounced light and dark elements.

CHINESE WHITE—An opaque white watercolor pigment.

CHISEL POINT—Drawing or lettering with a wide, flat point.

CHORES—Used to trap a dark element over a light background to avoid or minimize white space showing around the element during press plates misalignment.

CHROMA—*See* INTENSITY.

CIRCULAR SCREEN—A photographic screen used with a process camera, which allows screen adjustment to eliminate the wavelike or checkered effect, called moire.

CIRCUMFERENCE—The length of a line that forms a circle.

CIRCUMSCRIBED—To draw around or enclose within one geometric form another form or object.

CLICK ON—To select a computer function by clicking the buttons on a mouse.

Continued on next page

C (Continued)

CLIP ART—A collection of artwork filed away for future use.

CMYK—An acronym for cyan, magenta, yellow, and black, a color specification system for color separation and printing.

COATED PAPER—Paper coated with a finely ground filler or clay to produce a smooth surface.

COBALT DRIER—A liquid agent used in a medium to accelerate the drying of oil paints.

COLD COMPOSITION—Composition of type that uses no molten metal to form the image.

COLD MOUNT—A method of mounting artwork or photographs to a surface.

COLD PRESSED—A paper or illustration board with a medium to rough surface texture.

COLLAGE—Artwork made by arranging and pasting pieces of cloth, newspaper, and various other materials on a surface to form a composition.

COLLATING—Gathering single sheets or leaves in sequence.

COLLOTYPE—A method of reproducing paintings and drawings using a gelatin plate.

COLOR—A sensation caused by light waves of different lengths comprised of three elements: hue, value, and intensity.

COLOR BARS—Bars of color that appear on a video screen to facilitate fine tuning of the color resolution.

COLOR BLENDING—Blending or combining different colors to form another color or smooth gradient.

Continued on next page

C (Continued)

COLOR CHART—An arrangement of colors.

COLOR CYCLING—A spectral effect that creates the illusion of movement on the computer screen.

COLOR DIMENSIONS—The three elements of color: hue, value, and intensity.

COLOR GRAPHICS ADAPTER BOARD—*Also called* CGA or a Video Graphics Adapter (VGA). This IC chip defines the ability of the computer to execute commands during the creation of artwork in the computer.

COLOR HARMONY—A unified or aesthetically pleasing effect produced by a combination of colors.

COLOR INTERVAL—The degree of visual difference between two colors as measured by hue, value, and intensity.

COLOR KEY—The overall effect of the selected pallette; for instance, a high-key illustration of light, bright or vibrant color and a low-key illustration of dull or monotonous colors.

COLOR NOTATION—The specification of color by written symbols and numerals based on an established color system used on sketches for future reference.

COLOR PROOF—An engraver's or printer's proof showing the effect of final color in perfect registration.

COLOR SCALE—A series of colors that displays a change or gradation in hue, value, and intensity.

COLOR SCHEME—A group of colors that dominate a picture or create a unity within it.

Continued on next page

C (Continued)

COLOR SEPARATION—(1) The photographic process of separating full-color originals into the primary printing colors; (2) An artist manually separating the originals for full color reproduction in the creation stage of a master artwork.

COLOR SKETCH—A rough drawing or layout approximating the color in the final picture.

COLOR SYMBOLISM—The use of color to signify or suggest an emotion, idea, or characteristic.

COLOR WHEEL—A circular color chart with colors arranged according to their positions as a primary, secondary, or tertiary color.

COLUMN—(1) A section of text or other matter that makes up a vertically divided page; (2) A vertical section of a table.

COMBINATION PLATE—A press plate that combines both halftones and line work.

COMIC STRIP—A series of drawings, in panel format, portraying the adventures of characters, humorous or otherwise, usually published in newspapers.

COMMERCIAL ART—Artwork of any kind prepared for commercial advertising and general promotion.

COMPACT DISK—*Also caLLed* CD. A small disk of electronic files encased in a plastic casing.

COMPASS—An instrument for drawing circles and arcs.

COMPUTER DISPLAY MONITOR—An output device that allows the computer operator to see an image of electronic media on a cathode-ray screen similar to a television monitor.

Continued on next page

C (Continued)

COMPUTER PLATFORM—The use of a particular brand of computer to develop software programs specifically for that brand.

COMPLEMENTARY COLORS—Any two opposing hues on a color wheel.

COMPOSITE—Comprised of two or more parts.

COMPOSITION—The arrangement of forms, colors, lines, and other pictorial units.

COMPOSITOR—A machine that converts electronic data into an acceptable format for a printer.

COMPREHENSIVE—A layout of art or type, either in black-and-white or color.

COMPREHENSIVE SKETCH—A finished layout that defines all of the elements, such as type, illustration, and spacing.

COMPRESSED FILES—Compacting computer-generated files to save disk and memory space or to facilitate faxing.

COMPUTER GRAPHICS—Artwork created by the use of a computer.

CONSTRUCTION—The drawing of objects so that they appear solid or three dimensional.

CONSTRUCTION LINES—Lightly drawn lines used in the preliminary layout of a drawing.

CONTACT SCREEN—A screen placed in direct contact with the film or plate to obtain a halftone pattern from a continuous-tone original.

CONTINUOUS-TONE ART—Artwork created using any medium that does not use a halftone process to represent tone.

Continued on next page

C (Continued)

CONTOUR PEN—Adjustable pen nibs on a rotatable shaft used for drawing curvilinear lines.

CONTRAST—The range of tonal differences.

COOL COLOR—Colors that appear to project cooler temperatures.

COOLED COLOR—A color resulting from the addition of a cool color to a warmer color.

COPY—Any matter, including photographs, rules, designs, and text, used for producing printed matter.

COPYBOARD—A table or frame that holds original copy during a photographic exposure.

COPYFIT—Scaling copy to fit into an allotted space.

COPYRIGHT—Exclusive protection of ownership given to a creator of an original work.

COQUILLE BOARD—A drawing board that comes in a variety of roughened surfaces that break up crayon or brush strokes into texture more suitable for line reproduction.

COURSEWARE—All materials pertaining to a software program or course of instruction.

CPU—*See* CENTRAL PROCESSING UNIT.

CRAWL DEVICE—A rotating drum used to display credit lines for television transmissions.

CREMNITZ—*See* WHITE LEAD.

CROP—To cut off.

Continued on next page

C (Continued)

CROP MARKS—Marks used to define the limits of an image for reproduction.

CROPPING—Defining the limits of an image for reproduction.

CROSSHATCH—Parallel lines drawn across other parallel lines to indicate tone.

CROW QUILL—A fine, stiff pen nib with little spring used for drawing fine lines and lettering.

CRT—*Also caLled* CATHODE-RAY TUBE. A screen or monitor that converts light rays to electrical impulses for transmission or receiving.

CUBE—A solid form of six equal square sides.

CURSOR—A position indicator on a computer monitor.

CUTAWAY DRAWING—A drawing where a portion of the object is cut away revealing the internal structure.

CUTLINE—The placing of a caption in an illustration.

CUTTING PLANE LINE—A sectional view showing a theoretical cut on the item.

CYAN—Light blue-green color.

CYCLE OF ACTION—The completion of a single action of animated movement.

D

DAISY WHEEL PRINTER—A spinning wheel with spokes having raised letters and numbers.

DAMAR FINISH—Varnish used as a final protective coat over a painting or mixed as part of the painting medium.

Continued on next page

D (Continued)

DATA POINTS—Symbols used to plot information or events on a graph or chart.

DATUM LINE—A line that indicates the position of a datum plane.

DEADLINE—Final delivery date.

DEBUGGING—Locating and eliminating software deficiencies.

DECAL—*See* DECALCOMANIA.

DECALCOMANIA—An image printed on specially prepared paper or film for transfer to another surface.

DECKLE EDGE—The rough or uneven edge of paper intentionally produced during manufacturing.

DELINEATE—To give depth to line art by making particular lines heavier.

DENSITY RANGE—*Also called* DENSITY SCALE. Measured differences between the minimum and maximum densities of a particular negative or positive.

DEPICT—To represent.

DEPTH—Thickness as measured downward from the surface of an object.

DEPTH OF FIELD—The distance between the closest sharply focused point to the farthest point in focus.

DESCENDERS—The parts of lowercase letters that fall below the main body base line, such as g, p, and q.

DESIGN—A planned or intended arrangement of the elements in a composition.

DESIGNERS COLORS—Opaque watercolors of high quality.

Continued on next page

D (Continued)

DESKTOP PUBLISHING—The preparation of copy ready to go directly to press.

DETAIL DRAWING—A drawing that gives specific information.

DETAIL PEN—*Also called* SWEDE PEN. A broad nibbed, adjustable ruling pen with greater ink capacity than a standard ruling pen.

DETAIL VIEW—A view that shows part of the principal view of an item using the same plane and arrangement but in greater detail and in a larger scale.

DEVELOPER—A chemical that causes a reaction in an exposed emulsion to reveal an image in that emulsion.

DIAZO FILM—A flexible transparent base coated with an emulsion of diazo salts and couplers.

DIAZO PAPER—Paper treated with a diazo compound and azo dyestuff component.

DIAZOCHROME—Diazo sensitized films that produce colored dye images on a transparent plastic base.

DIFFUSED LIGHT—Evenly spread light.

DIMENSION LINE—A thin, unbroken line with each end terminating in an arrowhead used to define the dimensions of an object.

DIMETRIC PROJECTION—An axonometric projection of an object where two axes make equal angles with the plane of projection and the third axis makes a smaller or larger angle with the plane of projection.

DINGBATS—Stars or ornaments used to embellish type.

DISCHORD—Color or elements that compete or are not in visual harmony and create uneasy or unattractive images.

Continued on next page

D (Continued)

DISK—*Also called* DISC. (1) A flat photomatrix used in phototypesetting and computer equipment; (2) A layer of magnetic oxide used to store electronic data.

DISK DRIVE—A device that reads, adds, or deletes information stored on a disk.

DISPLAY LETTERING—Any large, prominent lettering used to attract attention.

DISPLAYS—A collection of objects and images arranged to tell a story.

DISPLAY TYPE—Large type used for headings and titles.

DISSOLVE—The fading of one scene as another replaces it.

DISSOLVE UNIT—An electronic device that automatically pulses a slide projector to dissolve an image and replace it with another.

DISTORTION—Changed or twisted out of natural shape.

DIVIDERS—An instrument used for dividing lines into equal segments and transferring measurements.

DOMINANT—Prominent or most important.

DOT MATRIX PRINTER—A printer that uses a number of pins to form letters and numbers.

DOTS PER INCH—*Also called* DPI. A standard measurement for resolution in the computer graphics industry.

DOUBLE-ACTION AIRBRUSH—An airbrush that requires the user to push down a button to expel air through the brush and to pull back the button to release paint.

Continued on next page

D (Continued)

DRAFTING MACHINE—A machine that combines the functions of a T-square or straightedge, a triangle, a ruler, and a protractor.

DRAWING—The representation of objects, ideas, or emotions on a flat surface using line, tone, or color.

DRAWING THROUGH—Sketching in the structural lines of an object as if it were transparent.

DRIER—A substance used to hasten the drying times of paint or ink.

DROP CARDS—Drop-out or drop-in title cards rigged to fall in and out of camera view.

DROP OUT—Masked or opaqued areas present in the halftone negative, print, or plate.

DROP-OUT HALFTONE—A halftone reproduction that eliminates the screen dots in white areas, often accomplished photographically by the platemaker or by re-etching.

DRY BRUSH—Drawing or painting with a brush that contains very little substance to create a textural effect.

DRY MOUNT—Mounting photographs without paste or rubber cement.

DRY MOUNT PRESS—An electrically heated press that activates an adhesive sheet or foil placed between the image and the illustration board.

DUCK—A lead weight used to position a spline while drawing irregular curves.

DUMMY—A rough draft or proposal of printed material pasted or bound together in exact reproduction size that show the areas illustration and text will occupy.

DUOTONE—Two-color halftone print made from a screened photograph.

Continued on next page

E

EARTH COLORS—Pigments made from earth minerals.

EDGE—The border or outline of a form or shape.

EDIT—To check, add, or delete.

EDIT CONTROLLER—A machine that locates the beginning and end of a scene used for cuing VCRs for presentation.

EGG-OIL TEMPERA—An opaque watercolor similar to egg-based tempura but with an added oil that makes the medium easier to handle and adaptable to a wider range of effects.

EGG TEMPURA—An opaque watercolor paint that uses egg yoke as a binder.

ELECTRONIC IMAGING—The creation, enhancement, and alteration of images through electronic or computer digitization.

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

ELITE—A type size for typewriters approximating 10 point printing type having 12 characters to the linear inch of copy and 6 lines to the vertical inch.

ELLIPSE—The enclosed plane forming a regular oval where the shortest dimension through the center is the minor axis and the longest dimension is the major axis.

EM—A measure of type equal to the square of the type body, derived from early type practices in which the letter *M* was cast on a square body.

EMPHASIS—Stress or accent on any part of a design or picture.

EMULSION—A suspension of fine drops or globules of one liquid in another liquid.

Continued on next page

E (Continued)

EN—A measure of type equal to one half of an EM.

ENCRUSTING—Taking a video image and wrapping it around an image of an object.

ENGINEERING DRAWING—An orthographic drawing of a piece of equipment or of its detailed parts containing information and instructions sufficient for manufacture.

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

ERASING SHIELD—A small, thin spring metal plate with variously sized and shaped openings used to protect the surrounding area of a drawing while erasing in an adjacent area.

ESSENTIAL AREA—The part of a picture that contains all of the title or lettering intended for viewer consumption and often corresponding with the safe title area.

EQUILATERAL—Equal angles and equal sides.

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

EXPOSURE INDEX—The degree of light sensitivity of film.

EXPORT—The transfer of files to another software application.

EXTENSION BAR—A leg extension to a standard compass, which expands the diameter of a circle that the compass is able to draw.

EXTENSION LINE—A line used to indicate the extent of a dimension.

EYE LEVEL—*Also called* HORIZON LINE. The horizontal plane at the artist’s eye level to which that person relates linear perspective.

Continued on next page

F

FACE—*Also called* TYPEFACE. A style of type.

FADE-IN—To bring an image from a pale version into full contrast gradually.

FADE-OUT—To bring an image from a full contrast of darks and lights to a pale version gradually.

FEATHER—A bleeding effect where small featherlike indications surround the characters.

FEATURE—A cartoon panel or strip appearing regularly in a publication.

FELT NIB PEN—A drawing pen with a felt nib or tip that ink soaks through from a reservoir.

FERRULE—The part of a brush that holds the hairs or bristles.

FIGURE—A line illustration or photograph of any kind used in a publication.

FILLS—Color, shades, or patterns added to computer-generated imagery.

FILM NEGATIVE—A photolithographic negative produced by a process camera.

FILM POSITIVE—A film- or acetate-based material having a black area or image and a translucent or clear background.

FILM SPEED—The degree of light sensitivity of film.

FINE ART—The personal expression of the artist who creates it.

FINISHED ART—Any piece of artwork complete or ready for reproduction.

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

Continued on next page

F (Continued)

FIRST GENERATION—Photographically reproduced copy made from the original.

FIX—To spray with a clear coat to protect or preserve an image surface.

FIXATIVE—Any clear solution sprayed or coated on a surface to stabilize, protect, or preserve an image.

FIXER—A solution or chemical that stabilizes the development of photosensitized films.

FLEXIBLE CURVE RULE—A scale or rule that bends in shape to irregular curved surfaces.

FLAKE WHITE—*See* WHITE LEAD.

FLANNEL BOARD—*Also called* FELTBOARD. A presentation board covered in felt or flannel that cut out shapes backed with a slightly abrasive backing will cling to.

FLAPPING—*See* MOUNTING AND FLAPPING.

FLAT BRUSH—A flat oil painting brush that is thicker and with longer bristles than the bright brush;

FLAT COLOR—Color that is dull or grayed or has a matte surface.

FLAT TONE—An area of uniform or even color.

FLIP CARD—One of a series of photographs or drawings shown in sequence to tell a story or deliver a message.

FLOP—To reverse from right to left or vice versa.

FLOPPY DISK—A disk of magnetic oxide that stores electronic data for retrieval by a computer disk drive.

Continued on next page

F (Continued)

FLOW CHART—A chart that shows the flow of data through a data processing system and the sequence of their performance.

FLOUROGRAPHIC—*See* DROP-OUT HALFTONE.

FLUSH—Even with the margin or the widest line in a column or page.

FOCAL POINT—Center of interest.

FOCAL LENGTH—The distance from the center of the lens to the film plane.

FOCI METHOD—A method of drawing ellipses by plotting a series of points as their circumference using two points on the major axis (foci) as reference and connecting these points with french curves.

FOCUS—Image sharpness.

FOLIO—A sheet of paper folded once giving four pages.

FONT—Typeface designs and sizes.

FORESHORTEN—To depict an object or line in less than its true length.

FORM—The shape and structure of an object or figure.

FORMAL BALANCE—*See* BALANCE or SYMMETRY.

FORMAT—A general structure or composition.

F/STOP—Settings on the lens diaphragm of a camera lens that measure the amount of light allowed to reach the film.

F/16 RULE—Setting the camera for an f/stop of f/16 and the shutter speed close to the ASA/ISO rating of the film.

FRAME—A single unit in a storyboard, a cartoon feature, or a film strip.

Continued on next page

F (Continued)

FRAME GRABBER—*Also caLled* VIDEO CAPTURE. A device that isolates one frame of a video image and inputs this frame into a computer.

FREEHAND DRAWING—Drawing without the use of mechanical aids.

FRENCH CURVES—Instruments used to draw smooth, irregular curves.

FRESCO—Painting on freshly spread, moist plaster with pigments.

FRESNEL LENS—A intense prismatic lens of concentric divisions, which concentrate and focus light through a transparent image onto a mirror and to a screen in an overhead projector.

FRISKET—A covering placed over part of a drawing or photograph to protect that section while working on the rest of the artwork.

FRONTISPIECE—An illustration preceding and usually facing the title page of a book.

FULL-COLOR PAINTING—A painting in which the three primary colors or some variation of them is evident.

FULL MEASURE—The entire width of a line of type flush with both margins measured in picas.

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

FULLER'S EARTH—A fine white powder used for preparing the surface of a photograph to accept retouching.

G

GALLEY PROOF—A rough proof of type made for proofreading, submitted before pages are made up.

GANG RUN—Several different jobs printed simultaneously on a large press in the same colors on one sheet to save time and reduce costs.

Continued on next page

G (Continued)

GANG SHOOTING—Photographing several pages of original copy at the same time.

GELATIN—A pure glue made from animal or vegetable matter.

GENERATION—A single step in a reproduction process.

GIGABYTE—Approximately one billion bytes of information, a kilobyte to the third power (1,024 x 1,024 x 1,024).

GLAZE—An application of a transparent color or value over another color or value.

GLOSSY PRINT—A print having a shiny finish, which does not readily absorb inks or paints.

GLYCERIN—A heavy oil, colorless and odorless, used in the preparation of watercolor pigment.

GOLDENROD—Paper or plastic mask material used to support negatives in making press plates.

GOTHIC—An alphabet or typeface characterized by strokes of equal or almost equal thickness, usually without serifs.

GOUACHE—An opaque watercolor.

GRADED WASH—A wash that blends a light tone to a dark tone or vice versa.

GRADUATED FILL—To fill with color, shade, or pattern that variegates from dark to light or vice versa.

GRAPHIC ARTS—A form of art specializing in work prepared primarily for conveying information.

Continued on next page

G (Continued)

GRAPHIC INTERFACE—Screen graphics on the computer screen that make the computer easier to use.

GRAPHICS PRINTER—A high-resolution printer capable of printing graphic images.

GRAPHICS TABLET—An electronic input device that allows the user to draw on the tablet before committing the image to memory.

GRAPHITE—The black marking substance in a lead pencil.

GRAVER—A needle or square pointed tool used to scratch lines into scratchboard.

GRAVURE—A photomechanical printing process (intaglio) with the images recessed below the surface of the plate.

GRAY—A color formed by mixing black and white or complementary colors.

GRISAILLE—A decorative gray monochromatic painting designed to create the illusion of a bias-relief sculpture.

GUM ARABIC—A water soluble gum used as a binder in some watercolors and tempura paints.

GUTTER—(1) The inner margin of a printed page extending from the printed portion to the fold or binding; (2) The area between two columns on a printed page.

H

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

HALFTONE—A tonal pattern of shades from white through black defined by a series of dots.

Continued on next page

H (Continued)

HALFTONE SCREEN—A screen placed in front of the negative material in a process camera to break up a continuous-tone image into a dot formation.

HARD COPY—Copy of any kind produced on paper or any substrate except film, used for proofing, checking, revising, or redrawing.

HARMONY—A pleasing arrangement of the picture elements, because of the similarity of one or more qualities.

HEXAGON—A six-sided figure.

HIDDEN LINE—Thick, short dashed lines used to show a hidden part or edge.

HIGHLIGHT HALFTONE—*See* DROP-OUT HALFTONE.

HIGH SURFACE—*See* HOT PRESSED.

HINGE JOINT—A joint limited to back-and-forth movement.

HOLDING LINE—A line usually drawn in black on a mechanical intended for reproduction.

HOOK AND LOOP BOARD—A briefing board covered with nylon hook material to which items backed with a nylon loop material will stick.

HORIZON LINE—An imaginary horizontal line representing the observer's line of sight.

HOT PRESSED—*Also calLed* HIGH SURFACE. A smooth art paper or illustration board.

HUE—The name given to distinguish any color.

HYPO—*See* SODIUM THIOSULFATE.

Continued on next page

I

ICON—Onscreen computer symbols that portray functions by graphic images.

ILLUMINATION—The hand decoration of text in a book, a manuscript, or a diploma.

ILLUSTRATION—A picture designed to interpret a story or an article.

ILLUSTRATION BOARD—Heavy paper board manufactured especially for artists available in a variety of sizes, surfaces, and weights.

IMAGE AREA—An area that encompasses a printed, drawn, or photographed image and the light or dark background space around the image.

IMPORT—The transfer of files from other software applications.

INDEFINITE BLENDING—Adding paint or ink to a wet surface to promote indefinite effects.

INDIA INK—Pigment made of lampblack and a binder suspended in water as a fluid ink.

INFINITY—The farthest distance marking on a lens.

INFORMAL BALANCE—*See* BALANCE.

INK JET PRINTER—A high-resolution printer that uses a minute jet spray of ink to create an image.

INPUT—Text or parameters entered into a computer memory or saved on disk.

INPUT DEVICE—*See* KEYBOARD or JOYSTICK. An accessory used to provide text or commands into a computer or disk.

INSCRIBED—An object completely enclosed by another.

Continued on next page

I (Continued)

INTAGLIO—Printmaking from engraved or etched lines and surfaces.

INTENSITY—The degree of strength, saturation, or purity of a color.

INTERFACE—Interaction between accessories.

INTERMEDIATE—A copy of an original on translucent or transparentized film, paper, or cloth, which now becomes a master to make other copies.

IRREGULAR CURVES—Curvilinear forms that do not contain arcs easily replicated by a compass or circle template.

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.

ITALICS—Letters whose form has an oblique slant to the right or left.

IVORY BLACK—A fine black pigment.

J

JOYSTICK—*See* TRACKBALL or MOUSE. A computer input device used for remote manipulation of a cursor.

JUSTIFICATION—Spacing within the line of type of a predetermined measure to align the margins.

JUXTAPOSITION—Side-by-side placement for a desired effect.

K

KERN—Part of a letter that appears as a hairline connection between adjacent letters.

KERNING—The addition of space between characters.

KEY—A scale of values, tones, or hues.

KEY ART—*See* BLACK ART.

Continued on next page

K (Continued)

KEY LINE—A line drawn in red on a mechanical to indicate position and size of a piece of copy that will not be visible in the reproduction.

KEYBOARD—A computer input device based on the principle of a typewriter keyboard used to input text and commands into a computer.

KEYSTONE EFFECT—Onscreen distortion created when the projector is not parallel to the deck or screen surface.

KID FINISH—A medium-textured surface of art paper or illustration board.

KILOBYTE—Abbreviated as K, a kilobyte is 1,024 bytes of data.

L

LAMINATE—(1) A transparent plastic or acrylic cover material; (2) To cover a surface with a transparent plastic or acrylic material.

LAMINATION—A plasticor acrylic used to cover a surface.

LAMPBLACK—A very fine black pigment used in various black paints and inks.

LASER—An acronym for Light Amplification by Simulated Emission of Radiation.

LASER PRINTER—A high-resolution printer that uses laser technology to create an image.

LAYING IN—The initial broad application of tone to a picture.

LAYOUT—The arrangement of a book, a magazine, or other publication so that text and illustrations follow a desired format.

LEADING—Spacing between lines of type, measured in points.

LEADER LINE—Thin, unbroken lines used to connect numbers, references, or notes to appropriate surfaces.

Continued on next page

L (Continued)

LEAF—A single sheet that includes both sides.

LEAK—An accidental escape of fill color or texture from an object or shape not completely enclosed by pixels.

LENS—Optical glass components arranged in a formation that creates a focal point at a specific distance from a screen.

LENS DIAPHRAGM—Controls the amount of light allowed to reach the film.

LEGEND—A description of any special or unusual marks, symbols, or line connections.

LENTICULAR SCREEN—A projection screen with a surface patterned to reflect a projected image with minimum glare.

LETTERHEAD—(1) The printed matter, usually the name and address of a company, at the head of a sheet of letter-quality paper; (2) A sheet of paper bearing a letterhead.

LETTERING—Letters and words formed or printed by hand.

LETTERPRESS PRINTING—A printing process in which the raised, inked surfaces of the type and/or plates transfer an impression directly to the paper.

LETTER-QUALITY PRINTER—A printer that imitates letters with resolution similar to a typewriter.

LETTERSPACING—Placing additional space between the letters of words to expand the length of a line or to improve and balance typography.

LIFT METHOD—(1) The process of using laminate material to remove or lift an image from clay-coated stock; (2) scanning text or graphics onto disk for importation to another application.

Continued on next page

L (Continued)

LIGHT BOX—A box with a translucent glass or plexiglass top illuminated from underneath, used for tracing and layout.

LIGHTFACE—The lightest and thinnest form of a type series.

LIGHT PEN—An electronic input device used to draw freehand against a CRT screen.

LIMITED PALETTE—(1) A palette with a restricted number of pigments; (2) A palette that lacks one or more of the three primary colors.

LINE—A continuous, unbroken mark made by a pen, a pencil, a brush, or other drawing instrument.

LINE AND WASH—A technique combining a black line with transparent wash.

LINE COPY—A composition of black lines and masses without gradation of tone.

LINE DRAWING—A drawing composed entirely of lines, dots, and areas of solid black.

LINE OF DIRECTION—The line the eye follows when looking at the picture.

LINES PER INCH—*Also called* LPI. A standard measurement of resolution for the color printing trade.

LINE WEIGHT—The thickness of pencil, ink, or other lines in artwork.

LINSEED OIL—An oil obtained by pressing the seeds of a plant, which produces linen fiber used as a medium in oil painting.

Continued on next page

L (Continued)

LITHOGRAPHY—*See* OFFSET PRINTING or OFFSET LITHOGRAPHY. A reproduction process in which grease crayon lines and masses drawn on a flat, polished stone print through the affinity of grease to grease (grease crayon and printer's ink). The wetted stone repels the ink from the other areas not covered with crayon.

LITHOGRAPHIC PENCILS—An oily pencil or crayon used to mark lithographic plates.

LOCAL COLOR—The actual color of an object without regard to the effect of changing light and shadow conditions.

LOCAL COLOR VALUE—The actual lightness or darkness of a color without regard to the effect of changing light and shadow conditions.

LOGOTYPE—*Also called* LOGO. The lettered signature, nameplate, or trademark of a commercial firm.

LONGSHOT—A picture showing a full figure or a distant view.

LACEY LUCY—*See* CAMERA LUCIDA.

M

MACHINE COMPOSITION—Type set by a machine.

MACRO LENS—A short focal-length lens specifically designed to allow closeup photography.

MAHLSTICK—A rod used in the palette hand to support or steady the painting hand.

MAKEUP—*See* LAYOUT. The arrangement of text and illustrations on a page in conformance to standard practices in the industry or to publication requirements.

MAGNETIC CHALKBOARD—A briefing board that accepts chalk markings and magnetic attachments.

Continued on next page

M (Continued)

MARS COLORS—Artificial earth colors.

MASKING—To block out a portion of an illustration by pasting paper over it to prevent it from reproducing.

MASKING TAPE—An opaque, paper tape used to cover the edges of a picture while painting and to fasten artwork temporarily to a drawing board.

MASTER—An original typed, drawn, or typeset copy intended for reproduction.

MAT—A cardboard or paper decorative enclosure around a picture.

MATCH DISSOLVE—Holding one element on a screen as one scene dissolves into another.

MATTE—Dull or without shine.

MATTE PRINT—A print having a dull finish.

MATTE SCREEN—A projection screen with a dull surface to reduce glare from overhead lights.

MEASURE—The length of a line of type measured in picas.

MEATBALL—*See* BULLET.

MEDIA INTEGRATION—*Also called* MULTIMEDIA. Mixing various presentation devices in the same presentation.

MECHANICAL—A page or layout prepared as an original for photomechanical reproduction.

MECHANICAL DRAWING—A method of drawing using precision tools to produce mathematically precise layouts, diagrams, and engineering drawings.

Continued on next page

M (Continued)

MEDIUM—(1) A liquid that dilutes a paint without damaging its adhesive; (2) The mode of expression employed; (3) The actual instrument or material used by the artist.

MEGABYTE—Abbreviated MB or M, approximately one million bytes of data.

MEMORY—That portion of computer hardware that retains data for later retrieval.

MENU—A selection of options displayed on a computer screen.

MICROCOMPUTER—Another name for a personal computer or computer workstation not attached to a mainframe system.

MILITARY STANDARDS—*Also called* MIL-STD. A formalized set of government standards.

MIXED MEDIUM—*Also called* MIXED MEDIA. A combination of two or more mediums.

MODEM—An electronic input/output device that connects computer workstations for communications. An acronym for the word modulator and demodulator.

MOIRÉ—An wavy or checkered pattern that results when photographing a halftone through a screen.

MONOCHROMATIC—Shades or tints of one color.

MONTAGE—*See* COMPOSITE. (1) Arranging a number of pictures or designs in a combination, often with some overlapping, so that they form a composite whole; (2) The resultant arrangement or composition.

MONITOR—The viewing screen of a computer system.

MOOD—An outward projection of a feeling or emotion that affects behavior communicated by action, situations, or symbology in a picture.

Continued on next page

M (Continued)

MORGUE—*See* PICTURE MORGUE, CLIP ART, or RESEARCH FILE.

MOUNT—To fasten onto another surface.

MOUNTING AND FLAPPING—Fastening original artwork or copy to a board allowing sufficient excess around the picture borders to accommodate attaching a protective overlay along one side.

MOUNTING BOARD—Heavy paper boards used as backboards to support drawings, paintings, and photographs.

MOUSE—A hand-held computer input device that allows rapid movement and selection.

MULTIMEDIA—*Also called* MEDIA INTEGRATION. A combination of presentation devices used in the same presentation.

MULTIPURPOSE BOARD—A briefing board with a slick, bright, white surface that accepts erasable marker, marker, and magnetic backed accessories.

MUNSELL COLOR SYSTEM—A system of color analysis and identification that distinguishes between the three measurable dimensions of hue, value, and chroma (intensity).

MURAL—Any picture painted or fixed permanently on a wall or ceiling.

MYLAR—Tough, highly stable, polyester film used as a base for engineering drawings, laminating, overlays, and a wide variety of other applications.

N

NARRATION—*Also called* VOICE OVER. The description or commentary that accompanies television and video presentations.

NCR PAPER—No Carbon Required paper; chemically coated paper that transfers a copy of an image to the sheet directly behind it without the use of a carbon.

Continued on next page

N (Continued)

NEGATIVE, PHOTOLITHOGRAPHIC—A film negative having a translucent image and a black background produced by a process camera and used primarily to make printing plates.

NEUTRAL COLOR—(1) A color that lacks hue and intensity; (2) A color that contains some amount of its complementary; (3) An earth color.

NIB—A point at the end of a pen or marker.

NOISE—Adding a random pattern of pixels over an image to add texture, create a new value, or give a painterly effect.

NORMAL LENS—*Also called* STANDARD LENS. A 50mm focal-length lens, which most closely approximates normal vision with minimal distortion.

O

OBLIQUE PROJECTION—A view produced when the projectors are at an angle to the plane of the object illustrated.

OCTAGON—A figure having eight sides.

OFFSET LITHOGRAPHY—*See* LITHOGRAPHY. Lithographic printing where an inked plate prints on a rubber blanket, which then offsets the image to paper stock.

OFFSET SECTION—A section view of two or more planes in an object to show features that do not lie in the same plane.

OIL PAINT—Any pigment ground in linseed oil or poppy oil.

OILSTONE—A stone or abrasive used to sharpen needlepoints and blades.

ONE POINT PERSPECTIVE—*Also called* PARALLEL PERSPECTIVE. When the height and width of an object are parallel to the plane of projection.

ONION SKIN—*Also called* MANIFOLD PAPER. Thin, translucent paper used to make a typewriter carbon copy or to serve as a tissue overlay for work requiring correction or protection.

Continued on next page

O (Continued)

ONSCREEN—An image that appears on the computer or television screen.

OPAQUE—(1) Impermeable to light; not transparent or translucent; (2) To paint over unwanted portions of a negative with a solution to prevent light from seeping through.

OPAQUE PROJECTOR—A device that projects an opaque object to a desired size on another surface.

OPAQUE WATERCOLOR—*See* WATERCOLOR. A creamy, opaque paint-like gouache or tempura, available in tubes, jars, or by mixing white with transparent colors.

OPAQUING—Covering up with opaque paint.

OPTICAL CENTER—A point slightly above (10%) the geometric center of a layout that the eye perceives as the center.

OPTICAL ILLUSION—An unreal or misleading image perceived by the eye as real.

OPTICAL SPACING—The arrangement of spacing between letters for legibility and appearance, which varies with the shape of the letters to achieve optical equalization.

ORGANIZATION CHART—A block chart or diagram showing the names, titles, departments, and responsibilities of personnel in an organization.

ORIGINAL—*See* MASTER. Copy submitted to the printer for reproduction.

ORTHOGRAPHIC PROJECTION—A method of projection with six principal views.

OSCILLATING AIRBRUSH—An airbrush with a reciprocating needle used for fine detailed work.

Continued on next page

O (Continued)

OUTPUT—The end product generated by an electronic device, such as a computer, printer, or copier.

OUTPUT DEVICE—An electronic accessory to a computer system that provides some type of end product either visually or as a hard copy.

OUTLINE—The outside edge of a shape or form.

OUTLINE DRAWING—A drawing where lines define the outer limits of the forms without the representation of modeling, light, or shadow.

OVERHEAD PROJECTION—A projector that uses of a system of mirrors and a fresnel lens to project a transparent image or object to another surface or screen.

OVERLAP—To cover a part of one shape or line with another.

OVERLAY—A transparent or translucent sheet taped over the original art for protection or to indicate instructions or corrections.

OVERPRINTING—Printing an image over another impression.

OZALID MACHINE—An ammonia process printmaking machine that produces the same—size copy from transparent or translucent originals.

P

PAINTING KNIFE—*See* PALETTE KNIFE. A type of palette knife made for applying paint to a picture.

PALETTE—(1) The surface on which the artist places paint and mixes colors before applying them to canvas or other painting surface; (2) A group of colors or gray values chosen for use in the same picture.

PALETTE KNIFE—A thin, flexible, steel blade set in a wooden or plastic handle available in a variety of shapes used for mixing paints and impasto, applying paint directly to a canvas or to create special textures directly on the surface of a picture.

Continued on next page

P (Continued)

PALETTING—Moving the pigment back and forth across a palette with a paint brush to achieve a certain consistency in texture or color or to load the brush with pigment adequately.

PANEL—(1) A given area in which a cartoon is drawn, with or without a defined frame; (2) One box or frame of a comic strip; (3) One unit of a storyboard.

PANORAMA—*Also called* PAN. Slow, steady camera movement from side to side.

PANTOGRAPH—A mechanical device based on the shape of a parallelogram, used to reduce, enlarge, or copy pictures.

PANTONE COLOR SYSTEM—An industry accepted system of color analysis and identification that distinguishes between the three measurable dimensions of hue, value, and chroma (intensity).

PARABOLIC REFLECTORS—Lamp reflectors that assist even illumination and shorten exposure time.

PARALLAX—Distortion present when exposing film through a lens not aligned with the veiwfinder, distortion corrected by a rangefinder camera.

PARALLEL PROJECTION—*See* ONE POINT PERSPECTIVE.

PARALLEL STRAIGHTEDGE—A long, straight edge supported at both ends to maintain parallel motion.

PARTIAL SECTION—A sectional view consisting of less than a half section.

PASTEL—(1) A dry pigment mixed with a variety of binders to form a stick or crayon for application to a picture surface; (2) A picture executed in the pastel medium.

Continued on next page

P (Continued)

PASTE-UP—The process of pasting an image or part of an image on a reproduction page or sheet before photographing for platemaking or printing.

PATTERN—(1) The regular or irregular distribution or arrangement of elements; (2) Regularly repeated flat designs used to create two-dimensional textures.

PENS, PLOTTER—A pen nib or jet spray attached to a plotter output device.

PENS, STEEL BRUSH—Steel pen nibs designed to create large poster size lettering.

PENS, TECHNICAL—Conical or tubular tipped pen nibs designed to produce a consistently even line of a predetermined weight in a standard or metric measurement available with and without a reservoir.

PENTAGON—A five-sided figure generally having equal sides and angles.

PERCENTAGE CHART—*Also called* PIE CHART. A circular chart divided into wedges whose sum equals 100% or 360°.

PERPENDICULAR—A vertical line meeting or intersecting a horizontal line at 90°.

PERSONIFICATION—Attributing human qualities to animals or inanimate objects.

PERSPECTIVE—The visual impression of lines moving closer together as distance increases.

PHANTOM LINES—*Also called* ALTERNATE POSITION LINES. Lines consisting of one long and two short dashes, evenly spaced, terminating in a long line, used to indicate an additional position of a part or object.

Continued on next page

P (Continued)

PHANTOM VIEW—A view showing an alternate position of a movable object.

PHOTOGRAPHIC TYPESETTERS—*See* TYPESETTERS, PHOTOGRAPHIC.

PHOTOLETTERING—A method of simulating hand lettering or display type by photographic means.

PHOTO LITHOGRAPHY—The transferring of a drawing to a lithographic plate by photography.

PHOTOMECHANICAL—Pertaining to any process of printing or duplicating images by mechanical means from a photographically prepared printing plate.

PHOTOSTAT—*Also called* STAT. A photographic image recorded by a camera so constructed that it photographs and develops directly on paper, in negative values.

PHOTOTYPE—Type set by photographic means.

PICA—A unit of measure equal to 12 points or l/6 of an inch.

PICKUP—A square of gum rubber used to remove excess rubber cement.

PICTORIAL DRAWING—Any drawing that depicts an object with recognizable clarity.

PICTURE AREA—The flat surface within the borders of a picture.

PICTURE MORGUE—*Also called* MORGUE. See CLIP ART.

PICTURE PLANE—An imaginary plane placed between the observer and the object, usually at right angles to an observer's line of vision.

PIE CHART—*See* PERCENTAGE CHART.

Continued on next page

P (Continued)

PIGMENT—Dry color matter that becomes paint when mixed with a vehicle or binder.

PINHOLE—A small light spot that appears on a developed photographic negative resulting from particles of dust and lint on the unexposed negative, the camera lens, the vacuum board glass, or other parts of the camera.

PIN REGISTER—A method of holding elements in place in overlay work and animation.

PIXEL—*Also called* PICTURE ELEMENT. A small bit of digital data from a computer screen.

PIXEL MAP—Also *called* BIT MAP. A matrix of pixels that form a digital image on the computer screen.

PIXILATED—Having jagged edges.

PIXEL—Specifying the size of a pixel on the computer screen.

PLAIN TITLE CARD—Printed information only on a card for television transmission of credit lines.

PLAN VIEW—A view of an object or area as it would appear if viewed from directly above.

PLANE—A flat surface.

PLANNING CARDS—A small card containing a idea or point placed in sequence on a storyboard.

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

PLATE FINISH—A smooth surfaced paper.

PLY—A single layer of drawing paper.

Continued on next page

P (Continued)

POINT—A standard type measure of 1/72 of an inch or 72 points equals 6 picas.

POLYMER—Paints that have polyvinyl acetate or acrylic resin as a binder used as either a transparent or opaque medium.

POLYGON—Common geometric constructions.

PORTRAITURE—The process or art of depicting an individual by drawing, painting, or photographing from life.

PORTRAY—To delineate or depict.

POSTER—A large cardboard or paper display sign.

POSTER BOARD—A medium weight cardboard suitable for show cards.

POSTER COLOR—An opaque watercolor used for making show cards.

POSTERIZATION—A technique for adding poster-like qualities to a photograph, a film, or an illustration by separating the normal tones of a subject into distinctly separated, strong tones.

POUNCE—A powdered substance that improves the ink-absorbing qualities of tracing cloths and papers.

PRELIMINARY DRAWINGS—Drawings done in preparation for a finished piece of art.

PRE-PRESS—The preparatory stage of art or copy immediately before committing the image to a plate.

PRIMARY COLORS—The red, yellow, and blue in a subtractive process and the red, yellow, and green in the additive process of color theory.

PRINT—An image made from a master negative or plate.

Continued on next page

P (Continued)

PRINTING—A process for reproducing copy.

PRINTING PLATE—*Also called* CUT. A flat piece of metal used on a printing press that contains the image either engraved or etched photographically on the surface.

PRISM—A transparent piece of crystal or optical glass having two plane surfaces which are not parallel that separate white light into the visible colors of the spectrum.

PROCESS COLOR REPRODUCTION—A combination of halftone plates, usually red, yellow, blue, and black, which when printed in perfect register, combine to produce a full-color reproduction.

PRODUCTION DEPARTMENT—The people responsible for purchasing and maintaining schedules on printing, typography, engravings, bindings, paper, and sometimes the purchase of art for an organization.

PROGRESSIVE PROOFS—Proofs showing the order of printing and shade of ink for each required plate.

PROGRESSIVE DISCLOSURE—Systematically revealing information on a partially obscured visual.

PROJECTION—The act or art of projecting lines and planes in orthographic and perspective drawings.

PROJECTOR—A device containing a light and lenses for projecting an image onto another surface.

PROJECTURAL—(1) An image projected onto another surface; (2) The image so projected.

PROOF—A printed impression from a negative, a plate, or a body of type submitted for examination or correction.

Continued on next page

P (Continued)

PROOFREADER'S MARKS—Standard marks placed in the margin nearest the word that indicate corrections in typeset copy.

PROPORTION—The relation to size of one part or thing to another or one portion of something to the whole.

PROPORTIONAL DIVIDERS—A drafting instrument used for transferring measurements from one scale to another or to divide lines and circles into equal parts.

PROPORTIONAL SPACING—*Also called* DIFFERENTIAL LETTERSPACING. The spacing of characters in proportion to size by means of the typewriters and office composing machines used in the preparation of cold composition copy.

PROPS—Accents or accessories that identify the time frame or location of a subject.

PROTRACTOR—A circular or semicircular rule for measuring off the degree of an angle.

Q

QUILL PEN—*See* CROW QUILL. A pen nib made from a feature quill.

R

RADIAL FILL—To fill an object with color, pattern, or shade that appears to radiate from the center of the object.

RADIATION—A divergence of lines, tones, or colors from a common point to different directions.

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

RADIUS CURVE—A drawing tool used to draw arcs of a predetermined radius.

Continued on next page

R (Continued)

RANDOM ACCESS MEMORY—*Also called* RAM. Retrievable computer memory accessible at will without sequential reading.

RANGEFINDER—The ground glass in a camera used to focus an image.

RASTER-BASED—An image based on the manipulation of a matrix of pixels or dots.

RASTER IMAGE PROCESSOR—*Also called* RIP. A device for converting vector-based imagery to high-resolution raster images.

READ—To access electronically stored data.

REAR PROJECTION SCREEN—A matte surface, translucent screen used when projecting an image from behind to a screen.

REBOOT—Restart the computer system.

RECEDING COLORS—Colors that appear to move away or create the illusion of distance.

RECTANGULAR COORDINATE GRAPH—A graph based on a grid system where values are plotted by X and Y coordinates.

REFERENCE NUMBERS—Numbers used on one drawing to refer to another drawing for further details.

REFERENCE PLANE—The normal plane used to reference all information.

REGISTER—To align a page or any elements of an image or impression to match the position of successive impressions.

REGISTER MARKS—Marks used to key an overlay to a drawing or mechanical as in color separation or combination plates.

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

Continued on next page

R (Continued)

RENDER—To represent, portray, or depict in a drawing or painting.

RENDERING—A drawing or painting in which tonal values vary from white through black or from light to dark shades.

REPRODUCIBILITY—The ability of line and halftone copy to reproduce as acceptable and legible.

REPRODUCIBLE ART—Second-generation art made from the original art and mortised or pasted onto the reproduction page.

REPRODUCTION—Making one or more copies of an original piece of work.

REPRODUCTION COPY—*Also called* CAMERA-READY COPY. Copy ready in all respects for photomechanical reproduction.

REPRODUCTION PROOFS—*Also called* REPROS. Exceptionally clean, sharp proofs on a highly coated paper used for reproduction.

REPROGRAPHICS—The reproduction of images by copying machines and their methods and processes.

RESCALE—To enlarge or reduce in size or to change in shape without changing proportion to fit new space configurations.

RESEARCH FILE—*See* MORGUE, PICTURE MORGUE, or CLIP ART.

RESOLUTION—Clarity, focus, or density.

RETOUCH—To delete unwanted image areas or make repairs to copy by painting out with an opaque solution.

RETOUCH GRAYS—A series of opaque watercolors ranging from white to black.

Continued on next page

R (Continued)

RETOUCHING—The alteration of detail or removal of spots and blemishes in a photographic print or negative.

RETOUCH VARNISH—A light, colorless varnish sprayed on a dull, dried-out area or an unfinished oil painting to restore the "wet" colors or values, making it easier to mate with new paint.

REVERSE—*See* FLOP. To turn over.

REVERSAL—*See* REVERSE PRINT.

REVERSE PRINT—A print where the black values of the originals are white.

REVISION BLOCK—Space located in the upper-right corner of a drawing to record any changes to the original drawing.

REVOLVED SECTION—A drawing of the internal cross section of an object superimposed on the basic drawing of the object.

ROMAN—One of a group of alphabets or typefaces characterized by thick and thin strokes and often with serifs.

ROSS BOARD—An illustration board that comes in a variety of roughened surfaces that divide crayon or brush strokes into broken textures suitable for reproduction.

ROTATION—A view in which the object is rotated or turned to reveal a different plane or aspect.

ROUND BRUSH—A cylindrical brush having an evenly tapered point.

RUBBER CEMENT—Semitransparent glue consisting of gum rubber and a petroleum or benzol solvent.

RUB-ONS—Transfer sheets containing reprinted characters, symbols, and numerals applied by burnishing over an acetate or paper back sheet.

Continued on next page

R (Continued)

RULING PEN—An instrument that holds ink between two adjustable blades.

RUNNING HEAD—The title repeated at the top of consecutive pages in a book or magazine.

S

SABLE BRUSH—A flat or round-shaped brush made from the tail hair of a Kolinsky (Asiatic) mink.

SAFELIGHT—A colored light used to illuminate a darkroom without harming photosensitive film or paper.

SANDPAPER PAD—A pad of sandpaper sheets mounted on a strip of wood used to sharpen a pencil lead or pastel.

SANS SERIF—Without serifs, a letter that does not have a finishing stroke.

SATURATION—The purity or intensity of color.

SCALE—(1) Proportions or relative dimensions; (2) To enlarge or reduce without changing the original proportions.

SCALE CLIP—A clip attached to a scale that focuses on the scale currently in use.

SCALE DRAWING—A drawing that shows relative sizes and proportions.

SCALING—*Also called* DIMENSIONING or SIZING. Enlarging or reducing copy or an image to the correct dimensions to occupy a given area.

SCANNING AREA—The total area or picture that the camera sees.

SCRAP FILE—*See* RESEARCH FILE.

SCRATCHBOARD—A type of illustration board with a chalky surface uniformly covered with ink.

Continued on next page

S (Continued)

SCREEN—A glass plate or film with crosshatched lines that photographically produces a halftone for reproduction from a continuous-tone original.

SCREEN PROCESS PRINTING—*Also called* SILKSCREEN. A form of stencil printing that uses silk, nylon, or metal screen to contain the image.

SCREEN REFRESH—A continuous update of computations that create the image on a computer screen.

SCRIPT—(1) Lettering based on hand writing; (2) A paper or papers that describe in detail all of the elements of a commercial or story.

SCROLL—A rapid up-or-down movement of a computer screen image during a search function.

SECONDARY COLORS—The colors (orange, green, and violet) that lie halfway between the three primary colors.

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

SECTIONAL VIEW—The view obtained by cutting away part of an object in an illustration to show the shape and construction of the interior.

SEPIA—A dark, warm brown color of low brilliance.

SEPIA INTERMEDIATE—An intermediate used in making duplicate transparencies by the whiteprint process.

SERIF—The finishing stroke or line projecting from the end of the main stroke of many letters in some typefaces.

SET PALETTE—One hue mixed with a group of colors to create color harmony or unity in a chosen palette.

Continued on next page

S (Continued)

SETTING—Background or surrounding.

SHADE—A mixture of pure color and black.

SHADING—Lines, values, or color applied to create form, shadow, or pattern.

SHADING MEDIUMS—Preprinted tones and patterns used to enhance the appearance of copy and artwork.

SHADING SHEETS—Sheets of cellophane or acetate preprinted with tones and patterns with a low—tack adhesive for applying to artwork.

SHAPE—The flat silhouette or two-dimensional form of an object.

SHELF LIFE—The length of time before sensitized material deteriorates.

SHIP'S CURVES—Instruments for drawing elongated, irregular curves that closely approximate the curves found in shipbuilding.

SHUTTER SPEED—A method of controlling the length of time that light can reach a film.

SIGHT LINE—An imaginary line extending from the eyes of a figure in a drawing to an object indicating that person's direction of glance.

SINGLE-ACTION AIRBRUSH—A device that releases both air and pigment by pressing down on a button.

SIGNATURE—A sheet of paper printed on both sides and folded to make up part of a publication.

SILHOUETTE—An outline of an object or figure filled in solidly without indication of modeling or surface structure.

SILKSCREEN—A method of printing through a stencil fixed to a screen of natural or synthetic fiber or metal mesh.

Continued on next page

S (Continued)

SIZE—*Also called* SIZING. Various gelatinous materials made from starch, clay, glue, and casein used for glazing or coating papers and cloths.

SKETCH—A quickly executed drawing as a preparation toward more finished work.

SKETCHING PENCIL—*See* CARPENTER'S PENCIL. A soft-leaded pencil used for freehand sketching.

SMALL CAPS—Capital letters smaller than the standard capitals of a typeface and the size of the body of the lowercase letters.

SODIUM THIOSULFATE—*Also called* HYPO. A salt with water solution that dissolves the silver halides used in photographic papers and films.

SOFT EDGE—A blended or graduated transition from one value or color to another.

SOFTWARE—Computer programs that direct the output devices and determine the input devices effectivity.

SPECIAL EFFECTS GENERATOR—A device that adds or creates effects to visual images during recording on videotape.

SPECIAL IRREGULAR CURVE—Irregular curves for a specific purpose, such as ship's curves, mechanical engineer's curves, conic sections, logarithmic spirals, and flexible curve rules.

SPECTRUM—The arrangement of colors side-by-side as refracted by a prism.

SPEEDBALL PENS—Lettering and drawing pens manufactured by the Hunt Manufacturing Company that are the hallmark of hand lettering pen nibs.

SPEED LINES—Extra lines following a moving figure or object in a cartoon representing the disturbance the movement causes in the atmosphere.

Continued on next page

S (Continued)

SPHERE—A form where all points are equidistant from the center.

SPINE—The bound edge of a book.

SPLINE—A flexible rule, held in place by lead ducks, used to draw irregular curves.

SPLIT BRUSH TECHNIQUE—*Also called* DRY BRUSH TECHNIQUE. Painting or drawing with a brush having the hairs separated to form more than one point.

SPLIT COMPLEMENT—A color scheme that uses a key hue with the two colors that lie adjacent to its opposite on the color wheel.

SPLIT FIELD—A rangefinder that focuses an image by dividing the image in half and requiring alignment into a whole.

SPOT COLOR—Using a combination of two individual colors, a main color, usually black, and an accent color instead of a full-color output.

SQUEEGEE—(1)An implement used on silk process printing presses that forces ink and ink compounds through the screen and stencil onto a printing surface to form the image; (2) The process of forcing pigment across a surface with other than a brush.

STABILIZER—A chemical that arrests the continued development of an image and fixes that image into the surface.

STABILO PENCIL—A pencil that uses grease or wax as a binder for pigment and is capable of writing on glass.

STAT—*See* PHOTOSTAT.

STATIC—Lacking in movement.

STATION POINT—The point of observation in the making of perspective drawings.

Continued on next page

S (Continued)

STILL LIFE—A pictorial arrangement of inanimate objects.

STIPPLE—The effect obtained by using a series of dots or flicks in drawing.

STOCK—Material printed or worked on by printers or artists.

STOP BATH—A chemical solution that stops photographic development.

STOPPER—An eye-catching device in a picture that grabs and holds a viewer's attention.

STORYBOARD—A panel presentation of rough sketches of a proposed series of views.

STRAIGHTEDGE—An instrument with long, straight edges.

STRIP IN—To position copy not pasted up on the mechanical before platemaking.

STRIPPING—Cutting out and placing in position.

STUDIO CARD—Illustration or pictorial information on a card intended for television transmission.

STUMP—A pencil-shaped roll of paper used to blend pastel, pencil, and charcoal.

STYLIZED—Characterized by an emphasis on style and design.

STYLUS—A scraping instrument with sharp or chiseled edge.

SUBHEAD—A secondary headline or title.

SUBTRACTIVE COLOR PROCESS—The process of forming colors by mixing pigments.

Continued on next page

S (Continued)

SUBORDINATION—Subduing part of a picture to make it less important than another part.

SUPERIMPOSED—*Also called* SUPER. One image or text placed over another without totally obscuring the first.

SUPERIMPOSED IMAGE—A rangefinder that focuses an image by requiring the alignment of two images over each other.

SUPPORT—The reinforcement or backing for a painted surface.

SURREALISM—An art movement whose objective is to explore the realm of unconscious emotion and dreams.

SWATCH—A small sample specimen.

SWEDE PEN—A broad nibbed, adjustable ruling pen.

SWIPE FILE—*See* RESEARCH FILE.

SYMBOL—A visual element that represents something else.

SYMMETRY—Similarity in size, shape, and relative position of parts on opposite sides of a dividing line.

T

TABOURET—A portable cabinet used to hold the artist's drawing tools and materials.

TEAR SHEETS—*Also called* CLIP ART and PICTURE MORGUE.

TECHNICAL ILLUSTRATION—Drawings for technical reports, proposals, manuals, and catalogs, as well as visual aids, briefing charts, projecturals, slides; and posters.

TECHNIQUE—(1) The method of using a tool or medium; (2) The characteristic appearance of a medium; (3) The particular style of an artist.

Continued on next page

T (Continued)

TELEPHOTO LENS—A long focal-length lens that has the effect of bringing far objects nearer.

TELEVISION GRAPHICS—Graphics created specifically for transmission via television.

TEMPURA—Dry pigment mixed with an emulsion of egg yolk or milk to form an opaque watercolor.

TEMPLATE—A guide made to ensure the uniform consistency of frequently used symbols.

TERTIARY COLORS—Any intermediate hue that contains some part of each of the three primary colors.

TEXT—Typewritten or printed matter forming the main body of a work.

TEXTURE—The feel or appearance of a surface created by the repetition of forms or design.

THERMAL TRANSFER PRINTER—A printer that uses heat to fuse the image to a paper surface.

THIRD DIMENSION—The effect of depth or bulk achieved by the artist on a flat surface.

THREE DIMENSIONAL—Possessing height, width, and depth.

THREE-QUARTER VIEW—A view of an object rotated to a position halfway between a front and a side view.

THREE-POINT PERSPECTIVE—A view where no dimension, height, width, or depth, is parallel to the plane of projection.

THUMBNAIL SKETCH—Page layouts showing the allocation of space for headings, photographs, line artwork, and text.

Continued on next page

T (Continued)

THUMBSPOTS—Visual indicators placed on a slide mount to identify the emulsion side of the film and simplify tray loading.

TILING—A fill pattern effect that repeats a pattern over and over.

TILT CARD—A vertical card that requires up-and-down camera movement.

TIME LINE—A projected plan of execution outlining significant milestones and deadlines used to monitor work in progress closely.

TINT—A mixture of pure color and white.

TISSUE OVERLAY—Thin, translucent paper placed over artwork for protection and corrections.

TITANIUM WHITE—An opaque white.

TITLE BLOCK—Space in the lower right corner that contains the identity of the drawing, the subject matter, the origins, the scale, and other data.

TITLE CARD—A television card that contains text only.

TONAL—Having gradations of gray or intermediate values.

TONE—(1) A value usually predominate that sets the key; (2) A thin layer of paint applied to a ground to eliminate the whiteness of the surface before painting.

TOOL BOX—*See* BUTTON BAR.

TOOTH—The ability of the paper surface to accept various mediums.

TORTILLON—*Also called* STUMP or STOMP. Tightly rolled paper, leather, or felt used to blend charcoal, pastels, pencil, chalk, or crayon.

TOUCHÉ—A liquid-masking agent or lithographic crayon applied by brush to a lithographic plate or stone.

Continued on next page

T (Continued)

TOUCH SCREEN TECHNIQUE—Activating the pixels on a CRT screen through the touch of an electronic light pen or the fingertip.

TRACING PAPER—A thin, transparent, or translucent paper used for transferring an image from one surface to another by tracing.

TRACKBALL—*See* JOYSTICK or MOUSE.

TRAMMEL—A mechanical device used to draw an ellipse.

TRANSFER SHEET—Preprinted characters and symbols on cellophane or acetate used in preparing cold composition, camera-ready copy.

TRANSLUCENT—The characteristic of allowing light to pass through without permitting objects to be seen clearly through it.

TRANSPARENCY—Any transparent material intended for projection that bears an image.

TRANSPARENT—The characteristic of allowing light and objects to be seen clearly through it.

TRAPS—A slight overlap of the outline of an element to prevent white space from showing around the edges minimizing the effect of press plate misalignment.

TRIAD—The use of any three pigments equally spaced on a color wheel.

TRIANGLE—A triangular shaped ruling guide available in various sizes and angles usually made of clear plastic or metal.

TRIM MARKS—Marks used on printed sheets or other substrate to indicate where to cut or trim stock both vertically and horizontally.

TRIMETRIC PROJECTION—An axonometric projection of an object where no two axes make equal angles with the plane of projection requiring three different foreshortening ratios.

Continued on next page

T (Continued)

T-SQUARE—A ruling guide with a 90° angled crosspiece at one end used in making horizontal lines.

TURPENTINE—A solvent distilled from the sap of pine or from pine wood used as a thinner and to clean brushes.

TUTORIAL—A lesson guide.

TWO DIMENSIONAL—Flat, without depth, having only width and height.

TWO-POINT PERSPECTIVE—*Also called* ANGULAR PERSPECTIVE. The most common type of perspective drawing where the object is sitting at an angle to the plane of projection and each object has two vanishing points.

TYPEFACE—The printing surface of an alphabet judged by its design, printability, wearability, and position on the letter body.

TYPE FAMILY—A group of typefaces similar although not exactly alike in design.

TYPE SERIES—Different sizes of the same typeface.

TYPESETTERS, PHOTOGRAPHIC—Machines that supply a variety of type designs and sizes, automatically letterspaced and justified on transparent film or plastic—coated opaque paper.

TYPOGRAPHY—The art of type selection and arrangement.

U

ULTRAVIOLET LIGHT—Actinic (shorter wavelength) or useable part of the light spectrum needed to react or harden light-sensitive coatings.

UNDERTONE—A color whose effect is modified by other colors imposed over them.

UNRETOUCHED—Not altered or improved by any means.

Continued on next page

U (Continued)

UPPERCASE—The capital letters of an alphabet.

USER INTERFACE—The visual and physical attributes of a software program including tools-, text-, and graphics-handling characteristics.

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

V

VALUE—The relative lightness and darkness of different areas of the picture represented in tones, shading, line balance, and layout.

VALUE SCALE—The complete range of values from the lightest to the darkest.

VAN DYKE—A brownprint negative and sometimes a brownline positive.

VANISHING POINT—The point at which parallel lines receding from the observer appear to converge in a perspective drawing or photograph.

VARIGRAPH—A lettering device that allows manipulation of letter size, slant, and shape.

VARNISH—A solution made of a resin in a volatile medium.

VEHICLE—A liquid used as a carrier of pigment in paint.

VECTOR-BASED—Images based on a series of plotted points that define precise lines and geometric shapes.

VELLUM—A kind of fine, translucent paper resembling parchment or onion skin used for duplicating copies made with a whiteprint machine.

VELOX—A print of a photograph or other continuous-tone copy prescreened before paste-up or platemaking with line copy eliminating the need for a composite negative.

Continued on next page

V (Continued)

VERTICAL SCAN RATE—*Also called* FRAME RATE. The number of times per second a screen redraws an image.

VIDEO DIGITIZING CAMERA—A camera or film recorder attached to the front of a CRT screen used to record images.

VIDEO DISPLAY TERMINAL (VDT)—A visual display used in photocomposition work in conjunction with a keyboard.

VIEWING PLANE LINE—*See* CUTTING PLANE LINE.

VIEWGRAPH—*See* PROJECTURAL.

VIEWPOINT—The eye level of the viewer and the distance from the scene.

VIGNETTE—Fading an image from heavier to lighter tones blending it into the background or eliminating the background altogether.

VISIBLE LINE—The outline used for all edges seen by the eye.

VISUALIZING PAPER—A white, semitransparent paper used for making layouts and preliminary drawings.

VISUAL LITERACY—The ability to communicate effectively using only visual language.

W

WARM COLORS—Colors associated with heat or fire.

WASH—A monochromatic rendering with a brush and transparent watercolor.

WASH DRAWING—A watercolor painting consisting mainly of washes.

WATERCOLOR—A dry pigment bound by an adhesive, such as gum arabic, and applied, greatly reduced by water, to a surface in a transparent fashion.

Continued on next page

W (Continued)

WAXER—A device that applies a thin layer of hot, adhesive wax to the back of a surface.

WET BRUSH—A blending technique of laying two pigments side-by-side and blurring the line of demarcation while the pigments are still wet.

WHITE LEAD—A fine, poisonous, opaque white pigment used in flake white and Cremnitz white oil paints.

WIDE ANGLE LENS—A very short focal-length lens that encompasses a larger horizontal view than a standard lens. This lens, depending on the focal length, records an image with increasingly pronounced (barrel) distortion.

WINDOW—*See* BLACK PATCH.

WORD PROCESSING—The transformation of a concept or idea into printed communication media by using mechanical or automated systems, methods, or processes.

WORD SPACING—The adjustment of spacing between words to shorten or extend a line to achieve justification.

WORKING DRAWING—A thorough preliminary drawing done on tracing paper then transferred to a working surface for the finished rendering.

WOVE PAPER—A broad range of papers having an even fiber formation produced over fine wire mesh.

WRAPPING—(1) A computer feature that automatically enters a soft return reveal code and continues to enter data from the same sentence on another line; (2) Selecting a pattern or design and wrapping it around an object on the screen.

WRICO—A hand-lettering system using a set of templates and a drop fed pen.

Continued on next page

X

XEROGRAPHY—A copying process that uses electrostatic forces to form an image.

Z

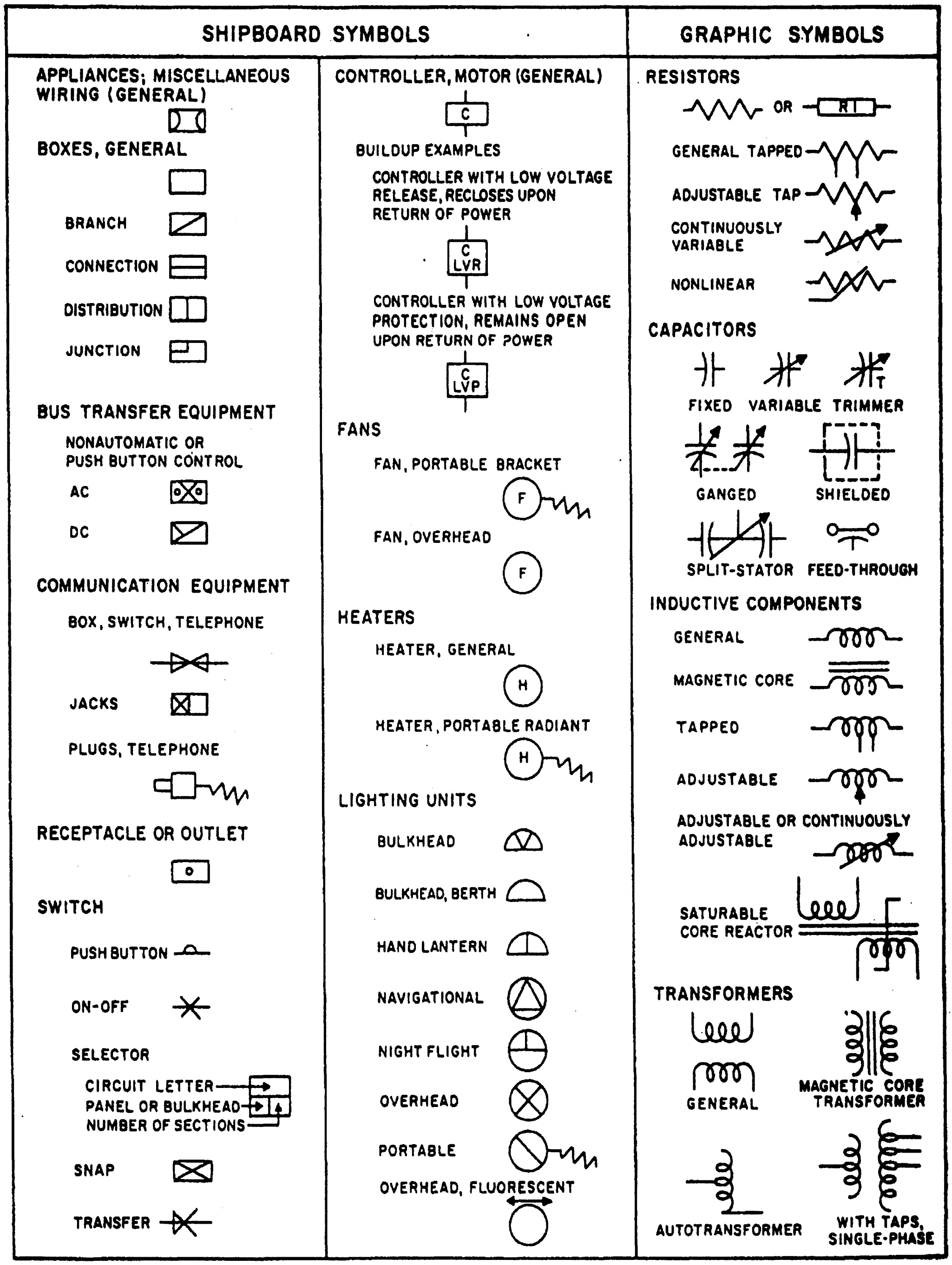
ZINC WHITE—A zinc-oxide based pigment that is less opaque than titanium and lead white.

ZIP-A-TONE—A transparent acetate sheet preprinted with patterns of dots or lines that create tone.

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

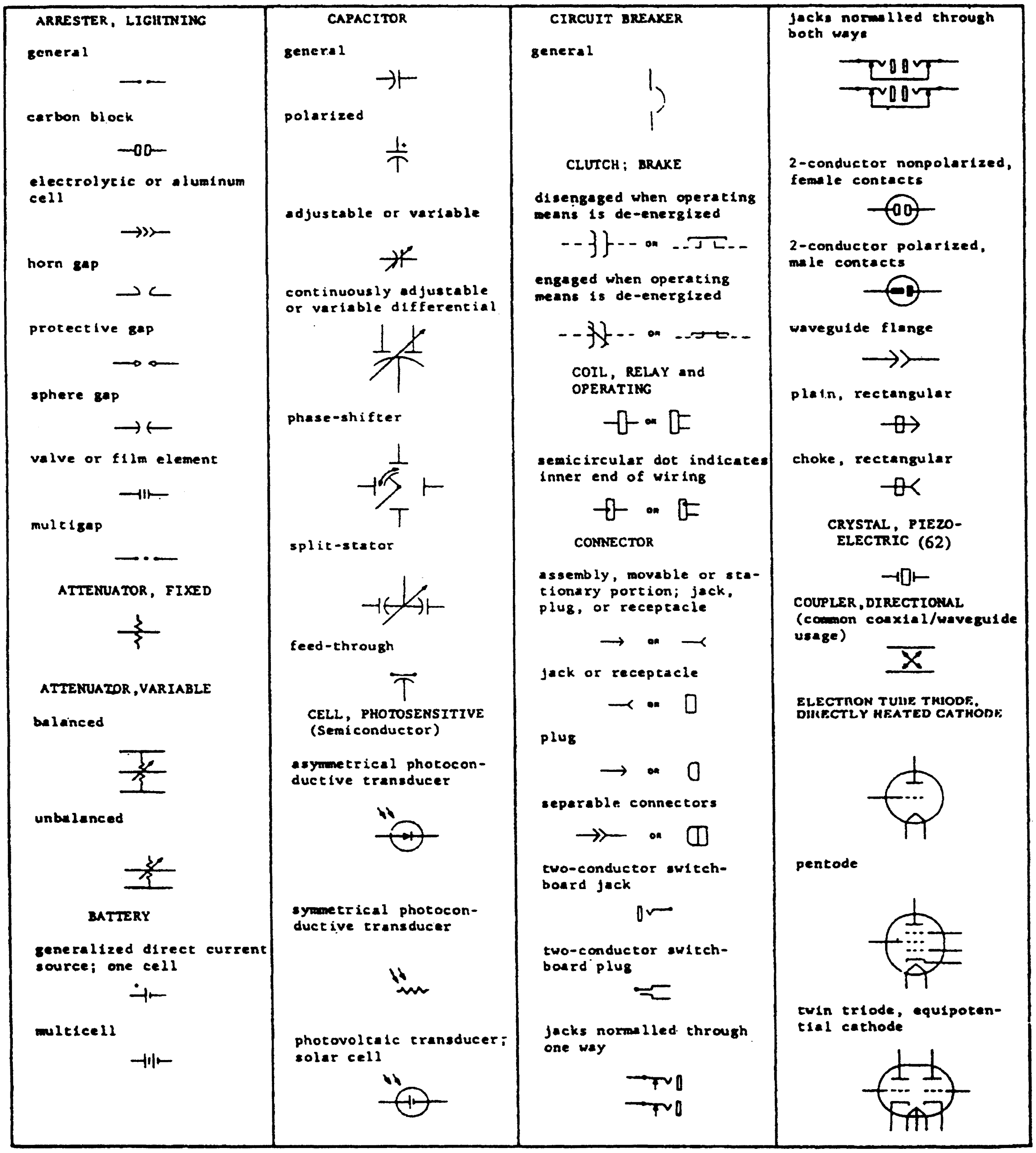
ZOOM LENS—A variable focal-length lens that functions as a telephoto lens but allows you to select the range of the object magnification.

APPENDIX II
Graphics Symbols for Electronic Diagrams



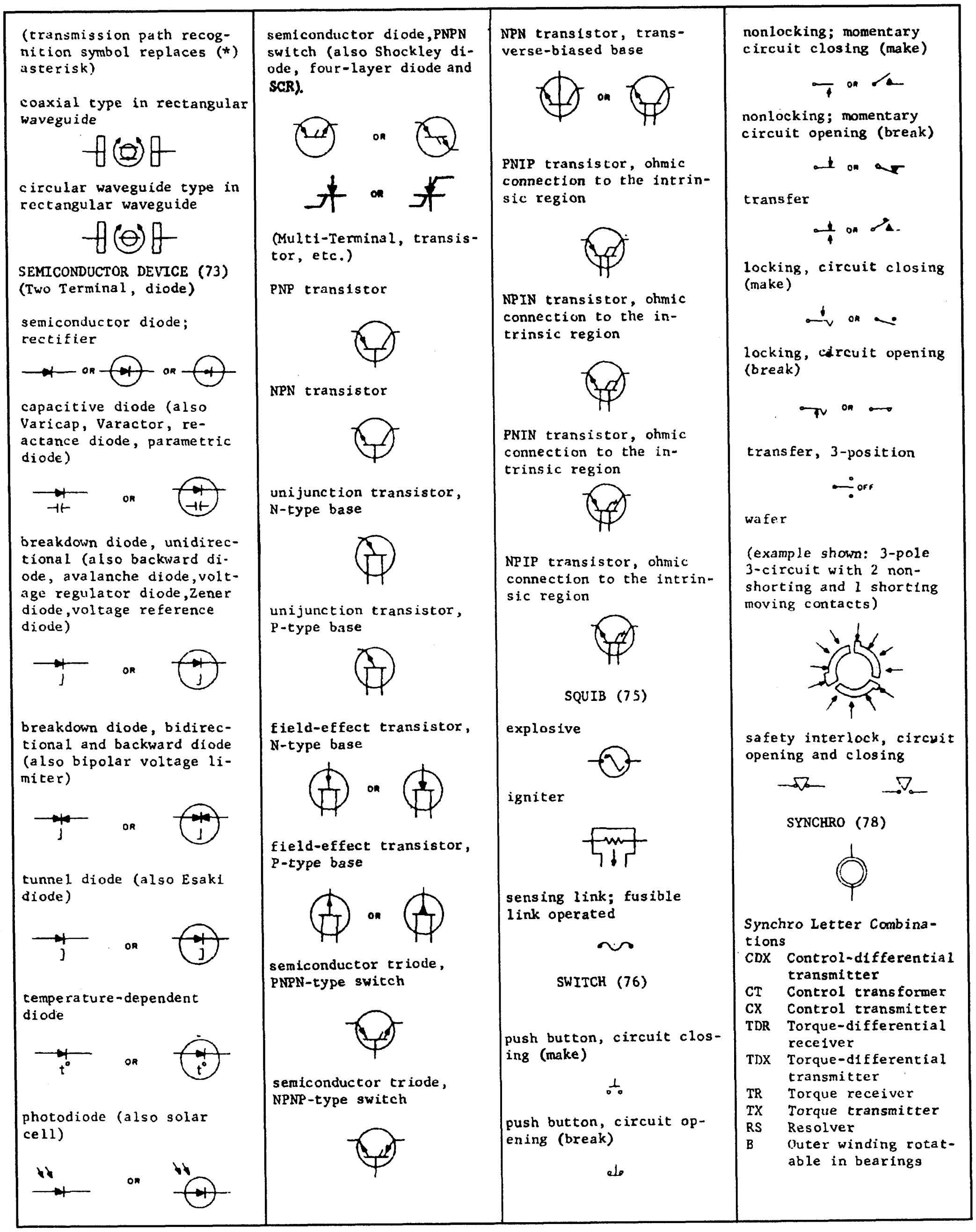
APPX II-1

Graphic Symbols for Electronic Diagrams



APPXII-2

Graphic Symbols for Electronic Diagrams



(transmission path recognition symbol replaces (*) asterisk)

coaxial type in rectangular waveguide

circular waveguide type in rectangular waveguide

SEMICONDUCTOR DEVICE (73)
(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

OR

photodiode (also solar cell)

OR

semiconductor diode, PNPN switch (also Shockley diode, four-layer diode and SCR).

OR

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 (75)

explosive

igniter

sensing link; fusible link operated

SWITCH (76)

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

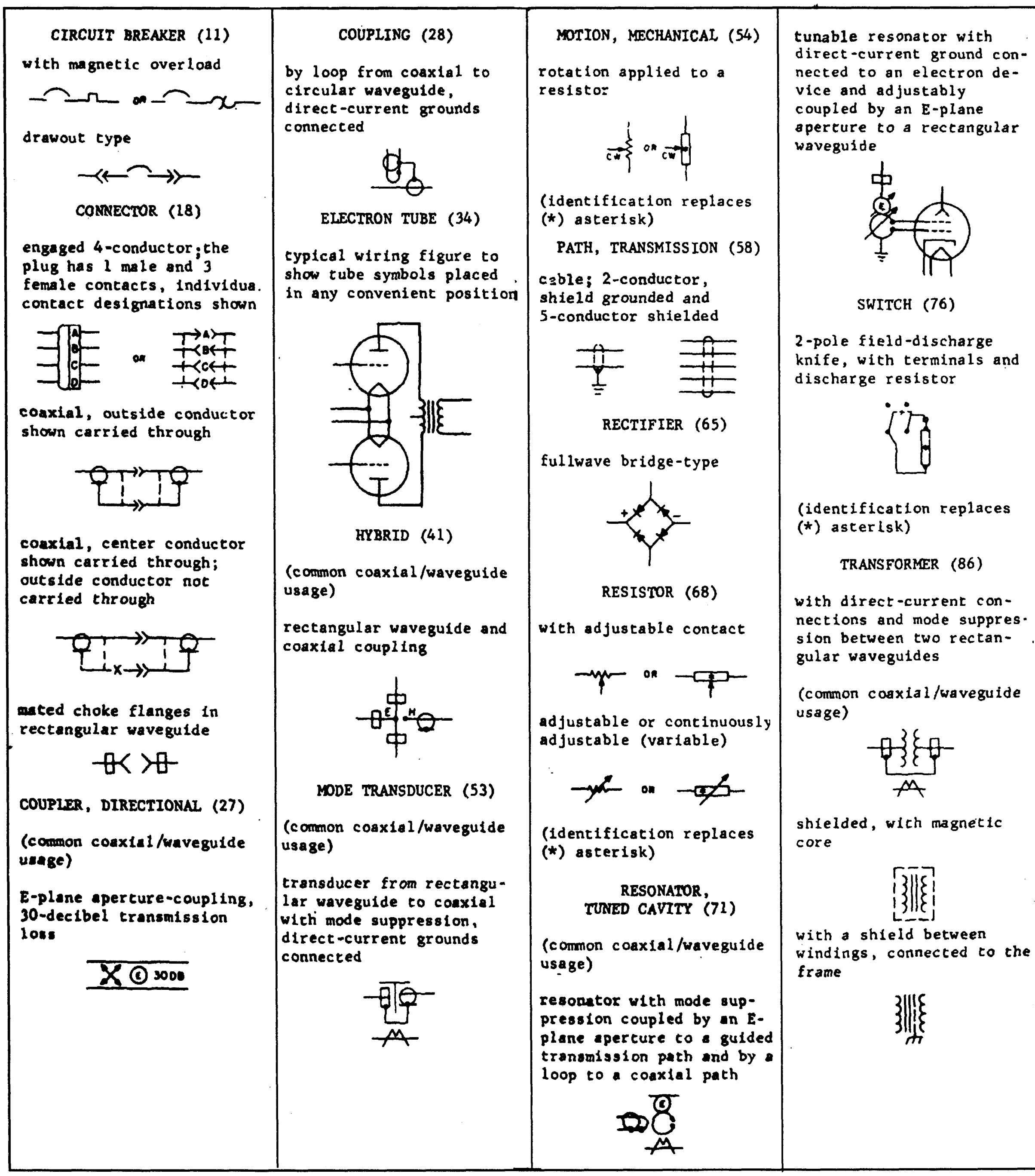
SYNCHRO (78)

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
B	Outer winding rotatable in bearings

APPXII-3

Graphic Symbols for Electronic Diagrams



CIRCUIT BREAKER (11)

with magnetic overload

drawout type

CONNECTOR (18)

engaged 4-conductor;the plug has 1 male and 3 female contacts, individua. 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 (27)

(common coaxial/waveguide usage)

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

COUPLING (28)

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

ELECTRON TUBE (34)

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

HYBRID (41)

(common coaxial/waveguide usage)

rectangular waveguide and coaxial coupling

MODE TRANSDUCER (53)

(common coaxial/waveguide usage)

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

MOTION, MECHANICAL (54)

rotation applied to a resistor

(identification replaces (*) asterisk)

PATH, TRANSMISSION (58)

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

RECTIFIER (65)

fullwave bridge-type

RESISTOR (68)

with adjustable contact

adjustable or continuously adjustable (variable)

(identification replaces (*) asterisk)

RESONATOR, TUNED CAVITY (71)

(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 (76)

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

(identification replaces (*) asterisk)

TRANSFORMER (86)

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

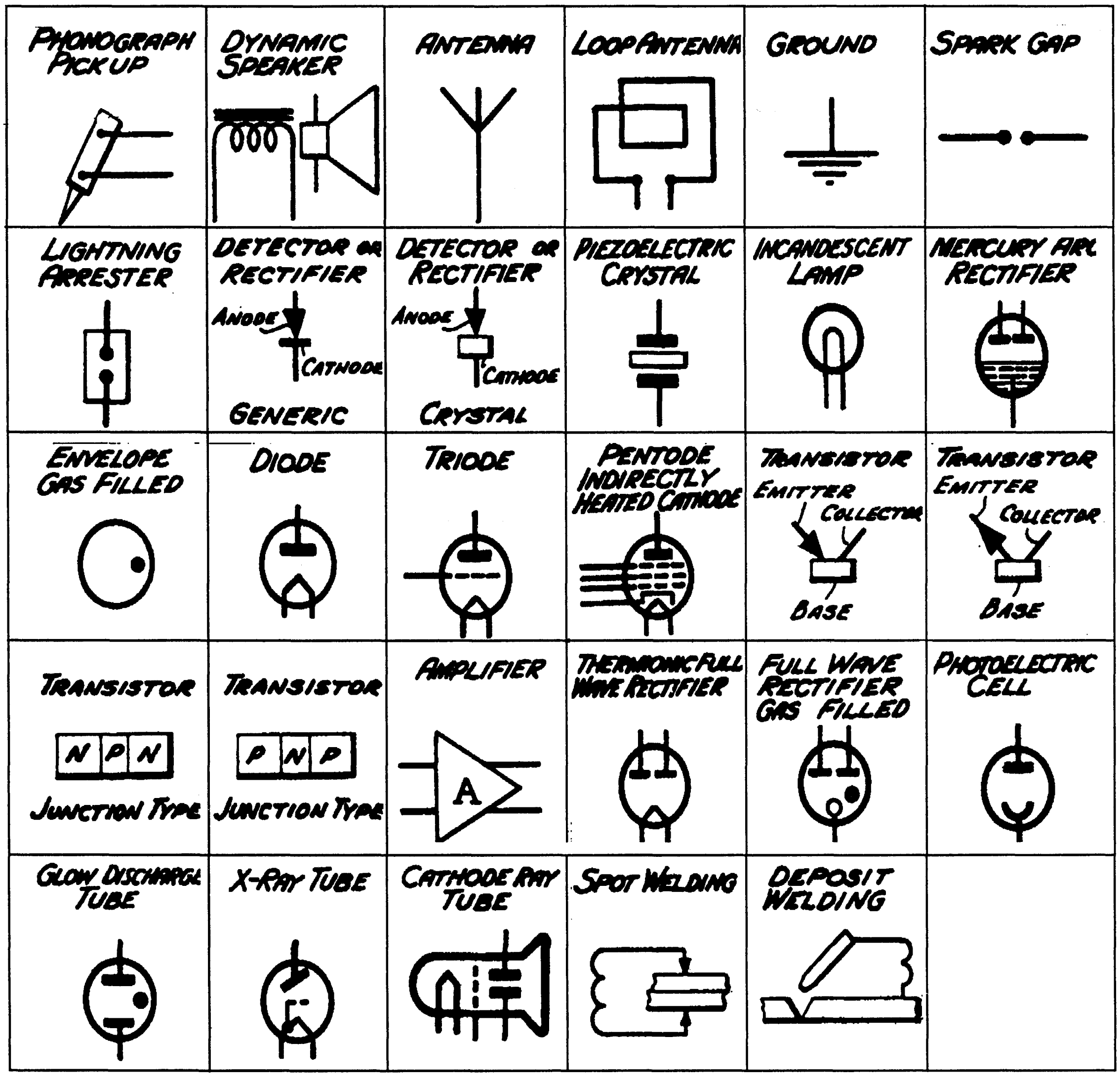
(common coaxial/waveguide usage)

shielded, with magnetic core

with a shield between windings, connected to the frame

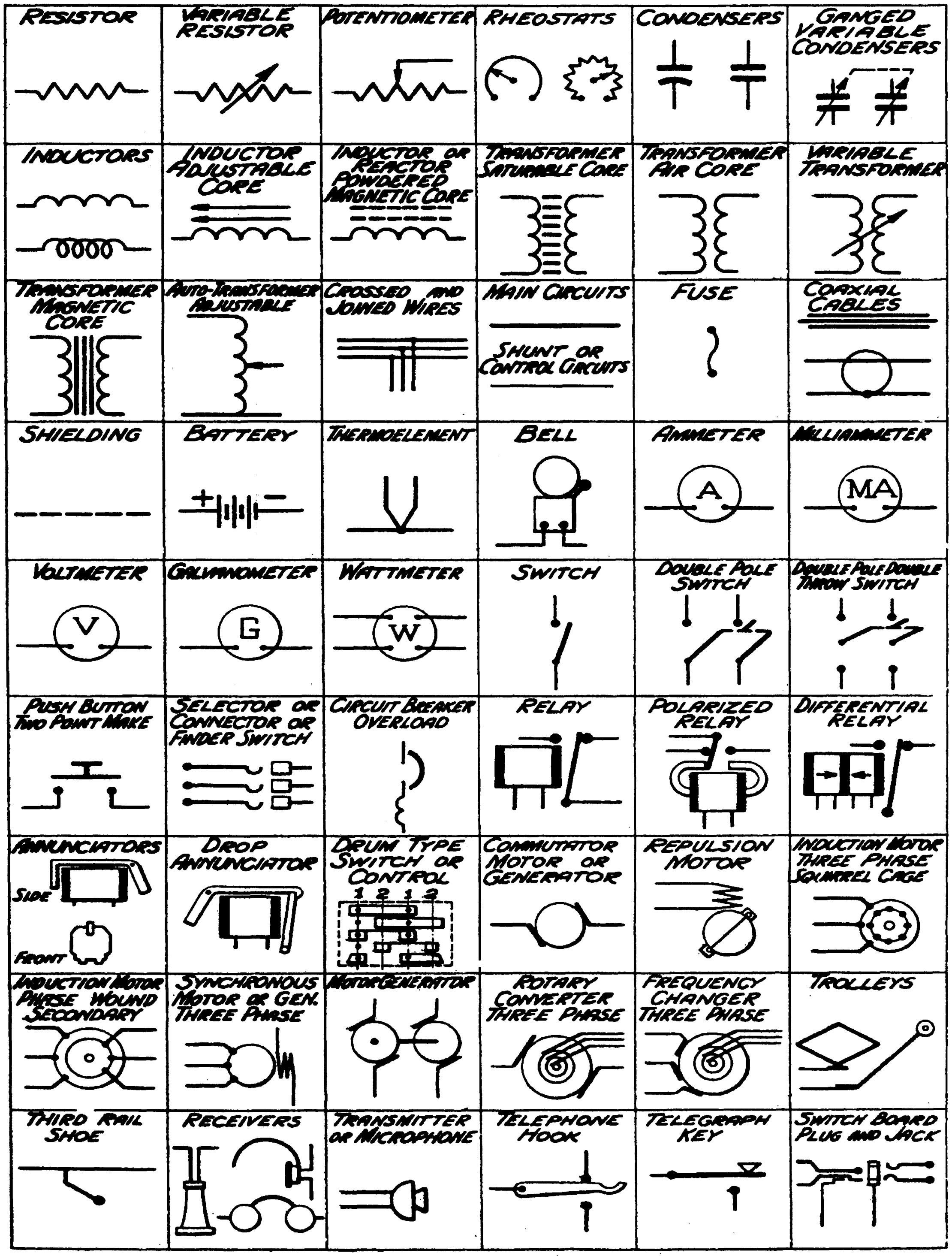
APPXII-4

APPENDIX III
General Electrical Symbols



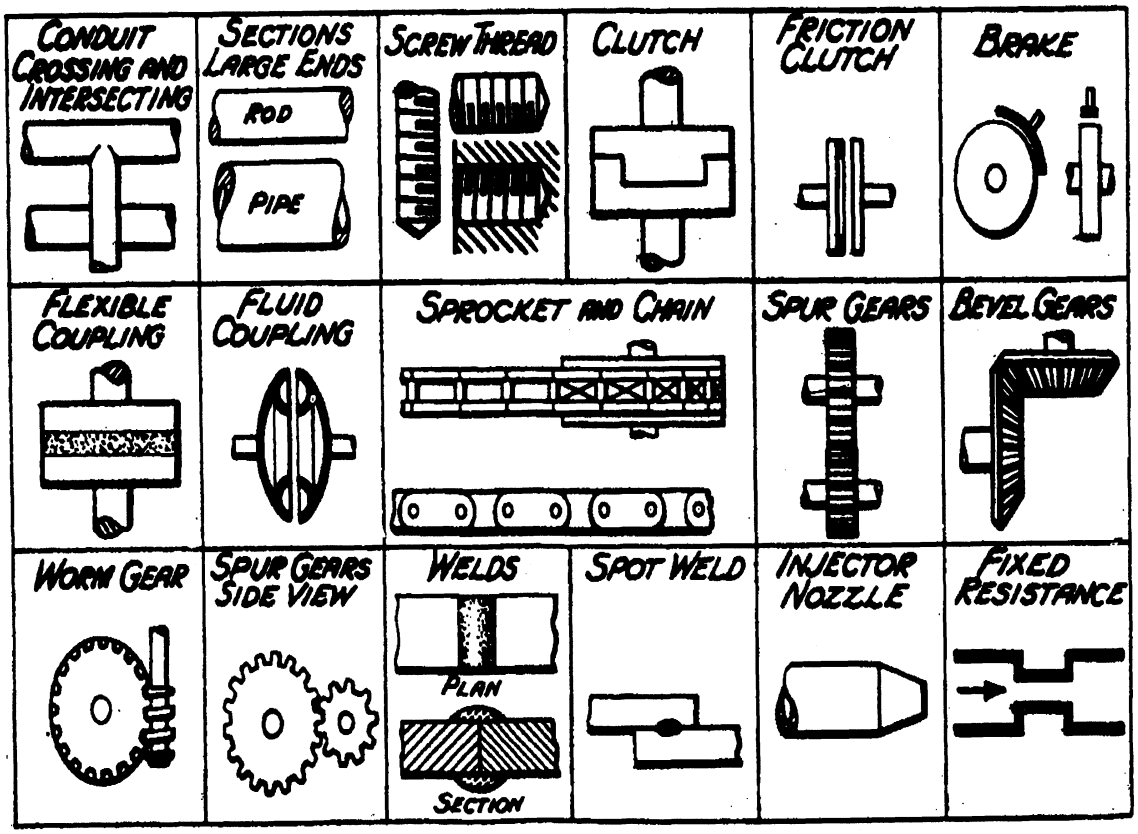
APPXIII-1

General Electrical Symbols



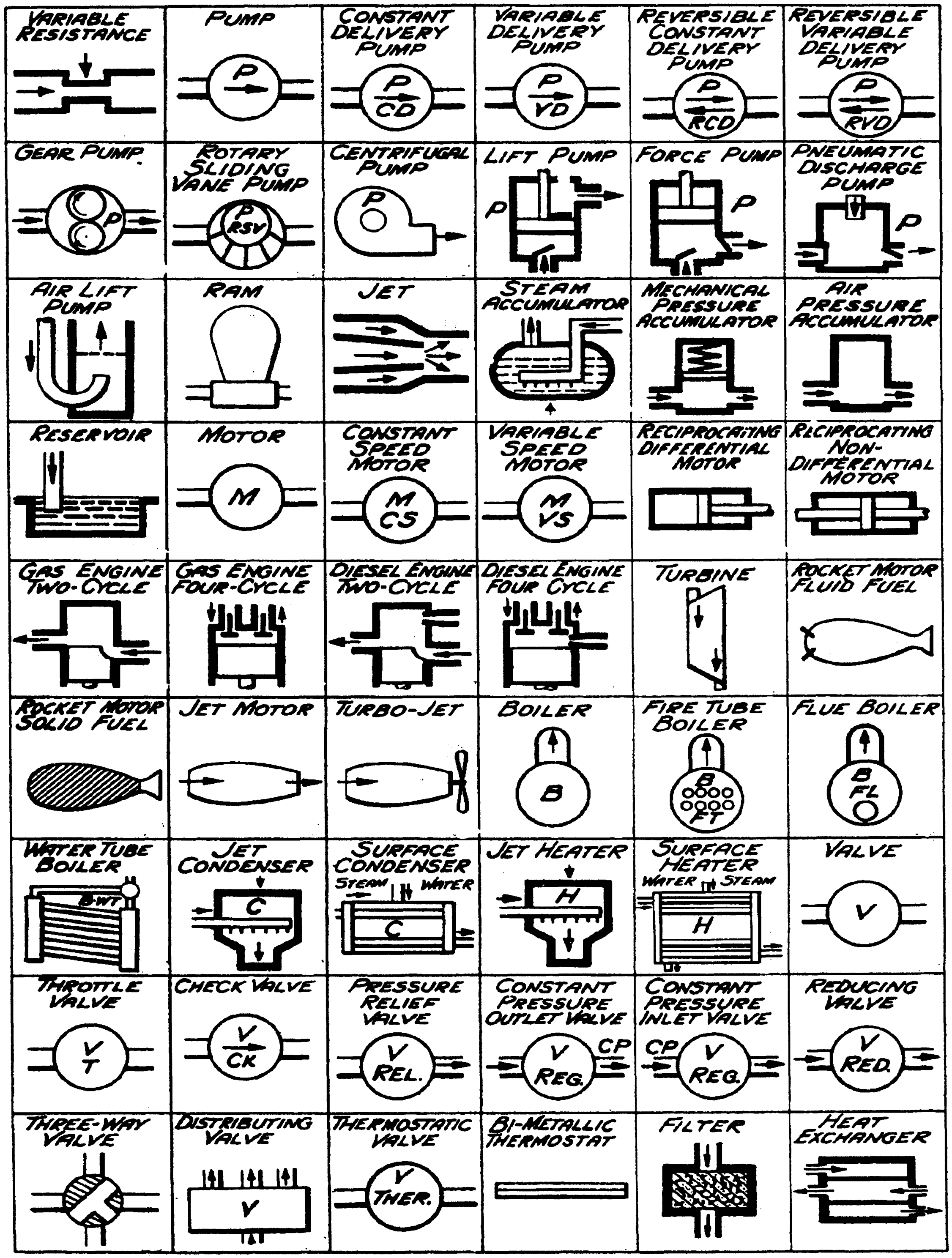
APPXIII-2

APPENDIX IV
General Mechanical Symbols



APPX.IV-1

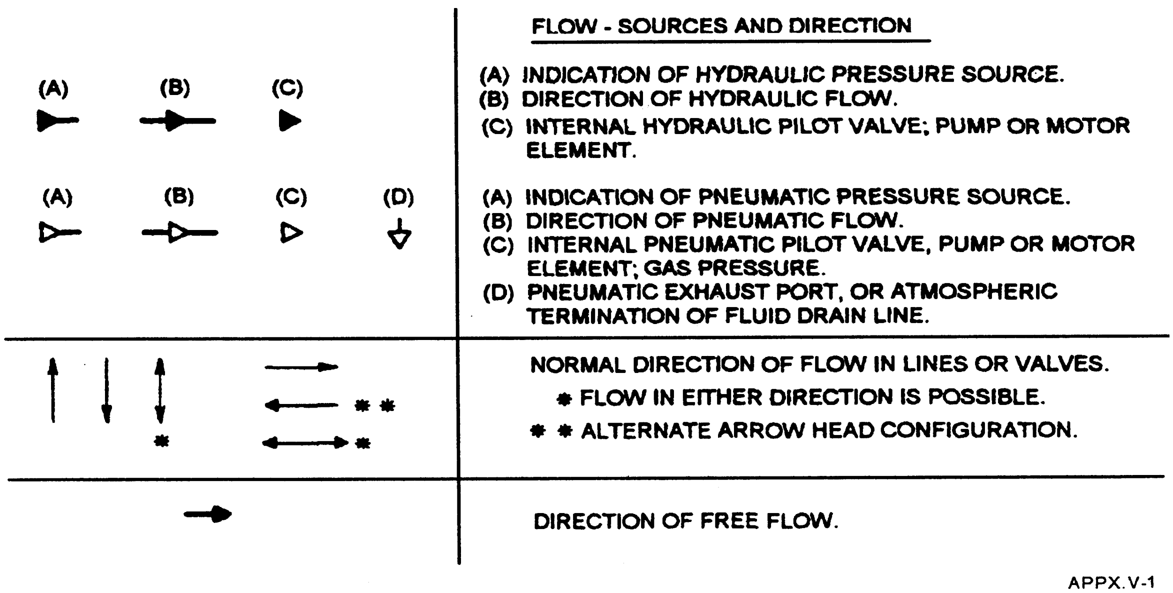
General Mechanical Symbols



APPX.IV-2

APPENDIX V
Graphic Symbols
for
Aircraft Hydraulic and Pneumatic Systems

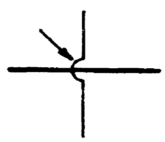
FLUID FLOW LINES - GENERAL



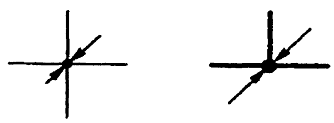
Graphic Symbols
for
Aircraft Hydraulic and Pneumatic Systems

FLUID FLOW LINES - GENERAL

CROSSING/JOINING

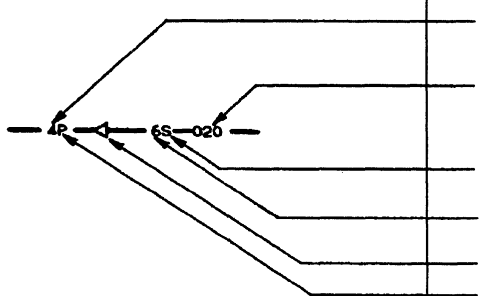


LINES CROSSING.



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.

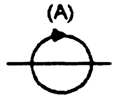
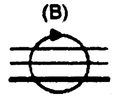
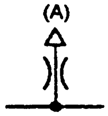
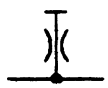
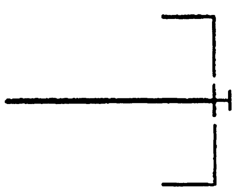
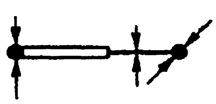
FUEL LINE. TO COMPLETE OIL-FUEL HEAT EXCHANGER SYMBOL WHERE NO OTHER FUEL LINE STANDARD EXISTS.

CAPILLARY LINE.

APPX.V-2

Graphic Symbols
for
Aircraft Hydraulic and Pneumatic Systems

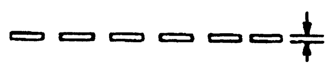
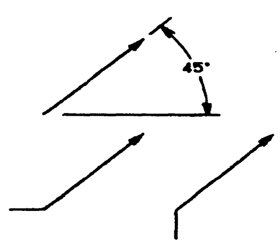
CONNECTORS - FLEXIBLE LINE

Symbol	Description
	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).

APPX.V-3

Graphic Symbols
for
Aircraft Hydraulic and Pneumatic Systems

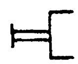
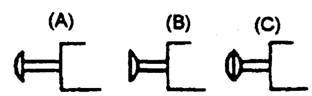
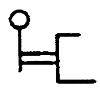
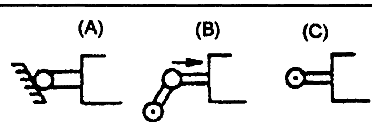
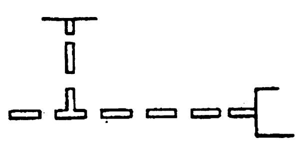
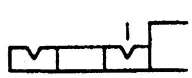
MECHANICAL, ELECTRICAL, AND FUNCTIONAL

	MECHANICAL LINKAGE.
	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.

APPX.V-4

Graphic Symbols
for
Aircraft Hydraulic and Pneumatic Symbols

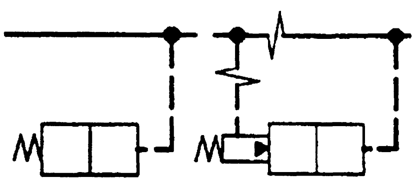
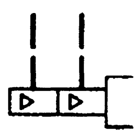
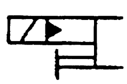
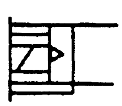
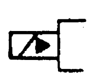
CONTROLS

	SPRING FOR VALVE CONTROL.
	MANUAL CONTROL
	(A) PUSH BUTTON (B) PULL BUTTON (C) PUSH-PULL BUTTON
	LEVER
	(A) PEDAL (B) TREADLE
	(A) MECHANICAL - GENERAL SYMBOL (B) PLUNGER
	(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.

APPX.V-5

Graphic Symbols
for
Aircraft Hydraulic and Pneumatic Systems

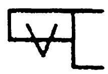
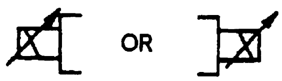
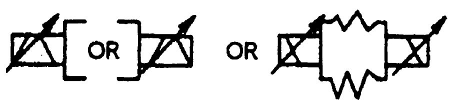
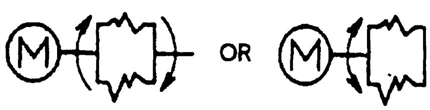
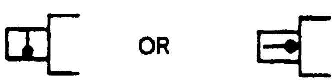
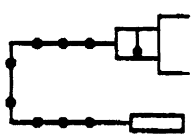
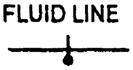
CONTROLS

	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

APPX.V-6

Graphic Symbols
for
Aircraft Hydraulic and Pneumatic Systems

CONTROLS

	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 VI

Trigonometric Functions

deg	sin	cos	tan	cot		deg	sin	cos	tan	cot	
40.0	0.6428	0.7660	0.8291	1.1918	50.0	43.0	0.6820	0.7314	0.9325	1.0724	47.0
.1	.6441	.7649	.8421	1.1875	.9	.1	.6833	.7302	.9358	1.0686	.9
.2	.6455	.7638	.8451	1.1833	.8	.2	.6845	.7290	.9391	1.0649	.8
.3	.6468	.7627	.8481	1.1792	.7	.3	.6858	.7278	.9424	1.0612	.7
.4	.6481	.7615	.8511	1.1750	.6	.4	.6871	.7266	.9457	1.0575	.6
.5	0.6494	0.7604	0.8541	1.1708	.5	.5	.6884	.7254	.9490	1.0538	.5
.6	.6508	.7593	.8571	1.1667	.4	.6	.6896	.7242	.9523	1.0501	.4
.7	.6521	.7581	.8601	1.1626	.3	.7	.6909	.7230	.9556	1.0464	.3
.8	.6534	.7570	.8632	1.1585	.2	.8	.6921	.7218	.9590	1.0428	.2
.9	.6547	.7559	.8662	1.1544	.1	.9	.6934	.7206	.9623	1.0392	.1
41.0	0.6561	0.7547	0.8693	1.1504	49.0	44.0	0.6947	0.7193	0.9657	1.0355	46.0
.1	.6574	.7536	.8724	1.1463	.9	.1	.6959	.7181	.9691	1.0319	.9
.2	.6587	.7524	.8754	1.1423	.8	.2	.6972	.7169	.9725	1.0283	.8
.3	.6600	.7513	.8785	1.1383	.7	.3	.6984	.7157	.9759	1.0247	.7
.4	.6613	.7501	.8816	1.1343	.6	.4	.6997	.7145	.9793	1.0212	.6
.5	.6626	.7490	.8847	1.1303	.5	.5	.7009	.7133	.9827	1.0176	.5
.6	.6639	.7478	.8878	1.1263	.4	.6	.7022	.7120	.9861	1.0141	.4
.7	.6652	.7466	.8910	1.1224	.3	.7	.7034	.7108	.9896	1.0105	.3
.8	.6665	.7455	.8941	1.1184	.2	.8	.7046	.7096	.9930	1.0070	.2
.9	.6678	.7443	.8972	1.1145	.1	.9	.7059	.7083	.9965	1.0035	.1
42.0	0.6691	0.7431	0.9004	1.1106	48.0	45.0	0.7071	0.7071	1.0000	1.0000	45.0
.1	.6704	.7420	.9036	1.1067	.9						
.2	.6717	.7408	.9067	1.1028	.8						
.3	.6730	.7396	.9099	1.0990	.7						
.4	.6743	.7385	.9131	1.0951	.6						
.5	.6756	.7373	.9163	1.0913	.5						
.6	.6769	.7361	.9195	1.0875	.4						
.7	.6782	.7349	.9228	1.0837	.3						
.8	.6794	.7337	.9260	1.0799	.2						
.9	.6807	.7325	.9293	1.0761	.1						
	cos	sin	cot	tan	deg		cos	sin	cot	tan	deg

APPX.VI-1

Trigonometric Functions

deg	sin	cos	tan	cot		deg	sin	cos	tan	cot	
0.0	.00000	1.0000	.00000		90.0	4.0	.06976	0.9976	.06993	14.301	86.0
.1	.00175	1.0000	.00175	573.0	.9	.1	.07150	.9974	.07168	13.951	.9
.2	.00349	1.0000	.00349	286.5	.8	.2	.07324	.9973	.07344	13.617	.8
.3	.00524	1.0000	.00524	191.0	.7	.3	.07498	.9972	.17519	13.300	.7
.4	.00698	1.0000	.00698	143.24	.6	.4	.07672	.9971	.07695	12.996	.6
.5	.00873	1.0000	.00873	114.59	.5	.5	.07846	.9969	.07870	12.706	.5
.6	.01047	0.9999	.10147	95.49	.4	.6	.08020	.9968	.08046	12.429	.4
.7	.01222	.9999	.01222	81.85	.3	.7	.08194	.9966	.08221	12.163	.3
.8	.01396	.9999	.01396	71.62	.2	.8	.08368	.9965	.08397	11.909	.2
.9	.01571	.9999	.01571	63.66	.1	.9	.08542	.9963	.08573	11.664	.1
1.0	.01745	0.9998	.01746	57.29	89.0	5.0	.08716	0.9962	.08749	11.430	85.0
.1	.01920	.9998	.01920	52.08	.9	.1	.08889	.9960	.08925	11.205	.9
.2	.02094	.9998	.02095	47.74	.8	.2	.09063	.9959	.09101	10.988	.8
.3	.02269	.9997	.02269	44.07	.7	.3	.09237	.9957	.09277	10.780	.7
.4	.02443	.9997	.02444	40.92	.6	.4	.09411	.9956	.09453	10.579	.6
.5	.02618	.9997	.02619	38.19	.5	.5	.09585	.9954	.09629	10.385	.5
.6	.02792	.9996	.02793	35.80	.4	.6	.09758	.9952	.09805	10.199	.4
.7	.02967	.9996	.02968	33.69	.3	.7	.09932	.9951	.09981	10.019	.3
.8	.03141	.9995	.03143	31.82	.2	.8	.10106	.9949	.10158	9.845	.2
.9	.03316	.9995	.03317	30.14	.1	.9	.10279	.9947	.10334	9.677	.1
2.0	.03490	0.9994	.03492	28.64	88.0	6.0	.10453	0.9945	.10510	9.514	84.0
.1	.03664	.9993	.03667	27.27	.9	.1	.10626	.9943	.10687	9.357	.9
.2	.03839	.9993	.03842	26.03	.8	.2	.10800	.9942	.10863	9.205	.8
.3	.04013	.9992	.04016	24.90	.7	.3	.10973	.9940	.11040	9.058	.7
.4	.04188	.9991	.04191	23.86	.6	.4	.11147	.9938	.11217	8.915	.6
.5	.04362	.9990	.04366	22.90	.5	.5	.11320	.9936	.11394	8.777	.5
.6	.04536	.9990	.04541	22.02	.4	.6	.11494	.9934	.11570	8.643	.4
.7	.04711	.9989	.04716	21.20	.3	.7	.11667	.9932	.11747	8.513	.3
.8	.04885	.9988	.04891	20.45	.2	.8	.11840	.9930	.11924	8.386	.2
.9	.05059	.9987	.05066	19.74	.1	.9	.12014	.9928	.12101	8.264	.1
3.0	.05234	0.9986	.05241	19.081	87.0	7.0	.12187	0.9925	.12278	8.144	83.0
.1	.05408	.9985	.05416	18.464	.9	.1	.12360	.9923	.12456	8.028	.9
.2	.05582	.9984	.05591	17.886	.8	.2	.12533	.9921	.12633	7.916	.8
.3	.05756	.9983	.05766	17.343	.7	.3	.12706	.9919	.12810	7.806	.7
.4	.05931	.9982	.05941	16.832	.6	.4	.12880	.9917	.12988	7.700	.6
.5	.06105	.9981	.06116	16.350	.5	.5	.13053	.9914	.13165	7.596	.5
.6	.06279	.9980	.06291	15.895	.4	.6	.13226	.9912	.13343	7.495	.4
.7	.06453	.9979	.06467	15.464	.3	.7	.13399	.9910	.13521	7.396	.3
.8	.06627	.9978	.06642	15.056	.2	.8	.13572	.9907	.13698	7.300	.2
.9	.06802	.9977	.06817	14.669	.1	.9	.13744	.9905	.13876	7.207	.1
	cos	sin	cot	tan	deg		cos	sin	cot	tan	deg

APPX.VI-2

Trigonometric Functions

deg	sin	cos	tan	cot	
32.0	0.5299	0.8480	0.6249	1.6003	58.0
.1	.5314	.8471	.6273	1.5941	.9
.2	.5329	.8462	.6297	1.5880	.8
.3	.5344	.8453	.6322	1.5818	.7
.4	.5358	.8443	.6346	1.5757	.6
.5	.5373	.8434	.6371	1.5697	.5
.6	.5388	.8425	.6395	1.5637	.4
.7	.5402	.8415	.6420	1.5577	.3
.8	.5417	.8406	.6445	1.5517	.2
.9	.5432	.8396	.6469	1.5458	.1
33.0	0.5446	0.8387	0.6494	1.5399	57.0
.1	.5461	.8377	.6519	1.5340	.9
.2	.5476	.8368	.6544	1.5282	.8
.3	.5490	.8358	.6569	1.5224	.7
.4	.5505	.8348	.6594	1.5166	.6
.5	.5519	.8339	.6619	1.5108	.5
.6	.5534	.8329	.6644	1.5051	.4
.7	.5548	.8320	.6669	1.4994	.3
.8	.5563	.8310	.6694	1.4938	.2
.9	.5577	.8300	.6720	1.4882	.1
34.0	0.5592	0.8290	0.6745	1.4826	56.0
.1	.5606	.8281	.6771	1.4770	.9
.2	.5621	.8271	.6796	1.4715	.8
.3	.5635	.8261	.6822	1.4659	.7
.4	.5650	.8251	.6847	1.4605	.6
.5	.5664	.8241	.6873	1.4550	.5
.6	.5678	.8231	.6899	1.4496	.4
.7	.5693	.8221	.6924	1.4442	.3
.8	.5707	.8211	.6950	1.4388	.2
.9	.5721	.8202	.6976	1.4335	.1
35.0	0.5736	0.8192	0.7002	1.4281	55.0
.1	.5750	.8181	.7028	1.4229	.9
.2	.5764	.8171	.7054	1.4176	.8
.3	.5779	.8161	.7080	1.4124	.7
.4	.5793	.8151	.7107	1.4071	.6
.5	.5807	.8141	.7133	1.4019	.5
.6	.5821	.8131	.7159	1.3968	.4
.7	.5835	.8121	.7186	1.3916	.3
.8	.5850	.8111	.7212	1.3865	.2
.9	.5864	.8100	.7239	1.3814	.1
	cos	sin	cot	tan	deg

deg	sin	cos	tan	cot	
36.0	.05878	0.8090	0.7265	1.3764	54.0
.1	.5892	.8080	.7292	1.3713	.9
.2	.5906	.8070	.7319	1.3663	.8
.3	.5920	.8059	.7346	1.3613	.7
.4	.5934	.8049	.7373	1.3564	.6
.5	.5948	.8039	.7400	1.3514	.5
.6	.5962	.8028	7427	1.3465	.4
.7	.5976	.8018	.7454	1.3416	.3
.8	.5990	.8007	.7481	1.3367	.2
.9	.6004	.7997	.7508	1.3319	.1
37.0	0.6018	0.7986	0.7536	1.3270	53.0
.1	.6032	.7976	.7563	1.3222	.9
.2	.6046	.7965	.7590	1.3175	.8
.3	.6060	.7955	.7518	1.3127	.7
.4	.6074	.7944	.7646	1.3079	.6
.5	.6088	.7934	.7673	1.3032	.5
.6	.6101	.7923	.7701	1.2985	.4
.7	.6115	.7912	.7729	1.2938	.3
.8	.6129	.7902	.7757	1.2892	.2
.9	.6143	.7891	.7785	1.2846	.1
38.0	0.6157	0.7880	0.7813	1.2799	52.0
.1	.6170	.7869	.7841	1.2753	.9
.2	.6184	.7859	.7869	1.2708	.8
.3	.6198	.7848	.7898	1.2662	.7
.4	.6211	.7837	.7926	1.2617	.6
.5	.6225	.7826	.7954	1.2572	.5
.6	.6239	.7815	.7983	1.2527	.4
.7	.6252	.7804	.8012	1.2482	.3
.8	.6266	.7793	.8040	1.2437	.2
.9	.6280	.7782	.8069	1.2393	.1
39.0	0.6293	0.7771	0.8098	1.2349	51.0
.1	.6307	.7760	.8127	1.2305	.9
.2	.6320	.7749	.8156	1.2261	.8
.3	.6334	.7738	.8185	1.2218	.7
.4	.6347	.7727	.8214	1.2174	.6
.5	.6361	.7716	.8243	1.2131	.5
.6	.6374	.7705	.8273	1.2088	.4
.7	.6388	.7694	.8302	1.2045	.3
.8	.6401	.7683	.8332	1.2002	.2
.9	.6414	.7672	.8361	1.1960	.1
	cos	sin	cot	tan	deg

APPX.VI-3

Trigonometric Functions

deg	sin	cos	tan	cot		deg	sin	cos	tan	cot	
24.0	0.4067	0.9135	0.4452	2.246	66.0	28.0	0.4695	0.8829	0.5317	1.881	62.0
.1	.4083	.9128	.4473	2.236	.9	.1	.4710	.8821	.5340	1.873	.9
.2	.4099	.9121	.4494	2.225	.8	.2	.4726	.8813	.5362	1.865	.8
.3	.4115	.9114	.4515	2.215	.7	.3	.4741	.8805	.5384	1.857	.7
.4	.4131	.9107	.4536	2.204	.6	.4	.4756	.8796	.5407	1.849	.6
.5	.4147	.9100	.4557	2.194	.5	.5	.4772	.8788	.5430	1.842	.5
.6	.4163	.9092	.4578	2.184	.4	.6	.4787	.8780	.5452	1.834	.4
.7	.4179	.9085	.4599	2.174	.3	.7	.4802	.8771	.5475	1.827	.3
.8	.4195	.9078	.4621	2.164	.2	.8	.4818	.8763	.5498	1.819	.2
.9	.4210	.9070	.4642	2.154	.1	.9	.4833	.8755	.5520	1.811	.1
25.0	0.4226	0.9063	0.4663	2.145	65.0	29.0	0.4848	0.8746	0.5543	1.804	61.0
.1	.4242	.9056	.4684	2.135	.9	.1	.4863	.8738	.5566	1.797	.9
.2	.4258	.9048	.4706	2.125	.8	.2	.4879	.8729	.5589	1.789	.8
.3	.4274	.9041	.4727	2.116	.7	.3	.4894	.8721	.5612	1.782	.7
.4	.4289	.9033	.4748	2.106	.6	.4	.4909	.8712	.5635	1.775	.6
.5	.4305	.9028	.4770	2.097	.5	.5	.4924	.8704	.5658	1.767	.5
.6	.4321	.9018	.4791	2.087	.4	.6	.4939	.8695	.5681	1.760	.4
.7	.4337	.9011	.4813	2.078	.3	.7	.4955	.8686	.5704	1.753	.3
.8	.4352	.9003	.4834	2.069	.2	.8	.4970	.8678	.5726	1.746	.2
.9	.4368	.8996	.4856	2.059	.1	.9	.4985	.8669	.5750	1.739	.1
26.0	0.4384	0.8988	0.4877	2.050	64.0	30.0	0.5000	0.8660	0.5774	1.7321	60.0
.1	.4399	.8980	.4899	2.041	.9	.1	.5015	.8652	.5797	1.7251	.9
.2	.4415	.8973	.4921	2.032	.8	.2	.5030	.8643	.5820	1.7162	.8
.3	.4431	.8965	.4942	2.023	.7	.3	.5045	.8634	.5844	1.7113	.7
.4	.4446	.8957	.4964	2.014	.6	.4	.5040	.8625	.5867	1.7045	.6
.5	.4462	.8949	.4986	2.006	.5	.5	.5075	.8616	.5890	1.6977	.5
.6	.4478	.8942	.5008	1.997	.4	.6	.5090	.8607	.5914	1.6909	.4
.7	.4493	.8934	.5029	1.988	.3	.7	.5105	.8599	.5938	1.6842	.3
.8	.4509	.8926	.5051	1.980	.2	.8	.5120	.8590	.5961	1.6715	.2
.9	.4524	.8918	.5073	1.971	.1	.9	.5135	.8581	.5985	1.6709	.1
27.0	0.4540	0.8910	0.5095	1.963	63.0	31.0	0.5150	0.8572	0.6009	1.6643	59.0
.1	.4555	.8902	.5117	1.954	.9	.1	.5165	.8643	.6032	1.6577	.9
.2	.4571	.8894	.5139	1.946	.8	.2	.5180	.8554	.6056	1.6512	.8
.3	.4586	.8886	.5161	1.937	.7	.3	.5195	.8545	.6080	1.6447	.7
.4	.4602	.8878	.5184	1.929	.6	.4	.5210	.8536	.6104	1.6383	.6
.5	.4617	.8870	.5206	1.921	.5	.5	.5225	.8526	.6128	1.6319	.5
.6	.4633	.8862	.5228	1.913	.4	.6	.5240	.8517	.6152	1.6255	.4
.7	.4648	.8854	.5250	1.905	.3	.7	.5255	.8508	.6176	1.6191	.3
.8	.4664	.8846	.5272	1.897	.2	.8	.5270	.8499	.6200	1.6128	.2
.9	.4679	.8838	.5295	1.889	.1	.9	.5284	.8490	.6224	1.6066	.1
	cos	sin	cot	tan	deg		cos	sin	cot	tan	deg

Trigonometric Functions

deg	sin	cos	tan	cot		deg	sin	cos	tan	cot	
16.0	0.2756	0.9613	0.2867	3.487	74.0	20.0	0.3420	0.9397	0.3640	2.747	70.0
.1	.2773	.9608	.2886	3.465	.9	.1	.3437	.9391	.3659	2.733	.9
.2	.2790	.9603	.2905	3.442	.8	.2	.3453	.9385	.3679	2.718	.8
.3	.2807	.9598	.2924	3.420	.7	.3	.3469	.9379	.3699	2.703	.7
.4	.2823	.9593	.2943	3.398	.6	.4	.3486	.9373	.3719	2.689	.6
.5	.2840	.9588	.2962	3.376	.5	.5	.3502	.9367	.3739	2.675	.5
.6	.2857	.9583	.2981	3.354	.4	.6	.3518	.9361	.3759	2.660	.4
.7	.2874	.9578	.3000	3.333	.3	.7	.3535	.9354	.3779	2.646	.3
.8	.2890	.9573	.3019	3.312	.2	.8	.3551	.9348	.3799	2.633	.2
.9	.2907	.9568	.3038	3.291	.1	.9	.3567	.9342	.3819	2.619	.1
17.0	0.2924	0.9563	0.3067	3.271	73.0	21.0	0.3584	0.9336	0.3839	2.605	69.0
.1	.2940	.9558	.3076	3.271	.9	.1	.3600	.9330	.3859	2.592	.9
.2	.2957	.9553	.3096	3.230	.8	.2	.3616	.9323	.3879	2.578	.8
.3	.2974	.9548	.3115	3.211	.7	.3	.3633	.9317	.3899	2.565	.7
.4	.2990	.9542	.3134	3.191	.6	.4	.3649	.9311	.3919	2.552	.6
.5	.3007	.9537	.3153	3.172	.5	.5	.3665	.9304	.3939	2.539	.5
.6	.3024	.9532	.3172	3.152	.4	.6	.3681	.9298	.3959	2.526	.4
.7	.3040	.9527	.3191	3.133	.3	.7	.3697	.9291	.3979	2.513	.3
.8	.3057	.9521	.3211	3.115	.2	.8	.3714	.9285	.4000	2.500	.2
.9	.3074	.9516	.3230	3.096	.1	.9	.3730	.9278	.4020	2.488	.1
18.0	0.3090	0.9511	0.3249	3.078	72.0	22.0	0.3746	0.9272	0.4040	2.475	68.0
.1	.3107	.9505	.3269	3.060	.9	.1	.3762	.9265	.4061	2.463	.9
.2	.3123	.9500	.3288	3.042	.8	.2	.3778	.9259	.4081	2.450	.8
.3	.3140	.9494	.3307	3.024	.7	.3	.3795	.9252	.4101	2.438	.7
.4	.3156	.9489	.3327	3.006	.6	.4	.3811	.9245	.4122	2.426	.6
.5	.3173	.9483	.3346	2.989	.5	.5	.3827	.9239	.4142	2.414	.5
.6	.3190	.9478	.3365	2.971	.4	.6	.3843	.9232	.4163	2.402	.4
.7	.3206	.9472	.3385	2.954	.3	.7	.3859	.9225	.4183	2.391	.3
.8	.3223	.9466	.3404	2.937	.2	.8	.3875	.9219	.4204	2.379	.2
.9	.3239	.9461	.3424	2.921	.1	.9	.3891	.9212	.4224	2.367	.1
19.0	0.3256	0.9455	0.3443	2.904	71.0	23.0	0.3907	0.9205	0.4245	2.356	67.0
.1	.3272	.9449	.3463	2.888	.9	.1	.3923	.9198	.4265	2.344	.9
.2	.3289	.9444	.3482	2.872	.8	.2	.3939	.9191	.4286	2.333	.8
.3	.3305	.9438	.3502	2.856	.7	.3	.3955	.9184	.4307	2.322	.7
.4	.3322	.9432	.3522	2.840	.6	.4	.3971	.9178	.4327	2.311	.6
.5	.3338	.9426	.3541	2.824	.5	.5	.3987	.9171	.4348	2.300	.5
.6	.3355	.9421	.3561	2.808	.4	.6	.4003	.9164	.4369	2.289	.4
.7	.3371	.9415	.3581	2.793	.3	.7	.4019	.9157	.4390	2.278	3
.8	.3387	.9409	.3600	2.778	.2	.8	.4035	.9150	.4411	2.267	.2
.9	.3403	.9403	.3620	2.762	.1	.9	.4051	.9143	.4431	2.257	.1
	cos	sin	cot	tan	deg		cos	sin	cot	tan	deg

APPX.VI-5

Trigonometric Functions

deg	sin	cos	tan	cot		deg	sin	cos	tan	cot	
8.0	.13917	0.9903	.14054	7.115	82.0	12.0	0.2079	0.9781	0.2126	4.705	78.0
.1	.14090	.9900	.14232	7.026	.9	.1	.2096	.9778	.2144	4.665	.9
.2	.14263	.9898	.14410	6.940	.8	.2	.2133	.9774	.2162	4.625	.8
.3	.14436	.9895	.14588	6.855	.7	.3	.2130	.9770	.2180	4.586	.7
.4	.14608	.9893	.14767	6.772	.6	.4	.2147	.9767	.2199	4.548	.6
.5	.14781	.9890	.14945	6.691	.5	.5	.2164	.9763	.2217	4.511	.5
.6	.14954	.9888	.15124	6.612	.4	.6	.2181	.9759	.2235	4.474	.4
.7	.15126	.9885	.15302	6.535	.3	.7	.2198	.9755	.2254	4.437	.3
.8	.15299	.9882	.15481	6.460	.2	.8	.2215	.9751	.2272	4.402	.2
.9	.15471	.9880	.15660	6.386	.1	.9	.2233	.9748	.2290	4.366	.1
9.0	.15643	0.9877	.15836	6.314	81.0	13.0	0.2250	0.9744	0.2309	4.331	77.0
.1	.15816	.9874	.16017	6.243	.9	.1	.2267	.9740	.2327	4.297	.9
.2	.15988	.9871	.16196	6.174	.8	.2	.2284	.9736	.2345	4.264	.8
.3	.16160	.9869	.16376	6.107	.7	.3	.2300	.9732	.2364	4.230	.7
.4	.16333	.9866	.16555	6.041	.6	.4	.2317	.9728	.2382	4.198	.6
.5	.16505	.9863	.16734	5.976	.5	.5	.2334	.9724	.2401	4.165	.5
.6	.16677	.9860	.16914	5.912	.4	.6	.2351	.9720	.2419	4.134	.4
.7	.16849	.9857	.17093	5.850	.3	.7	.2368	.9715	.2438	4.102	.3
.8	.17021	.9854	.17273	5.789	.2	.8	.2385	.9711	.2456	4.071	.2
.9	.17193	.9851	.17453	5.730	.1	.9	.2402	.9707	.2475	4.041	.1
10.0	.1736	0.9848	.1763	5.671	80.0	14.0	0.2419	0.9703	0.2493	4.011	76.0
.1	.1754	.9845	.1781	5.614	.9	.1	.2436	.9699	.2512	3.981	.9
.2	.1771	.9842	.1799	5.558	.8	.2	.2453	.9694	.2530	3.952	.8
.3	.1788	.9839	.1817	5.503	.7	.3	.2470	.9680	.2549	3.923	.7
.4	.1805	.9836	.1835	5.449	.6	.4	.2487	.9686	.2568	3.895	.6
.5	.1822	.9833	.1853	5.396	.5	.5	.2504	.9681	.2586	3.867	.5
.6	.1840	.9829	.1871	5.343	.4	.6	.2521	.9677	.2605	3.839	.4
.7	.1857	.9826	.1890	5.292	.3	.7	.2538	.9673	.2623	3.812	.3
.8	.1874	.9823	.1908	5.242	.2	.8	.2554	.9668	.2642	3.785	.2
.9	.1891	.9820	.1926	5.193	.1	.9	.2571	.9664	.2661	3.758	.1
11.0	.1908	0.9816	.1944	5.145	79.0	15.0	0.2588	0.9659	0.2679	3.732	75.0
.1	.1925	.9813	.1962	5.097	.9	.1	.2605	.9655	.2698	3.706	.9
.2	.1942	.9810	.1980	5.050	.8	.2	.2622	.9650	.2717	3.681	.8
.3	.1959	.9806	.1998	5.005	.7	.3	.2639	.9646	.2736	3.655	.7
.4	.1977	.9803	.2016	4.959	.6	.4	.2656	.9641	.2754	3.630	.6
.5	.1994	.9799	.2035	4.915	.5	.5	.2672	.9636	.2773	3.606	.5
.6	.2011	.9796	.2053	4.872	.4	.6	.2689	.9632	.2792	3.582	.4
.7	.2028	.9792	.2071	4.829	.3	.7	.2706	.9627	.2811	3.558	.3
.8	.2045	.9789	.2089	4.787	.2	.8	.2723	.9622	.2830	3.534	.2
.9	.2062	.9785	.2107	4.745	.1	.9	.2740	.9617	.2849	3.511	.1
	cos	sin	cot	tan	deg		cos	sin	cot	tan	deg

APPX.VI-6

APPENDIX VII

References Used To Develop The TRAMAN

NOTE: Although the following references were current when this TRAMAN was published, you will need to ensure you are studying the latest revision.

Chapter 1

Blueprint Reading and Sketching, NAVEDTRA 12014, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

Dondis, Donis A., *A Primer of Visual Literacy,* The Massachusetts Institute of Technology Press, Cambridge, MA, 1979.

Giesecke, Frederick E., Alva Mitchell, Henry Cecil Spencer, Ivan Leroy Hill, and John Thomas Dygdon, *Technical Drawing,* Macmillan Publishing Company, New York, NY, 1980.

Knobler, Nathan, *The Visual Dialogue,* Holt, Rinehart, and Winston, Inc., New York, NY, 1971.

Ocvirk, Otto G., Robert O. Bone, Robert E. Stinson, and Philip R. Wigg, Art *Fundamentals, Theory and Practice,* William C. Brown Company, Dubuque, IO, 1975.

Chapter 2

Giesecke, Frederick E., Alva Mitchell, Henry Cecil Spencer, Ivan Leroy Hill, and John Thomas Dygdon, *Technical Drawing,* Macmillan Publishing Company, New York, NY, 1980.

Chapter 3

Blueprint Reading and Sketching, NAVEDTRA 12014, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

Giesecke, Frederick, E., Alva Mitchell, Henry Cecil Spencer, Ivan Leroy Hill, and John Thomas Dygdon, *Technical Drawing,* Macmillan Publishing Company, New York, NY, 1980.

Guide For Patent Draftsmen, U. S. Department of Commerce Patent and Trademark Office, U. S. Government Printing Office, Washington, DC, 1975.

Continued on next page

Chapter 4

Blueprint Reading and Sketching, NAVEDTRA 12014, Naval Education and Training Professional Development and Technology Center, Pensacola, FL., 1994.

Giesecke, Frederick E., Alva Mitchell, Henry Cecil Spencer, Ivan Leroy Hill, and John Thomas Dygdon, *Technical Drawing*, Macmillan Publishing Company, New York, NY, 1980.

Chapter 5

Blueprint Reading and Sketching, NAVEDTRA 12014, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

Dondis, Donis A., *A Primer of Visual Literacy*, the Massachusetts Institute of Technology Press, Cambridge, MA, 1979.

Giesecke, Frederick E., Alva Mitchell, Henry Cecil Spencer, Ivan Leroy Hill, and John Thomas Dygdon, *TechnicaL Drawing*, Macmillan Publishing Company, New York, NY, 1980.

Guide For Patent Draftsmen, U.S. Department of Commerce Patent and Trademark Office, U.S. Government Printing Office, Washington, DC, 1975.

Knobler, Nathan, *The Visual Dialogue*, Holt, Rinehart, and Winston, Inc., New York, NY, 1971.

Ovkirk, Otto G., Robert O. Bone, Robert E. Stinson, and Philip R. Wigg, *Art Fundamentals, Theory and Practice*, William C. Brown Company, Dubuque, IO, 1975.

Chapter 6

Blueprint Reading and Sketching, NAVEDTRA 12014, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

Giesecke, Frederick E., Alva Mitchell, Henry Cecil Spencer, Ivan Leroy Hill, and John Thomas Dygdon, *Technical Drawing*, Macmillan Publishing Company, New York, NY, 1980.

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Assignment Questions

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

ASSIGNMENT 1

Textbook Assignment: "Composition," chapter 1, pages 1-1 through 1-56.

1-1. What is the first action you should take when preparing a new composition?

1. Gather all pertinent information
2. Limit compositional elements
3. Consider text and lettering
4. Decide on the size of the composition

1-2. When considering lettering or text in a layout, how should you approach the subject of composition?

1. Wait until you decide on a layout before adding text
2. Consider text as an integral part of the layout design
3. Select text and letter style before deciding on a layout
4. Add lettering or text after you select the main topic of the layout

1-3. Roughly drawn sketches that help you select effective layouts are referred to by what name?

1. Thumbspots
2. Doodles
3. Thumbnails
4. Thumbprints

1-4. What term is synonymous with the image area or area enclosed by the edges of a substrate?

1. Picture plane
2. Image plane
3. Substrate plane
4. Essential area

1-5. To emphasize the importance of an object in compositions, where should you place the object in the image area?

1. In the right corner
2. In the middle ground
3. In the background
4. In the foreground

1-6. What type of space dominates the eye?

1. Contrast
2. Tonal
3. Negative
4. Positive

1-7. You can use equal portions of negative and positive space to create what type of feeling?

1. Peace
2. Conflict
3. Excitement
4. Elegance

1-8. What compositional element makes images appear more realistic?

1. Contrast
2. Depth
3. Color
4. Clarity

1-9. What is the purpose of directional lines?

1. To create depth in a picture
2. To elicit an emotion from the viewer
3. To direct the viewer's line of sight
4. To create movement within a picture

1-10. Abrupt, clashing directional lines suggest what type of scene?

1. Tranquility
2. Violence
3. Exuberance
4. Joy

1-11. You can control the overall mood of a composition with what type of lines?

1. Parallel lines
2. Leader lines
3. Directional lines
4. Emotive lines

1-12. You should determine the basic value pattern of a picture at what stage of compositional development?

1. During the thumbnail sketch
2. Selecting the color scheme
3. Laying out guidelines
4. Evaluating preliminary data

1-13. What value area do viewers find most attractive?

1. Contrasts
2. Equal areas of black and white
3. Even tonal gradations
4. Light overall tones

1-14. A low-key composition contains predominately what type of tonal value range?

1. Light
2. Dark
3. 10 to 30 percent
4. 18 to 45 percent

1-15. What tonal value should you use to create the feeling of delicacy or lightness?

1. 10 percent
2. 30 percent
3. 70 percent
4. 90 percent

1-16. What element is the chief determinate in the tonal representation of a hue?

1. Temperature
2. Color
3. Value
4. Saturation

1-17. Which of the following combinations- translates into value areas of equal tonal representation?

1. Same hues of different values
2. Same hues of different intensities
3. Different hues of same intensity
4. Different hues of different temperatures

1-18. The process of dividing information into units within the picture area is known by what term?

1. Segmenting
2. Proportioning
3. Formatting
4. Composing

1-19. An image that leaves the viewer feeling as if something is wrong with the picture probably fails in what area of compositional structure?

1. Balance
2. Proportion
3. Layout
4. Value

1-20. Symmetry is a form of what type of balance?

1. Radial
2. Random
3. Informal
4. Formal

1-21. A composition where unlike items appear equally weighted to the viewer is known by what term?

1. Formal balance
2. Asymmetrical balance
3. Radial balance
4. Random balance

1-22. What is the key to successful compositions in radial balance?

1. Number of elements
2. Color
3. Weight
4. Repetition

1-23. Where should you place a singular regularly shaped object to appear balanced on a page?

1. At the top of the page, centered
2. At the mathematical center
3. At the optical center
4. At the bottom of the page, centered

1-24. Repeating a motif or pattern in compositions creates what effect?

1. Monotony
2. Theme
3. Variety
4. Rhythm

1-25. A decorative rendition of an image does NOT contain what dimension?

1. Weight
2. Height
3. Width
4. Depth

1-26. Plastic representations refer to objects rendered in what dimension?

1. Height only
2. Width only
3. Height and width only
4. Height, width, and depth

1-27. Computer-generated imagery may contain what additional dimension?

1. Width
2. Depth
3. Height
4. Time

1-28. Changing the gestures of figures in compositions may also change what about the composition?

1. Layout
2. Picture meaning
3. Picture borders
4. Color

1-29. What should props and settings do for a composition?

1. Overpower
2. Compete
3. Contribute
4. Contrast

1-30. How should you regard borders in laying out compositions?

1. As inviolate limitations
2. As cut-off points for the image
3. As immaterial to the picture area
4. As part of the picture area

1-31. In photographic compositions, the center of interest is the same as the center of the picture area.

1. True
2. False

1-32. Using the principle of thirds compositional formula, how many potential locations for the center of interest are there?

1. 1
2. 2
3. 3
4. 4

1-33. An overtly diagonal composition may indicate that the artist used what type of compositional formula?

1. Principle of thirds
2. Optical center
3. Dynamic symmetry
4. Mathematical center

1-34. To photograph a runner during a sports event, you placed the camera horizontally on the ground. What type of camera position have you assumed?

1. High-camera angle
2. High viewpoint
3. Low viewpoint
4. Low-camera angle

1-35. You are photographing an awards ceremony holding the camera at eye level and pointing upward toward the podium. What type of camera position have you assumed?

1. Low-camera angle
2. Low viewpoint
3. High camera angle
4. High viewpoint

1-36. What potential problem may occur when using a low-camera angle to photograph people?

1. Reduced chins
2. Enlarged nostrils
3. Sallow cheeks
4. Closed eyes

1-37. Before you use or release a photographic image you suspect may contain classified material, who should review it?

1. The admin officer
2. The ADPSSO officer
3. The photographic officer
4. The department head

1-38. When composing textural compositions, you should emphasize type to distinguish important information and create interest.

1. True
2. False

1-39. What is another term for composing textural compositions?

1. Digitizing
2. Typesetting
3. Formatting
4. Copy preparation

1-40. The Golden Mean rectangle for compositional formats has what width to height ratio?

1. 2:3
2. 3:5
3. 5:7
4. 8:10

1-41. How should you represent type that is smaller than 12 points in a thumbnail sketch of a textural composition?

1. With upper-case Xs
2. With lower-case Xs
3. With straight lines
4. With shading sheets

1-42. How should you should indicate the colors of ink required for each element of a textural composition?

1. On the back of the comprehensive layout
2. On the borders of the comprehensive layout
3. On overlays
4. On a separate detail sheet

1-43. What is another term for mechanicals?

1. Camera-ready layouts
2. Paste-up dummies
3. Preliminary dummies
4. Copy preparations

1-44. Industry standards for use on blueprints in the military environment are found in what publications?

1. CAD-CAM
2. CAD-STDs
3. ANSI standards
4. MIL-STDs

1-45. What is the margin dimension on a B-size drawing?

1. .25
2. .38
3. .50
4. .64

1-46. You should leave how much extra space beyond the right side of a roll-sized drawing as protection for the drawing once rolled?

1. 1 inch
2. 2 inches
3. 3 inches
4. 4 inches

1-47. The vertical margins on an A-size drawing are how wide?

1. .25
2. .38
3. .50
4. .64

1-48. Where should you locate the title block on master drawings?

1. Lower-left corner
2. Lower-right corner
3. Upper-right corner
4. Upper-left corner

1-49. Where should the drawing number appear on a master drawing?

1. The reverse of a rolled drawing only
2. Lower-right corner only
3. Upper-right corner near the border only
4. Lower-right corner of the title block, upper-right corner near the border, and the reverse side of a rolled drawing

1-50. Reference numbers indicate what about a blueprint?

1. There is a parts listed for the drawing
2. There is related correspondence to the drawing
3. There is a related drawing
4. There is additional references to standards

1-51. When scale does not appear on a drawing, you may make measurements directly from the blueprint.

1. True
2. False

1-52. What does the absence of a revision block on a blueprint indicate about the master drawing?

1. The revision block has been inadvertently omitted
2. The drawing is original and has never been modified
3. The revision has already been incorporated into the master drawing
4. The revision was unimportant

1-53. Where are revision blocks located on A-sized drawings?

1. Upper-right corner
2. Lower-right corner
3. Upper-left corner
4. Lower-left corner

1-54. Where should you look to find the larger unit or assembly drawing number on drawings that are unit parts?

1. Left side of the bill of materials
2. Left side of the title block
3. Above the title block
4. Below the revision block

1-55. To locate specific points on a complicated blueprint, what additional feature should you incorporate into the drawing?

1. Detail drawings
2. A rectangular coordinate grid
3. Zone numbers
4. Cutting plane views

1-56. What is the aeronautical equivalent in purpose to zone numbers?

1. Assembly points
2. Rib numbers
3. Detail markings
4. Station points

1-57. You should define special marks or symbols on a drawing by using what type of note?

1. Specifications
2. Legends
3. Statements
4. Bill of Materials

1-58. Where should you locate a legend?

1. Near the bill of materials
2. Above the title block
3. Under the revision block
4. Right of the assembly drawing block

ASSIGNMENT 2

Textbook Assignment: "Geometric Construction," chapter 2, pages 2-1 through 2-57.

2-1. How should you represent a point on paper?

1. Intersecting lines
2. Short cross hairs
3. Short cross bars
4. All of the above

2-2. What term refers to lines that remain equidistant along their entire length?

1. Parallel
2. Perpendicular
3. Angular
4. Rectilinear

2-3. Which of the following degrees of angularity indicates that the angle is obtuse?

1. 105°
2. 90°
3. 88°
4. 45°

2-4. Which of the following pairs of angles are supplementary?

1. 45 and 45
2. 45 and 135
3. 65 and 100
4. 65 and 25

2-5. What is the term for an angle with less than 90 degrees of angularity?

1. Straight
2. Obtuse
3. Acute
4. Right

2-6. What term may you correctly apply to lines that bisect isosceles triangles perpendicular to the base dividing the vertex into equal halves?

1. Side
2. Perpendicular
3. Scalene
4. Hypotenuse

2-7. Altitude refers to what part of a triangle?

1. Its sides
2. Its base
3. Its height
4. Its hypotenuse

2-8. What is the third degree of angularity for a triangle with a vertex of 88 degrees and base angle of 45 degrees?

1. 18°
2. 45°
3. 23°
4. 47°

2-9. What type of triangle would have a vertex of 88 and a base angle of 45 degrees?

1. Equilateral
2. Isosceles
3. Scalene
4. Equiangular

2-10. What is the degree of angularity of the vertex in an equilateral triangle?

1. 60°
2. 45°
3. 30°
4. 90°

2-11. What is the degree of angularity for the angle opposing the hypotenuse of a right triangle?

1. 90°
2. 60°
3. 45°
4. 30°

2-12. What is the degree of angularity at the vertex for an isosceles triangle with base angles of 45 degrees?

1. 90°
2. 60°
3. 45°
4. 30°

2-13. Which of the following shapes is a quadrilateral with equal opposing sides and equal opposing angles?

1. Trapezoid
2. Square
3. Rectangle
4. Rhomboid

2-14. Which of the following geometric shapes is a quadrilateral but not a parallelogram?

1. Rhomboid
2. Trapezium
3. Square
4. Rectangle

2-15. What is the term for a rectilinear geometric shape that contains no equal sides or angles and no parallel sides?

1. Trapezium
2. Trapezoid
3. Ellipse
4. Circle

2-16. Which of the following geometric shapes is also a regular polygon?

1. Nonagon
2. Dodecagon
3. Equilateral triangle
4. Rectangle

2-17. How many sides does a heptagon contain?

1. 7
2. 6
3. 5
4. 4

2-18. What is the name of a lo-sided polygon?

1. Pentagon
2. Dodecagon
3. Decagon
4. Nonagon

2-19. What is the length of the radii in a circle with a diameter of 60mm?

1. 10mm
2. 60mm
3. 30mm
4. 45mm

2-20. The portion of a circle between two given radii at 36 degrees angularity, including the bound portion of the circumference, is known by what term?

1. Sectors
2. Secants
3. Chords
4. Arcs

2-21. What term refers to multiple circles that do not share a common center?

1. Inscribed
2. Concentric
3. Circumscribed
4. Eccentric

2-22. A line of infinite length tangent to the inner most circle in a nest of four concentric circles has what relationship to the remaining three circles?

1. It is a chord
2. It is a secant
3. It is a sector
4. It is a diameter

2-23. An arc is a part of the curved segment of a circle bound by but not including two radii.

1. True
2. False

2-24. The Spiral of Archimedes is created by uniformly increasing or decreasing the distance from the center of what geometric element?

1. Letters
2. Radii
3. Points
4. Locus

2-25. What term refers to the plane surfaces of polyhedra?

1. Sides
2. Faces
3. Triangles
4. Cubes

2-26. What is a parallelepiped?

1. A prism with three parallel lateral faces, oblique truncated bases, and oblique altitudes
2. A solid with opposing bases, one lateral face, and one oblique face
3. A solid with bases composed of equal parallelogram-shaped regular polygons and three or more parallel lateral faces
4. A prism with oblique hexagonal bases

2-27. A generatrix of a right circular cylinder is equal in length to what other cylindrical component?

1. The base
2. The directrix
3. The helix
4. The altitude

2-28. What is the difference between a truncated pyramid and a frustum?

1. The truncated pyramid is oblique and the frustum is parallel to the base
2. The truncated pyramid is parallel and the frustum is oblique to the base
3. The truncated pyramid does not have a vertex and the frustum does
4. The truncated pyramid has an oblique altitude and the altitude of a frustum is perpendicular

2-29. What is the definition of a parabola?

1. The intersection of a cone at a lesser angle than the element
2. The intersection of a cone parallel to the element and oblique to the axis
3. The intersection of a cone oblique to both the axis and element
4. The intersection of a cone perpendicular to the axis

2-30. When you bisect a circular arc, to what distance should you set the compass?

1. Exactly one half the length of the arc
2. Twice the length of the arc
3. Greater than one half the length of the arc
4. Less than one half the length of the arc

2-31. When you bisect an angle, where should you draw the bisecting line?

1. Through the angle
2. Through the apex of the angle to the intersecting arcs
3. Perpendicular to one leg of the angle
4. At equal distance from the radius arcs

2-32. When dividing any given line into equal or proportional parts, what part of the scale should you place at the beginning of the given line?

1. The estimated length of the given line
2. The 1 inch mark
3. The first fully divided increment on the scale
4. The 0 on the scale

2-33. When drawing a circle tangent to a line at a particular point, what measurement should you lay off at that particular point?

1. The locus
2. The diameter of the circle
3. The estimated size of the circle
4. The radius of the circle

2-34. What method should you use to draw small radii arcs less than 5/8th inch by tangency construction?

1. Compass
2. Transference
3. Circle templates
4. Freehand

2-35. What term refers to taking measurements from the horizontal diameter of the circle while using the circumscribed method of polygonal construction?

1. Across the planes
2. Across the flats
3. Across the diameters
4. Across the corners

2-36. Drawing geometric figures around a circle is known as what method of polygonal construction?

1. Transcribed
2. Circumscribed
3. Inscribed
4. Prescribed

2-37. What drawing tool should you use in the preferred method of triangle construction?

1. Proportional scales
2. Triangles
3. Straightedges
4. Ames instrument

2-38. What drawing tool should you use to draw a triangle with a base angle of 40 degrees?

1. A triangle
2. A proportional scale
3. A protractor
4. An ames instrument

2-39. When constructing a square using the circumscribed method, to what is the diameter of the circle equal?

1. The distance across the corners
2. The sum of two isosceles triangles
3. The area of a circle
4. The distance across the flats

2-40. To construct an octagon using the circumscribed method of construction, you should take what action first?

1. Draw a square
2. Draw a circle
3. Draw diagonals
4. Draw intersecting horizontal and vertical lines

2-41. When constructing a square using the circumscribed method, from where are the sides of the square drawn?

1. The points where the diameters intersect the circle
2. The point where the compass intersects the paper
3. Around the outside of the circle
4. Anywhere a square can be drawn

2-42. Where you are using the inscribed method of constructing a square, where should you locate the circle?

1. Outside the square
2. Inside the square
3. Adjacent to the square
4. On top of the square

2-43. When you use a set of dividers to construct a pentagon, how is the circumference of a given circle divided?

1. With a scale
2. With a protractor
3. By trial and error
4. With mathematical computations

2-44. What polygon can you construct using only a combination of 30/60/90- and 45-degree triangles?

1. Nonagons
2. Octagons
3. Decagons
4. Dodecagons

2-45. To construct a hexagon using either of the preferred methods, you should use what type of triangle?

1. 45 degree
2. 30/60/90 degree
3. Adjustable
4. A transparent triangle

2-46. What is the common degree of angularity in a nonagon?

1. 10°
2. 20°
3. 30°
4. 40°

2-47. What is the common degree of angularity in a heptagon?

1. 35.6°
2. 21.7°
3. 51.3°
4. 40.2°

2-48. If the minor axis of an ellipse is 40mm, what must be the major axis?

1. 60mm
2. 30mm
3. 35mm
4. 40mm

2-49. One method of determining the foci of an ellipse is to use the diameter of a semicircle equal to the major axis of the ellipse.

1. True
2. False

2-50. Using the foci method of ellipse construction, you should plot what minimum number of points along the axis to increase accuracy?

1. 5
2. 2
3. 3
4. 4

2-51. What are the foci of an ellipse?

1. A series of intersecting arcs
2. A series of points along a circumference
3. Two points on the major axis
4. Two points on the minor axis

2-52. When you use the foci method of constructing an ellipse, what is your second step?

1. Locating the axes
2. Locating the center
3. Locating the foci
4. Locating the measurement of one half the major axis

2-53. Refer to figure 2-47 in the TRAMAN. To plot the second set of points on the circumference of an ellipse, where do you position the compass?

1. Point A2
2. Point B2
3. Points CB2 and DB2
4. Points F and F1

2-54. What drawing tool should you use to plot a series of points to construct an ellipse?

1. A straightedge
2. A scale
3. A protractor
4. A trammel

2-55. The diameters of the concentric circles represent what element of an ellipse?

1. The circumference
2. The foci
3. The trammel
4. The major and minor axes

2-56. Using the conjugate diameter method of ellipse construction, the initial two lines drawn are the diameters of the concentric circles perpendicular to each other.

1. True
2. False

2-57. When you are using the parallelogram method of ellipse construction, what is true of the sides of the parallelogram?

1. The sides must be perpendicular
2. The sides must be parallel
3. The sides must be tangent
4. The sides must be equal

ASSIGNMENT 3

Textbook Assignment: "General Drafting Practices," pages 3-1 through 3-69.

3-1. The lexicon through which every DM communicates with other draftsman is interpreted by what process?

1. Blueprint reading
2. Interpretation
3. Drafting
4. Drawing

3-2. How often are Department of Defense Index of Specifications and Standards issued?

1. Every month
2. Every 6 months
3. Every 3 months
4. Every year

3-3. What should you look for when the symbols on a drawing are unfamiliar to you?

1. A bill of materials
2. A supplement to DOD-MIL STDs
3. A legend
4. A letter of explanation

3-4. Drafting is most often done in what media?

1. Ink
2. Pencil
3. Pigment
4. Diazo

3-5. Crisp, black lines that reproduce well in microform reproduction are typical of what type pencil lead?

1. Wax
2. Graphite
3. Carbon
4. Plastic-graphite

3-6. To provide additional support to tracing paper when you are drawing, what action should you take?

1. Place the tracing paper on a Formica surface
2. Place illustration board over the drawing
3. Place a sheet of white paper under the tracing paper
4. Place a piece of stencil board under the drawing

3-7. Why should you keep a soft tissue near your desk when working with reservoir pens?

1. To keep the drawing surface clean
2. To keep the pen nib clean
3. To keep your hands clean
4. To keep your pen handle clean

3-8. In general, object outlines are drawn with what weight line‘?

1. Thick
2. Medium
3. Thin
4. Ultra-thin

3-9. Where over the pencil line should you place a correctly drawn ink line?

1. Parallel to the pencil line
2. Above the pencil line
3. Below the pencil line
4. Centered directly over the pencil line

3-10. What is the probable cause of rounded corners at the intersection of two or more ink lines?

1. An overfilled reservoir
2. A caked or clogged pen nib
3. Not allowing the first set of lines to dry
4. Not maintaining perpendicularity with the drawing surface

3-11. When preparing to ink in a drawing, what lines should you ink first?

1. Straight lines
2. Circles and arcs
3. Dimension lines
4. Extension lines

3-12. What should you do to prevent ink from seeping into paper fibers when an ink blot occurs?

1. Place ABC granules over the blot to absorb the ink
2. Soak the ink up with a wet red-sable brush
3. Allow the ink to thoroughly dry before erasing it
4. Soak up the excess ink with a tissue or scrap of paper

3-13. After erasing lines inked with a No. 2 reservoir pen, you should use a pen size of what number to replace a portion of the line?

1. 1
2. 2
3. 3
4. 4

3-14. Ink blots and seepage occur more frequently at places in a paper surface that exhibit abnormalities in the paper fibers.

1. True
2. False

3-15. What description of a line convention most closely resembles a centerline?

1. Dash, dot, dash
2. Long dash, long dash, long dash
3. Short dash, short dash, short dash
4. A long dash, short dash, long dash

3-16. How far past the object outline should centerlines extend?

1. 3/8"
2. 1/8"
3. 1/4”
4. 1/2”

3-17. Hidden lines should begin and end as a short dash in contact with the line from which it starts and stops.

1. True
2. False

3-18. To indicate that a hidden line lies below another hidden line, how should you draw the lowermost hidden line?

1. Break the uppermost hidden line by the lowermost hidden line
2. Break the lowermost hidden line by the uppermost hidden line
3. Allow the two hidden lines to intersect
4. Break both hidden lines at the point of intersection

3-19. How much of a gap should you leave between the object outline and an extension line?

1. 1/16"
2. 1/8"
3. 3/16"
4. 1/4"

3-20. How far beyond the last dimension line should extension lines project?

1. 1/16"
2. 1/8"
3. 3/16"
4. 1/4"

3-21. What is the minimum allowable distance between an object outline and the first dimension line?

1. 1/4"
2. 1/8"
3. 3/8"
4. 3/16"

3-22. What is the minimum allowable distance between dimension lines?

1. 1/8"
2. 1/4"
3. 3/16"
4. 3/8"

3-23. How should you depict multiple parallel dimensions?

1. Staggered
2. Vertically centered
3. Aligned flush left
4. Aligned flush right

3-24. How many times the width of an arrowhead should you draw the length of the arrowhead?

1. 1
2. 2
3. 3
4. 4

3-25. When carelessly drawn and varied in size, which of the following lines causes the drawing to look unprofessional?

1. Arrowheads
2. Dimension lines
3. Hidden lines
4. Centerlines

3-26. Which of the following information does leader lines terminating with a dot indicate?

1. The note refers to nonessential information
2. The leader line refers to non-dimensional information
3. The note applies to the object outline
4. The note applies to the object surface

3-27. You should use a long break line when drawing which of the following objects‘?

1. An allen wrench
2. A slot-head screwdriver
3. A broom or rake handle
4. A test tube

3-28. What line convention should you use to show a moving part in an alternate position?

1. Centerlines
2. Phantom lines
3. Hidden lines
4. Visible lines

3-29. What term refers to the portion of an object exposed by a cutting plane?

1. View
2. Cutting plane
3. Sectional view
4. Viewing plane

3-30. How should you handle depicting hidden lines in a sectional view?

1. Draw them as hidden lines
2. Draw them as visible lines
3. Do not draw hidden lines at all
4. Draw them as phantom lines

3-31. The arrows at the end of a cutting plane indicate what information?

1. The direction in which you place the reference letters
2. The viewing plane
3. The referenced letters
4. The direction in which you view the section

3-32. The dimensioning practice that places all dimensions to read from the bottom and right side of the drawing is known by what term?

1. Location
2. Unidirectional
3. Pictorial
4. Unilateral

3-33. Which of the following terms best describe(s) the notes and dimensions that are read from the bottom of the drawing?

1. Justified
2. Aligned
3. Clear
4. Unidirectional

3-34. Where should you place notes without leader lines on a drawing?

1. On the bottom of the drawing
2. Under the title block
3. Near the bill of materials
4. In the lower left corner of the drawing

3-35. Where should you place the arrowhead when dimensioning an arc where the center is not dimensionally located?

1. Inside the arc with an implied center
2. Outside the arc with a leader
3. Outside the arc with a projected center
4. Inside the arc with a broken line to indicate that the center is unimportant

3-36. What type of line should you use to indicate the center of radii?

1. A leader line
2. A small cross
3. A centerline
4. An extension line

3-37. When drawing rounded comers, you should first clarify what information?

1. Selected diameters
2. Overall size
3. Intended radii
4. Tangential edges and arcs

3-38. The depth dimension of a counterdrilled blind hole measures from the outer surface but does not include the varied depth of the bore.

1. True
2. False

3-39. What dimensions should you specify for countersunk holes?

1. The depth of the countersink
2. The diameter of the hole
3. The diameter and angle of the countersink
4. The depth of the hole

3-40. What technique should you depict to indicate a process or surface treatment that includes embedding a flat washer?

1. Counterdrill
2. Counterbore
3. Spot facing
4. Countersunk

3-41. How should you indicate an external chamfer of 45 degrees?

1. By lineation only
2. By angularity only
3. By notation only
4. By angularity and lineation

3-42. What type of chamfers should you specify with notes?

1. Linear
2. Metric
3. Angular
4. 45 degree

3-43. How should you indicate when the fit of two or more interrelating parts is critical?

1. By notation
2. By indicating tolerances
3. By an explanatory note near the revisions block on a drawing
4. By attaching written directions to the fabricator

3-44. What dimension stated in linear increments indicates the overall size of an object?

1. Basic size
2. Unilateral size
3. Design size
4. Nominal size

3-45. What term refers to the intentional difference between the maximum material limits of mating parts?

1. Unilateral tolerance
2. Tolerance
3. Surface finish
4. Allowance

3-46. What variation(s) do bilateral tolerances indicate?

1. Nominal size in both directions
2. Nominal size in one direction only
3. Design size in one direction only
4. Design size in both directions

3-47. When the design size of the hole is the basic size and the allowance applies to the shaft: this describes which of the following system of fits?

1. Tolerancing system
2. Basic shaft system
3. Basic hole system
4. Transition fit system

3-48. To obtain the diameter of the maximum sized shaft, what should you subtract from the basic hole size?

1. The tolerance
2. The allowance
3. The minimum clearance
4. The minimum hole

3-49. What is the minimum hole diameter for a basic shaft system with a basic shaft size of 1.5 inches and an allowance of .003 inch?

1. 1.497
2. 1.503
3. 15
4. 1.498

3-50. How many dimensions does a single-view drawing show?

1. One
2. Two
3. Three
4. Four

3-51. You can view objects from how many mutually perpendicular directions?

1. Five
2. Six
3. Three
4. Four

3-52. Which of the following views is NOT considered a regular view?

1. Top
2. Profile
3. Frontal
4. Bottom

3-53. What view(s) typically show(s) height?

1. Plan only
2. Front elevation only
3. Right-side elevation only
4. Front and right-side elevation

3-54. On a drawing of a symmetrically designed building, which of the following views is NOT a necessary view?

1. Right-side
2. Left-side
3. Top
4. Front

3-55. What is the purpose of an auxiliary view?

1. To show details indicated by hidden lines and revealed by a cutting plane
2. To show additional information in a more detailed insert
3. To show the true size and shape of shapes parallel to the plane of projection
4. To show the true shape and size of inclined surfaces

3-56. A primary auxiliary view perpendicular to the frontal plane has what type relationship to the profile plane and top view?

1. It is inclined
2. It is parallel
3. It is adjacent
4. It is perpendicular

3-57. How are exploded views most often presented?

1. Trimetrically
2. Dimetrically
3. Isometrically
4. Axonometrically

3-58. What is the first step in drawing a revolution?

1. Revolve the object around the plane of projection
2. Draw the object in an auxiliary view
3. Draw the inclined surface parallel to the plane of projection
4. Draw the object in its normal position

3-59. When drawing a revolution, you should observe which of the following rules?

1. The revolved view always shows the axis as a point and this view does not change in size and shape
2. Where the axis is shown as a line, the dimensions parallel to the axis changes
3. Lines parallel on the object are perpendicular in the revolved view
4. The revolved view always shows the axis as a line and this view does not change in size and shape

3-60. When you draw revolutions perpendicular to the front plane of projection, what causes foreshortening in the vertical dimensions?

1. The counterclockwise rotation of the axis
2. The side surfaces being oblique to the profile plane
3. The depth dimensions appearing as true size
4. The length and width dimensions appearing in true size

3-61. The axis of revolution appears as a point in the side view when you revolve the view in what fashion?

1. Parallel to the front plane of projection
2. Perpendicular to the auxiliary view
3. Perpendicular to the profile plane of projection
4. Parallel to the top plane of projection

3-62. What term identifies a line that indicates a plane which results in a sectional view?

1. Object outline
2. Cutting plane line
3. Viewing plane line
4. Break line

3-63. How much of an object does a cutting plane line expose in a full section?

1. All
2. Half
3. One third
4. One-quarter

3-64. To show one-quarter of an object's interior, what sectional view should you select?

1. Half section
2. Full section
3. Quarter section
4. Offset section

3-65. You may use a break line to expose a broken-out section.

1. True
2. False

3-66. How many degrees should you rotate a revolved section in a view?

1. 180°
2. 90°
3. 45°
4. 30°

3-67. How should you show a removed section of a drawing?

1. On a centerline extended from a section cut
2. Aligned to the closest end of the object
3. Revolved and overlapped over the object outline
4. Aligned with a side view

3-68. Bending the cutting plane line to show asymmetrical internal features results in what type of section?

1. A revolved section
2. A broken-out section
3. A removed section
4. An offset section

3-69. When should you draw an object using minimal representation or partial views?

1. When objects are simple
2. When objects are asymmetrical
3. When objects are symmetrical
4. When objects appear with other sectional views

3-70. Why are hidden lines removed in sectional views?

1. Because the cutting plane line replaces hidden lines
2. Because hidden lines become centerlines in sectional views
3. Because arrows show the location of the hidden lines
4. Because sectional views replace hidden lines

3-71. Besides showing internal features of objects, section linings indicate what other information?

1. The sides of the object
2. The material of the object
3. Various directions in section linings
4. The type of lines used

3-72. When section lining a drawing that has a portion of an object outline drawn at 45 degrees, at what angle should you draw the section lining?

1. 60
2. 30
3. 90
4. 110

3-73. When drawing section linings in adjacent parts, at what angles to the horizontal should you draw the lines in the section?

1. 45 degrees and 135 degrees
2. 45 degrees and 30 degrees
3. 30 degrees and 90 degrees
4. 90 degrees and 60 degrees

ASSIGNMENT 4

Textbook Assignment: "Technical Drawing," pages 4-1 through 4-68.

4-1. When you render technical drawings, what are your basic requirements?

1. Speed, accuracy, vagueness, and deficiency
2. Accuracy, technique, speed, and neatness
3. Neatness, technique, correct tools, and alertness
4. The most technically advanced tools, clean working space, and privacy

4-2. When technical sketching, what type of (a) pencil and (b) eraser should you use?

1. (a) HB (b) artgum
2. (a) 2H (b) pink pearl
3. (a) H (b) pink pearl
4. (a) 6H (b) artgum

4-3. Since technical sketches are not made to any scale, what method should you use to determine proportion?

1. Cross-sectioned paper
2. Proportional dividers
3. Mathematical calculation
4. Visual estimation using a dowel or pencil

4-4. Which of the following flaws causes technical sketches to appear poorly drawn?

1. Lack of scale
2. Poor lettering
3. Poor proportioning
4. Apparent erasures

4-5. When you are rendering technical sketches, what proportions should you initially establish?

1. Height to width
2. Length to width
3. 2:3
4. 3:4

4-6. When sketching, now should you make vertical lines?

1. From left to right
2. From the bottom up
3. From the top downward
4. By turning the paper and sketching from left to right

4-7. When beginning to sketch, what technique will help you develop proficiency sketching straight lines?

1. Using a straightedge
2. Placing dots and connecting them
3. Lightly drawing a line with a ruler and skyblue pencil
4. Using a triangle

4-8. How should you sketch circles and arcs?

1. Using short clockwise strokes
2. Using long clockwise strokes
3. Using long counterclockwise strokes
4. Using short counterclockwise strokes

4-9. When sketching arcs with tangential lines, what do you use to locate the ends of the arcs?

1. Small cross hairs
2. The diameters of the arcs
3. Short vertical lines
4. The straight lines tangent to the arcs

4-10. When freehand sketching small ellipses, you should hold the pencil naturally and above the paper. What should be your next step?

1. Sketch out an ellipse on the paper
2. Move the pencil rapidly in an elliptical path
3. Move the pencil rapidly in a circular path
4. Place dots on the paper in an approximately elliptical pattern

4-11. What technique should you use to transfer an image without using carbon or saral paper?

1. Place tracing paper over the image then flip the paper over and press down
2. Use a hard lead pencil and trace the image using extra pressure to indent the bottom sheet
3. Color the reverse side of the image in a contrasting color and trace
4. Color the image then trace

4-12. In architectural constructions, what is the strongest form of structural support?

1. A tee
2. An I beam
3. A channel
4. A WF beam

4-13. Given an angle support with a dimension of L 6 x 3 x 1/2, what part of the dimension represents the width of the leg?

1. 6
2. 1/2
3. 3
4. L

4-14. How many pounds per foot does a bearing pile with the given dimension of HP 14 x 73 weigh?

1. 14
2. 26
3. 73
4. 52

4-15. What is the term given to the amount of weight the earth is able to support?

1. Total dead load
2. Soil-bearing capacity
3. Total live load
4. Equilibrium capacity

4-16. Sill plates placed on a foundation of concrete are themselves the foundation for what other structural member?

1. Headers
2. Sole plates
3. Stud caps
4. Studs

4-17. Cantilevered construction is the type of construction technique normally applied to what type of structure?

1. An overhanging porch
2. A doorframe
3. A window casement
4. A girder

4-18. On trusses, what term indicates the horizontal distance between the peak and the heel?

1. Gusset
2. Slope distance
3. Rise
4. Half span

4-19. How should you show a spot weld on a weld symbol?

1. Place a square above the base
2. Place a small circle on the base
3. Place a small circle above the reference line
4. Place a square under the reference line

4-20. You should indicate temporary supports for complicated structures on what type of drawings?

1. Erection drawings
2. Fabrication drawings
3. Layout drawings
4. Falsework drawings

4-21. To find the length, thickness, and character of building walls, you should look at what type of drawing?

1. Elevation plan
2. Framing plan
3. Floor plan
4. Plan view

4-22. A list of written specifications and definition of terms are part of what drawing?

1. Specification drawings
2. Detail drawings
3. Fabrication drawings
4. Falsework drawings

4-23. Shipboard isometric wiring diagrams found in DC Central provide what type of information to the repair and fire parties during drills and emergencies?

1. Circuit functions
2. Equipment component connections
3. Equipment, panels, connection boxes, and cable run locations
4. Signal or current flow between major equipment components

4-24. What designation refers to a shipboard main electrical switchboard or switch gear group location?

1. 1SF
2. 2S
3. 2E
4. 2SF

4-25. A cable tag marked (4-168-1)-4P-A(1) indicates that the cable serves to power what function?

1. Propulsion power
2. Ship's service power
3. Ship's service lighting
4. Control power

4-26. In a shipboard isometric wiring diagram, what is the degree of angularity for drawing athwartship lines?

1. 30
2. 45
3. 60
4. 90

4-27. You should draw interdeck cabling at what angle to the centerline of the ship?

1. 30
2. 45
3. 60
4. 90

4-28. How large should you draw a shipboard wiring deck plan representing 200 linear feet of deck?

1. 12 inches
2. 35 inches
3. 24 inches
4. 50 inches

4-29. What aircraft wire identification number refers to wiring that controls the landing gear?

1. 2RL85G20N
2. 2RG85F20N
3. 2GL85F20N
4. 2LR85F20G

4-30. What is the major functional difference between electronic prints and electrical prints?

1. Electrical prints are more detailed and complex
2. Electronic prints are more detailed and complex
3. Electrical prints are color coded
4. Electronic prints are color coded

4-31. Electromechanical drawings are a combination of what two types of drawings?

1. Electronic and architectural
2. Electrical and electronic
3. Structural and electrical
4. Mechanical and electrical

4-32. Logic diagrams describe the binary functions of digital computers.

1. True
2. False

4-33. Sockets, pin numbers, and test points are part of what type of diagram?

1. Block diagram
2. Basic logic diagram
3. Detailed logic diagram
4. Location diagram

4-34. For troubleshooting electrical malfunctions in digitized devices, what type of drawing should you prepare?

1. Detailed logic diagrams
2. Basic logic diagrams
3. Block diagrams
4. Location diagrams

4-35. What publication sets industry-wide standards for all machine drawings?

1. MIL-STD 100A
2. MIL-STD 9A
3. ANSI 46.1
4. ANSI Y14.5M-1982

4-36. What method should you use to show acceptable variations in size and surface dimensions?

1. Fractionalizing
2. Fragmenting
3. Tolerancing
4. Proportioning

4-37. Which of the following indications of tolerance is bilateral?

1. 5.00, ± .002
2. 5.00, 4.098/5.002
3. 5.00, 5.002
4. 5.00, 4.098, 5.002

4-38. What feature control symbol should you use to indicate angularity?

1. ∠
2. √
3. ≤
4. ⊥

4-39. When accuracy is critical, what method should you use to draw screw threads?

1. Simplified
2. Schematic
3. Detailed
4. Minimal representation

4-40. How many threads per inch are on a bolt with an external thread designation of 1/4-35 UNC-2?

1. 15
2. 25
3. 35
4. 70

4-41. Which bolt has a left-handed fine thread?

1. 1/4-35-NF-LH-2
2. 1/4-LHNC-35-2
3. 2-3501/4-NF
4. 1/4-35-NCLH-2

4-42. What is the term for the surface of a thread that corresponds to the major diameter of an internal thread and minor diameter of an external thread?

1. Crest
2. Root
3. Depth
4. Pitch

4-43. How should you determine the pitch of a thread?

1. Multiply the measurement of the lead by the length of the external threads
2. Measure the thread depth and multiply by the threads per inch
3. Multiply threads per inch by length of external threads
4. Measure parallel to the axis a point on one thread to a corresponding point on the next thread

4-44. On a machine drawing with a circular pitch of 14 and a root diameter of 12, how many gear teeth should you draw?

1. 922
2. 644
3. Only enough to identify dimensions
4. Only enough to interface with adjacent gears

4-45. What term refers to the diameter of the addendum circle?

1. Dedendum
2. Addendum
3. Choral pitch
4. Outside diameter

4-46 How should you mathematically calculate the number of teeth on a gear?

1. Multiply the diametrical pitch by the diameter of the pitch circle
2. Multiply the addendum circle by the radii
3. Multiply the circular pitch by the diametral pitch
4. Multiply the root diameter by the outside diameter and divide by 360

4-47. The distance from the top of one gear tooth to its bottom, including any clearance is known by what term?

1. Working depth
2. Whole depth
3. Thickness
4. Rack teeth

4-48. What symbol provide a foundation for surface finish information?

1. √
2. ↲
3. ∪
4. ∧

4-49. At what degree to the horizontal should you draw the legs of a finish mark?

1. 30
2. 90
3. 45
4. 60

4-50. When should you draw an isometric single-line plumbing diagram?

1. When details are essential
2. When speed is essential and pipes are bent in more than one plane
3. When the print will be used to install pipes
4. When visual appearance is important

4-51. How should you show a permanent pipe connection?

1. With a crosshair and a note
2. With a small vertical line
3. With a heavy solid dot
4. With a open-faced square

4-52. On piping fittings such as crosses and elbows, what opening is read first?

1. The smallest opening
2. The largest opening
3. The opposing opening
4. The outlet end

4-53. On a typical 45° Y-bend with the dimensions of 45cm x 30cm x 60cm, what is the measurement of the outlet end?

1. 35cm
2. 30cm
3. 60cm
4. 75cm

4-54. A brown valve in your space on board ship indicates that the valve connects piping carrying what type of fluids?

1. Anesthetics
2. Flammable
3. Oxidizing
4. Toxic and poisonous

4-55. What additional hazard marking label should appear on piping with a brown valve?

1. FLAM
2. TOXIC
3. PHDAN
4. AAHM

4-56. Shipboard hydraulic lines carrying excess fluids overboard are known by what term?

1. Return lines
2. Operating lines
3. Vent lines
4. Supply lines

ASSIGNMENT 5

Textbook Assignment: "Perspective Projections," pages 5-1 through 5-37.

5-1. Which of the following projections depicts objects as they would actually look to the eye?

1. Central projection
2. Parallel projection
3. Barrel projection
4. Axonometric projection

5-2. The projectors in perspective projections have which of the following characteristics?

1. They are perpendicular to the picture plane
2. They seem to converge at a central point
3. They are parallel to the picture plane
4. They are perpendicular to each other

A. Vanishing point
B. Horizon line
C. Station point
D. Picture plane

Figure 5-A.—Terms of perspectives.

IN ANSWERING QUESTIONS 5-3 THROUGH 5-7, SELECT FROM FIGURE 5-A THE TERM THAT IS DEFINED IN THE QUESTION. TERMS MAY BE USED MORE THAN ONCE.

5-3. Known as the eye level.

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

5-4. Represents the position of the observer's eyes.

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

5-5. The imaginary vertical plane between the object and the observer.

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

5-6. The point at which parallel horizontal lines seem to converge.

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

5-7. Known as the center of vision.

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

5-8. How high up from the horizon line should you place eye level?

1. 6 feet 6 inches
2. 6 feet 5 inches
3. 5 feet 6 inches
4. 5 feet 4 inches

5-9. Which of the following elements of perspective drawing most influences the finished image?

1. The horizon line
2. The vanishing points
3. The cone of visual rays
4. The station point

5-10. An object placed above the horizon line appears in what form?

1. As seen from below
2. As seen from above
3. Distorted
4. In two dimensions

5-11. Moving the picture plane alters what dimension(s)?

1. Scale only
2. Perspective only
3. Perspective and scale
4. Proportion and perspective

5-12. What type of perspective do DMs use most often?

1. Aerial
2. Linear
3. One-point
4. Three-point

5-13. In reverse perspective, where is the location of the station point?

1. Behind the object
2. Behind the picture plane
3. At the picture plane
4. In front of the picture plane

5-14. Which of the following characteristics implies distance in aerial perspective?

1. Increased contrast
2. Intense color
3. Soft contours
4. Sharp line definition

5-15. What type of perspective drawing is known as parallel perspective?

1. One-point
2. Two-point
3. Three-point
4. Oblique

5-16. What dimension(s) are represented in true length on a one-point perspective drawing?

1. Height and depth
2. Height and width
3. Depth and width
4. Width and length

5-17. Why should you draw only the depth dimension in perspective when making a one-point perspective drawing?

1. The other two dimensions are not parallel to the picture plane
2. The other two dimensions have vanishing points
3. Height and width dimensions are parallel to the picture plane
4. The width dimension is oblique to the picture plane

5-18. Two-point perspective drawings are also referred to as what type of projection?

1. Bilateral
2. Linear
3. Aerial
4. Angular

5-19. What type of projection places the object at an angle to the picture plane while maintaining one set of vertical edges parallel to the picture plane?

1. One-point
2. Two-point
3. Three-point
4. Linear

5-20. Under which of the following circumstances is it possible to take some dimensions directly from a two-point perspective drawing?

1. When the station point is below the object
2. When the station point is on the ground line
3. When one edge of the projection touches the picture plane
4. When the vertical parallel edge is unaffected by station points

5-21. Which of the following attributes is characteristic to oblique perspective?

1. No object surfaces are parallel to the picture plane
2. Height is the only dimension having a vanishing point
3. Width and depth dimensions have a vanishing point
4. Height and width have no vanishing points

5-22. What should you do to make small objects appear better in three-point perspective drawings?

1. Place the vanishing points far apart
2. Place the vanishing points close together
3. Place one vanishing point above and two below
4. Place all three vanishing points above the horizon line

5-23. In a one-point perspective drawing using the plan-view method of construction, after drawing the plan view, picture plane, and station point, you should take what step next?

1. Locate the vanishing point
2. Project a vertical line from the station point to the horizon line
3. Project the width of the plan view to the ground line
4. Draw visual rays to the vanishing point

5-24. Where should you find the required information for using the plan-view method of mechanical construction of a perspective drawing?

1. An isometric drawing
2. An orthographic drawing
3. NAVSO P-35
4. MIL-STD 110A

5-25. What is the first step in constructing a one-point perspective drawing using the plan-view method?

1. Locate the station point
2. Obtain a depth dimension
3. Draw the plan view
4. Establish a horizon line

5-26. How are the vanishing points located?

1. Extend the vertical lines of the plan view to the ground line
2. Project a ground line parallel to the horizon line
3. Draw the horizon line and drop perpendiculars to the station points
4. Project a vertical line from the station point to the horizon line

5-27. How should you correct distortion in perspective drawings?

1. Move the ground line
2. Move the horizon line
3. Move the station points
4. Move the cone of visual rays

5-28. What is the best location to draw a plan view for use in constructing a one-point perspective drawing?

1. Draw it true size
2. Draw it in an arbitrary location
3. Draw it resting on top of the horizon line
4. Draw it parallel to the station point

5-29. When you place the station point closer than twice the width of the plan view, what happens to the appearance of the drawing?

1. It is in true size and shape
2. It distorts
3. It reduces
4. It enlarges

5-30. When you draw a plan view in front of the picture plane, what is the result?

1. The front view is distorted
2. The front view of the object is smaller
3. The front view of the object is the same size as the plan view
4. The front view of the object is larger

5-31. **REFER TO FIGURE 5-15 IN THE TEXT.** When drawing a one-point perspective drawing using a plan view, constructing a perpendicular line from the station point to the horizon line establishes what point?

1. VP
2. A
3. H
4. B

5-32. In a two-point perspective drawing constructed using the plan-view method, you should locate the station point by dropping a perpendicular line from what corner of the object?

1. The one that is already in perspective
2. The one that is parallel to the picture plan
3. The one that is perpendicular to the picture plan
4. The one that touches the picture plane

5-33. **REFER TO FIGURE 5-16 IN THE TEXT.** To draw the plan view in the desired angle to the picture plane, you should use angles in what degree increments?

1. 15, 45, 30, 90
2. 45, 30, 15, 25
3. 30, 15, 45, 60
4. 45, 75, 15, 30

5-34. **REFER TO FIGURE 5-16 IN THE TEXT.** How should you locate the station point?

1. Drop a perpendicular line of arbitrary length from the corner of the object (0)
2. Measure twice the width of the object and draw a vertical line from the ground line to the object
3. Intersect the picture plane and the horizon line taking half of that measure to locate the ground line and station point
4. Place an arbitrary point anywhere on the drawing

5-35. What is the angle created by projecting lines from the station point to the vanishing points?

1. 30°
2. 45°
3. 60°
4. 90°

5-36. Where are the vanishing points located?

1. On the ground line
2. On the horizon line
3. On the picture plane
4. On the front view

5-37. A 3-foot edge of an object represented on a drawing to a scale of 1"=2"-0" is parallel to the plane of projection. You should draw this edge to what size on you drawing?

1. 3/4 inches
2. 1.5 inches
3. 6 inches
4. 2 inches

5-38. A 3-foot edge of an object represented on a drawing to a scale of 1"=2"-0" is behind the plane of projection. How should you draw this edge?

1. Foreshortened
2. In true length
3. At a 2:1 scale
4. At 2/3rds full scale

5-39. A circle shown parallel to the plane of projection on a drawing in two-point perspective appears as what shape?

1. An ellipse
2. A circle
3. A parabola
4. A hyperbola

5-40. What should you do to determine the perspective of lines and planes inclined away from the picture plane?

1. Project an auxiliary view
2. Locate their station points
3. Locate their vanishing points
4. Revolve the view toward the plane of projection

5-41. How should you transfer the measurements of a circle that is shown oblique to the plane of projection?

1. Use a set of dividers
2. Inscribe a square within the circle
3. Use a trammel
4. Circumscribe the circle with a square

5-42. How many check points should you use when transferring measurements from a circle to a surface oblique to the plane of projection?

1. Six
2. Seven
3. Eight
4. Five

5-43. You should use a square to help you in drawing circles in perspective for what reason?

1. Squares have transferable measurements
2. Squares eliminate the need for vanishing points, plan views, and elevation views
3. Squares are equally proportional
4. Squares project as accurate picture planes

5-44. In one-point perspective, what is the easiest way to draw circular shapes?

1. Perpendicular to the picture plan
2. Parallel to the picture plane
3. Drawing them true size
4. Drawing them in true perspective

5-45. When you construct a perspective drawing of an object that contains inclined lines and planes, the plan and elevation serve what purpose?

1. Measuring
2. Projecting the vanishing points
3. Locating the picture plane
4. Projecting horizon line

5-46. What additional element influences drawing circles and arcs in two-point perspective?

1. Station points
2. Vanishing points
3. Horizon line
4. Ground line

5-47. What is the key to dividing a line or area into equal parts?

1. A vertical or horizontal line that is parallel to the picture plane
2. A fully-divided architect's scale
3. An inclined plane with the vanishing point resting on the horizon line
4. A line that can be equally divided

5-48. What is the final step in dividing a receding plane into equal parts?

1. Divide the verticals into equal parts
2. Draw the diagonals
3. Draw receding horizontal lines
4. Draw the vertical lines through the intersections

5-49. When finding equal points on a plane in perspective, what feature do all points share?

1. A common vanishing point
2. A height dimension
3. A similar degree of angularity
4. A length dimension

5-50. Equally divided points on a plane in perspective will appear to have what type of relationship?

1. Parallelism
2. Coordination
3. Angularity
4. Perpendicularity

5-51. To draw vertical divisions in perspective, you should first locate what dimension?

1. The length of the horizontal lines
2. The height of the vertical elements
3. The distance between vertical elements
4. The distance between the first vertical element and the vanishing point

5-52. When drawing a reflection, where should you locate the station points?

1. At the same location as the object station points
2. Opposite and above the object drawn
3. Opposite and below the object drawn
4. Directly above or below the station points of the object

5-53. When drawing reflections, what is the only dimension left for you to figure?

1. The horizontal width
2. The vertical height
3. The distance from the station point to the horizon line
4. The distance from station point to the picture plane

5-54. How do reflections appear to the eye?

1. As though YOU were above the scene looking down
2. In reverse
3. As though you were below the scene looking up
4. In exact duplic ate

5-55. How do reflections from object placed back off the horizon line appear?

1. Shorter than the real object
2. As tall as the real object
3. Taller than real object
4. As half of the real object

5-56. In a perspective drawing, where should you draw the vanishing points for a shadow?

1. To the right of the object
2. Either on or off your paper
3. Vertically below the light source
4. To the left of the object

5-57. To draw realistic shadow areas in perspective, what must you establish first?

1. A revolution about a reflecting surface
2. A light source and a vanishing point
3. The appropriate depth of the object only
4. The light source on the drawing and the depth of the object

5-58. How should you add realism to perspective drawings?

1. With depth
2. With color
3. With shading
4. With detail

5-59. What type drawings are ordinarily NOT shaded?

1. Isometric
2. One-point perspective
3. Technical
4. Working

ASSIGNMENT 6

Textbook Assignment: "Parallel Projections," pages 6-1 through 6-41.

6-1. In oblique projections, you should place the face of the object with what feature parallel to the picture plane?

1. The shortest dimension
2. The longest dimension
3. The face with the most flat surfaces
4. The face with the least number of sides

6-2. When you draw an object in oblique projection where the longest dimension conflicts with the most irregular surface, you should place the irregular surface parallel to the picture plane.

1. True
2. False

6-3. In oblique projections, lines perpendicular to the plane of projection that project in true length are at what degree of angularity to the horizontal plane?

1. >45°
2. <45°
3. 45°
4. $_{\wedge}$45°

6-4. Lines perpendicular to the plane of projection project in what length?

1. True
2. Infinite
3. Foreshortened
4. Proportioned

6-5. To emphasize features on the side of an object, you should draw receding lines at what angle to the plane of projection?

1. 45°
2. 60°
3. Greater than 45°
4. Less than 45°

6-6. In oblique projections, how should you draw receding lines in relation to the plane of projection?

1. Parallel only
2. Perpendicular only
3. Both perpendicular and parallel
4. At any angle other than perpendicular

6-7. How should you decrease distortion in oblique projections?

1. By placing the projection in correct scale
2. By reducing the length of the receding lines
3. By placing the projection obliquely to the plane of projection
4. By enlarging the dimensions parallel to the plane of projection and reducing the dimension of the receding axis

6-8. You should always draw the receding lines to half the scale of the front view in which of the following types of drawings?

1. Isometric
2. Cavalier
3. Cabinet
4. Perspective

6-9. You should draw the projectors to form an angle of 45° in what type of oblique projection?

1. Parallel
2. Cabinet
3. Caravaggio
4. Cavalier

6-10. Which of the following angles should you use to draw the receding axes of cavalier projections?

1. 30°
2. 45°
3. 60°
4. 90°

6-11. In oblique projections, a half circle parallel to the plane of projection appears as what shape?

1. A parabola
2. A partial ellipse
3. A half circle
4. A hyperbola

6-12. When using the four-center approximate ellipse method of drawing circles in cavalier projections, how should you locate the centers of the intermediate arcs?

1. Erect 45° bisectors to the inscribing parallelogram
2. Erect parallel bisectors to the circumscribing parallelogram
3. Erect horizontal and vertical bisectors to the inscribing parallelogram
4. Erect perpendicular bisectors to the circumscribing parallelogram

6-13. When drawing a circle oblique to the plane of projection in a cabinet drawing, by what length should you reduce the receding axis?

1. 1/2
2. 2/3
3. 3/5
4. 5/7

6-14. What type of sections can you show in oblique cabinet projections?

1. Broken-out sections only
2. Half sections only
3. Full sections only
4. All types of sections

6-15. Which of the following rules of dimensioning is of primary importance?

1. All lines and arrowheads must appear outside of the object to which they apply
2. All dimension lines, extension lines, and arrowheads must be lettered horizontally and legible from the bottom of the drawing
3. All dimension lines, extension lines, and arrowheads must lie in the planes of the object to which they apply
4. All lines and arrowheads must be aligned to the right side of the elevation

6-16. In orthographic projections, the technique you use to represent an object on the plane of projection involves which of the following elements?

1. The use of projectors that are parallel to each other and perpendicular to the plane of projection
2. The assumption that the viewer is infinitely distant from the object and its plane of projection
3. The assumption that the viewer is midway between the object and its plane of projection
4. The use of projectors that converge at a central point

6-17. What common feature classifies axonometric drawings as orthographic projections?

1. Only one plane of projection is shown
2. Three faces of the object are shown
3. The object is rotated into the plane of projection
4. The projectors are perpendicular to the plane of projection

6-18. A drawing that shows three faces of an object in one view and presents the object as it approximately appears to the observer is drawn to what type of projection?

1. Axonometric
2. Orthographic
3. Cabinet
4. Quadromatic

6-19. What is a distinguishing feature of axonometric projections?

1. The position of the views in relation to the plane of projection
2. The inclined position of the object to the plane of projection
3. The lack of distortion in the views
4. The position of the projectors to the plane of projection

6-20. Which of the following projections indicates equally foreshortened surfaces?

1. Oblique
2. Cabinet
3. Isometric
4. Orthographic

6-21. In isometric projections, isometric planes have what angular relationship at the intersection of the isometric axes?

1. 30°
2. 60°
3. 90°
4. 120°

6-22. When you make an isometric scale, what angle should you make with the horizontal?

1. 30°
2. 45°
3. 60°
4. 90°

6-23. Which of the following lines is an isometric line?

1. A line bisecting the isometric angles
2. A line parallel to the vertical axis
3. A line connecting isometric axes
4. A line perpendicular to isometric axes

6-24. Any line not parallel to the isometric axes is known as what type of line?

1. Nonisometric
2. Perspective
3. Foreshortened
4. Oblique

6-25. What is the purpose of an isometric scale?

1. To lay off intersecting lines
2. To project the object onto the plane of projection
3. To measure foreshortened lines
4. To measure diagonal lines

6-26. What is the difference between isometric drawings and isometric projections?

1. Lines are drawn foreshortened by two-thirds
2. Lines are drawn without the use of a scale in projections
3. Lines are drawn without the use of a scale in drawings
4. Lines are drawn true length

6-27. In comparison to an isometric projection, how does an isometric drawing appear?

1. Larger
2. Smaller
3. More accurate
4. More realistic

6-28. In an isometric drawing, how should you place the object on the plane of projection?

1. With the longest axis vertical
2. With the longest axis horizontal
3. With the shortest axis oblique
4. With the shortest axis parallel to the longest isometric axis

6-29. Changing the position of the isometric axes affects the viewpoint at which the object is seen.

1. True
2. False

6-30. How do circles appear on isometric planes?

1. As obloids
2. As circles
3. As ellipses
4. As parabolas

6-31. When transferring noncircular curves from a multiview drawing to any isometric drawing, what lines should you use?

1. Corresponding projectors on the multiview drawing
2. Corresponding nonisometric lines
3. Corresponding normal lines
4. Corresponding randomly spaced parallel lines

6-32. What feature determines when the diameters of an ellipse are conjugate?

1. When the diameter are parallel to the end tangents
2. When the diameters are perpendicular to the end tangents
3. When the minor diameter intersects the major diameter at 60°
4. When the major and minor diameters are complementary

6-33. A circle with a diameter of 65cm will project obliquely as an ellipse with a major diameter of what size?

1. 35cm
2. 55cm
3. 45cm
4. 65cm

6-34. Angles will only project true size when they are drawn in which of the following ways?

1. Parallel to the isometric axes
2. Foreshortened along the isometric axes
3. Parallel to the plane of projection
4. Perpendicular to the plane of projection

6-35. To draw an angle in an isometric projection, what should you do first?

1. Convert angular measurements to linear measurements
2. Draw the isometric axes
3. Project the angle from the axonometric projection to the plane of projection
4. Make an isometric drawing showing true shape and size

6-36. In an isometric drawing, what tool should you use to measure angles?

1. A protractor
2. A compass
3. An isometric protractor
4. A proportional scale

6-37. When drawing a half section in an isometric drawing, what should be your first step?

1. Drawing the circles in isometric
2. Drawing the cutting plane
3. Drawing the entire object
4. Drawing the portion of the drawing behind the cutting plane

6-38. Which fact remains true regardless of what method of dimensioning you chose?

1. Dimensions should remain consistent throughout the drawing
2. Dimension should read from the right side of the drawing
3. You should indicate tolerances on dimensions
4. You should letter all dimensions in upper-case letters

6-39. How many scales should you use for a dimetric projection?

1. One
2. Two
3. Three
4. Four

6-40. What type of axonometric projection contains two axes that make equal angles to the plane of projection?

1. Trimetric
2. Isometric
3. Dimetric
4. Noncircular

6-41. Which of the following are three primary planes of projection in orthographic projections?

1. Elevation, vertical, and profile
2. Top, bottom, and vertical
3. Horizontal, vertical, and elevation
4. Vertical, horizontal, and profile

6-42 In first-angle projection, the profile plane will show what view?

1. Right side
2. Left side
3. Top
4. Bottom

6-43 Why is third-angle projection considered more logical than first-angle projection?

1. The front view is located on the vertical plane
2. The right side of the object is toward the object's left
3. The top view is depicted above the front view
4. The top view is depicted below the front view

6-44. To draw the three principal views of an object on paper with the paper serving as a vertical plane, what action should you take to draw the top and right-side view?

1. Rotate the paper
2. Rotate the planes clockwise
3. Rotate the planes counterclockwise
4. Rotate the respective planes toward the observer

6-45. What technique should you use to layout the third view in a multiview projection?

1. Mitering
2. Drawing through
3. Rotation
4. Projection

6-46. When you use the miter-line method of laying out a third view, what controls the the distance between the front and right side view?

1. The size of the front and right-side views
2. A scale to measure the length of the miter line
3. Proportional dividers
4. Horizontal movement of the miter line

6-47. **REFER TO FIGURE 6-28 IN YOUR TEXTBOOK.** Given c-size drawing paper (11 x 17" with a 1/2" margin), you are to draw an object with the dimensions of 13 x 10 x 3" in a scale of 2:1. Spacing the views as in figure 6-28B, what is the distance between views?

1. 1
2. 2
3. 3
4. 4

6-48. When spacing the views of a circular object in a drawing, what must you try to equalize?

1. The areas of the views
2. The size of the views
3. The size of the paper
4. The areas of the spaces around and between the views

6-49. When can a one-view drawing completely describe an object?

1. When you state thickness as a dimension or note
2. Whenever the length dimension is on top
3. When all dimensions are equal
4. When objects have no top or bottom

6-50. Multiview projections should contain how many views?

1. Six
2. Two
3. Three
4. As many views as it takes to fully describe an object

6-51. You are given an object that has identical front and back views, identical right- and left-side views, and the bottom view varies from the top view only in that the visible lines of the bottom view are hidden lines in the top view. Using the general rules of view selection for multiview drawings, what views should you select?

1. Top, front, and right-side views
2. Bottom, front, and right-side views
3. Bottom, back, and left-side views
4. Top, back, and left-side views

6-52. When selecting views according to convenience, what general rule should you follow?

1. Show auxiliary views
2. Show the entire object
3. Show the object in the position it customarily occupies
4. Show all visible lines

6-53. When each of three possible two-dimension projections of an object conveys exactly the same information, on what basis should you select the particular view to draw?

1. Number of hidden lines in a view
2. Balanced appearance
3. Position the object normally occupies
4. Dimensions of horizontal margins on the drawing paper

6-54. What drawing technique helps you to identify a particular view of a complex object?

1. Corner point numbering
2. Visible numbering
3. Zone numbers
4. Arrowheads

6-55. Where are hidden corner points placed on a view?

1. Outside the view outline
2. Inside the view outline
3. Inside the dimension lines
4. Outside the dimension lines

6-56. In a multiview drawing, a line parallel to the plane of projection appears in what manner on a plane to which it is oblique?

1. Foreshortened
2. True length
3. Normal
4. Parallel

6-57. In a multiview drawing, a line that is parallel to two of the planes of projection and perpendicular to the third is known as what type of line?

1. Normal line
2. Isometric line
3. Inclined line
4. Dimetric line

6-58. In a multiview drawing, a circle oblique to the plane of projection projects as what geometric shape?

1. An ellipse
2. A circle
3. An oblate ellipsoid
4. A frustum

6-59. You should arbitrarily alter view placement on a multiview drawing if you incorrectly placed the views.

1. True
2. False

6-60. What type of lettering should you use on multiview drawings?

1. Single-stroke gothic
2. Copperplate gothic
3. Bookman bold
4. Helvetica